OKLAHOMA ENERGY RESOURCES BOARD

Quarterly Technical Progress Report

Project Title: ENVIRONMENTAL ASSESSMENT OF OKLAHOMA ABANDONED DRILLING AND PRODUCTION SITES AND ASSOCIATED PUBLIC EDUCATION/OUTREACH ACTIVITIES

Grant Number: DE-FG22-95MT95006

Institution: Oklahoma Energy Resources Board (OERB)

Report Date: January 29, 1996

Grant Start Date: February 8, 1995

Anticipated Completion Date: February 7, 1996

Government Award: $200,000

Program Manager: Mike Terry, OERB Executive Director

Principal Investigator(s): Mike Terry, OERB Executive Director

Contracting Officer's Representative (COR): Mike Terry, OERB Executive Director

Reporting Period: October - December 1995

2. **Provide a comprehensive public education/outreach program to increase public awareness of the importance of the Oklahoma oil (and gas) industry.**

Task 2 Public Education/Outreach Program

Task 2.1 Conduct baseline research
Task 2.2 Develop a Project Plan to implement a comprehensive public education/ outreach program, including project milestones, objectives, methods, and budgeting, and a plan on how to convey to producers and interest owners the benefits of supporting the OERB and its efforts.
Task 2.3 Implement a comprehensive public education/outreach program, including creation and production of multimedia public education/outreach products, and public education/outreach program evaluation.

SUMMARY OF TECHNICAL PROGRESS

Task 1 Environmental Assessment of Abandoned Oil and Gas Drilling and Production Sites and Environmental Technology Transfer

Task 1.1 Develop Environmental Site Remediation/Restoration Prioritization Scheme.

The initial remediation/restoration prioritization scheme was developed as discussed in the first Quarterly Technical Progress Report.

Further refinement of this process has continued during the course of the project. The final Environmental Site Remediation/Restoration Prioritization Scheme, along with the revised sample report form, is included as Attachment #1.

Task 1.2 Perform Phase I Environmental Site Assessments (ESA).

The program to date includes a total of 206 projects as submitted by the Oklahoma Corporation Commission (OCC) to the OERB. These projects are located in 35 counties and include 328 sites that will require individual attention.

The total number of projects to date includes 20 new projects submitted in October, 23 submitted in November, and 20 submitted in December. Phase I ESA's will be conducted on each of these projects. In the fourth quarter 41 Phase I ESAs were completed, making a total of 166 Phase I ESA's completed to date.

ENVIRONMENTAL ASSESSMENT OF OKLAHOMA ABANDONED DRILLING AND PRODUCTION SITES AND ASSOCIATED PUBLIC EDUCATION/OUTREACH ACTIVITIES

Quarterly Technical Progress Report
October-December 1995

Oklahoma oil producers and royalty owners are taking part in the nation's first oil industry funded environmental cleanup and education program. The program is administered by the Oklahoma Energy Resources Board (OERB), a state agency which was created by the Oklahoma Independent Energy Education and Marketing Act. The OERB is an unpaid 21 member board composed of independent producers, major oil company personnel, crude oil purchasing company representatives, and a royalty owner representative. The OERB administrates an assessment of two cents per barrel on all oil produced and sold in the state; the expenditure of these funds is divided between the program's two primary objectives.

OBJECTIVES

The purpose of this project will be accomplished through two primary objectives:

1. **Conduct environmental assessment of abandoned oil and gas drilling and production sites where no responsible owner can be found and transfer environmental technology to oil and gas operators.**

Task 1 Environmental Assessment of Abandoned Oil and Gas Drilling and Production Sites and Environmental Technology Transfer

- Task 1.1 Develop Environmental Site Remediation/Restoration Prioritization Scheme.
- Task 1.2 Perform Phase I Environmental Site Assessments (ESA).
- Task 1.3 Perform Phase II Environmental Site Assessments (ESA).
- Task 1.4 Characterize Technologies for Environmental Remediation and Restoration.
- Task 1.5 Environmental Technology Transfer.

Task 1.3 Perform Phase II Environmental Site Assessments (ESA).

To date there have been 99 Phase II sites completed. The work conducted through the Phase I and Phase II ESA's has facilitated the complete restoration of 71 sites by OERB. There are currently 15 projects in various stages of Phase II ESA. A number of additional sites are in the process of being reviewed.

A review of the restored sites completed by OERB indicate that the average site cleanup includes data acquisition, a physical site visit, environmental evaluation, some soil sampling and other laboratory evaluations, remediation of contaminated soils, removal of old equipment, tubulars and concrete, soil amendments, contouring, planting and fertilization. Ultimately the impacted lands will be returned to usable condition, through the restoration of grasslands and agricultural fields and pond building.

Cost analysis reveals the average cost to date inclusive of all environmental assessment and reclamation services has been approximately $6,500.00 per site.

Task 1.4 Characterize Technologies for Environmental Remediation and Restoration.

The evaluation of environmental technologies has continued during the environmental remediation and restoration processes. The Environmental Remediation and Restoration Technology Characterization Summary Report is included with this report as Attachment #2.

Task 1.5 Environmental Technology Transfer.

In the fourth quarter Mike Terry and Phil Spurlin have made a number of presentations on the activities and the progress of the OERB project to both industry groups and the general public. A workshop entitled "Proven Cost Effective Methods for Remediating Oil Field Pollution" was presented at the OIPA's fall conference in Oklahoma City on October 31, 1995. An abstract of the material presented is as follows:

Based on field experience gained from restoring over 50 abandoned sites, a practical approach has been developed in cleaning up locations. Environmental issues include petroleum based hydrocarbons in soil, barren areas, erosion, pits, and proper disposal of abandoned equipment.

Projects meeting certain criteria are selected by the Oklahoma Corporation Commission for inclusion in the Oklahoma Energy Resources Board environmental restoration program. Each site is evaluated using a number of tools, including data research, physical inspection, priority ranking, and sampling for contamination levels and agronomy parameters. Geophysical evaluation is used when site conditions and past operations dictate. Results from soil and water sampling for analytical testing of specific parameters assist in remediation design. Agronomy analysis of select samples provides critical data in fertility and productivity restoration of native soil.

Petroleum based hydrocarbons and chlorides in soils are the two most prevalent contaminants encountered in oilfield operations. A number of available technologies have been investigated for both issues. Land farming and in-situ bioremediation of hydrocarbons and dilution of chlorides with proper soil amendments have proven cost effective in the restoration of oilfield sites.

Task 2 Public Education/Outreach Program

Task 2.1 Conduct baseline research

In the first quarter of this project, pre-post research methodology was developed and a pre-campaign survey of the general public conducted. In the second quarter, a pre-campaign survey for the school systems was developed and conducted. This survey was utilized to measure the attitudes of teachers towards energy education and the oil industry.

Task 2.2 Develop a Project Plan to implement a comprehensive public education/outreach program, including project milestones, objectives, methods, and budgeting, and a plan on how to convey to producers and interest owners the benefits of supporting the OERB and its efforts.

After the conclusion and evaluation of the phone and focus group surveys results from the general population, a comprehensive education and public outreach plan was developed which is now being implemented. This Public Education/Outreach Project Plan follows this report as Attachment #3.

Task 2.3 Implement a comprehensive public education/outreach program, including creation and production of multimedia public education/outreach products, and public education/outreach program evaluation.

Public education and outreach efforts are continuing with both television and newspaper ads running throughout the state. Production was completed on all four new television commercials featuring OERB Spokeswoman Susan Howard. Extensive airtime was purchased for these commercials during the Christmas-New Years' weeks in the Oklahoma City, Tulsa, Lawton, and Ada markets. The messages contained in these commercials were discussed in the third Quarterly Technical Progress Report.

The OERB had a booth at the National Association of Royalty Owners (NARO) Annual Meeting, as well as the OIPA Fall conference, both held in Oklahoma City during October. At each meeting, Susan Howard addressed attendees and the new commercials were previewed. In addition, the NARO presented the OERB with an award for outstanding service on education and energy issues.

During November, the IPAA National Convention was held in San Diego, where Lew Ward, of Ward Petroleum, Enid, Oklahoma, was installed as Chairman. He presented to the membership a video featuring Susan Howard introducing a proposal to create a national checkoff program using the OERB as a model. Later in the month, the OERB had a booth at the Governor's Water Conference, displaying information about the environmental program and its progress. OERB Executive Director Mike Terry and Communication Director Rebecca Tallent have given progress reports at OIPA meetings in Oklahoma City, Tulsa, Bartlesville, Ardmore, Seminole, Woodward, Stillwater, and Okmulgee. In Ardmore, Mike Terry made a presentation to a combined meeting of the API and the Desk and Derrick Club .

OERB's public education and outreach contractor, Ackerman-McQueen (AM), began development of the new "Oilfield Safety Video". Funded by Koch Industries, Inc., with input from the OERB and the OIPA, this video deals with the prevention of oilfield related accidents. The video project has received the support of Oklahoma SAFE KIDS Coalition and Oklahoma Corporation Commissioner Ed Apple. The OERB has approached the Lieutenant Governor's office, the State Department of Education and other officials concerning assistance in the promotion and distribution of the video.

In addition to commercials, significant positive exposure through the news media has

resulted from an intensive public relations effort by the OERB staff. Meetings have been held with news directors and talk show producers from the television and larger radio stations throughout the state. The OERB has been the focus of local television news reports in Oklahoma City and Lawton, as well as the student station at the University of Central Oklahoma, Edmond. A general story pitch was made to the major market television and radio stations for the holiday season. Rebecca Tallent participated in a 30 minute talk show on the Sac and Fox Tribe's radio network which aired Christmas week. The Oklahoma Educational Television Authority (OETA) has combined an interview of OERB Board Member Harlan Krumme with a segment on the cleanup of the Roxana Field.

In newspapers: the *Oklahoma Gazette* ran cover story on the OERB; articles on the possible addition of natural gas assessment appeared in *The Daily Oklahoman,* the *Tulsa World, The Journal Record* and the Associated Press (AP); and the news of Lew Ward's advancement in the IPAA included information on the OERB in stories by *The Oil Daily, Platt's Oilgram News, The Daily Oklahoman* and the AP. Other newspaper stories included: a two-part interview of OERB Board Member Bill Dost by the *Okmulgee Times*; OCC Field inspector awards in their respective local newspapers; and educational volunteer training in the *Pryor Times.* Three television stations and three newspapers ran stories on the on-gong cleanup of the Roxana sites. A four-part series was mailed to 52 state newspapers (dailies and weeklies) about the OERB and the petroleum industry, with each article customized to each newspaper.

Educational outreach efforts in the school systems are expanding. The Oklahoma Historical Society has requested that the OERB assist in developing curriculum on the oil and gas industry to be included in Oklahoma history books.

As detailed in the third Quarterly Technical Progress Report, the ***Petro Pros*** ("Petroleum Professionals") program of industry volunteers continues to grow. More than 70 OIPA members have answered the call from the OERB and have signed on to give presentations in the classrooms. Training sessions have been held in Tulsa, Oklahoma City, Enid and Ardmore, with area coordinators located in each of these cities, plus Woodward and Duncan. Resource kits filled with maps and experiments have been developed to assist the volunteers and to enhance the learning experience for the students. Through November, 45 presentations have been make to 1,190 students in 19 different schools, with an additional 45 presentations scheduled. Response from the students has been very rewarding for the ***Petro Pros*** volunteers.

The OERB staff attended the Oklahoma Science Teachers Association's annual meeting where information about ***Fueling Around*** and ***Petro Pros*** programs was provided to approximately 200 teachers. A demonstration of a ***Fueling Around*** experiment was conducted by teacher leaders. The ***Fueling Around*** energy curriculum, sponsored by the OERB, has had early success with 121 eighth grade science teachers to date trained in this scientifically oriented hands-ons program that consists of constructive oil and gas experiments, not just experiments about oil pollution. Teacher response to this newly introduced program has been positive, and training classes have been filled, causing late enrollees to be switched to subse quent sessions. More training sessions will be added in the spring. Due to the successes of these programs the OERB is exploring the possibility of expanding into the grade school level and into private schools.

"Environmental Site Remediation/Restoration Prioritization Scheme"

The "Environmental Site Remediation/Restoration Prioritization Scheme" was originally developed as a logical method to rank sites when multiple sites have to be evaluated for restoration based on potential environmental impact. Based on a number of documents, the prioritization scheme, or ranking worksheet, takes into account three areas of concern. Physical site characterization, visual site profile, and contamination profile were broken down into sub-categories in order to effectively characterize the overall site components. The following review describes each component of the three major categories utilized in the "Environmental Site Remediation/Restoration Prioritization Scheme"

SITE CHARACTERIZATION: The Site Characterization category includes twelve sub-categories that effectively define the physical nature of the site. All information is available from state departments and federal agencies as free literature or at a nominal cost. The sub-categories are as follow.

ANNUAL PRECIPITATION - The annual precipitation is broken down into five divisions based on rainfall amounts and is ranked in ascending order as to potential impact on the site. Minimum score for the least rainfall (<10") is "1". Maximum score for the most rainfall (>40") is "5".

SOIL TYPE - The soil type (native soil series) associated with each site is necessary to determine the impact of rainfall on the site. The native soil name is required in the form as information only and does not have a numeric value assigned to it.

RELATIVE PERMEABILITY - The soil relative permeability gives an indication of rainfall infiltration and is separated into three divisions for ranking purposes. They are based on common descriptions typically found in United States Department of Agriculture county soil surveys. Minimum score for slow permeability is "0". Maximum score for rapid permeability is "5".

SLOPE - The soil slope gives an indication of amount of rainfall run-off over the site and is also separated into three divisions for ranking purposes. Minimum score for flat to gently sloping surfaces (0 to 3% slopes) is "0". Maximum score for moderately to steeply sloping (> 5% slopes) is "5".

HYDROLOGICALLY SENSITIVE GEOLOGICAL UNIT - The hydrologically sensitive geologic unit is determined by the presence of surface geology comprised of terraces and alluvium deposits and is either not a sensitive area (no) scored at "0" or is sensitive (yes) scored at "5".

MAJOR AQUIFER RECHARGE AREA - The underlying geologic rocks may be classified as a major aquifer recharge area if the subsurface rocks provide water to any type of well for any purpose. If the area is not a major aquifer recharge area, it is scored at a minimum of "0"; if the area is a major aquifer recharge area, then it is scored at a maximum of "5".

DISTANCE TO SURFACE WATER - The distance to surface water is broken down into five divisions based on proximity to the site and is ranked in descending order as to potential impact from any contamination which may be present on the site. Minimum score for the farthest away (> 1,000') is "1". Maximum score for the closet to the site (< 100') is "5".

DEPTH TO GROUND WATER - The depth to ground water is broken down into five divisions based on increments of 25 feet to 50 feet, with deeper ground water (> 200') having a minimum score of "1" and shallow ground water (< 25') or alluvium/terrace deposits having a maximum score of "5".

DISTANCE TO NEAREST WATER SUPPLY WELL - The distance to the nearest water supply well is of importance due to possible contamination from any potential constituents on site being transported to a conduit into aquifers. The ranking is divided into four divisions, with the farthest away (>5,280') ranked as "1" and the nearest to the site (< 600') ranked at "5".

REGIONAL GROUND WATER QUALITY - The regional ground water quality is based on total dissolved solids (TDS) expressed in parts per million (ppm) which may be impacted by possible site contamination following conduits into the aquifer and is broken into three divisions for ranking purposes. The greater the TDS (> 1,000 ppm) requires the minimum ranking score of "0". The lesser the TDS (< or equal to 500 ppm) requires the maximum score of "5".

WETLANDS - Wetlands are determined by the presence of surface water, certain soil types, and a particular flora/fauna as defined by the United States Department of the Interior, Fish and Wildlife Division. The site is either not in a wetlands area (no) scored at "0" or is in a wetlands area (yes) scored at "5".

FLOODPLAIN - Floodplains as determined by the Federal Emergency Management Administration are broken into three divisions based on previous surveys and public records. Minimum score for areas outside the 500 year floodplain is "0". Maximum score for areas inside the 100 year floodplain is "5".

SITE PROFILE - The Site Profile category includes three sub-categories that describe the visual nature of the site and document any land owner complaints. Information is available from state departments, federal agencies, public records, and may also require a physical site visit and land owner interview. The sub-categories are as follow.

POPULATION TYPE - The population type determines potentially effected human receptors and is broken into three divisions. Minimum score for rural agricultural areas is "0". Maximum score for urban residential areas is "5".

PUBLIC VISIBILITY - The public visibility is determined by proximity to roads and road classification. Minimum score for low public visibility (located off all roads) is "0". Maximum score for high public visibility (located on or near paved roads) is "5".

LAND OWNER COMPLAINT - Land owner complaints may impact critical project timing and are an issue due to land owner emotions and sensitivity to any activity on site. Minimum score for no complaints is "0". Maximum score for any complaints is "5".

CONTAMINANT PROFILE - The Contaminant Profile category includes four sub-categories that describe the nature of any visual contaminant issues and allows weighting for multiple chemical constituents associated with oil field operations. Information is based on a physical site visit and a minimal gamma emission survey for worker health protection. The sub-categories are as follow.

VISUAL CONTAMINANT TYPE - The visual contaminant type is based on the field site review and includes six parameters for describing the presence of typical drilling and production wastes associated with historical oil field operations. Minimum score for no visual contamination is "0". Maximum score for any suspect hazardous materials is "5". This sub-category may have multiple scores associated with the presence of more than one contaminant type which may be on site. If there are multiple contaminants presence, total maximum score is "15".

PRELIMINARY RADON INDICATOR - The Preliminary Radon Indicator (Field Measurements for Naturally Occurring Radioactive Materials, NORM) is a pro-active activity performed for worker protection from radon emissions resulting from excessively high levels of NORM which may be present and are generally found in oil field scales as the radioisotope radium. Background readings are taken in micro-roentgens as baseline data; site readings are then taken. The highest site reading is then used. Site NORM readings are broken down into six divisions for scoring. Minimum score for the lowest site reading that is < background up to background is "0". Maximum score for any site reading > 1000 micro-roentgens is "5".

SITE STATUS - The Site Status is determined by possible contaminant point sources and whether those point sources are inactive or active. Site status is broken down into three divisions for scoring. Minimum score for an abandoned point source (no visible impact) is "0". Maximum score for an active point source (open pits, actives lines, etc.) is "5". In the event inactive and active point sources both appear to have a visible impact, the total maximum score for this sub-category is "8".

RISK STATUS - The Risk Status is determined by the actual physical site visit, data research, interviews with state regulators and the land owner. The Risk Status sub-category is intended as either no apparent potential impact, scored at a minimum of "0", or as apparent potential impact to the environment, scored at a maximum of "15".

Based on the above scoring system, the maximum score a site may receive is "113". Once a number of sites have been ranked, they can then be prioritized for restoration activity.

It should be noted that there are components that require some consideration for restoration activities once sites have been prioritized. Personnel availability, weather, site accessibility, applicable state and federal laws, permitting, and restoration budget can influence timing once

the ranking has been completed.

OKLAHOMA ENERGY RESOURCES BOARD

ABANDONED SITE PRELIMINARY RANKING WORKSHEET	
SITE NAME:	**PROJ No:**
LOC:	
COUNTY:	**STATE:**
COMMENTS:	

SITE-SPECIFIC FACTORS	RANKING SCALE	FINAL RANKING SCORE
SITE CHARACTERIZATION		
Annual Precipitation		
<10"	1	
11" to 20"	2	
21" to 30"	3	
31" to 40"	4	
>40"	5	
Soil Type		
Native Soil Name:		
Relative Permeability		
Slow permeability	0	
Moderate permeability	3	
Rapid permeability	5	
Slope		
Flat to Gently Sloping (0 to 3 % Slopes)	0	
Gently to Moderately Sloping (4 to 5 % Slopes)	3	
Moderately to Steeply Sloping (> 5 % Slopes)	5	
Hydrologically Sensitive Geological Unit		
No	0	
Yes	5	
Major Aquifer Recharge Area		
No	0	
Yes	5	
Distance to Surface Water		
>1000'	1	
301' to 1000'	2	
201' to 300'	3	
100' to 200'	4	
<100'	5	

form:SITERNK4.WQ2

SITE NAME:		
SITE CHARACTERIZATION		
Depth to Ground Water		
>200'	1	
101' to 200'	2	
51' to 100'	3	
25' to 50'	4	
<25' or alluvium/terrace deposits	5	
Distance to Nearest Water Supply Well		
>5280'	0	
1321' to 5280'	1	
660' to 1320'	3	
<660'	5	
Regional Ground Water Quality		
>1000 TDS - ppm	0	
501 to 1000 TDS - ppm	3	
< or = 500 TDS - ppm	5	
Wetlands		
No	0	
Yes	5	
Floodplain		
Outside 500 Year Floodplain	0	
Between 100 and 500 Year Floodplains	3	
Inside 100 Year Floodplain	5	
SITE PROFILE		
Population Type		
Rural agricultural	0	
Rural residential	3	
Urban residential	5	
Public Visibility		
Low (located off all roads)	0	
Moderate (located on or near dirt roads)	3	
High (located on or near paved roads)	5	
Landowner Complaint		
No	0	
Yes	5	

form:SITERNK4.WQ2

SITE NAME:		
CONTAMINATION PROFILE		
Visual Contaminant Type		
No Visual Contaminant	0	
Drilling Mud/Cuttings	1	
Crude Oil	2	
Salt Water	3	
Refined Product or Unknown Material	4	
Suspect Hazardous Materials	5	
Preliminary RADON Indicator		
Field Measurement - NORM Background Reading:		
< Background to Background	0	
> Background but < 25	1	
25 to 50	2	
51 to 250	3	
251 to 1000	4	
> 1000	5	
Site Status		
Abandoned Point Source (no visible impact)	0	
Abandoned Point Source (visible impact)	3	
Active Point Source (open pits, active lines, etc.)	5	
Risk Status		
No Apparent Potential Impact	0	
Apparent Potential Impact to the Environment	15	
	TOTAL SCORE	
SUMMARY:		

ATTACH NECESSARY SUPPORT DOCUMENTATION

form:SITERNK4.WQ2

"Environmental Remediation and Restoration Technology Characterization Summary"

The "Environmental Remediation and Restoration Technology Characterization Summary" will review technology options for Petroleum Based Hydrocarbon and Chloride remediation for restoration in soils only. Due to the nature and scope of the Oklahoma Energy Resources Board's program and the fact that all sites typically have historical surface issues to deal with, ground water issues have not been addressed as of this date. The two principal issues will be addressed separately.

PETROLEUM BASED HYDROCARBONS - Petroleum based hydrocarbons present on historical oil field operational sites typically are highly weathered. Soil sampling and analytical testing confirm lighter hydrocarbon chains, or "ends" have volatilized through the years and generally do not pose any issues. The heavier hydrocarbon present are usually found as matted hydrocarbon masses principally due to the presence of asphaltenes and paraffins. Depth of soil infiltration is determined by soil type, slope, hydrocarbon volume, and the nature of the point source over several years. Line and surface vessel leaks, drips, and drops is a primary point source. Spillage from produced hydrocarbon trucking or pipeline operations is another point source. Occasional pipeline breaks or surface vessel failure, as well as produced hydrocarbon pits provides larger point source volumes often associated with single occurrence events. Restoration procedures vary according to volume of impacted soils and are summarized below.

DIG AND HAUL - Dig and haul is a method involving the digging, removal, and replacement of impacted soil. Costs include excavation expenses, trucking charges, disposal in an appropriately permitted landfill, and trucking and backfilling with clean soil. Liability remains with the impacted soil. Overall costs and remaining liability are primary considerations of this technology. It is not a viable option for the majority of abandoned oil field operational sites generally associated with exploration and production.

SOIL WASHING - Soil washing is a method involving the digging, removal, and washing of impacted soil. Costs include excavation expenses, equipment mobilization and set-up at the site, washing charges, and backfilling with the washed soil. Liability remains with the resulting wash water. Generally, the volume that may require disposal in an appropriately permitted landfill or disposal well is reduced. Overall costs and remaining liability are primary considerations of this technology. It is not a viable option for the majority of abandoned oil field operational sites generally associated with exploration and production.

INCINERATION - Incineration is a method involving the digging, removal, and incineration of impacted soil. The volume of impacted soil may dictate whether an incineration plant can be set up on site or if impacted soil have to be trucked to an incineration operation. Costs include excavation expenses, equipment mobilization and set-up at the site, possible trucking charges, and backfilling with clean soil. Liability remains with the resulting ash. Generally, the volume that may require disposal in an appropriately permitted landfill or disposal well is greatly reduced. Overall costs is a primary considerations of this technology; remaining liability is a minor consideration. This technology is not a viable option for the majority of abandoned oil field operational

sites generally associated with exploration and production.

ENCAPSULATION - Encapsulation involves mixing a chemical or compound that will encapsulate the hydrocarbons in place and typically involves removing impacted soil in layers of approximately 18 inches for effective encapsulation treatment. Soil impacted to greater depths is generally treated in layers and requires sufficient area to spread out the soil. Costs include chemical expenses, excavation, mixing, and replacement. Leaching may pose additional challenges to proper encapsulation. Natural remediation attenuation may be slowed. Overall costs is a primary considerations of this technology; remaining liability is a minor consideration. This technology is not a viable option for the majority of abandoned oil field operational sites generally associated with exploration and production.

OFF-SITE/ON-SITE SOIL FARMING - Off-site/on-site soil farming involves working the impacted soil to enhance the environment for naturally occurring microbes associated with bioremediation. Both soil farming off-site versus on-site require excavation, soil mixing, and possible chemical and/or microbe amendments. Permitting may be required based on site specific parameters. Costs include chemical and/or microbe expenses, excavation, mixing, and replacement. There will be additional costs associated with trucking for off-site remediation. Overall costs is a minimal consideration of this technology; liability is generally removed due to the bioremediation process and gradual degradation of hydrocarbons. This technology is a viable option and is generally an accepted means of site restoration for the majority of abandoned oil field operational sites associated with exploration and production.

IN-SITU BIOREMEDIATION - In-situ bioremediation involves working the impacted soil in place to enhance the environment for naturally occurring microbes associated with bioremediation. The process requires soil mixing, and possible chemical and/or microbe amendments. Costs include chemical and/or microbe expenses and soil mixing. Overall costs is a minimal consideration of this technology; liability is generally removed due to the bioremediation process and gradual degradation of hydrocarbons. This technology is a viable option and is generally an accepted means of site restoration for many abandoned oil field operational sites associated with exploration and production.

CHLORIDES - Chlorides present on historical oil field operational sites typically are generally found on the surface and dispersed several feet into the soil and underlying bedrock. Soil sampling and analytical testing confirm both sodium and chloride to be present as issues to be dealt with. In the central part on the United States, due to typical soil series, sodium generally does not pose an issue. Produced formation water salts can usually be found as crystals or as a salt crust on the soil surface. Depth of soil infiltration is determined by soil type, slope, produced water volume, and the nature of the point source over several years. Line and surface vessel leaks, drips, and drops is a primary point source. Spillage from produced water trucking or pipeline operations is another point source. Occasional pipeline breaks or surface vessel failure, as well as produced water pits provides larger point source volumes often associated with single occurrence events. Restoration procedures vary according to volume of impacted soils and are summarized below.

DIG AND HAUL - Dig and haul is a method involving the digging, removal, and replacement of impacted soil. Costs include excavation expenses, trucking charges, disposal in an appropriately permitted landfill, and trucking and backfilling with clean soil. Potential leaching and further contamination remains with the impacted soil. Overall costs and remaining liability are primary considerations of this technology. It is not a viable option for the majority of abandoned oil field operational sites generally associated with exploration and production.

SOIL WASHING - Soil washing is a method involving the digging, removal, and washing of impacted soil. Costs include excavation expenses, equipment mobilization and set-up at the site, washing charges, and backfilling with the washed soil. Liability remains with the resulting wash water. Generally, the volume that may require disposal in an appropriately permitted landfill or disposal well is reduced. Overall costs and remaining liability are primary considerations of this technology. It is not a viable option for the majority of abandoned oil field operational sites generally associated with exploration and production.

DILUTION - Dilution typically involves addition of clean soil in sufficient quantities to effectively lower chloride concentrations. Costs include clean soil acquisition, equipment mobilization and trucking, and final placement of the diluted soil. Minimal liability remains with the resulting mixed soil. Generally, the volume that may require disposal in an appropriately permitted landfill is reduced. Overall costs and the resulting soil volume are primary considerations of this technology. It is not a viable option for the majority of abandoned oil field operational sites generally associated with exploration and production.

BURIAL - Burial is a procedure for minimal quantities of chloride impacted soil and requires excavation and sufficient clean soil cover. The primary limiting factor is depth to ground water. Due to overburden pressure associated with the soil, chlorides tend to migrate downward into deeper soil and bedrock. The costs typically include dirt moving for dam construction and possible chemical costs as soil amendments. This technology is not a viable option as an accepted means of site restoration for many abandoned oil field operational sites associated with exploration and production.

OFF-SITE/ON-SITE TREATMENT - Off-site/on-site soil farming involves working the impacted soil with proper amendments to enhance soil conditions in order to flush chlorides out of the soil. Both soil farming off-site versus on-site require excavation, soil mixing, and chemical amendments. Permitting may be required based on site specific parameters. Costs include chemical expenses, excavation, mixing, and replacement. There will be additional costs associated with trucking for off-site remediation. Overall costs is a minimal consideration of this technology; liability is generally removed due to the soil process and gradual reduction of chlorides. This technology is a viable option and is generally an accepted means of site restoration for the majority of abandoned oil field operational sites associated with exploration and production

IN-SITU RECLAMATION - In-situ reclamation involves working the impacted soil in place to enhance soil conditions similar to on-site treatment. The process requires soil mixing, and possible chemical and/or microbe amendments. Costs include chemical expenses and soil mixing. Overall costs is a minimal consideration of this technology; liability is generally removed due to the soil restoration process and gradual dilution of chlorides. This technology is a viable option and is generally an accepted means of site restoration for many abandoned oil field operational sites associated with exploration and production.

POND BUILDING - Pond building is a viable option when chloride concentrations are so great as to render soil reclamation uneconomic. The primary limiting factor is depth to ground water. Due to overburden pressure associated with additional soil in the dam and the hydraulic gradient associated with the pond water itself, chlorides tend to migrate downward into soil and bedrock. The costs typically include dirt moving for dam construction and minimal chemical costs as soil amendments. This technology is a viable option and is generally an accepted means of site restoration for many abandoned oil field operational sites associated with exploration and production.

The above environmental remediation and restoration technology characterization summary includes technologies most commonly associated with soil restoration when economics are a primary consideration. These technologies are often used in various combinations as specific site conditions, regulatory specifications, and land owner requirements dictate.