Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale, Phase II

Final Report, August 1981 - December 1982

Volume I. Construction, Operation, Testing, and
Environmental Impact

By
A.L. Stevens
R.L. Zahradnik
R.J. Kaleel¹

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Work Performed Under Contract No.: DE-FC20-78LC10036

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Laramie Projects Office
Laramie, Wyoming

By
Occidental Oil Shale, Inc.
Grand Junction, Colorado

MASTER

And
TRC Environmental Consultants, Inc.
Englewood, Colorado

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I. SUMMARY

Occidental Oil Shale, Inc. (OOSI) recently completed the demonstration of mining, rubblization, ignition, and simultaneous processing of two commercial-sized modified in situ (MIS) retorts at the Logan Wash facility near De Beque, Colorado. This work was conducted under Phase II of the Cooperative Agreement between the Department of Energy (DOE) and Occidental Oil Shale, Inc. Upon completion of Retort 6 in 1978, Occidental began incorporating all of the knowledge previously acquired in an effort to design two more commercial-sized MIS retorts. Any commercial venture of the future would require the ability to operate simultaneously more than one retort. Thus, Retorts 7 and 8 were developed during 1980 and 1981 through joint funding of the DOE and OOSI in Phase II.

Rubblization of the retorts produced an average rubble void of 18.5 percent in the low grade shale (17 gallons per ton) at the Logan Wash site. After rubblization, bulkheads were constructed, inlet and offgas pipes were installed and connected to surface processing facilities and liquid product handling systems were connected to the retorts. Extensive instrumentation was installed in cooperation with Sandia National Laboratories for monitoring the complete operation of the retorts. After pre-ignition testing, Retort 8 was ignited in December of 1981 and Retort 7 was ignited in January of 1982. The retorts were operated without interruption from ignition until mid-November of 1982 at which time inlet gas injection was terminated and water quenching was begun. Total product yield from the two retorts was approximately 200,000 barrels of oil, or 70 percent of the Fischer Assay oil-in-place in the rubblized rock in the two retorts.

Water quenching studies were conducted over a period of several months, with the objective of determining the rate of heat extraction from the retorts as well as determining the quantity and quality of offgas and water coming out from the quenching process. Data from these studies are also included in this Summary Report.

II. INTRODUCTION

For approximately ten years Occidental Oil Shale, Inc. (OOSI) has been engaged in modified in situ (MIS) process technology development. Occidental's philosophy in developing this process for producing oil from oil shale is to maximize the recovery of in-place oil while minimizing cost and environmental impacts.

Retorts 7 and 8 were partially funded by the DOE until August 1981, under Phase II of the Cooperative Agreement. The intent of the work conducted under this agreement between the DOE and Occidental was to prove the technical feasibility of the MIS process - specifically by operating two MIS retorts simultaneously. The objectives of Phase II as stated in the Cooperative Agreement were:

- a) Construct and simultaneously process two side-by-side large scale retorts (Retorts 7 and 8) formed by blasting to a horizontal free face.
- b) Develop mine stability data for commercial-size retorts.
- c) In addition to seismic and airblast measurements, tracer test data, air flow tests and active void volume determinations are to be performed on each retort rubblized.
- d) Conduct small scale start-up tests prior to ignition of Retorts 7 and 8. These tests shall be done on at least two of the quarter-sized retorts which are to be formed with participants' money.
- e) Develop and test advanced retort ignition systems. The system selected is to be considered reliable and safe.
- f) Collect, evaluate and report environmental data (portions of this objective DOE funded).
- g) Test special mining equipment such as a continuous miner/feeder breaker system (to be DOE funded).
- h) Test remote sensing equipment (instrumentation) in rubblized retort to be used to measure mine stability, rubble evaluation, start-up procedures (burner operation), retorting, and post burn evaluations (DOE funded).

DOE funding ended in August 1981 (termed the Discontinuance); however, participation of Sandia continued through the operation life of the retorts. Sandia operated a computer based data acquisition system on site which

permitted real time analysis of the retort operation and performance. A general review is given here of information up through August 1981, but this time period is covered in more detail in the Final Report for the Period June 1, 1979 through August 31, 1981, published in March 1982 as well as previous Quarterly and Annual Reports (Appendix H lists all of the reports issued under the Cooperative Agreement). The Final Report summarized Phase II work up through the Discontinuance including: mining and formation of Retorts 7, 8 and Room 8X, construction of processing facilities, installation of mine stability and processing instrumentation, collection and analysis of Retorts 7 and 8 core, execution of a mini-retort blast and ignition test program, and continuous environmental support. This report is referenced in this text as the Final Report and may be obtained through the DOE, Technical Information Center in Oak Ridge, Tennessee.

This Summary Report covers the work and accomplishments at Logan Wash as covered by the agreement from the Discontinuance through the completion of the Phase II tasks and the shutdown of Retorts 7 and 8. It is organized into five main sections: 1) introductory material, 2) discussion of Retorts 7 and 8, 3) discussion of the Mini Retorts, 4) discussion of environmental information, and 5) appendix support material. For brevity, the raw data discussed in the text have been placed in the appendices.

Phase II objectives a) through f) have been fulfilled as indicated by the described activities, data and results in this and previous reports. Testing of special mining equipment, element g), was not funded by DOE. The tests of instrumentation and remote sensing equipment, element h), that were funded by DOE and conducted during Phase II are discussed in this Summary Report and in previous reports.

III. CONCLUSIONS AND RECOMMENDATIONS

With the successful completion of Retorts 7 and 8 and the completion of Phase II, several conclusions can be drawn:

1. Conventional hard rock mining technology is applicable for access mining and void-room mining for MIS processing of oil shale.
2. The Occidental proprietary rubblization technology has been demonstrated to produce rubble beds in commercial-sized retorts with particle size and void distribution appropriate for successful ignition and processing.
3. Ignition procedures have been demonstrated for start-up of retorts both individually and sequentially in clusters.
4. Operating procedures have been demonstrated for controlling and operating a cluster of retorts (two or more) from a common underground manifold system and surface processing facility.
5. A water-spray offgas cooling system has been demonstrated that reduces the thermal load on the offgas handling system and significantly increases the productive life of the retorts.
6. A water quenching technique has been demonstrated for shutting down retorts. Cooling water injected at the top of spent retorts removes heat from the retorts and eliminates subsequent thermal degradation of the pillars. The quality of resulting offgas and water is improved.
7. The use of an emulsion breaker additive eliminates the need for a heater treater system for separation of bulk solids and water from the bulkhead oil.
8. A condensed light shale oil (C.L.S.O.) collected by the offgas handling system has properties similar to No. 2 diesel fuel and constitutes a premium product stream from the process.
9. Continuous environmental monitoring through the life of the project has shown a minimal impact of the MIS process on the environment.

Based on the conclusions stated above, Occidental Oil Shale, Inc. recommends that its Modified In Situ Technology be advanced to commercial application.

IV. RETORTS 7 AND 8

A. Chronology and General Configuration

Retorts 7, 8 and 8X were developed as a subset of a retort cluster and were operated simultaneously to demonstrate the commercial readiness of the MIS technology. Figure IV.A-1 shows the general configuration of these retorts. Retort 8X, a partial retort (165 feet square by 63 feet high), was developed to test pillar stability and rubblization and was not processed. Figure IV.A-2 shows the retort elevations relative to the shale grade histogram at Logan Wash. This figure also shows the three-void-level design that was used in these retorts.

Construction for Retorts 7, 8 and 8X was begun in June 1979. Mining was begun in August 1979, and the drilling of raises and instrument holes ran concurrent with the mining activities. The construction, void and access mining and drilling activities are covered in detail in the Final Report of August 1981, and are reviewed in general in this report. The Final Report also covers the blasting and rubblization program which began in November 1979 and ended in April 1981, with the rubblization of Retort 8. After the completion of the gas tap and thermocouple installation and the construction of the bulkheads and offgas handling systems, tests were run to determine the leak rates and pressure drops of the retorts. These tests are covered further in Section IV.C.

In late 1981 and early 1982, Retorts 7 and 8 were ignited. A detailed chronology is shown in Table I. After ignition the retorts were operated without interruption until gas injection was terminated and water quenching began in November 1982. In order to extend the life of the retorts, a plan was developed to cool the offgas and reduce the thermal load on the bulkheads and downstream processing equipment. This plan was implemented on both retorts as shown in Table I. The offgas was continuously cooled and the retorts were never shutdown because of the maximum offgas temperature being reached and, as a result, the life of the retorts was extended by about three months and oil yield increased accordingly. In early 1983, after the retorts had been in the quench cycle for several months, the blowers followed by the contact condensers were turned off when the retorts reached an oil production rate at which it was no longer

Figure IV.A-1.
General Configuration of Retorts 7, 8 and 8X.

Figure IV.A-2.
Elevation of Retorts 7 and 8 Relative to the Shale Grade Histogram

practical to operate and the natural draft was sufficient to handle the dwindling flow of gas from the spent retorts.

TABLE I
RETORTS 7 AND 8 CHRONOLOGY OF PROCESSING EVENTS

<u>Event</u>	<u>Retort 8</u>	<u>Retort 7</u>
Rubblization Blast	04-04-81	02-21-81
Ignition - First Attempt	12-20-81	01-13-82
- Interruption by Equipment Failure	12-21-81	01-15-82
- Second Attempt	12-22-81	01-25-82
- HIGG Off, Ignition Complete	12-25-81	01-29-82
First Oil Recovered	01-10-82	03-02-82
Steam Turned On (Design = 20% Steam)	01-22-82	02-13-82
Inlet Gas Increased to Design Flow Rate (0.54 scfm/ft ²)	03-15-82	03-15-82
Offgas Temperature Moved Above Steam Plateau	06-15-82	07-15-82
Offgas Cooling Spray Turned On	07-08-82	08-30-82
Injection Steam Removed	10-01-82	10-02-82
Air Flow Reduced	10-08-82	10-08-82
Recycle Gas Injection Started	10-15-82	10-21-82
Recycle Gas Injection Terminated and Water Quenching Started	11-09-82	11-19-82
Blowers Turned Off	01-07-83	01-07-83
Offgas Cooling Spray Turned Off	01-17-83	12-22-82
Contact Condensers Turned Off	02-28-83	02-28-83

B. Preparation And Construction

1. Access and Void Mining

Development of the rubbled oil shale beds in Retorts 7 and 8 required mining of access drifts and initial retort-void rooms at three levels (Upper, Intermediate and Lower void rooms). These levels were extensions of existing mining levels in the Logan Wash Mine, as shown in Figures IV.B-1, 2 and 3. Mining and associated raise boring and drilling activities were completed prior to the Discontinuance and an extensive discussion of these activities appears in the Final Report. To provide space for expansion of the rubble during blasting, approximately 23 percent of the total retort chamber volume was mined out in forming the void rooms for each retort. Access drifts were extended around three sides of both retorts at all three levels to

Figure IV.B-1. Retorts 7 and 8 Upper Level Access and Void Mining

Figure IV.B-2 Retorts 7 and 8 Intermediate Level Access and Void Mining

Figure IV.B-3. Retorts 7 and 8 Lower Level Access and Void Mining

permit extensive instrumentation emplacement in the retort rubble and pillars. Product Level access drifts were mined approximately 20 feet below the floor of the retorts, that is, below the floor of the Lower void levels. Five, eight foot diameter drawports were constructed from the retort floor down to the Product Level drifts under each retort prior to rubblization to permit withdrawal of product liquids and offgas from the retorts during processing operations. To provide for equipment access and good mine ventilation during mining, two entry drifts were mined into each void level room (except the Retort 7 Upper and Lower void levels) as shown in Figures IV.B-1, 2 and 3.

2. Rubblization

An extensive discussion of the rubblization blasting and associated activities is contained in the Final Report. A non-proprietary description of the rubblization design and results for Retorts 7 and 8 has been presented previously by T. E. Ricketts and is listed in the references of this report. The Rock Fragmentation Programs running concurrent with Phase II were funded solely by Occidental Oil Shale, Inc., and, consequently, the detailed analyses, data and results are proprietary. For continuity in this report a very brief description of the blasting events will be given here. These comments are also a summary of the paper entitled, "Rubblization of Occidental's Retorts 7 and 8" by T. E. Ricketts.

Blastholes were drilled into the pillars in the three void level rooms and into the two shale layers between the three void rooms, as shown in Figure IV.B-4. Explosives were placed in these holes and detonated in proper sequence to rubblize the rock and distribute the pillars in the void rooms immediately prior to the main rubblization blast, and to rubblize and expand the shale-layer rock into the void rooms. In this way the void in the three rooms was redistributed throughout the rubble, providing the necessary permeability for flow of process gases.

Results of the rubblization were essentially identical for the two retorts. Figure IV.B-5 shows the volumes of total rubble, rubble

Figure IV.B-4. Retorts 7 and 8
Rubblization Plan

Retorts 7 & 8 Postshot

Figure IV.B-5. Retorts 7 and 8
Rubblization Results

Figure IV.B-6. Retort 7
Rubble Surface Elevation
Contours

Figure IV.B-7. Retort 8
Rubble Surface Elevation
Contours

void, the average void fraction, and the plenum void for the two retorts. The slight differences between the two retorts were attributable to the elevation differences of the voids within the formation, as indicated in Figure IV.A-2. The average void fraction within the rubble of both retorts was about 18.5 percent (18.2 percent for Retort 7 and 19 percent for Retort 8), and each retort had an approximately 15 foot high plenum between the top surface of the rubble and the roof of the Upper void room. Surface elevation contours were established by surveys of 81 points (a nine by nine array) on the rubble surface in each retort. The average of the survey elevations gave the plenum void heights listed in Figure IV.B-5. The standard deviation from the average plane of the rubble surface was 2.6 feet for Retort 7 and 3.3 feet for Retort 8. The design void fraction was 20 percent with an estimated plenum height of 10 feet. Figures IV.B-6 and 7 show the surface elevation contours of the rubble bed surface for Retorts 7 and 8, respectively. The plenum served as the distribution chamber for the hot inert gases during ignition of the retorts.

3. Thermocouple and Gas Tap Installation

Wells were drilled into the retort rubble after rubblization for emplacement of thermocouples and gas taps to monitor the progress of the retort front during processing. The holes were drilled from access drifts through the pillar and into the rubble to the desired location and the drill pipe was left in place. Directional surveys were made of the drill pipes to establish their locations relative to the wellhead or flange in the access drifts.

Thermocouples were assembled around a 0.5 inch diameter stainless steel gas-sampling tube and the assembly inserted into the drill pipe to the desired depth. The annulus between the tubing and the drill pipe was filled with grout to prevent convective heat transfer within the assembly. Provision was made to avoid plugging the open end of the gas sampling tube with grout. Grout was also extruded into the annulus between the drill pipe and the surrounding pillar rock to seal gas leaks between the retort chamber and the mine access drifts.

Survey results of the drill pipes (combined with thermocouple and gas tap tubing lengths) provided an accurate location of each thermocouple and gas tap for subsequent mapping of temperature, pressure and gas composition distribution within the retort. Most of this work was completed prior to the Discontinuance and was reported in the Sixth Quarterly Report and the Final Report. Surveying of the wellhead locations in the access drifts, drilling the wells and grouting of the drill stems into the pillars were accomplished by Occidental. Directional surveying of the thermal wells, design, construction, assembly, installation, grouting of the thermocouple and gas tap assemblies into the wells, and calculation of the final thermocouple and gas tap locations were accomplished by personnel from the Sandia National Laboratories (SNL).

The distribution of thermocouples and gas taps in the retort rubble and walls is shown in Figure IV.B-8 and Appendix A. Each thermal well had a gas tap located at the distant point and several thermocouples distributed within the rubble and retort walls. The total number of thermal wells, gas taps and thermocouples in and around the retorts is given in the following table:

TABLE II
THERMOCOUPLE AND GAS TAP SUMMARY

	<u>Retort 7</u>	<u>Retort 8</u>
Thermal Wells Drilled Into Retorts	63	88
Gas Taps		
In Thermal Wells	60	85
At Walls	<u>19</u>	<u>18</u>
Total Gas Taps	<u>79</u>	<u>103</u>
Thermocouples		
In Cased Wells	337	495
In Uncased Wells		
Roof	72	72
Floor	18	18
Rubble Surface	<u>20</u>	<u>20</u>
Total Thermocouples	<u>447</u>	<u>605</u>

An example of thermocouple and gas tap coordinates is given for Well #8130 in Table III. The x, y and z coordinates of each thermocouple

Figure IV.B-8. Thermal Well Distribution, Vertical Cross-Section Through Retorts 7 and 8*

* Information for This Figure Supplied by Sandia and Occidental.

are given for each of the following: 1) relative to the wellhead of the thermal well, 2) relative to the geodesic coordinates and 3) relative to the reference point of each retort. That reference point is the upper northwest corner of the plenum of each retort, as shown in Figure IV.B-9. The reader should note that the Reference Coordinates are rotated about the z-axis, relative to the geodesic coordinates, 8.00 degrees for Retort 7 and 8.43 degrees for Retort 8 (as seen in Appendix A).

In Table III it is seen that Well #8130 contains five thermocouples, noted A1 through E5. A1 is the thermocouple furthest into the thermal well and the gas tap is located at the same location as thermocouple A1. The nomenclature of the thermal wells was developed by Sandia for inclusion in the computer data base and is described in Table III using #8130 as an example. Appendix A, provided by Sandia, gives a tabular listing of the survey results of thermocouples and gas tap locations for all thermal wells in Retorts 7 and 8. Thermocouple histories, provided later in this report, are referenced to the particular thermocouple and its location within the specific thermal well.

4. Bulkhead Installation

After rubblization it was necessary to construct bulkheads in the entry drifts into each void level room to isolate the two retorts from the mine access drifts. As seen in Figures IV.B-1, 2 and 3 there were a total of ten bulkheads. These bulkheads were constructed of steel and tied into the drift floor, roof and ribs with cement and rockbolts; and air leaks were sealed by a shotcreting technique. A more thorough description of the steel bulkhead construction and installation is given in the Final Report.

Two entry drifts were inaccessible after rubblization; therefore, it was necessary to construct barriers to flow between the retorts prior to rubblization. One was located between Retorts 7 and 8 at the Lower void level (see Figure IV.B-3) and the other between Retorts 8

Retorts 7 and 8

Figure IV. B-9. Reference Point Locations for Retorts 7 and 8

TABLE III

RETORTS 7 & 8 THERMOCOUPLE COORDINATE INFORMATION*

Retort 8
Level 1 (Upper Level)**
Thermal well number

Sandia Well ID #8130 Log ID #2
Azimuth: 354.95 Zenith: -20.92

	<u>X-REL</u>	<u>Y-REL</u>	<u>Z-REL</u>	<u>X-GEO</u>	<u>Y-GEO</u>	<u>Z-GEO</u>	<u>X-OXY</u>	<u>Y-OXY</u>	<u>Z-OXY</u>
A1	-21.74	109.15	-77.47	58405.98	22248.20	7801.23	2.66	38.59	28.06
B2	-18.52	101.71	-70.80	58409.20	22240.76	7807.90	3.30	40.97	26.03
C3	-13.23	87.32	-57.05	58414.48	22226.37	7821.65	4.25	45.55	21.84
D4	-8.93	72.47	-42.27	58418.80	22211.52	7836.43	4.88	50.22	17.34
E5	-5.98	56.50	-28.98	58421.73	22195.55	7849.72	5.05	55.17	13.28

Relative to well-head survey location in geodesic coordinate system. (Units = feet)

Relative to geodesic coordinates (X, Y - see Appendix B) and elevation above sea level. (Units = feet)

Relative to retort Reference Point⁺. (Units = meters)

* Well ID nomenclature developed by Sandia for inclusion in computer data base.

** 1 = Well drilled from Upper Level.

2 = Well drilled from Intermediate Level.

3 = Well drilled from Lower Level.

+ The Reference Point for the retorts is the upper northwest corner of each plenum (See Figure IV.B-16). The geodesic coordinates and elevations of the Reference Points are:

	<u>Retort 7</u>	<u>Retort 8</u>
North (ft.)	22,055.15	22,372.2
East (ft.)	58,423.19	58,378.8
Elevation (ft.)	7,893.6	7,893.3

and 8X at the Upper void level (see Figure IV.B-1). A low-cost flow barrier technique consisting of filling the drifts with sand, protected at each end of the drifts by mine-run rock, was used and found to be effective for processing operations. To be an effective barrier to gas flow, the sand must remain filled completely to the top of the drift throughout the blasting operation. When pre-ignition tests (see Section IV.C.1) were first attempted, it was discovered that the flow barrier was not functioning properly. A small reservoir of sand had been placed in a notch in the roof of the drift to accomodate settling of the sand in the drift. This resevoir of sand was inadequate and it was necessary to refill it with sand. Access was by drillholes already in place from the Intermediate Level instrumentation drift down to the notch. After refilling with sand, the pressure tests proceeded as planned.

Because leakage of retort gases was possible through the flow barrier from Retort 8 into Retort 8X, and also potentially through the barrier pillar 50 feet thick, a steel bulkhead was installed in the entry drift between the Retort 8X Upper void room and the Instrumentation Access Drift.

5. Surface Processing Facilities

a. General Process Train

Principle elements of the Surface Processing Facilities (SPF) are shown in the Process Flow Diagram, Figure IV.B-10. A plot plan for the SPF is shown in Figure IV.B-11. Fresh air blowers and a Steam Generation Plant supplied process air and steam to the retorts through pipes from the Surface. Other blowers, operating in the suction mode, pulled the process gases through the retorts and up the offgas raise. Control valves at the Product Level bulkheads permitted maintaining subatmospheric pressure within each retort, neutral at the Upper Level bulkhead, to eliminate leakage of retorting gases into the mine ventilation air. As the offgas reached the Surface it was pulled through a system of three contact condensers for condensing water and oil and adsorbing ammonia from the offgas. From there it passed through

Figure IV.B-10. Simplified Process Flow Diagram Showing Liquid and Gas Sampling Points

Figure IV.B-11. Plot Plan of Surface Processing Facilities

the blowers and into the stack where it was vented to the atmosphere in accordance with several permits.

b. Contact Condensers

The contact condensers were counter-flow direct-contact cooler absorbers used to cool the offgas upstream of the blower suction. Water and oil were condensed and water soluble components of the offgas were absorbed. The product liquids from the contact condenser were pumped to the hold-up tanks where the light oil and water separated by gravity. The light oil was co-mingled with the bulkhead oil for shipment off-site. The water was circulated through the fin-fan coolers for cooling and then recycled to the contact condensers. Excess condensed water was used in the boilers or disposed of elsewhere in accordance with applicable permits. The major permitted disposal was for dust control; however, some condensate was used in the Water Treatment Plant as described below.

c. Blowers

The blower system consisted of nine Sutorbilt positive displacement blowers. Eight of the blowers had been used during the operation of previous retorts at Logan Wash. The inlet and exhaust piping and manifolding systems were arranged so that both retorts could be fed fresh air and also either or both retorts could be fed recycle gas. The latter feature was employed in the later stages of operation of both retorts (see Table I).

d. Steam Generation

The Steam Generation Plant consisted of two Thermal-Sludge boilers, each with a capacity to raise 22,000 pounds per hour of steam at 1,100 psig drum pressure and 595° F, at a fuel consumption rate of about 250 gallons per hour of shale oil. The boilers were operated at a maximum of 600 psig, 595° F, and 20,000 pounds per hour each. In addition to the use of steam as a process gas, it was also used for heat tracing of process

pipng, instrumentation controls and sensors during the cold weather conditions. Excess capacity was used at certain times to dispose of excess process waters by discharging steam to the atmosphere. Boiler blowdown was stored in sumps within the mine and used for subsequent retort quenching.

e. Water Treatment Plant

A Water Treatment Pilot Plant was constructed adjacent to the Boiler Building to study techniques for treating process condensate water. The plant consisted of three sections: a steam stripper section, a biological oxidation section with clarifier and a carbon column section. It was sized to handle up to six gallons per minute. While the details of the Water Treatment Plant are proprietary, its basic operating scheme was the same as the Monsanto Plant described in Day, Desai, and Limerick. The main objectives of this treatment plant were to dispose of excess water (in accordance with permits) and develop data for use in future full-scale water treatment plant designs.

A permit was issued by the State of Colorado in early 1982 for the discharge of treated process water. The Water Treatment Plant was operated from May through November of 1982. Dischargeable water was produced for only a short time; however, these waters were discharged under the first NPDES permit ever issued for such waters. Retorts 7 and 8 were approximately half-way through the retorting process when operation of the Water Treatment Plant began. The plant, with the exception of the biological system, was brought on-line in the next month and a half. The increasingly refractory nature of the condensed water near the end of the retorting period made a steady state operation difficult to achieve. Despite these problems the biological oxidation unit was brought on-line in August and dischargeable water was produced in September 1982 which met the following State imposed criteria:

<u>Parameter</u>	<u>Limitation</u>
pH, s.v.	6.0 - 9.0
Oil and Grease, mg/l	10
Total Suspended Solids, mg/l	30/45
Chemical Oxygen Demand, mg/l	110
Total Organic Carbon, mg/l	50/100
Ammonia Nitrogen, mg/l	100
Phenol, mg/l	0.05

In addition to this pilot plant, the Monsanto Research Company, under contract to the U.S. Environmental Protection Agency, operated a small pilot plant on the Logan Wash site during the operation of these retorts. That pilot plant was constructed to treat up to two gallons per minute of process waters. In summary, the results of the Monsanto pilot plant test demonstrated that retort water contains ammonia, TKN, alkalinity, dissolved organics, phenols, sulfide, and TDS. Gas condensate contains high concentrations of ammonia, TKN, dissolved organics, alkalinity, phenols, and sulfide. Steam stripping was effective in removing ammonia and alkalinity from the retort water and ammonia, alkalinity, TKN, nitrate, soluble COD, soluble BOD₅, DOC, phenols, sulfide, and TSS from gas condensate. Detailed information on this pilot plant test is presented in Day, Desai and Limerick.

f. Process Control

The processing operation was monitored in and/or controlled from the Process Control Building located on the Surface, as shown in IV.B-11. Signals from all critical points within the process train were routed to the control panel and displayed in analog form. These signals were also run to the digital data acquisition system, discussed below, for recording and analysis to further evaluate current operating performance. Control of the process operating conditions was accomplished from the Control Room using current analog data and the analyses from the digital data displayed on a TV monitor in the Control Room.

g. Instrumentation

The instrumentation system sensors included differential pressure transducers, gauge pressure transducers and thermocouples used

for density-corrected flow measurements. Also included were in situ thermocouples and offgas and intra-retort gas analysis systems. A computer based data acquisition system recorded or monitored the temperatures within and around the retorts and made periodic measurements of primary variables throughout the processing system. The computer system and ancillary equipment were provided and operated by personnel from the Sandia National Laboratories. Access to the computer by Occidental's operating and engineering personnel was by remote terminals. Both Sandia and Occidental personnel performed analyses on the data throughout the operation of the retorts.

Frequency of measurements depended upon the anticipated rate of change of the variables. On-line analyses of offgas compositions were made continuously by specific-gas analyzers (oxygen in the offgas, for instance) and periodically by gas chromatographs. Operating conditions were then computed and displayed on TV monitors for timely process evaluation and controlled guidance. Thermocouple survey results were incorporated in the computerized data base for use in subsequent mapping of temperature, pressure and gas composition distributions within the retorts.

An extensive discussion of the Instrumentation Program for Phase II of the Cooperative Agreement is contained in the Final Report and will not be repeated here.

C. Pre-Ignition Testing

1. Pressure Tests

After completion of the thermocouple and gas tap installation and construction of the bulkheads and offgas handling systems, tests were run to determine the leak rates and pressure drops of the retorts. Results of these tests were used to establish safe and efficient operating conditions. To conduct the pressure tests each retort was closed at the bottom, pressurized to 5 psi (140 inches of water column, IWC) using the inlet blowers and held for a minimum of five minutes. All of the bulkheads were certified to have met this design criteria.

Leak tests were conducted first to locate and correct leaks that would cause uncertainties in subsequent pressure drop tests. While holding the pressure in the retorts at 2 psi or greater, leaks were identified. Leaks through cracks in the pillars were sealed by pressure grouting techniques.

The air leakage rate was determined by pressurizing the retorts to between 2 and 5 psi, shutting the retorts in and observing the rate of pressure drop within the retorts. The maximum acceptable leakage rate was established by a set upper limit of two percent oxygen in the combustible offgas during process operations. The cycle of leakage rate tests, pressure tests and sealing of leaks was repeated until the leakage rate criteria was met.

With suction blowers downstream from the retorts in the process gas stream, pressures in the retort chambers were subatmospheric during processing and any air leakage was from the mine access drifts into the retorts (pressure differentials were maintained neutral across the Upper Level bulkheads during retorting).

2. Cold-Flow Pressure Drop Tests

The pressure drop through the retort rubble and the mean pressure and leakage rate into the retorts were expected to increase as retorting progressed. For this reason and, also, because the maximum pressure capability of the blowers was limited, it was appropriate to determine the cold-flow pressure drop through the process flow system (including retorts). The hot-flow pressure drop in the retorts was then estimated from the cold-flow pressure drop by scaling in accordance with experience from previous retorts.

Pressure drop measurements were made for a series of cold-flow rates through the retorts using all pressure taps distributed throughout the rubble bed and at the Upper, Intermediate, Lower, and Product Level bulkheads. Figure IV.C-1 shows the pressure data, plotted as a function of depth into the rubble, for a cold-flow rate of approximately 12,000 standard cubic feet per minute, an inlet gas flow rate

Figure IV.C-1.
Typical Pressure
Drop Results, Retort
7, at 12,000 SCFM
Flow Rate

Figure IV.C-2.
Summary of Pressure
Drop Results in Top
200 Feet of Rubble

near that used during processing. The total pressure drop through the rubble of 18.5 percent void is on the order of one inch of water column from the Upper Level plenum to within 20 feet of the floor of the retort. Figure IV.C-2 shows the linear relationship between pressure drop and flow rate over the range of flow rates up to 16,000 scfm, as tested, from the Upper Level plenum to within 20 feet of the retort floor.

These same measurements, on the other hand, showed unacceptably high pressure drops from the lower region of the retort through the drawports into the product level drifts of both retorts. Corrective measures were taken to enlarge the drawports at the bottom of both retorts by explosive means. This increased the interface area between the rubble and the drawports and reduced the zone of turbulent flow in the region of converging flowlines in the rubble near the drawport exits. On Retort 7, for example, repeated total pressure drop tests were made for a succession of drawport-to-rubble interface areas. The results of these tests are shown in Figure IV.C-3 as total pressure drop versus outlet flow rate. If the flow rate is scaled by the ratio of original-interface-area to area-on-date-of-test, the data all collapse to a single curve, as shown in Figure IV.C-4. This result strongly suggests the large pressure drop problem was due solely to a mis-design (and not to nonuniform rubble properties) and can be readily corrected in subsequent retorts. Before ignition the total pressure drop in Retort 8 was approximately 10 inches of water column and in Retort 7 it was approximately 15 inches of water column at design inlet flow rates. During retorting the pressure drops increased to 50 inches of water column and 90 inches of water column for Retort 8 and Retort 7, respectively. These pressure drop histories over the life of the retorts are shown in Section IV.E (Retort Operations).

This pressure drop increase was expected due to: 1) an increase in flow of gases generated from both combustion and pyrolysis, 2) an increase in viscosity of process gases as the rubble bed temperature increases with retorting, 3) a decrease in effective permeability as liquid products compete with process gases for void space, and 4) a

RETORT 7

Figure IV.C-3. Outlet Drawport ΔP Versus Flow Rate for a Series of Drawport Enlargements

RETORT 7

Figure IV.C-4. Outlet Drawport ΔP Versus Flow Rate, Area Corrected

potential slight decrease in effective void space as the shale expands (exfoliates) during the retorting process. No evidence was found to suggest that the rubble beds slumped during retorting.

3. Tracer Tests

During the Retort 6 tracer tests and those performed on Mini-Retorts 3 and 4, it was found that when a short pulse of tracer gas was injected into the plenum, only very disperse or diluted tracer gas was detected lower in the rubble bed. The dispersion was believed to be the result of extensive mixing and dilution in the plenum. As a result, tracer gas was injected below the rubble surface in all of the tracer tests for Retorts 7 and 8. Sulfur hexafluoride (SF_6) was used as a tracer in all tests. The air flow rate was maintained approximately constant at 16,000 SCFM during all tests.

Each retort was tracer tested in three test sequences:

1. Upper Level to Intermediate Level
2. Intermediate Level to Lower Level
3. Upper Level to Lower Level

In each sequence, tracer gas was injected into a single gas sampling tap while an array of taps were sampled at the Lower Level. The array was selected to obtain space time velocities and to measure the lateral as well as longitudinal flow through the retort. Wall taps were used to determine the degree of channeling that could be expected along the walls of the retorts. Data taken during these tracer test operations and a cursory analysis of the data are included in Volume II for both Retorts 7 and 8. Although a significant number of tests were conducted, a definitive analysis of the test data was abandoned in favor of mapping the flow pattern by the steam front.

An alternate analysis of the tracer data given in Volume II was made, however, in an attempt to ascertain the permeability distributions in both retorts. The results are shown in Figures IV.C-5 and IV.C-6 for Retorts 7 and 8, respectively. In each figure the percentage of total flow passing down through each of the sixteen

Figure IV.C-5. Flow Distribution (Percent of Total Flow) within Retort 7

Figure IV.C-6. Flow Distribution (Percent of Total Flow) within Retort 8

sections (denoted A through P) is shown in the respective section; further, the upper half and lower half of each retort are analyzed separately. Since the total number of tracer tests was relatively few (compared to the number that could have been made using all available gas taps) a computerized curve fitting technique was used to interpolate between available data points. The results show the higher permeability along the walls of the retorts, and the disproportionately high permeability in the corners of the retorts where rubble escaped during the rubblization events.

D. Retort Ignition

The objective of the ignition phase is to establish a combustion zone at the top surface of the rubble which will be propagated downward through the rubble column during the subsequent processing phase. Ignition must be accomplished in a safe and sure manner with minimum use of time and external energy. The basis for retort start-up procedures was developed through a series of laboratory tests, laboratory pilot plant experiments and Mini-Retorts 3 and 4. The resulting procedures were successfully tested on Mini-Retort 1 in September 1981 and described in Section V.

1. Ignition System

The basis for the retort start-up procedures was developed through a series of laboratory tests and laboratory pilot plant experiments; and the resulting procedures were successfully tested on Mini-Retort 1 in September 1981 (see Section V, Shen and Zahradnik, and Hommert). These simple procedures call for uniform heating of the top surface of the retort rubble to ignition temperature using an external heat source. When the ignition temperature is achieved, oxygen (air) is gradually introduced to transition from the external heat source to direct combustion within the rubble and then the external heat source is turned off.

Retorts 7 and 8 were ignited using a Hot Inert Gas Generator (HIGG), manufactured by the John Zink Company, as the external heat source. The general configuration of the HIGG and retort plenum is shown in

Figure IV.D-1. The HIGG is a horizontal, cylindrical, fire-brick lined apparatus utilizing a John Zink HIV burner, EA-7 oil gun and a John Zink designed quench water system. The HIGG was designed to deliver inert gas (i.e. exhaust gas with less than 0.5 percent oxygen) at about 1600° F to the retort plenum through the exhaust or flue gas distributor pipe shown in the figure. With proper design of the outlet section of the flue-gas pipe, the plenum is caused to act as a completely stirred tank for distributing the hot gas uniformly over the rubble surface. The operating characteristics of the HIGG are given in Table IV. When the ignition temperature of the rubble is achieved, oxygen (air) is gradually introduced into the plenum to make the transition from the external heat source to direct combustion within the rubble; then the HIGG is turned off.

TABLE IV
HIGG OPERATING CHARACTERISTICS

Fuel	Shale oil or diesel
Fuel Flow Rate	13 gpm, maximum
Combustion Air	18,500 SCFM, maximum
Firing Rate	20 to 106 million BTU/hr.
Flue Gas O ₂ Content	0.5 to 15 percent
Quench Water	85 gpm, maximum
Flue Gas Temperature Range	300° F to 1600° F

The temperature of the exhaust gas can be varied from 300° F to 1600° F through the use of a quench water system which injects water into the vessel through spray nozzles. The flow of water can be adjusted over the appropriate range to arrive at the desired exhaust gas temperature.

The HIGG control system governs both the oil and air valves to achieve the desired firing rate and the oxygen percentage in the exhaust gas. Typically the oxygen can be controlled to less than 0.125 percent. The system also includes a temperature controller that controls the quench water valve and indicates the temperature of the exhaust gas. The principle steps of the start-up plan are given in Table V.

HIGG AND PLENUM

Figure IV.D-1. Configuration of the Hot Inert Gas Generator (HIGG), Retort Plenum and Distributor Pipe.

TABLE V
RETORT START-UP PLAN

<u>Step</u>	<u>Time Required (Hours)</u>	<u>HIGG</u>	
		<u>Firing Rate</u>	<u>Outlet Temp. (°F)</u>
1. Heat-Up* (2% excess oxygen)	18 - 20	Maximum	1600° F
2. Oxygen Step-Up* (5-10-15% oxygen)	4 - 6	Maximum	1600° F
3. Full Oxygen	24	HIGG off	100% air
4. Plenum Cooling	24	Minimum	300° F
5. Retorting	Steady State	HIGG ready to move	

* In these steps, when retort offgas analysis indicates oxygen is being consumed by combustion, advance to next step.

Steps 1, 2 and 3 are required to ignite the rubble and establish a combustion zone of some thickness in the top layer of the rubble. At the same time, the walls and roof of the plenum are also retorting and burning. Step 4 cools the walls and roof and drives the combustion zone below the surface of the rubble, without dropping the peak temperature below the re-ignition temperature. Step 5 re-establishes the combustion zone and retorting progresses into a steady state.

2. Ignition Results

A chronology of events during the ignition of Retorts 7 and 8 is given in Table I. As indicated, operational upsets were experienced during the ignition of both retorts. About 20 hours after starting the HIGG on Retort 8 mechanical problems with the blower system were experienced which required two days to correct. During this period the quantity of heat resident in the plenum caused the plenum roof to slough. Nevertheless, after repair of the blower system, Retort 8 was successfully ignited.

In Retort 7 approximately 10 feet of the plenum roof fell onto the rubble surface in September 1981. Pilot plant tests indicated

that start-up procedures would be stretched only a few hours by this occurrence. Several hours after starting the HIGG on Retort 7 leaks were discovered caused by corrosion in the flue-gas pipe between the HIGG and the plenum, which required shutdown. Replacement of this stainless steel pipe required 10 days, during which additional sloughing of the plenum roof occurred. As in Retort 8, after repair of the problem, Retort 7 was successfully ignited.

Histories of various HIGG operating parameters measured and recorded during the ignition of both retorts are displayed in Figures IV.D-2 through IV.D-9 for Retort 7 and IV.D-10 through IV.D-17 for Retort 8. As verified by these figures, the plenum cooling step of the Start-Up Plan was not exercised on either retort. This was a direct result of the equipment problems that occurred during start-up of both retorts.

E. Retort Operation

1. Inlet and Offgas Flow Data

After ignition, the retorts were operated without interruption until gas injection was terminated and water quenching began in November 1982. A chronology of the significant milestones during processing is given in Table I. Figure IV.B-17 shows a simplified process flow diagram for operating the retorts. Air and steam were fed to the retorts through the inlet pipes from the Surface. The design conditions for total inlet flows to Retorts 7 and 8 were identical at a superficial gas velocity of 0.54 scfm per square foot. The design set point for steam injection was 20 percent by volume of the total inlet flow rate. Based on a 160 feet by 160 feet cross-section of the retort in the rubble region between the mined void rooms, this gives inlet flow rates of 11,200 SCFM of air and 2,800 SCFM of steam. These set-point levels are shown as heavy dashed lines in Figures IV.E-1 and IV.E-2. During early operation of both retorts the inlet flow rates were below these design conditions because of the difficulties in establishing a uniform ignition front after the equipment failure during start-up. However, starting in early March these design conditions were maintained until implementation of the

Figure IV.D-2. HIGG Combustion Air Flow Rate History, Retort 7

Figure IV.D-3. HIGG Fuel Flow Rate History, Retort 7

RETORT 7 BURNER WATER IN GPM

Figure IV.D-4. HIGG Quench Water Flow Rate History, Retort 7

RETORT 7 BURNER ATOMIZING AIR SCFM

Figure IV.D-5. HIGG Fuel Atomizing Air Flow Rate History, Retort 7

RETORT 7 BURNER FLUE GAS O2

Figure IV.D-6. HIGG Flue Gas Oxygen Content History, Retort 7

Figure IV.D-7. Flue Gas Temperature at HIGG Burner Discharge, Retort 7

RETORT 7 BURNER TIP1 TEMP IN DEG F

Figure IV.D-8. Flue Gas Temperature at Distribution Pipe Tip 1, Retort 7

Figure IV.D-9. Flue Gas Temperature at Distribution Pipe Tip 2, Retort 7

Figure IV.D-10. HIGG Combustion Air Flow Rate History, Retort 8

Figure IV.D-11. HIGG Fuel Flow Rate History, Retort 8

RETORT 8 BURNER WATER IN GPM

Figure IV.D-12. HIGG Quench Water Flow Rate History, Retort 8

Figure IV.D-13. HIGG Fuel Atomizing Air Flow Rate History, Retort 8

RETORT 8 BURNER FLUE GAS O2

Figure IV.D-14. HIGG Flue Gas Oxygen Content History, Retort 8

RETORT 8 BURNER DISCHARGE TEMP IN DEG F

Figure IV.D-15. Flue Gas Temperature at HIGG Burner Discharge, Retort 8

RETORT 8 BURNER TIP1 TEMP IN DEG F

Figure IV.D-16. Flue Gas Temperature at Distribution Pipe Tip 1, Retort 8

RETORT 8 BURNER TIP2 TEMP IN DEG F

Figure IV.D-17. Flue Gas Temperature at Distribution Pipe Tip 2, Retort 8

Figure IV.E-1. Inlet Air and Steam Flow Rate Histories for Retort 7

Figure IV.E-2. Inlet Air and Steam Flow Rate Histories for Retort 8

end-game plan. Figures IV.E-1 and IV.E-2 show the actual inlet and air/steam flow rate histories for Retorts 7 and 8, respectively. Figures IV.E-3 and IV.E-4 show the offgas flow rates for Retorts 7 and 8, respectively, at the Product Level bulkheads on a wet basis. The pressure histories at the bulkheads at the Upper Level, Intermediate Level, Lower Level, and Product Level for Retorts 7 and 8, respectively, are shown in Figures IV.E-5 and IV.E-6. Figures IV.E-7 and IV.E-8 show the offgas temperature histories for Retorts 7 and 8, respectively. Stack flow rates are shown in Figure IV.E-9.

As seen in the offgas temperature histories, about halfway through the processing life of the retorts the offgas temperature began to rise above the steam plateau. This increase in offgas temperature occurs in any retort (even one with an ideal flat reaction front and uniform permeability) with concentrated or localized offgas draw-ports. It is accentuated in cases where the reaction front is non-uniform and has been observed in previous field retorts. When the offgas temperature rises above the safe limit for maintaining structural integrity of the Product Level bulkheads (about 250° F) the retort processing must be terminated. This generally results in a significant reduction in sweep efficiency and, therefore, a loss in total retort production.

In order to extend the production life of Retorts 7 and 8, an end-game plan was developed to cool the offgas and reduce the thermal load on the bulkheads and downstream processing equipment while continuing to drive the retorting zone toward the floor of the retort. The plan consisted of the following elements:

1. Utilize a water spray system to cool the offgas in the drifts behind the bulkheads;
2. Reduce or eliminate steam in the inlet gas;
3. Reduce the inlet flow rate; and
4. Inject recycle gas instead of air.

The principal objective of the plan was simply to cool the offgas using the water spray system (element 1). If the spray system were of insufficient capacity to cool the quantity of offgas delivered to

RETORT 7 OFF GAS FLOW SCFM

Figure IV.E-3. Offgas Flow Rate History for Retort 7

RETORT 8 OFF GAS FLOW SCFM

Figure IV.E-4. Offgas Flow Rate History for Retort 8

Figure IV.E-5. Pressure Histories at the Upper, Intermediate and Product Level Bulkheads for Retort 7.

Figure IV.E-6. Pressure Histories at the Upper, Intermediate, Lower, and Product Level Bulkheads for Retort 8

RETORT 7 OFF GAS TEMP

Figure IV.E-7. Offgas Temperature History, Retort 7

RETORT 8 OFF GAS TEMP

Figure IV.E-8. Offgas Temperature History, Retort 8

OFF GAS FLOW UP STACK

Figure IV.E-9. Stack Flow Rate History

the Product Level drift, then the offgas flow rate could be reduced by reducing the inlet air and/or steam flow rates (elements 2 and 3). Finally, element 4, the injection of recycle gas (i.e., gas without oxygen) stops the generation of the heat of combustion within the retort and, further, would avoid any breakthrough of oxygen that might ultimately occur with air injection. The plan was implemented on both retorts as indicated in Table I and in Figure IV.E-1 and IV.E-2. The reduction in the total inlet flow rate for both retorts in early October was necessary when the capacity of the contact condensers to remove sufficient hydrocarbons from the offgas was exceeded.

As seen in the offgas temperature histories, the offgas was continuously cooled to about 180° F. The retorts were never shutdown because of reaching an unacceptable offgas temperature at the Product Level bulkheads and, as a result, the life of the retorts was extended about three months and the oil yield increased accordingly. This was particularly important for Retorts 7 and 8 because the richer mahogany zone was in the bottom half of the retorts, as seen in Figure IV.A-2.

2. Retort Thermocouple Temperature Histories

Retort rubble and wall thermocouples - With the retorts ignited and operating, progress of the reaction front down through the retorts was monitored by the thermocouples emplaced in the thermal wells. As indicated in Table II, over 800 thermocouples in thermal wells were monitored during the operations of these two retorts. The records of these thermocouple histories are included in Appendix B. Figure IV.E-10 shows a typical thermocouple history. The nomenclature designating the temperature record for the specific thermal well and thermocouple sensor with reference to the coordinates given in Appendix A is shown in Figure IV.E-10.

Retort Roof Thermocouples - Four thermocouple wells were drilled from the surface down through the overburden into the plenum of each retort. The locations of these wells are shown in Figure IV.E-11.

Figure IV.E-10. Thermocouple Record Nomenclature Definition

Figure IV.E-11. Plan Locations of Thermocouple Strings in Retort Roofs

Eighteen thermocouples were grouted into each of these wells above the plenum. The locations of each thermocouple, relative to the reference point coordinates, are given in Appendix A. The design, procurement, assembly, installation, and grouting of these eight thermocouple strings were accomplished by Sandia and the temperature histories of these thermocouples are given in Appendix C. Nomenclature of these thermal histories follows that of the thermal histories of the retort rubble and walls given in Figure IV.E-10 and Appendix B.

3. Underground Liquid and Offgas Handling

Two primary process streams were involved in the operation of Retorts 7 and 8 and required extensive sampling.

The first of these was the offgas handling system which consisted of seven Sutorbilt positive displacement offgas blowers pulling offgas, under negative pressure, from the bottom of each retort through steel pipes 36 inches in diameter into a common steel-cased raise to the Surface. The offgas traveled through a parallel arrangement of three graduated contact condensers into the blower header and was then discharged into the stack through another header.

The second process stream was the liquid handling system. Oil and water were collected at the lowest level of the retort in a sump behind the bulkhead. The liquid was then pumped outside the mine to a three compartment separator tank. From the separator, water was pumped to a process sump where it could be re-used. Oil was piped from the separator to a Heater Treater facility where it was stored for shipment. The design basis for Retorts 7 and 8 called for the use of a Heater Treater system to complete the separation of bulk solids and water (BS&W) from this oil stream. Tests of demulsifiers at varying rates early in the retort run showed that BS&W separation from the product stream could be accomplished without using the Heater Treater. By introducing a small quantity (0.2 percent by volume) of demulsifier into the oil as it left the Product Level bulkheads, the BS&W was reduced to 0.1 percent by volume (typical) by the time it went through the first oil/water separator tank.

The location of all of the sample points for this program are shown on Figure IV.B-10 and are explained below. Numbers in brackets [] indicate sample points shown in the figure.

a. Liquid

Two process liquid streams, oil and water, were sampled.

Oil - Raw oil and dry product oil were pulled for analysis each 1,000 barrels of production. Raw oil samples were pulled at the outlet of Tank 6 oil/water separator [1]. Dry product oil samples, representative of our shipped product, were taken from the truck loadout line [2] after the elimination of the Heater Treater. Condensed light oil was sampled from the product line coming off the holdup tanks [3]. These samples were pulled weekly. Additional random samples were taken from the liquid condensate in the bottom of the offgas raise [4] and the refrigerated condensate from the gas chromatograph conditioning systems [4, 5, 6]. Proportional mixing of the unit production samples provided composite aliquots representative of the entire retorting phase.

Water - The water portion of the schematic was generally sampled weekly with a few special items pulled monthly. The liquid off-gas condensate was analyzed from four different locations: base of the offgas raise [4], suction blowers drainage tank [7], base of the stack [8], and the holdup tanks [9].

Separate categories were derived to provide coverage for the steam plants to include feedwater [10] and continuous boiler blowdown [11], as well as monthly boiler blowdown special analyses [11] and monthly condensed steam analysis [12].

b. Gas

Stream sampling was accomplished by two methods: gas chromatographic and isokinetic sampling.

Gas Chromatographic (GC) - The offgas from each retort was sampled and analyzed four times per day for H₂, N₂, O₂, Ar, CO, CO₂, and light hydrocarbons. Once per day the H₂S and

COS were analyzed in each offgas stream [5, 6]. No CS₂ was detected in the offgas although it had been in previous retorts. Once a day a comparison analysis was taken from the offgas raise underground to represent the combined retort flow [4]. Similarly, samples were to be taken from the stack on an even more frequent schedule to provide emission levels. In practicality, however, equipment limitations virtually eliminated the surface stack sampling (except for some sulfur runs) [8]. The equipment used for this work was mostly HP 5830, HP 5730 and HP 5880 gas chromatographs with flame ionization detectors and with automatic gas sampling from a conditioned, continuous slipstream from the retort offgas duct. This slipstream passed through a multi-post sampling valve which was manually changed at the designated time intervals.

Isokinetic - The isokinetic sampling was designed to provide "loading" figures for both oil and H₂O aerosol, as well as ammonia levels as a basis for emission computations. These samples were normally done three times per week underground at the two bulkheads [5, 6] and daily at the stack [8]. Random samples were also pulled from the top of the offgas raise [13] and exit pipe from each of the three contact condensers [14]. During performance tests, a special set of isokinetic samples was drawn from the last four locations and from the offgas raise. These served as a base point for determining individual and composite contact condenser performance in relation to emissions removed.

4. Offgas Properties

Gas samples were taken by on-line gas chromatographs at several points along the offgas train, as shown in process flow diagram of Figure IV.B-17. At the Product Level samples were taken at the individual offgas lines from Retort 7 and Retort 8 and at the base of the offgas raise after the offgas from Retort 7 and Retort 8 was combined. At the Surface samples were taken from the top of the raise and at the base of the stack. Table VI shows the type of off-gas constituents measured and the make and model of the gas chromatograph used for the measurement.

TABLE VI
ON-LINE GAS CHROMATOGRAPH EQUIPMENT

<u>GC Make and Model</u>	<u>Constituents Measured</u>	<u>Detector</u>	<u>Sample Points Locations</u>
HP 5880 HP 5830	Hydrocarbon species and H ₂ , N ₂ , O ₂ , CO, CO ₂ , Ar	FID	Offgas line, R7; Offgas line, R8; Base of Raise (combined)
HP 5700 (Modified)	Sulfur species H ₂ S COS, CS ₂	FPD	Offgas line, R7 and R8 Base of Raise (combined)
HP 5730	Sulfur species H ₂ S, COS, CS ₂	FPD	Top of raise Stack
Perkin Elmer	Hydrocarbon species and H ₂ , N ₂ , O ₂ , CO, CO ₂	FID	Top of raise Stack

Table VII shows the list of constituents that were measured by these instruments. Plots showing the composition of the offgas as a function of time through the life of the retort are given in Appendix D. In observing the data on sulfur in the offgas it can be seen that the sulfur (H₂S and COS) increases gradually until "steady state" is attained, about halfway through the life of the retorts. No other sulfur species were detected. The composition and injection rate of the inlet changed (air/steam to air only to recycle gas) beginning early October (see Table I). The offgas compositions reflect these changes.

TABLE VII
OFFGAS CONSTITUENTS MEASURED
BY GAS CHROMATOGRAPHY

Hydrogen	Methane	Butane
Nitrogen	Ethene	Trans-Butene
Oxygen	Ethane	Isobutane
Argon	Propene	Pentane
Carbon Monoxide	Propane	Isopentane
Carbon Dioxide	Butene	Hydrogen Sulfide
		Carbonyl Sulfide

The modified EPA Isokinetic Method 5 was used for determining the aerosol loading at sample points along the offgas train (Reference: Determination of Particulate Emissions from Stationary Sources; Federal Register, V42, #160, Thursday, August 18, 1977, page 41,754 to 41,789). Results from these isokinetic measurements are also given in Appendix D. It should be noted that the "condensable organics" shown in Appendix D represent only the hydrocarbon species collected from the first three traps of the isokinetic apparatus and do not include the uncondensed hydrocarbons trapped in the silica gel dryer material of the final trap nor those that may have passed through all the traps.

Finally, the ammonia content of the offgas is also shown in Appendix D. The reader should be reminded that offgas was recycled into the retort inlets starting in mid October, at which time the offgas compositions changed significantly.

5. Product Oil Properties and Production Histories

Oil Properties - Table VIII lists the average properties of the dry bulkhead oil and the condensed light oil over the duration of the run. That is, each sample was made up of a composite of one-gallon samples from each 1,000 barrels of production. Also shown are the properties of the whole oil, a proportional composite of the dry bulkhead oil and the condensed light oil.

The following data summarizes the oil properties for Retorts 7 and 8. The Whole Oil is the proportioned composite of Dry Bulkhead Oil and Condensed Light Oil. (Samples of the Dry Bulkhead Oil and Condensed Light Oil were analyzed individually; a separate sample of the proportioned composite Whole Oil was also analyzed.) Samples of oil from the two individual retorts were not collected - only samples after the oil/water separation had occurred in the common separator tank.

TABLE VIII
RETORTS 7 AND 8 OIL PROPERTIES

<u>Parameter</u>	<u>Units</u>	<u>Dry Bulk- head Oil</u>	<u>Condensed Light Oil</u>	<u>Whole Oil</u>
API Gravity, 60°F	°API	23.5	37.1	24.8
BS&W	%	0.1	0.1	0.1
Fire Point				
Cleveland Open Cup	°F	275	185	260
Flash Point				
Cleveland Open Cup	°F	260	180	240
Pensky-Martin	°F	211	143	190
Gross Heating Value	BTU/lb	18,400	18,900	18,600
Pour Point	°F	25	-30	25
Viscosity, Kinematic				
100°F	CST	28.17	1.90	18.20
140°F	CST	11.22	1.34	8.09
Arsenic	µg/g	12	2.8	12
Asphaltenes	%	0.4	0.03	0.4
Carbon, Total	%	83.2	85.3	84.8
Hydrogen, Total	%	11.8	12.7	12.0
Nitrogen, Total	%	1.5	1.0	1.5
Sulfur, Total	%	0.85	0.51	0.83
Oxygen (by difference)	%	1.1	0.5	0.9
Mercury	µg/g	0.08	0.14	0.12
Nitrogen, Kjeldahl	%	1.4	0.8	1.3
Ash	%	0.03	0.005	0.03

Because the oil shale grade changes with depth in the retorts (the Mahogany Zone was in the bottom half of the retorts) and the average temperature within the retort and of the offgas changes over the life of the retorts, several of the properties of the oil also changed with time. Histories of these properties over the life of the retorts are given in Appendix E.

Analyses of the condensed light shale oil collected by the contact condensers showed it to have properties very similar to No. 2 diesel fuel (see Table IX). This product was tested in diesel powered mine equipment and found to function very satisfactorily without any adverse effects on the equipment.

TABLE IX
C.L.S.O./#2DF COMPARISON

<u>Property</u>	<u>C.L.S.O.</u>	<u>#2DF</u>
API Gravity, 60°F	37.1	32.8
BS&W	0.1	0.1
Flash Point, P.M., °F	145	168
Gross Heating Value, BTU/#	18,756	18,974
Pour Point, °F	-30	-10/+20
Kinematic Viscosity at 100°F	1.90	5.54
Total Sulfur, Wt.%	0.50	0.44
Total Nitrogen, Wt.%	0.8	0.233
Ash, Wt.%	0.005	0.000

C.L.S.O. = OXY Analysis

#2DF = Military Specs

Production Histories - The combined oil recovery from both retorts totalled 200,110 barrels (as of June 30, 1983), representing about 70 percent yield of the Fischer assay oil-in-place in the rubblized rock. (The reader should note that oil production continued at a low and decreasing rate after quenching was initiated.) The definition of yield used here has been used previously by Occidental and others for evaluating MIS retorts. The definition is based on the oil-in-place in the target rubble in the retorts, that is, the rubble produced by the explosive rubblization process. The target rubble includes pillar rubble as well as shale layer rubble (see Figure IV.B-4). The definition does not account for oil residing in the roof slough rock, nor in the retort walls that enters into the total process.

Total oil production includes oil pumped from the retort bulkheads, oil mists and vapors condensed in contact condensers, condensable C₅+ vapors found in the stack gas and a small amount of oil in the bulkhead water. The partitioning of the total product between these four streams is shown in Table X together with other data.

TABLE X

PARTITIONING OF PRODUCT OIL
(barrels, retorting results, data as of June 30, 1983)

	<u>Retort 7</u>	<u>Retort 8</u>	<u>Total</u>	<u>of Total</u>
Bulkhead Oil	60,630	61,205	121,835	60.9
Condensed Light Oil	7,842	11,061	18,903	9.5
Uncondensed Light Oil	22,687	32,002	54,690	27.3
Oil in Water	1,942	2,740	4,682	2.3
	<u>93,101</u>	<u>107,008</u>	<u>200,110</u>	<u>100.0</u>
Oil-in-Place, barrels	142,200	140,100	283,300	
Yield, % FA	65.0	76.4	70.6	

Cumulative production curves for each retort, in addition to the total, are shown in Figure IV.E-12. Bulkhead oil production is, of course, directly measureable for each retort. The production rates measured after combining streams from both retorts (i.e., light shale oil from the contact condensers, uncondensed C₅+ lost to the stack and oil in the process waters) were partitioned between Retorts 7 and 8 in accordance with the isokinetic sampling results from the offgas at the exit from each of the Product Level bulkheads. These partitioned values were added to the respective bulkhead production to arrive at the curves for Retorts 7 and 8. Additional details about the production are included in Stevens and Zaradnik.

6. Material and Energy Balances

Material and energy balances covering the start-up and operation of Retorts 7 and 8 are included in Tables XI and XII. They include the period from the beginning of start-up to the end of inlet gas flow for both retorts (see Table I for chronology of events). The removal of heat from the retorts during the quenching process is discussed in the next section.

F. Shutdown

Quenching of the retorts began in mid-November 1982, as indicated in the table of chronologic events. The purpose of quenching was twofold:

Figure IV.E.12. Cumulative Total Production

TABLE XI
SULFUR, CARBON AND WATER BALANCES

RETORTS 7 AND 8 SULFUR BALANCE

Sulfur in place = 3,600 tons in raw shale	
Sulfur in products - oil	180 tons
- water	10 tons
- gas	920 tons
- spent shale (by difference)	2,500 tons

RETORTS 7 AND 8 CARBON BALANCE

Carbon in place = 89,000 tons in raw shale (60% organic/40% inorganic)	
Start-up fuel - diesel - 310 tons	
Carbon in product - gas (59% from organic C/ 41% from inorganic C)	55,000 tons
- oil	23,000 tons
- water	610 tons
- spent shale (by difference)	11,000 tons

RETORTS 7 AND 8 WATER BALANCE

Water in - steam	43,000 tons
- ground water	8,300 tons
Water in place (before rubbing blast)	9,800 tons*
Water generated - diesel combustion	420 tons
- oil combustion	12,000 tons*
Water out - water vapor	101,000 tons
- liquid water	8,600 tons

* Estimate

TABLE XII
ENERGY BALANCE

RETORTS 7 AND 8 ENERGY BALANCE SUMMARY

Energy in place (in rubbled rock) - $1,700 \times 10^9$ BTU*

Usable energy out - oil aerosol and vapor 320×10^9 BTU

- shale oil 680×10^9 BTU

- offgas 770×10^9 BTU

$1,770 \times 10^9$ BTU

$$\% \text{ of in place energy recovered} = \frac{1,770 \times 10^9 \text{ BTU}}{1,700 \times 10^9 \text{ BTU}} \times 100 = 104\%$$

Energy required for processing retort - start-up fuel 12×10^9 BTU

- steam generation 170×10^9 BTU

- electricity 90×10^9 BTU

TOTAL 272×10^9 BTU

$$\text{Operating energy efficiency} = \frac{(1,770 - 272) \times 10^9 \text{ BTU}}{1,700 \times 10^9 \text{ BTU}} \times 100 = 88\%$$

Energy required for constructing retort - explosives 1.8×10^9 BTU

- mining and constructing** 7.2×10^9 BTU

- drilling** 3.9×10^9 BTU

- retort equipment** 3.0×10^9 BTU

- mine equipment** 6.0×10^9 BTU

TOTAL 21.9×10^9 BTU

$$\text{Overall energy efficiency} = \frac{(1,770 - 210 - 22) \times 10^9 \text{ BTU}}{1,700 \times 10^9 \text{ BTU}} \times 100 = 84\%$$

* Does not account for retorting penetration into walls or roof-slough rock.

** Note: Energy required for mining, construction, drilling, and equipment based on data published by Cha and Garrett, "Energy Efficiency of the Garrett In Situ Oil Shale Process," 8th CSM Oil Shale Symposium, April 1975.

- 1) to cool the retorts quickly and reduce the transport of heat into the mine pillars, thus improving mine stability in a multi-retort design and
- 2) to utilize surplus water during the cooling process.

Surface air inlet pipes were used for water injection into Retort 8. Holes were drilled from the Upper mine level into the top of the spent rubble pile in Retort 7. Both means of water injection were effective and simple to use. An extensive analysis of the initial quenching operations, indicating the heat removal rate and water quality monitoring results have been presented by Hester and Jacobson.

G. Mine Stability

The Bureau of Mines (Twin Cities, MN) performed tests at Logan Wash prior to and after rubblization of Retorts 7 and 8 to make an "explosive damage assessment for in situ retorting of oil shale". They used a cross-borehole acoustic technique, where signals were transmitted through the rock from one borehole to another along a path parallel to the rubble/wall interface. No report has been issued by the Bureau of Mines on this work.

The Rock Mechanics Instrumentation Program for Retorts 7, 8 and 8X utilized Terrametrics, Inc. multiple position rod extensometers (REX) and Irad Gage, Inc. vibrating wire stressmeters in various locations above and between Retorts 7, 8 and 8X. The majority of this instrumentation was installed in early 1980 and has been monitored at various intervals since that time. All instrumentation holes (REX and Irad, surface and underground) were grouted at least twenty feet in compliance with the Retorts 7 and 8 Mine Safety and Health Administration (MSHA) variance.

Figures IV.G-1 and IV.G-2 show a cross-section of Retorts 7, 8 and 8X and the as-built Rock Mechanics instrumentation locations. Table XIII shows the major events and corresponding dates which could have affected gauge readings. Graphs illustrating the average monthly movement (or lack of) for each instrument are included in Appendix G.

Figure IV.G-1. As-Built Rock Mechanics Instrumentation Locations, Retorts 7 and 8

Figure IV.G-2. As-Built Rock Mechanics Instrumentation,
Retorts 8 and 8X

TABLE XIII
MAJOR EVENTS AFFECTING
ROCK MECHANICS INSTRUMENTATION

<u>Event</u>	<u>Retort 8X</u>	<u>Retort 7</u>	<u>Retort 8</u>
Mining Upper Void Level Complete	09-25-80*	07-31-80*	10-30-80*
Mining Intermediate Void Level Complete	-	11-13-80*	12-18-80*
Mining Lower Void Level Complete	-	10-02-80*	11-13-80*
Rubblization	01-27-81	02-21-81	04-04-81
Retort 7 Roof-Fall	-	**	-
Ignition - First Attempt	-	01-13-82	12-20-81
Ignition - Second Attempt	-	01-25-82	12-22-81
Ignition - Complete	-	01-29-82	12-25-81
Retorting Front at Intermediate Level	-	05-20-82***	04-05-82***
Recycle Began	-	10-21-82	10-15-82
Recycle Completed and Quenching Began	-	11-19-82	11-09-82

* Date of mine progress survey.

** Retort was bulkheaded for a period of time, preventing access. The roof-fall occurred during this time. The bulkhead was re-opened September 1981.

*** Approximate

V. MINI-RETORT TESTS

A. Introduction

The major objective of the mini-retort (MR) ignition tests was to obtain the data and experience necessary for the successful ignition of Retorts 7 and 8. Initially, two MR ignition tests were planned. The first test was on MR-3 using a downhole burner to ignite the rubble surface at a single point (the nominal center) in this "bulked-full" retort. The second, MR-4, used a hot inert gas generator (HIGG) as the external source of heat and made use of the plenum between the retort roof and the top surface of the rubble for distributing the heat uniformly over the rubble surface.

Based on the results from MR-3 and MR-4, the hot inert gas generator method was selected for ignition of Retorts 7 and 8. Although MR-3 was successfully ignited using the downhole burner, the unit was judged not to be technically ready for simultaneous application in groups of 16 as needed for ignition of Retorts 7 and 8 (one burner would be required in each of the 16 holes from the surface to ignite a 40 feet by 40 feet section of the retort).

The HIGG performed as designed during the ignition of MR-4, nevertheless, an additional test (MR-1) was run to test the complete ignition procedures prior to ignition of Retorts 7 and 8.

Ignition tests on MR-3, MR-4 and MR-1 are discussed below.

B. MR-3 Test

The objective of the MR-3 ignition test was to test a downhole burner and associated start-up procedures for use in igniting retorts. Two burners were designed and fabricated by Foster-Miller Associates for these tests.

The Quarterly Progress Report for September 1980 through November 1980, presents diagrams of the MR-3 test setup, tables and a detailed general discussion of the results of the MR-3 test. The second Annual Report, June 1, 1980 through May 31, 1981, contains the operating summary for the tests. The Final Report, June 1, 1979 through August 31, 1981, contains further details. In addition, a paper entitled "Instrumentation and Data

Analysis from Occidental Retorts MR-3 and MR-4," by P. J. Hommert in the Proceedings of the 15th Oil Shale Symposium contains an extensive analysis of the MR-3 test results.

In summary, two attempts were made to ignite MR-3. The first attempt, conducted from November 1 through 5, 1980, was not successful because both burners failed mechanically when high pressure steam formed in the cooling jacket. After modification of the burners to prevent damage from cooling water loss, ignition was again attempted during the period of April 23 through 27, 1981. This ignition attempt was successful; however, the burners still experienced instabilities at high firing rates as well as ceramic liner failure.

Details of the ignition are given in the reports noted above. Some details of the continued operation of MR-3 are also included in the above reports; however, the mini-retort program was designed to provide optimum ignition systems and procedures for Retorts 7 and 8. The mini-retort outlet configuration and product collection systems, for example, were not designed for complete retorting as an objective.

Tracer test results for MR-3 are included in Volume II. A discussion of the tracer test results is given in the Annual Report for June through May 1980, and in the Final Report.

C. MR-4 Test

The objectives of the MR-4 ignition test were to test the HIGG and associated procedures for use in igniting retorts. The HIGG was designed and fabricated by John Zink Company. Details of its operation, a schematic of MR-4 with the HIGG, a start-up test operating summary, and oil and water production curves are given in the Annual Report for June 1980 through May 1981. The Quarterly Report for December 1980 through February 1981 contains thermocouple data, offgas data and a process flow diagram. Further details are given in the Final Report and the paper by Hommert includes an extensive analysis of the results from MR-4.

Tracer test results for MR-4 are included in Volume II. A discussion of the tracer test results is given in the Annual Report for June 1980 through May 1981 and in the Final Report.

D. MR-1 Test

After the completion of MR-3 and MR-4, a third mini-retort, MR-1, was constructed and ignited using the same hot inert gas generator (HIGG) as was used on MR-4. The objective of this test was to demonstrate the final ignition procedure to be used to start-up the full-scale Retorts 7 and 8.

MR-1 was one of the five 40 feet square by 100 feet high mini-retorts that were mined and rubblized as part of the Occidental-funded Rock Fragmentation Program of Phase II. Thus, the construction necessary to conduct the ignition test included completion of rubblization of MR-1 to form the plenum at the Upper Level, construction of the bulkhead and product handling system, installation of an air inlet pipe from the surface into the center of the plenum, installation of the HIGG, thermocouples, and process monitoring instrumentation. Sandia Labs was not able, because of budgetary constraints, to monitor this test on the computer system; therefore, measurements were recorded by datalogger.

Figure V.D-1 shows the plan and side views of the MR-1 configuration. The HIGG was a reduced-scale model (six million BTU/hour firing rate) of the one used to ignite Retorts 7 and 8. The test was scaled to deliver the same heat flux to the rubble surface as in Retorts 7 and 8.

The steps of the ignition procedure for MR-1 are given here:

Purge - Stoichiometric HIGG operation to deliver inert offgas at 300° F into the plenum at a sufficiently low flow rate to safely purge the oxygen-bearing air from the retort into the offgas handling system. This step is not necessary on a single retort, but is necessary in cluster operation where the offgas pipes contain hydrocarbon gasses. In such a case the retort can be purged into the offgas system at a slow enough

V.D-1. MR-1 Configuration

V.D-2. Rubble Surface Temperature History

rate to keep the oxygen below explosive limits in the offgas. When the retort is purged of oxygen, the subsequent high flow rate steps can proceed. Time required for this step depends upon the volume of the retort (about three hours for MR-1).

Heat Up - Fire the HIGG at the maximum firing rate attainable (about six million BTU/hour), keeping the flue gas temperature at 1600° F. By operating the HIGG with two percent O₂ in the flue gas, the onset of combustion in the rubble can be detected by a decrease in O₂ in the retort offgas. This step requires about 24 hours. When combustion begins and offgas O₂ drops below one percent go to the next step.

Oxygen Step-Up - Introduce excess air through the HIGG; increase in steps to provide 5 percent, 10 percent, 15 percent oxygen in the flue gas while maintaining 1600° F flue gas temperature. Monitor the retort offgas and proceed to next step when offgas O₂ drops below one percent. Each step requires about two to three hours.

Cold Air - Turn the HIGG off and introduce cold air through the pipe entering the roof of the plenum and operate at design flow rate for 24 hours to establish a reservoir of heat in the top layer of rubble. Continue to monitor O₂ in the offgas.

Thermal Drive - Turn off the air entering the plenum. Restart the HIGG and operate at stoichiometric conditions to deliver 300° F flue gas at the maximum flow rate. The purpose of this step is to extinguish combustion in the walls and roof of the plenum and drive the high temperature zone down into the rubble (without dropping the peak rubble temperature below re-ignition temperature).

Restart Combustion - Re-introduce air to restart combustion. Proceed to design operating conditions.

The steps of this procedure were followed during the ignition of MR-1. The results were as planned and have been reported in a paper by Shen and Zahradnik, together with a more detailed discussion of the development of the start-up procedures.

Figure V.D-2 shows the temperature history of the rubble surface during the start-up period of the steps discussed above. Numerical simulation models were used to predict performance during the inert gas phases of start-up and the model predictions are also shown in the figure.

Start-up of MR-1 began on September 13, 1981 and all ignition steps were complete by September 16. Retorting proceeded until October 22, 1981, when the retort was cooled by quenching.

VI. ENVIRONMENTAL IMPACT

The purpose of this section is to present a summary of permit status and to update the environmental monitoring and analyses performed in conjunction with oil shale retorting development and demonstration activities at the Occidental Oil Shale, Inc. (OOSI) Logan Wash mine site. Environmental monitoring was conducted in accordance with requirements of applicable permits and the Environmental Research Plan submitted under the U.S. Department of Energy (DOE) contract. This report covers the period of August 1981 through the completion of Retorts 7 and 8. Work before August 1981 was covered in the Final Report.

A. Permits

The current status of Logan Wash permits is shown in Table XIV. It is planned that during 1983 most permits will be cancelled or allowed to expire as follows:

Air Permits - All permits will be cancelled.

Water Permits - NPDES and Sewage permits will be kept active, all others will be cancelled.

Land Permits - Various land, well and access permits will be cancelled as phasedown and restoration proceed. Basic road access will remain active.

Solid Waste - Cancelled.

Toxic Substances - Cancelled.

Others - Cancelled.

B. Monitoring Status

1. Summary

In accordance with applicable permits and the Environmental Research Plan prepared under the DOE contract, environmental data was collected for various air, water and biological related parameters. The purpose of this report is to provide a summary of the environmental monitoring performed in conjunction with the oil shale demonstration activities at the Logan Wash Research Facility.

Environmental parameters which were in the Air and Water Monitoring Program are presented in Tables XV and XVI. These tables identify

TABLE XIV
LOGAN WASH PERMIT STATUS REPORT
CURRENT PERMITS/NOTICES

<u>Permit Title</u>	<u>Purpose</u>	<u>Permitting Agency</u>	<u>Permit Number</u>	<u>Date Submitted</u>	<u>Date Approved</u>	<u>Date of Expiration</u>	<u>Remarks</u>
Air 1) PSD	Operate Retorts 7 & 8	EPA		03-24-79	11-01-79		All monitoring and reporting activity ceased 01-83 with the shut-in of Retorts 7 & 8.
2) Emission Permit (APEN)	Screening Plant	CAPCD	C-10,619	02-19-75	03-03-75	Indefinite	
3) Emission Permit (APEN)	Shale Oil Heater	CAPCD	C-10,761	03-28-75	04-22-75	Indefinite	
4) Emission Permit (APEN)	Hot Water Circulator (HT)	CAPCD	C-10,762	03-28-75	04-22-75	Indefinite	
5) Emission Permit (APEN)	Hot Water Circulator (LB)	CAPCD	C-10-901	07-14-75	08-06-75	Indefinite	
6) Emission Permit (APEN)	Retort 4	CAPCD	C-10,454		12-03-75	Indefinite	
7) Emission Permit (APEN)	Retort 6	CAPCD	C-11,708		04-19-75	Indefinite	
8) Emission Permit (APEN)	Retort 7	CAPCD	C-12,319-1(SP)	01-26-79	07-25-79	Indefinite	
9) Emission Permit (APEN)	Retort 8	CAPCD	C-12,319-2(SP)	01-26-79	07-25-79	Indefinite	
10) Emission Permit (APEN)	Process Steam Boiler #1	CAPCD	C-12,319-3(SP)	01-26-79	07-25-79	Indefinite	
11) Emission Permit (APEN)	Process Steam Boiler #2	CAPCD	C-12,319-4(SP)	01-26-79	07-25-79	Indefinite	
12) Emission Permit (APEN)	Process Steam Boiler #3	CAPCD	C-12,319-5(SP)	01-26-79	07-25-79	Indefinite	
13) Emission Permit (APEN)	Heater Treater Expansion	CAPCD	C-13,005	07-24-80	01-28-81	Indefinite	
14) Emission Permit (APEN)	Steam Generator	CAPCD	C-11,894	01-31-79	01-07-80	Indefinite	
15) Emission Permit (APEN)	Sour Water Stripper	CAPCD	C-13,494	09-09-81	01-14-82	Indefinite	

TABLE XIV
LOGAN WASH PERMIT STATUS REPORT
CURRENT PERMITS/NOTICES

Permit Title	Purpose	Permitting Agency	Permit Number	Date Submitted	Date Approved	Date of Expiration	Remarks
<u>Water</u>							
1) NPDES (National Pollution Discharge Elimination System)	Mine water discharge	EPA, CWQCD	CO-0029947			12-31-83	Amended to add discharge point 003 for discharge of treated condensate water, 08-82.
2) 1900 GPD Sewage Plant	Sewage treatment	Garfield County	231		02-19-76	Indefinite	
3) Sewage Plant Site Approval	Sewage plant location	Garfield County				Indefinite	
4) Water Well #2	Well #2 construction	Garfield County	80320	06-02-75	08-07-75	Indefinite	
<u>Land</u>							
1) Special Land Use Permit	Observation well (LW-112)	BLM	CO-76SL11 (GJ-6-105N)	02-18-76	04-22-76	04-21-81	Permit under review with BLM for update and consolidation.
2) Temporary Use Permit	Flume - Smith Gulch (LW-102)	BLM	CO-078-TU-80-5	07-22-80	07-24-80	01-24-81	Permit under review with BLM for update and consolidation.
3) Temporary Use Permit	Flume Riley Gulch (LW-104)	BLM	CO-078-TU-80-6	07-22-80	07-24-80	01-24-81	Permit under review with BLM for update and consolidation.
4) Temporary Use Permit	Observation well and Flume - Bowdish Gulch (LW-121)	BLM	CO-070-TU-78-21		09-12-78	09-11-80	Permit under review with BLM for update and consolidation.
5) Right-of-Way	Tramroad	BLM	C-23027	09-09-75	04-20-77	07-19-2007	Gate to mine and experimental adit. Annual rental paid 04-06-82.
6) Right-of-Way	Heater Treater and Pipeline	BLM	C-22434	02-07-75	06-16-75	06-16-2005	Annual rental paid 06-82.

TABLE XIV
LOGAN WASH PERMIT STATUS REPORT
CURRENT PERMITS/NOTICES

Permit Title	Purpose	Permitting Agency	Permit Number	Date Submitted	Date Approved	Date of Expiration	Remarks
7) Special Land Use	Observation well (LW-101)	BLM	CO-76SL4 (GJ-6-53)		11-01-75	10-31-80	Permit under review with BLM for update and consolidation.
8) Special Land Use Permit	Observation well (LW-108)	BLM	CO-76SL8	01-06-76	02-23-76	02-22-86	Permit under review with BLM for update and consolidation.
9) Special Land Use Permit	Corehole Shale 2	BLM	CO-76SL9 (GJ-6-108)	02-28-76	04-22-76	04-21-81	Permit under review with BLM for update and consolidation.
10) Special Land Use Permit	Observation well (LW-101A)	BLM	CO-76SL10	02-18-76	04-22-76	04-21-81	Permit under review with BLM for update and consolidation.
11) Right-of-Way	Upper road access	BLM	CO-23027 (CO-946)	10-12-79	03-12-80	04-19-2007	
12) MLRB Permit	Surface disturbance	CMLRB	77-424	10-07-77	03-14-80 (06-01-79- Anniversary date; surety accepted.)	03-27-2038 08-26-85	Annual Report and fee of \$275 paid 05-13-82. Annual fee of \$200 paid 08-28-82.
13) Russell & Mary Hugh Scott Mark Longfield, Inv. Mgr.	Observation well - Smith Gulch (LW-102)	Private Property					
14) Exxon (Access/Right- of-Way)	Observation well - Kelly Gulch (LW-103)	Private Property			06-22-76	Indefinite	
15) Union Oil (Access/Right- of-Way)	Observation well - Riley Gulch (LW-104)	Private Property			10-22-75	Indefinite	
16) Mineral Waste Dump	Mine dump	Garfield County	131	01-19-76	05-01-76	When full	Capacity permitted is 8.8×10^6 cubic yards.

TABLE XIV
LOGAN WASH PERMIT STATUS REPORT
CURRENT PERMITS/NOTICES

Permit Title	Purpose	Permitting Agency	Permit Number	Date Submitted	Date Approved	Date of Expiration	Remarks
17) Conditional Use Permit	Access road and benches	Garfield County		03-15-74	04-04-74	Indefinite	
18) Conditional Use Permit	Tank farm and gate	Garfield County	008	08-07-74	09-25-74	Indefinite	
19) Conditional Use Permit	6% access road	Garfield County	009	10-21-74	12-17-74	Indefinite	
20) Conditional Use Permit	69 KV substation	Garfield County	011	05-75	06-04-75	Indefinite	
21) Conditional Use Permit	Heater Treater & pipeline	Garfield County	015	03-28-75	06-26-75	Indefinite	
22) Conditional Use Permit	69 KV powerline	Garfield County	016	06-20-75	06-26-75	Indefinite	
23) Lease Agreement	Roan Creek lease (Tank farm and gate area)	Getty Oil		02-22-76			Annual lease payment of \$1,000 plus taxes paid 04-02-82. Negotiating to turn area over to Chevron Shale Oil Co.
24) Temporary Use Permit	Alligator Gulch	BLM	C-19,370				Permit under review with BLM for update and consolidation.
25) Temporary Use Permit	Topsoil storage area	BLM	C0-076-TU-81-22	06-23-81	07-21-81		Permit under review with BLM for update and consolidation.
26) Temporary Use Permit	Observation well (LW-242)	BLM	C0-076-TU-81-34	10-08-81	02-01-82	12-01-85	

TABLE XIV
LOGAN WASH PERMIT STATUS REPORT
CURRENT PERMITS/NOTICES

<u>Permit Title</u>	<u>Purpose</u>	<u>Permitting Agency</u>	<u>Permit Number</u>	<u>Date Submitted</u>	<u>Date Approved</u>	<u>Date of Expiration</u>	<u>Remarks</u>
27) Temporary Use Permit	Observation well (LW-241)	BLM	CO-076-TU-81-35	10-08-81	02-01-82	12-31-85	
28) Exxon (Access/Right-of-Way)	69 KV powerline	Private Property		09-14-81		Indefinite	
29) Union (Access/Right-of-Way)	69 KV powerline	Private Property			07-03-75	Indefinite	
<u>Solid Waste</u>							
1) RCRA	Storage of hazardous wastes	EPA	EPA ID#COD 000824128	11-19-80			
<u>Toxic Substances</u>							
1) TSCA-Premanufacture Notice-Shale Oil	Regulates all aspects of production, distribution and use.	EPA		04-26-78	N/A	N/A	A premanufacture notice will not be required.
<u>Others</u>							
1) Communication Station Authorization	Microwave Station	FCC	None issued	04-02-75	05-01-78	Indefinite	
2) Variance to CBM Bulletin 20	Allimak Hoist	CBM	None issued	05-12-78	08-09-78	Life of mine	
3) Radioactive Materials License	Krypton	Colo. Dept. Health	267-01		05-10-76	04-30-85	

TABLE XIV
LOGAN WASH PERMIT STATUS REPORT
CURRENT PERMITS/NOTICES

<u>Permit Title</u>	<u>Purpose</u>	<u>Permitting Agency</u>	<u>Permit Number</u>	<u>Date Submitted</u>	<u>Date Approved</u>	<u>Date of Expiration</u>	<u>Remarks</u>
4) Environmental Assessment	Phase II Cooperative Agreement	DOE	DOE/EA0095	01-79	11-79		
5) Petition for Modification to 30 CFR 57.4-58	Retorts 7 & 8	MSHA	Docket # M-81-19-M	04-10-81	Interim Relief Granted 10-21-81	30 days after complete quench of Rts. 7&8	To allow permanent underground flame. (MIS retorting)
6) Petition for Modification to 30 CFR 57.4-53	Retorts 7 & 8	MSHA	Docket # M-81-48-M	08-06-81	Interim Relief Granted 10-21-81	30 days after complete quench of Rts. 7&8	To allow use of propane underground.
7) DOE/Cooperative Agreement - Monitoring Plan, Phase II	Retorts 7 & 8	DOE, LETC, OSTF		12-11-80			Sampling plan mutually agreed upon with OOSI and OSTF and has been completed.

TABLE XIV
LOGAN WASH PERMIT STATUS REPORT
ADDITIONAL PERMITS/NOTICES

<u>Permit Title</u>	<u>Purpose</u>	<u>Permitting Agency</u>	<u>Permit Number</u>	<u>Date Submitted</u>	<u>Date Approved</u>	<u>Date of Expiration</u>	<u>Remarks</u>
Land 1) Right-of-Way	Access to LW 121 and LW 102	BLM		09-08-80			Permit under review with BLM for update and consolidation.

TABLE XV
AIR QUALITY/METEOROLOGICAL MONITORING
STATIONS AT LOGAN WASH SITE

<u>Station Location</u>	<u>Station Code</u>	<u>Measurement</u>	<u>Elevation Level</u>
Guard Gate	LW04	Temperature Relative Humidity	2 Meters
Heater Treater	LW01	Wind Direction Wind Speed Temperature Acoustic Radar Ambient CO	10 Meters
Lower Bench*	LW03	Temperature Relative Humidity	2 Meters
Meteorological Tower	LW02	Particulates Temperature Relative Humidity Solar Radiation Wind Speed Wind Direction Ambient H ² S	30 Meters
Heater Treater	LW33	Temperature Relative Humidity	2 Meters

* Station discontinued June 9, 1981; moved to Heater Treater (LW33).

TABLE XVI
MONITORING FREQUENCY GOALS

<u>Water Type</u>	<u>Station</u>	<u>Frequency</u>	<u>Depth</u>	
			(M)	(Ft.)
Alluvial Wells	LWA022	Monthly		
	LWA100	Monthly	26	87
	LWA101 (LWA101A)	Monthly	26	87
	LWA102 (LWA202)	Monthly	40	130
	LWA103	Quarterly		
	LWA104	Quarterly	18	60
	LWA112	Monthly	20	67
	LWA115	Monthly		
	LWA121	Monthly		
Deep Wells	LWD032	Quarterly	344	1,129
	LWD033	Quarterly	276	905
	LWD045	Quarterly	247	809
	LWD046	Quarterly	319	1,056
	LWD047	Quarterly	427	1,400
	LWD106	Quarterly	320	1,050
	LWD108	Monthly	293	960
	LWD116	Quarterly		
	LWD241	Monthly	83	273
	LWD242	Monthly	62	203
	LWD243	Monthly	90	295
	LWD430	Monthly	99	325
Retort 7 Wells	LWD701	Monthly	83	272
	LWD702	Monthly	92	302
Retort 8 Wells	LWD801	Monthly	74	241
	LWD802	Monthly	91	300
Springs	LWP001	Quarterly		
	LWP002	Quarterly		

the stations in use as well as the parameters measured. They also include the computer codes utilized in OOSI's computerized data base. Biology is discussed in Section VI.B.4.

A map showing the locations of the environmental monitoring installations is shown in Figure VI.B-1. The various types of monitoring stations are identified by different-shaped symbols.

2. Hydrology and Water Quality

The hydrology and water quality monitoring program has been in existence since 1976 to develop a baseline for determining the potential effects modified in situ (MIS) processing has upon groundwaters. The program has been modified through the years to meet permit requirements by the State for each retort or set of retorts designed. This section describes the permits and monitoring frequency required for the monitoring program. This program includes monitoring of deep wells, alluvial wells, surface springs, mine water, and retort sump waters. Chemical characteristics analyzed for these water types are discussed throughout this hydrology section.

a. Permit Requirements and Experimental Design

Subsurface Disposal - A new monitoring program was initiated for Retorts 7 and 8 operations. This program complies with a subsurface disposal permit granted by the Colorado Department of Health and Water Quality Control Commission. The Colorado legislature passed a new Water Quality Control Act in 1981 which eliminated Section 505 of the old act that required subsurface disposal permits. The monitoring program was amended to provide good data in a cost effective manner. This monitoring program went into effect on January 1, 1982.

The locations of all retorts are shown for reference. Several water quality wells located near the retorts within the mine are not shown on Figure VI.B-1 but are shown in Figures VI.B-2, 3, 4, and 5.

Figure VI.B-1. Environmental Monitoring Installations

100

Figure VI.B-2. Well Locations in Upper Level

101

Figure VI.B-3. Retort 6 Well Locations in Lower Intermediate Level

Figure VI.B-4. Well Locations in Lower Level

Figure VI.B-5. Well and Discharge Locations at the Research Mine

An isometric schematic showing Retort 6 water sampling well locations is presented in Figure VI.B-6. The locations of monitoring wells near Retorts 7 and 8 are shown in Figures VI.B-7 and 8. An elevation profile along a cut from alluvial well 101 to the Retort 6 stack and then to the Meteorological Tower to depict the terrain variations is shown in Figure VI.B-9. Even though the horizontal scale is compressed in the figure, the steep slope and change in elevation are quite significant.

Monitored water types include deep wells, alluvial wells, process mine water, surface flows, and retort sump water. Depth, flow and characteristic chemical parameters are examined. Applicable permits include Subsurface Disposal (made unnecessary by a change in Colorado law) and National Pollution Discharge Elimination System (NPDES). NPDES discharge criteria were met at all times by mine water discharges. Occasional exceedances were encountered for oil and grease during high precipitation events from run-off of the dump. However, levels of exceedance were quite low and no citations were received. Straw and absorbants were placed in the valley below the dump as corrective measures.

The alluvial wells included three in Logan Wash and one each in Smith, Riley and Kelly Gulches (see Figure VI.B-1). These were sampled monthly except for Kelly and Riley Gulches which were sampled quarterly. Four deep wells around the tract were used to monitor groundwater on a quarterly basis. The surface waters in Logan and Bowdish Washes and Smith Gulch were sampled monthly whenever flowing. Dry Gulch in the upper Logan Wash drainage was sampled whenever flow occurred. Roan Creek was sampled monthly from sites above and below the mouth of Logan Wash. Parachute Creek was sampled quarterly above and below the mouth of Riley Gulch. Kelly and Riley Gulch surface flows were sampled quarterly.

Wells in the mine area included satellite wells located immediately adjacent to Retorts 6, 7 and 8 and other wells which monitor specific processing sites. These wells were sampled monthly.

Figure VI.B-6. Isometric Schematic of Retort 6 Water Sampling Wells

Figure VI.B-7. Monitoring Well Locations in Product Level Near Retorts 7 and 8

Figure VI.B-8. Monitoring Well Locations in Upper Level
Near Retorts 7 and 8

Figure VI.B-9. Elevation Profile for Logan Wash Mine Area

Waters from the process water sumps beneath the retorts were monitored three times before retorting began, monthly during retorting and with a frequency after retorting which decreases to quarterly.

Chemical characteristics analyzed for alluvial wells, deep wells, Retort 6 satellite wells, and springs were as follows: temperature, specific conductance, pH and dissolved oxygen sampled in the field; laboratory tests run for major cations (Na, Ca, K, Mg, and $\text{NH}_3\text{-N}$), major anions (NO_3 , SO_4 , Cl, HCO_3 , and CO_3), trace elements (Si, Li, Mo, Zn, F, Hg, Ag, Mn, Al, As, Ba, B, Cu, Fe, Sr, V, Se), Kjeldahl nitrogen, total dissolved solids, suspended solids, chemical and biological oxygen demands, phenols, dissolved and total organic carbon, fecal and total coliforms, oil and grease, total alkalinity, thiocyanate, thiosulfate, silica, and radioactivity.

Retort sump water analyses were slightly different. Laboratory tests run for major cations (Na, Ca, K, NH_3 , and Mg), major anions (NO_3 , Cl, SO_4 , HCO_3 , and CO_3), trace elements (Li, F, As, Hg, B, Se, Si, V, Cu, Mo, Zn, Al, Ba, Sr, Fe, Ag, Cd, Mn, Pb, and Ni), phenols, oil and grease, total dissolved solids, total suspended solids, fecal and total coliforms, Kjeldahl nitrogen, sulfite, thiosulfate, alpha and beta radiation, and Ra^{226} .

A thorough analysis of the effects of MIS retorting on groundwater is given in the paper by Hester. The paper discussed the concerns that the scientific community have raised about the consequences of MIS technology on the groundwater. Well data is examined for evidence of contamination by retort waters. Retort leaching trends are analyzed and the following conclusions are drawn:

1. The variables total alkalinity, ammonia, phenols, dissolved organic carbon, thiosulfate, and thiocyanide are significantly higher in retort water than in natural waters.

2. The variables aluminum, magnesium and calcium are lower in retort water than in natural waters.
3. Monitoring data from wells near the retorting operations show no "discernable" trends that can be interpreted as evidence of contamination.
4. Data from Retorts 1 through 6 show that species monitored by retorting are rapidly removed and that concentrations of chemicals in "leachate" quickly approach the same range of values as seen in natural groundwaters.

b. National Pollution Discharge Elimination System (NPDES)

Permit Requirements - A water monitoring program was carried out in compliance with NPDES Permit CO-0029947 issued to OOSI under the Federal Clean Water Act and the Colorado Water Quality Control Act. The monitoring continues to be performed on a weekly basis whenever discharge takes place. The water is tested for the following parameters: flow, total dissolved solids, total suspended solids, chemical and biological oxygen demands, phenols, sulfide, ammonia-nitrogen, oil and grease, fluoride, arsenic, zinc, molybdenum, copper, iron, boron, and chromium. The discharge samples are taken just below the flume in Dry Gulch (LWM001) and outside the portal to the Research Mine (LWM002), see Figure VI.B-1. The results of the monitoring program are submitted quarterly on standard forms to the State Water Quality Control Division and to the Environmental Protection Agency (EPA) Regional Administrator. Exceedances are noted and corrective actions are reported.

Method of Analysis - Water is sampled, preserved and analyzed by approved EPA methods, when applicable, as outlined in "Methods for Chemical Analysis of Water and Wastes," "Standard Methods for the Examination of Water and Wastewater" and the "Handbook for Analytical Quality Control in Water and Wastewater Laboratories."

Results and Discussion - Level and water quality data for the various water types--springs, Retort 6 satellite wells and NPDES discharge points--were analyzed in Quarterly and Annual reports

during the Phase I program. Summaries of these analyses and additional analytical techniques were discussed in the last report.

Level Data - Water levels in both deep wells and alluvial wells were recorded at the Logan Wash mining facility in an attempt to understand the natural characteristics and seasonal fluctuation which occur as part of the existing hydrology of the area. Data collected have shown uncommon fluctuations of water levels in the wells due to the difficulties involved in measuring well depths; there is some question as to the accuracy of these readings.

Water Quality (Well) - Different methods for interpretation of water quality data have been continually researched to obtain meaningful information from the quantities of data collected. The most recent approach to the analyses has been to compare the mean values of well water variables with those of the retort water variables. This approach has identified the following variables as key to identify contamination in the groundwaters; total alkalinity, ammonia, phenols, dissolved organic carbon, thiosulfate, and thiocyanate. A paper describing the approach used for this analysis was presented at the 16th Oil Shale Symposium by Hester.

Water Quality (Retort) - Retort sump water was sampled before, during and after retorting on a scheduled basis, which is explained under Permit Requirements. Also see part VI.B.2 for a full parameter list. A statistical analysis of the retort waters collected through the completion of Retorts 7 and 8 is included with the groundwater analysis described in Hester.

Water Quality (NPDES Discharge Points) - Water quality samples were collected weekly during discharges and analyzed for those parameters listed under Permit Requirements. In addition, four of the parameters have effluent limitations which must be met in accordance with the NPDES permit. The parameters and effluent limitations are:

	<u>30 Day Average</u>	<u>Daily Maximum</u>
Total Suspended Solids	30 mg/ℓ	45 mg/ℓ
Total Iron	3.5 mg/ℓ	7.0 mg/ℓ
pH	N/A	6-9 units
Oil and Grease	N/A	10 mg/ℓ - no visible sheen

In the past, there have been several occasions when the parameters listed above have been exceeded. When this does occur, the Regional Administrator and the State Water Quality Control Division are notified in writing within five days. This notification includes a description of the discharge, the cause and period of exceedance and the steps being taken to reduce, eliminate and prevent a recurrence. Most of the exceedances experienced at Logan Wash were with total suspended solids.

Various mitigative measures, such as construction of small settling ponds, are being taken to alleviate this problem. Water quality data required by the NPDES permit are presented in Appendix K of this report.

Water Quality (Streams) - As part of the subsurface disposal permit for Retorts 7 and 8, baseline data on seven local streams were collected. These streams include Roan Creek, Bowdish Creek, Logan Wash, Dry Gulch, Smith Gulch, Riley Gulch, and Parachute Creek. Water Quality data collected at these streams are presented in the paper by Hester for locations shown in Figure VI.B-1. *see paper by Hester*

3. Air Quality and Meteorology

Air quality and meteorology parameters monitored included suspended particulates, carbon monoxide, wind speed and direction, temperature, relative humidity, solar radiation, and temperature inversion heights. Data was collected at four separate stations, see Figure VI.B-1. Other equipment included two solar powered, portable H₂S monitors and associated meteorological instruments located at Peanut Point and Shale Mountain; meteorological equipment located at the surface and

Heater Treater; and an H₂S monitor at the Meteorological Tower. Table XV lists the monitoring stations, the station computer codes, the parameters measured, and the elevation above ground. Figure VI.B-7 shows an elevation profile of the Logan Wash mine area where the actual location and elevation above mean sea level of each station can be seen.

A requirement of the air emissions permit with the State of Colorado was that modeling be done on the H₂S data to compare measured values with those predicted by state-of-the-art complex terrain air pollution models. The modeling effort requires not only the H₂S data, but also the meteorology (wind speed and direction, temperature and solar radiation).

TRC Environmental Consultants, Inc., under contract to Occidental Oil Shale, Inc., has conducted an evaluation of the performance of five Gaussian complex terrain models. The purpose of this effort was to satisfy a permit condition required by the Colorado Air Pollution Control Division to utilize meteorological and air quality data measured at Occidental's Logan Wash oil shale processing facility in a comparative assessment with model predictions.

The five models tested were MPTER, COMPLEX I, COMPLEX II, COMPLEX II with modified terrain correction factors, and COMPLEX II with modified stability classes. Both long-term (about 7.5 months) and short-term (hourly) average concentrations of hydrogen sulfide (H₂S) were computed by each of the models; the results from which were compared to actual measurements performed at Logan Wash in 1981. Several statistical tests were utilized to facilitate the evaluation of the performance of these models.

The results from these analyses indicate that these models are very poor predictors of H₂S concentrations at Logan Wash. The models demonstrated little skill in predicting the magnitude, time, location, or frequency of peak pollutant impacts. Only rarely were modeled concentrations within an order of magnitude from the observed concentrations. This is because many of the assumptions that are

implicit in these models are of questionable validity in complex terrain environments, so the results that they provide in such situations are, at best, of dubious value. Detailed analysis of this data can be found in the TRC Report in Appendix F.

a. Air Quality

The long-term purpose of the Air Quality Monitoring Program has been to establish additional air quality baseline data and to monitor any effects retorting may have on the ambient air.

Suspended Particles - Data on suspended particulates were collected through the use of a high volume sampler located at the Meteorological Tower site. When the high volume sampler was in operation air was drawn into the sampler and through a filter by a high-flow-rate blower (40-60 ft³/min). This allowed total suspended particulates (TSP) with diameters >100 μ to collect on the filter surface. The mass concentration (g/m³) in ambient air was computed by measuring the mass of TSP collected and the volume of air sampled. This method is applicable to the measurement of the mass concentration of TSP in ambient air. TSP data is included in Volume III.

Carbon Monoxide - A Beckman Model 866 ambient carbon monoxide (CO) analyzer was utilized at Logan Wash to analyze and collect ambient CO data. The analyzer, located at the Heater Treater, automatically and continuously analyzed ambient air for carbon monoxide by using a differential measurement of the absorption of non-dispersed infrared energy. The instrument has been designated by the EPA as a reference method for CO monitoring in the 0 to 50 ppm concentration range. It initially was installed in October 1980. Carbon monoxide data is included in Volume III.

b. Meteorology and Climatology

Wind Speed and Direction - Wind speed and direction were measured at two locations. The first station (LW01) was located at the Heater Treater Plant and was a portable meteorological data

gathering system which was mounted approximately ten meters off the ground. Data from these sites is shown in Volume III and analyzed in Appendix F.

Temperature - Air temperature was measured and recorded at four locations. Due to instrument malfunctions, recorder failures and severe weather conditions, significant amounts of valid data were not collected for 1980. New temperature probes were installed at Logan Wash during the summer of 1981 in an attempt to remedy this situation. Temperatures are listed in Volume III of this report and analyzed in Appendix F.

Relative Humidity - Relative humidity was measured and recorded by hydrothermographs which were located at the Guard Gate, the Heater Treater and the Meteorological Tower. These instruments were positioned approximately two meters above ground. Relative humidity is listed in Volume III of this report.

Solar Radiation - Solar radiation from sun and sky was measured by a bimetallic recording pyranometer which was located at the Meteorological Tower site. Diurnal tables of data are presented in Volume III of this report and analyzed in Appendix F.

Upper Air Studies - Temperature inversion heights were measured by means of an acoustic radar. The acoustic radar was located at the Heater Treater site, 7,000 feet above mean sea level. The output of the instrument is a continuous strip chart record of reflected sound signals associated with thermal turbulence signatures. Such signatures vary in character depending on whether the atmosphere is stable or unstable. The chart provides a means to determine the height in meters of temperature inversions and mixing layers above ground level. Figure VI.B-10 gives a pictorial definition of mixing and inversion heights. Data recovery from this instrument was not as good as could be hoped due to frequent malfunctions. Volume III shows the available data with data analyzed as part of Appendix F.

M = Mixing Height

I = Inversion (TOP) Height

Note: If $h(\text{stack}) > I$ (either case) then
 $\dot{M} = \infty$

Figure VI.B-10. Definitions of Mixing Height and Inversion Height

4. Biology and Land Reclamation

Biological surveys for the Logan Wash site began in 1974. These surveys were to identify major plant communities, major vertebrate species found in each community and their relative abundance in these communities. Data collected was used to establish a data base to test the null hypothesis that mining activities were not affecting the vertebrate populations. The data base also is a source of information for future comparisons of vegetation data so that effects of climatological and seasonal changes not related to mining activities may be identified. The last biological surveys were conducted in the Spring and Summer of 1981 and were reported in the Final Report. Flora and fauna sections are also covered in the Final Report. No additional biological surveys are planned for the Logan Wash Site.

Revegetation - Occidental has posted bonds to guarantee the restoration and revegetation of all disturbed areas at the Logan Wash mine. Table XVII lists the disturbed areas and revegetation activities. Table XVIII is a species listing for revegetation. Several areas of the Logan Wash Site will remain in active use. Access roads, the mine bench and much of the surface facilities will need to be available for equipment removal, etc. for quite some time. However, areas with no activity will undergo a three year plan for restoration and revegetation. Within one year of abandonment, the areas of interest will undergo recontouring and an initial seeding of native grasses. During the second year, the grasses are fertilized and seedlings, native shrubs and trees are planted. During the third year BLM/MLRB staff inspect the site to confirm establishment of the plant community and OOSI is either released from the bond or required to carry on further corrective action.

Environmental Photography - No photographic surveys were done after 1981.

5. EPA Stretford H₂S Scrubber Test

The Stretford technology for H₂S removal was tested at Logan Wash during the Summer of 1982. As the result of a cooperative agreement

TABLE XVII

Estimates of Acreage Disturbed, Under Reclamation and Reclaimed*

Disturbed Area**	Acreage Disturbed		Acreage Reclaimed		Acreage Remaining	Under Rec- lamation In 1982
	Before 1982	During 1982	Before 1982	During 1982		
1. The Dump	13.36				13.36	
2. Upper Portal and Bench	0.74				0.74	
3. Lower Mine Bench	2.10				2.10	
4. Research Mine Bench and Dump	4.26				4.26	
5. Main Surface Buildings and Drill Pads	1.82		1.29	0.23	0.30	
6. Two Overflow Ponds	2.86			2.36	0.50	
7. Future Equipment, Parts, and Storage	0.67		0.67		0.00	
8. Ventilation Fan Site	0.41				0.41	
9. Power Substation (See Area 19)	0.75				0.75	
10. Helo Pad	0.24				0.24	0.24
11. Entrance, Parking and Traffic Control	8.30				8.30	
12. Meteorological Tower	0.80				0.80	
13. Miscellaneous Access Roads	15.58				15.58	4.00
14. Oil Transfer Pipe	0.50				0.50	
15. Heater Treater and Loadout Facility	2.96				2.96	
16. Communication Facility	0.11				0.11	
17. Exhaust Stack (See Area 19)	3.00				3.00	
18. Logan Wash Access Road	53.43***				0.00***	
19. Surface Process Control Facility	1.00				1.00	
20. Topsoil Stockpile****	0.25				0.25	
21. Berm Repair Material****	0.33				0.33	
22. Heater Treater Met. Station****	0.18				0.18	
Realignment of Area 18 (B1-B10)	6.00		6.00		0.00	
TOTALS*****	(119.65) +	0.00)	-	(7.69 +	2.59) =	(94.10 - 53.43) = 55.67

See attached sheet for explanation of footnotes.

TABLE XVII (CONTINUED)

* Acreage based on aerial photos taken in 1980.

** Numerated disturbed areas correspond to numerated areas on Disturbed Area Maps in Logan Wash Reclamation Plan.

*** This area is not to be reclaimed (See Exhibit E, Area #18, of the Logan Wash Reclamation Plan).

**** Acreage is an estimate; did not come from aerial photos.

***** Total acreage disturbed to date = 119.65 (Area #18, Access Road, (53.43) not to be reclaimed)

Total acreage reclaimed to date = 10.55

Total remaining to be reclaimed = 55.67

TABLE XVIII

Species List for Logan Wash Reclamation

Broadcast Seeding Rate (P.L.S.)

<u>Grasses:</u>	<u>Lbs/Acre</u>
<u>Agropyron dasystachyum</u> - Critana (thick spike wheatgrass)	3
<u>A. desertorum</u> - nordan (crested wheatgrass)	1
<u>A. intermedium</u> - oahe (intermediate wheatgrass)	3
<u>A. smithii</u> (Western wheatgrass)	2
<u>A. trachycaulum</u> - primar (slender wheatgrass)	-
<u>A. spicatum</u> (Blue Bunch wheatgrass)	3
<u>A. trichophorum</u> (pubesent wheatgrass)	2
<u>Oryzopsis hymenoides</u> (Indian ricegrass)	-
<u>Stipa comata</u> (needle-and-thread-grass)	2
<u>Bromus inermis</u> (Smooth brome)	2
<u>Elymus junceus</u> (Russian wild/rye)	1
<u>Forbs:</u>	
<u>Hedysarum boreale</u> - <u>utahensis</u> (Utah Sweetvetch)	1
<u>Penstemon palmeri</u> - (Palmer penstemon)	1
<u>Spharalcea sp.</u> (Globe mallow)	-
<u>Melilotus officinalis</u> (yellow sweet clover)	1/2
<u>Linum lewisii</u> (Lewis Flax)	1/2
Total	22
<u>Shrubs:</u>	
<u>Amelanchier alnifolia</u> (service berry)	100
<u>Cercocarpum montanus</u> (mountain mahogany)	100
<u>Cowania mexicana stansburiana</u> (stansbury cliffrose)	100
<u>Purshia tridentata</u> (antelope bitterbrush)	100
Total	400/Acre

Note: P.L.S. - Pure Live Seed
Broadcast rates would be double the drilled rate.

between OOSI and the U.S. EPA Industrial, Environmental, Research Laboratory, an EPA contractor (Pedco Environmental, Inc.) brought to the site a pilot scale test facility. The results of the study have been made available in a report (too lengthy to be included with this document) titled "Characterization and Control of Pollutants Present in The Retort Offgas of Occidental Oil Shale, Incorporated." This report is available from the EPA Project Officer, Robert Thurnau, U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Fuels Technology Branch, Cincinnati, Ohio, 45268.

6. Decommissioning of Retorts

Monitoring results analyzed in the report presented by Hester have shown that the MIS retorts at Logan Wash do not present a leaching problem after two to three years. Natural influx of groundwaters leach out the soluble materials quite rapidly, and the water that collects at the bottom of the retorts quickly approaches the quality of uncontaminated mine water.

Permits have been requested from the Colorado Department of Health to discharge the water collecting in Retorts 1 through 4. It is anticipated that within three additional years, the waters from Retorts 5, 6, 7, and 8 will also be dischargeable. Because of the fact that the Logan Wash retorts are accessible from the side of the mountain and that the retort water can simply flow out, no additional decommissioning activities are anticipated.

APPENDIX A

RETORTS 7 & 8 THERMOCOUPLE COORDINATE INFORMATION*

Retort 8
Level 1 (Upper Level)**
Thermal well number

Sandia Well ID #8130 Log ID #2
Azimuth: 354.95 Zenith: -20.92

	<u>X-REL</u>	<u>Y-REL</u>	<u>Z-REL</u>	<u>X-GEO</u>	<u>Y-GEO</u>	<u>Z-GEO</u>	<u>X-OXY</u>	<u>Y-OXY</u>	<u>Z-OXY</u>
A1	-21.74	109.15	-77.47	58405.98	22248.20	7801.23	2.66	38.59	28.06
B2	-18.52	101.71	-70.80	58409.20	22240.76	7807.90	3.30	40.97	26.03
C3	-13.23	87.32	-57.05	58414.48	22226.37	7821.65	4.25	45.55	21.84
D4	-8.93	72.47	-42.27	58418.80	22211.52	7836.43	4.88	50.22	17.34
E5	-5.98	56.50	-28.98	58421.73	22195.55	7849.72	5.05	55.17	13.28

Relative to well-head survey location in geodesic coordinate system. (Units = feet)

Relative to geodesic coordinates (X, Y - see Appendix B) and elevation above sea level. (Units = feet)

Relative to retort Reference Point⁺. (Units = meters)

* Well ID nomenclature developed by Sandia for inclusion in computer data base.

- ** 1 = Well drilled from Upper Level.
2 = Well drilled from Intermediate Level.
3 = Well drilled from Lower Level.

⁺ The Reference Point for the retorts is the upper northwest corner of each plenum (See Figure IV.B-16). The geodesic coordinates and elevations of the Reference Points are:

	<u>Retort 7</u>	<u>Retort 8</u>
North (ft.)	22,055.15	22,372.2
East (ft.)	58,423.19	58,378.8
Elevation (ft.)	7,893.6	7,893.3

```

1
2 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
3 SANDIA WELL ID # 7172 LOG ID # 1
4 AZIMUTH: 350.12 ZENITH: -14.31
5 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
6 A1 -40.88 120.90 -21.45 58428.22 21953.90 7857.75 -2.78 30.77 10.93
7 B2 -40.50 119.97 -21.35 58428.59 21952.98 7857.85 -2.70 31.07 10.90
8 C3 -36.10 109.73 -20.28 58430.00 21942.73 7858.92 -1.81 34.35 10.57
9 D4 -27.71 90.83 -18.09 58441.37 21923.83 7861.11 -0.08 40.41 9.90
10 E5 -21.32 76.58 -16.47 58447.78 21909.58 7862.73 1.25 44.98 9.41
11
12 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
13 SANDIA WELL ID # 7161 LOG ID # 1
14 AZIMUTH: 352.88 ZENITH: -9.63
15 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
16 A1 -41.80 121.63 -18.70 58429.11 21954.92 7860.80 -2.47 30.50 10.00
17 B2 -41.30 120.77 -18.65 58429.61 21954.06 7860.85 -2.35 30.78 9.98
18 C3 -32.81 105.88 -17.23 58438.09 21939.17 7862.27 -0.42 35.64 9.55
19 D4 -23.69 83.22 -15.05 58447.22 21921.52 7864.45 1.58 41.35 8.88
20 E5 -13.81 62.39 -10.90 58457.11 21895.69 7868.60 3.47 49.57 7.62
21
22 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
23 SANDIA WELL ID # 7162 LOG ID # 2
24 AZIMUTH: 353.47 ZENITH: -9.70
25 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
26 A1 -23.19 133.00 -14.91 58467.52 21957.88 7865.29 9.25 31.24 8.63
27 B2 -20.67 120.40 -13.93 58470.03 21945.27 7866.22 9.48 35.15 8.35
28 C3 -16.64 100.92 -12.37 58474.06 21925.72 7867.33 9.86 41.22 8.01
29 D4 -12.92 81.32 -11.60 58477.00 21906.12 7868.60 10.16 47.30 7.62
30 E5 -10.96 70.56 -10.47 58479.75 21895.35 7869.73 10.29 50.63 7.28
31
32 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
33 SANDIA WELL ID # 7163 LOG ID # 2
34 AZIMUTH: 353.17 ZENITH: -6.31
35 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
36 A1 -11.82 73.01 -7.53 58492.53 21905.30 7872.92 14.59 48.17 6.30
37 B2 -11.64 77.03 -7.55 58492.77 21904.33 7872.95 14.61 48.48 6.29
38 C3 -11.45 76.05 -7.52 58492.95 21903.34 7872.98 14.62 48.78 6.28
39 D4 -11.30 75.26 -7.48 58493.09 21902.55 7873.02 14.63 49.02 6.27
40 E5 -10.42 70.05 -7.14 58493.98 21897.65 7873.36 14.69 50.54 6.17
41 F6 -9.57 65.44 -6.79 58494.83 21892.73 7873.71 14.74 52.06 6.06
42

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APPENDIX A-1

SURVEY RESULTS OF THERMOCOUPLE AND GAS TAP LOCATIONS

Thermowell directional surveys and tabulation of the results in this appendix were provided by Sandia National Laboratories.

LOCATION DATA

43 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

44 SANDIA WELL ID # 7173 LOG ID # 2

45 AZIMUTH: 348.23 ZENITH: -16.78

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
46										
47	A1	-55.47	127.23	-36.57	58463.62	21955.48	7843.73	7.98	31.80	15.20
48	B2	-52.63	121.47	-35.26	58466.47	21949.67	7845.04	8.59	33.67	14.80
49	C3	-43.92	103.00	-30.94	58475.17	21931.29	7849.37	10.44	39.59	13.48
50	D4	-35.25	84.69	-26.53	58483.84	21912.90	7853.72	12.27	45.51	12.16
51	E5	-26.81	63.56	-22.34	58492.20	21896.77	7857.96	14.14	50.74	10.86

52
53 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

54 SANDIA WELL ID # 7164 LOG ID # 1

55 AZIMUTH: 346.80 ZENITH: -12.48

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
56										
57	A1	-39.81	123.90	-16.26	58479.78	21954.70	7863.74	12.82	32.72	9.10
58	B2	-39.47	122.97	-16.20	58480.12	21953.77	7863.80	12.89	33.02	9.00
59	C3	-32.66	104.19	-15.17	58486.94	21934.98	7864.83	14.14	39.97	8.77
60	D4	-25.99	85.38	-13.93	58493.61	21916.17	7866.07	15.36	44.93	8.39
61	E5	-18.65	64.74	-12.04	58500.94	21895.54	7867.96	16.70	51.47	7.82

62
63 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

64 SANDIA WELL ID # 7165 LOG ID # 2

65 AZIMUTH: 350.88 ZENITH: -7.94

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
66										
67	A1	-25.83	131.15	-9.87	58512.01	21972.46	7870.83	23.55	28.76	6.94
68	B2	-25.60	130.18	-9.89	58513.06	21971.48	7870.80	23.58	29.06	6.95
69	C3	-23.70	122.10	-10.10	58515.00	21963.40	7870.60	23.82	31.59	7.01
70	D4	-19.30	102.60	-10.13	58519.41	21943.90	7870.52	24.32	37.66	7.04
71	E5	-13.99	77.17	-9.10	58524.72	21918.47	7871.52	24.85	45.56	6.73
72	F6	-9.93	57.64	-7.63	58528.72	21898.94	7873.07	25.23	51.63	6.26

73
74 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

75 SANDIA WELL ID # 7166 LOG ID # 2

76 AZIMUTH: 353.38 ZENITH: -16.34

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
77										
78	A1	-14.36	86.60	-37.92	58540.73	21922.31	7842.18	29.85	45.08	15.67
79	B2	-12.49	77.94	-33.28	58543.59	21913.65	7846.02	30.04	47.78	14.26
80	C3	-10.68	69.30	-20.60	58544.42	21905.00	7851.50	30.22	50.46	12.83
81	D4	-8.40	57.90	-22.59	58546.59	21893.68	7857.51	30.40	53.97	11.00
82	E5	-7.69	53.55	-20.40	58547.41	21889.26	7859.70	30.46	55.34	10.33
83	F6	-6.92	49.10	-18.27	58548.17	21884.00	7861.83	30.50	56.72	9.68

84

85 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

86 SANDIA WELL ID # 7174 LOG ID # 2

87 AZIMUTH: 347.70 ZENITH: -14.81

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
88										
89	A1	-38.02	126.73	-30.23	58545.39	21964.84	7848.72	33.05	32.44	13.68
90	B2	-37.68	125.82	-30.03	58545.72	21963.93	7848.96	33.11	32.73	13.60
91	C3	-30.90	107.96	-24.87	58552.50	21946.06	7854.13	34.41	38.41	12.03
92	D4	-24.01	88.87	-20.36	58559.39	21926.97	7858.64	35.68	44.47	10.65
93	E5	-20.07	75.92	-18.22	58563.33	21914.02	7860.78	36.31	48.54	10.00

94
95 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

96 SANDIA WELL ID # 7167 LOG ID # 1

97 AZIMUTH: 346.62 ZENITH: -11.96

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
98										
99	A1	-41.16	125.32	-20.13	58541.94	21963.41	7851.67	31.95	32.73	12.78
100	B2	-39.74	121.65	-27.40	58543.36	21959.76	7852.40	32.22	33.89	12.56
101	C3	-32.61	103.26	-24.14	58550.40	21941.36	7855.66	33.59	39.75	11.56
102	D4	-25.89	84.70	-20.91	58557.20	21922.00	7858.89	34.84	45.63	10.58
103	E5	-20.27	69.77	-17.12	58562.03	21907.87	7862.68	35.90	50.38	9.42

104
105 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

106 SANDIA WELL ID # 7169 LOG ID # 4

107 AZIMUTH: 347.03 ZENITH: -16.83

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
108										
109	A1	-36.96	123.02	-54.40	58567.95	21965.02	7824.20	39.87	33.34	21.15
110	B2	-36.67	122.13	-54.07	58568.23	21964.12	7824.53	39.92	33.63	21.05
111	C3	-31.64	106.54	-47.12	58573.27	21948.54	7831.48	40.78	38.55	18.94
112	D4	-26.12	89.24	-38.73	58578.73	21931.24	7839.87	41.71	44.00	16.38
113	E5	-15.65	57.75	-22.33	58589.25	21899.75	7856.22	43.53	53.95	11.39
114	F6	-10.44	40.24	-14.35	58594.47	21882.24	7864.25	44.36	59.46	8.95

115
116 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

117 SANDIA WELL ID # 7169 LOG ID # 2

118 AZIMUTH: 353.17 ZENITH: -7.00

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
119										
120	A1	-15.60	87.40	-8.66	58600.00	21940.91	7871.74	49.45	42.11	6.66
121	B2	-15.39	86.42	-8.57	58603.20	21939.93	7871.83	49.47	42.42	6.64
122	C3	-13.50	77.86	-7.88	58605.20	21931.36	7872.53	49.69	45.09	6.42
123	D4	-12.43	72.99	-7.50	58606.20	21926.43	7872.90	49.81	46.60	6.31
124	E5	-11.40	63.11	-7.12	58607.00	21921.61	7873.29	49.91	48.12	6.19
125	F6	-10.43	63.22	-6.70	58608.20	21916.72	7873.70	49.99	49.63	6.07

126

127 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

128 SANDIA WELL ID # 7160 LOG ID # 2

129 AZIMUTH: 81.75 ZENITH: -10.78

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY	
130										
131	A1	44.17	8.81	-9.29	58433.77	21963.66	7871.91	-0.69	28.06	6.61
132	B2	41.30	8.15	-8.74	58430.89	21963.01	7872.46	-1.58	28.14	6.44
133	C3	38.42	7.51	-8.20	58428.02	21962.36	7873.00	-2.43	28.21	6.28
134	D4	35.54	6.89	-7.62	58425.14	21961.74	7873.57	-3.37	28.28	6.10
135	E5	32.67	6.28	-7.00	58422.27	21961.13	7874.20	-4.27	28.34	5.91
136	F6	29.79	5.69	-6.40	58419.39	21960.55	7874.80	-5.16	28.39	5.73
137	G7	26.91	5.12	-5.77	58416.50	21959.97	7875.43	-6.06	28.45	5.54

138

139 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

140 SANDIA WELL ID # 7151 LOG ID # 2

141 AZIMUTH: 170.70 ZENITH: -12.10

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY	
142										
143	A1	31.00	-124.91	-17.27	58463.50	21994.79	7862.53	9.61	19.93	9.47
144	B2	29.02	-115.31	-17.14	58460.72	22004.40	7862.66	9.18	16.91	9.43
145	C3	22.98	-96.25	-16.54	58454.67	22023.45	7863.26	8.16	10.90	9.25
146	D4	17.40	-77.06	-15.31	58449.17	22042.64	7864.49	7.31	4.88	8.87
147	E5	13.26	-61.75	-13.39	58444.97	22057.95	7866.41	6.69	0.00	8.29

148

149 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

150 SANDIA WELL ID # 7152 LOG ID # 1

151 AZIMUTH: 169.30 ZENITH: -10.10

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY	
152										
153	A1	15.26	-82.41	-14.55	58460.45	22038.89	7866.25	10.56	6.49	8.34
154	B2	13.41	-73.37	-13.43	58458.61	22047.93	7867.37	10.39	3.68	7.99
155	C3	12.21	-67.54	-12.62	58457.42	22053.76	7868.18	10.27	1.87	7.75
156	D4	11.23	-62.70	-11.87	58456.42	22053.60	7868.93	10.18	0.37	7.52
157	E5	10.23	-57.87	-11.04	58455.44	22063.43	7869.76	10.08	-1.13	7.27
158	F6	9.30	-53.03	-10.20	58454.50	22063.27	7870.60	10.01	-2.63	7.01

159

160 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

161 SANDIA WELL ID # 7170 LOG ID # 1

162 AZIMUTH: 162.23 ZENITH: -10.49

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY	
163										
164	A1	47.90	-110.24	-31.81	58400.00	22013.16	7848.59	23.43	14.68	13.72
165	B2	46.46	-107.42	-31.30	58394.55	22020.93	7849.02	23.11	13.76	13.59
166	C3	36.90	-88.94	-28.54	58394.90	22039.46	7851.36	21.01	7.78	12.72
167	D4	26.74	-69.17	-24.49	58394.03	22059.23	7855.91	18.78	1.38	11.49
168	E5	18.14	-50.74	-19.20	58376.20	22077.66	7861.12	16.97	-4.54	9.90

126

169
170 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
171 SANDIA WELL ID # 7153 LOG ID # 1
172 AZIMUTH: 162.07 ZENITH: -10.90
173 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
174 A1 42.51 -115.83 -19.40 58499.72 22010.30 7860.90 21.20 16.78 9.97
175 B2 41.45 -113.14 -19.16 58490.67 22012.99 7861.14 20.99 15.93 9.89
176 C3 34.28 -94.50 -17.21 58491.50 22031.55 7863.09 19.62 10.02 9.30
177 D4 23.50 -67.85 -14.03 58488.72 22050.30 7866.22 17.50 1.49 8.34
178 E5 16.02 -49.32 -10.60 58474.03 22076.02 7869.62 16.27 -4.38 7.31
179
180 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
181 SANDIA WELL ID # 7154 LOG ID # 2
182 AZIMUTH: 173.95 ZENITH: -10.63
183 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
184 A1 31.87 -125.27 -14.01 58517.47 22004.20 7866.19 26.30 19.38 8.35
185 B2 20.93 -115.72 -13.90 58514.53 22013.76 7866.30 25.82 16.37 8.32
186 C3 22.06 -96.66 -14.03 58500.47 22032.30 7866.17 24.79 10.36 8.36
187 D4 16.83 -77.63 -12.91 58502.44 22051.84 7867.29 23.78 4.36 8.02
188 E5 12.40 -63.36 -11.58 58498.02 22066.10 7868.62 23.05 -0.13 7.61
189
190 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
191 SANDIA WELL ID # 7155 LOG ID # 2
192 AZIMUTH: 164.15 ZENITH: -9.75
193 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
194 A1 34.11 -78.16 -15.90 58540.25 22049.60 7863.40 37.51 6.98 9.21
195 B2 29.07 -69.65 -14.42 58540.22 22050.11 7864.88 36.36 4.20 8.75
196 C3 23.27 -59.34 -12.44 58537.41 22068.42 7866.86 35.04 0.04 8.15
197 D4 20.98 -54.98 -11.57 58535.12 22072.73 7867.73 34.53 -0.57 7.89
198 E5 18.72 -50.60 -10.70 58532.86 22077.16 7868.60 34.04 -1.99 7.62
199 F6 16.53 -46.21 -9.74 58530.67 22081.55 7869.56 33.56 -3.41 7.33
200
201 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
202 SANDIA WELL ID # 7171 LOG ID # 1
203 AZIMUTH: 176.53 ZENITH: -16.00
204 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
205 A1 18.56 -129.21 -34.04 58531.69 21997.03 7844.86 30.32 21.90 14.86
206 B2 16.70 -114.55 -30.10 58529.01 22012.48 7848.80 30.38 17.40 13.66
207 C3 13.96 -94.35 -25.07 58527.00 22032.69 7853.83 30.41 11.19 12.12
208 D4 9.57 -68.67 -19.74 58522.69 22058.36 7859.16 30.17 3.25 10.50
209 E5 5.74 -43.57 -15.05 58510.07 22078.46 7863.85 29.87 -2.90 9.07
210

211 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

212 SANDIA WELL ID # 7156 LOG ID # 2

213 AZIMUTH: 169.95 ZENITH: -9.40

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
214										
215	A1	25.52	-128.47	-20.62	58543.92	22004.00	7859.28	35.78	20.77	10.46
216	B2	23.03	-118.83	-19.67	58546.44	22013.65	7860.23	35.44	17.76	10.17
217	C3	17.97	-99.61	-17.48	58541.37	22032.86	7862.42	34.73	11.74	9.50
218	D4	11.38	-69.68	-12.92	58534.78	22062.80	7866.98	34.01	2.43	8.12
219	E5	8.38	-50.23	-9.39	58531.70	22082.24	7870.51	33.93	-3.57	7.04

220

221 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

222 SANDIA WELL ID # 7157 LOG ID # 1

223 AZIMUTH: 160.10 ZENITH: -10.90

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
224										
225	A1	63.03	-111.93	-19.46	58593.37	22020.56	7860.24	49.90	17.66	10.17
226	B2	56.71	-104.23	-18.61	58587.06	22028.27	7861.08	48.32	15.07	9.91
227	C3	44.35	-88.62	-16.74	58574.69	22043.87	7862.96	45.25	9.83	9.34
228	D4	32.88	-72.30	-15.37	58569.22	22060.20	7864.33	42.48	4.42	8.92
229	E5	24.64	-58.74	-13.33	58554.93	22073.75	7866.37	40.57	-0.02	8.30

230

231 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

232 SANDIA WELL ID # 7158 LOG ID # 1

233 AZIMUTH: 166.97 ZENITH: -6.72

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
234										
235	A1	16.73	-77.93	-7.44	58561.86	22049.01	7873.16	41.59	7.74	6.23
236	B2	15.79	-74.04	-7.28	58560.92	22052.89	7873.32	41.48	6.52	6.18
237	C3	11.98	-57.49	-6.50	58557.11	22069.44	7874.10	41.03	1.37	5.94
238	D4	10.85	-52.64	-6.11	58555.97	22074.29	7874.49	40.89	-0.14	5.83
239	E5	9.73	-47.79	-5.67	58554.84	22079.14	7874.93	40.76	-1.66	5.69
240	F6	8.67	-42.92	-5.20	58553.78	22084.01	7875.40	40.64	-3.17	5.55

241

242 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

243 SANDIA WELL ID # 7159 LOG ID # 2

244 AZIMUTH: 162.22 ZENITH: -12.00

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
245										
246	A1	49.56	-118.40	-23.40	58603.80	22028.06	7856.90	54.08	16.05	11.19
247	B2	45.14	-109.54	-21.98	58604.39	22036.92	7858.32	53.92	13.19	10.75
248	C3	36.21	-91.85	-19.26	58595.45	22054.61	7861.04	51.97	7.47	9.93
249	D4	27.40	-74.15	-16.27	58586.66	22072.31	7864.03	50.07	1.75	9.01
250	E5	19.46	-56.10	-12.95	58573.70	22090.36	7867.35	48.44	-4.03	8.00

251

252 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

253 SANDIA WELL ID # 7261 LOG ID # 2
 254 AZIMUTH: 348.63 ZENITH: 18.21
 255 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
 256 A1 -29.43 130.99 43.36 58442.59 21953.02 7761.76 1.52 31.65 40.19
 257 B2 -28.76 127.84 42.26 58443.27 21949.97 7760.67 1.59 32.63 40.52
 258 C3 -24.56 108.32 35.75 58447.47 21930.35 7754.15 2.03 38.70 42.50
 259 D4 -20.63 88.70 29.37 58451.39 21910.73 7747.78 2.39 44.79 44.45
 260 E5 -17.03 72.36 23.94 58454.98 21894.39 7742.34 2.78 49.87 46.11

261

262 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

263 SANDIA WELL ID # 7274 LOG ID # 1

264 AZIMUTH: 343.30 ZENITH: -0.37

265 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
 266 A1 -26.22 133.50 -2.30 58440.42 21956.30 7714.90 3.42 30.91 54.47
 267 B2 -25.40 128.60 -2.14 58449.23 21951.47 7715.06 3.46 32.40 54.42
 268 C3 -21.98 108.98 -1.63 58452.66 21931.77 7715.56 3.66 38.49 54.27
 269 D4 -18.41 89.31 -1.13 58456.23 21912.10 7716.06 3.91 44.58 54.11
 270 E5 -14.65 69.67 -0.77 58459.98 21892.46 7716.43 4.21 50.67 54.00

271

272 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

273 SANDIA WELL ID # 7262 LOG ID # 1

274 AZIMUTH: 350.13 ZENITH: 17.44

275 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
 276 A1 -22.75 100.31 35.03 58469.12 21936.50 7751.43 8.83 37.76 43.33
 277 B2 -22.55 107.30 34.72 58469.33 21935.56 7751.12 8.85 38.05 43.43
 278 C3 -17.19 83.55 26.73 58474.69 21911.73 7743.13 9.46 45.47 45.86
 279 D4 -12.71 63.85 20.29 58479.17 21892.05 7736.69 9.98 51.61 47.83
 280 E5 -10.66 53.96 17.10 58481.22 21882.14 7733.50 10.18 54.68 48.80

281

282 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

283 SANDIA WELL ID # 7263 LOG ID # 1

284 AZIMUTH: 353.10 ZENITH: 24.97

285 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
 286 A1 -3.76 80.00 38.16 58501.20 21909.16 7753.15 17.35 47.38 42.81
 287 B2 -4.41 75.77 36.15 58500.56 21904.84 7751.15 16.98 48.65 43.42
 288 C3 -6.03 64.44 30.90 58490.94 21893.51 7745.90 16.01 52.00 45.02
 289 D4 -6.77 59.42 28.52 58490.20 21888.48 7743.52 15.57 53.49 45.74
 290 E5 -7.51 54.36 26.24 58497.46 21883.43 7741.24 15.13 54.98 46.44
 291 F6 -8.25 49.34 23.86 58496.72 21878.41 7738.86 14.70 56.46 47.17

292

293 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

294 SANDIA WELL ID # 7264 LOG ID # 2

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295 AZIMUTH: 358.50 ZENITH: 3.12
296 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
297 A1 -5.91 140.83 6.05 58518.02 21974.40 7717.95 25.20 28.40 53.54
298 B2 -5.87 139.13 6.00 58518.06 21972.70 7717.90 25.14 28.91 53.55
299 C3 -5.31 117.95 5.22 58518.64 21951.52 7717.12 24.41 35.33 53.79
300 D4 -4.66 96.78 4.40 58519.30 21930.34 7716.30 23.72 41.75 54.04
301 E5 -3.64 74.12 3.53 58520.31 21907.68 7715.48 23.06 48.63 54.29
302
303 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
304 SANDIA WELL ID # 7275 LOG ID # 2
305 AZIMUTH: 359.28 ZENITH: 17.00
306 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
307 A1 -0.83 130.28 39.30 58522.53 21964.02 7752.20 26.12 31.72 43.10
308 B2 -0.94 125.69 37.89 58522.47 21959.44 7750.79 25.91 33.10 43.53
309 C3 -1.18 106.57 32.04 58522.22 21940.31 7744.94 25.02 38.86 45.31
310 D4 -1.41 87.41 26.30 58522.00 21921.16 7739.20 24.14 44.64 47.06
311 E5 -1.19 69.03 20.75 58522.22 21902.77 7733.65 23.43 50.19 48.75
312
313 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
314 SANDIA WELL ID # 7265 LOG ID # 1
315 AZIMUTH: 352.92 ZENITH: 17.65
316 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
317 A1 -14.15 127.01 40.59 58526.03 21964.47 7752.69 27.44 31.77 42.95
318 B2 -13.65 122.47 39.10 58527.33 21959.93 7751.20 27.40 33.16 43.40
319 C3 -11.50 102.18 32.66 58529.43 21939.64 7744.76 27.18 39.37 45.37
320 D4 -8.69 79.27 25.39 58532.28 21916.73 7737.49 27.06 46.41 47.58
321 E5 -6.40 59.00 18.03 58534.50 21896.47 7730.98 26.87 52.62 49.57
322
323 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
324 SANDIA WELL ID # 7266 LOG ID # 2
325 AZIMUTH: 347.07 ZENITH: 25.00
326 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
327 A1 -30.17 86.40 42.70 58526.39 21924.37 7753.90 25.60 43.85 42.58
328 B2 -29.21 84.35 41.66 58527.36 21922.31 7752.86 25.81 44.51 42.90
329 C3 -23.77 71.59 35.20 58532.00 21909.55 7746.40 26.91 48.60 44.87
330 D4 -21.64 66.09 32.47 58534.92 21884.05 7743.67 27.32 50.35 45.70
331 E5 -19.56 60.50 29.71 58537.00 21890.55 7740.91 27.71 52.10 46.54
332 F6 -17.97 56.35 27.53 58538.59 21894.31 7738.78 28.01 53.44 47.19
333
334 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
335 SANDIA WELL ID # 7267 LOG ID # 2
336 AZIMUTH: 354.33 ZENITH: 20.32

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	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
337										
338	A1	-16.94	126.42	547.43	58553.48	21969.53	7756.33	35.70	31.37	41.84
339	B2	-16.31	125.50	547.06	58553.61	21968.62	7755.96	35.70	31.65	41.95
340	C3	-14.65	110.54	541.26	58555.78	21953.65	7750.16	35.72	36.26	43.72
341	D4	-11.11	86.26	532.08	58559.31	21929.37	7740.98	35.75	43.74	46.52
342	E5	-8.50	66.17	524.50	58561.92	21909.28	7733.48	35.69	49.91	48.81
343	F6	-6.03	46.04	517.15	58564.39	21889.15	7726.05	35.58	56.09	51.07

344

345 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

346 SANDIA WELL ID # 7276 LOG ID # 1

347 AZIMUTH: 349.80 ZENITH: 9.51

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
348										
349	A1	-24.85	123.38	57.74	58545.64	21966.44	7715.34	33.26	31.98	54.33
350	B2	-24.65	122.40	57.63	58546.05	21965.47	7715.28	33.28	32.28	54.35
351	C3	-21.86	108.51	56.78	58548.81	21951.56	7714.38	33.53	36.59	54.63
352	D4	-17.94	88.93	55.62	58552.75	21931.99	7713.22	33.88	42.67	54.98
353	E5	-13.55	66.91	54.14	58557.14	21909.98	7711.74	34.27	49.50	55.43

354

355 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

356 SANDIA WELL ID # 7268 LOG ID # 2

357 AZIMUTH: 351.86 ZENITH: 29.78

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
358										
359	A1	9.20	127.11	545.92	58599.08	21971.39	7752.22	49.54	32.74	43.09
360	B2	8.30	121.90	544.07	58598.17	21966.18	7750.37	49.04	34.28	43.66
361	C3	4.78	101.84	536.39	58594.66	21946.12	7743.19	47.13	40.18	45.85
362	D4	0.72	76.50	527.07	58590.61	21920.78	7734.17	44.83	47.66	48.59
363	E5	-1.55	56.28	520.64	58586.33	21900.56	7726.94	43.29	53.66	50.80

364

365 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

366 SANDIA WELL ID # 7277 LOG ID # 1

367 AZIMUTH: 348.48 ZENITH: 7.35

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
368										
369	A1	-29.45	131.79	516.81	58559.33	21974.69	7722.11	37.68	30.06	52.27
370	B2	-26.21	118.49	515.07	58562.56	21961.38	7720.37	38.09	34.21	52.80
371	C3	-21.60	99.19	512.56	58567.17	21942.09	7717.86	38.66	40.23	53.57
372	D4	-16.76	79.22	510.04	58572.02	21922.12	7715.34	39.28	46.47	54.33
373	E5	-12.38	59.06	507.61	58576.37	21902.76	7712.91	39.77	52.50	55.07

374

375 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

376 SANDIA WELL ID # 7269 LOG ID # 2

377 AZIMUTH: 0.17 ZENITH: -5.40

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
378									

379	A1	-12.11	105.03	-0.21	58591.34	21949.09	7724.21	46.26	39.15	51.63
380	B2	-16.05	123.00	-0.23	58587.39	21967.06	7724.19	45.83	33.55	51.64
381	C3	-12.70	107.56	-0.21	58590.75	21951.62	7724.21	46.19	38.36	51.63
382	D4	-11.37	101.92	-0.19	58592.08	21945.98	7724.23	46.35	40.12	51.62
383	E5	-10.04	96.17	-0.18	58593.42	21940.23	7724.24	46.51	41.91	51.62
384	F6	-0.75	90.41	-0.18	58594.70	21934.48	7724.24	46.65	43.70	51.62

385

386 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

387 SANDIA WELL ID # 7269 LOG ID # 1

388 AZIMUTH: 6.20 ZENITH: 20.61

		X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
389										
390	A1	11.13	92.85	51.32	58619.19	21935.55	7756.41	54.09	44.41	41.81
391	B2	10.24	88.06	40.56	58610.30	21930.76	7753.66	53.61	45.82	42.65
392	C3	8.04	74.30	40.96	58616.09	21917.09	7746.06	52.37	49.86	44.97
393	D4	7.35	69.34	38.19	58615.41	21912.04	7743.29	51.95	51.35	45.82
394	E5	6.73	64.22	35.32	58614.80	21906.92	7740.42	51.55	52.37	46.69
395	F6	6.18	59.06	32.50	58614.23	21901.77	7737.60	51.16	54.40	47.55

396

397 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

398 SANDIA WELL ID # 7260 LOG ID # 2

399 AZIMUTH: 71.85 ZENITH: 10.39

		X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
400										
401	A1	78.84	26.28	17.15	58464.36	21991.50	7761.25	9.73	20.96	40.34
402	B2	64.90	21.26	13.36	58455.41	21986.48	7757.46	5.30	21.88	41.50
403	C3	55.45	18.22	10.99	58440.97	21983.44	7755.09	2.33	22.40	42.22
404	D4	49.58	16.35	9.71	58435.09	21981.57	7753.81	0.47	22.71	42.61
405	E5	44.82	14.80	8.75	58430.33	21980.02	7752.85	-1.03	22.98	42.90
406	F6	40.05	13.24	7.81	58425.56	21978.46	7751.91	-2.54	23.25	43.19

407

408 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

409 SANDIA WELL ID # 7251 LOG ID # 1

410 AZIMUTH: 172.62 ZENITH: 1.02

		X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
411										
412	A1	12.70	-132.02	-1.14	58448.75	21983.55	7756.27	3.38	20.97	41.86
413	B2	11.09	-122.16	-1.42	58442.12	21980.41	7755.98	3.31	17.93	41.95
414	C3	8.27	-102.97	-1.79	58439.31	22013.20	7755.61	3.30	11.84	42.06
415	D4	6.28	-80.47	-2.09	58437.33	22040.10	7755.31	3.63	5.14	42.15
416	E5	5.60	-62.50	-1.55	58436.64	22053.07	7755.85	4.19	-0.31	41.99

417

418 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

419 SANDIA WELL ID # 7270 LOG ID # 2

420 AZIMUTH: 170.70 ZENITH: -19.65

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
421										
422	A1	31.11	-113.33	-53.99	58463.23	22005.55	7701.01	9.99	16.67	58.70
423	B2	30.27	-111.45	-53.34	58462.41	22007.48	7701.66	9.81	16.05	58.50
424	C3	22.48	-93.16	-46.03	58454.59	22025.77	7708.97	8.24	10.20	56.28
425	D4	15.48	-73.84	-35.93	58447.59	22045.09	7719.07	6.94	4.07	53.20
426	E5	10.78	-56.11	-25.32	58442.91	22062.82	7729.68	6.28	-1.48	49.96

427

428 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

429 SANDIA WELL ID # 7252 LOG ID # 1

430 AZIMUTH: 172.47 ZENITH: -4.79

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
431										
432	A1	10.73	-03.76	-10.27	58456.36	22038.48	7747.33	9.30	6.44	44.58
433	B2	9.80	-75.80	-9.30	58456.42	22046.37	7748.29	9.36	4.02	44.29
434	C3	8.86	-67.90	-8.45	58454.48	22054.27	7749.15	9.41	1.59	44.03
435	D4	8.13	-62.08	-7.67	58453.75	22060.16	7749.93	9.44	-0.22	43.79
436	E5	7.62	-58.16	-7.09	58453.25	22064.09	7750.51	9.45	-1.43	43.61
437	F6	6.93	-53.26	-6.28	58452.61	22068.98	7751.32	9.47	-2.93	43.37

438

439 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

440 SANDIA WELL ID # 7253 LOG ID # 0

441 AZIMUTH: 176.80 ZENITH: -0.69

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
442										
443	A1	7.26	-129.80	-1.57	58464.01	21992.87	7756.23	14.93	20.53	41.87
444	B2	6.14	-109.83	-1.33	58462.89	22012.84	7756.47	13.78	14.45	41.80
445	C3	5.02	-89.86	-1.09	58461.77	22032.81	7756.71	12.59	8.33	41.72
446	D4	3.85	-68.89	-0.83	58460.60	22053.78	7756.97	11.35	2.00	41.65
447	E5	2.74	-49.92	-0.59	58459.49	22073.75	7757.21	10.17	-4.07	41.57

448

449 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

450 SANDIA WELL ID # 7254 LOG ID # 1

451 AZIMUTH: 168.70 ZENITH: -1.60

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
452										
453	A1	33.45	-135.71	-2.43	58511.78	21987.00	7755.97	23.85	24.33	41.95
454	B2	31.39	-126.50	-3.57	58509.73	21996.20	7754.83	23.62	21.46	42.30
455	C3	29.14	-116.79	-4.24	58507.46	22005.92	7754.16	23.36	18.44	42.50
456	D4	24.23	-97.43	-5.29	58502.50	22025.28	7753.11	22.69	12.38	42.82
457	E5	19.34	-78.04	-5.22	58497.69	22044.66	7753.18	22.04	6.33	42.80
458	F6	14.20	-58.22	-4.24	58492.55	22064.48	7754.16	21.33	0.13	42.50

459

460 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

461 SANDIA WELL ID # 7255 LOG ID # 1

462 AZIMUTH: 172.02 ZENITH: -1.11

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
463										
464	A1	1.99	-69.92	-2.29	58495.33	22044.20	7756.40	21.31	6.37	41.82
465	B2	2.00	-68.92	-2.28	58495.33	22045.20	7756.41	21.35	6.06	41.81
466	C3	2.01	-67.92	-2.28	58495.34	22046.20	7756.42	21.40	5.76	41.81
467	D4	2.07	-62.92	-2.15	58495.39	22051.20	7756.55	21.63	4.26	41.77
468	E5	2.20	-57.93	-1.99	58495.53	22056.19	7756.71	21.88	2.75	41.72
469	F6	2.43	-52.94	-1.80	58495.77	22061.18	7756.90	22.16	1.26	41.67

470

471 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

472 SANDIA WELL ID # 7256 LOG ID # 1

473 AZIMUTH: 168.87 ZENITH: 0.52

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
474										
475	A1	16.44	-86.22	2.29	58530.69	22043.92	7761.99	31.97	7.95	40.11
476	B2	15.98	-84.18	2.05	58530.20	22045.96	7761.75	31.91	7.31	40.19
477	C3	11.58	-64.72	0.74	58525.81	22065.41	7760.44	31.41	1.25	40.59
478	D4	7.73	-45.11	0.49	58521.97	22085.03	7760.19	31.08	-4.83	40.66
479	E5	3.98	-22.43	0.16	58518.22	22107.71	7759.86	30.91	-11.83	40.77
480	F6	0.51	-2.75	0.02	58514.75	22127.38	7759.72	30.70	-17.92	40.81

481

482 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

483 SANDIA WELL ID # 7272 LOG ID # 2

484 AZIMUTH: 159.35 ZENITH: -17.01

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
485										
486	A1	71.94	-124.31	-36.96	58595.77	22008.30	7721.34	50.11	21.46	52.50
487	B2	66.16	-115.75	-35.05	58590.00	22016.85	7723.26	48.72	18.64	51.92
488	C3	54.37	-98.78	-31.31	58578.20	22033.82	7726.99	45.38	13.01	50.78
489	D4	42.86	-81.70	-27.26	58566.69	22050.91	7731.04	43.13	7.37	49.55
490	E5	32.42	-66.91	-22.98	58556.25	22065.69	7735.32	40.61	2.46	48.25
491	F6	22.19	-49.42	-17.53	58546.02	22083.19	7740.77	38.26	-3.25	46.58

492

493 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

494 SANDIA WELL ID # 7257 LOG ID # 1

495 AZIMUTH: 172.82 ZENITH: -3.86

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
496										
497	A1	14.52	-137.09	-5.81	58536.19	21995.20	7753.39	31.56	22.89	42.74
498	B2	13.91	-131.62	-5.94	58535.56	22000.66	7753.26	31.61	21.22	42.78
499	C3	12.33	-119.73	-6.00	58533.98	22012.55	7753.21	31.64	17.56	42.79
500	D4	9.66	-99.92	-5.68	58531.33	22032.37	7753.52	31.67	11.46	42.70
501	E5	7.37	-80.06	-5.30	58529.03	22052.23	7753.89	31.82	5.37	42.58
502	F6	5.53	-60.15	-4.69	58527.19	22072.13	7754.50	32.11	-0.71	42.40

503

504 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

505 SANDIA WELL ID # 7258 LOG ID # 2
 506 AZIMUTH: 169.62 ZENITH: -3.73
 507 X-REL Y-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
 508 A1 5.90 -85.56 -3.36 58550.73 22049.75 7756.64 38.27 7.04 41.75
 509 B2 5.58 -79.57 -3.80 58550.42 22059.73 7756.20 38.60 4.01 41.88
 510 C3 5.48 -65.58 -3.95 58550.33 22069.73 7756.05 38.99 0.99 41.93
 511 D4 5.55 -60.58 -3.81 58550.39 22074.73 7756.19 39.22 -0.51 41.88
 512 E5 5.65 -55.58 -3.64 58550.48 22079.73 7756.36 39.47 -2.02 41.83
 513 F6 5.68 -50.59 -3.41 58550.53 22084.72 7756.59 39.69 -3.52 41.76

514
 515 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
 516 SANDIA WELL ID # 7259 LOG ID # 3
 517 AZIMUTH: 176.68 ZENITH: -0.49
 518 X-REL Y-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
 519 A1 5.95 -143.34 -4.78 58559.22 21993.27 7755.52 33.43 24.45 42.09
 520 B2 5.41 -133.36 -4.74 58558.67 22003.25 7755.56 38.69 21.41 42.08
 521 C3 4.40 -113.39 -4.60 58557.67 22023.22 7755.70 39.24 15.34 42.03
 522 D4 3.29 -93.43 -4.13 58556.55 22043.18 7756.17 39.75 9.27 41.89
 523 E5 2.08 -66.48 -3.00 58555.34 22070.12 7757.30 40.53 1.09 41.54
 524 F6 1.76 -46.52 -1.90 58555.03 22090.09 7758.40 41.28 -4.96 41.21

525
 526 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
 527 SANDIA WELL ID # 7273 LOG ID # 1
 528 AZIMUTH: 170.15 ZENITH: -17.57
 529 X-REL Y-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
 530 A1 27.66 -131.00 -52.81 58581.97 22002.08 7705.49 45.67 22.75 57.34
 531 B2 25.57 -122.80 -49.76 58579.87 22010.28 7708.54 45.39 20.19 56.41
 532 C3 20.10 -103.82 -42.63 58574.89 22029.25 7715.67 44.54 14.23 54.23
 533 D4 14.93 -84.97 -34.95 58569.23 22048.09 7723.35 43.78 8.32 51.89
 534 E5 12.41 -71.84 -29.10 58566.70 22061.23 7729.20 43.58 4.25 50.11
 535 F6 9.33 -53.01 -20.35 58563.62 22080.05 7737.96 43.44 -1.56 47.44

536
 537 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
 538 SANDIA WELL ID # 7357 LOG ID # 2
 539 AZIMUTH: 354.80 ZENITH: 20.83
 540 X-REL Y-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
 541 A1 -9.61 114.23 44.53 58465.30 21945.35 7664.54 8.05 34.93 69.82
 542 B2 -9.52 113.80 44.17 58465.39 21944.42 7664.19 8.04 35.21 69.93
 543 C3 -9.32 111.16 43.35 58465.61 21942.28 7663.37 8.02 35.87 70.18
 544 D4 -7.44 91.00 35.64 58467.62 21922.20 7655.64 7.78 42.01 72.53
 545 E5 -5.78 73.22 28.77 58469.39 21904.36 7643.77 7.55 47.47 74.62
 546

547 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

548 SANDIA WELL ID # 7358 LOG ID # 2

549 AZIMUTH: 351.85 ZENITH: 28.53

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
550									
551 A1	-1.19	96.20	52.45	58509.58	21950.42	7673.25	21.63	35.28	67.16
552 B2	-1.38	88.48	48.24	58509.37	21942.70	7669.04	21.24	37.60	68.45
553 C3	-2.15	72.40	39.53	58508.61	21926.61	7660.33	20.33	42.42	71.10
554 D4	-2.41	67.31	36.76	58508.36	21921.52	7657.57	20.04	43.95	71.94
555 E5	-2.75	62.11	34.00	58508.02	21916.33	7654.80	19.72	45.50	72.79
556 F6	-3.07	57.02	31.25	58507.70	21911.23	7652.05	19.40	47.02	73.63

557

558 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

559 SANDIA WELL ID # 7359 LOG ID # 2

560 AZIMUTH: 346.53 ZENITH: 19.95

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
561									
562 A1	-36.12	132.37	49.99	58508.06	21968.29	7669.59	20.42	29.60	68.28
563 B2	-31.83	119.71	45.18	58507.36	21955.65	7664.78	21.18	33.60	69.75
564 C3	-25.82	100.28	37.93	58513.36	21936.21	7657.52	22.17	39.73	71.96
565 D4	-18.85	74.41	28.21	58520.34	21910.34	7647.81	23.13	47.83	74.92
566 E5	-15.81	61.91	23.50	58520.37	21897.84	7643.10	23.57	51.73	76.35

567

568 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

569 SANDIA WELL ID # 7360 LOG ID # 3

570 AZIMUTH: 352.73 ZENITH: 23.89

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
571									
572 A1	-17.60	90.66	52.10	58526.97	21930.34	7673.50	26.03	42.08	67.09
573 B2	-16.70	86.25	49.53	58527.94	21925.92	7670.93	26.14	43.45	67.87
574 C3	-13.02	70.76	40.52	58531.62	21910.43	7661.92	26.59	48.28	70.62
575 D4	-11.04	65.86	37.65	58532.81	21905.53	7659.05	26.74	49.81	71.49
576 E5	-10.63	60.86	34.76	58534.00	21900.53	7656.16	26.89	51.37	72.37
577 F6	-9.57	55.93	31.89	58535.00	21895.60	7653.29	27.00	52.90	73.25

578

579 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

580 SANDIA WELL ID # 7361 LOG ID # 2

581 AZIMUTH: 351.80 ZENITH: 21.24

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
582									
583 A1	-29.03	136.87	51.67	58569.87	21933.39	7672.13	41.24	27.88	67.51
584 B2	-26.77	126.96	48.03	58572.23	21973.43	7668.48	41.53	30.99	68.62
585 C3	-22.23	107.13	40.75	58576.97	21953.52	7661.18	42.11	37.20	70.84
586 D4	-18.33	90.06	34.48	58581.03	21936.37	7654.90	42.61	42.55	72.76
587 E5	-14.03	71.25	27.57	58585.02	21917.48	7647.97	43.16	48.44	74.87

588

589 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

590 SANDIA WELL ID # 7356 LOG ID # 3

591 AZIMUTH: 87.12 ZENITH: 18.51

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
592										
593	A1	186.88	-18.82	57.39	58568.38	21966.57	7663.29	48.84	32.89	78.28
594	B2	179.99	-17.47	55.89	58561.41	21967.93	7661.29	38.82	32.19	78.81
595	C3	168.88	-13.28	58.31	58541.41	21972.28	7655.71	32.16	38.85	72.51
596	D4	148.18	-8.31	44.58	58521.59	21977.89	7649.98	26.39	27.74	74.26
597	E5	128.28	-3.88	38.85	58581.69	21981.68	7644.25	28.57	25.53	76.88
598	F6	108.17	-1.49	32.59	58481.56	21983.91	7637.99	14.68	23.98	77.91

600 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

601 SANDIA WELL ID # 7355 LOG ID # 4

602 AZIMUTH: 84.66 ZENITH: 28.58

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
603										
604	A1	168.54	-5.45	64.44	58587.78	22883.37	7675.81	32.39	28.49	66.63
605	B2	158.68	-4.54	68.38	58527.81	22884.26	7678.98	29.42	19.88	67.88
606	C3	138.76	-2.53	52.82	58587.97	22886.27	7662.62	23.51	18.35	78.48
607	D4	118.95	-8.56	43.65	58488.16	22888.24	7654.25	17.62	16.91	72.95
608	E5	91.11	1.32	35.33	58468.31	22818.12	7645.93	11.71	15.51	75.49
609	F6	71.18	2.68	27.38	58448.31	22811.39	7637.98	5.73	14.27	77.94

611 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

612 SANDIA WELL ID # 7354 LOG ID # 6

613 AZIMUTH: 88.98 ZENITH: 15.19

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
614										
615	A1	191.65	49.92	58.85	58567.64	22882.92	7663.74	44.78	-2.25	78.86
616	B2	176.27	46.59	46.23	58552.27	22879.59	7659.93	48.88	-1.98	71.22
617	C3	156.56	41.33	41.24	58532.56	22874.32	7654.94	33.83	-1.15	72.74
618	D4	137.85	35.39	36.23	58513.83	22869.38	7649.93	27.69	-8.18	74.27
619	E5	117.53	29.53	31.17	58493.53	22862.52	7644.87	21.55	8.76	75.81
620	F6	98.88	23.88	26.83	58474.88	22856.88	7639.72	15.41	1.66	77.38

622 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

623 SANDIA WELL ID # 7351 LOG ID # 2

624 AZIMUTH: 175.88 ZENITH: 22.91

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
625										
626	A1	25.26	-125.78	53.15	58458.75	21996.38	7673.85	5.82	13.93	66.98
627	B2	23.51	-115.97	49.84	58449.82	22886.83	7669.74	5.71	15.92	68.23
628	C3	21.68	-106.24	45.88	58447.19	22815.76	7665.78	5.57	12.91	69.47
629	D4	16.23	-87.19	36.94	58441.72	22834.81	7657.63	4.73	6.92	71.92
630	E5	11.84	-69.98	29.58	58436.53	22852.18	7658.28	3.98	1.49	74.16

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631 F6      7.09 -51.85 21.92 58432.59 22070.15 7642.62 3.47 -4.13 76.50
632
633 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
634 SANDIA WELL ID # 7352 LOG ID # 3
635 AZIMUTH: 171.90 ZENITH: 20.52
636 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
637 A1 28.17 -125.33 47.44 58465.89 21997.87 7668.14 10.46 19.10 68.72
638 B2 27.37 -115.49 43.85 58465.83 22007.71 7664.55 10.63 16.10 69.81
639 C3 26.21 -106.23 40.57 58463.91 22016.97 7661.27 10.67 13.25 70.82
640 D4 21.20 -06.79 33.25 58453.91 22036.41 7653.96 9.99 7.17 73.04
641 E5 13.72 -68.12 25.95 58451.42 22055.09 7646.65 8.52 1.22 75.27
642 F6 8.34 -40.79 18.56 58446.05 22074.42 7639.25 7.72 -4.85 77.53
643
644 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
645 SANDIA WELL ID # 7353 LOG ID # 3
646 AZIMUTH: 172.90 ZENITH: 20.67
647 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY V-OXY Z-OXY
648 A1 11.63 -88.09 32.61 58457.42 22034.80 7653.61 9.47 7.59 73.15
649 B2 7.84 -58.55 21.87 58453.64 22064.34 7642.87 9.58 -1.48 76.42
650 C3 6.00 -46.65 17.50 58451.87 22076.24 7638.50 9.56 -5.15 77.76
651 D4 4.63 -36.80 13.86 58450.42 22086.10 7634.86 9.53 -8.19 78.86
652 E5 3.93 -31.41 11.85 58449.73 22091.49 7632.85 9.55 -9.84 79.48
653 F6 3.31 -25.91 9.79 58449.09 22096.98 7630.79 9.60 -11.53 80.11

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TOTAL RECORDS WRITTEN = 654/ 146

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1
2 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
3 SANDIA WELL ID # 8130 LOG ID # 2
4 AZIMUTH: 354.95 ZENITH: -20.92
5 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY Y-OXY Z-OXY
6 A1 -21.74 109.15 -77.47 58405.98 22248.20 7801.23 2.66 38.59 28.06
7 B2 -18.52 101.71 -70.00 58409.20 22240.76 7807.90 3.30 40.97 26.03
8 C3 -13.23 87.32 -57.05 58414.48 22226.37 7821.65 4.25 45.55 21.84
9 D4 -8.93 72.47 -42.27 58410.00 22211.52 7836.43 4.02 50.22 17.34
10 E5 -5.98 56.50 -28.98 58421.73 22195.55 7849.72 5.05 55.17 13.28

11
12 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
13 SANDIA WELL ID # 8113 LOG ID # 2
14 AZIMUTH: 356.17 ZENITH: -0.10
15 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY Y-OXY Z-OXY
16 A1 -25.12 125.12 -36.65 58402.83 22262.25 7843.35 2.34 34.21 15.22
17 B2 -22.11 116.10 -33.57 58405.84 22253.23 7846.43 2.84 37.06 14.28
18 C3 -16.51 97.88 -27.51 58411.44 22235.01 7852.49 3.71 42.81 12.44
19 D4 -11.62 79.60 -21.03 58416.33 22216.73 7858.96 4.37 48.54 10.47
20 E5 -9.50 70.41 -17.71 58418.45 22207.55 7862.29 4.60 51.40 9.45

21
22 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
23 SANDIA WELL ID # 8114 LOG ID # 1
24 AZIMUTH: 353.20 ZENITH: -10.74
25 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY Y-OXY Z-OXY
26 A1 -24.14 127.12 -16.11 58422.86 22260.52 7864.49 8.66 33.21 8.78
27 B2 -18.86 107.89 -14.69 58428.16 22249.28 7865.91 9.39 39.25 8.35
28 C3 -18.86 107.89 -14.69 58428.16 22249.28 7865.91 9.39 39.25 8.35
29 D4 -12.52 81.69 -13.23 58434.50 22223.09 7867.37 10.13 47.43 7.90
30 E5 -8.50 62.21 -11.14 58430.52 22203.61 7869.46 10.48 53.49 7.27
31 F6 -6.28 49.54 -9.29 58440.73 22190.94 7871.31 10.58 57.40 6.70

32
33 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
34 SANDIA WELL ID # 8124 LOG ID # 2
35 AZIMUTH: 349.72 ZENITH: -37.87
36 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-OXY Y-OXY Z-OXY
37 A1 -17.85 64.72 -83.55 58444.03 22209.61 7794.36 12.40 51.92 30.16
38 B2 -15.89 59.16 -72.41 58445.98 22204.05 7805.49 12.75 53.69 26.77
39 C3 -13.99 53.45 -61.38 58447.89 22198.34 7816.52 13.07 55.49 23.40
40 D4 -12.20 47.60 -52.32 58449.67 22192.57 7825.53 13.35 57.31 20.64
41 E5 -11.18 44.24 -47.14 58450.69 22189.13 7830.76 13.50 58.39 19.06
42 F6 -10.10 40.54 -42.16 58451.77 22185.43 7835.74 13.66 59.56 17.54

43

44 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

45 SANDIA WELL ID # 8115 LOG ID # 1

46 AZIMUTH: 351.85 ZENITH: -9.50

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
47										
48	A1	-12.03	83.26	-20.51	58449.75	22228.10	7859.89	14.96	46.60	10.18
49	B2	-10.32	73.78	-17.83	58451.45	22218.62	7862.57	15.05	49.54	9.37
50	C3	-8.68	64.37	-14.06	58453.09	22209.22	7865.54	15.12	52.45	8.46
51	D4	-7.95	59.66	-13.36	58453.83	22204.51	7867.04	15.13	53.90	8.00
52	E5	-7.28	54.90	-11.98	58454.50	22199.74	7868.43	15.12	55.36	7.58
53	F6	-6.64	50.13	-10.64	58455.12	22194.97	7869.76	15.10	56.83	7.17

54

55 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

56 SANDIA WELL ID # 8131 LOG ID # 1

57 AZIMUTH: 351.15 ZENITH: -10.00

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
58										
59	A1	-18.69	121.51	-58.90	58457.36	22271.34	7820.20	19.18	33.91	22.28
60	B2	-17.39	112.03	-54.58	58458.66	22261.86	7824.52	19.15	36.82	20.97
61	C3	-17.39	112.03	-54.58	58458.66	22261.86	7824.52	19.15	36.82	20.97
62	D4	-15.03	93.51	-44.99	58461.02	22243.34	7834.11	19.04	42.51	18.04
63	E5	-12.17	75.23	-34.98	58463.07	22225.12	7844.12	19.08	48.13	14.99
64	F6	-10.72	63.04	-30.58	58465.33	22217.87	7848.52	19.20	50.38	13.65

65

66 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

67 SANDIA WELL ID # 8116 LOG ID # 1

68 AZIMUTH: 352.40 ZENITH: -11.50

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
69										
70	A1	-28.33	119.04	-21.83	58447.69	22268.95	7858.37	16.16	34.20	10.65
71	B2	-27.30	114.57	-21.57	58448.70	22264.47	7858.63	16.27	35.59	10.57
72	C3	-22.23	95.34	-19.56	58453.78	22245.23	7860.64	16.94	41.62	9.96
73	D4	-16.68	76.28	-17.15	58459.33	22226.17	7863.05	17.76	47.61	9.22
74	E5	-13.61	65.85	-15.47	58462.41	22215.75	7864.73	18.22	50.89	8.71

75

76 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

77 SANDIA WELL ID # 8117 LOG ID # 2

78 AZIMUTH: 348.33 ZENITH: -9.99

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
79										
80	A1	-28.73	107.82	-15.59	58466.48	22264.17	7863.60	21.60	36.47	9.05
81	B2	-28.44	106.87	-15.38	58466.78	22263.22	7863.71	21.65	36.77	9.02
82	C3	-23.13	89.66	-13.61	58472.05	22246.00	7865.49	22.48	42.20	8.48
83	D4	-17.11	70.64	-12.16	58478.06	22226.99	7866.94	23.45	48.20	8.03
84	E5	-11.81	51.52	-9.68	58483.37	22207.87	7869.42	24.19	54.20	7.28

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85
86 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
87 SANDIA WELL ID # 8118 LOG ID # 1
88 AZIMUTH: 352.32 ZENITH: -10.24
89 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
90 A1 -16.33 69.90 -21.39 58494.12 22228.37 7857.91 28.35 48.51 10.79
91 B2 -15.94 68.73 -20.89 58494.52 22227.12 7858.41 28.41 48.90 10.63
92 C3 -14.61 64.32 -18.96 58495.84 22222.70 7860.34 28.61 50.29 10.05
93 D4 -13.32 59.88 -17.04 58497.12 22218.27 7862.26 28.80 51.68 9.46
94 E5 -12.07 55.40 -15.21 58498.37 22213.79 7864.09 28.98 53.09 8.90
95 F6 -10.85 50.89 -13.44 58499.59 22209.27 7865.86 29.15 54.51 8.36

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96
97 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
98 SANDIA WELL ID # 8132 LOG ID # 1
99 AZIMUTH: 347.67 ZENITH: -16.80
100 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
101 A1 -40.49 111.74 -34.58 58485.50 22272.05 7844.43 27.70 34.95 14.90
102 B2 -40.11 110.84 -34.35 58485.87 22271.16 7844.65 27.77 35.24 14.83
103 C3 -40.11 110.84 -34.35 58485.87 22271.16 7844.65 27.77 35.24 14.83
104 D4 -33.91 96.44 -30.73 58492.08 22256.75 7848.27 29.00 39.86 13.73
105 E5 -25.92 77.78 -25.34 58500.06 22238.09 7853.66 30.57 45.84 12.03
106 F6 -21.16 66.64 -21.89 58504.81 22226.95 7857.11 31.51 49.41 11.03

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107
108 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
109 SANDIA WELL ID # 8119 LOG ID # 0
110 AZIMUTH: 349.67 ZENITH: -6.65
111 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
112 A1 -23.41 128.38 -15.11 58502.12 22290.35 7864.79 40.84 30.19 8.69
113 B2 -21.61 118.55 -13.95 58503.92 22280.52 7865.95 41.82 33.23 8.34
114 C3 -21.61 118.55 -13.95 58503.92 22280.52 7865.95 41.82 33.23 8.34
115 D4 -18.03 98.87 -11.64 58507.50 22260.84 7886.26 43.78 39.33 7.63
116 E5 -14.44 79.19 -9.32 58511.09 22241.16 7870.58 45.74 45.42 6.93
117 F6 -11.57 63.45 -7.47 58513.96 22225.42 7872.43 47.31 50.29 6.36

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118
119 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
120 SANDIA WELL ID # 8127 LOG ID # 0
121 AZIMUTH: 347.08 ZENITH: -20.09
122 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
123 A1 -29.95 130.61 -63.10 58495.52 22291.91 7814.10 38.78 29.42 24.14
124 B2 -29.73 129.63 -62.63 58495.74 22290.93 7814.57 38.89 29.73 24.00
125 C3 -29.73 129.63 -62.63 58495.74 22290.93 7814.57 38.89 29.73 24.00
126 D4 -25.21 109.95 -53.12 58500.26 22271.25 7824.08 41.13 35.87 21.10

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127	E5	-20.21	88.11	-42.57	58505.26	22249.41	7834.63	43.62	42.67	17.88
128	F6	-14.53	63.36	-30.61	58510.94	22224.66	7846.59	46.43	50.39	14.24

129

130 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

131 SANDIA WELL ID # 8120 LOG ID # 2

132 AZIMUTH: 351.53 ZENITH: -5.54

		X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
133										
134	A1	-30.66	135.88	-11.29	58510.20	22303.57	7869.41	37.46	26.68	7.28
135	B2	-24.90	117.47	-10.84	58510.97	22285.16	7869.86	38.37	32.49	7.15
136	C3	-19.20	98.33	-9.70	58524.66	22266.02	7870.92	39.23	38.52	6.82
137	D4	-13.71	79.16	-8.30	58530.14	22246.85	7872.39	40.03	44.54	6.37
138	E5	-11.71	70.45	-7.30	58532.14	22230.13	7873.40	40.25	47.26	6.07
139	F6	-8.06	50.89	-5.25	58535.00	22210.58	7875.45	40.48	53.32	5.44

140

141 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

142 SANDIA WELL ID # 8125 LOG ID # 1

143 AZIMUTH: 350.27 ZENITH: -39.77

		X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
144										
145	A1	-21.73	76.85	-67.71	58536.25	22249.77	7810.39	42.01	43.93	25.27
146	B2	-19.01	70.25	-62.07	58538.97	22243.17	7816.03	42.53	46.04	23.55
147	C3	-15.38	61.04	-54.28	58542.59	22233.96	7823.82	43.21	48.98	21.18
148	D4	-13.83	56.46	-50.24	58544.16	22229.39	7827.86	43.48	50.43	19.95
149	E5	-12.36	51.03	-46.23	58545.61	22224.76	7831.87	43.71	51.89	18.72
150	F6	-10.96	47.20	-42.20	58547.02	22220.12	7835.90	43.93	53.36	17.49

151

152 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

153 SANDIA WELL ID # 8121 LOG ID # 2

154 AZIMUTH: 352.10 ZENITH: -10.75

		X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
155										
156	A1	-17.99	81.33	-16.86	58540.11	22254.59	7863.94	43.38	42.65	8.95
157	B2	-15.28	72.82	-15.09	58542.01	22246.09	7865.71	43.82	45.34	8.41
158	C3	-12.63	63.39	-13.12	58545.45	22236.64	7867.68	44.19	48.30	7.81
159	D4	-11.60	59.60	-12.37	58546.50	22232.85	7868.43	44.34	49.49	7.58
160	E5	-10.37	54.83	-11.48	58547.73	22228.09	7869.32	44.50	50.98	7.31
161	F6	-9.21	50.07	-10.48	58548.09	22223.33	7870.32	44.64	52.47	7.00

162

163 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

164 SANDIA WELL ID # 9112 LOG ID # 2

165 AZIMUTH: 81.55 ZENITH: -3.53

		X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
166										
167	A1	59.50	12.11	-11.20	58409.07	22261.10	7869.50	4.26	34.85	7.25
168	B2	54.75	10.82	-10.33	58404.62	22259.01	7870.37	2.77	35.02	6.99

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169 C3      47.15    8.80   -8.85 58397.03 22257.79 7871.85  0.39 35.30  6.54
170 D4      42.39    7.67   -7.82 58392.27 22256.66 7872.88 -1.10 35.42  6.22
171 E5      37.61    6.67   -6.76 58387.48 22255.66 7873.94 -2.59 35.51  5.90
172
173 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
174 SANDIA WELL ID # 8111      LOG ID # 1
175 AZIMUTH:    78.80      ZENITH:   -11.21
176      X-REL  Y-REL  Z-REL  X-GEO  Y-GEO  Z-GEO  X-OXY  Y-OXY  Z-OXY
177 A1      32.62  17.36 -19.65 58420.53 22317.66 7860.75 10.16 18.30  9.92
178 B2      68.33  14.65 -16.42 58406.23 22314.45 7863.98  5.71 18.63  8.94
179 C3      58.82  12.50 -14.19 58396.73 22312.30 7866.21  2.75 18.85  8.26
180 D4      54.09  11.42 -13.00 58392.05 22311.22 7867.40  1.27 18.96  7.89
181 E5      49.36  10.35 -11.80 58387.31 22310.14 7868.60 -0.20 19.08  7.53
182 F6      44.63   9.27 -10.57 58382.58 22309.07 7869.83 -1.68 19.19  7.15
183 G7      39.90   8.20  -9.37 58377.04 22308.00 7871.03 -3.15 19.30  6.79
184
185 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
186 SANDIA WELL ID # 8101      LOG ID # 1
187 AZIMUTH:   171.40      ZENITH:   -13.40
188      X-REL  Y-REL  Z-REL  X-GEO  Y-GEO  Z-GEO  X-OXY  Y-OXY  Z-OXY
189 A1      23.33 -130.84 -46.14 58406.31 22312.56 7836.06  5.78 19.22 17.45
190 B2      20.72 -121.83 -42.71 58404.19 22321.57 7839.49  5.39 16.38 16.40
191 C3      15.78 -103.85 -35.43 58399.25 22339.55 7846.72  4.71 10.74 14.20
192 D4      11.55 -85.66 -28.33 58395.02 22357.74 7853.87  4.25  5.07 12.02
193 E5       7.85 -65.49 -20.36 58391.31 22377.91 7861.84  4.03 -1.18  9.59
194
195 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
196 SANDIA WELL ID # 8123      LOG ID # 1
197 AZIMUTH:   171.63      ZENITH:   -33.71
198      X-REL  Y-REL  Z-REL  X-GEO  Y-GEO  Z-GEO  X-OXY  Y-OXY  Z-OXY
199 A1      17.23 -64.43 -92.43 58415.84 22380.00 7787.77 11.52 -0.71 32.17
200 B2      15.81 -60.63 -81.04 58414.41 22383.80 7799.15 11.26 -1.92 28.70
201 C3      14.13 -55.82 -70.09 58412.73 22383.62 7810.11 10.97 -3.45 25.36
202 D4      13.23 -53.13 -64.69 58411.84 22391.30 7815.51 10.82 -4.30 23.71
203 E5      12.37 -50.51 -59.25 58410.90 22393.93 7820.95 10.68 -5.13 22.05
204 F6      11.43 -47.53 -53.99 58410.03 22396.86 7826.21 10.52 -6.05 20.45
205
206 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
207 SANDIA WELL ID # 8102      LOG ID # 1
208 AZIMUTH:   173.87      ZENITH:   -9.48
209      X-REL  Y-REL  Z-REL  X-GEO  Y-GEO  Z-GEO  X-OXY  Y-OXY  Z-OXY
210 A1      12.12 -87.01 -19.16 58410.72 22350.31 7863.94  8.94  6.05  8.95

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211	B2	11.44	-83.63	-18.51	58410.05	22360.19	7864.59	8.89	5.00	8.75
212	C3	9.02	-71.15	-15.84	58407.62	22372.67	7867.26	8.72	1.13	7.94
213	D4	8.18	-66.30	-14.59	58406.73	22377.44	7868.51	8.68	-0.35	7.55
214	E5	7.36	-61.60	-13.38	58405.97	22382.22	7869.71	8.65	-1.82	7.19
215	F6	6.56	-56.79	-12.27	58405.17	22387.03	7870.83	8.62	-3.31	6.85

216

217 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

218 SANDIA WELL ID # 8129 LOG ID # 1

219 AZIMUTH: 171.93 ZENITH: -17.31

220		X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
221	A1	22.87	-112.27	-59.46	58430.14	22336.52	7823.44	15.70	13.30	21.29
222	B2	22.61	-111.42	-59.00	58435.87	22337.37	7823.90	15.66	13.04	21.15
223	C3	22.61	-111.42	-59.00	58435.87	22337.37	7823.90	15.66	13.04	21.15
224	D4	18.77	-98.80	-51.86	58432.05	22349.99	7831.04	15.07	9.06	18.98
225	E5	11.71	-74.20	-35.37	58424.93	22374.52	7847.53	14.03	1.35	13.95
226	F6	7.75	-56.37	-23.26	58421.02	22392.42	7859.64	13.64	-4.23	10.26

227

228 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

229 SANDIA WELL ID # 8103 LOG ID # 1

230 AZIMUTH: 172.83 ZENITH: -13.21

231		X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
232	A1	30.05	-118.96	-27.30	58443.77	22326.76	7855.50	17.56	16.59	11.52
233	B2	28.32	-113.70	-26.51	58442.02	22332.02	7856.29	17.27	14.92	11.28
234	C3	22.08	-94.95	-23.42	58435.73	22350.77	7859.38	16.23	8.99	10.34
235	D4	16.91	-79.09	-20.15	58430.61	22366.62	7862.65	15.38	3.98	9.34
236	E5	11.32	-60.45	-15.56	58425.02	22385.27	7867.24	14.52	-1.89	7.94

237

238 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

239 SANDIA WELL ID # 8126 LOG ID # 2

240 AZIMUTH: 170.92 ZENITH: -27.70

241		X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
242	A1	27.23	-107.90	-65.01	58440.70	22338.30	7815.20	17.18	12.98	23.81
243	B2	26.92	-107.15	-65.35	58440.47	22339.13	7815.65	17.12	12.71	23.67
244	C3	26.92	-107.15	-65.35	58440.47	22339.13	7815.65	17.12	12.71	23.67
245	D4	21.35	-92.22	-56.56	58434.39	22354.06	7824.44	16.11	7.96	20.99
246	E5	16.70	-70.88	-40.23	58430.25	22367.41	7832.77	15.30	3.73	18.45
247	F6	11.25	-61.21	-36.32	58424.80	22385.07	7844.60	14.44	-1.84	14.82

248

249 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

250 SANDIA WELL ID # 8104 LOG ID # 1

251 AZIMUTH: 170.22 ZENITH: -14.61

252		X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
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253	A1	23.50	-97.15	-24.36	58457.36	22347.21	7857.84	22.57	11.03	10.81
254	B2	23.20	-96.21	-24.21	58457.06	22348.16	7857.99	22.53	10.73	10.76
255	C3	23.20	-96.21	-24.21	58457.06	22343.16	7857.99	22.53	10.73	10.76
256	D4	22.89	-95.27	-24.05	58456.75	22349.09	7858.15	22.47	10.43	10.71
257	E5	19.83	-85.64	-22.11	58453.69	22358.73	7860.09	21.98	7.39	10.12
258	F6	11.91	-59.41	-16.32	58445.77	22304.95	7865.87	20.76	-0.87	8.36

259

260 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

261 SANDIA WELL ID # 8105 LOG ID # 2

262 AZIMUTH: 167.93 ZENITH: -8.39

		X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
263										
264	A1	21.55	-92.36	-13.41	58472.42	22346.72	7869.99	27.09	11.85	7.10
265	B2	19.21	-82.68	-12.43	58470.09	22356.39	7870.96	26.82	8.83	6.81
266	C3	16.86	-73.03	-11.28	58467.73	22366.04	7872.12	26.54	5.82	6.46
267	D4	15.73	-68.21	-10.56	58466.59	22370.86	7872.84	26.41	4.31	6.24
268	E5	14.62	-63.40	-9.80	58465.48	22375.67	7873.60	26.30	2.81	6.00
269	F6	13.56	-59.57	-9.02	58464.42	22380.50	7874.38	26.19	1.31	5.77

270

271 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

272 SANDIA WELL ID # 8128 LOG ID # 1

273 AZIMUTH: 171.50 ZENITH: -21.50

		X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
274										
275	A1	29.97	-112.27	-44.26	58493.02	22338.57	7833.74	32.94	15.23	16.63
276	B2	29.50	-111.39	-44.00	58492.62	22339.45	7839.00	32.86	14.94	16.55
277	C3	29.50	-111.39	-44.00	58492.62	22339.45	7839.00	32.86	14.94	16.55
278	D4	25.86	-102.70	-41.43	58488.91	22343.14	7841.57	32.13	12.16	15.77
279	E5	15.31	-75.57	-32.15	58470.06	22375.27	7850.85	30.31	3.53	12.94
280	F6	10.02	-55.82	-24.38	58473.03	22395.02	7858.62	29.45	-2.68	10.57

281

282 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

283 SANDIA WELL ID # 8106 LOG ID # 0

284 AZIMUTH: 172.92 ZENITH: -10.96

		X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
285										
286	A1	12.21	-98.24	-18.83	58475.75	22351.21	7864.37	30.17	10.66	8.82
287	B2	12.00	-97.25	-18.64	58475.62	22352.20	7864.56	30.09	10.36	8.76
288	C3	11.96	-96.26	-18.45	58475.50	22353.19	7864.75	30.01	10.05	8.70
289	D4	9.91	-79.79	-15.29	58473.45	22369.66	7867.91	28.65	4.99	7.74
290	E5	7.45	-59.94	-11.49	58470.99	22309.51	7871.71	27.02	-1.10	6.58

291

292 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

293 SANDIA WELL ID # 8107 LOG ID # 1

294 AZIMUTH: 174.68 ZENITH: -6.40

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
295									
296 A1	4.92	-143.70	-10.03	58480.66	22311.91	7864.67	30.43	23.07	8.73
297 B2	3.94	-130.70	-17.61	58487.67	22324.91	7865.88	30.72	19.11	8.36
298 C3	2.71	-110.89	-15.16	58486.44	22344.72	7868.34	31.23	13.08	7.61
299 D4	2.12	-91.12	-12.25	58485.86	22364.49	7871.25	31.94	7.09	6.72
300 E5	2.00	-60.42	-8.58	58485.73	22387.20	7874.92	32.92	0.24	5.60

301

302 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

303 SANDIA WELL ID # 8122 LOG ID # 1

304 AZIMUTH: 171.38 ZENITH: -36.34

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
305									
306 A1	19.53	-93.12	-60.19	58517.45	22364.91	7820.81	41.40	8.38	22.09
307 B2	17.35	-86.68	-56.79	58515.27	22371.35	7824.21	41.11	6.34	21.06
308 C3	13.23	-74.00	-49.78	58511.14	22383.95	7831.22	40.43	2.35	18.92
309 D4	11.69	-60.95	-46.05	58509.61	22389.08	7834.15	40.20	0.74	18.03
310 E5	10.29	-63.04	-43.83	58503.20	22394.20	7837.17	40.00	-0.36	17.11
311 F6	9.04	-58.70	-40.79	58506.95	22399.33	7840.21	39.86	-2.47	16.18

312

313 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

314 SANDIA WELL ID # 8100 LOG ID # 1

315 AZIMUTH: 170.22 ZENITH: -10.01

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
316									
317 A1	15.21	-82.46	-14.39	58513.27	22374.73	7868.91	40.66	5.23	7.43
318 B2	15.01	-81.49	-14.25	58513.06	22375.70	7869.05	40.64	4.93	7.39
319 C3	13.57	-74.32	-13.12	58511.62	22382.86	7870.18	40.53	2.71	7.05
320 D4	12.64	-69.47	-12.33	58510.69	22387.70	7870.93	40.46	1.20	6.80
321 E5	11.69	-64.64	-11.50	58509.75	22392.54	7871.80	40.40	-0.30	6.55
322 F6	10.75	-59.78	-10.76	58500.00	22397.40	7872.54	40.33	-1.80	6.33

323

324 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

325 SANDIA WELL ID # 8109 LOG ID # 2

326 AZIMUTH: 170.00 ZENITH: -6.97

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
327									
328 A1	46.45	-125.07	-15.41	58500.45	22334.40	7867.85	52.78	19.46	7.76
329 B2	44.77	-122.00	-15.29	58507.73	22337.47	7867.97	52.41	18.45	7.72
330 C3	44.77	-122.00	-15.29	58507.73	22337.47	7867.97	52.41	18.45	7.72
331 D4	35.30	-104.33	-14.22	58540.37	22355.09	7869.04	50.37	12.72	7.39
332 E5	21.55	-74.63	-10.81	58534.55	22384.84	7872.45	47.53	3.13	6.36
333 F6	14.64	-56.04	-8.23	58527.64	22403.43	7875.03	46.27	-2.78	5.57

334

335 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

336 SANDIA WELL ID # 8110 LOG ID # 2

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337 AZIMUTH: 173.67 ZENITH: -0.86
338 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-ORV Y-ORV Z-ORV
339 A1 5.71 -137.05 -3.21 58543.53 22323.62 7830.69 49.02 22.22 3.84
340 B2 6.00 -132.09 -2.61 58548.87 22320.58 7881.29 49.33 20.74 3.66
341 C3 6.27 -127.14 -1.98 58549.14 22333.53 7881.92 49.64 19.26 3.47
342 D4 6.52 -122.10 -1.38 58549.39 22333.48 7882.52 49.93 17.77 3.29
343 E5 6.71 -117.21 -0.90 58549.00 22343.46 7883.00 50.22 16.28 3.14

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344
345 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

346 SANDIA WELL ID # 8223

LOG ID # 1

347 AZIMUTH: 351.72 ZENITH: 16.70

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348 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-ORV Y-ORV Z-ORV
349 A1 -22.97 123.05 38.06 58403.52 22267.27 7796.26 2.77 32.73 29.58
350 B2 -22.01 118.41 37.27 58404.43 22262.63 7794.67 2.85 34.17 30.06
351 C3 -18.15 98.66 30.60 58403.93 22242.88 7788.00 3.13 40.29 32.09
352 D4 -14.39 78.86 24.04 58412.09 22223.09 7781.44 3.38 46.43 34.10
353 E5 -10.77 57.53 17.51 58415.72 22201.74 7774.91 3.52 53.03 36.00

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354
355 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

356 SANDIA WELL ID # 8212

LOG ID # 2

357 AZIMUTH: 348.17 ZENITH: 4.89

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358 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-ORV Y-ORV Z-ORV
359 A1 -30.36 114.62 10.33 58395.95 22259.39 7767.13 0.13 34.76 38.46
360 B2 -30.06 113.67 10.21 58396.25 22258.45 7767.01 0.18 35.06 38.49
361 C3 -24.43 95.51 8.31 58401.84 22240.28 7765.11 1.06 40.79 39.07
362 D4 -18.47 76.53 6.37 58407.84 22221.30 7763.17 2.02 46.78 39.66
363 E5 -14.55 62.11 5.17 58411.77 22205.87 7761.97 2.56 51.30 40.03

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364
365 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

366 SANDIA WELL ID # 8235

LOG ID # 1

367 AZIMUTH: 353.43 ZENITH: -15.42

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368 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-ORV Y-ORV Z-ORV
369 A1 -25.96 133.63 -18.69 58403.02 22278.62 7736.41 3.12 29.28 47.82
370 B2 -24.10 123.25 -18.67 58404.86 22269.17 7736.43 3.21 32.51 47.81
371 C3 -20.15 102.43 -18.08 58400.93 22247.36 7737.02 3.48 38.97 47.63
372 D4 -15.44 81.00 -16.86 58413.53 22226.73 7738.23 3.98 45.40 47.26
373 E5 -11.59 65.78 -14.87 58417.97 22210.70 7740.22 4.42 50.40 46.66

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374
375 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

376 SANDIA WELL ID # 8213

LOG ID # 1

377 AZIMUTH: 358.67 ZENITH: 16.53

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378 X-REL V-REL Z-REL X-GEO V-GEO Z-GEO X-ORV Y-ORV Z-ORV

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379	A1	-1.78	127.27	36.20	58444.17	22273.64	7793.40	15.31	32.62	30.45
380	B2	-0.72	108.10	30.63	58445.23	22254.46	7787.83	14.77	38.45	32.15
381	C3	0.23	88.94	24.98	58446.19	22235.30	7782.18	14.21	44.27	33.87
382	D4	0.33	74.54	20.80	58446.28	22220.91	7778.00	13.59	48.62	35.14
383	E5	0.31	55.26	15.49	58446.27	22201.63	7772.69	12.72	54.43	36.76

384

385 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

386 SANDIA WELL ID # 8236 LOG ID # 1

387 AZIMUTH: 355.03 ZENITH: -15.94

		X-REL	V-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
388										
389	A1	-15.89	134.70	-21.33	58430.59	22282.39	7734.87	11.61	29.38	48.29
390	B2	-13.40	113.76	-19.19	58433.08	22261.45	7737.00	11.42	35.80	47.64
391	C3	-11.09	92.75	-17.53	58435.39	22240.44	7738.67	11.18	42.24	47.13
392	D4	-9.37	76.71	-16.27	58437.11	22224.40	7739.93	10.98	47.15	46.75
393	E5	-6.43	55.15	-13.07	58440.00	22202.34	7743.13	10.89	53.78	45.77

394

395 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

396 SANDIA WELL ID # 8214 LOG ID # 1

397 AZIMUTH: 355.67 ZENITH: -0.92

		X-REL	V-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
398										
399	A1	-2.79	86.99	-1.92	58459.02	22235.52	7756.18	18.08	44.78	41.79
400	B2	-2.65	77.00	-2.22	58459.14	22225.52	7755.88	17.67	47.80	41.88
401	C3	-2.51	67.00	-2.30	58459.20	22215.52	7755.80	17.27	50.82	41.91
402	D4	-2.44	62.00	-2.21	58459.36	22210.52	7755.89	17.07	52.33	41.88
403	E5	-2.39	57.00	-2.10	58459.41	22205.52	7756.00	16.86	53.84	41.85
404	F6	-2.31	52.01	-1.95	58459.48	22200.53	7756.15	16.66	55.35	41.80

405

406 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

407 SANDIA WELL ID # 8237 LOG ID # 1

408 AZIMUTH: 352.82 ZENITH: -24.61

		X-REL	V-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
409										
410	A1	-11.27	80.22	-37.04	58450.34	22236.01	7719.16	15.49	44.24	53.08
411	B2	-10.15	77.51	-33.64	58451.48	22225.30	7722.56	15.35	47.53	52.04
412	C3	-9.06	68.60	-30.60	58452.58	22216.47	7725.60	15.29	50.24	51.12
413	D4	-8.40	63.92	-28.09	58453.22	22211.70	7727.30	15.27	51.70	50.60
414	E5	-7.63	58.28	-26.71	58454.00	22206.06	7729.49	15.25	53.44	49.93
415	F6	-6.94	53.11	-24.66	58454.69	22200.90	7731.54	15.23	55.02	49.30

416

417 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

418 SANDIA WELL ID # 8224 LOG ID # 1

419 AZIMUTH: 350.90 ZENITH: 13.01

		X-REL	V-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
420										

421	A1	-22.45	143.02	31.00	58452.53	22294.62	7789.50	18.77	26.67	31.64
422	B2	-20.07	133.02	28.86	58454.91	22284.62	7787.36	19.04	29.79	32.29
423	C3	-17.91	123.05	26.84	58457.06	22274.65	7785.34	19.24	32.89	32.91
424	D4	-13.86	102.87	22.70	58461.12	22254.46	7781.20	19.57	39.16	34.17
425	E5	-10.23	82.63	18.42	58464.75	22234.23	7776.92	19.75	45.43	35.47
426	F6	-7.76	66.96	15.14	58467.23	22218.55	7773.64	19.80	50.26	36.47

427

428 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

429 SANDIA WELL ID # 8238 LOG ID # 2

430 AZIMUTH: 345.43 ZENITH: -16.05

		X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
431										
432	A1	-41.24	136.38	-43.71	58434.78	22286.66	7714.29	13.06	28.28	54.56
433	B2	-38.09	126.74	-40.98	58437.94	22277.02	7717.02	13.58	31.33	53.73
434	C3	-35.03	117.07	-38.26	58440.93	22267.35	7719.74	14.07	34.38	52.90
435	D4	-28.47	97.97	-32.54	58447.55	22248.24	7725.46	15.19	40.43	51.16
436	E5	-22.52	78.77	-26.44	58453.50	22229.05	7731.56	16.13	46.49	49.30
437	F6	-17.66	61.92	-20.89	58458.96	22212.20	7737.11	16.84	51.78	47.61

438

439 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

440 SANDIA WELL ID # 8216 LOG ID # 2

441 AZIMUTH: 2.13 ZENITH: 5.19

		X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
442										
443	A1	7.26	136.87	10.78	58483.41	22290.43	7768.97	27.89	29.31	37.89
444	B2	7.02	131.19	10.33	58483.17	22284.76	7768.53	27.57	31.01	38.03
445	C3	6.12	111.27	8.86	58482.27	22264.83	7767.05	26.40	36.98	38.48
446	D4	5.12	91.35	7.37	58481.28	22244.91	7765.56	25.22	42.94	38.93
447	E5	4.02	73.43	6.13	58480.17	22226.99	7764.33	24.03	48.30	39.31
448	F6	2.82	53.52	4.63	58478.97	22207.09	7762.83	22.83	54.25	39.77

449

450 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

451 SANDIA WELL ID # 8239 LOG ID # 1

452 AZIMUTH: 350.08 ZENITH: -18.81

		X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
453										
454	A1	-37.44	129.85	-38.66	58459.22	22293.25	7717.84	20.72	27.38	53.48
455	B2	-36.03	126.52	-37.88	58460.62	22289.92	7718.62	21.00	28.45	53.24
456	C3	-28.51	107.19	-33.53	58463.14	22270.58	7722.97	22.40	34.62	51.92
457	D4	-22.45	89.78	-29.35	58474.20	22253.17	7727.15	23.45	40.13	50.64
458	E5	-16.00	70.48	-24.18	58480.64	22233.87	7732.32	24.53	46.24	49.07
459	F6	-10.28	51.28	-17.90	58486.37	22214.68	7738.60	25.40	52.28	47.15

460

461 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

462 SANDIA WELL ID # 8217 LOG ID # 2

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463 AZIMUTH: 354.18 ZENITH: 0.15
464 X-REL V-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY V-OXY Z-OXY
465 A1 -6.65 85.31 3.40 58502.09 22242.52 7762.40 31.38 44.60 39.90
466 B2 -5.76 75.40 2.45 58502.97 22232.60 7761.45 31.21 47.62 40.19
467 C3 -5.03 65.36 1.57 58503.72 22222.56 7760.57 30.98 50.68 40.46
468 D4 -4.70 60.43 1.24 58504.03 22217.69 7760.24 30.86 52.17 40.56
469 E5 -4.40 55.50 0.99 58504.33 22212.70 7759.98 30.73 53.68 40.63
470 F6 -4.13 50.51 0.78 58504.61 22207.72 7759.78 30.59 55.20 40.70

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471
472 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

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473 SANDIA WELL ID # 8240 LOG ID # 1

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474 AZIMUTH: 351.30 ZENITH: -24.38

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475 X-REL V-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY V-OXY Z-OXY
476 A1 -22.80 80.89 -50.32 58493.50 22236.81 7706.87 27.03 45.71 56.82
477 B2 -19.04 72.06 -44.37 58492.25 22227.98 7712.83 27.77 48.54 55.01
478 C3 -16.44 65.93 -39.93 58494.86 22221.86 7717.27 28.23 50.50 53.65
479 D4 -14.65 61.63 -36.82 58496.64 22217.55 7720.38 28.62 51.88 52.71
480 E5 -12.95 57.27 -33.74 58498.34 22213.20 7723.46 28.94 53.27 51.77
481 F6 -11.39 52.82 -30.73 58499.91 22208.74 7726.47 29.21 54.68 50.85

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482
483 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

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484 SANDIA WELL ID # 8225 LOG ID # 2

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485 AZIMUTH: 349.17 ZENITH: -20.36

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486 X-REL V-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY V-OXY Z-OXY
487 A1 -28.85 113.31 -36.85 58493.36 22296.27 7719.25 31.15 28.00 53.05
488 B2 -28.54 112.39 -36.60 58493.67 22295.34 7719.50 31.20 28.29 52.97
489 C3 -28.23 111.48 -36.34 58493.97 22294.43 7719.76 31.25 28.58 52.90
490 D4 -23.23 96.33 -32.11 58493.97 22279.28 7723.99 32.08 33.37 51.61
491 E5 -17.38 76.97 -26.49 58504.03 22259.92 7729.61 32.98 39.47 49.89
492 F6 -10.48 46.83 -17.35 58511.73 22229.84 7738.74 33.72 48.85 47.11

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493
494 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

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495 SANDIA WELL ID # 8218 LOG ID # 2

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496 AZIMUTH: 349.47 ZENITH: 9.13

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497 X-REL V-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY V-OXY Z-OXY
498 A1 -22.57 136.45 22.00 58515.93 22297.45 7781.58 38.03 28.65 34.05
499 B2 -21.47 128.34 20.70 58517.03 22289.34 7700.20 37.99 31.15 34.47
500 C3 -20.09 118.56 19.09 58518.45 22279.57 7778.59 37.97 34.15 34.96
501 D4 -17.19 99.06 15.77 58521.36 22260.07 7775.27 37.93 40.16 35.98
502 E5 -12.60 69.78 11.16 58525.95 22230.78 7770.65 36.05 49.20 37.38
503 F6 -7.87 40.52 6.51 58530.60 22201.53 7766.01 38.17 53.23 38.80

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504

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505 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
506 SANDIA WELL ID # 8241 LOG ID # 2
507 AZIMUTH: 348.47 ZENITH: 12.93
508 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
509 A1 -32.97 123.13 31.63 58506.12 22289.35 7791.68 34.71 30.50 30.97
510 B2 -32.67 127.21 31.44 58506.42 22288.93 7791.44 34.76 30.79 31.05
511 C3 -29.80 117.96 28.95 58509.28 22279.68 7788.95 35.21 33.71 31.81
512 D4 -24.16 98.42 23.71 58514.92 22260.14 7783.71 36.04 39.85 33.40
513 E5 -18.96 78.74 18.54 58520.12 22240.46 7778.54 36.73 46.02 34.98
514 F6 -10.42 42.62 9.96 58520.67 22204.34 7769.96 37.69 57.29 37.59
515
516 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
517 SANDIA WELL ID # 8219 LOG ID # 1
518 AZIMUTH: 354.72 ZENITH: -2.29
519 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
520 A1 -12.81 122.01 -9.23 58532.87 22283.81 7750.97 42.51 33.52 43.38
521 B2 -12.65 121.03 -9.20 58533.05 22282.83 7751.00 42.52 33.82 43.37
522 C3 -11.04 110.03 -8.40 58534.66 22271.87 7751.80 42.51 37.20 43.13
523 D4 -8.52 90.37 -6.13 58537.17 22252.17 7754.07 42.39 43.25 42.44
524 E5 -6.85 69.51 -4.45 58538.84 22230.30 7755.75 41.92 49.92 41.93
525 F6 -4.98 48.64 -3.09 58540.70 22210.44 7757.11 41.59 55.99 41.51
526
527 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
528 SANDIA WELL ID # 8242 LOG ID # 2
529 AZIMUTH: 353.82 ZENITH: -17.64
530 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
531 A1 -12.59 130.02 -34.23 58533.16 22292.07 7724.47 42.96 31.04 51.46
532 B2 -12.50 129.83 -34.13 58533.25 22291.09 7724.56 42.95 31.34 51.43
533 C3 -11.19 112.25 -31.68 58534.56 22273.50 7727.02 42.56 36.70 50.68
534 D4 -9.61 91.03 -27.07 58536.14 22253.03 7731.63 42.12 42.93 49.28
535 E5 -8.18 74.29 -22.83 58537.56 22235.55 7735.87 41.76 48.28 47.98
536 F6 -6.21 54.00 -17.52 58539.05 22215.32 7741.18 41.46 54.47 46.37
537
538 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
539 SANDIA WELL ID # 8220 LOG ID # 1
540 AZIMUTH: 353.05 ZENITH: -0.80
541 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
542 A1 -9.78 80.40 -3.77 58540.14 22243.30 7757.33 42.89 46.06 41.44
543 B2 -9.45 77.32 -3.69 58540.47 22240.21 7757.41 42.85 47.00 41.42
544 C3 -8.10 65.41 -3.41 58541.03 22228.30 7757.69 42.73 50.66 41.33
545 D4 -7.48 60.45 -3.19 58542.44 22223.34 7757.91 42.69 52.18 41.27
546 E5 -6.87 55.49 -2.95 58543.05 22213.33 7758.15 42.65 53.70 41.19

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547 F6      -6.27   50.54   -2.63  58543.66 22213.43  7758.47  42.61  55.22  41.10
548
549 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
550 SANDIA WELL ID # 8243      LOG ID # 2
551 AZIMUTH:   352.12    ZENITH:   -30.60
552      X-REL   Y-REL   Z-REL   X-GEO   Y-GEO   Z-GEO   X-OXY   Y-OXY   Z-OXY
553 A1      -16.43   83.36  -49.54  58532.83 22246.60  7707.96  40.83  44.74  56.49
554 B2      -14.19   73.71  -44.10  58535.00 22236.96  7713.40  41.08  47.74  54.83
555 C3      -11.92   64.07  -30.46  58537.34 22227.31  7719.04  41.33  50.76  53.12
556 D4      -10.86   59.33  -35.68  58538.41 22222.58  7721.82  41.44  52.23  52.27
557 E5       -9.83   54.53  -32.99  58539.44 22217.77  7724.51  41.54  53.73  51.45
558 F6       -8.85   49.72  -30.29  58540.42 22212.96  7727.21  41.62  55.22  50.63
559
560 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
561 SANDIA WELL ID # 8211      LOG ID # 1
562 AZIMUTH:   85.30     ZENITH:   -0.22
563      X-REL   Y-REL   Z-REL   X-GEO   Y-GEO   Z-GEO   X-OXY   Y-OXY   Z-OXY
564 A1       54.78    3.52   -0.57  58483.53 22234.52  7757.23   2.81  42.83  41.47
565 B2       50.59    3.24   -0.52  58484.34 22234.24  7757.28   1.54  42.72  41.46
566 C3       45.60    2.93   -0.46  58399.36 22233.93  7757.34   0.02  42.59  41.44
567 D4       40.61    2.63   -0.40  58394.36 22233.62  7757.40  -1.50  42.46  41.42
568 E5       35.62    2.32   -0.23  58399.37 22233.33  7757.52  -3.01  42.33  41.39
569
570 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
571 SANDIA WELL ID # 8210      LOG ID # 1
572 AZIMUTH:   82.48     ZENITH:    0.90
573      X-REL   Y-REL   Z-REL   X-GEO   Y-GEO   Z-GEO   X-OXY   Y-OXY   Z-OXY
574 A1       79.22   10.22   1.10  58422.92 22293.42  7759.18   9.78  25.71  40.88
575 B2       65.14    8.50   0.50  58453.84 22291.70  7758.58   5.46  25.60  41.06
576 C3       56.23    7.25   0.37  58399.94 22290.46  7758.37   2.72  25.58  41.13
577 D4       51.20    6.54   0.27  58394.98 22289.74  7758.27   1.20  25.57  41.16
578 E5       46.33    5.84   0.16  58390.03 22289.05  7758.15  -0.33  25.56  41.19
579 F6       41.38    5.17   0.07  58385.50 22288.37  7758.07  -1.85  25.54  41.22
580 G7       36.42    4.52  -0.01  58380.12 22287.73  7757.99  -3.37  25.51  41.24
581
582 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
583 SANDIA WELL ID # 8201      LOG ID # 2
584 AZIMUTH:  175.12     ZENITH:    0.17
585      X-REL   Y-REL   Z-REL   X-GEO   Y-GEO   Z-GEO   X-OXY   Y-OXY   Z-OXY
586 A1      18.22 -130.07    7.39  58405.73 22302.99  7765.89   5.03  22.06  38.84
587 B2      16.22 -129.29    5.53  58403.73 22311.77  7764.03   4.82  19.32  39.40
588 C3      12.14 -109.90    2.28  58399.66 22331.08  7760.78   4.45  13.31  40.39

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589 D4 8.65 -90.45 -0.03 58396.17 22350.62 7758.42 4.28 7.27 41.11
 590 E5 6.26 -69.60 -0.56 58393.77 22371.46 7757.94 4.48 0.88 41.26
 591

592 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

593 SANDIA WELL ID # 8226 LOG ID # 2

594 AZIMUTH: 176.60 ZENITH: -17.10

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
596 A1	9.65	-134.62	-35.42	58397.00	22306.75	7721.18	2.58	20.53	52.46
597 B2	9.29	-132.37	-35.08	58396.69	22303.99	7721.52	2.57	19.84	52.36
598 C3	6.91	-111.79	-31.69	58394.31	22329.57	7724.91	2.78	13.53	51.33
599 D4	6.91	-111.79	-31.69	58394.31	22329.57	7724.91	2.78	13.53	51.33
600 E5	4.76	-89.84	-26.80	58392.16	22351.52	7729.80	3.11	6.82	49.83

601

602 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

603 SANDIA WELL ID # 8202 LOG ID # 2

604 AZIMUTH: 171.72 ZENITH: 0.25

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
606 A1	17.18	-95.29	1.70	58416.31	22349.11	7760.40	10.28	8.62	40.51
607 B2	14.31	-85.75	0.85	58413.44	22353.65	7759.54	9.64	5.62	40.77
608 C3	10.70	-69.17	0.15	58409.83	22375.23	7758.85	9.49	0.46	40.98
609 D4	9.90	-64.23	0.14	58409.02	22380.16	7758.84	9.47	-1.07	40.98
610 E5	9.12	-59.29	0.11	58400.25	22385.11	7758.81	9.46	-2.59	40.99
611 F6	8.37	-54.35	0.10	58407.50	22390.05	7758.79	9.45	-4.11	41.00

612

613 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

614 SANDIA WELL ID # 8227 LOG ID # 1

615 AZIMUTH: 169.93 ZENITH: -24.39

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
617 A1	25.85	-67.16	-33.61	58425.06	22376.56	7722.69	14.15	0.74	52.00
618 B2	25.39	-66.38	-33.19	58424.61	22377.34	7723.11	14.05	0.48	51.88
619 C3	24.92	-65.59	-32.81	58424.14	22378.14	7723.49	13.94	0.22	51.76
620 D4	24.08	-64.18	-32.06	58423.30	22379.55	7724.24	13.75	-0.24	51.53
621 E5	21.53	-59.74	-29.78	58420.75	22383.98	7726.52	13.18	-1.69	50.84
622 F6	19.11	-55.37	-27.49	58410.33	22383.36	7728.81	12.64	-3.12	50.14

623

624 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

625 SANDIA WELL ID # 8222 LOG ID # 2

626 AZIMUTH: 172.35 ZENITH: 14.50

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY
628 A1	25.77	-128.76	35.09	58439.75	22316.93	7793.09	15.91	19.37	30.54
629 B2	23.90	-121.18	32.92	58437.89	22324.51	7790.92	15.69	17.00	31.21
630 C3	18.83	-101.62	27.21	58432.81	22344.07	7785.21	15.63	10.33	32.94

631 D4 12.32 -76.46 19.90 58426.31 22369.23 7777.90 14.20 3.00 35.17
 632 E5 8.17 -56.00 14.38 58422.16 22389.69 7772.38 13.86 -3.35 36.86
 633

634 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

635 SANDIA WELL ID # 8203 LOG ID # 2

636 AZIMUTH: 164.73 ZENITH: 6.37

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
637									
638 A1	38.70	-129.16	18.17	58453.69	22316.09	7775.77	20.08	20.25	35.82
639 B2	34.21	-115.15	15.99	58449.12	22330.10	7773.59	19.32	15.82	36.49
640 C3	28.32	-96.27	13.00	58443.22	22348.98	7770.60	18.39	9.87	37.40
641 D4	22.52	-77.36	10.07	58437.42	22367.89	7767.67	17.48	3.90	38.29
642 E5	16.94	-58.31	7.59	58431.04	22386.93	7765.19	16.65	-2.09	39.05

643
 644 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

645 SANDIA WELL ID # 8228 LOG ID # 2

646 AZIMUTH: 169.73 ZENITH: -15.06

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
647									
648 A1	29.71	-112.37	-29.19	58446.41	22334.03	7727.81	18.68	14.51	50.44
649 B2	29.41	-111.43	-29.02	58446.09	22334.97	7727.98	18.63	14.22	50.39
650 C3	25.58	-99.74	-26.82	58442.27	22346.66	7730.18	18.00	10.52	49.72
651 D4	18.55	-77.68	-22.24	58435.25	22363.72	7734.76	16.87	3.56	48.32
652 E5	12.94	-57.97	-17.63	58429.62	22380.43	7739.32	16.05	-2.64	46.93

653
 654 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

655 SANDIA WELL ID # 8204 LOG ID # 2

656 AZIMUTH: 171.22 ZENITH: 6.27

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
657									
658 A1	19.84	-112.75	11.65	58454.36	22335.72	7769.25	21.31	14.38	37.81
659 B2	19.63	-111.78	11.55	58454.66	22336.70	7769.15	21.29	14.00	37.84
660 C3	19.02	-103.86	11.22	58454.05	22339.62	7768.82	21.24	13.17	37.94
661 D4	15.20	-89.33	9.31	58450.22	22359.15	7766.90	20.95	7.11	38.53
662 E5	11.90	-70.70	7.60	58446.92	22377.77	7765.20	20.79	1.35	39.05

663
 664 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

665 SANDIA WELL ID # 8229 LOG ID # 1

666 AZIMUTH: 171.53 ZENITH: -19.47

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
667									
668 A1	24.99	-117.50	-37.27	58458.73	22331.48	7719.73	22.23	15.83	52.90
669 B2	24.70	-116.57	-37.07	58458.44	22332.41	7719.93	22.24	15.54	52.84
670 C3	22.55	-109.59	-35.34	58456.28	22339.38	7721.66	21.90	13.34	52.32
671 D4	22.55	-109.59	-35.34	58456.28	22339.38	7721.66	21.90	13.34	52.32
672 E5	11.56	-67.95	-23.82	58445.30	22381.02	7733.18	20.45	0.30	48.80

673

674 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

675 SANDIA WELL ID # 8205 LOG ID # 1

676 AZIMUTH: 171.45 ZENITH: 0.08

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
677										
678	A1	12.18	-84.21	-0.66	58460.75	22366.96	7757.54	24.48	5.23	41.38
679	B2	12.05	-83.22	-0.63	58460.61	22367.95	7757.52	24.48	4.92	41.39
680	C3	10.41	-71.74	-0.66	58459.97	22379.43	7757.54	24.50	1.39	41.38
681	D4	9.71	-66.79	-0.63	58453.27	22384.38	7757.57	24.51	-0.14	41.37
682	E5	9.02	-61.84	-0.56	58457.50	22389.33	7757.64	24.52	-1.66	41.35
683	F6	8.34	-56.80	-0.51	58456.09	22394.28	7757.69	24.54	-3.18	41.33

684

685 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

686 SANDIA WELL ID # 8230 LOG ID # 1

687 AZIMUTH: 171.85 ZENITH: -25.76

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
688										
689	A1	27.63	-91.63	-42.74	58476.31	22358.77	7712.95	28.80	8.39	54.97
690	B2	24.77	-83.32	-39.41	58473.45	22367.09	7716.29	28.32	5.76	53.95
691	C3	19.61	-68.66	-33.58	58468.30	22381.74	7722.12	27.41	1.11	52.18
692	D4	17.91	-63.83	-31.57	58466.59	22386.57	7724.12	27.12	-0.43	51.56
693	E5	16.21	-58.91	-29.51	58464.91	22391.49	7726.19	26.83	-1.98	50.94
694	F6	14.02	-52.35	-26.61	58462.70	22393.05	7729.09	26.46	-4.06	50.05

695

696 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

697 SANDIA WELL ID # 8221 LOG ID # 2

698 AZIMUTH: 176.92 ZENITH: 15.35

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
699										
700	A1	19.96	-90.99	25.41	58481.94	22363.48	7783.41	30.71	7.22	33.49
701	B2	19.64	-90.09	25.12	58481.61	22364.37	7783.12	30.65	6.94	33.58
702	C3	19.32	-89.19	24.83	58481.30	22365.28	7782.83	30.60	6.65	33.67
703	D4	14.82	-74.97	20.62	58476.70	22379.50	7778.62	29.87	2.16	34.96
704	E5	12.14	-65.19	17.87	58474.11	22389.27	7775.87	29.50	-0.90	35.79

705

706 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

707 SANDIA WELL ID # 8206 LOG ID # 2

708 AZIMUTH: 173.17 ZENITH: 0.26

	X-REL	Y-REL	Z-REL	X-GEO	Y-GEO	Z-GEO	X-OXY	Y-OXY	Z-OXY	
709										
710	A1	15.95	-115.97	1.40	58476.16	22337.66	7759.60	27.81	14.75	40.75
711	B2	15.83	-114.98	1.37	58476.05	22338.65	7759.57	27.82	14.45	40.76
712	C3	14.18	-101.39	0.88	58474.37	22352.24	7759.08	27.93	10.27	40.91
713	D4	11.70	-81.54	0.51	58471.93	22372.09	7758.71	28.10	4.18	41.02
714	E5	8.94	-61.75	0.20	58469.16	22391.80	7758.40	28.12	-1.91	41.12

155

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715
716 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
717 SANDIA WELL ID # 8231 LOG ID # 2
718 AZIMUTH: 170.10 ZENITH: -16.68
719 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
720 A1 28.52 -118.44 -34.43 58491.73 22334.95 7722.27 32.39 16.26 52.13
721 B2 28.42 -117.86 -34.30 58491.64 22335.52 7722.40 32.39 16.09 52.09
722 C3 24.37 -97.73 -29.91 58487.59 22355.66 7726.79 32.07 9.83 50.75
723 D4 20.04 -82.12 -26.32 58489.27 22371.27 7730.38 31.46 4.93 49.66
724 E5 14.60 -62.63 -20.73 58477.81 22390.76 7735.97 30.69 -1.19 47.95
725
726 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
727 SANDIA WELL ID # 8207 LOG ID # 0
728 AZIMUTH: 174.28 ZENITH: -6.62
729 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
730 A1 12.90 -128.86 -14.94 58492.06 22325.35 7743.06 36.24 19.19 45.79
731 B2 12.80 -127.86 -14.82 58491.96 22326.35 7743.18 36.17 18.88 45.76
732 C3 11.25 -112.34 -13.02 58490.41 22341.37 7744.98 35.01 14.13 45.21
733 D4 9.25 -92.44 -10.72 58488.41 22361.77 7747.28 33.52 8.04 44.51
734 E5 7.26 -72.54 -8.41 58486.42 22381.67 7749.59 32.03 1.95 43.80
735
736 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
737 SANDIA WELL ID # 8232 LOG ID # 2
738 AZIMUTH: 175.52 ZENITH: -18.67
739 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
740 A1 9.05 -123.02 -40.83 58486.73 22331.13 7716.12 30.73 17.19 54.01
741 B2 9.00 -122.07 -40.58 58486.73 22332.09 7716.42 30.75 16.90 53.91
742 C3 8.45 -110.67 -37.20 58486.17 22343.48 7719.80 31.10 13.44 52.88
743 D4 8.45 -110.67 -37.20 58486.17 22343.48 7719.80 31.10 13.44 52.88
744 E5 5.06 -62.51 -22.10 58482.80 22391.65 7734.90 32.23 -1.23 48.28
745
746 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
747 SANDIA WELL ID # 8208 LOG ID # 0
748 AZIMUTH: 171.20 ZENITH: 0.56
749 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
750 A1 14.81 -95.66 0.09 58510.19 22361.19 7758.79 40.11 9.19 41.00
751 B2 13.31 -85.98 0.09 58500.69 22370.87 7758.79 39.22 6.20 41.00
752 C3 11.17 -72.14 0.07 58506.55 22384.71 7758.77 37.96 1.94 41.00
753 D4 10.40 -67.20 0.07 58505.78 22389.65 7758.77 37.51 0.41 41.01
754 E5 9.64 -62.26 0.06 58505.28 22394.59 7758.76 37.06 -1.11 41.01
755 F6 8.87 -57.32 0.06 58504.25 22399.53 7758.76 36.60 -2.64 41.01
756

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757 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
758 SANDIA WELL ID # 8233 LOG ID # 1
759 AZIMUTH: 170.77 ZENITH: -23.75
760 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
761 A1 30.27 -91.50 -39.87 58525.41 22365.43 7716.73 43.90 8.58 53.82
762 B2 26.27 -83.36 -37.06 58521.41 22373.58 7719.54 43.06 5.94 52.96
763 C3 10.62 -67.47 -31.17 58513.77 22389.46 7725.43 41.17 0.81 51.17
764 D4 16.53 -62.72 -29.34 58511.67 22394.20 7727.26 41.05 -0.71 50.61
765 E5 14.54 -57.87 -27.38 58509.69 22399.06 7729.22 40.67 -2.27 50.01
766 F6 12.68 -53.09 -25.40 58507.81 22403.84 7731.20 40.32 -3.79 49.41
767
768 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
769 SANDIA WELL ID # 8209 LOG ID # 0
770 AZIMUTH: 175.18 ZENITH: -0.00
771 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
772 A1 9.62 -114.20 -0.17 58517.59 22346.00 7758.53 43.02 14.10 41.08
773 B2 9.54 -113.20 -0.17 58517.51 22347.00 7758.53 42.95 13.80 41.00
774 C3 8.30 -98.48 -0.14 58516.27 22361.75 7758.56 41.91 9.29 41.07
775 D4 6.62 -78.52 -0.12 58514.59 22381.68 7758.58 40.52 3.21 41.06
776 E5 5.36 -63.57 -0.09 58513.33 22396.63 7758.61 39.47 -1.35 41.06
777
778 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
779 SANDIA WELL ID # 8234 LOG ID # 2
780 AZIMUTH: 172.20 ZENITH: -15.74
781 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
782 A1 45.83 -136.72 -30.79 58550.16 22324.87 7726.61 51.97 22.27 50.81
783 B2 37.68 -117.44 -29.22 58550.00 22344.16 7728.18 50.37 16.09 50.33
784 C3 28.75 -98.56 -27.07 58541.00 22363.03 7730.34 48.52 10.00 49.67
785 D4 21.44 -81.73 -24.02 58533.77 22379.36 7733.38 47.07 4.60 48.74
786 E5 14.60 -62.40 -19.54 58526.92 22399.20 7737.86 45.87 -1.54 47.38
787
788 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
789 SANDIA WELL ID # 8311 LOG ID # 2
790 AZIMUTH: 1.97 ZENITH: 21.00
791 X-REL Y-REL Z-REL X-GEO Y-GEO Z-GEO X-OXY Y-OXY Z-OXY
792 A1 -6.14 118.01 46.75 58421.14 22265.10 7667.45 7.98 34.17 68.84
793 B2 -6.05 117.09 46.39 58421.23 22264.18 7667.09 7.97 34.45 68.95
794 C3 -5.39 107.19 42.37 58421.91 22254.29 7663.07 7.73 37.46 70.17
795 D4 -3.27 87.46 34.36 58424.03 22234.57 7655.06 7.49 43.50 72.62
796 E5 -1.54 73.28 28.61 58425.75 22220.38 7649.31 7.38 47.86 74.37
797 F6 0.43 52.52 20.45 58427.73 22199.62 7641.15 7.05 54.20 76.86
798

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799 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

800 SANDIA WELL ID # 8312 LOG ID # 2

801 AZIMUTH: 353.67 ZENITH: 17.57

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
802									
803	A1	-28.40	122.71	36.56	58410.92	22270.91	7657.07	5.16	31.96
804	B2	-27.97	120.93	36.06	58411.34	22269.13	7656.56	5.21	32.51
805	C3	-25.49	110.90	33.29	58413.80	22259.10	7653.79	5.50	35.65
806	D4	-18.90	91.33	27.75	58420.39	22239.53	7648.25	6.62	41.85
807	E5	-11.78	72.00	21.93	58427.52	22220.20	7642.47	7.90	47.99
808	F6	-6.62	49.97	15.30	58432.67	22193.18	7635.80	8.47	54.86

809

810 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

811 SANDIA WELL ID # 8313 LOG ID # 1

812 AZIMUTH: 359.35 ZENITH: 29.03

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
813									
814	A1	-7.05	80.31	44.29	58436.14	22229.31	7666.79	10.91	45.63
815	B2	-1.28	51.25	28.13	58441.92	22200.25	7650.63	11.35	54.65
816	C3	-0.53	41.88	23.01	58442.67	22190.88	7645.51	11.16	57.51
817	D4	-0.27	32.59	17.93	58442.94	22181.59	7640.43	10.82	60.32
818	E5	-0.22	27.50	15.15	58442.98	22176.50	7637.65	10.61	61.86
819	F6	-0.27	22.34	12.30	58442.94	22171.34	7634.79	10.37	63.41

820

821 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

822 SANDIA WELL ID # 8310 LOG ID # 3

823 AZIMUTH: 81.13 ZENITH: 12.33

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
824									
825	A1	192.01	40.22	44.03	58544.53	22259.64	7667.59	44.94	41.33
826	B2	191.87	40.01	43.85	58543.45	22259.41	7667.35	44.61	41.35
827	C3	170.82	35.10	38.79	58522.41	22254.50	7662.29	38.04	41.89
828	D4	150.64	30.67	34.01	58502.23	22250.07	7657.51	31.77	42.32
829	E5	132.81	26.57	29.69	58484.41	22245.97	7653.19	26.20	42.76
830	F6	109.23	21.01	24.40	58465.83	22240.41	7647.90	18.85	43.39

831

832 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

833 SANDIA WELL ID # 8309 LOG ID # 1

834 AZIMUTH: 82.71 ZENITH: 15.56

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY
835									
836	A1	159.10	20.77	44.23	58509.23	22264.87	7670.04	34.55	38.18
837	B2	153.61	20.27	42.85	58503.81	22264.37	7668.65	32.88	38.03
838	C3	132.30	18.21	36.96	58482.50	22262.30	7662.77	26.36	37.75
839	D4	112.78	16.18	31.41	58462.93	22260.23	7657.21	20.38	37.51
840	E5	93.14	13.57	25.78	58443.34	22257.67	7651.58	14.34	37.40

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841 F6      72.76  10.38  20.07 58422.97 22254.48 7645.87  8.06  37.45  75.42
842
843 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
844 SANDIA WELL ID # 8308      LOG ID # 5
845 AZIMUTH:   84.13      ZENITH:   11.57
846      X-REL  V-REL  Z-REL  X-GEO  V-GEO  Z-GEO  X-OXY  V-OXY  Z-OXY
847 A1      168.24  10.50  31.31 58514.96 22278.99 7660.31  36.71  34.14  71.02
848 B2      167.25  10.43  31.17 58519.96 22278.92 7660.18  36.41  34.12  71.06
849 C3      166.26  10.36  31.04 58512.96 22278.05 7660.04  36.10  34.10  71.10
850 D4      155.41   9.61  29.44 58501.50 22273.11 7658.44  32.79  33.84  71.59
851 E5      135.18   8.29  26.33 58481.23 22276.79 7655.37  26.64  33.33  72.52
852 F6      110.62   6.88  21.95 58456.72 22275.38 7650.95  19.17  32.66  73.87
853
854 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
855 SANDIA WELL ID # 8301      LOG ID # 1
856 AZIMUTH:  171.59      ZENITH:   4.52
857      X-REL  V-REL  Z-REL  X-GEO  V-GEO  Z-GEO  X-OXY  V-OXY  Z-OXY
858 A1      31.76 -133.92  -3.23 58430.97 22310.58 7654.47  12.98  20.90  72.80
859 B2      29.24 -125.29  -2.78 58428.45 22319.20 7654.92  12.61  18.18  72.66
860 C3      23.72 -106.10  -1.79 58422.92 22333.41 7655.91  11.30  12.15  72.36
861 D4      18.20  -86.90  -0.75 58417.41 22357.60 7656.95  10.99   6.11  72.04
862 E5      11.83  -64.33   0.51 58411.08 22379.67 7658.21  10.07  -0.83  71.66
863
864 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
865 SANDIA WELL ID # 8302      LOG ID # 1
866 AZIMUTH:  176.34      ZENITH:   4.16
867      X-REL  V-REL  Z-REL  X-GEO  V-GEO  Z-GEO  X-OXY  V-OXY  Z-OXY
868 A1      23.42 -134.53   6.70 58437.92 22312.27 7665.70  15.15  20.70  69.37
869 B2      20.42 -118.32   5.92 58434.92 22320.48 7664.92  14.97  15.68  69.61
870 C3      16.53  -98.72   5.09 58431.02 22340.07 7664.09  14.67   9.59  69.86
871 D4      11.75  -77.20   4.07 58426.25 22369.52 7663.07  14.19   2.91  70.17
872 E5       6.94  -57.89   3.17 58421.44 22383.90 7662.17  13.61  -3.15  70.45
873
874 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES
875 SANDIA WELL ID # 8303      LOG ID # 1
876 AZIMUTH:  170.84      ZENITH:   3.09
877      X-REL  V-REL  Z-REL  X-GEO  V-GEO  Z-GEO  X-OXY  V-OXY  Z-OXY
878 A1      31.09 -135.92   9.35 58466.09 22312.37 7668.95  23.65  21.92  68.38
879 B2      28.53 -126.59   8.75 58463.59 22321.71 7668.35  23.30  18.99  68.56
880 C3      23.72 -107.21   7.54 58459.72 22341.09 7667.13  22.71  12.94  68.94
881 D4      18.88  -87.85   6.29 58453.87 22360.45 7665.89  22.11   6.88  69.31
882 E5      13.60  -67.88   4.90 58449.09 22380.41 7664.50  21.42   0.63  69.74

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883

884 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

885 SANDIA WELL ID # 8304 LOG ID # 2

886 AZIMUTH: 172.26 ZENITH: 6.45

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY	
887										
888	A1	7.61	-96.45	6.01	58455.91	22354.06	7666.61	22.44	8.90	69.10
889	B2	6.75	-86.49	5.65	58455.05	22364.01	7666.25	22.63	5.86	69.21
890	C3	5.05	-72.20	5.04	58453.36	22378.30	7665.64	22.76	1.48	69.39
891	D4	4.55	-67.23	4.85	58452.34	22383.27	7665.45	22.82	-0.04	69.45
892	E5	4.13	-62.25	4.67	58452.44	22388.24	7665.27	22.92	-1.56	69.50
893	F6	3.75	-57.27	4.48	58452.05	22393.23	7665.08	23.03	-3.08	69.56

894

895 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

896 SANDIA WELL ID # 8305 LOG ID # 5

897 AZIMUTH: 171.62 ZENITH: 5.17

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY	
898										
899	A1	25.66	-136.87	12.24	58483.75	22315.93	7674.14	30.64	21.86	66.80
900	B2	21.23	-118.46	10.76	58484.33	22334.34	7672.66	30.13	16.12	67.25
901	C3	16.84	-99.02	9.13	58479.92	22353.73	7671.03	29.67	10.06	67.75
902	D4	12.43	-81.64	7.59	58475.53	22371.16	7669.49	29.12	4.62	68.22
903	E5	8.20	-62.19	5.75	58471.28	22390.61	7667.65	28.71	-1.43	68.78

904

905 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

906 SANDIA WELL ID # 8306 LOG ID # 2

907 AZIMUTH: 171.83 ZENITH: 4.79

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY	
908										
909	A1	17.58	-139.71	9.71	58505.36	22317.39	7675.61	35.72	22.16	66.35
910	B2	14.65	-130.11	9.10	58502.64	22326.99	7675.00	35.32	19.15	66.54
911	C3	10.50	-110.64	7.72	58498.30	22346.46	7673.62	34.88	13.08	66.96
912	D4	7.20	-87.92	6.38	58495.05	22369.18	7672.29	34.90	6.09	67.37
913	E5	5.39	-68.05	5.10	58493.19	22389.05	7671.00	35.25	0.02	67.76

914

915 OXY RETORT #7 & #8 THERMOCOUPLE COORDINATES

916 SANDIA WELL ID # 8307 LOG ID # 5

917 AZIMUTH: 174.06 ZENITH: 0.44

	X-REL	V-REL	Z-REL	X-GEO	V-GEO	Z-GEO	X-OXY	V-OXY	Z-OXY	
918										
919	A1	4.76	-140.88	1.00	58517.47	22318.41	7667.20	39.41	22.40	68.92
920	B2	4.00	-120.90	0.80	58516.70	22330.40	7667.00	40.07	16.34	68.98
921	C3	3.02	-100.93	0.54	58515.72	22358.37	7666.74	40.67	10.27	69.06
922	D4	2.03	-78.95	0.30	58514.78	22380.34	7666.50	41.37	3.61	69.13
923	E5	1.73	-68.96	0.30	58514.44	22390.34	7666.50	41.71	0.57	69.13

TOTAL RECORDS WRITTEN = 924/ 205

COORDINATES OF THERMOCOUPLES

HERMOCOUPLES

A-2

APPENDIX

COORDINATES OF THERMOCOUPLES IN ROOF OF RETORT 7, IN METERS

WELL ID: 7051	WELL ID: 7052	WELL ID: 7053	Well ID: 7054
TC ID: A X= 7.72 Y= 3.22 Z= -0.12	TC ID: A X= 16.02 Y= 20.65 Z= -2.87	TC ID: A X= 20.82 Y= 26.75 Z= -2.71	TC ID: A X= 43.10 Y= 43.30 Z= 0.03
TC ID: B X= 7.71 Y= 3.22 Z= -0.58	TC ID: B X= 16.03 Y= 20.65 Z= -3.32	TC ID: B X= 20.83 Y= 26.75 Z= -3.17	TC ID: B X= 43.10 Y= 43.31 Z= -0.43
TC ID: C X= 7.71 Y= 3.22 Z= -1.04	TC ID: C X= 16.04 Y= 20.65 Z= -3.78	TC ID: C X= 20.83 Y= 26.74 Z= -3.63	TC ID: C X= 43.11 Y= 43.31 Z= -0.83
TC ID: D X= 7.71 Y= 3.22 Z= -1.49	TC ID: D X= 16.05 Y= 20.65 Z= -4.24	TC ID: D X= 20.84 Y= 26.73 Z= -4.08	TC ID: D X= 43.11 Y= 43.32 Z= -1.34
TC ID: E X= 7.70 Y= 3.21 Z= -1.95	TC ID: E X= 16.05 Y= 20.65 Z= -4.69	TC ID: E X= 20.84 Y= 26.73 Z= -4.54	TC ID: E X= 43.11 Y= 43.32 Z= -1.80
TC ID: F X= 7.70 Y= 3.21 Z= -2.41	TC ID: F X= 16.06 Y= 20.64 Z= -5.15	TC ID: F X= 20.85 Y= 26.72 Z= -5.00	TC ID: F X= 43.12 Y= 43.32 Z= -2.26
TC ID: G X= 7.70 Y= 3.21 Z= -2.87	TC ID: G X= 16.07 Y= 20.64 Z= -5.61	TC ID: G X= 20.86 Y= 26.71 Z= -5.46	TC ID: G X= 43.12 Y= 43.33 Z= -2.71
TC ID: H X= 7.70 Y= 3.21 Z= -3.32	TC ID: H X= 16.07 Y= 20.64 Z= -6.07	TC ID: H X= 20.86 Y= 26.71 Z= -5.91	TC ID: H X= 43.13 Y= 43.33 Z= -3.17
TC ID: I X= 7.69 Y= 3.21 Z= -3.78	TC ID: I X= 16.08 Y= 20.64 Z= -6.52	TC ID: I X= 20.87 Y= 26.70 Z= -6.37	TC ID: I X= 43.13 Y= 43.34 Z= -3.63
TC ID: J X= 7.69 Y= 3.21 Z= -4.24	TC ID: J X= 16.09 Y= 20.64 Z= -6.98	TC ID: J X= 20.87 Y= 26.69 Z= -6.83	TC ID: J X= 43.13 Y= 43.34 Z= -4.08
TC ID: K X= 7.68 Y= 3.20 Z= -5.15	TC ID: K X= 16.10 Y= 20.63 Z= -7.89	TC ID: K X= 20.89 Y= 26.68 Z= -7.74	TC ID: K X= 43.14 Y= 43.35 Z= -5.00
TC ID: L X= 7.68 Y= 3.20 Z= -6.07	TC ID: L X= 16.12 Y= 20.63 Z= -8.81	TC ID: L X= 20.90 Y= 26.67 Z= -8.66	TC ID: L X= 43.15 Y= 43.36 Z= -5.91
TC ID: M X= 7.67 Y= 3.19 Z= -6.98	TC ID: M X= 16.13 Y= 20.63 Z= -9.72	TC ID: M X= 20.91 Y= 26.66 Z= -9.57	TC ID: M X= 43.16 Y= 43.37 Z= -6.83
TC ID: N X= 7.66 Y= 3.19 Z= -7.89	TC ID: N X= 16.14 Y= 20.62 Z= -10.64	TC ID: N X= 20.92 Y= 26.64 Z= -10.48	TC ID: N X= 43.17 Y= 43.37 Z= -7.74
TC ID: O X= 7.66 Y= 3.19 Z= -8.81	TC ID: O X= 16.16 Y= 20.62 Z= -11.55	TC ID: O X= 20.93 Y= 26.63 Z= -11.40	TC ID: O X= 43.17 Y= 43.38 Z= -8.66
TC ID: P X= 7.64 Y= 3.18 Z= -11.25	TC ID: P X= 16.20 Y= 20.61 Z= -13.99	TC ID: P X= 20.97 Y= 26.68 Z= -13.84	TC ID: P X= 43.19 Y= 43.41 Z= -11.09
TC ID: Q X= 7.63 Y= 3.17 Z= -13.69	TC ID: Q X= 16.23 Y= 20.60 Z= -16.43	TC ID: Q X= 21.00 Y= 26.56 Z= -16.27	TC ID: Q X= 43.21 Y= 43.43 Z= -13.53
TC ID: R X= 7.61 Y= 3.16 Z= -16.12	TC ID: R X= 16.27 Y= 20.59 Z= -18.87	TC ID: R X= 21.03 Y= 26.53 Z= -18.71	TC ID: R X= 43.24 Y= 43.45 Z= -15.97

COORDINATES OF THERMOCOUPLES IN ROOF OF RETORT 8, IN METERS

WELL ID: 8001	WELL ID: 8002	WELL ID: 8003	WELL ID: 8004
TC ID: A X= -1.34 Y= 39.61 Z= -0.21	TC ID: A X= 1.07 Y= 36.20 Z= -0.21	TC ID: A X= 21.12 Y= 36.10 Z= -0.20	TC ID: A X= 19.17 Y= 26.96 Z= -0.06
TC ID: B X= -1.33 Y= 39.61 Z= -0.67	TC ID: B X= 1.09 Y= 36.20 Z= -0.67	TC ID: B X= 21.11 Y= 36.09 Z= -0.66	TC ID: B X= 19.18 Y= 26.96 Z= -0.52
TC ID: C X= -1.32 Y= 39.61 Z= -1.13	TC ID: C X= 1.11 Y= 36.20 Z= -1.13	TC ID: C X= 21.11 Y= 36.07 Z= -1.11	TC ID: C X= 19.19 Y= 26.96 Z= -0.98
TC ID: D X= -1.30 Y= 39.61 Z= -1.58	TC ID: D X= 1.12 Y= 36.21 Z= -1.58	TC ID: D X= 21.10 Y= 36.06 Z= -1.57	TC ID: D X= 19.20 Y= 26.96 Z= -1.43
TC ID: E X= -1.29 Y= 39.61 Z= -2.04	TC ID: E X= 1.14 Y= 36.21 Z= -2.04	TC ID: E X= 21.10 Y= 36.05 Z= -2.03	TC ID: E X= 19.21 Y= 26.96 Z= -1.89
TC ID: F X= -1.28 Y= 39.61 Z= -2.50	TC ID: F X= 1.15 Y= 36.21 Z= -2.50	TC ID: F X= 21.09 Y= 36.04 Z= -2.48	TC ID: F X= 19.22 Y= 26.96 Z= -2.35
TC ID: G X= -1.27 Y= 39.61 Z= -2.96	TC ID: G X= 1.17 Y= 36.21 Z= -2.95	TC ID: G X= 21.09 Y= 36.02 Z= -2.94	TC ID: G X= 19.22 Y= 26.96 Z= -2.80
TC ID: H X= -1.26 Y= 39.61 Z= -3.41	TC ID: H X= 1.18 Y= 36.21 Z= -3.41	TC ID: H X= 21.08 Y= 36.01 Z= -3.40	TC ID: H X= 19.23 Y= 26.96 Z= -3.26
TC ID: I X= -1.24 Y= 39.61 Z= -3.87	TC ID: I X= 1.20 Y= 36.21 Z= -3.67	TC ID: I X= 21.07 Y= 36.00 Z= -3.85	TC ID: I X= 19.24 Y= 26.96 Z= -3.72
TC ID: J X= -1.27 Y= 39.61 Z= -4.33	TC ID: J X= 1.22 Y= 36.22 Z= -4.33	TC ID: J X= 21.07 Y= 35.98 Z= -4.31	TC ID: J X= 19.25 Y= 26.96 Z= -4.18
TC ID: K X= -1.21 Y= 39.61 Z= -5.24	TC ID: K X= 1.25 Y= 36.22 Z= -5.24	TC ID: K X= 21.06 Y= 35.96 Z= -5.23	TC ID: K X= 19.27 Y= 26.96 Z= -5.09
TC ID: L X= -1.16 Y= 39.61 Z= -6.15	TC ID: L X= 1.28 Y= 36.22 Z= -6.15	TC ID: L X= 21.05 Y= 35.93 Z= -6.14	TC ID: L X= 19.28 Y= 26.96 Z= -6.03
TC ID: M X= -1.16 Y= 39.60 Z= -7.07	TC ID: M X= 1.31 Y= 36.22 Z= -7.07	TC ID: M X= 21.03 Y= 35.91 Z= -7.05	TC ID: M X= 19.38 Y= 26.96 Z= -6.92
TC ID: N X= -1.13 Y= 39.60 Z= -7.98	TC ID: N X= 1.34 Y= 36.23 Z= -7.98	TC ID: N X= 21.02 Y= 35.88 Z= -7.97	TC ID: N X= 19.32 Y= 26.96 Z= -7.83
TC ID: O X= -1.11 Y= 39.60 Z= -8.90	TC ID: O X= 1.37 Y= 36.23 Z= -8.90	TC ID: O X= 21.01 Y= 35.86 Z= -8.88	TC ID: O X= 19.33 Y= 26.96 Z= -8.75
TC ID: P X= -1.04 Y= 39.60 Z= -11.33	TC ID: P X= 1.45 Y= 36.24 Z= -11.33	TC ID: P X= 20.96 Y= 35.79 Z= -11.32	TC ID: P X= 19.36 Y= 26.96 Z= -11.18
TC ID: Q X= -0.98 Y= 39.60 Z= -13.77	TC ID: Q X= 1.54 Y= 36.25 Z= -13.77	TC ID: Q X= 20.95 Y= 35.72 Z= -13.76	TC ID: Q X= 19.42 Y= 26.96 Z= -13.62
TC ID: R X= -0.91 Y= 39.59 Z= -16.21	TC ID: R X= 1.62 Y= 36.25 Z= -16.21	TC ID: R X= 20.92 Y= 35.65 Z= -16.19	TC ID: R X= 19.47 Y= 26.96 Z= -16.05

APPENDIX A-3
THERMAL WELL LOCATIONS

Thermal Well Locations, Layer 1 (Top),
Horizontal Drilled from Upper Level

Thermal Well Locations, Layer 4, Drilled Up-Slant From Intermediate Level

Shorter sample line is 1/2" sch 40 pipe in annulus between 2-3/8" OD casing and pillar hole.

Thermal Well Locations, Layer 5, Drilled Horizontal From Intermediate Level

Thermal Well Locations, Layer 6, Drilled Down-Slant from Intermediate Level

Thermal Well Locations, Layer 7 (Bottom), Drilled Up-Slant from Lower Level

APPENDIX B

RETORT THERMOCOUPLE TEMPERATURE HISTORIES

APPENDIX B-1

RETORT 7 UPPER LEVEL

RETORT 7 UPPER LEVEL

ELEVATION 7840

APPENDIX B-2

RETORT 7 INTERMEDIATE LEVEL

RETORT 7 INTERMEDIATE ELEVATION 7755

RETORT 7 INTERMEDIATE

ELEVATION 7710

APPENDIX B-3

RETORT 7 LOWER LEVEL

RETORT 7 LOWER LEVEL ELEVATION 7670

APPENDIX B-4

RETORT 8 UPPER LEVEL

RETORT 8 UPPER LEVEL

ELEVATION 7840

RETORT 8 UPPER LEVEL

ELEVATION 7815

APPENDIX B-5
RETORT 8 INTERMEDIATE LEVEL

RETORT 8 INTERMEDIATE
ELEVATION 7790

RETORT 8 INTERMEDIATE

ELEVATION 7755

RETORT 8 INTERMEDIATE
ELEVATION 7710

APPENDIX B-6

RETORT 8 LOWER LEVEL

RETORT 8 LOWER LEVEL ELEVATION 7670

APPENDIX C
ROOF THERMOCOUPLE TEMPERATURE HISTORIES

APPENDIX C.1
RETORT 7 THERMOCOUPLE HISTORIES

RT7 SILL TEMP PROFILES DEG F - JDAY

1134 TR7051SJ

RT7 SILL TEMP PROFILES DEG F - JDAY

1137 TR7051SK

1140 TR7051SL

1149 TR7051S0

1158 TR7051SR

1163 TR7052SA

RT-7 SILL TEMP PROFILES DEG F - JDAY

1166 TR7052SB

1169 TR7052SC

1190 TR7052SJ

RT7 SILL TEMP PROFILES DEG F - JDAY

RT7 SILL TEMP PROFILES DEG F - JDAY

RT7 SILL TEMP PROFILES DEG F - JDAY

1246 TR7053SJ

1252 TR7053SL

1267 TR7053S0

RT7 SILL TEMP PROFILES DEG F - JDAY

1270 TR7053SR

1275 TR7054SA

1278 TR7054SB

RT7 SILL TEMP PROFILES DEG F - JDAY

1284 TR7054SD

RT7 SILL TEMP PROFILES DEG F - JDAY

1287. TR7054SE.

RT7 SILL TEMP PROFILES DEG F - JDAY

1290 TR7054SF.

1293 TR7054SG

1296 TR7054SH

1302.TR7054SJ.

1317 TR7054S0

1320 TR7054SP

1326 TR7054SR

1190 TR8001SA

RETORT 8 THERMOCOUPLE HISTORIES

APPENDIX E-2

1208 TR8001SG

RT8 SILL TEMP PROFILES DEG F - JDAY

1211 TR8001SH

RT8 SILL TEMP PROFILES DEG F - JDAY

1214 TR8001SI

1217 TR8001SJ.

RT8 SILL TEMP PROFILES DEG F - JDAY

1223 TR8001SL

RT8 SILL TEMP PROFILES DEG F - JDAY

1235 TR8001SP

1238 TR8001S0

1241.1R8001SR

1249 TR8002SB

RT8 SILL TEMP PROFILES DEG F - JDAY

RT8 SILL TEMP PROFILES DEG F - JDAY

1258 TR8002SE

RT8 SILL TEMP PROFILES DEG F - JDAY

1270 TR8002SI.

1255 TR7053SM

1258 TR7053SN

1273 TR8002SJ

1276 TR8002SK

1282 TR8002SM

RT8 SILL TEMP PROFILES DEG F - JDAY

1285 TR8002SN

1288 TR8002S0

51

1291 TR8002SP

1305 1R8003SB

RT8 SILL TEMP PROFILES DEG F - JDAY

1308 TR8003SC

RT8 SILL TEMP PROFILES DEG F - JDAY

RT8 SILL TEMP PROFILES DEG F - JDAY

RT8 SILL TEMP PROFILES DEG F - JDAY

RT8 SILL TEMP PROFILES DEG F - JDAY

1338 TR8003SM

RT8 SILL TEMP PROFILES DEG F - JDAY

1347 TR8003SP

1350 TR8003SQ

1353 TR8003SR

RT8 SILL TEMP PROFILES DEG F - JDAY

1361 TR8004SB

RT8 SILL TEMP PROFILES DEG F - JDAY

1364 TR8004SC

1370 TR8004SE.

1376 TR8004SG

RT8 SILL TEMP PROFILES DEG F - JDAY

1379 TR8004SH

1382 TR8004S1

RT8 SILL TEMP PROFILES DEG F - JDAY

RT8 SILL TEMP PROFILES DEG F - JDAY

RT8 SILL TEMP PROFILES DEG F - JDAY

1400 TR8004SD

RETORT 7 HYDROGEN

APPENDIX D-1

APPE

0

RETORT 7 OFFGAS COMPOSITION HISTORIES

RETORT 7 OXYGEN

RETORT 7 NITROGEN

RETORT 7 ARGON

RETORT 7 CARBON MONOXIDE

RETORT 7 CARBON DIOXIDE

RETORT 7 METHANE

RETORT 7 ETHENE

RETORT 7 ETHANE

RETORT 7 PROPENE

RETORT 7 PROPENE

RETORT 7 PROPANE

RETORT 7 BUTENE

RETORT 7 TRANS-BUTENE

RETORT 7 BUTANE

RETORT 7 ISOBUTANE

RETORT 7 PENTANE

RETORT 7 ISOPENTANE

RETORT 8 OFFGAS COMPOSITION HISTORIES

RETORT 8- NITROGEN

RETORT 8 OXYGEN

RETORT-8 ARGON

RETORT 8 CARBON DIOXIDE

RETORT 8 CARBON MONOXIDE

RETORT 8 METHANE

RETORT 8 ETHENE

RETORT 8 ETHANE

RETORT 8 PROPENE

RETORT 8 PROPANE

RETORT 8 BUTENE

RETORT 8 TRANS-BUTENE

356

RETORT 8 BUTANE

RETORT 8 ISOBUTANE

RETORT 8 PENTANE

RETORT 8 ISOPENTANE

RETORT SULFUR H₂S

RI=7

RETORT SULFUR H₂S
RT=7

RETORT SULFUR COS

RJ=7.

RETORT SULFUR H2S RI=8

RETORT SULFUR COS

RT=8

COMBINED SULFUR H2S

COMBINED-SULFUR COS

RAISE SULFUR H2S

RAISE SULFUR COS

368

STACK SULFUR H2S

369

STACK SULFUR COS

370

RETORT 7

CONDENSABLE ORGANICS IN OFFGAS

RETORT 8
CONDENSABLE ORGANICS IN OFFGAS

OFFGAS RAISE
CONDENSABLE ORGANICS IN OFFGAS

CONTACT CONDENSER 42"
CONDENSABLE ORGANICS IN OFFGAS

CONTACT CONDENSER 24"
CONDENSABLE ORGANICS IN OFFGAS

CONTACT CONDENSER 12"
CONDENSABLE ORGANICS IN OFFGAS

STACK
CONDENSABLE ORGANICS IN OFFGAS

RETORT 7
NH₃ IN OFFGAS

RETORT 8

NH₃ IN OFFGAS

OFFGAS RAISE
NH₃ IN OFFGAS

STACK
NH₃ IN OFFGAS

461510

APPENDIX E-1

RETORTS 7 AND 8
DRY OIL
BOTTOM SEDIMENT AND WATER

%

2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125

THOUSAND BARREL SAMPLES

RETORTS 7 AND 8
 DRY OIL
 CLEVELAND OPEN COP - FIRE POINT

°F

384

400

300

200

100

THOUSAND BARREL SAMPLES

387

RETORTS 7 AND 8
DRY OIL
POUR POINT

°F

388

60
50
40
30
20
10
0
-10
-20

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125

THOUSAND BARREL SAMPLES

RETORTS 7 AND 8
DRY OIL
VISCOSITY, KINEMATIC - 140°F

CST
390

391
μg/g

RETORTS 7 AND 8
DRY OIL
ARSENIC

5.0
4.0
3.0
2.0
1.0

5 10 15 20 25 30 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125

THOUSAND BARREL SAMPLES

RETORTS 7 AND 8
 DRY OIL
 ASPHALTENES

392

2.0
 1.0

THOUSAND BARREL SAMPLES

394

RETORTS 7 AND 8
 DRY OIL
 HYDROGEN, TOTAL

THOUSAND BARREL SAMPLES

396 %

RETORTS 7 AND 8
 DRY OIL
 SULFUR, TOTAL

2.0

1.0

THOUSAND BARREL SAMPLES

398

1.20
1.19
1.18
1.17
1.16
1.15
1.14
1.13
1.12
1.11
1.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01

RETORTS 7 AND 8
DRY OIL
ASH

THOUSAND BARREL SAMPLES

RETORTS 7 AND 8
DRY OIL
NITROGEN, KJELDAHL

399

%

2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

<
=

THOUSAND BARREL SAMPLES

401

°F

400

300

200

100

RETORTS 7 AND 8
LIGHT OIL
CLEVELAND OPEN CUP - FLASH POINT

WEEK

403

CST

RETORTS 7 AND 8
LIGHT OIL
VISCOSITY, KINEMATIC @ 100°F

4.0
3.0
2.0
1.0

WEEK

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

461510

406

%

.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01

RETORTS 7 AND 8
LIGHT OIL
ASPHALTENES

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

WEEK

407

RETORTS 7 AND 8
LIGHT OIL
CARBON, TOTAL

461510

408

%

RETORTS 7 AND 8
LIGHT OIL
HYDROGEN, TOTAL

1.4

1.3

1.2

1.1

1.0

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

WEEK

409

410

RETORTS 7 AND 8
LIGHT OIL
SULFUR, TOTAL

2.0
1.0

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

WEEK

411

412

RETORTS 7 AND 8
LIGHT OIL
NITROGEN, KJELDHAL

413

%

2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

W

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

WEEK

APPENDIX F

"EVALUATION OF THE PERFORMANCE OF FIVE GAUSSIAN DISPERSION
MODELS IN A COMPLEX TERRAIN ENVIRONMENT"

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EXECUTIVE SUMMARY

TRC Environmental Consultants, Inc., under contract to Occidental Oil Shale, Inc., has conducted an evaluation of the performance of five Gaussian complex terrain models. The purpose of this effort is to satisfy a permit condition required by the Colorado Air Pollution Control Division to utilize meteorological and air quality data measured at Occidental's Logan Wash oil shale processing facility in a comparative assessment of model predictions.

The five models tested were MPTR, COMPLEX I, COMPLEX II, COMPLEX I with modified terrain correction factors, and COMPLEX I employing an alternate plume height option. Both long-term (about 7.5 months) and short-term (hourly) average concentrations of hydrogen sulfide (H_2S) were computed by each of the models, the results from which were compared to actual measurements collected at Logan Wash during 1982. Several statistical tests were utilized to facilitate the evaluation of the performance of these models.

The results from these analyses indicate that these models are poor predictors of H_2S concentrations at Logan Wash. The models demonstrated limited skill in predicting the magnitude, time, location, or frequency of peak pollutant impacts. This is not surprising because many of the assumptions that are implicit in these models are of questionable validity in complex terrain environments, so the results that they provide in such situations are, at best, of dubious value.

1.0 INTRODUCTION AND BACKGROUND

With the projected increase in industrial activity in mountainous areas, there is a desire on the part of regulatory agencies and industry to assess the performance of complex terrain dispersion models. Because sophisticated numerical simulation models require detailed input data and computer resources that may not be widely available, the interest in the last few years has focused upon the simpler Gaussian models which incorporate modifications to account for complex terrain. These models will probably be used to simulate the majority of pollutant sources permitted in the Rocky Mountain west.

TRC Environmental Consultants, Inc., under contract to Occidental Oil Shale, Inc., has conducted an evaluation of the performance of five Gaussian complex terrain models. The purpose of this effort is to satisfy Occidental's obligation to the Colorado Air Pollution Control Division to "...compare monitoring results with modeling projections, with the intent of improving modeling expertise in ...Colorado." This stipulation was required by the State as a condition for granting Occidental a permit to test two commercial-sized modified in-situ (MIS) retorts at its Logan Wash facility northeast of DeBeque, Colorado. The location of Occidental's Logan Wash facility is shown in Figure 1. Since the Logan Wash facility was constructed to serve as a demonstration of MIS technology, and was not intended to operate for a long period of time, the State APCD and the U.S. EPA agreed that controls of sulfur emissions from the retorts' off-gas would not be required. In return, Occidental agreed to collect air quality and meteorological data at Logan Wash, and to use that data to evaluate the performance of the dispersion models being used by local regulatory agencies for permitting purposes. This report is the culmination of that effort.

The basis for the model performance evaluation was the monitoring data collected over a ten-month period by Occidental at the Logan Wash facility during 1982. The monitoring network consisted of four separate measurement locations surrounding the retort stack. In addition to the

FIGURE 1 - LOCATION OF OCCIDENTAL OIL SHALE'S
LOGAN WASH FACILITY IN WESTERN COLORADO

meteorological and air quality measurements, Occidental also performed intermittent in-stack H_2S concentration and volume flow measurements. The on-site meteorological and the in-stack H_2S data were used to compute hourly H_2S concentrations utilizing five different Gaussian dispersion models. The predicted concentrations were then compared to measured H_2S levels to evaluate the performance of the models.

Section 2 of this report describes the models selected, the methodologies used for reducing the monitoring data into usable formats, and the statistical analyses employed to evaluate the models. Section 3 discusses the results of the modeling and statistical analyses. Finally, conclusions and recommendations regarding the use of these models for regulatory applications are presented in Section 4.

2.0 METHODOLOGY

2.1 DATA BASE PREPARATION

METEOROLOGICAL DATA

The first task required before the execution of the dispersion models could be performed was the preparation of the meteorological, emissions, and ambient air quality data collected by Occidental. TRC performed rudimentary checks of the data for consistency, and any obvious anomalies were removed from the data base. TRC did not undertake detailed quality assurance procedures. Meteorological and air quality data were collected at four separate locations surrounding the retort stack. The locations of these monitors are shown in Figure 2, and the various parameters measured at each site are summarized in Table 1. As shown in Figure 2, the retort stack is located near the summit of a peak at an altitude of about 8,500 feet above sea level. Only two of the monitoring locations (LW02 and LW06) are at elevations that are higher than the stack base. Site LW05 is located almost 500 feet below stack base, while Site LW01 is about 1,500 feet below the base of the stack.

TABLE 1

PARAMETERS MEASURED AT OCCIDENTAL'S LOGAN WASH FACILITY

SITE	PARAMETERS
LW01	U, V, T ₁₀ , M, CO
LW02	U, V, T ₃ , T ₃₃ , H ₂ S*
LW05	U, V, T ₁₀ , H ₂ S*
LW06	U, V, T ₁₀ , S _i , H ₂ S*

KEY: U - Wind Direction M - Mixing Height
V - Wind Speed S_i - Solar Radiation (incoming)
T₃ - Temperature (3 meters) CO - Carbon Monoxide Concentration
T₁₀ - Temperature (10 meters) H₂S - Hydrogen Sulfide Concentration
T₃₃ - Temperature (33 meters)

*NOTE: The lower detectable limit of the H₂S monitor at Site LW02 (TECO) is assumed to be 1 ppb (1.4 ug/m³) and at sites LW05 and LW06 (International Sensor) the limit is assumed to be 1 ppm (1,390 ug/m³).

This site is highly complex in meteorological terms, because of significant terrain elevation changes. Wind speed and direction and temperature can differ dramatically between sites in close proximity to each other. Wind and temperature measurements collected at Site LW02 were selected for modeling purposes because this site is reasonably representative of conditions occurring at the location of the retort stack. This site is closer to the stack than any of the sites, is not overly affected by localized terrain influences, and is close to the same elevation as the emission release point. It is recognized however that some differences in meteorology may occur between the tower and the stack.

The acoustic sounder measurements performed from Site LW01 were analyzed by Occidental and were supplied to TRC on magnetic tape in the form of hourly mixing heights. The acoustic sounder did not provide as many usable hourly measurements (about 30 percent data capture from January through October 1982) as did the other meteorological monitoring instruments and thus severely limited the number of periods that could be modeled. To increase the size of the meteorological data base,

a mixing height value of 5,000 meters was assumed for those hours when the acoustic sounder measurements were missing.

As mentioned previously, both solar radiation and differential temperature (ΔT) measurements were conducted at the Logan Wash facility. However, the solar radiation measurements only included incoming (daytime) radiation and not the outgoing, infrared (nighttime) component. Hence, it was not possible to determine atmospheric stability classes for the evening hours from these data. For this reason, the atmospheric stability parameters used for modeling purposes were determined using the ΔT method recommended by the U.S. Nuclear Regulatory Commission¹ and are summarized in Table 2. A correction factor, based on Turner's Workbook² was applied to the ΔT categories to account for expected changes in stability caused by variations in wind speed.

The differences in computed stability categories determined using the ΔT method and from solar radiation measurements have been evaluated. Stability classes were determined for each daylight hour using solar radiation measurements by employing a method described by Zishka, et al.³. This method is summarized in Table 3. A comparison of daytime stability classes determined using both the ΔT and solar radiation measurements is presented in Table 4. It is evident from this table that the ΔT method predicts a greater frequency of occurrence of both the most unstable (Class A), and the most stable (Classes E and F) categories. Given the traditional knowledge that stable atmospheric conditions are typically associated with peak pollutant impacts in areas with complex terrain, it is expected that the ΔT method would yield the most conservative modeling results for this exercise. Indeed the occurrence of stable atmospheres during daylight hours, as indicated by the ΔT method, gives testimony to the conservatism of this approach.

STACK PARAMETERS

The stack parameters and hourly emission rates which describe the characteristics and magnitude of the H₂S emissions from the retorts were supplied on magnetic tape by Occidental, and are summarized below:

- East Coordinate: 744115 meters
- North Coordinate: 4367215 meters

TABLE 2

STABILITY CLASSIFICATION SCHEME USING DIFFERENTIAL
TEMPERATURE (ΔT) BETWEEN 3 AND 33 METERS

TEMPERATURE DIFFERENCE ($^{\circ}\text{K}/30$ meters)	SURFACE WIND SPEED (meters/second)	STABILITY CLASS
≤ -0.57	≤ 3.0	A
	$> 3.0, \leq 5.0$	B
	$> 5.0, \leq 8.0$	C
	> 8.0	D
$\leq -0.51, > -0.57$	≤ 5.0	B
	$> 5.0, \leq 8.0$	C
	> 8.0	D
$\leq -0.45, > -0.51$	≤ 8.0	C
	> 8.0	D
$\leq -0.15, > -0.45$	All speeds	D
$\leq 0.45, > -0.15$	≤ 5.0	E
	> 5.0	D
> 0.45	≤ 3.0	F
	$> 3.0, \leq 5.0$	E
	> 5.0	D

TABLE 3

STABILITY CLASSIFICATION SCHEME
USING SOLAR RADIATION MEASUREMENTS

NET RADIATION (Langleys)	SURFACE WIND SPEED (meters/second)	STABILITY CLASS
> 57.7	≤ 2.83	A
	> 2.83, ≤ 4.89	B
	> 4.89	C
> 42.2, ≤ 57.7	≤ 0.77	A
	> 0.77, ≤ 3.86	B
	> 3.86, ≤ 5.92	C
	> 5.92	D
> 23.8, ≤ 42.2	≤ 1.80	B
	> 1.80, ≤ 4.89	C
	> 4.89	D
> 11.6, ≤ 23.8	≤ 1.80	C
	> 1.80	D
> 0.0, ≤ 11.6	All speeds	D

TABLE 4

COMPARISON OF FREQUENCY DISTRIBUTIONS OF DAYTIME STABILITY
CLASSES DETERMINED BY ALTERNATE METHODS

STABILITY CLASS	DELTA T METHOD (PERCENT)	SOLAR RADIATION METHOD (PERCENT)
A	13.5	3.9
B	16.7	14.2
C	16.8	20.6
D	35.2	61.3
E	11.3	0.0
F	6.4	0.0

- H₂S Emission Rate: 45.06 grams/second
- Stack Height: 50.3 meters
- Exhaust Temperature: 333.0°K
- Stack Diameter: 0.9 meters
- Exit Velocity: 25.0 meters/second
- Stack Base Elevation: 8517 feet ASL.

Missing data periods were filled in by interpolating between the preceding and subsequent values. These data, along with the meteorological data described previously in this section and an appropriate array of receptor locations, formed the basis for the dispersion modeling analysis. The combination of these data formed a relatively continuous seven-month period of record extending from March 20 through October 31, 1982, interrupted occasionally by breakdowns of monitoring equipment. Ambient pollutant concentrations were not computed by the dispersion models during periods when any of the meteorological data were missing. This insured that the results of the statistical analyses would not be biased by artificially generated input parameters that may not have been representative of actual conditions.

RECEPTORS

As mentioned above, a receptor array was developed which described the basic terrain features in the vicinity of the retort stack. The elevations of 68 receptor locations were determined from U.S. Geological Survey topographic maps. The receptors, which were identified in terms of the UTM (Universal Transverse Mercator) coordinate system, were located at 0.25 kilometer intervals surrounding the locations of monitoring sites LW02, LW05, and LW06 as shown in Figure 2. Site LW01 was not used for modeling purposes because it is physically located about 1,500 feet below the elevation of the base of the retort stack. Because the models being evaluated assume a level, horizontal plume centerline, no pollutant concentrations would be predicted at this site. Certainly this assumption represents a limitation on the application of these models in complex terrain.

2.2 MODEL SELECTION AND EXECUTION

The present study was conducted to evaluate models that have been or will be widely used for regulatory applications in areas where the terrain is complex. Current guidance from the Environmental Protection

Agency⁵ recommends the use of the Single Source (CRSTER) model for short-term analyses of isolated sources in rural areas with moderate terrain complexity. In areas where the terrain is sufficiently complex the VALLEY algorithm is recommended as a screening technique for estimating the impact of emission sources. These algorithms and variations of them are commonly used by regulatory agencies for the determination of impacts from pollutant sources located in complex terrain.

The limitations inherent in each of these models, however, make their use in this type of analysis quite cumbersome. For example, the CRSTER model requires the use of an awkward radial receptor array centered at the emission source which would involve a number of model executions to attain the resolution required for proper performance evaluation. The use of the VALLEY model would have been even more difficult because the model requires that the meteorological data be input as a joint frequency distribution of wind direction, speed, and stability class. Fortunately, models which are very similar to CRSTER and VALLEY in terms of their treatment of plume behavior but are easier to apply for this type of study, are available from the EPA--MPSTER and COMPLEX I. MPSTER, unlike CRSTER, allows the user the flexibility of placing receptors at discrete locations. The COMPLEX I model is similar to VALLEY in many respects but accepts hourly meteorological data rather than the joint frequency distribution, and is therefore preferable to VALLEY for computing short-term concentration estimates. Also, both of these models allow for the input of hourly emission rates, thereby allowing for better simulation of actual conditions. These two models, along with EPA's COMPLEX II algorithm, form the basis of the performance evaluations conducted in this study. In addition, two variations of these models have been tested to determine whether improvements to the above models can be identified. A brief discussion of each of the five models evaluated in this report is provided.

MODEL 1 - MPSTER

MPSTER was developed by the EPA and is routinely used for regulatory applications. It computes pollutant concentrations from a number of emission sources for both short- and long-term averages. The model accepts both hourly emission rates and hourly meteorological conditions,

so short-term variations in the facility's operating rate or in the factors affecting plume transport and dispersion are adequately represented.

The model does provide for corrections of plume behavior due to the influence of moderate terrain features. It utilizes a "half-height" correction of the plume height above the terrain for unstable or neutral atmospheric conditions, but no correction is applied during stable conditions. The model is of limited usefulness in areas where the terrain is significant, however, because it cannot estimate pollutant concentrations at receptors with elevations higher than the top of the stack. Since much of the terrain, and two of the monitoring sites at Logan Wash, are above the height of the stack, the description of the terrain provided to the model was simplified. This was accomplished by reducing to stack height those receptors that are, in reality, higher than the top of the stack.

MODEL 2 - COMPLEX I

COMPLEX I provides a much more thorough treatment of the influence of significant terrain features on plume behavior than does MPTER. It utilizes the same "half-height" correction for unstable atmospheres used in MPTER, but does allow the plume to "impact" terrain features that are taller than the stack. This is accomplished by assuming that the plume centerline remains at 10 meters above the terrain as it rises over it. Like the VALLEY model, COMPLEX I assumes a homogenous pollutant distribution horizontally within a 22.5° sector. COMPLEX I is different from VALLEY in two important respects: its use of the "half-height" correction for unstable and neutral conditions as mentioned above, and the enhancement of vertical dispersion induced by the initial buoyancy of the effluent plume. The buoyancy induced dispersion enhancement accounts for turbulent motions experienced by an effluent plume during its rise that are due to entrainment of ambient air into the plume and to turbulence caused by the stack itself.

MODEL 3 - COMPLEX II

This model is similar to COMPLEX I and is recommended by EPA as a screening model in areas, like Logan Wash, which have complex terrain. It is different from COMPLEX I in that it uses horizontal dispersion

coefficients (σ_y), which vary with downwind distance and stability class, rather than integrating over a 22.5° sector. Also, buoyancy induced plume dispersion is accounted for, both horizontally and vertically, through an enhancement of the dispersion coefficient values.

MODEL 4 - COMPLEX I WITH MODIFIED TERRAIN CORRECTION FACTORS

All of the models previously mentioned utilize the "half-height" correction to modify the plume trajectory over terrain features during unstable and neutral atmospheric conditions. No correction is applied during stable conditions. In order to test the performance of these correction factors, as they are applied at Logan Wash, and also to see if other values might perform better than those recommended by the EPA, an alternate set of terrain correction factors was used in conjunction with the COMPLEX I model. The alternate values were selected jointly by the State Air Pollution Control Division and TRC at the outset of the project, and, although selected somewhat arbitrarily, provide a basis for comparison with the traditional values. A plume height correction factor of 0.65 was chosen for unstable and neutral conditions, which provides greater plume separation from the terrain than would occur using the EPA value of 0.50. During stable conditions, a factor of 0.25 was applied, which has the effect of forcing the plume closer to the terrain than would be predicted during unstable hours but would still provide a greater plume separation from the ground than would EPA's value of 0.0.

MODEL 5 - COMPLEX I ALTERNATE WITH PLUME HEIGHT OPTION (IOPT[25] = 3)

The COMPLEX I and II models discussed above all assume that an effluent plume is deflected upwards by the presence of terrain obstacles. Although this process can and does, in fact, occur in complex terrain settings, other plume transport processes have been observed as well. The EPA⁵ has identified conditions, mostly under stable atmospheres when vertical movements in the atmosphere are inhibited, when plumes travel around terrain obstacles rather than over them. Under these conditions the plume does not experience the distortions caused by the mechanical uplifting process, but rather remains essentially unchanged in its vertical and horizontal dimensions.

The EPA has provided a means to simulate this process in its COMPLEX I model. Model Option 25 was set equal to 3 to evaluate whether

plume flow around terrain obstacles is a more accurate description of actual processes occurring at Logan Wash than is plume flow over them. With this option the COMPLEX I model assumes that the terrain does not distort the horizontal and vertical dimensions of the plume. Rather, the model computes concentrations at individual receptor locations in complex terrain by assuming that the receptors are "suspended" (as though on a tower) above flat ground, at a height equal to the terrain.

Each of these models was executed on an hour-by-hour basis using the input data bases described in Section 2.1. Hourly H_2S concentrations predicted by the models at each receptor location were stored on magnetic tape and were then paired, using a predetermined set of criteria, with the concentrations measured at Logan Wash. These criteria, and the statistical tests used to evaluate the agreement between the model predicted and the measured values, are discussed in the following section.

2.3 STATISTICAL ANALYSES

A number of rather simple statistical test were utilized in this study to determine whether the concentrations predicted by the models are equivalent to the H_2S concentrations observed at Logan Wash. The tests were designed to identify the strengths and weaknesses of as many model components as possible with the data available. Case-by-case comparisons of the highest concentrations observed at Logan Wash were compared to those computed by the models, and, where the sample sizes were large enough, descriptive statistics were computed.

Agreement of short-term peak concentrations was considered to be a more important indicator of model performance than agreement of long-term averages for several reasons. Long-term H_2S concentrations at Logan Wash are low because the monitors only occasionally recorded nonzero values. Comparison of near-zero long-term measured and modeled averages is therefore not very meaningful. Also, the relatively high threshold detection limit for two of the three monitors was so high (1 ppm) that significant H_2S concentrations may well have gone undetected. Most complex terrain models are utilized to predict short-term pollutant concentrations against which ambient air quality standards are compared,

so it is reasonable to test short-term concentrations as a measure of model performance. Finally, the accumulation of hourly concentration estimates into long-term averages may mask errors that occur randomly because the effects of a random error occurring on a given hour may be canceled by errors occurring in subsequent hours. For these reasons, the primary indicator of model performance used in this study is the agreement between H_2S concentrations measured on an hourly basis at Logan Wash and model predicted concentrations. Long-term averages are nevertheless presented, but are not the primary focus of this study.

The ability of each of the five models to provide accurate concentration estimates was evaluated through the use of case-by-case comparisons by actual predicted and observed values, and by computation of descriptive test statistics. The case-by-case comparisons have been provided for the ten highest predicted and observed values to allow a direct assessment of not only the magnitudes of the highest values, but of the frequency at which these concentrations occur. These comparisons also provide a convenient means of identifying anomalously high predicted or observed values.

Analysis of such small data samples can often lead to erroneous conclusions, so it is desirable to test as large a sample as is possible. To simplify the task of analyzing large data sets, descriptive statistics, or parameters which represent the characteristics of a given distribution, are usually employed. In general, the samples evaluated in the present study consisted of the highest 100 data pairs constructed using the criteria outlined later in this section.

Much of the present study is based upon the analysis of residual--that is, the differences between the observed and predicted H_2S concentrations. Good agreement between actual concentrations and those simulated by the dispersion models is indicated if the residuals are small in magnitude, and if the number of negative residuals approximately equals the number of positive residuals. However, relatively large residuals which approach the magnitude of either the observed or predicted concentrations are indicative of poor model performance. A large negative residual occurs when a high concentration was predicted, but little is actually measured, and is thus indicative of

model overprediction. Similarly a large positive residual indicates that the model underpredicted an elevated measured concentration. If the model consistently over- or under-predicts observed concentrations, and is therefore biased, the number of positive residuals should be greatly different from the number of negative residuals.

A common assessment of the performance of dispersion models is that model predictions are usually within a factor of two from observed values. To test the validity of this conventional "wisdom" at Logan Wash, the magnitude of the errors, or differences between predicted and observed results, has been addressed by normalizing the predicted result to the observed value (i.e., the predicted divided by the observed).

Measured H_2S concentrations were paired in a number of different ways with concentrations computed by the five models. To avoid bias, the peak values were defined by the model as well as the measurements for some tests. This was done because models which consistently predict high concentrations all of the time would appear to perform well if the measured peaks were the only basis for comparison. Overall, the observed and predicted concentrations were combined in a number of different ways. The criteria used to establish the data pairs for each of the models tested are as follows:

- Rank the highest observed concentrations; pair with the highest predicted values. This test will identify whether or not the models accurately predict the frequency and magnitude of expected peak impacts without regard to temporal or spatial considerations.
- Rank the highest predicted concentrations; pair with the highest values predicted on the same hour. Ranking by the highest predicted values, and the inclusion of the temporal limitation, allows an assessment of whether the worst case conditions identified by the models are the conditions causing elevated concentrations to be measured.
- Rank the highest observed concentrations; pair with the highest values predicted on the same hour. Ranking by the highest observed concentrations for this test, identifies the worst case conditions causing actual, elevated impacts to occur at Logan Wash. This test, then, will show whether the models correctly identify these conditions as worst case.

- Rank the highest observed concentrations; pair with the highest values predicted at the same location. The inclusion of the spatial limitation on model predictions will identify weaknesses in model components which govern a plume's location in three dimensions, namely the wind direction and the plume height.
- Rank the highest predicted concentrations; pair with the values predicted at the same location. This test, and the subsequent one, are the most restrictive tests since good agreement between the observed and predicted values for this scenario implies that all of the model components and inputs which govern transport and dispersion are correct.
- Rank the highest predicted concentrations; pair with the values observed at the same location on the same hour. As with the previous test, this scenario is not restrictive in its use of both spatial and temporal limitations. In this case, the models identify the conditions causing the worst impacts to be predicted at specific locations. Comparison with the observed values indicates the correctness with which the model identified those conditions.
- Rank the highest observed concentrations for each stability class; pair with the highest values predicted for the same class. This test identifies the sensitivity of peak measured and modeled concentrations to atmospheric stability categories. No temporal or spatial restrictions were applied for this test.

These tests, by being increasingly restrictive, should provide detailed indications of the presence or absence of bias, or of gross errors in model predictions. It should be noted that test statistics were not always computed for all of the data pairs established using the above criteria because in some cases the resulting samples were too small to yield meaningful results. For example, long-term mean H_2S concentrations were measured at just three sampling locations, and only one of those provided valid long-term averages. Statistical analysis of a sample this small would yield results which are meaningless. Similarly, descriptive statistics were not utilized for the cases where the data were paired by stability class, again, because the resulting samples were too small. For these instances, the highest observed and predicted concentrations were compared directly by listing the actual data pairs obtained from each test.

3.0 RESULTS OF THE MODEL PERFORMANCE EVALUATIONS

In this study, five Gaussian models were evaluated for a complex terrain setting through a comparison of the predicted impacts of Occidental's Logan Wash retort plume with observed H_2S concentrations measured during the period of March 20 to October 31, 1982. Model predictions were obtained using on-site meteorological measurements and actual hourly H_2S emission rates. This section presents the results of the model performance evaluations obtained using the predefined approach described in Section 2 of this report. The results for each successive pairing of predicted and observed concentrations are summarized for each model. Case-by-case comparisons of the highest ten occurrences, and the detailed results of the statistical analyses performed on much larger samples of data pairs are included in Appendix I of this report. A comparison of long-term averages is also presented since these results were readily available from the analyses performed.

A consistent notation has been applied throughout this section to summarize the test results. Observed H_2S concentrations are referred to in many of the tables as 'O', while 'P' denotes a predicted concentration. The difference, or the residual, between an observed and a predicted concentration for a given data pair (O,P), is denoted by (O-P). Similarly the ratio of a predicted to an observed value is referred to in many of the following tables by (P/O).

3.1 STATISTICAL ANALYSES

Highest Observed Paired with the Highest Predicted Values

For this analysis, the highest predicted H_2S concentrations were paired with the highest observed values without applying any temporal or spatial restrictions on the model predictions. The results of this test are summarized in Table 5; case-by-case comparisons and more detailed statistical results are included in Appendix I (tables I.1 and I.2).

From Table 5 it is evident that all of the models underpredict both the magnitude and the frequency of peak H_2S concentrations observed at Logan Wash. The maximum concentrations predicted by the models were

TABLE 5

SUMMARY OF MODEL PERFORMANCE - HIGHEST OBSERVED
PAIRED WITH THE HIGHEST PREDICTED

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	1,420	5,152	15,960	2,075	2,576
O _{max} (ug/m ³)	20,430	20,430	20,430	20,430	20,430
Mean: (P/O)	0.1	0.2	0.4	0.1	0.1
Mean: O-P	10,759	9,654	6,643	10,802	10,706
Frequency of Overprediction (%)	0	0	0	0	0
Frequency of Underprediction (%)	100	100	100	100	100

TABLE 6

SUMMARY OF MODEL PERFORMANCE - HIGHEST PREDICTED
PAIRED WITH THE HIGHEST OBSERVED ON THE SAME HOUR

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	1,420	5,152	15,960	2,075	2,576
O _{max} (ug/m ³)	1,251	973	1,251	1,529	973
Mean: (P/O)	1.0	2.1	5.0	0.9	1.1
Mean: O-P	457	1,249	4,187	573	560
Frequency of Overprediction (%)	49	95	100	49	47
Frequency of Underprediction (%)	51	5	0	51	53

generally one fourth to one tenth of the peak observed concentration of 20,430 ug/m³; only Model 3 (COMPLEX II) predicted an hourly concentration that approached the maximum measured value. The mean absolute residuals, the average separation between measured and modeled concentrations, indicate that the models underpredicted the 100 highest observed concentrations by 6,643 to 10,802 ug/m³! In fact, of the 100 data pairs constructed for each model using these least restrictive criteria, not once did the modeled concentration exceed the corresponding observed value.

Highest Predicted Paired with the Highest Observed on the Same Hour

For this test, the highest predicted H₂S concentrations were paired with the highest values that were observed on the same hour. No spatial restrictions were applied for this test. In other words, the predicted and observed values need not be coincident in location, only in time of occurrence. The results of this analysis are summarized in Table 6, while more detailed listings appear in Appendix I (tables I.3 and I.4).

Much better agreement between modeled and measured results were obtained for this test, versus the previous one. Models 1, 4, and 5 overpredicted the maximum observed concentrations to varying degrees, but analysis of the highest 100 data pairs shows no bias toward either over- or under-prediction. Overall, the predicted concentrations for these models is well within a factor of 2 of the measured values. By contrast, Model 2 (COMPLEX I) over-predicted the observed value on 95 of the 100 data pairs, and Model 3 (COMPLEX II) over-predicted virtually every observed value. These two models exhibit little skill in identifying the specific periods when elevated H₂S concentrations were observed.

Highest Observed Paired with the Highest Predicted on the Same Hour

The results of this evaluation are summarized in Table 7, and are included in greater detail in tables I.5 and I.6 in Appendix I. This test is similar to the previous one in that no spatial restrictions are

TABLE 7

SUMMARY OF MODEL PERFORMANCE - HIGHEST OBSERVED
 PAIRED WITH THE HIGHEST PREDICTED ON THE SAME HOUR

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	12	0	10	0	0
O _{max} (ug/m ³)	20,430	20,430	20,430	20,430	20,430
Mean: (P/O)	0.0	0.0	0.0	0.0	0.0
Mean: O-P	11,765	11,781	11,790	11,779	11,795
Frequency of Overprediction (%)	0	0	0	0	0
Frequency of Underprediction (%)	100	100	100	100	100

TABLE 8

SUMMARY OF MODEL PERFORMANCE - HIGHEST OBSERVED
 PAIRED WITH THE HIGHEST PREDICTED AT SITE LW02

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	1,221	4,143	10,090	1,135	2,072
O _{max} (ug/m ³)	830	830	830	830	830
Mean: (P/O)	2.1	6.1	5.9	3.2	3.3
Mean: O-P	245	1,164	1,127	493	528
Frequency of Overprediction (%)	100	100	100	100	100
Frequency of Underprediction (%)	0	0	0	0	0

applied. However, as the previous analysis allowed the models to identify the hours which cause elevated concentrations to be predicted, the present test uses the actual observations to identify the worst hours.

From Table 7, it is evident that the models exhibit little skill in identifying actual worst case conditions. Virtually all of the 100 highest observed concentrations were underpredicted by all of the models--by an average of almost 12,000 $\mu\text{g}/\text{m}^3$! The degree of bias evidenced by these results clearly indicates that some "process" (whether physical or man-made) which caused or contributed to the measurement of elevated concentrations at Logan Wash has not been accounted for by any of the models tested.

Highest Observed Paired with the Highest Predicted at the Same Location

For this test the highest observed were paired with the highest values predicted by the models at the exact location of each of the monitors. The predicted values did not have to occur on the same hour that the measurements were performed however. This examination should help to identify the models' ability to correctly predict the magnitude of the plume at a given distance and terrain height. The results of this comparison are shown for each of the 3 monitor locations in tables 8, 9, and 10, and, in Appendix I, tables I.7 through I.12.

From tables 8, 9, and 10 it is evident that the models perform differently at different monitor locations. At location LW02 (Table 8), all five models consistently overpredicted the highest measured concentrations to varying degrees. Model 1 (MPTEP) provided the best concentration estimates, based on the relatively low (P/O) ratio, and the mean absolute residual. Conversely, Model 2 (COMPLEX I) and Model 3 (COMPLEX II) grossly overestimated observed concentration levels at this site.

The results obtained at Site LW05 (Table 9) are dramatically different than those from Site LW02. All five models consistently

TABLE 9

SUMMARY OF MODEL PERFORMANCE - HIGHEST OBSERVED
 PAIRED WITH THE HIGHEST PREDICTED AT SITE LW05

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	256	163	144	192	113
O _{max} (ug/m ³)	20,430	20,430	20,430	20,430	20,430
Mean: (P/O)	0.0	0.0	0.0	0.0	0.0
Mean: O-P	11,710	11,784	11,793	11,773	11,809
Frequency of Overprediction (%)	0	0	0	0	0
Frequency of Underprediction (%)	100	100	100	100	100

TABLE 10

SUMMARY OF MODEL PERFORMANCE - HIGHEST OBSERVED
 PAIRED WITH THE HIGHEST PREDICTED AT SITE LW06

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	1,320	3,066	12,400	2,075	1,283
O _{max} (ug/m ³)	9,452	9,452	9,452	9,452	9,452
Mean: (P/O)	0.2	0.2	0.2	0.2	0.2
Mean: O-P	2,578	2,249	1,955	2,408	2,858
Frequency of Overprediction (%)	0	0	1	0	0
Frequency of Underprediction (%)	100	100	99	100	100

underpredicted the observed by wide margins. It is not surprising that the models performed badly at this location, since the monitor was physically located about 500 feet below the elevation of the base of the retort stack. Obviously, a plume from this stack must be significantly tilted downward to impact site LW05, a condition which is possible in reality, but is not represented by any of the models tested. Since each of these models assumes a horizontal plume over flat or downward sloping terrain, it is expected that the models will not be adequate for situations such as this.

What is surprising about the data contained in Table 9 and Table I.9 was the magnitude of the peak concentrations observed at LW05, as compared to the other two sites. It might have been expected that Site LW02 would have measured consistently higher concentrations than the other two sites since this monitor is the closest to the stack, and is located at an elevation that is close to the height of the top of the retort stack. However the highest concentration measured at Site LW02 (830 ug/m^3) is lower than the minimum detectable limit of the other two instruments ($1,390 \text{ ug/m}^3$). Assuming that the measurements from these sites are accurate, then the differences exhibited between the sites must be indicative of differences in the physical processes which cause each of the sites to be impacted by the retort's effluent plume. For this reason, all of the subsequent analyses were performed separately for each monitor location.

Finally, from tables 10, I.11, and I.12 the models again consistently underpredicted concentrations observed at Site LW06. Virtually all of the top 100 values predicted at this location were significantly less than the values observed.

Highest Predicted Paired with the Highest Observed At The Same Location
On The Same Hour

This evaluation, and the subsequent one, are the most restrictive model comparisons of the tests applied in this study in that they both

require the models to provide representative concentrations at the precise time and location that specific observations were made. This test allows the models to identify the worst impact periods, and then compares the results to actual measurements performed on the same hours at each monitoring site. The results of these comparisons are shown in Tables 11, 12, and 13 (and Tables I.13 through I.18 in Appendix I).

At monitoring location LW02, each of the 5 models have identified worst case periods that are not verified by actual observations as shown in Table 11. All of the models consistently overpredicted the concentrations that were observed during those periods identified by the models as being "worst-case" at this location.

From Table 12, the models again demonstrate their inability to properly simulate H_2S concentrations at Site LW05. In contrast to the excessively high values computed at Site LW02, at LW05 the models tend to underpredict concentrations. Although the frequency of occurrence of positive residuals (ie., number of times the models underpredict) is roughly equal to the occurrences when the residuals were negative, the magnitude of those residuals (MEAN: $1(O-P)1$), and the average ratio of the predicted to the observed concentrations (MEAN: (P/O)) indicate that when the models underpredict, they do so to a large degree. This result is better illustrated by Tables I.15 and I.16 in Appendix I, which show that when non-zero concentrations were measured, the measured values greatly exceed the levels provided by the models.

Interestingly, the models provided comparatively good predictions at Site LW06 for this evaluation (Table 13). Models 1 through 4 tended to overpredict measured concentrations on most of the top 100 occurrences, but, with the exception of Model 3 (COMPLEX II), the predicted values were generally within a factor of two from those observed. Model 5, however, underpredicted the observed concentrations most of the time, unlike the other four models. Model 5 differs from Model 2 (COMPLEX I) in its treatment of the plume height above the terrain (option 25 = 3 for Model 5, and option 25 = 1 for Model 2).

TABLE 11

SUMMARY OF MODEL PERFORMANCE - HIGHEST PREDICTED
 PAIRED WITH THE OBSERVED ON THE SAME HOUR AT SITE LW02

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	1,221	4,143	10,090	1,135	2,072
O _{max} (ug/m ³)	10	0	17	0	0
Mean: (P/O)	29.8	88.6	83.9	45.9	46.3
Mean: O-P	460	1,378	1,340	707	741
Frequency of Overprediction (%)	99	100	100	100	100
Frequency of Underprediction (%)	1	0	0	0	0

TABLE 12

SUMMARY OF MODEL PERFORMANCE - HIGHEST PREDICTED
 PAIRED WITH THE OBSERVED ON THE SAME HOUR AT SITE LW05

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	256	163	144	192	113
O _{max} (ug/m ³)	4,865	0	0	0	0
Mean: (P/O)	0.1	0.0	0.0	0.1	0.0
Mean: O-P	1,272	1,343	1,323	1,336	1,378
Frequency of Overprediction (%)	36	44	45	45	44
Frequency of Underprediction (%)	64	56	55	55	56

TABLE 13

SUMMARY OF MODEL PERFORMANCE - HIGHEST PREDICTED
 PAIRED WITH THE OBSERVED ON THE SAME HOUR AT SITE LW06

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	1,320	3,066	12,400	2,075	1,283
O _{max} (ug/m ³)	1,390	1,529	1,390	1,529	0
Mean: (P/O)	1.1	1.5	2.5	1.2	0.3
Mean: O-P	436	650	1,006	570	618
Frequency of Overprediction (%)	62	61	72	58	34
Frequency of Underprediction (%)	38	39	28	42	66

TABLE 14

SUMMARY OF MODEL PERFORMANCE - HIGHEST OBSERVED
 PAIRED WITH THE PREDICTED ON THE SAME HOUR AT SITE LW02

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	0	0	0	0	0
O _{max} (ug/m ³)	830	830	830	830	830
Mean: (P/O)	0.1	0.2	0.3	0.1	0.1
Mean: O-P	228	242	264	230	228
Frequency of Overprediction (%)	2	4	3	4	4
Frequency of Underprediction (%)	98	96	97	96	96

Model 2 assumes that a plume which is transported over rising terrain will pass no closer than one-half its original height during non-stable periods, and no closer than 10 meters during stable hours. Model 5 makes no modifications to the height of the plume in complex terrain but rather will allow direct impaction on terrain features with elevations above plume height. The results for Model 5 don't necessarily imply that the assumption of plume impaction causes the model to underpredict concentrations however. It is more likely that this model has identified worst case periods that are not substantiated by the measurements at this location. In other words, during periods when Model 5 simulated plume impaction to occur at Site LW06, the plume was, in reality, in a different location, and therefore no detectable concentrations were observed.

Highest Observed Paired With The Highest Predicted At The Same Location
On The Same Hour

For this comparison, the highest hourly H_2S concentrations observed at each of the three sites were paired with the values predicted by the models at the same location and time of occurrence. These results are summarized in Tables 14, 15, and 16 in the test, and Tables I.19 through I.24 in Appendix I.

At all three monitoring locations, the models consistently underpredicted the measured concentrations, or, more appropriately, the models did not correctly identify the actual worst case conditions which caused peak impacts to be observed. Based on the ratios of predicted to the observed concentrations (P/O) and the mean absolute values of the residuals, the models performed best (though hardly good) at Site LW02, and, as expected, did the worst at Site LW05.

TABLE 15

SUMMARY OF MODEL PERFORMANCE - HIGHEST OBSERVED
 PAIRED WITH THE PREDICTED ON THE SAME HOUR AT SITE LW05

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	0	0	0	0	0
O _{max} (ug/m ³)	20,430	20,430	20,430	20,430	20,430
Mean: (P/O)	0.0	0.0	0.0	0.0	0.0
Mean: O-P	11,837	11,840	11,839	11,839	11,840
Frequency of Overprediction (%)	0	0	0	0	0
Frequency of Underprediction (%)	100	100	100	100	100

TABLE 16

SUMMARY OF MODEL PERFORMANCE - HIGHEST OBSERVED
 PAIRED WITH THE PREDICTED ON THE SAME HOUR AT SITE LW06

STATISTIC	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
P _{max} (ug/m ³)	0	0	0	0	0
O _{max} (ug/m ³)	9,452	9,452	9,452	9,452	9,452
Mean: (P/O)	0.0	0.0	0.0	0.0	0.0
Mean: O-P	3,071	3,065	3,071	3,067	3,074
Frequency of Overprediction (%)	0	0	0	0	0
Frequency of Underprediction (%)	100	100	100	100	100

Highest Observed Paired With The Highest Predicted For Each Stability Class

The highest ten observed concentrations were paired with the highest ten predicted concentrations for each stability category. Larger sample sizes could not be constructed because, for some categories, no more than ten observations were available from each of the monitors. The highest hourly values are compared in Table 17, while complete listings of the highest ten data pairs for each stability category appear in Table I.25 in Appendix I.

Consistent with the previous analyses, the performance of the models was strongly dependent on the monitor location used for comparison. At location LW02, all of the models consistently overpredicted the peak concentrations that were observed for each stability class. However, at the other two locations, and especially at Site LW05, the models tended to underpredict hourly H_2S concentrations.

It is interesting to note that the highest H_2S concentrations observed at Site LW02 and, to a lesser extent, Site LW06 occurred during stable categories E and F. However, the observations at Site LW05 were insensitive to the stability class -- high values were recorded in all six categories. The modeled concentrations more closely followed the traditional pattern that stable atmosphere's cause the highest pollutant impacts in complex terrain. All five models computed the highest impacts during the most stable (Class F) conditions.

Long-Term Average H_2S Concentrations

Long-term (about 7.5 months) mean H_2S concentrations were computed by each of the five Gaussian models being tested. The mean concentrations computed by the models at the receptor location corresponding to Site LW02 are compared in Table 18 to the observed long-term, arithmetic average obtained from this site. Comparisons are

TABLE 17

SUMMARY OF MODEL PERFORMANCE - HIGHEST OBSERVED PAIRED
WITH THE HIGHEST PREDICTED FOR EACH STABILITY CLASS*

STABILITY CLASS	OBSERVED			MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
	LW02	LW05	LW06					
A	336	20,430	3,614	530	916	521	885	825
B	239	14,320	4,170	602	684	624	619	505
C	281	17,650	3,892	601	628	703	486	614
D	631	19,320	5,877	633	521	1,137	320	682
E	830	12,090	3,475	1,238	3,443	8,828	1,926	1,721
F	506	19,460	9,452	1,420	5,152	15,960	2,075	2,576

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE 18

LONG-TERM H₂S CONCENTRATIONS
PREDICTED AND OBSERVED AT LOGAN WASH--SITE LW02*

MONITOR	PARAMETER	OBSERVED	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
LW02	Long-term Mean Conc.	14.8	12.5	36.6	30.3	21.6	21.1
	(P/O)	--	0.8	2.5	2.0	1.5	1.4
	Sample Size	4,580	5,424	5,424	5,424	5,424	5,424

*H₂S concentrations are expressed as micrograms per cubic meter.

not provided at the other two sites because the minimum detectable concentration at these sites was so high ($1,390 \text{ ug/m}^3$) that such a comparison would be meaningless. In other words, an ambient concentration which approaches the expected long-term mean value (15 ug/m^3 at Site LW02) would be recorded at sites LW05 and LW06 as a zero, hence a reliable long-term mean cannot be computed from these data.

At Site LW02, the models provided concentration estimates that reasonably approximate the measured long-term average. Models 1, 4, and 5 predicted concentrations that are within a factor of two of the observed, with Model 1 slightly underpredicting the measured value, and Models 4 and 5 slightly overpredicting. Models 2 and 3 significantly overpredicted the observed value, with Model 2 (COMPLEX I) providing the worst estimate. Little can be concluded regarding model performance from this comparison, however, since only one data pair is available for each of the models tested.

3.2 DISCUSSION OF RESULTS

The most significant finding of the model performance evaluations presented in this report is that the assumption used by all of the models tested that the simulated plume remains level over downward sloping terrain represents a serious deficiency in complex terrain settings. None of the models could provide concentration estimates that are representative of the values observed at Logan Wash at Site LW05. As explained, this monitoring site was physically located at an elevation of almost 500 feet below the height of the base of the stack. Measurement of non-zero H_2S concentrations at this site implies that the actual plume emitted from the retort stack often experienced a significant downward transport, a situation that the five Gaussian models tested are unable to simulate. The fact that this monitoring site routinely measured the highest H_2S concentrations at Logan Wash further underlines the importance of this model deficiency.

The problem of model simulation posed by monitoring site LW05 is unique in that the other two sites were located at heights above stack base, and should therefore be better represented by the models. For this reason, the performance evaluations must be reviewed by monitor location because conclusions based on the results at site LW05 would not necessarily be applicable at the other two sites. Further, the results vary drastically for different tests making it difficult to provide general conclusions regarding model performance. When the predicted values were used for sorting the data pairs into descending order, the results generally indicate that the models overpredict (except at LW05). From this examination it is observed that the models do a reasonable job of identifying conditions causing non-zero H_2S concentrations to be observed at Logan Wash, if not always replicating the magnitudes of those concentrations. But, when sorting by the observed values, that is, when testing the models ability to identify actual, worst-case conditions causing the highest H_2S levels to be measured, the models consistently underpredicted the values observed. It cannot be concluded from this however that the models underpredict actual H_2S concentrations. It is more appropriate to conclude that the models cannot identify and then adequately simulate the actual, worst-case conditions at this facility.

Another observation that can be made from these results is that the models consistently predict the highest concentrations during stable hours when plume dispersal is minimal. It is interesting to note that the observed concentrations are not nearly as sensitive to atmospheric stability than are the models' predictions. In fact, the measured concentrations from Site LW05 were found to be completely insensitive to stability category. Again the models were not capable of correctly identifying the actual, worst-case conditions which caused the highest impacts to be observed.

Finally it would be appropriate to conclude this section by specifying which of the models tested in this analysis performed the best, and also which of the models provided the worst representation of plume dispersion at Logan Wash. However, the results of these investigations indicate that none of the models performed well, so it is

only possible to separate the model or models that were "poor" from those that are worse.

As mentioned, those tests that involved sorting the data pairs by the observed values indicated that none of the models could adequately identify the observed worst-case conditions. It is therefore not possible to determine significant differences in the performance of each of the models. However, when the model predictions were the basis for ordering the data pairs, Models 1, 4, and 5 (MPTEP, and the two variants of COMPLEX I) often provided concentration estimates within a factor of two of the observed values. Hence the conditions identified by the models as causing measureable ground-level H_2S impacts were often verified by the measurements.

Interestingly the two variants of COMPLEX I frequently outperformed COMPLEX I itself, or more appropriately, the options in COMPLEX I most frequently specified by regulatory agencies. This may be due to the fact that the options required by most regulatory agencies are often those that provide the highest concentration estimates, and not necessarily the best estimates. Indeed, Model 2 (COMPLEX I) predicted consistently higher concentration estimates than either Models 4 or 5. Since the use of less conservative options represented by Models 4 and 5 caused these models to outperform COMPLEX I, a need exists for a re-examination of the options required by current regulatory guidelines.

Finally, the "worst-of-the-worst" of the models evaluated was clearly COMPLEX II. This model consistently predicted higher H_2S concentrations than the other models, and failed to provide representative estimates for any of the tests employed in this report.

4.0 CONCLUSIONS

The primary objective of this study was to assess the validity of the predictions of ambient pollutant concentrations provided by widely used plume dispersion models. The results of the model performance evaluations have been presented in Section 3 of this report. Overall, the models evaluated demonstrate little skill in predicting H_2S concentrations at Logan Wash for the following reasons:

- The models cannot properly simulate impacts on terrain features that have elevations lower than the base of the stack;
- The models are incapable of identifying the conditions which cause the highest H_2S concentrations to be observed at Logan Wash;
- For those conditions when the models correctly identified that ground-level impacts would occur, they usually could not provide estimates of the same magnitude as those observed.

Finally, it must be emphasized that the steady-state assumptions that are implicit in Gaussian models, such as straight-line plume transport, are violated in many cases in complex terrain applications. These models represent average conditions and should not be expected to predict specific one-hour occurrences observed at discrete locations, even in flat terrain environments. Their application in areas characterized as complex terrain, such as Logan Wash, Colorado, provides results that are, at best, of dubious value.

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TABLE I.1

HIGHEST TEN OBSERVED PAIRED WITH THE HIGHEST
PREDICTED H₂S CONCENTRATIONS*

RANK	OBSERVED CONC.	MODEL 1 CONC. (P/O)	MODEL 2 CONC. (P/O)	MODEL 3 CONC. (P/O)	MODEL 4 CONC. (P/O)	MODEL 5 CONC. (P/O)
1	20,430	1,420 (0.1)	5,152 (0.3)	15,960 (0.8)	2,075 (0.1)	2,576 (0.1)
2	19,460	1,386 (0.1)	5,134 (0.3)	15,430 (0.8)	2,059 (0.1)	2,567 (0.1)
3	19,320	1,349 (0.1)	5,073 (0.3)	15,280 (0.8)	2,041 (0.1)	2,537 (0.1)
4	17,790	1,343 (0.1)	4,496 (0.3)	12,400 (0.7)	1,926 (0.1)	2,248 (0.1)
5	17,790	1,338 (0.1)	4,143 (0.2)	10,360 (0.6)	1,894 (0.1)	2,072 (0.1)
6	17,650	1,328 (0.1)	3,712 (0.2)	10,270 (0.6)	1,502 (0.1)	1,856 (0.1)
7	17,380	1,320 (0.1)	3,683 (0.2)	10,090 (0.6)	1,427 (0.1)	1,842 (0.1)
8	15,570	1,317 (0.1)	3,675 (0.2)	9,899 (0.6)	1,426 (0.1)	1,837 (0.1)
9	15,570	1,311 (0.1)	3,443 (0.2)	9,244 (0.6)	1,406 (0.1)	1,745 (0.1)
10	15,430	1,298 (0.1)	3,441 (0.2)	9,043 (0.6)	1,327 (0.1)	1,737 (0.1)

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.2

STATISTICAL SUMMARY OF THE HIGHEST OBSERVED PAIRED
WITH THE HIGHEST PREDICTED H₂S CONCENTRATIONS*

PARAMETER	OBSERVED	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean	11,866	1,107	2,212	5,222	1,064	1,160
(P/O)	--	0.1	0.2	0.4	0.1	0.1
Sample Size	100	100	100	100	100	100
Frequency: (O-P) <0.0	--	0	0	0	0	0
Frequency: (O-P) >0.0	--	100	100	100	100	100
Mean: (O-P)	--	10,759	9,654	6,643	10,802	10,706

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.3

HIGHEST TEN PREDICTED PAIRED WITH THE HIGHEST H₂S
CONCENTRATIONS OBSERVED AT THE SAME TIME*

RANK	MODEL 1			MODEL 2			MODEL 3			MODEL 4			MODEL 5		
	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)
1	1,420	1,251	(1.1)	5,152	973	(5.3)	15,960	1,251	(12.8)	2,075	1,529	(1.4)	2,576	973	(2.7)
2	1,386	1,251	(1.1)	5,134	1,529	(3.4)	15,430	1,529	(10.1)	2,059	973	(2.1)	2,567	1,529	(1.7)
3	1,349	2,641	(0.5)	5,073	1,251	(4.1)	15,280	973	(15.7)	2,041	1,390	(1.5)	2,537	1,251	(2.0)
4	1,343	695	(1.9)	4,496	1,390	(3.2)	12,400	1,390	(8.9)	1,926	556	(3.5)	2,248	1,390	(1.6)
5	1,338	834	(1.6)	4,143	278	(14.9)	10,360	1,112	(9.3)	1,894	1,251	(1.5)	2,072	278	(7.5)
6	1,328	834	(1.6)	3,712	695	(5.3)	10,270	1,112	(9.2)	1,502	973	(1.5)	1,856	695	(2.7)
7	1,320	1,390	(1.0)	3,683	695	(5.3)	10,090	0	(**)	1,427	1,112	(1.3)	1,842	695	(2.7)
8	1,317	2,085	(0.6)	3,675	834	(4.4)	9,899	3,058	(3.2)	1,426	695	(2.1)	1,837	834	(2.2)
9	1,311	417	(3.1)	3,443	556	(6.2)	9,244	1,390	(6.7)	1,406	1,390	(1.0)	1,745	834	(2.1)
10	1,298	2,085	(0.6)	3,441	834	(4.1)	9,043	1,251	(7.2)	1,327	0	(**)	1,737	834	(2.1)

*H₂S concentrations are expressed as micrograms per cubic meter.

** (P/O) ratio greater than 100.

TABLE I.4

STATISTICAL SUMMARY OF THE HIGHEST PREDICTED PAIRED WITH THE
HIGHEST H₂S CONCENTRATIONS OBSERVED AT THE SAME TIME*

PARAMETER	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean (Predicted)	1,107	2,212	5,222	1,064	1,160
Sample Mean (Observed)	1,096	1,041	1,036	1,149	1,080
(P/O)	1.0	2.1	5.0	0.9	1.1
Sample Size	100	100	100	100	100
Frequency: (O-P) < 0.0	49	95	100	49	47
Frequency: (O-P) > 0.0	51	5	0	51	53
Mean: (O-P)	457	1,249	4,187	573	560

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.5

HIGHEST TEN OBSERVED PAIRED WITH THE HIGHEST
H₂S CONCENTRATIONS PREDICTED AT THE SAME TIME*

RANK	OBSERVED CONC.	MODEL 1 CONC. (P/O)	MODEL 2 CONC. (P/O)	MODEL 3 CONC. (P/O)	MODEL 4 CONC. (P/O)	MODEL 5 CONC. (P/O)
1	20,430	12 (0.0)	0 (0.0)	10 (0.0)	0 (0.0)	0 (0.0)
2	19,460	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
3	19,320	31 (0.0)	7 (0.0)	2 (0.0)	13 (0.0)	0 (0.0)
4	17,790	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
5	17,790	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
6	17,650	208 (0.0)	32 (0.0)	40 (0.0)	53 (0.0)	4 (0.0)
7	17,380	16 (0.0)	0 (0.0)	11 (0.0)	0 (0.0)	0 (0.0)
8	15,570	222 (0.0)	384 (0.0)	210 (0.0)	390 (0.0)	364 (0.0)
9	15,570	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
10	15,430	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.6

STATISTICAL SUMMARY OF THE HIGHEST OBSERVED PAIRED WITH
THE HIGHEST H₂S CONCENTRATIONS PREDICTED AT THE SAME TIME*

PARAMETER	OBSERVED	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean	11,866	101	85	76	87	71
(P/O)	--	0.0	0.0	0.0	0.0	0.0
Sample Size	100	100	100	100	100	100
Frequency: (O-P) < 0.0	--	0	0	0	0	0
Frequency: (O-P) > 0.0	--	100	100	100	100	100
Mean: (O-P)	--	11,765	11,781	11,790	11,779	11,795

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.7

HIGHEST TEN OBSERVED PAIRED WITH THE HIGHEST H₂S
CONCENTRATIONS PREDICTED AT SITE LW02*

RANK	OBSERVED CONC.	MODEL 1 CONC. (P/O)	MODEL 2 CONC. (P/O)	MODEL 3 CONC. (P/O)	MODEL 4 CONC. (P/O)	MODEL 5 CONC. (P/O)
1	830	1,221 (1.5)	4,143 (5.0)	10,090 (12.2)	1,135 (1.4)	2,072 (2.5)
2	634	1,110 (1.8)	3,712 (5.9)	9,899 (15.6)	1,115 (1.8)	1,856 (2.9)
3	631	1,043 (1.7)	3,675 (5.8)	7,293 (11.6)	1,105 (1.8)	1,837 (2.9)
4	506	1,005 (2.0)	3,441 (6.8)	5,119 (10.1)	1,102 (2.2)	1,745 (3.4)
5	474	955 (2.0)	3,423 (7.2)	4,837 (10.2)	1,101 (2.3)	1,737 (3.7)
6	443	891 (2.0)	3,358 (7.6)	4,820 (10.9)	1,101 (2.5)	1,679 (3.8)
7	438	889 (2.0)	3,260 (7.4)	3,264 (7.5)	1,098 (2.5)	1,630 (3.7)
8	438	881 (2.0)	2,972 (6.8)	2,611 (6.0)	1,095 (2.5)	1,600 (3.7)
9	438	873 (2.0)	2,715 (6.2)	2,610 (6.0)	1,087 (2.5)	1,423 (3.2)
10	409	848 (2.1)	2,624 (6.4)	2,588 (6.3)	1,085 (2.7)	1,398 (3.4)

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.8

STATISTICAL SUMMARY OF THE HIGHEST OBSERVED PAIRED WITH THE
HIGHEST H₂S CONCENTRATIONS PREDICTED AT SITE LW02*

PARAMETER	OBSERVED	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean	229	474	1,394	1,356	723	757
(P/O)	--	2.1	6.1	5.9	3.2	3.3
Sample Size	100	100	100	100	100	100
Frequency: (O-P) <0.0	--	100	100	100	100	100
Frequency: (O-P) >0.0	--	0	0	0	0	0
Mean: (O-P)	--	245	1,164	1,127	493	528

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.9

HIGHEST TEN OBSERVED PAIRED WITH THE HIGHEST H₂S
CONCENTRATIONS PREDICTED AT SITE LW05*

RANK	OBSERVED CONC.	MODEL 1 CONC. (P/O)	MODEL 2 CONC. (P/O)	MODEL 3 CONC. (P/O)	MODEL 4 CONC. (P/O)	MODEL 5 CONC. (P/O)
1	20,430	256 (0.0)	163 (0.0)	144 (0.0)	192 (0.0)	113 (0.0)
2	19,460	254 (0.0)	163 (0.0)	139 (0.0)	192 (0.0)	99 (0.0)
3	19,320	228 (0.0)	162 (0.0)	133 (0.0)	191 (0.0)	84 (0.0)
4	17,790	219 (0.0)	139 (0.0)	123 (0.0)	163 (0.0)	80 (0.0)
5	17,790	219 (0.0)	135 (0.0)	110 (0.0)	158 (0.0)	79 (0.0)
6	17,650	218 (0.0)	117 (0.0)	109 (0.0)	125 (0.0)	78 (0.0)
7	17,380	215 (0.0)	107 (0.0)	102 (0.0)	118 (0.0)	77 (0.0)
8	15,570	201 (0.0)	102 (0.0)	89 (0.0)	118 (0.0)	77 (0.0)
9	15,570	192 (0.0)	101 (0.0)	86 (0.0)	115 (0.0)	75 (0.0)
10	15,430	190 (0.0)	99 (0.0)	86 (0.0)	114 (0.0)	70 (0.0)

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.10

STATISTICAL SUMMARY OF THE HIGHEST OBSERVED PAIRED WITH THE
HIGHEST H₂S CONCENTRATIONS PREDICTED AT SITE LW05*

PARAMETER	OBSERVED	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean	11,841	131	57	48	68	32
(P/O)	--	0.0	0.0	0.0	0.0	0.0
Sample Size.	100	100	100	100	100	100
Frequency: (O-P) <0.0	--	0	0	0	0	0
Frequency: (O-P) >0.0	--	100	100	100	100	100
Mean: (O-P)	--	11,710	11,784	11,793	11,773	11,809

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.11

HIGHEST TEN OBSERVED PAIRED WITH THE HIGHEST H₂S
CONCENTRATIONS PREDICTED AT SITE LW06*

RANK	OBSERVED CONC.	MODEL 1 CONC. (P/O)	MODEL 2 CONC. (P/O)	MODEL 3 CONC. (P/O)	MODEL 4 CONC. (P/O)	MODEL 5 CONC. (P/O)
1	9,452	1,320 (0.1)	3,066 (0.3)	12,400 (1.3)	2,075 (0.2)	1,283 (0.1)
2	6,533	1,291 (0.2)	3,031 (0.5)	4,760 (0.7)	2,059 (0.3)	1,250 (0.2)
3	5,977	1,208 (0.2)	3,004 (0.5)	4,693 (0.8)	2,041 (0.3)	1,212 (0.2)
4	5,143	1,207 (0.2)	2,495 (0.5)	4,652 (0.9)	1,926 (0.4)	1,201 (0.2)
5	5,004	1,119 (0.2)	1,710 (0.3)	4,639 (0.9)	1,256 (0.3)	751 (0.2)
6	4,865	1,098 (0.2)	1,515 (0.3)	3,750 (0.8)	1,210 (0.2)	630 (0.1)
7	4,309	1,065 (0.2)	1,465 (0.3)	3,283 (0.8)	1,101 (0.3)	481 (0.1)
8	4,170	1,059 (0.3)	1,464 (0.4)	3,208 (0.8)	1,100 (0.3)	441 (0.1)
9	4,170	1,038 (0.2)	1,428 (0.3)	3,159 (0.8)	1,083 (0.3)	403 (0.1)
10	4,031	884 (0.2)	1,318 (0.3)	2,982 (0.7)	1,074 (0.3)	381 (0.1)

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.12

STATISTICAL SUMMARY OF THE HIGHEST OBSERVED PAIRED WITH THE
HIGHEST H₂S CONCENTRATIONS PREDICTED AT SITE LW06*

PARAMETER	OBSERVED	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean	3,076	498	827	1,180	668	218
(P/O)	--	0.2	0.3	0.4	0.2	0.1
Sample Size	100	100	100	100	100	100
Frequency: (O-P) < 0.0	--	0	0	1	0	0
Frequency: (O-P) > 0.0	--	100	100	99	100	100
Mean: (O-P)	--	2,578	2,249	1,955	2,408	2,858

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.13
HIGHEST TEN PREDICTED PAIRED WITH THE H₂S
CONCENTRATIONS OBSERVED AT THE SAME TIME AT SITE LW02*

RANK	MODEL 1			MODEL 2			MODEL 3			MODEL 4			MODEL 5		
	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)
1	1,221	10	(**)	4,143	0	(**)	10,090	17	(**)	1,135	0	(**)	2,072	0	(**)
2	1,110	0	(**)	3,712	0	(**)	9,899	10	(**)	1,115	14	(80.2)	1,856	0	(**)
3	1,043	0	(**)	3,675	11	(**)	7,293	0	(**)	1,105	13	(88.3)	1,837	11	(**)
4	1,005	17	(60.3)	3,441	13	(**)	5,119	57	(90.0)	1,102	0	(**)	1,745	13	(**)
5	955	0	(**)	3,423	0	(**)	4,837	0	(**)	1,101	0	(**)	1,737	0	(**)
6	891	0	(**)	3,358	0	(**)	4,820	0	(**)	1,101	11	(99.0)	1,679	0	(**)
7	889	0	(**)	3,260	0	(**)	3,264	38	(87.0)	1,098	0	(**)	1,630	0	(**)
8	881	57	(15.5)	2,972	14	(**)	2,611	154	(16.9)	1,095	0	(**)	1,600	14	(**)
9	873	4	(**)	2,715	0	(**)	2,610	0	(**)	1,087	0	(**)	1,423	0	(**)
10	848	0	(**)	2,624	21	(**)	2,588	0	(**)	1,085	31	(35.5)	1,398	0	(**)

*H₂S concentrations are expressed as micrograms per cubic meter.
**(P/O) ratio greater than 100.

TABLE I.14
STATISTICAL SUMMARY OF THE HIGHEST PREDICTED PAIRED WITH THE
H₂S CONCENTRATIONS OBSERVED AT THE SAME TIME AT SITE LW02*

PARAMETER	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean (Predicted)	474	1,394	1,356	723	757
Sample Mean (Observed)	16	16	16	16	16
(P/O)	29.8	88.6	83.9	45.9	46.3
Sample Size	100	100	100	100	100
Frequency: (O-P) < 0.0	99	100	100	100	100
Frequency: (O-P) > 0.0	1	0	0	0	0
Mean: (O-P)	460	1,378	1,340	707	741

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.15

HIGHEST TEN PREDICTED PAIRED WITH THE H₂S
CONCENTRATIONS OBSERVED AT THE SAME TIME AT SITE LW05*

RANK	MODEL 1			MODEL 2			MODEL 3			MODEL 4			MODEL 5		
	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)
1	256	4,865	(0.1)	163	0	(**)	144	0	(**)	192	0	(**)	113	0	(**)
2	254	0	(**)	163	0	(**)	139	0	(**)	192	0	(**)	99	0	(**)
3	228	0	(**)	162	0	(**)	133	0	(**)	191	0	(**)	84	0	(**)
4	219	0	(**)	139	0	(**)	123	0	(**)	163	0	(**)	80	0	(**)
5	219	0	(**)	135	0	(**)	110	0	(**)	158	0	(**)	79	0	(**)
6	218	0	(**)	117	2,363	(0.1)	109	0	(**)	125	0	(**)	78	0	(**)
7	215	0	(**)	107	0	(**)	102	0	(**)	118	2,363	(0.0)	77	0	(**)
8	201	0	(**)	102	0	(**)	89	2,363	(0.0)	118	0	(**)	77	0	(**)
9	192	0	(**)	101	0	(**)	86	0	(**)	115	0	(**)	75	0	(**)
10	190	0	(**)	99	3,058	(0.0)	86	2,085	(0.0)	114	3,058	(0.0)	70	0	(**)

*H₂S concentrations are expressed as micrograms per cubic meter.

** (P/O) ratio greater than 100.

TABLE I.16

STATISTICAL SUMMARY OF THE HIGHEST PREDICTED PAIRED WITH THE
H₂S CONCENTRATIONS OBSERVED AT THE SAME TIME AT SITE LW05*

PARAMETER	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean (Predicted)	131	57	48	68	32
Sample Mean (Observed)	1,318	1,351	1,326	1,347	1,380
(P/O)	0.1	0.0	0.0	0.1	0.0
Sample Size	100	100	100	100	100
Frequency: (O-P) < 0.0	36	44	45	45	44
Frequency: (O-P) > 0.0	64	56	55	55	56
Mean: (O-P)	1,272	1,343	1,323	1,336	1,378

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.17

HIGHEST TEN PREDICTED PAIRED WITH THE H₂S
CONCENTRATIONS OBSERVED AT THE SAME TIME AT SITE LW06*

RANK	MODEL 1			MODEL 2			MODEL 3			MODEL 4			MODEL 5		
	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)	PRED.	OBS.	(P/O)
1	1,320	1,390	(1.0)	3,066	1,529	(2.0)	12,400	1,390	(8.9)	2,075	1,529	(1.4)	1,283	0	(**)
2	1,291	0	(**)	3,031	0	(**)	4,760	0	(**)	2,059	0	(**)	1,250	1,529	(0.8)
3	1,208	1,390	(0.9)	3,004	1,390	(2.2)	4,693	1,390	(3.3)	2,041	1,390	(1.5)	1,212	0	(**)
4	1,207	0	(**)	2,495	0	(**)	4,652	0	(**)	1,926	0	(**)	1,201	1,390	(0.9)
5	1,119	0	(**)	1,710	0	(**)	4,639	0	(**)	1,256	0	(**)	751	0	(**)
6	1,098	0	(**)	1,515	0	(**)	3,750	0	(**)	1,210	0	(**)	630	0	(**)
7	1,065	0	(**)	1,465	0	(**)	3,283	0	(**)	1,101	0	(**)	481	1,390	(0.4)
8	1,059	0	(**)	1,464	0	(**)	3,208	0	(**)	1,100	0	(**)	441	0	(**)
9	1,038	0	(**)	1,428	1,946	(0.7)	3,159	0	(**)	1,083	1,946	(0.6)	403	0	(**)
10	884	0	(**)	1,318	0	(**)	2,982	0	(**)	1,074	0	(**)	381	0	(**)

*H₂S concentrations are expressed as micrograms per cubic meter.

** (P/O) ratio greater than 100.

TABLE I.18

STATISTICAL SUMMARY OF THE HIGHEST PREDICTED PAIRED WITH THE
H₂S CONCENTRATIONS OBSERVED AT THE SAME TIME AT SITE LW06*

PARAMETER	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean (Predicted)	498	827	1,180	668	218
Sample Mean (Observed)	435	553	464	557	681
(P/O)	1.1	1.5	2.5	1.2	0.3
Sample Size	100	100	100	100	100
Frequency: (O-P) < 0.0	62	61	72	58	34
Frequency: (O-P) > 0.0	38	39	28	42	66
Mean: (O-P)	436	650	1,006	570	618

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.19

HIGHEST TEN OBSERVED PAIRED WITH THE H₂S CONCENTRATIONS
PREDICTED AT THE SAME TIME AT SITE LW02*

RANK	OBSERVED CONC.	MODEL 1 CONC. (P/O)	MODEL 2 CONC. (P/O)	MODEL 3 CONC. (P/O)	MODEL 4 CONC. (P/O)	MODEL 5 CONC. (P/O)
1	830	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2	634	0 (0.0)	0 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)
3	631	0 (0.0)	0 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)
4	506	429 (0.9)	1,360 (2.7)	2,358 (4.7)	786 (1.6)	800 (1.6)
5	474	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
6	443	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
7	438	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
8	438	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
9	438	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
10	409	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.20

STATISTICAL SUMMARY OF THE HIGHEST OBSERVED PAIRED WITH
THE H₂S CONCENTRATIONS PREDICTED AT THE SAME TIME AT SITE LW02*

PARAMETER	OBSERVED	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean	229	18	39	57	26	23
(P/O)	--	0.1	0.2	0.3	0.1	0.1
Sample Size	100	100	100	100	100	100
Frequency: (O-P) < 0.0	--	2	4	3	4	4
Frequency: (O-P) > 0.0	--	98	96	97	96	96
Mean: (O-P)	--	228	242	264	230	228

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.21

HIGHEST TEN OBSERVED PAIRED WITH THE H₂S CONCENTRATIONS
PREDICTED AT THE SAME TIME AT SITE LW05*

RANK	OBSERVED CONC.	MODEL 1 CONC. (P/O)	MODEL 2 CONC. (P/O)	MODEL 3 CONC. (P/O)	MODEL 4 CONC. (P/O)	MODEL 5 CONC. (P/O)
1	20,430	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2	19,460	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
3	19,320	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
4	17,790	0 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
5	17,790	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
6	17,650	148 (0.0)	32 (0.0)	40 (0.0)	53 (0.0)	4 (0.0)
7	17,380	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
8	15,570	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
9	15,570	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
10	15,430	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.22

STATISTICAL SUMMARY OF THE HIGHEST OBSERVED PAIRED WITH
THE H₂S CONCENTRATIONS PREDICTED AT THE SAME TIME AT SITE LW05*

PARAMETER	OBSERVED	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean	11,841	4	1	2	2	1
(P/O)	--	0.0	0.0	0.0	0.0	0.0
Sample Size	100	100	100	100	100	100
Frequency: (O-P) < 0.0	--	0	0	0	0	0
Frequency: (O-P) > 0.0	--	100	100	100	100	100
Mean: (O-P)	--	11,837	11,840	11,839	11,839	11,840

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.23

HIGHEST TEN OBSERVED PAIRED WITH THE H₂S CONCENTRATIONS
PREDICTED AT THE SAME TIME AT SITE LW06*

RANK	OBSERVED CONC.	MODEL 1 CONC. (P/O)	MODEL 2 CONC. (P/O)	MODEL 3 CONC. (P/O)	MODEL 4 CONC. (P/O)	MODEL 5 CONC. (P/O)
1	9,452	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2	6,533	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
3	5,977	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
4	5,143	132 (0.0)	82 (0.0)	142 (0.0)	71 (0.0)	17 (0.0)
5	5,004	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
6	4,865	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
7	4,309	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
8	4,170	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
9	4,170	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
10	4,031	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.24

STATISTICAL SUMMARY OF THE HIGHEST OBSERVED PAIRED WITH
THE H₂S CONCENTRATIONS PREDICTED AT THE SAME TIME AT SITE LW06*

PARAMETER	OBSERVED	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean	3,076	5	11	5	9	2
(P/O)	--	0.0	0.0	0.0	0.0	0.0
Sample Size	100	100	100	100	100	100
Frequency: (O-P) < 0.0	--	0	0	0	0	0
Frequency: (O-P) > 0.0	--	100	100	100	100	100
Mean: (O-P)	--	3,071	3,065	3,071	3,067	3,074

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.23

HIGHEST TEN OBSERVED PAIRED WITH THE H₂S CONCENTRATIONS
PREDICTED AT THE SAME TIME AT SITE LW06*

RANK	OBSERVED CONC.	MODEL 1 CONC. (P/O)	MODEL 2 CONC. (P/O)	MODEL 3 CONC. (P/O)	MODEL 4 CONC. (P/O)	MODEL 5 CONC. (P/O)
1	9,452	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2	6,533	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
3	5,977	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
4	5,143	132 (0.0)	82 (0.0)	142 (0.0)	71 (0.0)	17 (0.0)
5	5,004	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
6	4,865	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
7	4,309	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
8	4,170	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
9	4,170	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
10	4,031	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.24

STATISTICAL SUMMARY OF THE HIGHEST OBSERVED PAIRED WITH
THE H₂S CONCENTRATIONS PREDICTED AT THE SAME TIME AT SITE LW06*

PARAMETER	OBSERVED	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Sample Mean	3,076	5	11	5	9	2
(P/O)	--	0.0	0.0	0.0	0.0	0.0
Sample Size	100	100	100	100	100	100
Frequency: (O-P) < 0.0	--	0	0	0	0	0
Frequency: (O-P) > 0.0	--	100	100	100	100	100
Mean: (O-P)	--	3,071	3,065	3,071	3,067	3,074

*H₂S concentrations are expressed as micrograms per cubic meter.

TABLE I.25 - HIGHEST TEN OBSERVED AT EACH MONITOR
LOCATION PAIRED WITH THE HIGHEST H₂S
CONCENTRATIONS PREDICTED FOR EACH
STABILITY CLASS*

STAB CLASS	RANK	OBSERVED	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
		SITE 2	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)
		5		(P/O ₅)		(P/O ₅)		(P/O ₅)		(P/O ₅)		(P/O ₅)
		6		(P/O ₆)		(P/O ₆)		(P/O ₆)		(P/O ₆)		(P/O ₆)
A	1	336	530	(1.6)	916	(2.7)	521	(1.6)	885	(2.6)	825	(2.5)
		20,430		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		3,614		(0.1)		(0.3)		(0.1)		(0.2)		(0.2)
A	2	318	526	(1.7)	916	(2.9)	484	(1.5)	885	(2.8)	824	(2.6)
		17,790		(0.0)		(0.1)		(0.0)		(0.0)		(0.0)
		3,336		(0.2)		(0.3)		(0.1)		(0.3)		(0.2)
A	3	274	522	(1.9)	895	(3.3)	476	(1.7)	869	(3.2)	814	(3.0)
		17,380		(0.0)		(0.1)		(0.0)		(0.0)		(0.0)
		3,197		(0.2)		(0.3)		(0.1)		(0.3)		(0.3)
A	4	252	521	(2.1)	833	(3.3)	469	(1.9)	811	(3.2)	761	(3.0)
		15,570		(0.0)		(0.1)		(0.0)		(0.1)		(0.0)
		2,780		(0.2)		(0.3)		(0.2)		(0.3)		(0.3)
A	5	127	512	(4.0)	771	(6.1)	455	(3.6)	792	(6.2)	703	(5.5)
		14,180		(0.0)		(0.1)		(0.0)		(0.1)		(0.0)
		2,780		(0.2)		(0.3)		(0.2)		(0.3)		(0.3)
A	6	114	506	(4.4)	747	(6.6)	442	(3.9)	765	(6.7)	687	(6.0)
		13,210		(0.0)		(0.1)		(0.0)		(0.1)		(0.1)
		2,641		(0.2)		(0.3)		(0.2)		(0.3)		(0.3)
A	7	110	503	(4.6)	739	(6.7)	438	(4.0)	761	(6.9)	671	(6.1)
		12,650		(0.0)		(0.1)		(0.0)		(0.1)		(0.1)
		2,641		(0.2)		(0.3)		(0.2)		(0.3)		(0.3)
A	8	99	476	(4.8)	719	(7.3)	437	(4.4)	736	(7.4)	670	(6.8)
		12,510		(0.0)		(0.1)		(0.0)		(0.1)		(0.1)
		2,641		(0.2)		(0.3)		(0.2)		(0.3)		(0.3)
A	9	93	465	(5.0)	719	(7.7)	431	(4.6)	733	(7.9)	660	(7.1)
		12,370		(0.0)		(0.1)		(0.0)		(0.1)		(0.1)
		2,641		(0.2)		(0.3)		(0.2)		(0.3)		(0.2)
A	10	75	460	(6.1)	690	(9.2)	428	(5.7)	708	(9.4)	631	(8.4)
		11,950		(0.0)		(0.1)		(0.0)		(0.1)		(0.1)
		2,502		(0.2)		(0.3)		(0.2)		(0.3)		(0.3)

(continued)

TABLE I.25 - (continued)

STAB CLASS	RANK	OBSERVED	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
		SITE 2	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)
		5		(P/O ₅)		(P/O ₅)		(P/O ₅)		(P/O ₅)		(P/O ₅)
		6		(P/O ₆)		(P/O ₆)		(P/O ₆)		(P/O ₆)		(P/O ₆)
B	1	239	602	(2.5)	684	(2.9)	624	(2.6)	619	(2.6)	505	(2.1)
		14,320		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		4,170		(0.1)		(0.2)		(0.1)		(0.1)		(0.1)
B	2	225	532	(2.4)	641	(2.8)	548	(2.4)	579	(2.6)	498	(2.2)
		14,180		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		3,753		(0.1)		(0.2)		(0.1)		(0.2)		(0.1)
B	3	184	523	(2.8)	608	(3.3)	540	(2.9)	564	(3.1)	483	(2.6)
		13,760		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		3,753		(0.1)		(0.2)		(0.1)		(0.2)		(0.1)
B	4	174	521	(3.0)	588	(3.4)	539	(3.1)	542	(3.1)	475	(2.7)
		13,480		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		3,197		(0.2)		(0.2)		(0.2)		(0.2)		(0.1)
B	5	157	486	(3.1)	561	(3.6)	486	(3.1)	516	(3.3)	454	(2.9)
		13,340		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,780		(0.2)		(0.2)		(0.2)		(0.2)		(0.2)
B	6	146	482	(3.3)	556	(3.8)	482	(3.3)	512	(3.5)	447	(3.1)
		13,210		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,780		(0.2)		(0.2)		(0.2)		(0.2)		(0.2)
B	7	145	479	(3.3)	554	(3.8)	479	(3.3)	510	(3.5)	421	(2.9)
		13,210		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,780		(0.2)		(0.2)		(0.2)		(0.2)		(0.2)
B	8	135	468	(3.5)	545	(4.0)	473	(3.5)	505	(3.7)	418	(3.1)
		12,930		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,780		(0.2)		(0.2)		(0.2)		(0.2)		(0.2)
B	9	125	459	(3.7)	541	(4.3)	446	(3.6)	493	(3.9)	414	(3.3)
		12,650		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,641		(0.2)		(0.2)		(0.2)		(0.2)		(0.2)
B	10	121	446	(3.7)	512	(4.2)	443	(3.7)	469	(3.9)	413	(3.4)
		11,950		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,641		(0.2)		(0.2)		(0.2)		(0.2)		(0.2)

(continued)

TABLE I.25 - (continued)

STAB CLASS	RANK	OBSERVED	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
		SITE 2	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)
		5		(P/O ₅)		(P/O ₅)		(P/O ₅)		(P/O ₅)		(P/O ₅)
		6		(P/O ₆)		(P/O ₆)		(P/O ₆)		(P/O ₆)		(P/O ₆)
C	1	281	601	(2.1)	628	(2.2)	703	(2.5)	486	(1.7)	614	(2.2)
		17,650		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		3,892		(0.2)		(0.2)		(0.2)		(0.1)		(0.2)
C	2	254	584	(2.3)	531	(2.1)	636	(2.5)	434	(1.7)	470	(1.9)
		15,290		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		3,058		(0.2)		(0.2)		(0.2)		(0.1)		(0.2)
C	3	215	561	(2.6)	483	(2.2)	629	(2.9)	410	(1.9)	407	(1.9)
		14,180		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,641		(0.2)		(0.2)		(0.2)		(0.2)		(0.2)
C	4	204	548	(2.7)	476	(2.3)	604	(3.0)	399	(2.0)	400	(2.0)
		14,040		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,363		(0.2)		(0.2)		(0.3)		(0.2)		(0.2)
C	5	168	546	(3.3)	473	(2.8)	601	(3.6)	390	(2.3)	349	(2.1)
		13,620		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,224		(0.2)		(0.2)		(0.3)		(0.2)		(0.2)
C	6	140	537	(3.8)	456	(3.3)	600	(4.3)	386	(2.8)	340	(2.4)
		13,070		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,224		(0.2)		(0.2)		(0.3)		(0.2)		(0.2)
C	7	124	513	(4.1)	445	(3.6)	582	(4.7)	370	(3.0)	324	(2.6)
		12,790		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,085		(0.2)		(0.2)		(0.3)		(0.2)		(0.2)
C	8	118	506	(4.3)	438	(3.7)	574	(4.9)	362	(3.1)	324	(2.7)
		12,650		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,085		(0.2)		(0.2)		(0.3)		(0.2)		(0.2)
C	9	103	478	(4.6)	435	(4.2)	535	(5.2)	358	(3.5)	323	(3.1)
		12,650		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,085		(0.2)		(0.2)		(0.3)		(0.2)		(0.2)
C	10	100	477	(4.8)	414	(4.1)	506	(5.1)	351	(3.5)	316	(3.2)
		12,230		(0.0)		(0.0)		(0.0)		(0.0)		(0.0)
		2,085		(0.2)		(0.2)		(0.2)		(0.2)		(0.2)

(continued)

TABLE I.25 - (continued)

STAB	CLASS	RANK	OBSERVED	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
			SITE	2	PRED (P/O ₂)	PRED (P/O ₂)	(P/O ₂)	PRED (P/O ₂)	(P/O ₂)	PRED (P/O ₂)	(P/O ₂)	PRED (P/O ₂)	(P/O ₂)
			5		(P/O ₅)	(P/O ₅)	(P/O ₅)	(P/O ₅)	(P/O ₅)	(P/O ₅)	(P/O ₅)	(P/O ₅)	(P/O ₅)
			6		(P/O ₆)	(P/O ₆)	(P/O ₆)	(P/O ₆)	(P/O ₆)	(P/O ₆)	(P/O ₆)	(P/O ₆)	(P/O ₆)
D		1	631	633	(1.0)	521	(0.8)	1,137	(1.8)	320	(0.5)	682	(1.1)
			19,320		(0.0)		(0.0)		(0.1)		(0.0)		(0.0)
			5,977		(0.1)		(0.1)		(0.2)		(0.1)		(0.1)
D		2	474	624	(1.3)	514	(1.1)	1,064	(2.2)	307	(0.6)	642	(1.4)
			13,480		(0.0)		(0.0)		(0.1)		(0.0)		(0.0)
			5,143		(0.1)		(0.1)		(0.2)		(0.1)		(0.1)
D		3	443	608	(1.4)	503	(1.1)	1,025	(2.3)	304	(0.7)	637	(1.4)
			13,210		(0.0)		(0.0)		(0.1)		(0.0)		(0.0)
			5,004		(0.1)		(0.1)		(0.2)		(0.1)		(0.1)
D		4	328	600	(1.8)	500	(1.5)	1,021	(3.1)	303	(0.9)	635	(1.9)
			12,790		(0.0)		(0.0)		(0.1)		(0.0)		(0.0)
			4,865		(0.1)		(0.1)		(0.2)		(0.1)		(0.1)
D		5	323	593	(1.8)	499	(1.5)	1,016	(3.1)	299	(0.9)	634	(2.0)
			12,650		(0.0)		(0.0)		(0.1)		(0.0)		(0.1)
			4,031		(0.1)		(0.1)		(0.3)		(0.1)		(0.2)
D		6	303	590	(1.9)	492	(1.6)	1,012	(3.3)	298	(1.0)	631	(2.1)
			12,650		(0.0)		(0.0)		(0.1)		(0.0)		(0.0)
			3,892		(0.2)		(0.1)		(0.3)		(0.1)		(0.2)
D		7	289	579	(2.0)	480	(1.7)	973	(3.4)	298	(1.0)	621	(2.1)
			11,820		(0.0)		(0.0)		(0.1)		(0.0)		(0.1)
			3,892		(0.1)		(0.1)		(0.3)		(0.1)		(0.2)
D		8	259	573	(2.2)	479	(1.8)	868	(3.4)	297	(1.1)	620	(2.4)
			11,680		(0.0)		(0.0)		(0.1)		(0.0)		(0.1)
			3,753		(0.2)		(0.1)		(0.2)		(0.1)		(0.2)
D		9	259	573	(2.2)	473	(1.8)	813	(3.1)	295	(1.1)	618	(2.4)
			11,680		(0.0)		(0.0)		(0.1)		(0.0)		(0.1)
			3,475		(0.2)		(0.1)		(0.2)		(0.1)		(0.2)
D		10	236	571	(2.4)	468	(2.0)	812	(3.4)	294	(1.2)	617	(2.6)
			10,840		(0.1)		(0.0)		(0.1)		(0.0)		(0.1)
			3,336		(0.2)		(0.1)		(0.2)		(0.1)		(0.2)

(continued)

TABLE I.25 - (continued)

STAB CLASS	RANK	OBSERVED	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
		SITE 2	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)
		5		(P/O ₅)		(P/O ₅)		(P/O ₅)		(P/O ₅)		(P/O ₅)
		6		(P/O ₆)		(P/O ₆)		(P/O ₆)		(P/O ₆)		(P/O ₆)
E	1	830	1,238	(1.5)	3,443	(4.1)	8,828	(10.6)	1,926	(2.3)	1,721	(2.1)
		12,090		(0.1)		(0.3)		(0.7)		(0.2)		(0.1)
		3,475		(0.4)		(1.0)		(2.5)		(0.6)		(0.5)
E	2	634	1,224	(1.9)	3,118	(4.9)	6,176	(9.7)	1,502	(2.4)	1,559	(2.5)
		6,394		(0.2)		(0.5)		(1.0)		(0.2)		(0.2)
		3,197		(0.4)		(1.0)		(1.9)		(0.5)		(0.5)
E	3	438	1,205	(2.8)	2,971	(6.8)	5,353	(12.2)	1,426	(3.3)	1,486	(3.4)
		4,031		(0.3)		(0.7)		(1.3)		(0.4)		(0.4)
		3,058		(0.4)		(1.0)		(1.8)		(0.5)		(0.5)
E	4	438	1,165	(2.7)	2,614	(6.0)	5,119	(11.7)	1,210	(2.8)	1,307	(3.0)
		3,614		(0.3)		(0.7)		(1.4)		(0.3)		(0.4)
		2,919		(0.4)		(0.9)		(1.8)		(0.4)		(0.4)
E	5	381	1,144	(3.0)	2,395	(6.2)	5,024	(13.2)	1,127	(3.0)	1,197	(3.1)
		3,336		(0.3)		(0.7)		(1.5)		(0.3)		(0.4)
		2,780		(0.4)		(0.9)		(1.8)		(0.4)		(0.4)
E	6	378	1,106	(2.9)	2,256	(6.0)	4,646	(12.3)	1,116	(3.0)	1,128	(3.0)
		3,058		(0.4)		(0.7)		(1.5)		(0.4)		(0.4)
		2,641		(0.4)		(0.9)		(1.8)		(0.4)		(0.4)
E	7	359	1,094	(3.0)	2,229	(6.2)	4,484	(12.5)	1,074	(3.0)	1,114	(3.1)
		3,058		(0.4)		(0.7)		(1.5)		(0.4)		(0.4)
		2,641		(0.4)		(0.8)		(1.7)		(0.4)		(0.4)
E	8	313	1,068	(3.4)	2,220	(7.1)	4,430	(14.2)	1,069	(3.4)	1,110	(3.5)
		2,919		(0.4)		(0.8)		(1.5)		(0.4)		(0.4)
		2,641		(0.4)		(0.8)		(1.7)		(0.4)		(0.4)
E	9	291	1,050	(3.6)	2,102	(7.2)	4,177	(14.4)	1,067	(3.7)	1,051	(3.6)
		2,919		(0.4)		(0.7)		(1.4)		(0.4)		(0.4)
		2,502		(0.4)		(0.8)		(1.7)		(0.4)		(0.4)
E	10	288	1,049	(3.6)	1,956	(6.8)	3,964	(13.8)	1,060	(3.7)	978	(3.4)
		2,919		(0.4)		(0.7)		(1.4)		(0.4)		(0.3)
		2,502		(0.4)		(0.8)		(1.6)		(0.4)		(0.4)

(continued)

TABLE 1.25 - (continued)

STAB CLASS	RANK	OBSERVED	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
		SITE 2	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)	PRED	(P/O ₂)
		5		(P/O ₅)		(P/O ₅)		(P/O ₅)		(P/O ₅)		(P/O ₅)
		6		(P/O ₆)		(P/O ₆)		(P/O ₆)		(P/O ₆)		(P/O ₆)
F	1	506	1,420	(2.8)	5,152	(10.2)	15,960	(31.5)	2,075	(4.1)	2,576	(5.1)
		19,460		(0.1)		(0.3)		(0.8)		(0.1)		(0.1)
		9,452		(0.2)		(0.5)		(1.7)		(0.2)		(0.3)
F	2	438	1,386	(3.2)	5,134	(11.7)	15,430	(35.2)	2,059	(4.7)	2,567	(5.9)
		17,790		(0.1)		(0.3)		(0.9)		(0.1)		(0.1)
		6,533		(0.2)		(0.8)		(2.4)		(0.3)		(0.4)
F	3	409	1,349	(3.3)	5,073	(12.4)	15,280	(37.4)	2,041	(5.0)	2,537	(6.2)
		15,570		(0.1)		(0.3)		(1.0)		(0.1)		(0.2)
		4,309		(0.3)		(1.2)		(3.5)		(0.5)		(0.6)
F	4	242	1,343	(5.5)	4,496	(18.6)	12,400	(51.2)	1,894	(7.8)	2,248	(9.3)
		15,430		(0.1)		(0.3)		(0.8)		(0.1)		(0.1)
		4,170		(0.3)		(1.1)		(3.0)		(0.5)		(0.5)
F	5	165	1,338	(8.1)	4,143	(25.1)	10,360	(62.8)	1,427	(8.6)	2,072	(12.6)
		14,460		(0.1)		(0.3)		(0.7)		(0.1)		(0.1)
		4,031		(0.3)		(1.0)		(2.6)		(0.4)		(0.5)
F	6	147	1,328	(9.0)	3,712	(25.3)	10,270	(69.9)	1,406	(9.6)	1,856	(12.6)
		13,900		(0.1)		(0.3)		(0.7)		(0.1)		(0.1)
		3,753		(0.4)		(1.0)		(2.7)		(0.4)		(0.5)
F	7	104	1,320	(12.7)	3,683	(35.4)	10,090	(97.0)	1,327	(12.8)	1,842	(17.7)
		13,070		(0.1)		(0.3)		(0.8)		(0.1)		(0.1)
		3,614		(0.4)		(1.0)		(2.8)		(0.4)		(0.5)
F	8	76	1,317	(17.3)	3,675	(48.4)	9,899	(**)	1,304	(17.2)	1,837	(24.2)
		12,930		(0.1)		(0.3)		(0.8)		(0.1)		(0.1)
		3,197		(0.4)		(1.1)		(3.1)		(0.4)		(0.6)
F	9	70	1,311	(18.7)	3,441	(49.2)	9,244	(**)	1,277	(18.2)	1,745	(24.9)
		12,090		(0.1)		(0.3)		(0.8)		(0.1)		(0.1)
		3,197		(0.4)		(1.1)		(2.9)		(0.4)		(0.5)
F	10	68	1,298	(19.1)	3,423	(50.3)	9,043	(**)	1,269	(18.7)	1,737	(25.5)
		11,680		(0.1)		(0.3)		(0.8)		(0.1)		(0.1)
		3,197		(0.4)		(1.1)		(2.8)		(0.4)		(0.5)

*H₂S concentrations expressed as micrograms per cubic meter.

** (P/O) ratio greater than 100.

APPENDIX G
GRAPHS ILLUSTRATING THE AVERAGE MONTHLY MOVEMENT
FOR MINE STABILITY INSTRUMENTATION

Appendix G-1. Mine Stability History - Surface REX - Well LW 156

Appendix G-2. Mine Stability History - Surface REX - Well LW 157

Appendix G-3. Mine Stability History - Surface REX - Well LW 159

Appendix G-3a. Mine Stability History - Surface REX - Well LW 159

Appendix G-4. Mine Stability History - Surface REX - Well LW 160

477

Relative Position (inches)

1.10
1.00
0.90
0.80

LW 161

#1 not installed
#2 @ 200' from collar
#3 @ 300' from collar
#4 @ 400' from collar
#5 @ 535' from collar
#6 @ 745' from collar

#6

#2

#5

#4

#3

head destroyed 6-26-80,
lost all anchors

APR MAY JUN JUL AUG SEP
1980

Appendix G-6. Mine Stability History - Surface REX - Well LW 162

Appendix G-7. Mine Stability History - Upper Level REX - RM 1

Appendix G-8. Mine Stability History - Upper Level REX - RM 3

Appendix G-9. Mine Stability History - Upper Level REX RM 4

Appendix G-11. Mine Stability History - Upper Level IRAD - RM 5

Appendix G-11a. Mine Stability History - Upper Level IRAD Thermistor - RM 5

Appendix G-12. Mine Stability History - Upper Level IRAD - RM 15

Appendix G-12a. Mine Stability History - Upper Level IRAD Thermistor - RM 15

Appendix G-13. Mine Stability History - Upper Level IRAD - RM 16

Appendix G-14. Mine Stability History - Intermediate Level REX - RM 7

Appendix G-15. Mine Stability History - Intermediate Level REX - RM 9

Appendix G-16. Mine Stability History - Intermediate Level REX - RM 12

Appendix G-17. Mine Stability History - Intermediate Level IRAD - RM 8

Appendix G-17a. Mine Stability History - Intermediate Level IRAD Thermistor - RM 8

Appendix G-18. Mine Stability History - Intermediate Level IRAD - RM 11

Appendix G-18a. Mine Stability History - Intermediate Level IRAD Thermistor - RM 11

Appendix G-19. Mine Stability History - Intermediate Level IRAD - RM 17

Appendix G-19a. Mine Stability History - Intermediate Level IRAD Thermistor - RM 17

LIST OF PHASE II PROGRESS REPORTS AVAILABLE
THROUGH THE DEPARTMENT OF ENERGY, TECHNICAL
INFORMATION CENTER

PHASE II REPORT

1st Quarterly	<u>Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale, Phase II, Quarterly Progress Report for the Period June 1, 1979 through August 31, 1979 (October 1979).</u>
2nd Quarterly	<u>Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale, Phase II, Quarterly Progress Report for the Period September 1, 1979 through November 30, 1979 (December 1979).</u>
3rd Quarterly	<u>Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale, Phase II, Quarterly Progress Report for the Period December 1, 1979 through February 29, 1980 (March 1980).</u>
1st Annual	<u>Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale, Phase II, Annual Progress Report for the Period June 1, 1979 through May 31, 1980 (August 1980).</u>
4th Quarterly	<u>Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale, Phase II, Quarterly Progress Report for the Period June 1, 1980 through August 31, 1980 (September 1980).</u>
5th Quarterly	<u>Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale, Phase II, Quarterly Progress Report for the Period September 1, 1980 through November 30, 1980 (January 1981).</u>
6th Quarterly	<u>Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale, Phase II, Quarterly Progress Report for the Period December 1, 1980 through February 28, 1981 (May 1981).</u>
2nd Annual	<u>Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale, Phase II, Annual Progress Report for the Period June 1, 1980 through May 31, 1981 (November 1981).</u>
Final Report	<u>Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale, Phase II, Final Report for the Period June 1, 1979 through August 31, 1981 (March 1982).</u>

ENVIRONMENTAL REPORTS

<u>Classification</u>	<u>Report</u>	<u>DOE Source</u>
Biology	1. West, N. E. and Irvine, J. R., <u>Appendix H to An Ecological Baseline Study of Flora, Vegetation and Soils on the Occidental Oil Shale, Inc. Logan Wash Site Near De Beque, Colorado, Vegetation Data and Analysis for September 1979, Occidental Oil Shale, Inc., Grand Junction, CO (November 1979).</u>	2nd Quarterly
	2. Wirtz, W. O., <u>Small Mammal Populations in Colorado Oil Shale Country, 60th Annual Meeting, American Society of Mammalogists, University of Rhode Island, Providence, RI (June 8-12, 1980).</u>	1st Annual
	3. West, N. E. and Irvine, J. R., <u>Appendix I to An Ecological Baseline Study of Flora, Vegetation and Soils on the Occidental Oil Shale, Inc. Logan Wash Site Near De Beque, Colorado, Vegetation Data and Analysis for September 1980, (prepared for Occidental Oil Shale, Inc., Grand Junction, CO) (November 1980).</u>	5th Quarterly
	4. Wirtz, W. O., and Brown, J. S., <u>Vertebrate Populations at the Occidental Oil Shale, Inc. Logan Wash Site, Summer 1980, (prepared for Occidental Oil Shale, Inc., Grand Junction, CO) (November 1980).</u>	5th Quarterly
Hydrology and Water Resources	5. Coors Labs Water Quality Analysis, Coors/Spectro-Chemical Laboratory, Golden, CO (prepared for Occidental Oil Shale, Inc., Grand Junction, CO) (September and October 1979).	2nd Quarterly
	6. <u>Logan Wash Tract Water Analysis January 1, 1980 through February 15, 1980, Alluvial Wells, Surface Sites, Bedrock Wells, Mine Water, and Process Water, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	3rd Quarterly
	7. Stover, C. S. and Rogers, D., <u>Results of Logan Wash Water Quality Monitoring Program for Retort 6, Occidental Oil Shale, Inc., Grand Junction, CO (March 10, 1980).</u>	1st Annual

<u>Classification</u>	<u>Report</u>	<u>DOE Source</u>
Hydrology and Water Resources (continued)	8. <u>Logan Wash Tract Water Analysis, March 13, 1980 through May 8, 1980, Surface Sites, Alluvial Wells, Bedrock Wells, Mine Water, and Process Water, Occidental Oil Shale, Inc., Grand Junction, CO (June 9, 1980).</u>	1st Annual
	9. <u>Air Quality and Water Quality Data, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	4th Quarterly
	10. <u>Site Water Analysis, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	4th Quarterly
Meteorology, Air Quality, and Gaseous Emissions	11. <u>Air Quality and Water Quality Data, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	4th Quarterly
Permit Status	12. <u>Logan Wash Permit Status Compiled February 29, 1980, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	3rd Quarterly
	13. <u>Logan Wash Permit Status, Compiled August 7, 1980, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	4th Quarterly
	14. <u>Logan Wash Permit Status Compiled February 9, 1981, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	6th Quarterly
General	15. <u>Environmental Data - May, June and July 1979, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	1st Quarterly
	16. <u>Environmental Data - August, September and October 1979, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	2nd Quarterly
	17. <u>Environmental Data - November and December 1979, and January 1980, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	3rd Quarterly
	18. <u>Environmental Data Analysis, Occidental Oil Shale, Inc., Grand Junction, CO (1979 - 1980).</u>	1st Annual
	19. <u>Environmental Data - Data Not Previously Reported in Quarterly Reports, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	5th Quarterly

<u>Classification</u>	<u>Report</u>	<u>DOE Source</u>
General (continued)	20. <u>Environmental Data, Occidental Oil Shale, Inc., Grand Junction, CO (1980).</u>	6th Quarterly
	21. <u>Environmental Data, Occidental Oil Shale, Inc., Grand Junction, CO (1980 - 1981).</u>	2nd Annual
	22. <u>Retorts 7 and 8 Monitoring Programs, Occidental Oil Shale, Inc., Grand Junction, CO (1981).</u>	2nd Annual

MARKETING REPORTS

1.	<u>Engineering Program for Market Evaluations Including Upgrading and Logistics, Occidental Oil Shale, Inc., Grand Junction, CO.</u>	4th Quarterly
2.	<u>Pipeline Transportation of Shale Oil, Phase I: State-of-the-Art Literature Search, Williams Brothers Engineering Company, Resource Sciences Center, Tulsa, OK (prepared for Occidental Oil Shale, Inc., Grand Junction, CO) (September 30, 1980).</u>	5th Quarterly
3.	<u>Pipeline Transportation of Shale Oil, Phase II: Shale Oil Rheology, Phase III: Pipeline Conceptual Design, Williams Brothers Engineering Company, Resource Sciences Center, Tulsa, OK (prepared for Occidental Oil Shale, Inc., Grand Junction, CO) (February 1981).</u>	2nd Annual
4.	<u>Overview of Shale Oil Development and Utilization, The Pace Company Consultants & Engineers, Inc., Houston, TX (prepared for Occidental Oil Shale, Inc.) (November 1980).</u>	2nd Annual

MINE STABILITY REPORTS

1.	<u>F. G. Horino, USBM Mine Stability Correspondence, May 1977 through May 1979, Mine Structure Design, Denver Mining Research Center (written to I. G. Studebaker, Occidental Oil Shale, Inc., Grand Junction, CO).</u>	4th Quarterly
2.	<u>F. G. Horino, D. R. Dolimar, D. L. Bickel, Mechanical Properties In Situ Stress and Temperature Measurements - Logan Wash Oil Shale Site, Denver Research Center, U.S. Department of the Interior, Denver, CO, Progress Report 10025 (1981).</u>	2nd Annual

	<u>DOE Source</u>
3. <u>Retorts 7 and 8 Mine Stability Data, Occidental Oil Shale, Inc., Grand Junction, CO (1980).</u>	2nd Annual
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MINI-RETORT DATA

MR-4 Start-up Data	6th Quarterly
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RETORTS 7 AND 8 DATA

Core Analysis

Core Analysis (Core Hole LW-156)	5th Quarterly
BuMines RI 7357, <u>Appendix B, Lithologic Descriptions</u>	5th Quarterly
Core Analysis	6th Quarterly

Instrumentation

G. P. Gruber, et al., <u>DOE/Cooperative Agreement Phase II Instrumentation Plan, Occidental Oil Shale, Inc., Grand Junction, CO (1980).</u>	4th Quarterly
Sampling and Analyses Program	6th Quarterly
Thermocouple and Sample Tap Plan	6th Quarterly

APPENDIX I

REFERENCES

N.E. Hester, Effects of Modified In Situ Retorting on Groundwaters, in 16th Oil Shale Symposium Proceedings, Golden, CO (April 1983).

N.E. Hester and C.L. Jacobson, Utilization of Residual Heat in Spent Modified In Situ Retorts for Wastewater Treatment and Process Improvements, in 16th Oil Shale Symposium Proceedings, Golden, CO (April 1983).

P.J. Hommert, Instrumentation and Data Analysis From Occidental Retorts MR-3 and MR-4, in 15th Oil Shale Symposium Proceedings, Golden, Co (April 1982).

T.E. Ricketts, Rubblization of Occidental's Retorts 6 and 7, in 16th Oil Shale Symposium Proceedings, Golden, CO (April 1983).

J.E. Shen and R.L. Zahradnik, Start-up of Modified in Situ Retorts, in 17th Intersociety Energy Engineering Conference Proceedings, Los Angeles, CA (August 1982).

A.L. Stevens and R.L. Zahradnik, Results From the Simultaneous Processing of Modified In Situ Retorts 7 and 8, in 16th Oil Shale Symposium Proceedings, Golden, CO (April 1983).