DOE/EA-1482

ENVIRONMENTAL ASSESSMENT

PILOT EXPERIMENT FOR GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE IN SALINE AQUIFER BRINE FORMATIONS

FRIO FORMATION, LIBERTY COUNTY, TEXAS

OCTOBER 2003

U.S. DEPARTMENT OF ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

National Environmental Policy Act (NEPA) Compliance
Cover Sheet

Proposed Action:
The U.S. Department of Energy (DOE) proposes to provide funds for a field test of the geological sequestration of carbon dioxide (CO_2). The Bureau of Economic Geology (BEG) at The University of Texas at Austin, under contract with DOE, has studied the potential for sequestration of CO_2 in geologic formations of the United States as part of a broader series of DOE-sponsored research projects to investigate potentially practical, affordable methods to control the buildup of CO_2, a greenhouse gas, in the atmosphere. As an outcome of the work by BEG, brine formations of the upper Texas Gulf coast have been identified as possessing excellent potential for geological sequestration. While CO_2 injection is commonly used to enhance the production from some oil fields, to research technology for geological sequestration of CO_2, BEG has proposed a controlled experiment to inject a limited quantity of CO_2 into a brine formation of the South Liberty oil field in Liberty County, Texas, and to closely monitor and model the subsurface disposition of the injected CO_2. If approved, DOE would provide approximately $2.5 million for the pilot experiment.

Type of Statement: Environmental Assessment (EA)

Lead Agency: U.S. Department of Energy; National Energy Technology Laboratory (NETL)

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Abstract:
DOE prepared this EA to analyze the potential environmental effects that would result from the proposed action. The test proposed by BEG would build on historical data covering subsurface geotechnical characteristics for an operating oil field and would use existing infrastructure of the South Liberty oil field in Liberty County, Texas, to support the experiment. At an existing well site, BEG would inject CO_2 over a time period of less than 60 days into a brine-bearing sandstone of the Frio Formation in the Gulf Coast of Texas. Two existing wells would be upgraded to monitor the behavior of the injected CO_2 for up to 1 year, and the resulting data would be used to enhance models for predicting the behavior of CO_2 injected into brine formations. The field test would have the following objectives: (1) demonstrate that CO_2 can be injected into a brine formation without adverse health, safety, or environmental effects; (2) determine the subsurface location and distribution of the injected CO_2; (3) demonstrate an understanding of computer models for predicting CO_2 behavior; (4) demonstrate methods for monitoring of CO_2 injected into brine formations; and (5) establish a knowledge base for use in considering geological sequestration opportunities.

No substantive adverse environmental concerns were identified in analyzing the effects of the field test.

Public Comments:
DOE encourages public participation in the NEPA process. A draft of this EA was distributed to cognizant Federal and state agencies and made available to the public for review and comment. By the closing date of September 12, 2003, established for receipt of comments, neither adverse comments nor suggestions for consideration in the environmental analysis were received.

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List of Abbreviations and Acronyms

AOR	Area-of-Review
bbl	barrel(s)
BEG	Bureau of Economic Geology at The University of Texas at Austin
cc	cubic centimeter(s)
cf	cubic feet
CFR	Code of Federal Regulations
cm	centimeter(s)
cm^3	cubic centimeters
CO_2	carbon dioxide
DOE	U.S. Department of Energy
EA	Environmental Assessment
EOR	Enhanced Oil Recovery
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act
ft	feet
ft^3	cubic feet
g	gram(s)
gal	gallon(s)
hr	hour
in	inch
kg	kilogram
km	kilometer
km^2	square kilometers
L	liter(s)
lb	pound(s)
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
m	meter(s)
M	thousand
m^3	cubic meters
md	millidarcies
mg	milligram
mg/L	milligrams per liter
mi	mile(s)
mi^2	square miles
MIT	Mechanical Integrity Test
mL	milliliter(s)
MM	million
MSDS	Material Safety Data Sheet
NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory

ng	nanogram(s)
ORNL	Oak Ridge National Laboratory
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
psig	pounds per square inch (gauge)
RRC	Texas Railroad Commission
s	second(s)
SARA	Superfund Amendments and Reauthorization Act
SGH	Sun-Gulf-Humble
TARC	Texas American Resources Company
TARL	Texas Archeological Research Laboratory
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
UIC	Underground Injection Control
VSP	Vertical Seismic Profile
yd^3	cubic yards
yr	year(s)
°C	degrees Celsius
°F	degrees Fahrenheit
µ	micro
µg	microgram
µg/mL	microgram per milliliter

1.0 INTRODUCTION

This Environmental Assessment (EA) provides the results of an evaluation of the potential environmental consequences of a proposed pilot experiment for injection of carbon dioxide (CO_2) into a subsurface brine-bearing formation, a process known as geologic sequestration. The U.S. Department of Energy (DOE) is proposing to provide approximately $2.5 million to examine the viability of geologic sequestration of CO_2 and to determine if geologic sequestration can be modeled, measured, and monitored.

Increasing concentrations of CO_2 in the atmosphere are believed by many scientists to have potential for creating global change toward a warmer climate. These changes may have negative impacts on human systems as well as ecosystems. DOE is supporting research activities to develop a knowledge base and understanding of candidate options for mitigating global climate change.

Geologic sequestration is a potentially viable method for stabilizing the amount of CO_2 released to the atmosphere from combustion of fossil fuel. In this method, the CO_2 from a stationary industrial source of CO_2, would be captured, compressed, and injected into the subsurface. The injection site must possess geologic properties that would assure that the CO_2 remains trapped in the subsurface and isolated from the atmosphere. The natural capacity of the subsurface to trap and retain buoyant fluids such as oil and natural gas is well known. Technologies for injection of fluids, particularly CO_2, into the subsurface to enhance recovery of oil and for injection of wastes for disposal are both widely applied.

This project was proposed by the Bureau of Economic Geology (BEG) at The University of Texas at Austin under a competitive solicitation (DE-RA26-98FT35008) issued by DOE to solicit research proposals on potentially practical, affordable methods to prevent carbon dioxide and other greenhouse gases from building up in the atmosphere. The proposal from BEG was selected for funding support. Initial work by BEG focused on technical studies to identify optimal environmental conditions for geologic sequestration of CO_2 in brine formations of the United States. The upper Texas Gulf coast was identified by BEG as a region with excellent potential for geologic sequestration.

This proposed pilot experiment would involve the controlled injection of CO_2 over a maximum of 60 days into the sandstone brine formation of an oil field and close monitoring of the performance of the subsurface in holding CO_2. To minimize risks, the experiment would be designed to inject the minimum volume of CO_2 that would be required for effective subsurface measurement using a variety of techniques. Monitoring would be performed for up to 1 year. The results obtained from monitoring a small volume of injected CO_2 would provide reliable information for determining the feasibility of safely and effectively injecting CO_2 into a geologic environment and the potential for subsurface retention of the CO_2 over a long time frame. Monitoring and modeling tools developed by researchers from Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), Lawrence Livermore National Laboratory (LLNL), and National Energy Technology Laboratory (NETL) would be applied.

The purpose of the EA is to determine if the proposed action could potentially cause significant impacts to the environment. If potentially significant environmental impacts are identified, and if they cannot be reduced to insignificance or avoided, then a more detailed Environmental Impact Statement would be prepared. If no significant environmental impacts are identified, a Finding of No Significant Impact would be prepared and made available to the public, along with the EA itself, before the proposed action proceeds.

This study was prepared in accordance with the National Environmental Policy Act (NEPA) of 1969 (42 United States Code 4321 *et seq.*), the Council on Environmental Quality’s Regulations [Title 40, Code of Federal Regulations (CFR), Parts 1500-1508], and Department of Energy’s NEPA Implementing Procedures (Title 10, CFR, Part 1021).

2.0 PURPOSE AND NEED FOR THE PROPOSED ACTION

2.1 Background

The concentration of carbon dioxide (CO_2) in the atmosphere has increased by 17.4% over the past 60 years (Keeling and Whorf, 2002). The Intergovernmental Panel on Climate Change (2001) has concluded that these changes result principally from accumulation of anthropogenic CO_2 emitted to the atmosphere from changing land use patterns and combustion of fossil fuels, such as coal, oil, and natural gas, to produce energy. Predictions of global energy use suggest that anthropogenic carbon emissions will continue to increase, resulting in continued increase in atmospheric concentrations of CO_2 unless major changes are made in the way that energy is produced and used (U.S. Department of Energy, 1999, p 1-1).

Uncertainty exists regarding predictions of the effects from the change in CO_2 concentration in the atmosphere. However, significant risk exists that continued increase in atmospheric concentrations could force changes in global climate, which may have a variety of serious consequences (see U.S. Climate Change Science Program / U.S. Global Change Research [2003] for regional summaries or the Intergovernmental Panel on Climate Change).

DOE has prepared several documents that consider U.S. energy policy and the options that can be evaluated in response to concerns over the impact of anthropogenic CO_2 releases on climate change. The National Energy Policy Development Group (2001) considered a broad spectrum of energy issues, and in Chapter 3 (Protecting America's Environment) states that "Industry and the federal government are researching various new technologies that will reduce greenhouse gas emissions or sequester those emissions, in geologic formations, oceans, and elsewhere." The U.S. Department of Energy (1999) document "Carbon Sequestration" provides a detailed assessment of the role of carbon sequestration in reducing anthropogenic CO_2 emissions. Three categories of technologically driven solutions are proposed: (1) energy conservation and efficiency; (2) substituting lower carbon or carbon-free energy sources for current sources - for example, switching to renewable energy sources, nuclear power, and low-carbon fuels; and (3) carbon sequestration, by which CO_2 is removed from combustion emissions and stored directly underground or in the deep ocean or indirectly by enhanced uptake by soils, vegetation, and the oceans.

On June 11, 2001, the President committed the Federal Government to pursue a broad range of strategies to reduce greenhouse gas emissions through three initiatives: (1) a Climate Change Research Initiative to guide establishment of climate policy based on science; (2) a National Climate Change Technology Initiative to develop new technologies that address climate change issues; and (3) increase cooperation with other countries to engage others on climate change and clean technologies. In February 2002, the President complemented these initiatives by establishing a goal for the U.S. to reduce greenhouse gas emissions (as a percent of gross domestic product) by 18% by the year 2012. This Presidential Climate Change Initiative is directed at using new technologies and economic incentives to slow the growth of CO_2 emissions.

2.2 DOE's Purpose and Need

In partial fulfillment of the President's Initiatives, DOE's need is to establish a scientific understanding of carbon sequestration and to develop to the point of deployment those options that could potentially ensure environmentally acceptable sequestration to reduce anthropogenic CO_2 emissions and/or atmospheric concentrations.

The purpose for the proposed action is to support rigorous testing of a potential technological solution for carbon sequestration within a geologic formation. This testing would provide key information needed to increase scientific understanding of carbon sequestration and to assure that this option, if successful, would be capable of providing an effective option for reducing atmospheric concentrations of CO_2.

One option that has the potential to achieve DOE's goal is sequestration of CO_2 in unique geologic formations, such as oil and gas fields, coal beds, and porous brine-bearing formations. The history of reservoir characterization by U.S. industries has produced sufficient knowledge and understanding of the subsurface in containing gases and fluids to help make geologic sequestration an attractive option. The ability of the subsurface to store oil and gas for geologically significant periods is well known, lending credibility to the concept that injected CO_2, which would be buoyant like oil and natural gas in most geological environments, could be sequestered for long periods (Hitchon, 1996). Technologies for introducing gas and fluids to the subsurface are also mature. For decades oil producers have injected CO_2 into oil reservoirs to act as a solvent for enhanced oil recovery (EOR), a process known as CO_2 EOR. In many parts of the U.S., surface water is protected from contamination by disposal of waste fluids into the subsurface using a permitted process, Underground Injection Control (UIC), which assures protection of the public by disposal of waste into deep subsurface formations that are below and hydrologically isolated from potable water. CO_2 is already being sequestered geologically offshore in the North Sea, where approximately one million tonnes annually of CO_2 are stripped from natural gas and reinjected into the subsurface to prevent release to the atmosphere (U.S. Department of Energy, 1999).

Although the processes of geologic sequestration are relatively well known, additional research is needed to fill gaps in the scientific understanding of carbon sequestration and to develop stakeholder experience with the process. Extensive laboratory and modeling studies have been completed to assess how CO_2 geologic sequestration would work in the subsurface (for example, Hitchon, 1996; U.S. Department of Energy, 1999). Comparing predictions from bench scale tests and numerical models with field results is necessary to validate the models and demonstrate that scientific understanding is correct.

The extensive experience developed in the U.S. with CO_2 injection for EOR is inadequate to validate the models because the fate of the injected CO_2 is not quantified. CO_2 injected for EOR can be sorbed in the oil, held by capillary forces in pore space, trapped by buoyancy forces in stratigraphic or structural compartments, dissolved in pore water, produced and reused, or leaked from the injection zone. The absence of accounting for CO_2 fate in the complex EOR system leaves a gap in scientific understanding, although leakage of CO_2 from the injection zone is assumed to be small relative to the other fates.

Another significant experience gap between EOR and the ability to validate models is related to the type of reservoir host rock. Hovorka and others (2000) inventoried 21 geologic formations in the onshore U.S. that could potentially serve as host injection intervals for CO_2 and identified areas where these formations are near numerous and large CO_2 sources. Geologic formations that could most easily receive and retain large volumes of CO_2 are thick, porous, and permeable sandstones. Such sandstones underlie CO_2 sources on much of the Gulf of Mexico coast. Unfortunately, most experience with EOR is in lower permeability carbonate rocks in the interior basins distant from most anthropogenic sources.

In the North Sea, Statoil (a Norwegian oil company) is injecting CO_2 into a thick, porous, and permeable sandstone. However, reservoir performance and CO_2 fate cannot be closely observed because injection occurs at an offshore site where monitoring wells are not an economic possibility.

A third significant experience gap relates to the process of permitting an injection well for CO_2 sequestration. Commercial and industrial disposal wells are commonly located at sites vertically or laterally isolated from hydrocarbon reservoirs and aquifers. All wells in the zone of influence are required to be properly completed or plugged to protect against leakage. In contrast, CO_2 injection wells for EOR are located within producing oilfields and are intended to increase production at as many wells as possible. Regulators currently lack experience with combined objective projects for CO_2 beneficial use plus CO_2 disposal. Before CO_2 sequestration could be implemented, regulators would require development of methods needed to assure stakeholders and the public that CO_2 injected for dual purposes would be retained in the subsurface and that the beneficial uses of enhanced production could be safely achieved.

To address these experience gaps, a field experiment in a high-porosity, high-permeability formation similar to those that might be viable for consideration as sinks for sequestering CO_2 would be necessary. The proposed pilot experiment would be performed onshore to facilitate adequate monitoring to determine whether the CO_2 remains within the injection zone and to maximize scientific understanding. The proposed pilot experiment would be conducted at a small scale to (1) pioneer the permitting process, (2) minimize health, safety, and environmental risks, (3) minimize costs, and (4) obtain results quickly so that experience would be available for use by others in considering future activities to meet U.S. objectives. The proposed location would provide subsurface conditions that are as simple as possible, thus maximizing the chances of matching numerical model results with field observations.

2.3 BEG Proposal

The Bureau of Economic Geology (BEG) at The University of Texas at Austin proposes to lead a team in conducting a well-monitored, small-scale, short-duration CO_2 injection into brine-bearing sandstone of the Frio Formation in the Gulf Coast of Texas. The site is within the South Liberty oilfield, where extensive geotechnical data are currently available for use in modeling and predicting the expected behavior of injected CO_2. Use of existing infrastructure and location within an operating field would minimize both cost and environmental impact. This site was proposed by BEG following an assessment of optimal geological environments for geologic sequestration in brine formations in the onshore U.S. (Hovorka and others, 2000). The Frio Formation along the upper Texas Gulf Coast was identified as a candidate area for sequestration due to (a) the large concentration of a variety of CO_2 sources and (b) the presence of a thick, widespread, and high-permeability formation ideal for sequestration. The BEG team (Table 1) identified the following objectives for the injection experiment:

- Demonstrate that CO_2 can be injected into a saline formation without adverse health, safety, or environmental effects;
- Determine the subsurface location and distribution of the CO_2 cloud;
- Demonstrate understanding of conceptual models;
- Demonstrate field-test monitoring methods; and
- Establish a knowledge base for use in considering CO_2 geological sequestration opportunities.

Table 1. Project team for the proposed pilot experiment

Participant	Responsibility	Objective(s)
Bureau of Economic Geology (BEG), The University of Texas at Austin	Prime contractor. Coordination and reporting of all activities. Subsurface characterization.	Improve understanding of subsurface behavior and fate of injected CO_2.
Texas American Resources Company (TARC)	Operator of existing well and lessee of subsurface minerals.	Facilitate demonstration of additional uses for mature oil and gas fields.
Lawrence Berkeley National Laboratory (LBNL)	Model-predicted subsurface results. Seismic monitoring. Pressure transient testing. Noble gas tracer modeling and monitoring.	Optimize flow-modeling software for geologic sequestration. Demonstrate use of seismic tests to monitor CO_2 plume.
Lawrence Livermore National Laboratory (LLNL)	Tracer geochemical modeling.	Demonstrate use of tracers in monitoring of CO_2 migration.

Participant	Responsibility	Objective(s)
Oak Ridge National Laboratory (ORNL)	Tracer tests. Stable isotope and perfluorocarbon geochemistry.	Demonstrate use of introduced tracers and naturally occurring isotopes in monitoring CO_2 migration.
National Energy Technology Laboratory (NETL)	Perfluorocarbon tracer geochemistry, and surface monitoring.	Demonstrate use of tracers in monitoring CO_2 migration.
Alberta Research Council)	Geochemical sampling plan.	Advise on basis of past subsurface experience.
Sandia Technologies, LLC	Field-services engineering, safety, oversight, and coordination.	Apply experience in deep injection of wastes to CO_2 sequestration.
W.A. Flanders, Transpetco Engineering of the Southwest, Inc.	Injection: engineering and oversight.	Apply CO_2 EOR engineering to sequestration projects.
BP	Industry advisor. Supplier of CO_2 from Texas City refinery through Praxair.	Advise on the basis of experience. Explore sequestration options.
Schlumberger	Industry sponsor.	Support sequestration projects and apply completion and logging techniques to sequestration.
U.S. Department of Energy, National Energy Technology Laboratory (NETL)	Project sponsor.	Demonstrate technologies for safe and effective geologic sequestration.

The BEG project team is diverse, consisting of staff at a State geologic survey, four national laboratories, a nonprofit Canadian research company, a small independent oil and gas producer, a major oil and gas producer and refiner, a large oilfield service company, and experts in the fields of deep subsurface waste disposal and EOR operation. Project staff would include geologists, geophysicists, and engineers experienced in detailed subsurface characterization and numerical description as well as in waste-isolation projects; experts in geochemical tracer testing; specialists in numerical modeling of CO_2 subsurface behavior and flow simulation; engineers and petrophysicists experienced in well drilling, completion, logging, and log interpretation; and geophysicists experienced in seismic and other geophysical methods of detection of CO_2.

2.5 DOE's Decision

The decision to be made by DOE is whether to commit funds totaling approximately \$2.5 million to conduct the "Pilot Experiment for Geological Sequestration of Carbon Dioxide in Saline Aquifer Brine Formations" in Liberty County, Texas.

2.6 Scoping

Internal scoping discussions were conducted to identify significant issues associated with the proposed project. Reviews of the proposed technology, experimental requirements, the scope of injection requirements and monitoring, the proposed project site and the environmental setting for the project, environmental information from BEG, and other information available on the project were evaluated.

2.7 Scope of the Environmental Assessment

The scope of the Environmental Assessment was determined after reviewing the proposed technology, the extent of testing that would be performed, the changes that would be required, the proposed setting for the project, and available environmental information related to the proposed action. Based on internal scoping studies, the key issues for the proposed action were determined to be associated with surface land use, groundwater issues, health and safety of employees and the public, and transportation impacts.

3.0 ALTERNATIVES, INCLUDING THE PROPOSED ACTION

3.1 Overview

Several alternatives are available for satisfying DOE's need for developing information on potential technological solutions for carbon sequestration. The proposed pilot experiment would be conducted in an oilfield, where drilling and other subsurface activities familiar to the surrounding communities have occurred for many decades, where well-work-over and maintenance companies are headquartered, where a mature oilfield setting provides abundant subsurface data, and where many well bores are idle and, thus, potentially available for injection or monitoring activities. The short duration (less than 1 year) proposed for field activities, to minimize costs and impacts to the environment, would be appropriate for providing the scientific data needed to assess the feasibility of geologic sequestration.

Alternatives to the proposed pilot experiment include: (1) conducting the experiment at another field site in the same sedimentary basin, (2) conducting the experiment in another geographic area (different sedimentary basin), and (3) conducting the experiment in an oil- or gas-bearing interval. All are reasonable alternatives, but for various reasons are less attractive from an operational, scientific, or long-term need perspective.

3.2 Description of the Proposed Action

The proposed action is for the U.S. Department of Energy (DOE) to provide funding to the team led by the Bureau of Economic Geology (BEG) at The University of Texas at Austin to prepare the site, modify two existing wells, drill a new injection well, conduct pre-injection baseline monitoring and testing, inject CO_2 over a period of less than 60 days, conduct monitoring activities during and after the injection, monitor until subsurface conditions begin to stabilize (expected within nine months of injection), and close and restore the site. The overall work activities would require about 2 years to complete.

The pilot experiment would result in injecting 3,750 tons (2 million m^3 or 71.2 million ft^3) of CO_2 into a brine-bearing Frio sandstone at a depth of about 1,500 m (5,000 ft). The site is within an existing oilfield on the flank of a salt dome approximately 56 km (35 mi) northeast of Houston, Texas. Other nearby land uses include timber production and sparse rural residences, although no dwellings lie within a 0.5-km (0.3-mi) radius of the site. Numerous existing geophysical well logs and a 3-D seismic survey are available for characterizing the injection interval. A numerical simulation model created by LBNL would be used to predict subsurface results for planning purposes. Baseline surface and subsurface seismic and geochemical surveys would be completed before injection; repeat surveys would be completed during and after injection to monitor CO_2 distribution, and the integrity of structural and stratigraphic seals of the injection interval would be assessed.

The proposed activities would be consistent with current land use. No endangered species occur in the study area, and no known archeological sites are located within the study area. Direct impacts would include (1) clearing up to 2 hectares (5 acres) of upland habitat for minor expansion of the well pad and for providing narrow pathways to allow truck-mounted drilling-rig access for seismic studies and drilling 3 shallow groundwater monitoring wells; (2) transporting 75 truckloads of CO_2 over 79.2 km (49.1 mi) of public roads through commercial, industrial, and rural areas; and (3) transporting 30 truckloads of produced brine and 60 truckloads of drilling mud less than 32 km (<20 mi) over mostly rural roads to permitted disposal wells. Modeling studies suggest that the injected CO_2 would be likely to remain within the injection zone and migrate less than 200 m (<656 ft) from the injection well. Based on modeling studies, subsurface pressure increases under maximum injection rate scenarios would be expected to be 35% below fracture-pressure limitations and 22% below pressures that might affect nearby growth faults. Monitoring of formation pressure, temperature, and near-well-bore CO_2 saturation would continue until changes become minimal, indicating significant stabilization of the subsurface physical environment, which would be anticipated to occur less than 1 year after the end of injection.

3.2.1 Project Plan

During most of the time associated with the proposed 2-year-project, from preparing environmental applications through final reporting, office activities involving geologic interpretation, engineering design, procedure planning, post-experiment analysis, and publication and presentation of results would be performed. During about a 7-month period, field activities with potential for environmental and social impacts and low-impact monitoring activities would be conducted. Table 2 provides a milestone description, work breakdown structure, and anticipated timeline for the experiment. The timeline depends on State regulatory approval, CO_2 availability, favorable weather, and drilling-rig availability. Initial site examination and conceptual planning began in 2002. Reviews by two State agencies, the Railroad Commission of Texas (RRC—petroleum resource protection) and the Texas Commission on Environmental Quality (TCEQ—groundwater protection and engineering review) would be performed in 2003, and field activities would begin upon completion of environmental planning and review requirements. Two existing wells would be modified for use as monitoring wells and a new injection well would be drilled in 2003. The injection event would occur in a window between February 2004 and April 2004, depending on seasonal availability of compressed food-grade CO_2 and other logistical considerations. Post-injection tests, analyses, and synthesis of results would continue through October 2004. Documentation and presentation of project results would begin in September 2004. The project would be completed by January 2005. Site closure and restoration could begin as early as May 2004 and be completed by January 2005.

Table 2. Milestone description and work breakdown structure

Description	Initiation date*	Completion date*
Task 1 – Environmental Permitting		
1. Prepare and submit UIC Class V application to TCEQ	2/2003	9/2003
2. Secure TCEQ review and approval	9/2003	10/2003
Task 2 – Pre-Field Mobilization Characterization		
1. Characterize field site	3/2002	8/2002
2. Identify candidate geochemical sampling and tracer methods	6/2002	3/2003
3. Computer-simulate CO_2 subsurface behavior	6/2002	3/2003
4. Identify geophysical monitoring requirements	6/2002	3/2003
5. Establish preliminary field procedures and engineering plans	6/2002	3/2003
6. Assess safety requirements and training needs	4/2003	5/2003
Task 3 – Pre-injection Field Activities		
1. Prepare site	10/2003	11/2003
2. Prepare monitor wells	10/2003	11/2003
3. Drill and complete injection well	10/2003	11/2003
4. Conduct baseline geophysical survey, fluid sampling	11/2003	11/2003
5. Conduct pressure-transient test	11/2003	1/2004
Task 4 – CO_2 Injection Experiment		
1. Implement safety plan	11/2003	11/2003
2. Install CO_2 storage and injection equipment	1/2004	2/2004
3. Inject CO_2	2/2004	4/2004
4. Perform post-injection testing	5/2004	1/2005
5. Analyze and interpret results	5/2004	08/2004
6. Site closure and restoration	5/2004	1/2005
6. Synthesize observations and results	8/2004	10/2004
7. Project final reporting and technology transfer	9/2004	1/2005
* Tentative dates, based on start of field activities in October 2003,contingent upon completion of the NEPA review, State regulatory approval, CO_2 availability, weather conditions, and rig availability.		

3.2.2 Pre-injection Activities

Analysis of geologic and geophysical data acquired to characterize the site would be conducted at the Bureau of Economic Geology in Austin, Texas. Project activities (Table 3) would include literature review, computer workstation use, and limited transportation to and from offices of team members and the field site. Geochemical tracer design, geophysical monitoring design, simulation of CO_2 subsurface behavior, and field planning/engineering design would require similar activities at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee;

Lawrence Berkeley National Laboratory (LBNL) in Berkeley, California; Lawrence Livermore National Laboratory (LLNL) in Livermore, California; National Energy Technology Laboratory (NETL) in Pittsburgh, Pennsylvania and Morgantown West Virginia; Alberta Research Council in Calgary, Alberta, Canada; and Sandia Technologies, LLC, in Houston, Texas. Project planning, data collection, engineering design, and administrative support would occur in Texas American Resources Company's offices in Austin and Houston, Texas. Log engineering design and data interpretation would occur in the Ridgefield, Connecticut, offices of Schlumberger-Doll Research. Field-support services (well logging) would originate from the Schlumberger Oilfield Services office in Liberty, Texas, approximately 11.25 km (7 mi) from the field site. BEG's Houston Core Research Center (1611 West Little York Road, Houston, Texas) would serve as a nearby facility during field activities for office work and staging/handling of geochemical samples. BP project advisors would be located in Houston, Texas. Project oversight would be provided from DOE's National Energy Technology Laboratory (NETL) offices in Pittsburgh, Pennsylvania, and Morgantown, West Virginia.

Table 3. Work sites and activities

Location	Team member	Activity
Liberty County, Texas	All	Field activities
Austin, Texas	Bureau of Economic Geology	Office activities
Berkeley, California	LBNL	Office activities
Livermore, California	LLNL	Office activities
Oak Ridge, Tennessee	ORNL	Office and laboratory activities
Houston, Texas	Sandia Technologies, LLC	Office activities
Houston, Texas	Bureau of Economic Geology; Houston Core Research Center	Office and laboratory activities
Austin and Houston, Texas	Texas American Resources Company	Office activities
Calgary, Alberta, Canada	Alberta Research Council	Office activities
Ridgefield, Connecticut	Schlumberger-Doll Research	Office activities
Liberty, Texas	Schlumberger Oilfield Services	Office and laboratory activities
Houston, Texas	BP	Office activities
Pittsburgh, Pennsylvania Morgantown, West Virginia	NETL	Office and laboratory activities
Texas City, Texas	BP, Praxair	Refinery and gas processing

The proposed field site is located in Liberty County, Texas, about 56 km (35 mi) northeast of Houston (Figure 1), near the town of Dayton. The site lies on a 30 m × 30 m (100 ft × 100 ft) clearing within a low-relief upland area dominated by small deciduous trees and is 400 m (1,312 ft) west of wetlands of the Trinity River floodplain margin (Figures 2 and 3). The area has been an active oilfield from 1951 to present and is sparsely populated. Residential neighborhoods have been developed over the past 2 decades to the north, southwest, and south of the site (Figure 2), but no residences lie within 0.5 km (0.3 mi) of the site. Approximately 250 land blocks within 2 km (3.2 mi) of the site are platted for residences. Intermittent logging has occurred in the vicinity for decades; an idle lumber mill lies about 0.4 km (0.25 mi) north of the site. The area west of highway FM 1409 (Figure 2) is primarily agricultural. The project would impact less than 2 hectares (5 acres) within an oilfield where oil and gas activities have impacted 6,980 hectares (17,280 acres). State and Federal records indicate no known archeological sites or endangered species at or near the site. Groundwater is within a few meters of the ground surface.

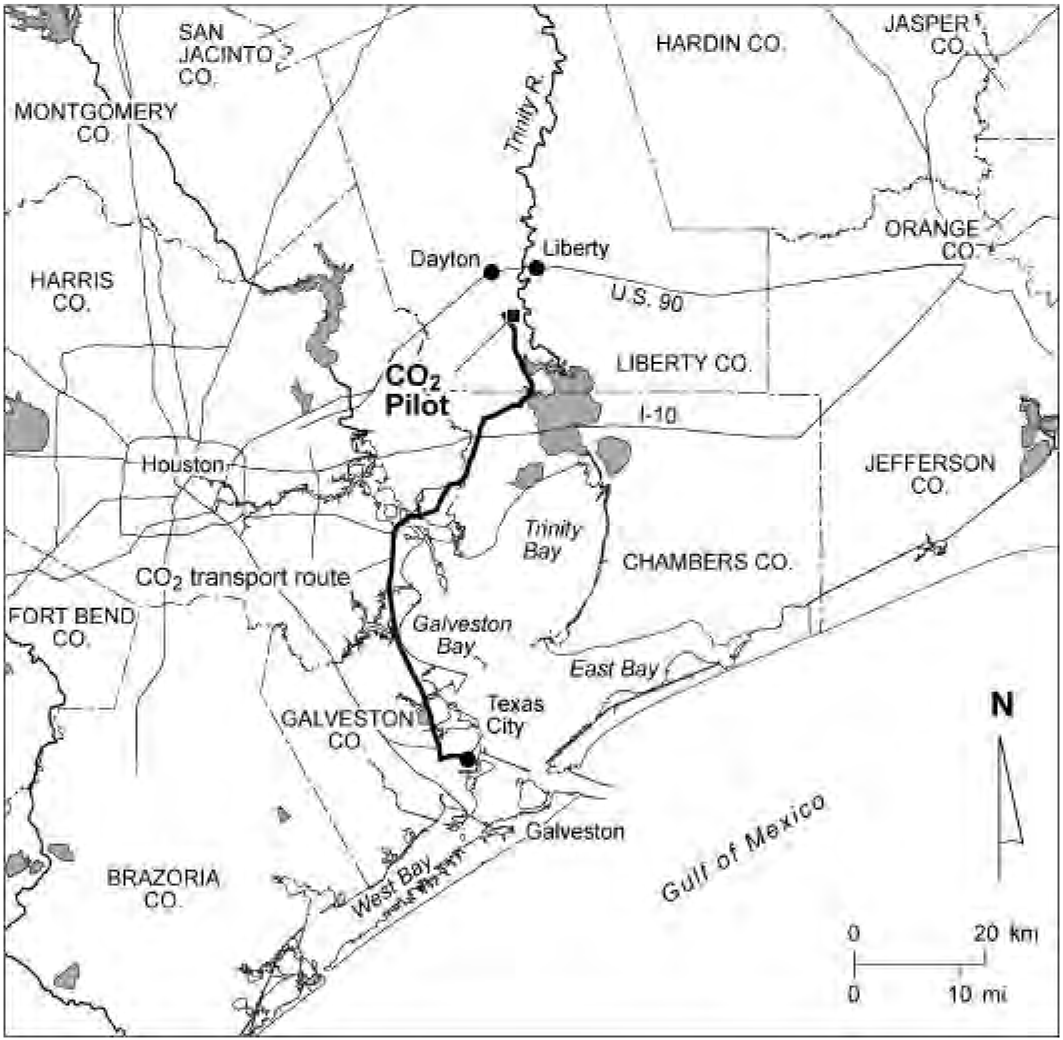

Figure 1. Map of the southeast Texas coastal region (showing the location of the CO_2 pilot project, including the transportation route).

Site preparation would include improving about 1 km (~0.6 mi) of unpaved lease road by adding road base and grading and incrementally expanding one well pad, which would require clearing of no more than 0.4 hectares (1 acre) of vegetation. Expansion of the well pad and associated loss of vegetation would be minimized by directionally drilling the injection well from the margin of an existing pad, rather than clearing a new pad and building an access road within the vegetated upland.

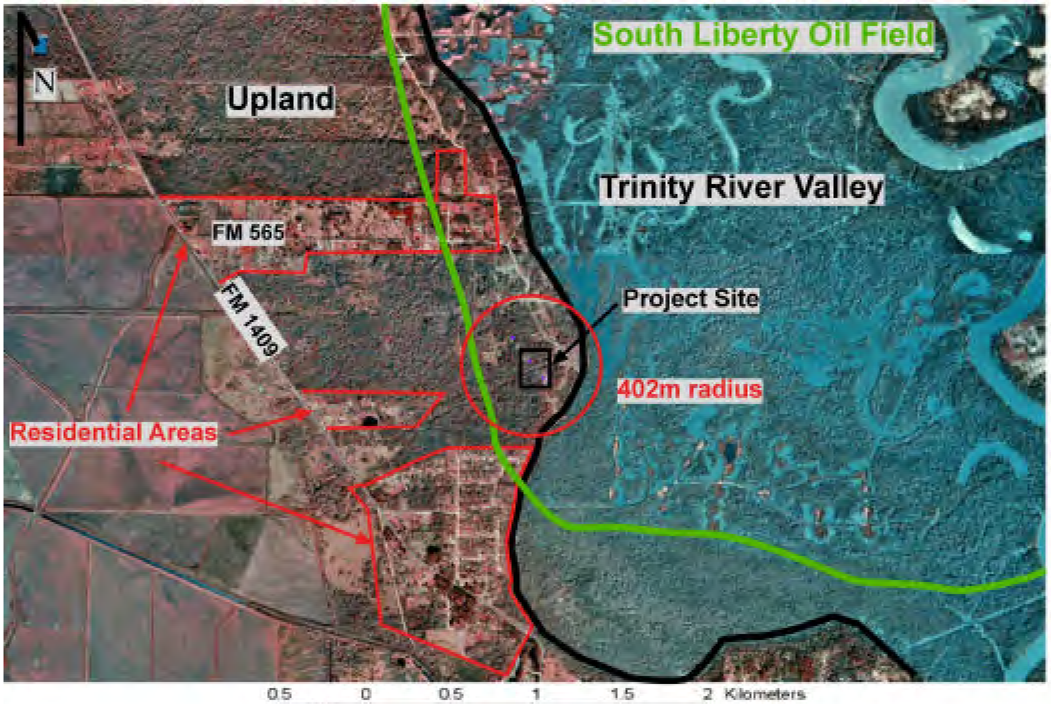

Figure 2. Aerial photograph of the area surrounding the project site, showing major land features, roads, residential areas, the South Liberty oilfield outline, and the 402 m (0.25 mi) radius of the Area of Review. Aerial photo base modified from Texas Natural Resources Information System.

Soil gas, pore water, and shallow groundwater would be sampled and analyzed prior to CO_2 injection to establish background CO_2 concentrations. Because background values vary seasonally with changes in biologic activity, a sample grid would be established and re-sampled over several months before and after injection. These points would also be monitored throughout the injection and post-injection phases. Shallow auger holes would be used to sample soil gas. Three shallow water wells would be drilled to sample groundwater in accordance with TCEQ monitoring well protocols.

Two existing wells, Sun-Gulf-Humble #4 and #3 (SGH 4 and SGH 3; Figures 3 and 6) would be converted to monitoring wells, requiring mobilization of a truck-mounted work-over rig to the well pad along lease roads. SGH 4 would be the primary monitoring well; the new injection well would be drilled 30 m (100 ft) south of SGH 4. SGH 3 is 135 m (440 ft) southeast of SGH 4. Minor modifications would be made to this well to facilitate limited CO_2 plume monitoring. Standard oilfield techniques would be implemented to determine casing condition, cement the well-bore annulus in the injection zone, and perforate that same zone to prepare for monitoring. These activities would occur at depth, within the saline aquifer, well below and isolated from potentially potable groundwater.

Standard oilfield techniques and equipment would be employed to drill and complete an injection well on the same pad as SGH 4 (Figure 3A). A shallow drilling-mud pit would be constructed adjacent to the well pad and lined in accordance with TCEQ requirements to prevent subsurface infiltration. The drilling mud would be water based. The volume of well cuttings (natural earth materials extracted during well drilling) would be about 400 m^3 (550 yd^3). Cuttings would be buried on site as municipal solid waste in accordance with Texas Administrative Code Chapter 330. Drilling fluids, estimated to be less than 7,000 barrels, would be trucked to an RRC-authorized disposal well within 48 km (30 mi) of the project site. The new well would be cemented and perforated according to oil-industry standards. Minor amounts of excess nonhazardous material and debris would be removed from the site to a municipal landfill.

Newly established perforations in the injection well and monitor well would undergo Mechanical Integrity Tests (MIT) to verify casing-to-formation bond and ensure that injected materials escape from the intended zone through the well annulus. Part of the routine MIT involves injection into the perforated zone at 1,500 m (5,000 ft) depth of 20 cc of ^{131}I solution containing a total of 20 millicuries of radiation. This isotope has an 8-day half-life. The wells would sit idle for at least 2 weeks before production or injection of fluids begins, thus preventing return of hazardous levels of radioactivity to the surface. Radioactivity of produced fluids would be tested to assure that exposure levels conform to acceptable levels in Article 213 of the DOE Radiological Control Manual.

A series of extraction and injection tests would be conducted to evaluate subsurface fluid characteristics and pressure response within the injection interval. Brine produced during each pumping test, equaling no more than 3,000 barrels (351 m^3), would be sampled, temporarily stored on site, and then re-injected with a groundwater tracer into the original well in a subsequent injection test.

Two baseline geophysical surveys – a crosswell seismic survey and a 3-D vertical seismic profile (VSP) – would be conducted before injecting CO_2. The crosswell survey would consist of a downhole seismic source (high-frequency oscillating) in the SGH 4 monitoring well and seismic detectors placed in the injection well. The 3-D VSP would employ a surface seismic source and the injection-well detectors. As many as sixty-six (66) 18-m-deep (60-ft) shot holes would be drilled along four lines passing through the injection well and extending up to 400 m (1,312 ft) from the well (see Section 4.2). A small jeep-mounted rig would be used to drill the shot holes near existing lease roads wherever possible, impacting less than 0.8 hectares (<2 acres). A maximum charge of 1.5 kg (3 lb) of biodegradable explosive (Dynoseis®, consisting of sodium perchlorate and diethylene glycol [MSDS in Appendix B]) would be used to produce the seismic energy for the survey. After detonation, shot holes would be filled with soil and the areas would be compacted.

Figure 3. Photographs of the proposed project site. (A) View, looking north, of well pad where existing well SHG 4 is located. New well would be drilled on a southward extension of this pad. (B) View, looking northwest, of well pad where existing well SHG 3 is located—the two water-storage tanks were used when the well was a salt-water disposal well.

3.2.3 Injection Activities

A maximum of 3,750 tons (71.2 MMcf) of CO_2 would be injected intermittently into the subsurface over a maximum period of 60 days at rates not exceeding about 8.5 tons/hr (161 Mcf/hr). Downhole pressure increases would not exceed 116.4 bar (1,688 psi), which is established by TCEQ regulation and is about 7 bar (100 psi) below the calculated fracture pressure of the formation. TCEQ regulations also require that pressure increases within a 402-m (one-quarter-mi) radius area of review (AOR) not exceed a calculated value of 11.4 bar (165 psi), assuming a hydraulic gradient of 0.098 bar/m (0.433 psi/ft). Flow simulations by LBNL using TOUGH2 (Pruess and others, 1999; Hovorka and others, 2001) and formation-specific petrophysical properties were used to calculate pressure response under proposed injection rates and durations. Figure 4 provides a map view of the modeled pressure increase for a conservative scenario that assumes CO_2 injection of 5,000 tons, rather than the proposed 3,750 tons, over a shorter time period of 20 days. The northeast, northwest, and southeast model boundaries are faulted and considered no-flow boundaries. The southwest boundary is open (unfaulted) and allows pressure dissipation. Maximum pressure increase at the injection well would be 20.8 bar (304 psi), which is less than 20% of the regulated limit. Maximum pressure increase within the fault block at 402 m (0.25 mi) from the well would be less than 6 bar (<87 psi), about half of the regulated limit. Subsequent models to be constructed before injection would be refined to include more detailed geologic information from an existing 3-D seismic volume, hydrologic tests of the injection formation, and information from core and log data in the new injection well. These model refinements, combined with pressure monitoring during injection, would ensure that the experiment would be performed within regulatory requirements.

CO_2 for injection would be delivered to the site by commercial truck and temporarily stored in a 1,000-barrel pressure tank placed on a 6 × 24 m (20 ×80 ft) concrete pad. The CO_2, at 15 bar (220 psig) and –19°C (–3°F), would be compressed prior to injection by a pad- or skid-mounted pump that would occupy an area of less than 3 × 6 m (10 ×20 ft). Both the tank and pump would be removed following injection.

The injection of CO_2 would be suspended several times during the experiment to allow for downhole logging, sampling, and geophysical measurements. During these suspensions, produced formation brine would be injected to prevent return of CO_2 gases to the surface through the well bore. Standard oilfield procedures would be used to log and sample the well. To monitor CO_2 plume behavior, 3-D VSP surveys would be repeated during injection.

The focal point of the proposed activity would be monitoring of the injected CO_2 to understand subsurface flow paths. Formation temperature and pressure would be recorded nearly constantly to determine formation response. Additionally, tracers would be injected with the CO_2 in minor amounts, and both the injection and monitoring wells would be sampled to identify the tracer and CO_2 concentrations. Geochemical tracer techniques would include (1) isotopic profiles of injected CO_2, (2) introduced noble gases, and (3) introduced perfluorocarbons. A maximum of 3,000 barrels of fluid in one monitoring well (SGH 4) would be produced by nitrogen lift during the injection period to monitor tracer and CO_2 concentration. These fluids would not be re-injected into the formation because of their potential to interfere with long-term monitoring. These fluids would be trucked to a TCEQ-permitted UIC Class 1 non-hazardous well within 32 km (20 mi) of the site for disposal into a subsurface formation.

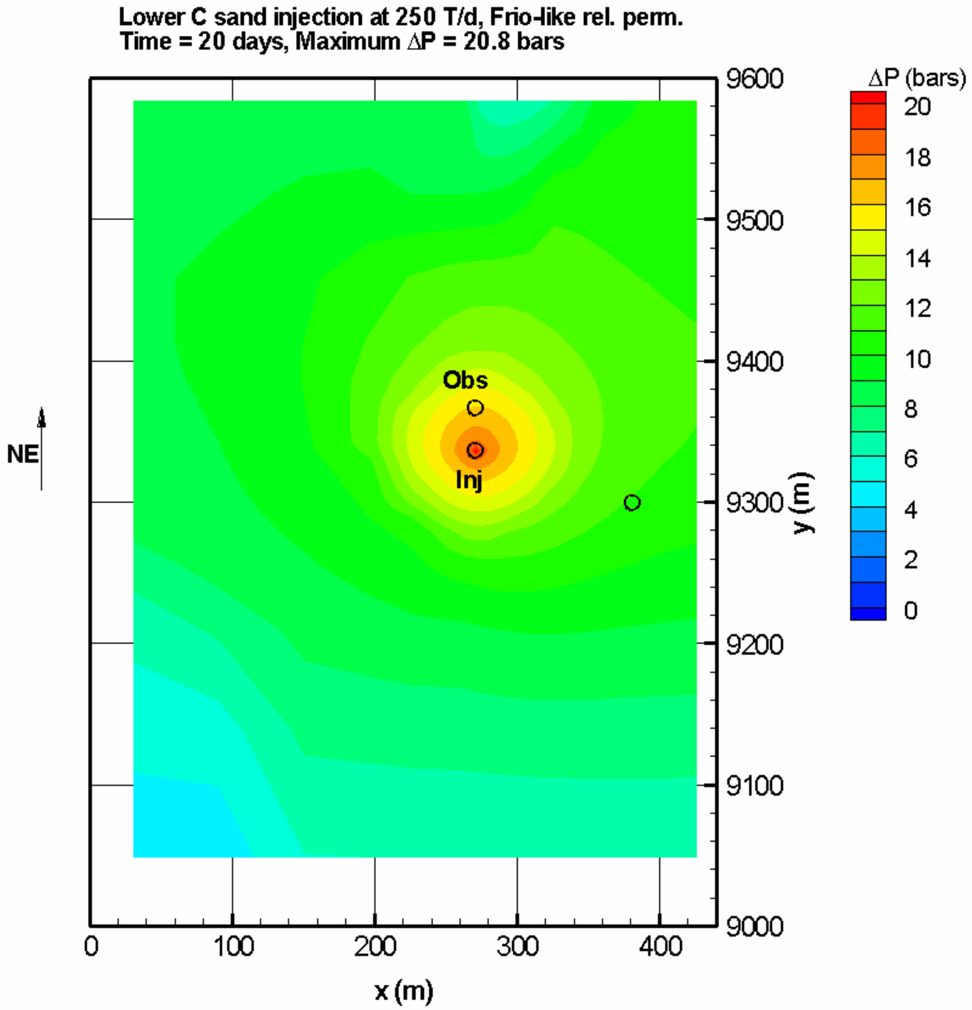

Figure 4. Map-view results of Tough2 numerical simulation, showing incremental pressure increases in the injection interval after 20 days of injecting CO_2 at a rate of 250 tons per day. Note that the total injection quantity of CO_2 modeled is 5,000 tons rather than the proposed amount of 3,750 tons, in order to investigate upper limits of pressure increase, which was calculated to be 20.8 bars (304 psi).

3.2.4 Post-injection Activities

Following CO_2 injection, downhole fluid samples would be taken from the injection zone and the immediately overlying zone in both the injection well and primary monitoring well (SGH 4). Purging of the well bore to obtain fresh samples from the formation could yield up to 172 barrels of formation brine, which would be transported to a TCEQ-permitted disposal well.

The existing completions would remain open in the injection and monitoring wells for a period anticipated to be less than 1 year to allow extended monitoring. Monitoring would include pressure and temperature measurements and other activities that could include well logging, crosswell or surface seismic surveys, or geochemical sampling and analyses. Monitoring of CO_2 in the wells would decrease in frequency as changes in pressures and concentrations become minimal, indicating significant stabilization of the subsurface physical environment. This stabilization would be expected to occur less than 1 year after the end of injection. Shallow-groundwater dissolved gas and soil-gas concentrations would be monitored throughout this time at sample points established during pre-injection field activities. Impacts of surface seismic surveys and geochemical sampling (waste formation brine) would be treated as previously described in Section 3.2.2.

Following the completion of downhole logging and sampling, the injection and monitoring zone perforations would be plugged by cement following standard oil-industry practices. The wells would either be plugged and abandoned according to RRC rules or converted to a use approved by the appropriate agency.

Other post-injection activities would include additional office work to analyze and interpret results at the various team members' sites (Table 3). Results and interpretations would be synthesized by the Bureau of Economic Geology, and a final project report would be prepared. Technology transfer to interested parties would continue sporadically until project completion in January 2005.

3.3 Range of Reasonable Alternatives

Reasonable alternatives to the proposed action, including the no-action alternative, are listed in Table 4, along with comments on each. Action alternatives range from siting the experiment in an adjacent area to conducting the experiment in a hydrocarbon-bearing formation.

Table 4. Comparison of alternatives

Alternative	Comments
Alternate location in same basin	Need oilfield setting. Would need to find other operators to host the experiment and supply data.
Injection in a different basin	Other large basins having significant CO_2 sources would require comparable subsurface data and service-industry infrastructure.
Injection in an oil or gas reservoir	Presence of hydrocarbons in even minor concentrations would interfere with critical fluid flow characteristics and rock-water interactions, which would require investigation.
No action	Development of information on sequestration alternatives would suffer increased risks or substantial delays, thus reducing options available for consideration by the U.S. for climate change mitigation.

Considering the Frio Formation in the upper Texas Gulf Coast as an advantageous setting, one action alternative would be to conduct the experiment in another area of dense subsurface control. The small fault blocks associated with salt domes in this basin would offer significant benefits by providing a more closed compartment. The small volumes of material injected into a more closed compartment would have a larger pressure response because the pressure would not be as rapidly dispersed as in unnecessarily large pore volume. Similarly, flanks of salt domes commonly have steeper dips that would accentuate the response of the buoyant injected CO_2 plume to the effects of gravity, which would be a key parameter for evaluation as part of any experiment to examine geological sequestration. The effects of conducting the pilot experiment in a comparable alternate location within the same geologic basin would not be substantially different from the effects of the proposed action.

Many other basins across the U.S. contain formations suited to CO_2 sequestration (Hovorka and others, 2000). Few of these basins, however, are characterized by a high concentration of CO_2 sources and an abundance of available subsurface data in the form of well logs and 3-D seismic data. Fewer still have a robust well-servicing industry, which would reduce experiment cost through a competitive business climate and relatively low mobilization costs.

Another alternative would be to conduct the experiment in the same basin as that proposed but use existing infrastructure and completed wells in an oil or gas reservoir. This option would reduce well-construction costs and potentially add value by enhancing hydrocarbon production as a result of the injection. The daily activity in such settings, however, would substantially increase the difficulty of detailed scientific monitoring. Background electromagnetic and seismic noise would reduce the achievable resolution of geophysical surveys. Additionally, the pilot experiment would require periods in which wells would need to be idle, which would result in loss of revenue for producers. Most important, the presence of hydrocarbons would substantially affect CO_2 sorption, pressure response, and flow processes that are the experimental objectives of the project. The presence of a native gas phase in the formation would significantly increase the compressibility of the formation fluid, making response to injection difficult to predict and interpret. The presence of oil in the formation fluid would complicate multiphase flow effects.

3.4 The No Action Alternative

No action, meaning that DOE funds to support the proposed experiment would not be provided, regardless of setting or project scope, would delay by several years the development of information needed to assess technological options for carbon sequestration. From a national perspective, therefore, the no action alternative would adversely affect the ability to provide options to help meet the President's objective for greenhouse gas emissions reductions by 2012. The increased understanding of subsurface behavior of CO_2 would not be gained, and an example of successful and safe sequestration, on any scale, could not be offered for consideration by the public, policy makers, and regulators during any future consideration of CO_2 sequestration proposals. In the absence of an adequate base of knowledge, the complexities of future projects could result in long delays for public and regulatory approval, thereby jeopardizing goals for action on climate change issues. Delays of 3 years, for example, in development of technological options for CO_2 sequestration would result in increased CO_2 emissions of approximately 5% and increased atmospheric concentrations of CO_2 before any stabilization effort would be started.

4.0 AFFECTED ENVIRONMENT AND THE ENVIRONMENTAL CONSEQUENCES OF THE PROPOSED ACTION

4.1 Site Description

The pilot experiment is proposed for the South Liberty field in southern Liberty County, Texas, a largely rural county with an estimated population of 72,620 in 2001 (U.S. Census Bureau, 2001). The site would be located on an upland area adjacent to the Trinity River valley on the coastal-plain physiographic province. The site and the sparsely populated, immediately surrounding area are within an oilfield that has been active since 1951. Low-density residential neighborhoods have developed over the past 2 decades to the north, southwest, and south of the site (Figure 2). No residences lie within 0.5 km (0.3 mi) of the site. Approximately 250 land blocks within 2 km (1.25 mi) of the site are platted for residences. Timber has been harvested sporadically in the vicinity for many decades; an idle lumber mill is located about 0.4 km (0.25 mi) north of the site. The area west of highway FM 1409 (Figure 2) has historically been used for agriculture.

The project site would be about 25 km (~15.5 mi) upstream of Trinity Bay, about 65 km (40.3 mi) inland from the Gulf of Mexico, about 60 km (37 mi) northeast of downtown Houston (Figure 1), and nearest to the small communities of Dayton (7.5 km, or 4.5 mi, to the northwest) and Liberty (9 km, or 5.5 mi, to the northeast). Liberty County is on the northeast margin of the heavily populated Houston metropolitan area. Harris County, home of most of Houston's residents, had an estimated 2001 population of 3,460,589; populations estimated for adjacent counties within the regional impact area are 255,865 for Galveston County and 26,859 for Chambers County (U.S. Census Bureau, 2001).

4.1.1 Field History

The South Liberty field was discovered in 1925. The first commercial production was from the Oligocene Frio Formation shallow on the east flank of a piercement salt dome, and a significant drilling boom followed (Halbouty, 1962). Attention was drawn to the area in 1901 by surface shows of sulfur, oil, and gas, and by the discovery of Spindletop Dome. The cumulative production from the South Liberty field in 1925 was 4,416,000 barrels of oil. Production steadily declined through the mid 1940's, but discoveries of oil in the deeper Eocene Yegua and Cockfield Formations on all flanks of the dome in 1948 and 1949 reinvigorated the field (Halbouty, 1962). A large number of the wells in the area of the proposed pilot experiment were drilled in 1950 and 1951 as a new drilling boom spread. Annual production peaked at 5,271,847 barrels in 1958 and has been gradually declining since then. Annual production for 2001 was 253,000 barrels of oil and 437 million ft^3 of gas (Railroad Commission of Texas, 2002).

No production has been found over the top of the dome (caprock area), where salt rises to within 84 m (275 ft) of the surface (Halbouty, 1962). According to a Texas Railroad Commission database, the South Liberty field contains 654 wells (Figure 5). About 55 leases are currently producing (with multiple oil wells but only one gas well possible per lease), with a large number of wells, perhaps several hundred, standing idle. From January 1, 1998, through January 1, 2003, only 11 wells were permitted within the field, all on the east and north flanks of the dome, with at least 5 of those permits granted in 2002. Exploration for deeper oil or gas objectives continues, as evidenced by the increase in well permits in 2002 and the recent completion of a large 3-dimensional seismic reflection survey in the area.

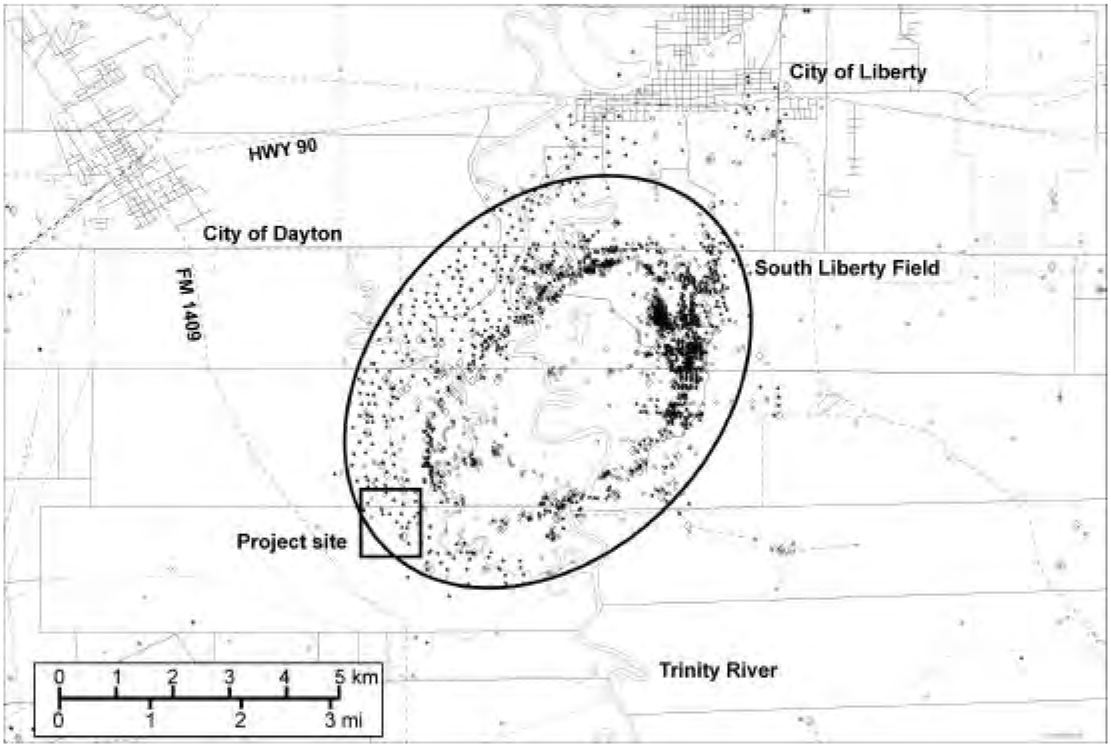

Figure 5. Map of oil and gas wells in the South Liberty field and surrounding area. Modified from Railroad Commission of Texas (2002).

4.1.2 Surface Geology and Soils

The proposed new CO_2 injection well and existing monitoring wells would be located on the Beaumont Formation (Aronow and Barnes, 1982), a Pleistocene fluvial-deltaic depositional system composed of fine sandy channels and interchannel muds. Fisher and others (1972) mapped the site as a heavily to sparsely tree-covered meander-belt sand. The pilot experiment site would be about 300 m (~1,000 ft) west of the erosional bluff marking the geomorphic boundary between the Pleistocene upland at surface elevations of about 20 m (~66 ft) above sea level and the floodplain of the Trinity River at elevations of 2 to 6 m (6.6 to 20 ft) above sea level (Figure 6). The main channel of the Trinity River passes about 2,700 m (~1.7 mi) east of the site. Depositional units within the floodplain, mapped as Quaternary alluvium by Aronow and Barnes (1982), include tree-covered meander-belt sand, overbank flood-basin mud, and mud-filled abandoned channels (Fisher and others, 1972).

Figure 6. Topographic map of the experiment site, showing bluff to east of the site and a small lake (stippled area) within the Trinity River valley. Note also locations of existing wells to be converted to monitor wells, SGH 4 and 3, and location of the new CO_2 injection well, about 30 m (100 ft) south of SGH 4. Gray shading designates vegetated areas. The contour interval is 5 ft. Modified from U.S. Geological Survey Moss Bluff 7.5-minute quadrangle.

The Natural Resources Conservation Service has mapped three soil units at and near the site (U.S. Department of Agriculture, 1996), as shown in Figure 7. On the upland is the Aldine-Aris complex, a thick soil with texture ranging from very fine sandy loam to clay (Aldine) and sandy clay loam to clay (Aris). Geologic maps indicate that the dominant soil texture at the site is sandy loam rather than clay. This soil unit is considered to be very slowly permeable and has a high water-holding capacity. The depth to water, where present, is less than 1 m (<3 ft). Organic matter content is 2 percent or less.

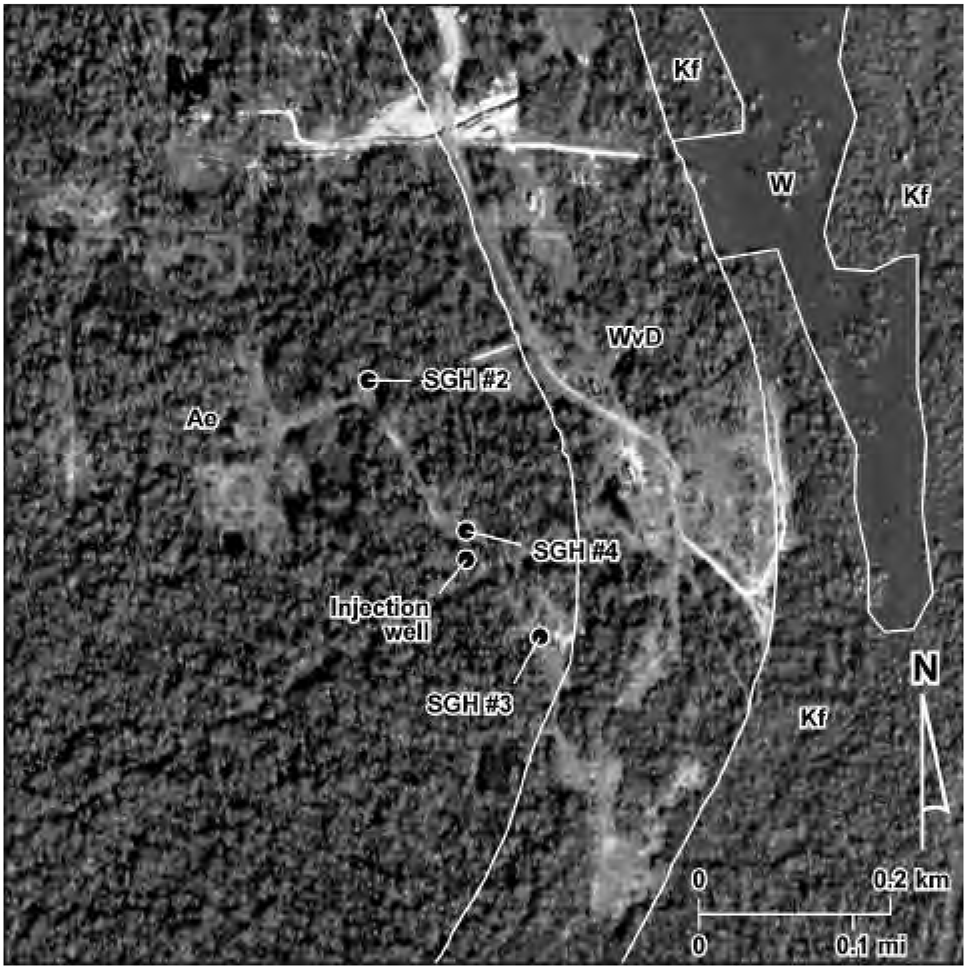

Figure 7. Distribution of soil units at the experiment site. Soil units are those of the Natural Resources Conservation Service (U.S. Department of Agriculture, 1996). W = water; Ae = Aldine-Aris complex; Kf = Kaman clay; and WvD = Woodville fine sandy loam. Aerial photo base modified from Texas Natural Resources Information System.

Soils of the Woodville fine sandy loam are mapped for the bluff separating the upland site for the pilot experiment and the Trinity River floodplain. This soil, with a surface slope of 5 to 8 percent, has a thin sandy surface layer overlying clay substrata. Permeability is classified as very slow; water-holding capacity is high. The depth to water, where present, is 2 m (6.6 ft) or more.

The Trinity River floodplain adjacent to the proposed experiment site is classified as either Kaman clay or open water. The Kaman clay is a very deep, wet, and poorly drained unit that is frequently flooded. This soil is classified as clay to silty clay with an organic content of 3 percent or less and with a high water-holding capacity.

4.1.3 Subsurface Geology

The proposed injection would occur in brine-bearing sandstones near the top of the approximately 600-m-thick (~2,000-ft) Oligocene Frio Formation at about 1,500 m (~5,000 ft) below ground surface, on the southwest flank of the South Liberty salt dome. Hydrocarbon production in this part of the field comes from sandstones of the Eocene-age Yegua/Cockfield and Cook Mountain Formations between 2,500 and 2,750 m (8,200 and 9,000 ft) below ground level (Figure 8). The interval between the production (Yegua/Cockfield) and injection (Frio) formations is a shale-dominated section that includes the Eocene Jackson and Oligocene Vicksburg formations (Figure 8). The Frio is overlain by the 75-m-thick (250-ft) Oligocene Anahuac Shale, which, in turn, is overlain by an approximately 1,300-m-thick (~4,200-ft) interval of Miocene interbedded sandstones and shales (projected from cross sections in Morton and others, 1985). These include, in order of oldest (deepest) to youngest (shallowest), the Oakville (~470 m [~1,500 ft] thick), Fleming (~565 m [~1,850 ft] thick), and Goliad Formations (~245 m [~800 ft] thick). Above these units is the sand-dominated interval extending to the surface and including the Pliocene Willis Formation (~60 m [~200 ft] thick; Galloway and others, 1991; Guevara-Sanchez, 1974), the Pleistocene Lissie (~45 m [~150 ft] thick), and the Beaumont (~25 m [~80 ft] thick; Guevara-Sanchez, 1974) Formations.

Typical structure within the central and upper Texas Gulf Coastal Plain dips gently toward the Gulf of Mexico and is cut every few kilometers by northeast-trending, down-to-the-coast growth faults. Along the upper Texas coast (including the study area), the growth-fault pattern is disrupted by numerous salt domes. The area proposed for the pilot experiment lies on the south flank of the South Liberty salt dome. The Frio Formation dips southerly to slightly southeasterly at high angles (greater than 30°) near the salt-dome flank, decreasing south and west of the pilot location to a dip of less than 5°. The salt flank is cut by a series of normal faults that radiate from the salt dome and typically dip and throw to the west-northwest (Figure 9). Major fault offsets vary from 90 to more than 120 m (300 to >400 ft), decreasing away from the dome as dips flatten. Minor fault offsets detectable with well logs and seismic correlation range from 15 to 45 m (50 to 150 ft), with many of these faults dying out not far south of the pilot area (Figure 9).

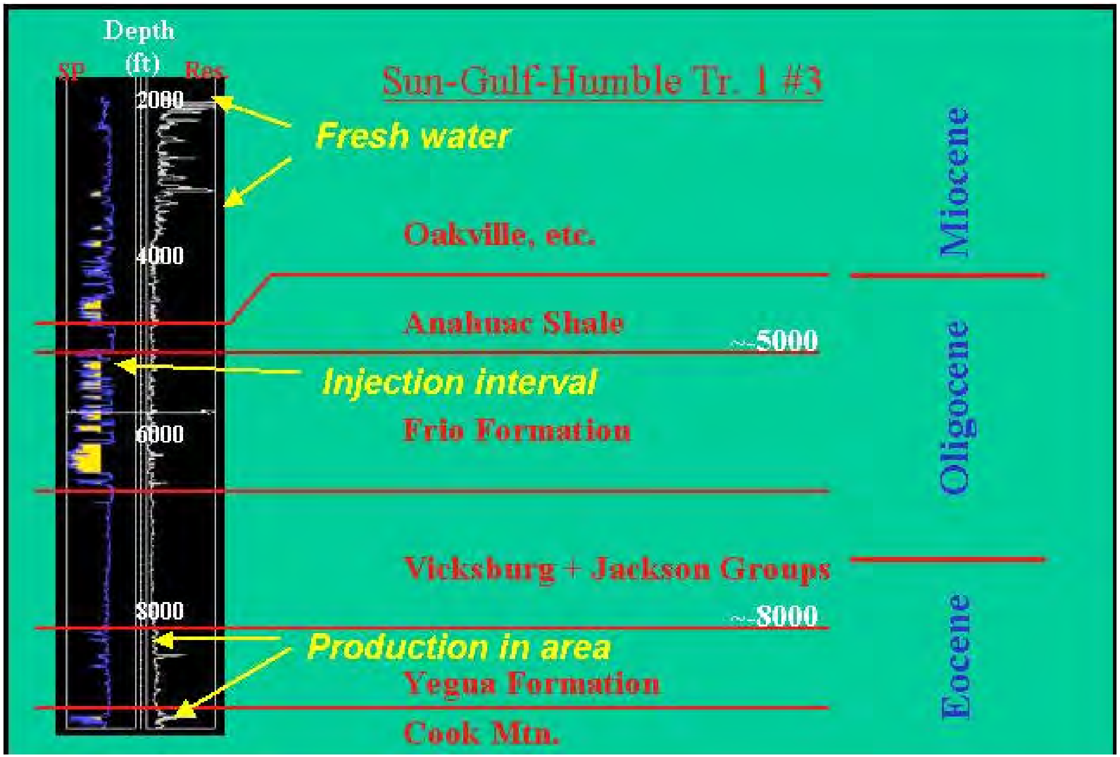

Figure 8. Type log from SGH 3 showing depth to the injection interval, underlying oil and gas production, and fresh-water aquifers substantially above the injection interval.

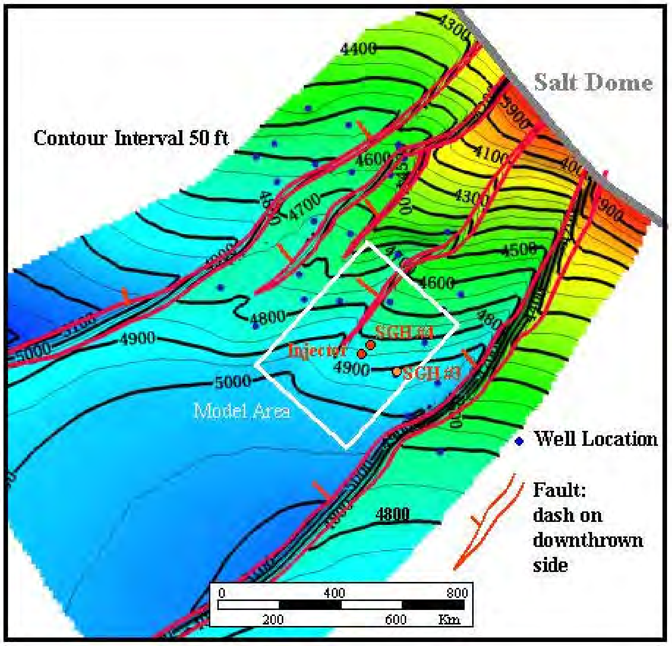

Figure 9. Structure-contour map of the southwest flank of the South Liberty salt dome, showing the relationship of experiment well locations to faults and the edge of the salt dome. The white rectangle indicates the extent of the numerical model. The contour interval is 50 ft.

Individual sandstones at the top of the Frio (the injection zone) range from less than 3 to more than 15 m (<10 to >50 ft) thick and are separated by laterally continuous shale beds from 1 to more than 4 m (3 to >15 ft) thick. Sandstones at the project site have been given informal letter designations, with "A" being the shallowest (Figure 10). CO_2 would be injected into the thicker "C" sandstone, and both the "C" and "B" sandstones would be monitored for response. Although hydrocarbons have been encountered in the "A" and "B" sandstones in nearby fault blocks adjacent to the salt dome, no indications of hydrocarbons have been found in logs from the "C" sandstone.

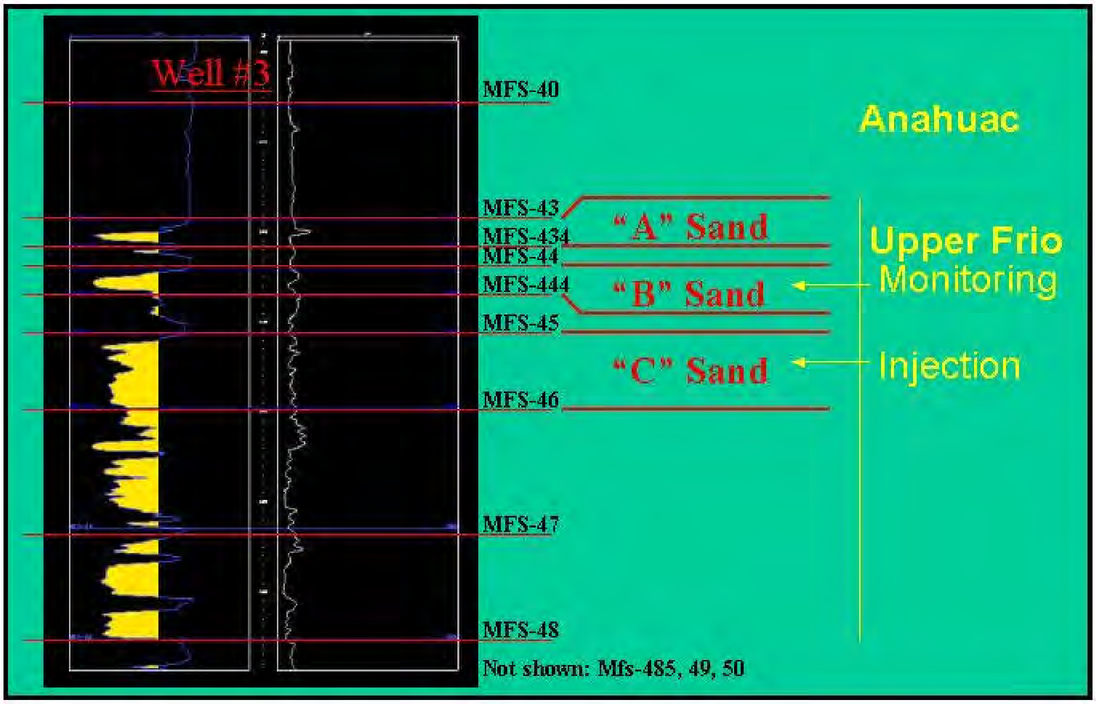

Figure 10. Detailed type log from SGH 3 showing interval nomenclature, correlated horizons, and sandstones (yellow on curve).

Sandstones are generally laterally continuous over 1 km (0.6 mi) or more and were deposited in fluvial and deltaic settings (Galloway and others, 1982). Sandstone framework compositions are dominantly subarkose to lithic arkose, having quartz compositions between 45 and 80 percent (Loucks and others, 1984). Regional formation-water salinity trends (Morton and Land, 1987) and log-derived, site-specific data indicate that these sandstones contain waters with more than 120,000 ppm of total dissolved solids. Log-derived porosities range from about 20 to more than 30 percent, averaging about 29 percent. Although no core from the area immediately surrounds the injection site, sandstones with similar log character but deeper depths in a cored well in adjacent Chambers County have permeabilities ranging from 50 millidarcies (md) to several darcies. Frio sandstones in the pilot area would be expected to have permeabilities of several hundred to nearly 1,000 md. Permeabilities would have a large impact on pressure response and distribution of the injected CO_2, as would residual gas saturations. On the basis of log-derived porosities and a porosity–residual-saturation relationship derived from the literature (Figure 11), residual-gas saturations for the injected CO_2 of approximately 30 percent would be anticipated. Residual saturations could be as low as 5 percent, which would be an end-member possibility in modeling. Pressures and temperatures in the injection interval would be expected to be about 151 bar (2,195 psi) and 66°C (151°F) on the basis of regional gradients of 0.099 bar/m (0.439 psi/ft) and 3.32°C/100 m (1.82°F/100 ft). Values would be measured in project wells during initial field activities to verify these estimates.

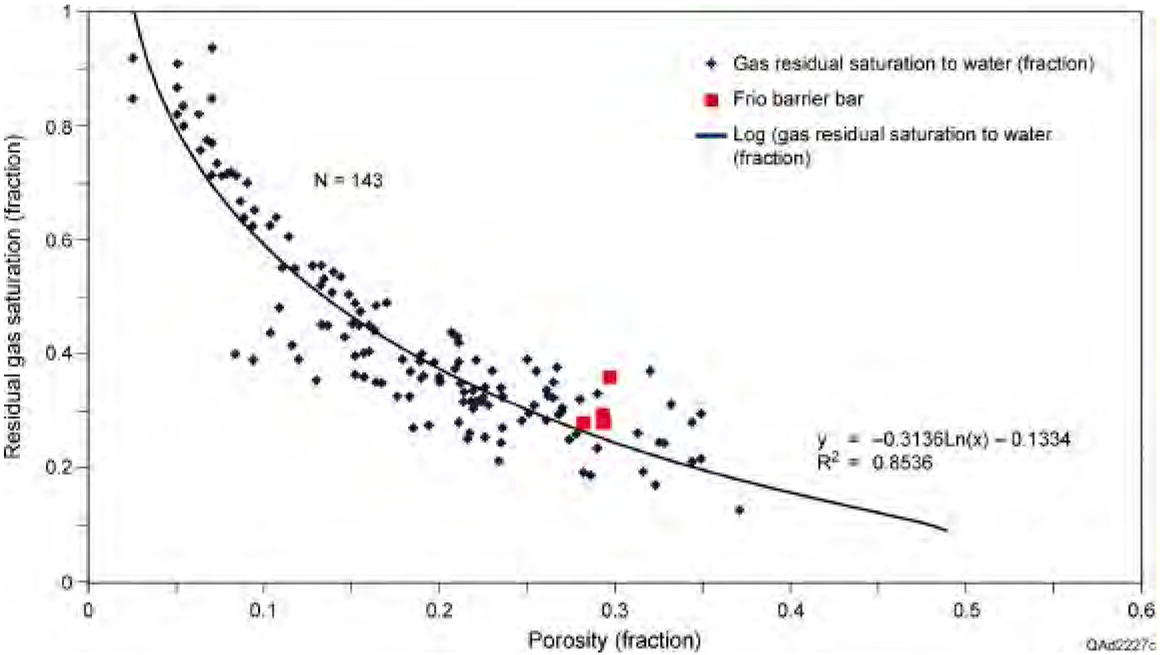

Figure 11. Cross plot of residual gas saturation and porosity, showing 140 data points collected from the literature and 4 data points from a Frio sandstone core recovered from a well about 32 km (~20 mi) south of the experiment site. The accumulated points indicate a logarithmic relationship with a high correlation coefficient of 0.85.

4.1.4 Groundwater

Fresh-water aquifers in the pilot area include the Alluvium and Beaumont, upper and lower Chicot, and Evangeline Formations (Dutton, 1990). The first and uppermost extends to the base of the Beaumont (see Dutton, 1990). The upper Chicot extends to the upper part of the Lissie, and the lower Chicot includes the remainder of the Lissie and Willis Formations (Figure 12; Carr and others, 1985). The Evangeline aquifer includes the Goliad and the upper part of the Fleming Formation (Dutton, 1990). The base of usable-quality water, defined as containing less than 3,000 mg/L (<3,000 ppm) total dissolved solids (TDS), is at a depth of about 670 m (~2,200 ft) (Baker, 1979). Below the Evangeline aquifer is the Burkeville confining unit near the middle of the Fleming Formation. Below this is the Jasper aquifer, which includes the lower part of the Fleming Formation and the upper part of the Oakville Formation (Figure 12; Baker, 1979). The base of potentially usable-quality water (also referred to as the base of the lowermost U.S. Drinking Water standard), defined as containing less than 10,000 mg/L (<10,000 ppm) TDS, is at a depth of about 1,035 m (~3,400 ft), which would be about 500 m (~1,600 ft) above the injection zone and separated from the injection zone by more than 75 m (>250 ft) of Anahuac Shale Formation.

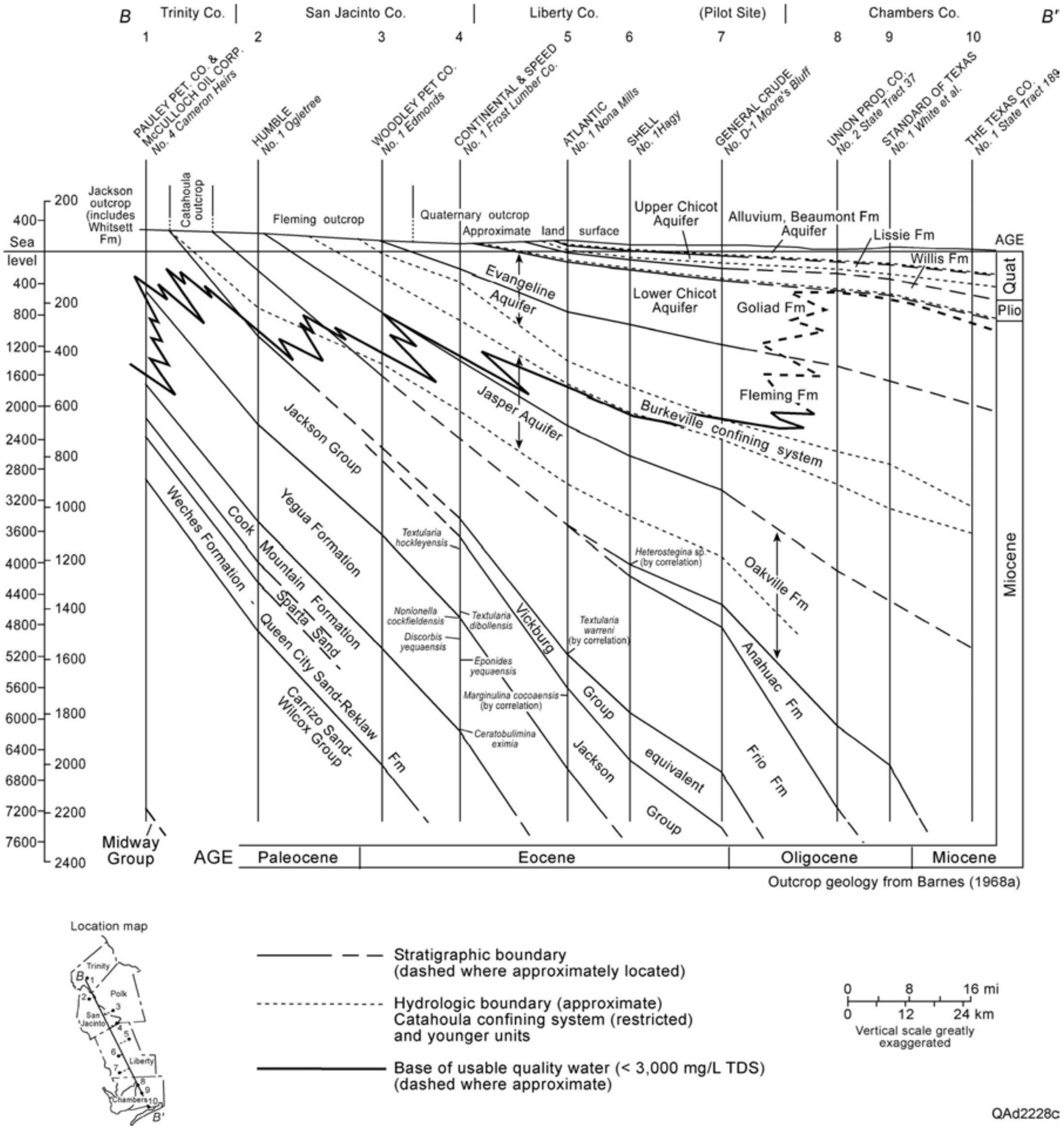

Figure 12. Dip-oriented regional cross-section through experiment site, showing relationship of stratigraphic units to hydrologic units. Modified from Baker (1979). Some stratigraphy and thicknesses for units above the Anahuac taken from Morton and others (1985), Galloway and others (1991), and Guevara-Sanchez (1974).

Depth to groundwater is uncertain and would be investigated prior to CO_2 injection. The amount of unsaturated section in the shallow subsurface would act as a buffer if CO_2 were to leak from the deep subsurface (see Section 4.2.3). Saturation profile most likely varies across the site area depending on season, geomorphic position, and surface elevation. Information from mapped soil types suggests that water-saturated soil lies less than 1 m below ground level at the sites for the injection and monitoring wells. With the interbedded sand/clay nature of the shallow subsurface, this shallow water would likely represent a perched water table. The nearest residential water well (well 64-02-102) would be about 1,250 m (~4,100 ft) northwest of the injection well. This well, which was drilled in 1972 to a depth of 73 m (240 ft), produces water from the Chicot aquifer. Water level in this well bore is 8 m (26 ft) below ground surface. If this aquifer is unconfined in this location, a substantial unsaturated zone could exist. Finally, the level of standing water in the adjacent Trinity River floodplain, commonly about 10m (~30 ft) below the project area, may indicate the approximate top of the saturated zone. Depth to water would be determined during drilling of initial shot holes for seismic data acquisition.

4.1.5 Climate

As part of the upper coast climatic province (Bomar, 1983), Liberty County experiences a warm, temperate, and humid climate. In January, historically the coldest month, temperatures range from an average low of 4.9°C (41°F) to an average high of 16.6°C (62°F) (Bomar, 1983). In July, historically the warmest month, temperatures range from an average low of 22.5°C (72°F) to an average high of 34.2°C (94°F) (Bomar, 1983). Temperatures fall below the freezing point of water an average of 11 times each year between the average date of the first freeze (December 6) and the average date of the last freeze (February 15). Recorded temperature extremes are a low of –15°C (5°F) in January 1940 and a high of 41.7°C (107°F) in August 1980.

Average wind vectors are from the north-northwest at 13 km/hr (8 mi/hr) in January, from the south-southeast at 14 km/hr (8.7 mi/hr) in April, from the south at 11 km/hr (6.8 mi/hr) in June, and from the east-southeast at 10 km/hr (6.2 mi/hr) in October (Bomar, 1983). Highest wind speeds occur during the approach and passage of cold fronts, which are most common from October through March. Extreme weather conditions are associated with the occasional tropical storm, which brings torrential rains, high-sustained winds, and tornadoes to the area. Hurricane season begins on June 1 and ends on December 1. Tropical storms are most common in the months of June, August, and September.

Average annual rainfall in the Houston area is 114 cm/yr (44.5 in/yr) (Bomar, 1983). The months of May and September have the highest historical rainfall averages.

4.1.6 Access

The pilot experiment site would be located on existing well sites accessed using privately owned lease roads in the active South Liberty oilfield. Access to the field would be provided from Texas Farm-to-Market Road 1409 between Dayton, where FM 1409 intersects U.S. Highway 90, and Mont Belvieu. The major transportation routes in this area are Interstate Highway 10, which passes about 15 km (~9.3 mi) south of the site, and U.S. 90, which passes about 7 km (~4.3 mi) north of the site. At the nearest point, FM 1409 would be about 1.3 km (~0.8 mi) southwest of the pilot experiment site.

The planned transport route for trucks carrying CO_2 to the pilot experiment site for injection would be from the supply plant in Texas City (Galveston County) onto Texas 146 (Figure 1). This major state highway passes through the cities of Texas City and Kemah in Galveston County, Seabrook, La Porte, and Baytown in Harris County, and Mont Belvieu in Chambers County, for a cumulative route distance of 55 km (34 mi). At Mont Belvieu, the route turns east onto Loop 207 for 1.3 km (0.8 mi) before turning east again onto FM 565 for a distance of 6 km (3.7 mi) to the intersection with FM 1409. The route turns north onto FM 1409 and continues to the lease road entrance 16.9 km (10.5 mi) from the intersection with FM 565. The total distance from the CO_2 supply plant to the pilot experiment site would be 79.2 km (49.1 mi).

4.1.7 Historical and Archaeological Resources

The Texas Archeological Research Laboratory (TARL), The University of Texas at Austin, is the curator of archaeological and historical sites for the State of Texas. Upon review of site maps and the location of the proposed experiment, TARL staff determined that, within one kilometer (0.6 mi) of the proposed delineated project area, no recorded archaeological or historical sites exist. TARL staff also confirmed that no sites registered as State Archeological Landmarks or listed in the National Register of Historic Places would be affected by the proposed project. A copy of the review request and the determination response letter are included in Appendix A. For additional assurance that neither historical nor archaeological resources would be affected by the pilot experiment, all work areas associated with the drilling pad, mud pit, and seismic tests would be surveyed by project archaeologists to ensure the absence of such resources before work is initiated.

4.1.8 Endangered Species

Staff from the Clear Lake Ecological Services Field Office of the U.S. Fish and Wildlife Service reviewed the experiment location and have determined that “no federally listed or proposed threatened or endangered species are likely to occur at the project site. The project site would not be located within officially designated critical habitat." Copies of the review request and the determination letter are included in Appendix A.

4.1.9 Flood Potential

The western margin of the floodplain from the Trinity River, which would provide the principal risk for flooding at the pilot experiment site, lies about 400 m (~1,300 ft) east of the site. The current channel of the river is about 2.7 km (~1.7 mi) east of the site. Normal and peak stream flows of the Trinity River in this area are relatively well known from operation of a stream-gauging station on the Trinity River at Liberty (U.S. Geological Survey station 08067000) since 1940.

The drainage area for the Trinity River above the Liberty stream-gauging station totals 45,242 km^2 (17,644 mi^2) (Dougherty, 1980). Maximum discharge measured at the Liberty gauge was 3,230 m^3/s (114,084 ft^3/s) on May 12, 1942, which corresponded to a gauge height of 8.955 m (29.37 ft). The gauge datum is 0.68 m (2.23 ft) below mean sea level. Thus, the peak flood elevation at Liberty, as reported by Dougherty (1980), since 1940 was 8.275 m (27.14 ft) above sea level. Dougherty (1980) stated that the 1942 discharge maximum was the greatest since at least 1903. The most recent discharge data in Dougherty (1980) are from 1975. In 1994, more recent data reported from the U.S. Geological Survey's National Water Information System (http://waterdata.usgs.gov/nwis/) show that peak discharge since 1975 was 3,823 m^3/s (135,028 ft^3/s), corresponding to a gauge height of 9.45 m (31.00 ft) and an elevation of 8.77 m (28.77 ft) above the 1929 National Geodetic Vertical Datum. Over the century represented by the pre- and post-1975 monitoring, the peak flood elevation was sufficient to inundate the lowland floodplain adjacent to the pilot experiment site at typical elevations of 2 to 6 m (6.5 to 20 ft) above sea level. However, water elevations of the Trinity River during the extreme floods of 1942 and 1994 were more than 10 m (>33 ft) below the land-surface elevation of about 20 m (~66 ft) above sea level at the pilot experiment site on the upland.

4.1.10 Wetlands

The pilot experiment site, which would be located in a low-relief, high-rainfall area on the upland adjacent to the Trinity River valley, would be near wetlands identified both in the *Atlas of the Submerged Lands of Texas* (White and others, 1985) and on wetland maps published by the U.S. Fish and Wildlife Service. White and others (1985) depicted the area around the pilot experiment site as an upland environment that is about 400 m (~1,300 ft) west of the Trinity River floodplain margin and elevated 14 to 18 m (46 to 59 ft) above it. Wetlands on the modern floodplain nearest the site are classified as WL (woodlands in fluvial areas), where water-tolerant trees and shrubs are found on river floodplains and in poorly drained areas, and as FH (high marsh), where fresh-water plants make up the vegetation assemblage.

National Wetlands Inventory maps (U.S. Fish and Wildlife Service, 1997; see Cowardin and others, 1979, for basis) depict the wetlands habitats at the pilot experiment site (Figure 13, at the 7.5-minute quadrangle scale). Mapped units at the site are classified as U (upland); adjacent and nearby mapped units are PFO1A, PEM1C, and PUBFx on the upland, PFO1C on the bluff, and PFO1/2F and PEM1F on the Trinity River floodplain adjacent to the site. The "U" classification, which encompasses the pilot experiment site (Figure 14A), denotes an upland environment (non-wetland). Unit PFO1A is mapped on the topographic upland adjacent to the "U" (upland) unit but is classified as a palustrine forested unit with broad-leaf deciduous trees (Figure 14B). The Palustrine System designation (units beginning with the letter P) includes "all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens" (Cowardin and others, 1979). Unit PEM1C is classified as a palustrine, emergent, persistent, and seasonally flooded wetland. Unit PUBFx, which is located about 200 m (~650 ft) west of the site, is classified as an excavated, semi-permanently flooded palustrine wetland with an unconsolidated bottom.

On the bluff between the upland and the Trinity River floodplain, unit PFO1C designates a palustrine wetland composed of broad-leaf deciduous trees that is seasonally flooded (Figure 15A). On the Trinity floodplain, unit PFO1/2F designates a forested palustrine wetland with broad- and needle-leaf deciduous vegetation that is semi-permanently flooded. The other nearby floodplain unit, PEM1F, denotes a persistent, semi-permanently flooded palustrine emergent habitat (Figure 15B).

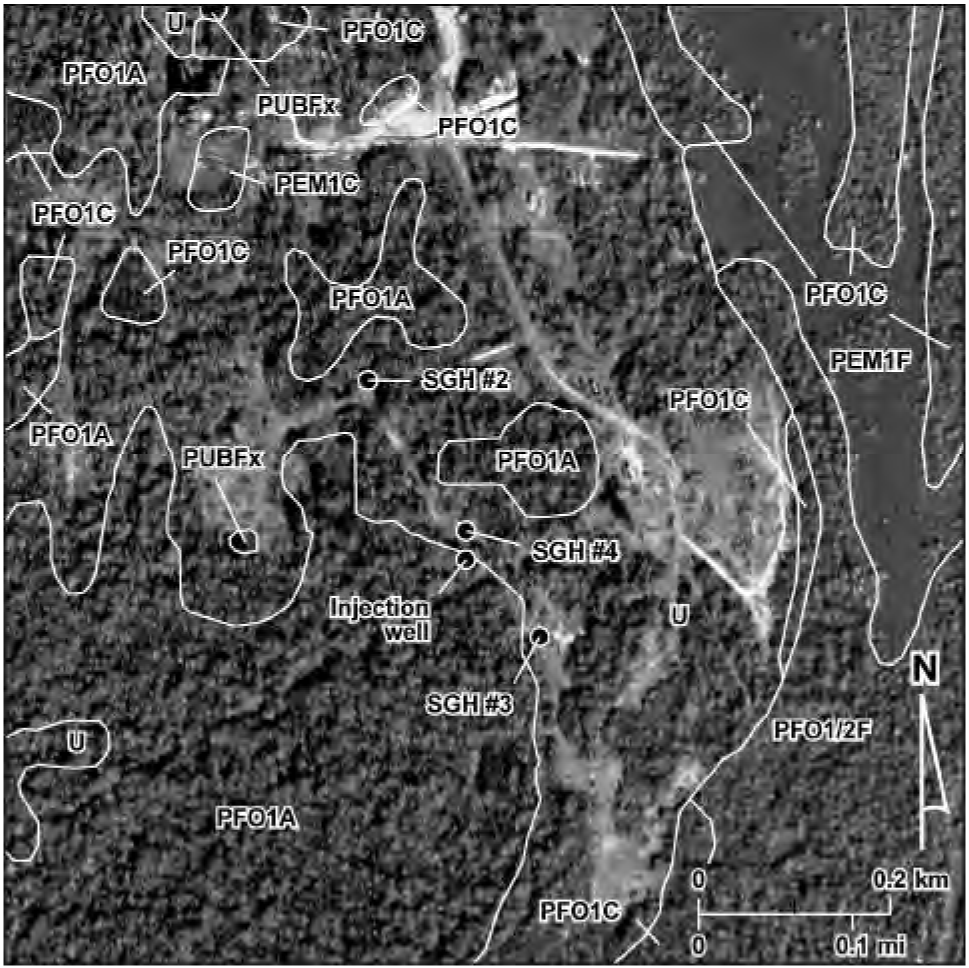

Figure 13. Distribution of mapped wetlands units at the experiment site. Wetlands units are those of the National Wetlands Inventory (U.S. Fish and Wildlife Service, 1997). PEM1C = palustrine, emergent, seasonally flooded; PEM1F = palustrine, emergent, semi-permanently flooded; PFO1A = palustrine, forested, broad-leaf deciduous trees; PFO1C = palustrine, forested, broad-leaf deciduous trees, seasonally flooded; PFO1/2F = palustrine, forested, broad- and needle-leaf deciduous trees, semi-permanently flooded; PUBFx = palustrine, excavated, semi-permanently flooded, unconsolidated bottom; and U = upland (non-wetland). Aerial photo base modified from Texas Natural Resources Information System.

Figure 14. Representative photographs of upland vegetation assemblages from the pilot experiment site and surroundings. (A) Upland environment ("U" classification) at the injection site. (B) Mixture of broad-leaf deciduous trees and evergreen trees (Unit PF01A) about 100 m (~330 ft) north of the pilot experiment site. Photos taken during February 2002.

Figure 15. Representative photographs of lowland vegetation assemblages near the pilot experiment site. (A) Unit PF01C, a palustrine wetland on the bluff between the upland area of the experiment site and the Trinity River floodplain. (B) Unit PEM1F, a semi-permanent flooded palustrine emergent habitat within the Trinity River floodplain, at the Sun Fee Lot 45 #1 well pad. Raised well platform accommodates occasional flooding. Photos taken during February 2002.

4.2 Environmental Consequences

Direct environmental effects at the Liberty County pilot experiment site could potentially result from (1) surface activities, (2) injection of agents into the subsurface environment, and (3) leakage of injected agents back to the surface or groundwater. As noted in Section 4.1, environmental resources associated with historic or archaeological properties; endangered, threatened, or listed species; critical habitat; wetlands; and floodplains do not exist at areas that would be affected by the proposed pilot experiment; thus, no adverse impacts on such resources would be anticipated. The description of pre-injection activities in Section 3.2.2 provides information on project requirements related to land disturbance and on materials that would be used and produced during well drilling activities, as well as disposition plans for produced materials. The well drilling operations required for the proposed pilot experiment would be identical in nature to ongoing activities within the South Liberty oilfield and would be performed by experienced personnel in full accordance with Texas Administrative Code and TCEQ requirements. No adverse effects would result. The risks of adverse impacts from proposed activities at the pilot experiment site would be low.

4.2.1 Surface Impacts

Traffic impacts from delivery of CO_2 to the site and removal of wastes to disposal facilities would be minor and similar to on-going drilling activities that occur in the South Liberty oilfield. Although the risks of significant surface leaks of CO_2 would be minor, the effects on human health if a release would occur could be significant. The presence of large volumes of compressed CO_2 during relatively short duration of CO_2 injection activities would represent a significant health and safety risk because of the high injection pressures (up to 168 bar or 2,454 psi) and asphyxiation hazard.

CO_2 is a nontoxic inert gas that is essential for fundamental biological processes in all living things (Benson and others, 2003). Exposure to elevated concentrations can cause adverse reactions. At exposures to concentrations between 3 and 5% (30,000 and 50,000 ppm), humans experience discomfort and impacts on respiratory rate. Loss of consciousness can occur from exposures to concentrations above 5% (50,000 ppm) and would occur within seconds from exposures to concentrations above 25 to 30%, at which point death would be imminent (Benson and others., 2003). CO_2 is denser than air and can concentrate in low-lying or confined areas if not dispersed or mixed with air by winds. Contingency plans in the unlikely event of a large-scale CO_2 leak would be prepared by Sandia Technologies, complete with an audible and visual warning system, escape procedures, and emergency notification plans. A site-safety training plan designed by a safety expert with substantial experience in CO_2 EOR operations would be administered to all on-site personnel. In addition, activities at the pilot experiment site would be staffed by trained personnel at all times when CO_2 is being stored or injected at the site. Relevant health and safety procedures, such as the Emergency Planning and Community Right-to-Know Act (EPCRA, or SARA Title III), would be followed.

Land use, air emissions associated with equipment operations, aesthetics, and noise related to project activities would occur over a short time duration, be intermittent in nature, or be consistent with previous and on-going activities at the South Liberty oilfield. No adverse impacts by the proposed pilot experiment from these environmental interactions would be anticipated.

4.2.2 Subsurface Impacts

Direct effects to the subsurface environment from introduction of CO_2 would have minimal environmental impact because of the relatively small volume introduced and the isolated nature of the setting. Introduced tracer materials would have negligible impacts because of the small volumes and benign nature of the materials. Table 5 lists the chemicals that could be used as tracers and identifies potentially harmful effects. The candidate tracers include perfluorocarbons and noble gases. MSDS sheets for these materials are provided in Appendix B. None of the tracer materials are listed in 40 CFR 261 Subpart D as hazardous materials.

Table 5. Tracer materials to be used and their concentrations

Tracer	Concen-tration (Injectate)	Concen-tration (Produced Fluids)	Maximum total weight	Comments
FLUTEC-TG PMCH (perfluoromethylcyclohexane)	30 µg/mL (30 ppm)	1 ng/mL (1 ppb)	Perfluoro-carbons: 60 kg total.	No known human- or eco-toxicity
FLUTEC-TG PTMCH (perfluoro-1,3,5-trimethylcyclohexane)	30 µg/mL (30 ppm)	1 ng/mL (1 ppb)	Perfluoro-carbons: 60 kg total.	No known human- or eco-toxicity
FLUTEC-TG o-PDMCH (perfluoro-1,2-dimethylcyclohexane)	30 µg/mL (30 ppm)	1 ng/mL (1 ppb)	Perfluoro-carbons: 60 kg total.	No known human- or eco-toxicity
FLUTEC-TG m-PDMCH (perfluoro-1,3-dimethylcyclohexane)	7 µg/mL (7 ppm)	0.2 ng/mL (0.2 ppb)	Perfluoro-carbons: 60 kg total.	No known human- or eco-toxicity
FLUTEC-TG p-PDMCH (perfluoro-1,4-dimethylcyclohexane)	7 µg/mL (7 ppm)	0.2 ng/mL (0.2 ppb)	Perfluoro-carbons: 60 kg total.	No known human- or eco-toxicity
FLUTEC-TG PMCP (perfluoromethylcyclopentane)	30 µg/mL (30 ppm)	1 ng/mL (1 ppb)	Perfluoro-carbons: 60 kg total.	No known human- or eco-toxicity
FLUTEC-TG PDMCB (perfluorodimethylcyclobutane)	7 µg/mL (7 ppm)	0.2 ng/mL (0.2 ppb)	Perfluoro-carbons: 60 kg total.	No known human- or eco-toxicity
FLUTEC-TG PECH (perfluoroethylcyclohexane)	7 µg/mL (7 ppm)	0.2 ng/mL (0.2 ppb)	Perfluoro-carbons: 60 kg total.	No known human- or eco-toxicity
^{20}Ne (Neon 20)	30.3 ppm	Variable	0.63 kg	No known human- or eco-toxicity
^{36}Ar (Argon 36)	164 ppm	Variable	3.42 kg	No known human- or eco-toxicity

^{84}Kr (Krypton 84)	7.64 ppm	Variable	0.16 kg	No known human- or eco-toxicity
^{132}Xe (Xenon 132)	0.4 ppm	Variable	0.01 kg	No known human- or eco-toxicity
Eosin	1 ppm	5 ppb	10kg	No known human- or eco-toxicity

Perfluorocarbons are used in human medical treatments, and noble gases are chemically inactive. A maximum total of 60 kg (132 lb) of perfluorocarbon tracers would be used during the experiment, with maximum concentrations in the injectate of 30 μg/mL (30 ppm) and concentrations at the monitoring well at the radial distance of 30 m (100 ft) expected to be lower than 1 ng/mL (1 ppb). A maximum of 4.22 kg (9.33 lb) of noble gases would be used. Concentrations in the injectate would range from 0.04 to 164 ppm, depending on the gas type. Concentrations at the monitor well would vary from 100% of the gas phase initially to no measurable concentration several days after injected gases reach the monitor well. Eosin fluorescent dye has been approved for use in groundwater tracing and has been widely used in drinking water and environmentally sensitive areas. Less than 10 kg would be added to the hydrologic test brine before re-injection to the subsurface and would result in concentrations ranging from ppm levels in the injectate to ppb levels at the monitoring well.

Shot holes used for the 3-D VSP would leave minor amounts of residue within shallow saturated zones. A biodegradable explosive such as Dynoseis®, which contains sodium perchlorate and diethylene glycol, would be used instead of more traditional and less expensive, but potentially more harmful, explosives such as Pentalite. Shot holes would be filled following use, and the soil would be compacted.

4.2.3 Potential Leakage Impacts

Risks associated with return of injected CO_2 to groundwater or the surface would be low. The injection zone would be overlain by a 75-m-thick (250-ft) shale seam and approximately 1,375 m (~4,500 ft) of interbedded sandstone and shale that would serve as alternating barriers to vertical migration and sinks for any escaped CO_2. Incremental pressures throughout the injection phase would be controlled and below regulatory limits established by TCEQ, in adherence to U.S. Environmental Protection Agency rules. The limits are designed to prevent migration of injected fluids out of the injection zone over a 10,000-year period. Numerical modeling indicates that CO_2 would not travel more than 200 m (>650 ft) from the injection well. Under pilot experiment conditions, faults would not be conduits for fluid or gas escape. Monitoring, which would be the central focus of the pilot experiment, would be performed to assure that the CO_2 in the subsurface would behave as predicted. Pre-injection engineering and during-injection monitoring would be conducted to provide assurance that the wells would perform as planned and would not leak fluids or gases. In the unlikely event of a leak, project activities and well data would be re-examined to identify causes and apply corrective measures.

To evaluate the potential impact of a leak at a theoretical site where these assurances would not be present, the fate and transport of a release from the injection interval equivalent to 10% of the total CO_2 injected was investigated. The most likely scenario is that the rising gas would be retained by capillary forces and residual saturation effects in the pores of the sandstones through which it ascends. If the gas was to rise along a conduit in which little contact with porous rock occurred, a significant percentage could reach either the groundwater or the ground surface.

If the CO_2 were to ascend into an aquifer, impacts would be minor. Dissolution of CO_2 in water would decrease pH (increases acidity) slightly. Chemical reactions between the acid waters and the surrounding rock would moderate this reaction, thus limiting pH changes. Modeling by LLNL (K. Knauss, LLNL, personal communication) indicates that pH would be reduced from 6.74 to 5.28 for a radial distance of less than 20 m (<65 ft) from the leak point, assuming an aquifer of 6-m (20-ft) thickness, salinity of <1,000 ppm, and rate of leakage equivalent to rate of injection. A statewide database of water well locations maintained by the Texas Water Development Board records no water wells within 1 km (0.6 mi) of the proposed injection well. The nearest known residential water well (well 64-02-102) is located on the Pleistocene upland, about 1,250 m (~4,100 ft) northwest of the injection well. This well, which was drilled in 1972 to a depth of 73.2 m (240 ft), produces water from the Chicot aquifer. A field survey would be conducted prior to injection operations to locate any undocumented water wells within a 402-m (0.25 mi) radius of the injection well. Any wells within this area would be monitored for changes in pH during the pilot experiment. Three monitoring wells would be drilled near the injection well to monitor shallow groundwater.

In the unlikely event that CO_2 were to ascend to the ground surface, impacts would be minor. Numerical modeling by Oldenburg and others (2002a, b) demonstrates that CO_2 rising from the subsurface would collect in the unsaturated zone and spread laterally, accumulating to nearly 100% vapor concentration in the shallow soil because the density of CO_2 is greater than the density of air. Only when the unsaturated-zone pore space becomes filled with CO_2 would significant flux to the atmosphere occur (Oldenburg, 2002a). Under conditions of significant leakage, topographic lows and enclosed subsurface structures such as basements could accumulate significant concentrations of CO_2 from the unsaturated zone. Any such points within 400 m (0.25 mi) of the experiment site would be identified and monitored during and following CO_2 injection.

Increasing concentrations of CO_2 in soil gas could forewarn of a potential flux to the atmosphere. The grid of groundwater and soil-gas sample points to be established on the well pad and at other potential leak sites (see Section 3.2.2) would be monitored throughout the injection and post-injection phases.

At the end of the chain of unlikely events is the possibility that CO_2 might seep into the atmosphere, which could be triggered by high flux rates through groundwater or limited pore space in the unsaturated zone that results in filling the unsaturated zone and creating flux to the surface. Oldenburg and others (2002a) modeled a scenario where subsurface flux rates equivalent to 10% of project volumes returned to the surface over a 1-year period. Under such conditions, the CO_2 concentrations at ground level near the leak site would be nearly 100% but would dissipate to background atmospheric concentrations within about 28 m (~90 ft) in wind speeds typical of the proposed location for the pilot experiment (7.2 km/hr).

As shown in Table 5, perfluorocarbon and noble gas tracers that would be used in the pilot experiment have no known toxicity. Due to their lack of toxic character and proposed low concentrations, tracer agents that might leak to the groundwater or the surface would be expected to result in negligible impacts.

5.0 REGULATORY COMPLIANCE

5.1 State Permitting Requirements

State permitting requirements were discussed with the two Texas agencies that would be expected to have jurisdiction over the drilling and injection activities envisioned for the proposed pilot experiment. Discussions regarding State regulatory requirements were held with personnel responsible for regulation of Underground Injection Control (UIC) at the Railroad Commission of Texas (RRC) and UIC Permits at the Texas Commission on Environmental Quality (TCEQ).

The UIC program encompasses of five classes of wells, from I to V, each generally requiring a permit for operation under Texas Water Code, Chapter 27, and Texas Health and Safety Code, Chapter 361 (Class II wells fall under different codes). Federal guidelines for UIC wells have been established by the U.S. Environmental Protection Agency (EPA). The TCEQ and the RRC have been delegated authority by EPA to administer UIC programs in Texas, which are at least as stringent as those implemented by EPA. Additional rules governing the various classes can be found in Title 30 of the Texas Administrative Code, Chapter 331, with supporting information and rules in Chapters 1–100, 281, and 305. Class I wells are used for long-term injection of hazardous and non-hazardous wastes and are permitted by the TCEQ. Class II wells are designated for injection of water or other chemicals into existing oil and gas reservoirs or injection of oilfield wastes into non-reservoir intervals and are permitted by the State oil and gas regulatory agency (RRC). UIC Class III is reserved for wells that inject fluids for extraction of minerals other than oil and gas. The Class IV category applies to wells that dispose of hazardous wastes above formations that contain underground sources of drinking water and are generally prohibited. Class V wells are those that are not included in Classes I through IV. Class V wells have numerous purposes, ranging from disposal of storm runoff and motor vehicle waste to aquifer recharge and remediation. One Class V category covers “experimental” wells for subsurface fluid distribution, under which the proposed pilot experiment would be expected to be permitted.

Because the injection interval would not be an oil or gas reservoir, and because the source of the injected CO_2 would be post-refinery, the pilot experiment would fall under the jurisdiction of the UIC program at TCEQ. Discussions with TCEQ regarding the short duration of the experiment and the small volume of gas proposed for injection resulted in a request by TCEQ for an application for a Class V well, accompanied by a report providing relevant additional information typically required in Class I filings. A public information meeting, wherein local citizens, public officials, local and regional political representatives, and other interested stakeholders would be invited to review the project plan and provide nonbinding comments, would be required and hosted by the Bureau of Economic Geology. Public comments would be considered, and any appropriate adjustments to the field activities would be made.

The TCEQ Class V application would include responsible-party contact information, well-site information, downhole design, and a review of hydrogeological data, including information about formation water chemistry, relationship to aquifers, and locations of injection or water wells within a one-quarter-mile radius. The additional report required by the TCEQ would include the following:

- a detailed land-ownership map with contact information,
- additional detailed site information (relationship of the site to government entities and jurisdictions),
- contact information for local government agencies and political representatives,
- financial assurance for site closure,
- a concise description of the geologic and hydrogeologic setting,
- engineering drawings and plans for surface and subsurface equipment approved by a registered professional engineer,
- a discussion of injection zone mechanics that includes flow-simulation model results indicating expected changes in pressure and injectate saturations through time,
- an Area-of-Review (AOR) study documenting all wells within 402 m (0.25 mi) of the pilot wells and their current conditions,
- a discussion of injected fluids and their expected reactivity with formation and construction materials, and
- a letter from the RRC indicating that activities would not adversely affect any known hydrocarbon accumulations.

6.0 CUMULATIVE AND INDIRECT EFFECTS AND LONG-TERM ENVIRONMENTAL CONSEQUENCES

Cumulative impacts result from the incremental impact of a proposed action when added to the impacts of other past, present, and reasonably foreseeable future actions. Cumulative impacts include direct impacts that occur at the same time and place as the proposed action and indirect impacts that can occur later in time or farther in distance from the site of the proposed action. Direct cumulative effects of the proposed project, as described in Section 4.2, would be limited because of the short duration of field activities and would be expected to span only several months, with CO_2 injection being performed over a time period lasting less than 2 months. Indirect cumulative effects would predominantly relate to long-term fate of the injected CO_2.

6.1 Direct Cumulative Effects

Direct cumulative effects would include impacts of CO_2 transportation, traffic and capacity impacts associated with disposal of produced water, impacts on flora and fauna of proposed field activities, and noise- and light-pollution impacts of nighttime operations.

Cumulative transportation impacts would be minimal, since the 10 CO_2 truck shipments per day during the comparatively short injection phase would be minor in comparison to the moderate to heavy commercial, agricultural, industrial, and private traffic volume that is currently experienced on planned routes. Transport during heavy commuting hours would be avoided along Highway 146 between Seabrook and the east end of Baytown to further minimize effects.

Disposal of less than 30 truckloads of produced brine, a non-hazardous material, over the duration of the project would entail an approximately 22.5-km (~14-mi) drive along public rural roads. A maximum of 595 barrels (5 truckloads) of produced water would undergo disposal each day into a commercial UIC Class I non-hazardous disposal well that has a disposal capacity of up to 950,000 gallons per day and that typically receives other deliveries amounting to less than 150,000 gallons per day. A maximum of 7,000 barrels (bbl) (60 truckloads) of drilling fluids would undergo disposal at a TCEQ-permitted disposal facility approximately 48 km (30 mi) from the experiment site. Drilling-fluid disposal would be spread over at least 6 days, thus reducing traffic impacts. The disposal well has a capacity of 20,000 bbl/day with a typical use of 1,200 bbl/day, or 6% of disposal capacity. Delivery of an average load of 1,166 bbl/day during the 6-day delivery period would approximately double the use level of the disposal well to about 12% of daily disposal capacity, which would not create any adverse cumulative impact on the disposal facility.

Cumulative effects to flora and fauna would be minor and local. The project would impact less than 2 additional hectares (5 acres) of land surface in an oilfield where exploration and development activities span an area of 6,980 hectares (17,280 acres).

Drilling, work-over, and CO_2 injection activities could occur at night. Associated light and noise impacts would be minimized by the 0.6-km (0.35-mi) distance between the well site and the nearest residence and the limited duration of intensive drilling and injection activities.

6.2 Indirect and Indirect-Cumulative Effects

Indirect cumulative effects include the long-term fate of injected CO_2, the post-project disposition of the three wells used, the potential for increased drilling and land use in the project area associated with potential project success, and the impacts of increased sequestration activities throughout the U.S.

6.2.1 Fate of Injected CO_2

A primary goal of the proposed pilot experiment is to document the fate of injected CO_2. Numerical modeling and accumulated knowledge on the behavior of fluids and gases in the subsurface suggest that the CO_2 would remain within the injection zone and travel less than 200 m (650 ft) from the injection well (Doughty and Pruess, 2003). Alternative models have been constructed to investigate possible but unexpected scenarios, including upward leaks that might occur (1) through overlying formations, (2) along well-bore annuli, and (3) along faults. Factors that diminish leakage risks would include (1) the presence above the injection zone of the 75-m-thick (250-ft) Anahuac Shale, which possesses documented capability to retain gases for geologic time spans, and the overlying 1,475-m-thick (4,500-ft) section of interbedded sandstones and shales, (2) the presence in well-bore annuli of remnant drilling mud with a density sufficient to contain anticipated pressure increases outside the 402-m (0.25-mi) Area of Review (AOR) established by TCEQ, and (3) planned maximum fluid pressures that would be 22 percent below the pressure required to induce seismicity and fault leakage. No adverse risks to human health, safety, or the environment would result from these alternative scenarios. Numerical models would be refined using site-specific data after field activities begin but before any CO_2 would be injected.

Subsurface numerical models were constructed at Lawrence Berkeley National Laboratory using the TOUGH2 code (Doughty and Pruess, 2003). The models incorporate reasonable scientific assumptions (Pruess and others, 1999; Holtz, 2003) and geologic assessments based on regional knowledge of the injection horizon (Doughty and others, 2001; Hovorka and others, 2000; Doughty and Pruess, 2003) and site-specific geotechnical data derived from well logs and a 3-D seismic survey (Figure 16). Knowledge of subsurface fluid behavior is available from the multitude of engineering and geologic studies conducted to determine subsurface-oil and gas-reservoir characteristics.

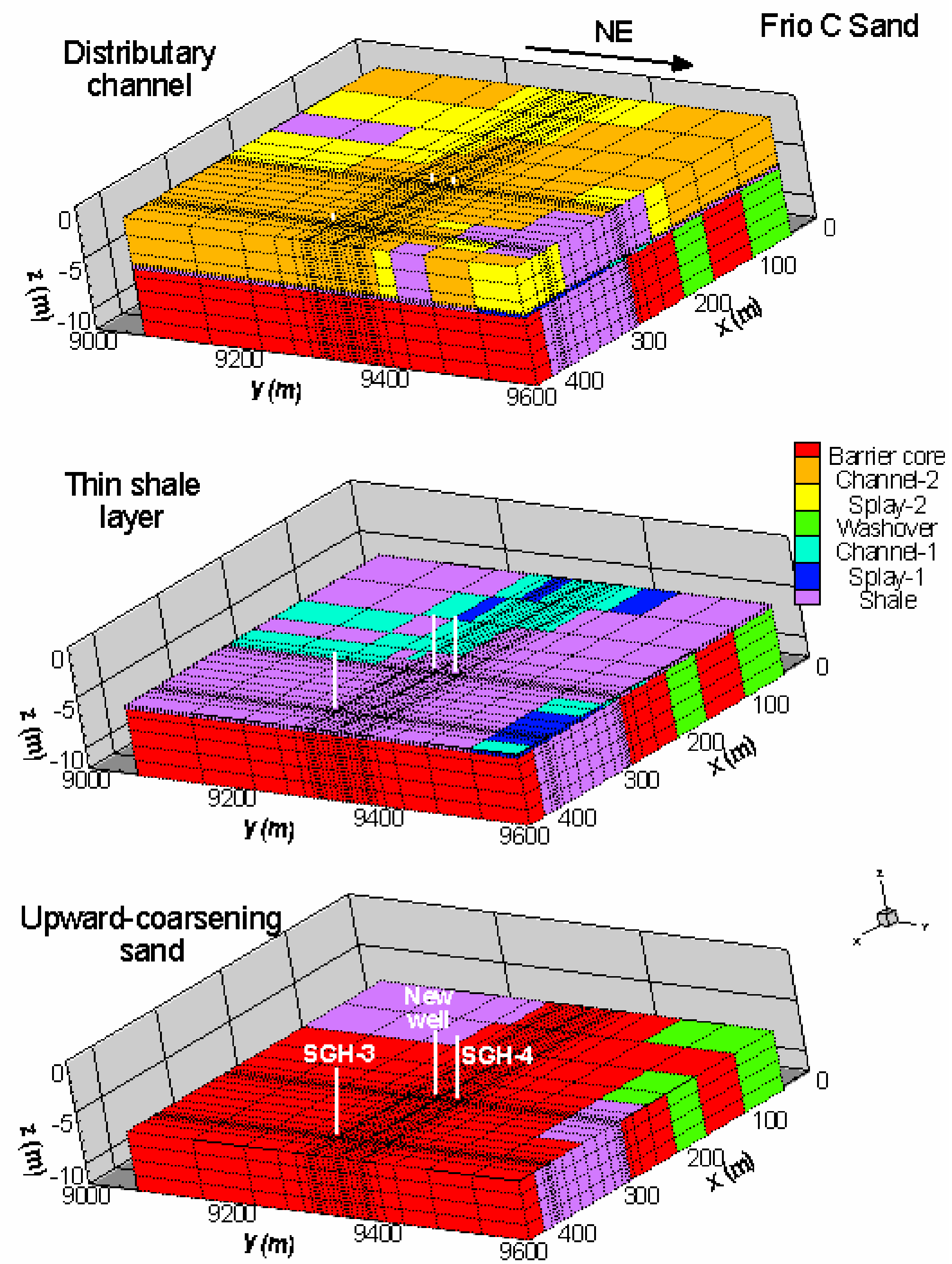

Figure 16. Numerical simulation model construction parameters for the "C" sand (injection interval). A thin shale in the middle of the sandstone separates a lower upward-coarsening sandstone deposited in a probable delta front setting from a dominantly upward-fining sandstone deposited in a distributary channel. North is toward the right side of the images. Grid refinement around well bores allows greater detail in imaging injection response. Simulation grid prepared by Christine Doughty, LBNL.

Models show that the CO_2 injected into the subsurface during the experiment would behave buoyantly because of its low density (0.6 grams/cm^3) compared with that of native formation brines (1.075 grams/cm^3). The buoyant plume of concentrated immiscible CO_2 would migrate updip within the injected stratigraphic interval toward the salt dome (Figure 9). Some percentage of the CO_2 would remain behind the migrating plume, because it would be trapped in rock pores by capillary behavior and relative permeability effects (Wardlaw, 1982; Holtz, 2002). Holtz (2003) indicated that, for the ranges of porosities in the injection interval, as much as 30% of the pore space would sequester the CO_2 in what is termed *residual saturation*. Numerical flow simulation models constructed on this basis suggest that the plume would stop moving entirely within 5 years after moving less than 200 m (<650 ft) updip (Figure 17). The CO_2 would remain in place at least until local geologic conditions change significantly, a time period expected to exceed 1,000 years.

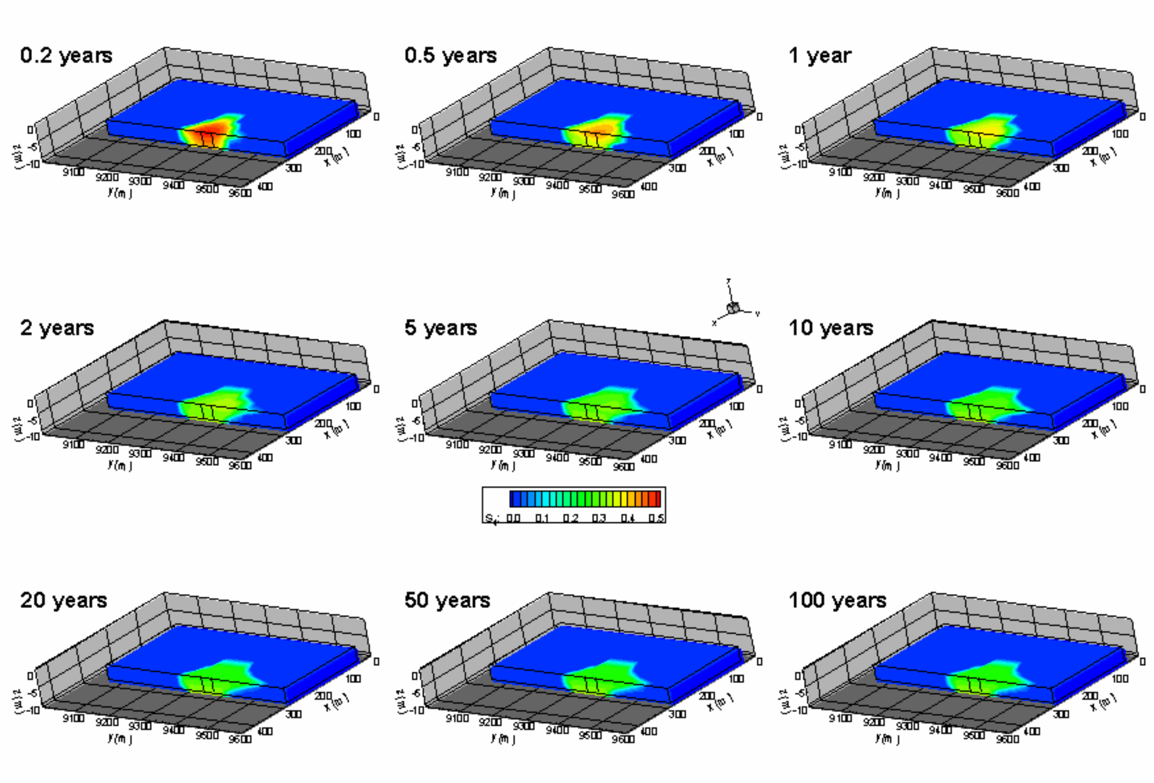

Figure 17. CO_2 saturation distributions around the injection well from 0.2 to 100 years after starting injection. The model uses best estimates of porosity and residual gas saturation. The model block is tilted up toward the northeast. Note that very little movement of the plume would occur after the initial injection period. Simulation results from TOUGH2 prepared by Christine Doughty, LBNL.

If the current understanding of residual saturation behavior or subsurface pressure conditions is inaccurate, the CO_2 could continue migrating updip to the north within the injection interval. The faults to the northwest and southeast of the injection well would focus the CO_2 plume as it moves up and is trapped against the salt dome. Such a scenario could be produced, as shown by numerical modeling, if residual saturation were actually 5%, as opposed to the 30% estimated (Figures 18 and 19).

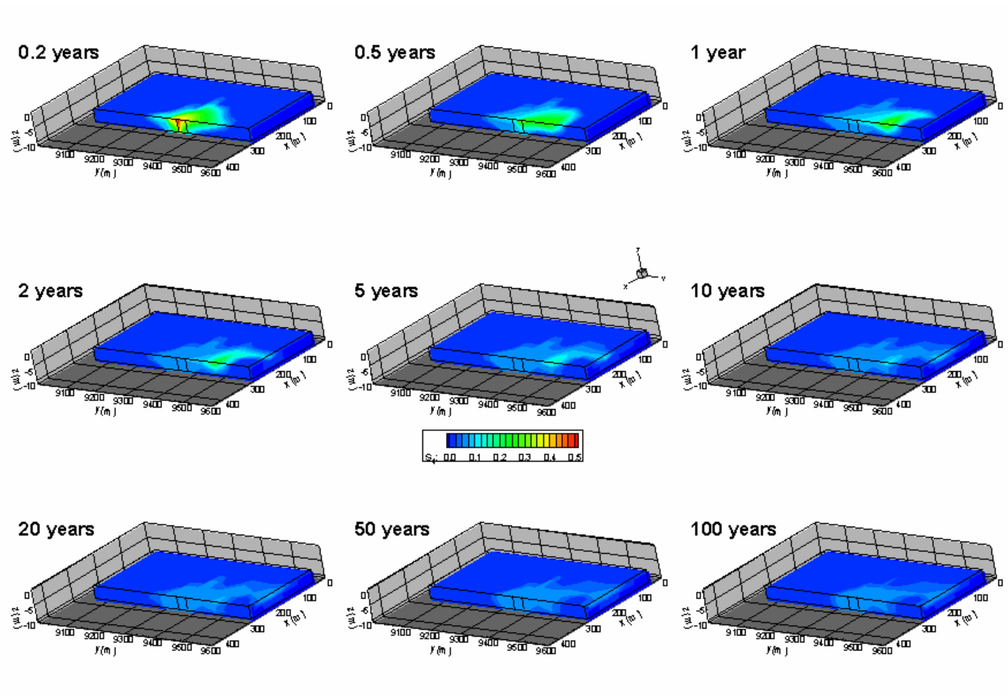

Figure 18. CO_2 saturation distributions around the injection well for low-residual gas saturation case from 0.2 to 100 years after starting injection. The model uses best estimates of porosity and a maximum of 5% residual gas saturation. The model block is tilted up toward the northeast. Note that the plume continues to migrate updip for perhaps 10 years before being immobilized by the residual gas saturation effect. Simulation results from TOUGH2 prepared by Christine Doughty, LBNL

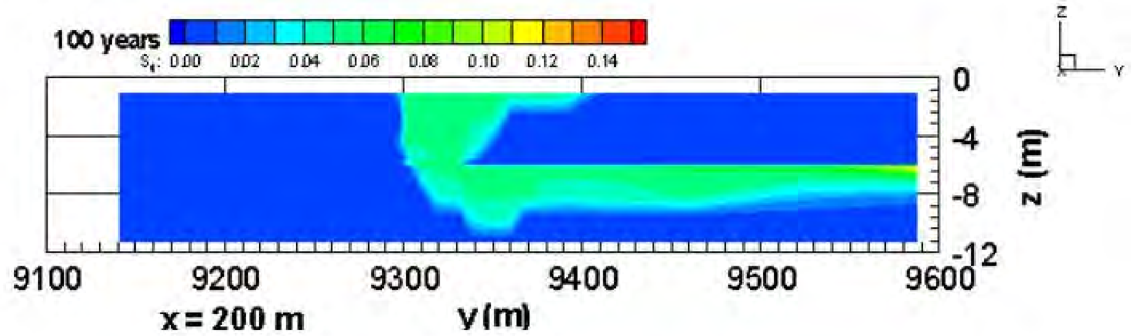

Figure 19. CO_2 saturation distributions in northeast-southwest (dip) section cross-sectional view of injection zone for low-residual gas saturation case at 100 years after starting injection. Updip is to the right in this section through the center axis of the model. CO_2 has escaped from the lower half of the "C" sandstone through a theoretical break in a thin shale midway up the sandstone body. Only the CO_2 plume in this half of the sandstone has sufficient volume to continue migrating to the updip end of the model. Simulation results from TOUGH2 prepared by Christine Doughty, LBNL.

With a mobile CO_2 plume, the dominant risk would be that the plume might encounter a conduit leading up and out of the injection zone. Possible conduits include (1) cross-formational flow (discontinuous seal), (2) well-bore annuli, and (3) faults, including the interface between the formation and the salt dome. Each possible conduit is unlikely, for the following reasons:

- In addition to the two 3-m-thick (10-ft) laterally continuous shales separating the injection zone from overlying sandstones in the Frio Formation, the injection zone would be overlain by the 75-m-thick (250-ft) Anahuac Shale. This shale has retained both oil and gas over geologic periods of time at the South Liberty Salt Dome, as evidenced by the presence of oil and gas reservoirs in the uppermost Frio sandstones (Halbouty, 1962). Additionally, maximum subsurface pressures during the pilot experiment, based on LBNL models, would be 169 bar (2,469 psi), or 35% below the fracture pressure as calculated by the Eaton method (Eaton, 1969).

- Well bores within the 402-m (0.25-mi) Area of Review (AOR) established by the TCEQ would be assessed for proper completion or abandonment using RRC file data and would be remediated if found to be noncompliant. Annuli of surrounding wells outside the AOR should be filled with 9 lb/gal drilling mud that would be present in the well before emplacement of casing. Incremental formation pressures outside the AOR during the pilot experiment of less than 10 bar or 146 psi would be 12% below the Critical Incremental Pressure of 11.4 bar (166.4 psi) required to overcome the hydrostatic head of the mud column. This rationale for assessment of upward leakage potential was established by TCEQ for UIC operations. Adherence to these conditions is a prerequisite for approval of a Class V well application. For a Class V well to qualify for a TCEQ permit, wells within the AOR must have cemented casing emplaced below the base of Usable Quality Groundwater (TDS < 3,000 ppm). In the unlikely event that CO_2 pressure might overcome mud-column heads in the annulus of the injection well, the cemented casing would prevent the gas from entering aquifers.

- Ambient confining pressures keep faults at depths greater than 1 km (~ 3,000 ft) closed to fluid migration unless fluids are injected into the fault plane at excessive fluid pressures (Rasmussen, 1997) or unless the fault slips (Hooper, 1991). A lack of fault scarps at the surface in the vicinity of the proposed pilot experiment indicates that faults in the area have not been active in the recent geologic past. Injection-induced excess fluid pressures can reactivate faults (Wesson and Nicholson, 1987). However, the maximum fluid pressure of 169 bar (2,469 psi) associated with the proposed experiment would be 22% below the 264 bar (3,853 psi) calculated by the Wesson and Nicholoson (1987) method as likely to induce seismicity.

- If unforeseen events were to occur and the CO_2 gradually escaped to an aquifer or to the surface, the impacts would be minor and limited in geographic extent. The conditions of immediate escape of CO_2 were addressed previously in Section 4.2. Events that occur over longer periods of time would have reduced impact compared to the impacts previously described in Section 4.2. Following completion of injection, subsurface pressure anomalies would decay as the pressure pulse becomes absorbed by the surrounding formation volume. Any potential for rapid leakage would be reduced as the CO_2 plume spreads and pressure declines. Gradual leakage, if it occurs, would be at substantially reduced rates, increasing chances for broad, slow dispersion in water-saturated sediments or near-surface soils, thus reducing the possibility for CO_2 buildup to dangerous levels in the air around the pilot experiment site.

As discussed previously in Section 4.2, groundwater-dissolved gases and soil gases would be monitored for increases in CO_2 above baseline values. This monitoring would be decreased in frequency as measurable pressure and temperature effects in the subsurface decay over time. Monitoring would cease when asymptotic values of change occur, which would be expected to occur within 1 year after the end of injection.

6.2.2 Post-project Well Disposition

Following project completion, the three wells used during the pilot experiment would be abandoned, in accordance with Rule 14, section 3.14 of the RRC “Statewide Rules for Oil, Gas, and Geothermal Operations,” or converted to another use authorized by RRC and TCEQ. Neither of these alternatives would have adverse indirect or cumulative effect on the South Liberty oilfield, where similar activities are routine for the hundreds of existing wells in the field.

6.2.3 Increase in Sequestration Activities in the Pilot Area

The site proposed for the pilot experiment was selected because it possesses suitable technical attributes for a small-scale project. Success of the pilot experiment could increase interest in larger projects, perhaps in the same geographic area. Any such project would require considerable further study, including assessing potential environmental impacts and obtaining appropriate permits.

6.2.4 Increase in Domestic Sequestration Activities

With successful conduct and completion of the proposed experiment and other sequestration studies, government and industry would be expected to have access to sufficient information for considering future activities involving management of atmospheric CO_2

concentrations through geologic sequestration. Estimates of operating costs dictate that any large-scale CO_2 sequestration activity would need to occur in an area near major CO_2 sources. Many of these areas would be likely to involve existing oil and gas fields, where impacts would be incremental and minimal. At locations where CO_2 sources are present but oil and gas fields are absent, sequestration options could include (1) piping or trucking the CO_2 to some distant location where an existing oil or gas field could be used for sequestration or (2) drilling a well to inject CO_2 into a brine-bearing formation locally. Economic and logistical lessons learned from the proposed pilot experiment would help determine the comparative feasibility of these approaches.

7.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Principal resources required for the proposed CO_2 injection and monitoring experiment would comprise: (1) the materials (steel, water, and cement) needed to drill a new injection well and refit the existing monitoring wells; (2) the CO_2 required to create the subsurface plume; (3) the fossil fuels consumed in drilling, refitting, and sampling wells and in transporting CO_2 and wastes; and (4) minor amounts of land surface clearing during extension of well pads and drilling of shot holes for the 3-D VSP. For the new injection well, several truckloads of caliche road base would be applied to expand the existing well pad for drilling the new well, up to 6,000 barrels of water for drilling mud would be used to advance the drill bit to an estimated depth of 1,820 m (6,000 ft) and return cuttings to the surface, steel surface and injection casing would be installed to protect shallow, fresh groundwater and permit injection at the selected stratigraphic interval, and steel wellhead valves and pipes would be used to control CO_2 injection. The 3,750 tons of CO_2 proposed for use would possess a commercial market value of approximately $375,000. The CO_2 to be used for the project, however, would be obtained from a source that would have vented the CO_2 to the atmosphere as a waste. Fossil fuels, primarily diesel fuel, would be used by the drilling and work-over rigs and by the trucks hauling 165 loads of CO_2, produced water, and drilling fluids. Based on the relatively small quantities of common and widely available materials that would be used, no adverse effects on material resources would be expected.

8.0 ENVIRONMENTAL CONSEQUENCES OF THE NO ACTION ALTERNATIVE

Under the No Action Alternative, no change in current hydrocarbon extraction or other activities at the South Liberty Oilfield would result. The minimal local environmental consequences associated with drilling a new well (well-pad expansion, mud-pit excavation, and well drilling) would be avoided. The experiment to inject 3,750 tons of CO_2 into a subsurface saline aquifer, monitor the lateral migration of the CO_2 plume, and assess the performance of stratigraphic sealing horizons in sequestering CO_2 underground would not be conducted. The 3,750 tons of CO_2 that would have been injected into the subsurface would be released to the atmosphere. Because underground CO_2 injection into saline aquifers is one of the candidate approaches being evaluated for technical viability as a possible method for CO_2 sequestration, the No Action Alternative would result in a lost opportunity to develop information on a potentially viable approach for helping to avoid the climate-altering effects from increases in the atmospheric concentration of greenhouse gases.

9.0 SIMILAR ACTIONS AND ACTIONS BEING CONSIDERED UNDER OTHER NEPA REVIEWS

The proposed action, for DOE support in evaluating the suitability of CO_2 sequestration in deep saline aquifers, is not similar to any other action being considered (or currently being implemented) by DOE and is not a segment of any other action for which review under NEPA would be required.

10.0 RELATIONSHIP OF THE PROPOSED ACTION TO APPLICABLE LAND USE PLANS AND POLICIES

The proposed pilot experiment would not require any change in the current land use of the Liberty County site as an operating oilfield. The proposed incremental enlargement of an existing well pad, the drilling of a new well, injection of CO_2, and monitoring of CO_2 at existing wells would represent no substantive changes to current land use plans and policies. Similar drilling and fluid-extraction activities have been ongoing in the area since hydrocarbon production began in the 1920s.

11.0 CONSULTATION AND PUBLIC PARTICIPATION

11.1 Consultation

The agencies and organizations identified in Table 6 were contacted as part of the environmental evaluation process for the proposed pilot experiment. Copies of correspondence exchanged with the two resource agencies, the Texan Archeological Research Laboratory and the U.S. Fish and Wildlife Service, that have authorities over historic properties and endangered species, respectively, are provided in Appendix A.

Table 6. Agency and organization contacts

No.	Agency contacted	Date	Author	Response Date	Author
1	Texas Archeological Research Laboratory	10/4/2002	Paine	10/7/2002	Azulay
2	U.S. Fish and Wildlife Service	10/9/2002	Paine	10/30/2002	Morgan
3	U.S. Army Corps of Engineers	10/9/2002	Paine	10/9/2002	Dunn
4	Texas Commission on Environmental Quality (Underground Injection Control Section)	Varied	Knox	Varied	Fred Duffy
5	Texas Commission on Environmental Quality (surface casing and groundwater protection)	12/6/2002	Paine, Knox		Traylor
6	Railroad Commission of Texas	Varied	Hovorka, Knox	Varied	Ginn
7	Liberty County		Knox		
8	City of Dayton		Knox		
9	City of Liberty		Knox		
10	Texas Department of Health (Radiation Control Section)	3/24/03	Knox	3/24/03	R. Cortez

11.2 Public Participation

A draft EA was distributed for review and comment to Federal and State agencies and to the public; copies were made available for review at both the Dayton Library in Dayton, Texas, and the Liberty Municipal Library in Liberty, Texas. The draft EA was also posted on the National Energy Technology Laboratory’s web site for public review and comment. Public notices announcing availability of the draft EA for review and comment were published in the Liberty Gazette on August 27 and September 3, 2003, and in The Vindicator on August 24 and 27, 2003. Both newspapers are printed in Liberty, Texas, and are generally circulated within Liberty County. By the close of the public comment period on September 12, 2003, no adverse comments regarding the proposed action were received; only one comment was received, indicating interest in using CO_2 for commercial purposes. Since closing of the comment period, no comments were received.

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BOC GASES

MATERIAL SAFETY DATA SHEET

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PRODUCT NAME: ARGON

1. Chemical Product and Company Identification

BOC Gases,
Division of
The BOC Group, Inc.
575 Mountain Avenue
Murray Hill, NJ 07974

TELEPHONE NUMBER: (908) 464-8100
24-HOUR EMERGENCY TELEPHONE NUMBER:
CHEMTREC (800) 424-9300

BOC Gases
Division of
BOC Canada Limited
5975 Falbourne Street, Unit 2
Mississauga, Ontario L5R 3W6

TELEPHONE NUMBER: (905) 501-1700
24-HOUR EMERGENCY TELEPHONE NUMBER:
(905) 501-0802
EMERGENCY RESPONSE PLAN NO: 20101

PRODUCT NAME: ARGON
CHEMICAL NAME: Argon
COMMON NAMES/SYNONYMS: Argon, compressed
TDG (Canada) CLASSIFICATION: 2.2
WHMIS CLASSIFICATION: A

PREPARED BY: Loss Control (908)464-8100/(905)501-1700
PREPARATION DATE: 6/1/95
REVIEW DATES: 6/7/96

2. Composition, Information on Ingredients

INGREDIENT	% VOLUME	PEL-OSHA[1]	TLV-ACGIH[2]	LD_{50} or LC_{50} Route/Species
Argon FORMULA: Ar CAS: 7440-37-1 RTECS #: CF2300000	100.0	Simple Asphyxiant	Simple Asphyxiant	Not Available

[1] As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)

[2] As stated in the ACGIH 1994-95 Threshold Limit Values for Chemical Substances and Physical Agents

3. Hazards Identification

EMERGENCY OVERVIEW

Simple Asphyxiant - This product does not contain oxygen and may cause asphyxia if released in a confined area. Maintain oxygen levels above 19.5%. Nonflammable.

ROUTE OF ENTRY:

Skin Contact	Skin Absorption	Eye Contact	Inhalation	Ingestion
Yes	No	Yes	Yes	No

HEALTH EFFECTS:

Exposure Limits No	Irritant No	Sensitization No
Teratogen No	Reproductive Hazard No	Mutagen No
Synergistic Effects None reported		

Carcinogenicity: -- NTP: No IARC: No OSHA: No

EYE EFFECTS:
No adverse effects anticipated.

SKIN EFFECTS:
No adverse effects anticipated.

INGESTION EFFECTS:
No adverse effects anticipated.

INHALATION EFFECTS:
Product is a non-toxic simple asphyxiant. Effects of oxygen deficiency resulting from simple asphyxiants may include: rapid breathing, diminished mental alertness, impaired muscular coordination, faulty judgement, depression of all sensations, emotional instability, and fatigue. As asphyxiation progresses, nausea, vomiting, prostration, and loss of consciousness may result, eventually leading to convulsions, coma, and death.

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

NFPA HAZARD CODES		**HMIS HAZARD CODES**		**RATINGS SYSTEM**
Health:	0	Health:	0	0 = No Hazard
Flammability:	0	Flammability:	0	1 = Slight Hazard
Reactivity:	0	Reactivity:	0	2 = Moderate Hazard
				3 = Serious Hazard
				4 = Severe Hazard

4. First Aid Measures

EYES:
Never introduce ointment or oil into the eyes without medical advice! If pain is present, refer the victim to an ophthalmologist for treatment and follow up.

SKIN:
None anticipated.

INGESTION:
Ingestion is unlikely as product is a gas at room temperature.
INHALATION:

PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS. Victims should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area, and if breathing has stopped, administer artificial resuscitation and supplemental oxygen. Further treatment should be symptomatic and supportive.

5. Fire Fighting Measures

Conditions of Flammability: Nonflammable		
Flash point: None	Method: Not Applicable	Autoignition Temperature: None
LEL(%): None	UEL(%): None	
Hazardous combustion products: None		
Sensitivity to mechanical shock: None		
Sensitivity to static discharge: None		

FIRE AND EXPLOSION HAZARDS:
None. Nonflammable

EXTINGUISHING MEDIA:
None required. Use as appropriate for surrounding materials.

6. Accidental Release Measures

Evacuate all personnel from affected area. Use appropriate protective equipment. If leak is in container or container valve, contact the appropriate emergency telephone number listed in Section 1 or call your closest BOC location.

7. Handling and Storage

Electrical classification:
Non-hazardous.

This gas mixture is noncorrosive and may be used with all common structural materials.

Use only in well-ventilated areas. Valve protection caps must remain in place unless container is secured with valve protection outlet piped to use point. Do not drag, slide or roll cylinders. Use a suitable hand truck for cylinder movement. Use a pressure reducing regulator when connecting cylinder to lower pressure (<3000 psig) piping or systems. Do not heat cylinder by any means to increase the discharge rate of product from the cylinder. Use a check valve or trap in the discharge line to prevent hazardous back flow into the cylinder.

Protect cylinders from physical damage. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Do not allow the temperature where cylinders are stored to exceed 125 ^{o}F (52 ^{o}C). Cylinders should be stored upright and firmly secured to prevent falling or being knocked over. Use a "first in-first out" inventory system to prevent full cylinders being stored for excessive periods of time.

For additional recommendations, consult Compressed Gas Association Pamphlets P-1, P-14, P-9, and Safety Bulletin SB-2.

Never carry a compressed gas cylinder or a container of a gas in cryogenic liquid form in an enclosed space such as a car trunk, van or station wagon. A leak can result in a fire, explosion, asphyxiation or a toxic exposure.

8. Exposure Controls, Personal Protection

EXPOSURE LIMITS[1]:

INGREDIENT	% VOLUME	PEL-OSHA[2]	TLV-ACGIH[3]	LD_{50} or LC_{50} Route/Species
Argon FORMULA: Ar CAS: 7440-37-1 RTECS #: CF2300000	100.0	Simple Asphyxiant	Simple Asphyxiant	Not Available

[1] Refer to individual state of provincial regulations, as applicable, for limits which may be more stringent than those listed here.
[2] As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)
[3] As stated in the ACGIH 1994-1995 Threshold Limit Values for Chemical Substances and Physical Agents.

ENGINEERING CONTROLS:
Local exhaust to prevent accumulation of high concentrations so as to reduce the oxygen level in the air to less than 19.5%.

EYE/FACE PROTECTION:
Safety goggles or glasses as appropriate for the job.

SKIN PROTECTION:
Protective gloves of material appropriate for the job.

RESPIRATORY PROTECTION:
Positive pressure air line with full-face mask and escape bottle or self-contained breathing apparatus should be available for emergency use.

OTHER/GENERAL PROTECTION:
Safety shoes or other footwear as appropriate for the job.

9. Physical and Chemical Properties

PARAMETER	VALUE	UNITS
Physical state (gas, liquid, solid)	: Gas	
Vapor pressure	: Not Available	
Vapor density (Air = 1)	: 1.38	
Evaporation point	: Not Available	
Boiling point	: -302.6	^{o}F
	: -185.9	^{o}C
Freezing point	: -308.9	^{o}F
	: -189.4	^{o}C
pH	: Not Applicable	
Specific gravity	: Not Available	
Oil/water partition coefficient	: Not Available	
Solubility (H20)	: Slight	
Odor threshold	: Not Applicable	
Odor and appearance	: Colorless, odorless gas	

10. Stability and Reactivity

STABILITY:
Stable

INCOMPATIBLE MATERIALS:
None

HAZARDOUS POLYMERIZATION:
Does not occur.

11. Toxicological Information

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

No data given in the Registry of Toxic Effects of Chemical Substances (RTECS) or Sax, Dangerous Properties of Industrial Materials, 7th ed.

12. Ecological Information

No data given.

13. Disposal Considerations

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED, WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to BOC Gases or authorized distributor for proper disposal.

14. Transport Information

PARAMETER	United States DOT	Canada TDG
PROPER SHIPPING NAME:	Argon, compressed	Argon, compressed
HAZARD CLASS:	2.2	2.2
IDENTIFICATION NUMBER:	UN 1006	UN 1006
SHIPPING LABEL:	NONFLAMMABLE GAS	NONFLAMMABLE GAS

15. Regulatory Information

SARA TITLE III NOTIFICATIONS AND INFORMATION

SARA TITLE III - HAZARD CLASSES:
Sudden Release of Pressure Hazard

16. Other Information

Compressed gas cylinders shall not be refilled without the express written permission of the owner. Shipment of a compressed gas cylinder which has not been filled by the owner or with his/her (written) consent is a violation of transportation regulations.

DISCLAIMER OF EXPRESSED AND IMPLIED WARRANTIES:
Although reasonable care has been taken in the preparation of this document, we extend no warranties and make no representations as to the accuracy or completeness of the information contained herein, and assume no responsibility regarding the suitability of this information for the user’s intended purposes or for the consequences of its use. Each individual should make a determination as to the suitability of the information for their particular purpose(s).

DYNO
Dyno Nobel Inc

MATERIAL SAFETY DATA SHEET
DYNO NOBEL INC
11TH FLOOR CROSSROADS TOWER
SALT LAKE CITY, UTAH 84144
801-364-4800 TELEX 388353
FOR 24 HOUR EMERGENCY CALL 800-424-9300

MSDS# 1093

DATE: 02/05/96

Supersedes MSDS
1093 12/20/95

SECTION I - PRODUCT IDENTIFICATION

Trade Name(s): DYNOSEIS™

Product Class: Seismic Explosive

Product Appearance & Odor: White solid with no odor.

DOT Hazard Shipping Description: Substance, Explosives n.o.s.
(Sodium Perchlorate/Diethylene Glycol)
1.1D UN0475

SECTION II - HAZARDOUS INGREDIENTS

Ingredients:	CAS#	% (Range)	TLV-ACGIH
Sodium Perchlorate	7601-89-0	66-72	No Value Established
Diethylene Glycol	111-46-6	22-27	No Value Established

Ingredients, other than those mentioned above, as used in this product are not hazardous as defined under current Department of Labor regulations.

SECTION III - PHYSICAL DATA

Boiling Point: N/A

Vapor Density: (Air = 1) N/A

Percent Volatile by Volume: <5

Evaporation Rate (Butyl Acetate = 1): <1

Vapor Pressure: N/A

Density: 1.65 - 1.85 g/cc

Solubility in Water: Completely soluble

N/A = Not Applicable or Not Available

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

Flash Point: N/A **Flammable Limits:** N/A

Extinguishing Media: (See Special Fire Fighting Procedures section).

Special Fire Fighting Procedures: Do not attempt to fight fires involving explosive materials. Evacuate all personnel to predetermined safe location, no less than 2,500 feet.

Unusual Fire and Explosion Hazards: Can explode under fire conditions. Burning material may produce toxic vapors.

SECTION V - HEALTH HAZARD DATA

Effects of Overexposure

Eyes: Can cause irritation, redness, and tearing.

Skin: Prolonged contact may cause irritation.

Ingestion: Large amounts may be harmful if swallowed.

Inhalation: May cause dizziness, nausea, intestinal upset.

Systemic or Other Effects: None known.

Emergency and First Aid Procedures

Eyes: Irrigate with running water for at least 15 minutes. If irritation persists seek medical attention.

Skin: Wash with soap and water.

Ingestion: Induce vomiting, seek medical attention.

Inhalation: Remove to fresh air.

Special Considerations: None.

SECTION VI - REACTIVITY DATA

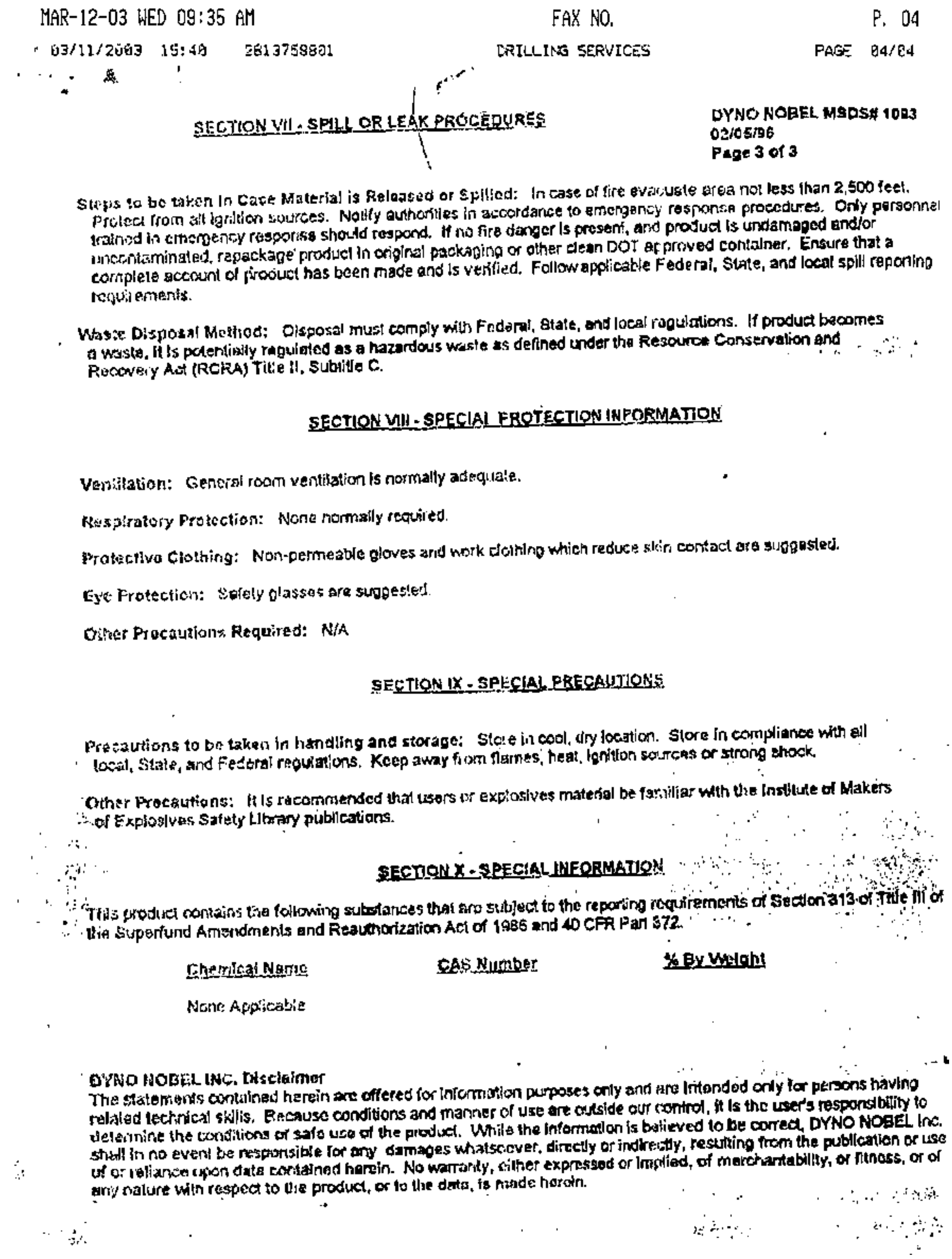
Stability: Stable under normal conditions, may explode when subjected to fire or supersonic shock, or high energy projectile impact especially when confined or in large quanities.

Conditions to Avoid: Keep away from heat, flame, ignition sources, and strong shock.

Materials to Avoid (Incompatibility): Strong acids and alkali.

Hazardous Decomposition Products: Nitrous Oxides $(NO)_x$, Carbon Monoxide (CO), Chlorine $(Cl)_2$, Hydrogen Chloride (HCl)

Hazardous Polymerization: N/A



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02/05/96
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SECTION VII - SPILL OR LEAK PROCEDURES

Steps to be taken in Case Material is Released or Spilled: In case of fire evacuate area not less than 2,500 feet. Protect from all ignition sources. Notify authorities in accordance to emergency response procedures. Only personnel trained in emergency response should respond. If no fire danger is present, and product is undamaged and/or uncontaminated, repackage product in original packaging or other clean DOT approved container. Ensure that a complete account of product has been made and is verified. Follow applicable Federal, State, and local spill reporting requirements.

Waste Disposal Method: Disposal must comply with Federal, State, and local regulations. If product becomes a waste, it is potentially regulated as a hazardous waste as defined under the Resource Conservation and Recovery Act (RCRA) Title II, Subtitle C.

SECTION VIII - SPECIAL PROTECTION INFORMATION

Ventilation: General room ventilation is normally adequate.

Respiratory Protection: None normally required.

Protective Clothing: Non-permeable gloves and work clothing which reduce skin contact are suggested.

Eye Protection: Safety glasses are suggested.

Other Precautions Required: N/A

SECTION IX - SPECIAL PRECAUTIONS

Precautions to be taken in handling and storage: Store in cool, dry location. Store in compliance with all local, State, and Federal regulations. Keep away from flames, heat, ignition sources or strong shock.

Other Precautions: It is recommended that users of explosives material be familiar with the Institute of Makers of Explosives Safety Library publications.

SECTION X - SPECIAL INFORMATION

This product contains the following substances that are subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372.

Chemical Name	CAS Number	% By Weight
None Applicable		

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The statements contained herein are offered for information purposes only and are intended only for persons having related technical skills. Because conditions and manner of use are outside our control, it is the user's responsibility to determine the conditions of safe use of the product. While the information is believed to be correct, DYNO NOBEL Inc. shall in no event be responsible for any damages whatsoever, directly or indirectly, resulting from the publication or use of or reliance upon data contained herein. No warranty, either expressed or implied, of merchantability, or fitness, or of any nature with respect to the product, or to the data, is made herein.

MSDS
EOSIN

**** SECTION 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION ****

MSDS Name: **Eosin** Y
Catalog Numbers:
S71268, S71268-1, S71271-1, BP2419-100, BP2419-25, E511 100, E511 25, E511-100, E511-25, E511100, E51125, NC9487912, NC9671661, S712681, S712711, XXE51110KG
Synonyms:
Acid Red 87; Bromoeosine; Disodium **Eosine**; **Eosine** Yellowish; Tetrabromfluorescein, CI 45380.
Company Identification: Fisher Scientific
1 Reagent Lane
Fairlawn, NJ 07410
For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

**** SECTION 2 - COMPOSITION, INFORMATION ON INGREDIENTS ****

CAS#	Chemical Name	%	EINECS#
17372-87-1	ACID RED 87	100	241-409-6

Hazard Symbols: None Listed.
Risk Phrases: None Listed.

**** SECTION 3 - HAZARDS IDENTIFICATION ****

EMERGENCY OVERVIEW

Appearance: red to brown.
Caution! The toxicological properties of this material have not been fully investigated. May cause eye and skin irritation. May cause respiratory and digestive tract irritation.
Target Organs: No data found.

Potential Health Effects
Eye:
May cause eye irritation. This product contains an anionic dye. Similar dyes have not caused injury to the cornea or conjunctiva in documented exposure cases with human or rabbit eyes.
Skin:
May cause skin irritation.
Ingestion:
May cause gastrointestinal irritation with nausea, vomiting and diarrhea. The toxicological properties of this substance have not been fully investigated.
Inhalation:
May cause respiratory tract irritation. The toxicological properties of this substance have not been fully investigated.
Chronic:
No information found.

**** SECTION 4 - FIRST AID MEASURES ****

Eyes:

Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.

Skin:

Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists.

Ingestion:

If victim is conscious and alert, give 2-4 cupfuls of milk or water. Get medical aid immediately.

Inhalation:

Remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

Notes to Physician:

The use of sodium chloride as antidotal treatment for bromine salt overdose should be made only by qualified medical personnel (Medical Toxicology,

**** SECTION 5 - FIRE FIGHTING MEASURES ****

General Information:

As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.

Extinguishing Media:

In case of fire, use water, dry chemical, chemical foam, or alcohol-resistant foam.

Autoignition Temperature:Not available.
Flash Point: Not available.
Explosion Limits, lower:Not available.
Explosion Limits, upper:Not available.
NFPA Rating: (estimated) Health: 1; Flammability: 0; Reactivity: 0

**** SECTION 6 - ACCIDENTAL RELEASE MEASURES ****

General Information: Use proper personal protective equipment as indicated in Section 8.

Spills/Leaks:

Sweep up, then place into a suitable container for disposal. Avoid generating dusty conditions.

**** SECTION 7 - HANDLING and STORAGE ****

Handling:

Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Minimize dust generation and accumulation. Avoid contact with skin and eyes. Keep container tightly closed. Avoid ingestion and inhalation.

Storage:

Store in a cool, dry, well-ventilated area away from incompatible substances.

**** SECTION 8 - EXPOSURE CONTROLS, PERSONAL PROTECTION ****

Engineering Controls:

Use adequate ventilation to keep airborne concentrations low.

Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
ACID RED 87	none listed	none listed	none listed

OSHA Vacated PELs:

ACID RED 87:

No OSHA Vacated PELs are listed for this chemical.

Personal Protective Equipment

Eyes:

Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin:

Wear appropriate protective gloves to prevent skin exposure.

Clothing:

Wear appropriate protective clothing to minimize contact with skin.

Respirators:

Follow the OSHA respirator regulations found in 29CFR 1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

**** SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES ****

Physical State:	Solid
Appearance:	red to brown
Odor:	none reported
pH:	Not available.
Vapor Pressure:	Negligible.
Vapor Density:	Not applicable.
Evaporation Rate:	Negligible.
Viscosity:	Not available.
Boiling Point:	Not applicable.
Freezing/Melting Point:	Not available.
Decomposition Temperature:	Not available.
Solubility in water:	Soluble in water.
Specific Gravity/Density:	Not available.
Molecular Formula:	$C_{20}H_8Br_4O_5.2Na$
Molecular Weight:	693.6486

**** SECTION 10 - STABILITY AND REACTIVITY ****

Chemical Stability:
Stable under normal temperatures and pressures.
Conditions to Avoid:
High temperatures, incompatible materials.
Incompatibilities with Other Materials:
Strong oxidizers.
Hazardous Decomposition Products:
Carbon monoxide, carbon dioxide, hydrogen bromide.
Hazardous Polymerization: Has not been reported.

**** SECTION 11 - TOXICOLOGICAL INFORMATION ****

RTECS#:
CAS# 17372-87-1: LM5850000
LD50/LC50:
CAS# 17372-87-1: Oral, mouse: LD50 = 2344 mg/kg.
Carcinogenicity:
ACID RED 87 -
Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA.
Epidemiology:
No information available.
Teratogenicity:
No information available.
Reproductive Effects:
No information available.
Neurotoxicity:
No information available.
Mutagenicity:
Please refer to RTECS# LM5850000 for specific information.
Other Studies:
None.

**** SECTION 12 - ECOLOGICAL INFORMATION ****

Other
No information available.

**** SECTION 13 - DISPOSAL CONSIDERATIONS ****

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste.
US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

**** SECTION 14 - TRANSPORT INFORMATION ****

US DOT
No information available

Canadian TDG
No information available.

**** SECTION 15 - REGULATORY INFORMATION ****

US FEDERAL
TSCA
CAS# 17372-87-1 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
None of the chemicals in this product are under a Chemical Test Rule.
Section 12b
None of the chemicals are listed under TSCA Section 12b.
TSCA Significant New Use Rule
None of the chemicals in this material have a SNUR under TSCA.
SARA
Section 302 (RQ)
None of the chemicals in this material have an RQ.
Section 302 (TPQ)
None of the chemicals in this product have a TPQ.
SARA Codes
CAS # 17372-87-1: acute.
Section 313
No chemicals are reportable under Section 313.
Clean Air Act:
This material does not contain any hazardous air pollutants.
This material does not contain any Class 1 Ozone depletors.
This material does not contain any Class 2 Ozone depletors.
Clean Water Act:
None of the chemicals in this product are listed as Hazardous Substances under the CWA.
None of the chemicals in this product are listed as Priority Pollutants under the CWA.
None of the chemicals in this product are listed as Toxic Pollutants under the CWA.
OSHA:
None of the chemicals in this product are considered highly hazardous by OSHA.
STATE
ACID RED 87 is not present on state lists from CA, PA, MN, MA, FL, or NJ.
California No Significant Risk Level:
None of the chemicals in this product are listed.
European/International Regulations
European Labeling in Accordance with EC Directives
Hazard Symbols: Not available.
Risk Phrases:
Safety Phrases:
WGK (Water Danger/Protection)
CAS# 17372-87-1: 1
United Kingdom Occupational Exposure Limits

Canada
CAS# 17372-87-1 is listed on Canada's DSL List.
This product has a WHMIS classification of D2B.

CAS# 17372-87-1 is not listed on Canada's Ingredient Disclosure List.
Exposure Limits

**** SECTION 16 - ADDITIONAL INFORMATION ****

MSDS Creation Date: 12/12/1997 Revision #2 Date: 8/02/2000

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no way shall the company be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if the company has been advised of the possibility of such damages.

FLUTEC TG m-PDMCH^{TM}

1 – SUBSTANCE IDENTIFICATION

Trade Name:	Flutec TG m-PDMCH
Material Type:	Perfluorocarbon
Company:	F2 Chemicals Ltd
Address:	Lea Lane Lea Town Preston Lancashire PR4 0RZ UK
Telephone:	+44 (0) 1772 775804
Fax:	+44 (0) 1772 775809
Emergency Telephone:	+44 (0) 1772 775833

2 - COMPOSITION

a) Substances	Predominantly Perfluoro-1,3-dimethylcyclohexane
b) CAS Number	335-27-3

3 – HAZARD IDENTIFICATION

a) Hazard Symbols:	Not applicable
b) Risk and Safety	Keep container tightly closed. Caution, avoid prolonged and repeated breathing of concentrated vapour. Thermal decomposition may produce toxic products. Small amounts of decomposition may occur above 400°C. When using do not smoke. Do not empty into drains.

4 – FIRST AID MEASURES

a) Inhalation:	In case of severe exposure; remove from exposure , rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.
b) Skin contact:	Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.
c) Eye contact:	Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.
d) Ingestion:	Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES

a) Suitable Extinguishers:	Carbon dioxide Alcohol resistant foam Powder Halons Water Fog Water Jets Inert material – Sand, earth, etc Non-combustible material
b) Unsuitable Extinguishers:	Not applicable.
c) Hazardous Decomposition:	Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.
d) Special Procedures:	Use water spray to cool containers. Contact with flames gives rise of toxic vapours, avoid inhalation of these vapours. Use approved self contained breathing apparatus. Non-essential personnel should be evacuated from the area until any fumes have dispersed. Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.

6 – ACCIDENTAL RELEASE MEASURES

a) Exposure Controls	Flutec liquid spillages produce very slippery surfaces which may be hazardous to personnel. Evacuate area. Do not allow spillage to enter drains and watercourse. If water is contaminated inform relevant authority immediately.
b) Personnel Protection:	Wear laboratory coat. Respiratory protection not normally required. Wear impermeable gloves. Wear chemical safety spectacles or goggles.
c) Disposal Considerations:	Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer. Do not allow spillage to enter drains/sewers/water courses. Dispose of in accordance with local authority regulations.

7 – HANDLING AND STORAGE

a) Handling	Do not smoke when handling. Avoid contact of vapour or liquid with red hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride. Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable. Allow sufficient ullage when drum filling to allow for thermal expansion.
b) Storage	Store in original, tightly closed, labelled container. Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.

8 – EXPOSURE CONTROLS

a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None

9 – PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	102°C
Pour Point:	-70°C
Vapour Pressure:	48 mbar
Density:	1.828 kg/l @25°C
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.

10 – STABILITY AND REACTIVITY

a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.

11 – TOXICOLOGICAL INFORMATION

a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION

a) Ecotoxicity:	No specific data available

13 – DISPOSAL CONSIDERATIONS

Contact manufacturer.
Dispose of through an authorised contractor to a licensed landfill site.
Do not discharge into drains or watercourses.
Large quantities should be incinerated by a waste disposal organisation.

14 – TRANSPORT INFORMATION

Non-hazardous liquid not regulated for transport services.
UN Number – not applicable
IATA/ICAO – not regulated
ADR – not regulated
IMDG – not regulated
Transport name – not applicable
Hazchem code – not applicable.

15 – REGULATORY INFORMATION

a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and / or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.

16 – OTHER REGULATION

a) Suitability for purpose:	F2 Chemicals Ltd cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals for advice.

Material Safety Data Sheet

FLUTEC-TG o-PDMCH

Last updated: 20th May 2002

1 – SUBSTANCE IDENTIFICATION

Trade Name:	FLUTEC-TG o-PDMCH
Material Type:	Perfluorocarbon
Company:	F2 Chemicals Ltd
Address:	Lea Lane Lea Town Preston Lancashire PR4 0RZ UK
Telephone:	+44 (0) 1772 775804
Fax:	+44 (0) 1772 775809
Emergency Telephone:	+44 (0) 1772 775833

2 - COMPOSITION

a) Substances	Predominantly perfluoro-1,2-dimethylcyclohexane
b) CAS Number	306-98-9

3 – HAZARD IDENTIFICATION

a) Hazard Symbols:	Not applicable
b) Risk and Safety	Keep container tightly closed. Caution, avoid prolonged and repeated breathing of concentrated vapour. Thermal decomposition may produce toxic products. Small amounts of decomposition may occur above 400°C. When using do not smoke. Do not empty into drains.

4 – FIRST AID MEASURES

a) Inhalation:	In case of severe exposure; remove from exposure , rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.
b) Skin contact:	Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.
c) Eye contact:	Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.
d) Ingestion:	Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES

a) Suitable Extinguishers:	Carbon dioxide Alcohol resistant foam Powder Halons Water Fog Water Jets Inert material – Sand, earth, etc Non-combustible material
b) Unsuitable Extinguishers:	Not applicable.
c) Hazardous Decomposition:	Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.
d) Special Procedures:	Use water spray to cool containers. Contact with flames gives rise to toxic vapours; avoid inhalation of these vapours. Use approved self-contained breathing apparatus. Non-essential personnel should be evacuated from the area until any fumes have dispersed. Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.

6 – ACCIDENTAL RELEASE MEASURES

a) Exposure Controls	FLUTEC liquid spillages produce very slippery surfaces which may be hazardous to personnel. Evacuate area. Do not allow spillage to enter drains and watercourse. If water is contaminated inform relevant authority immediately.
b) Personnel Protection:	Wear laboratory coat. Respiratory protection not normally required. Wear impermeable gloves. Wear chemical safety spectacles or goggles.
c) Disposal Considerations:	Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer. Do not allow spillage to enter drains/sewers/water courses. Dispose of in accordance with local authority regulations.

7 – HANDLING AND STORAGE

a) Handling	Do not smoke when handling. Avoid contact of vapour or liquid with red-hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride. Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable. Allow sufficient ullage when drum filling to allow for thermal expansion.
b) Storage	Store in original, tightly closed, labelled container. Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.

8 – EXPOSURE CONTROLS

a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None

9 – PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	102 °C
Pour Point:	-30 °C
Molecular Weight:	400
Density:	1.828 kg/l
Surface Tension:	16.6 mN/m
Vapour Pressure:	48 mbar
Specific Heat:	0.85* kJ/kg °C
Critical Temperature:	241* °C
Critical Temperature:	514* K
Critical Pressure:	19* bar
Critical Volume:	1.5* l/kg
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.

10 – STABILITY AND REACTIVITY

a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.

11 – TOXICOLOGICAL INFORMATION

a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION

a) Ecotoxicity:	No specific data available

13 – DISPOSAL CONSIDERATIONS

Contact manufacturer.
Dispose of through an authorised contractor to a licensed landfill site.
Do not discharge into drains or watercourses.
Large quantities should be incinerated by a waste disposal organisation.

14 – TRANSPORT INFORMATION

Non-hazardous liquid not regulated for transport services.
UN Number – not applicable
IATA/ICAO – not regulated
ADR – not regulated
IMDG – not regulated
Transport name – not applicable
Hazchem code – not applicable.

15 – REGULATORY INFORMATION

a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and/or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.

16 – OTHER REGULATION

a) Suitability for purpose:	F2 Chemicals Ltd. cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals Ltd. for advice.

FLUTEC TG-PECH™

1 – SUBSTANCE IDENTIFICATION

Trade Name:	Flutec TG-PECH
Material Type:	Perfluorocarbon
Company:	F2 Chemicals Ltd
Address:	Lea Lane Lea Town Preston Lancashire PR4 0RZ UK
Telephone:	+44 (0) 1772 775804
Fax:	+44 (0) 1772 775809
Emergency Telephone:	+44 (0) 1772 775833

2 - COMPOSITION

a) Substances	Predominantly Perfluoroethylcyclohexane
b) CAS Number	335-21-7

3 – HAZARD IDENTIFICATION

a) Hazard Symbols:	Not applicable
b) Risk and Safety	Keep container tightly closed. Caution, avoid prolonged and repeated breathing of concentrated vapour. Thermal decomposition may produce toxic products. Small amounts of decomposition may occur above 400°C. When using do not smoke. Do not empty into drains.

4 – FIRST AID MEASURES

a) Inhalation:	In case of severe exposure; remove from exposure , rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.
b) Skin contact:	Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.
c) Eye contact:	Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.
d) Ingestion:	Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES

a) Suitable Extinguishers:	Carbon dioxide Alcohol resistant foam Powder Halons Water Fog Water Jets Inert material – Sand, earth, etc Non-combustible material
b) Unsuitable Extinguishers:	Not applicable.
c) Hazardous Decomposition:	Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.
d) Special Procedures:	Use water spray to cool containers. Contact with flames gives rise of toxic vapours, avoid inhalation of these vapours. Use approved self contained breathing apparatus. Non-essential personnel should be evacuated from the area until any fumes have dispersed. Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.

6 – ACCIDENTAL RELEASE MEASURES

a) Exposure Controls	Flutec liquid spillages produce very slippery surfaces which may be hazardous to personnel. Evacuate area. Do not allow spillage to enter drains and watercourse. If water is contaminated inform relevant authority immediately.
b) Personnel Protection:	Wear laboratory coat. Respiratory protection not normally required. Wear impermeable gloves. Wear chemical safety spectacles or goggles.
c) Disposal Considerations:	Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer. Do not allow spillage to enter drains/sewers/water courses. Dispose of in accordance with local authority regulations.

7 – HANDLING AND STORAGE

a) Handling	Do not smoke when handling. Avoid contact of vapour or liquid with red hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride. Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable. Allow sufficient ullage when drum filling to allow for thermal expansion.
b) Storage	Store in original, tightly closed, labelled container. Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.

8 – EXPOSURE CONTROLS

a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None

9 – PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	101.7°C
Melting Point:	-70°C
Vapour Pressure:	28.7 mbar
Density:	1.829 kg/l @25°C
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.

10 – STABILITY AND REACTIVITY

a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.

11 – TOXICOLOGICAL INFORMATION

a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION

a) Ecotoxicity:	No specific data available

13 – DISPOSAL CONSIDERATIONS

Contact manufacturer.
Dispose of through an authorized contractor to a licensed landfill site.
Do not discharge into drains or watercourses.
Large quantities should be incinerated by a waste disposal organisation.

14 – TRANSPORT INFORMATION

Non-hazardous liquid not regulated for transport services.
UN Number – not applicable
IATA/ICAO – not regulated
ADR – not regulated
IMDG – not regulated
Transport name – not applicable
Hazchem code – not applicable.

15 – REGULATORY INFORMATION

a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and / or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.

16 – OTHER REGULATION

a) Suitability for purpose:	F2 Chemicals Ltd cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals for advice.

Material Safety Data Sheet

FLUTEC-TG PMCP

Last updated: 20th May 2002

1 – SUBSTANCE IDENTIFICATION

Trade Name:	FLUTEC-TG PMCP
Material Type:	Perfluorocarbon
Company:	F2 Chemicals Ltd
Address:	Lea Lane Lea Town Preston Lancashire PR4 0RZ UK
Telephone:	+44 (0) 1772 775804
Fax:	+44 (0) 1772 775809
Emergency Telephone:	+44 (0) 1772 775833

2 - COMPOSITION

a) Substances	Predominantly perfluoromethylcyclopentane
b) CAS Number	1805-22-7

3 – HAZARD IDENTIFICATION

a) Hazard Symbols:	Not applicable
b) Risk and Safety	Keep container tightly closed. Caution, avoid prolonged and repeated breathing of concentrated vapour. Thermal decomposition may produce toxic products. Small amounts of decomposition may occur above 400°C. When using do not smoke. Do not empty into drains.

4 – FIRST AID MEASURES

a) Inhalation:	In case of severe exposure; remove from exposure , rest and keep warm. Apply artificial respiration if breathing has ceased. Obtain medical attention if effects are other than slight.
b) Skin contact:	Remove contaminated clothing and wash off with soap and water. Obtain medical attention if adverse symptoms arise.
c) Eye contact:	Irrigate thoroughly with water. Obtain medical attention if adverse symptoms arise.
d) Ingestion:	Wash out mouth with water. Obtain medical attention if adverse symptoms persist.

5 – FIRE FIGHTING MEASURES

a) Suitable Extinguishers:	Carbon dioxide Alcohol resistant foam Powder Halons Water Fog Water Jets Inert material – Sand, earth, etc Non-combustible material
b) Unsuitable Extinguishers:	Not applicable.
c) Hazardous Decomposition:	Toxic fumes may be produced on thermal decomposition. In the presence of other reactive substances and in a fire situation where hydrogen containing compounds are present, Hydrogen Fluoride and other toxic products may be formed.
d) Special Procedures:	Use water spray to cool containers. Contact with flames gives rise to toxic vapours; avoid inhalation of these vapours. Use approved self-contained breathing apparatus. Non-essential personnel should be evacuated from the area until any fumes have dispersed. Handle contaminated fluid in a ventilated area, avoiding inhalation of vapour.

6 – ACCIDENTAL RELEASE MEASURES

a) Exposure Controls	FLUTEC liquid spillages produce very slippery surfaces which may be hazardous to personnel. Evacuate area. Do not allow spillage to enter drains and watercourse. If water is contaminated inform relevant authority immediately.
b) Personnel Protection:	Wear laboratory coat. Respiratory protection not normally required. Wear impermeable gloves. Wear chemical safety spectacles or goggles.
c) Disposal Considerations:	Absorb in inert material eg. sand, vermiculite absorbent granules, place in plastic container for transfer. Do not allow spillage to enter drains/sewers/water courses. Dispose of in accordance with local authority regulations.

7 – HANDLING AND STORAGE

a) Handling	Do not smoke when handling. Avoid contact of vapour or liquid with red-hot surfaces, flames or electrical arcs as this may give rise to toxic gases such as Hydrogen Fluoride. Do not use sodium or similar metals or their hydrides for removing water from the liquid; other desiccants are acceptable. Allow sufficient ullage when drum filling to allow for thermal expansion.
b) Storage	Store in original, tightly closed, labelled container. Incompatible with Lithium, Sodium, Potassium, Calcium and Barium.

8 – EXPOSURE CONTROLS

a) Occupational Exposure Limit:	None
b) Biological Exposure Limit:	None

9 – PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Clear colourless liquid
Odour:	Odourless
Boiling Point:	48 °C
Pour Point:	-70 °C
Molecular Weight:	300
Density:	1.707 kg/l
Viscosity (kinematic):	0.58 mm^2/s
Viscosity (dynamic):	0.993 mPa s
Surface Tension:	12.4 mN/m
Vapour Pressure:	451 mbar
Heat of Vaporisation at b.p.:	90.5* kJ/kg
Specific Heat:	0.563 kJ/kg °C
Refractive index:	1.2650 N^D_{20}
Oxygen Solubility:	45* ml per 100g
Solubility in Water:	Insoluble
Solubility in Organic Solvents:	Sparingly soluble in most common solvents. Miscible with CFCs.

10 – STABILITY AND REACTIVITY

a) Stability:	Extremely stable.
b) Conditions to Avoid:	Naked flames, hot surfaces.
c) Materials to Avoid:	Lithium, Sodium, Potassium, Calcium, and Barium.

11 – TOXICOLOGICAL INFORMATION

a) Chronic Effects:	None known
b) Inhalation:	No irritation or anaesthetic effects.
c) Skin Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
d) Eye Contact:	Non-irritating but hot liquid or vapour may cause thermal burns.
e) Routes of Exposure	Inhalation, skin and eye absorption, ingestion.

12 – ECOLOGICAL INFORMATION

a) Ecotoxicity:	No specific data available

13 – DISPOSAL CONSIDERATIONS

Contact manufacturer.
Dispose of through an authorised contractor to a licensed landfill site.
Do not discharge into drains or watercourses.
Large quantities should be incinerated by a waste disposal organisation.

14 – TRANSPORT INFORMATION

Non-hazardous liquid not regulated for transport services.
UN Number – not applicable
IATA/ICAO – not regulated
ADR – not regulated
IMDG – not regulated
Transport name – not applicable
Hazchem code – not applicable.

15 – REGULATORY INFORMATION

a) Hazard symbols:	None
b) Risk and Safety phrases:	S41: In case of fire and/or explosion do not breathe fumes.
c) Other regulations:	Health and Safety at Work Act 1974.
d) Transport Information:	See 14. Transport Information.

16 – OTHER REGULATION

a) Suitability for purpose:	F2 Chemicals Ltd. cannot guarantee the suitability of this material for any particular purpose. It is the responsibility of the customer to satisfy himself that the product is suitable for his purpose. In the event of doubt the customer may contact F2 Chemicals Ltd. for advice.

MDS Nordion

MATERIAL SAFETY DATA SHEET

DATE: 2005 January 12

SECTION 1	**MATERIAL IDENTIFICATION**	**For Internal Use Only** HAZARD RATING LABEL
CHEMICAL NAME	Sodium Iodide Iodine 131 (I-131) Solution	
CHEMICAL SYNONYMS	$Na^{131}I$ in Na0H containing 0.02M Na_2S0_4 pH-9-13	
CHEMICAL FAMILY	Base; Sodium Iodide in dilute sodium hydroxide solution	
MANUFACTURER /SUPPLIER NAME	MDS Nordion Inc. 447 March Road Kanata, Ontario K2K 1X8 Telephone: (613) 592-2790 - Radiation Safety	

SECTION 2 HAZARDOUS INGREDIENTS

INGREDIENT	**Activity or %**	**Radiation Category**	**%**	**TLV**
High Radioactivity	200-10000 mCi/ml	High energy gamma and high energy beta Half-Life: 8.02 days		
Sodium Hydroxide	< 2.8 mg/ml (< 0.3% w/v)			

AECB Permitted Exposures: 50 mSv/y for Radiation Workers; 5 mSv/y for Public

SECTION 3 PHYSICAL DATA

BOILING POINT: 760 mm Hg (°C)	100-105°C	**SOLUBILITY IN WATER, % by weight @ 25°C**	100
VAPOUR PRESSURE: 20°C (mm Hg)	N/A	**SPECIFIC GRAVITY (H_2O = 1)**	1.003
VAPOUR DENSITY (air = 1)	> 1.0	**EVAPORATION RATE (butylacetate = 1)**	N/A
pH		**MELTING POINT**	
APPEARANCE AND ODOUR:	Product appears like water and is contained in a shielded and securely sealed package. No odour.		

SECTION 4 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (°C); TEST METHOD:	None	**FLAMMABLE LIMITS**	**LEL** N/A	**UEL** N/A
AUTOIGNITION TEMPERATURE (°C)	None			
EXTINGUISHING MEDIA:	N/A			

SPECIAL FIREFIGHTING PROCEDURES: N/A

UNUSUAL FIRE AND EXPLOSION HAZARDS: None

SECTION 5 REACTIVITY DATA

STABILITY:	**STABLE**X	**CONDITIONS TO AVOID**: None
	UNSTABLE ☐	
INCOMPATIBILITY:	N/A	
HAZARDOUS DECOMPOSITION PRODUCTS:		
HAZARDOUS	**WILL NOT OCCUR**X	**CONDITIONS TO AVOID:** Not identified.

POLYMERIZATION:	 **MAY OCCUR** ☐	

N/A - Not Applicable

SECTION 6 HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE:	**INHALATION:** Will result in heavy thyroid radiation dose. No respiratory symptoms.
	INGESTION: Will result in heavy thyroid radiation dose. Sodium hydroxide concentration low, may cause throat irritation and burning sensation.
	EYES: Sodium hydroxide will have irritation effect; wash immediately.
	SKIN: Corrosive effect and high radiation on contact; wash immediately.
EMERGENCY FIRST AID PROCEDURES:	**INHALATION:** Remove to fresh air and stand upwind if outside. Ascertain if individual has allergies to iodine. If not, administer stable iodine (eg. Lugol's solution). Seek medical attention for radiation intake.
	INGESTION: Ascertain if individual has allergies to iodine. If not, administer stable iodine (eg. Lugol's solution). Do not induce vomiting, due to corrosive effect of solution. Remove from source. Seek medical aid for radiation intake.
	EYES: Flush open eye(s) continuously for 15 minutes with clean water. Remove from source. See Physician for external radiation or if irritation persists.
	SKIN: Wash well with soap and water to remove contamination. Remove contaminated clothing. Remove from source. See Physician for external radiation or if irritation persists.
	NOTE: IN ALL CASES, OBTAIN MEDICAL AID PROMPTLY.

SECTION 7 SPECIAL PROTECTION INFORMATION

VENTILATION:	With I-131 local ventilation is very important, if I-131 gasses off. Wear respiratory protection, and stand upwind (if outside).
RESPIRATORY PROTECTION:	Air purifying respirator with combination radio-nuclide cartridge or SCBA where spill has occurred.
PROTECTIVE CLOTHING:	If package is damaged, wear lead-lined gloves before handling.
EYE PROTECTION:	☐ NOT NORMALLY NECESSARY ☐ SAFETY GLASSES WITH SIDE SHIELDS ☐ SAFETY GLASSES ☐ GASTIGHT GOGGLES OR EQUIVALENT X CHEMICAL WORKERS GOGGLES ☐ OTHER

SECTION 8 SPECIAL PRECAUTIONS

PRECAUTIONS IN HANDLING AND STORAGE:	All shippers and consignees must possess radioisotope license and conform with all conditions of license.
OTHER PRECAUTIONS:	

SECTION 9 SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL SPILLED OR LEAKED: Note also Section 7. If wet spill occurs, isolate contaminated area using vermiculite or charcoal. When acidified this material will release I-131. If in transport mode, call CANUTEC at (613) 996-6666 in Canada or National Response Centre at 1-800-424-8802 in USA.

WASTE DISPOSAL METHOD: If on site, follow instructions on site license or as directed by local Radiation Control Officer.

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PRODUCT NAME: KRYPTON

1. Chemical Product and Company Identification

BOC Gases,
Division of
The BOC Group, Inc.
575 Mountain Avenue
Murray Hill, NJ 07974

TELEPHONE NUMBER: (908) 464-8100
24-HOUR EMERGENCY TELEPHONE NUMBER:
CHEMTREC (800) 424-9300

BOC Gases
Division of
BOC Canada Limited
5975 Falbourne Street, Unit 2
Mississauga, Ontario L5R 3W6

TELEPHONE NUMBER: (905) 501-1700
24-HOUR EMERGENCY TELEPHONE NUMBER:
(905) 501-0802
EMERGENCY RESPONSE PLAN NO: 20101

PRODUCT NAME: KRYPTON
CHEMICAL NAME: Krypton
COMMON NAMES/SYNONYMS: Krypton, compressed
TDG (Canada) CLASSIFICATION: 2.2
WHMIS CLASSIFICATION: A

PREPARED BY: Loss Control (908)464-8100/(905)501-1700
PREPARATION DATE: 6/1/95
REVIEW DATES: 6/7/96

2. Composition, Information on Ingredients

INGREDIENT	% VOLUME	PEL-OSHA[1]	TLV-ACGIH[2]	LD_{50} or LC_{50} Route/Species
Krypton FORMULA: Kr CAS: 7439-90-9 RTECS #: Not Available	99.95 to 99.995	Simple Asphyxiant	Simple Asphyxiant	Not Available

[1] As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)

[2] As stated in the ACGIH 1994-95 Threshold Limit Values for Chemical Substances and Physical Agents

3. Hazards Identification

EMERGENCY OVERVIEW

Simple Asphyxiant - This product does not contain oxygen and may cause asphyxia if released in a confined area. Maintain oxygen levels above 19.5%. Nonflammable.

ROUTE OF ENTRY:

Skin Contact	Skin Absorption	Eye Contact	Inhalation	Ingestion
No	No	No	Yes	No

HEALTH EFFECTS:

Exposure Limits No	Irritant No	Sensitization No
Teratogen No	Reproductive Hazard No	Mutagen No
Synergistic Effects None reported		

Carcinogenicity: -- NTP: No   IARC: No   OSHA: No

EYE EFFECTS:
None known.

SKIN EFFECTS:
None known.

INGESTION EFFECTS:
None known. Ingestion is unlikely as product is gas at room temperature.

INHALATION EFFECTS:
Product is a non-toxic simple asphyxiant. High concentrations may exclude an adequate supply of oxygen to the lungs. Effect of oxygen deficiency resulting from simple asphyxiants may include: rapid breathing, diminished mental alertness, impaired muscular coordination, faulty judgement, depression of all sensations, emotional instability, and fatigue. As asphyxiation progresses, nausea, vomiting, prostration, and loss of consciousness may result, eventually leading to convulsions, coma, and death.

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

NFPA HAZARD CODES		**HMIS HAZARD CODES**		**RATINGS SYSTEM**
Health:	0	Health:	0	0 = No Hazard
Flammability:	0	Flammability:	0	1 = Slight Hazard
Reactivity:	0	Reactivity:	0	2 = Moderate Hazard
				3 = Serious Hazard
				4 = Severe Hazard

4. First Aid Measures

EYES:
None required.

SKIN:
None required.

INGESTION:
None required.

INHALATION:
PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS. Victims should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area, and if breathing has stopped, administer artificial resuscitation and supplemental oxygen. Further treatment should be symptomatic and supportive.

5. Fire Fighting Measures

Conditions of Flammability: Nonflammable		
Flash point: None	Method: Not Applicable	Autoignition Temperature: None
LEL(%): None	UEL(%): None	
Hazardous combustion products: None		
Sensitivity to mechanical shock: None		
Sensitivity to static discharge: None		

FIRE AND EXPLOSION HAZARDS:
None. Nonflammable

EXTINGUISHING MEDIA:
None required. Use as appropriate for surrounding materials.

6. Accidental Release Measures

Evacuate all personnel from affected area. Use appropriate protective equipment. If leak is in container or container valve, contact the appropriate emergency telephone number listed in Section 1 or call your closest BOC location.

7. Handling and Storage

Electrical classification:
Non-hazardous.

This gas mixture is noncorrosive and may be used with all common structural materials.

Use only in well-ventilated areas. Valve protection caps must remain in place unless container is secured with valve protection outlet piped to use point. Do not drag, slide or roll cylinders. Use a suitable hand truck for cylinder movement. Use a pressure reducing regulator when connecting cylinder to lower pressure (<3000 psig) piping or systems. Do not heat cylinder by any means to increase the discharge rate of product from the cylinder. Use a check valve or trap in the discharge line to prevent hazardous back flow into the cylinder.

Protect cylinders from physical damage. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Do not allow the temperature where cylinders are stored to exceed 125°F (52°C). Cylinders should be stored upright and firmly secured to prevent falling or being knocked over. Use a "first in-first out" inventory system to prevent full cylinders being stored for excessive periods of time.

For additional recommendations, consult Compressed Gas Association Pamphlets P-1, P-14, P-9, and Safety Bulletin SB-2.

Never carry a compressed gas cylinder or a container of a gas in cryogenic liquid form in an enclosed space such as a car trunk, van or station wagon. A leak can result in a fire, explosion, asphyxiation or a toxic exposure.

8. Exposure Controls, Personal Protection

EXPOSURE LIMITS[1]:

INGREDIENT	% VOLUME	PEL-OSHA[2]	TLV-ACGIH[3]	LD_{50} or LC_{50} Route/Species
Krypton FORMULA: Kr CAS: 7439-90-9 RTECS #: Not Available	99.95 to 99.995	Simple Asphyxiant	Simple Asphyxiant	Not Available

[1] Refer to individual state of provincial regulations, as applicable, for limits which may be more stringent than those listed here.

[2] As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)

[3] As stated in the ACGIH 1994-1995 Threshold Limit Values for Chemical Substances and Physical Agents.

ENGINEERING CONTROLS:
Local exhaust to prevent accumulation of high concentrations so as to reduce the oxygen level in the air to less than 19.5%.

EYE/FACE PROTECTION:
Safety goggles or glasses as appropriate for the job.

SKIN PROTECTION:
Protective gloves of material appropriate for the job.

RESPIRATORY PROTECTION:
Positive pressure air line with full-face mask and escape bottle or self-contained breathing apparatus should be available for emergency use.

OTHER/GENERAL PROTECTION:
Safety shoes or other footwear as appropriate for the job.

9. Physical and Chemical Properties

PARAMETER	VALUE	UNITS
Physical state (gas, liquid, solid)	: Gas	
Vapor pressure at STP	: Not Available	
Vapor density (Air = 1)	: 2.92	
Evaporation point	: Not Available	
Boiling point	: -244	^{o}F
	: -153.3	^{o}C
Freezing point	: -250.9	^{o}F
	: -157.2	^{o}C
pH	: Not Applicable	
Specific gravity	: Not Available	
Oil/water partition coefficient	: Not Available	
Solubility (H20)	: Negligible	
Odor threshold	: Not Applicable	
Odor and appearance	: An odorless, colorless gas	

10. Stability and Reactivity

STABILITY:
Stable

INCOMPATIBLE MATERIALS:
None

HAZARDOUS POLYMERIZATION:
Does not occur

11. Toxicological Information

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

No data given in the Registry of Toxic Effects of Chemical Substances (RTECS) or Sax, Dangerous Properties of Industrial Materials, 7th ed.

12. Ecological Information

No data given.

13. Disposal Considerations

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED, WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to BOC Gases or authorized distributor for proper disposal.

14. Transport Information

PARAMETER	United States DOT	Canada TDG
PROPER SHIPPING NAME:	Krypton, compressed	Krypton, compressed
HAZARD CLASS:	2.2	2.2
IDENTIFICATION NUMBER:	UN 1056	UN 1056
SHIPPING LABEL:	NONFLAMMABLE GAS	NONFLAMMABLE GAS

15. Regulatory Information

SARA TITLE III NOTIFICATIONS AND INFORMATION

SARA TITLE III - HAZARD CLASSES:
Sudden Release of Pressure Hazard

16. Other Information

Compressed gas cylinders shall not be refilled without the express written permission of the owner. Shipment of a compressed gas cylinder which has not been filled by the owner or with his/her (written) consent is a violation of transportation regulations.

DISCLAIMER OF EXPRESSED AND IMPLIED WARRANTIES:
Although reasonable care has been taken in the preparation of this document, we extend no warranties and make no representations as to the accuracy or completeness of the information contained herein, and assume no responsibility regarding the suitability of this information for the user's intended purposes or for the consequences of its use. Each individual should make a determination as to the suitability of the information for their particular purpose(s).

BOC GASES

MATERIAL SAFETY DATA SHEET

Distributed by: **MSDS:000085**
Machine & Welding Supply Co.
P.O. Box 1708 **Phone: (910) 892-4016**
Hwy 301 South **Fax: (910) 892-3575**
Dunn, NC 28335 **Internet: www.mwsc.com**

PRODUCT NAME: NEON

1. Chemical Product and Company Identification

BOC Gases,
Division of
The BOC Group, Inc.
575 Mountain Avenue
Murray Hill, NJ 07974

TELEPHONE NUMBER: (908) 464-8100
24-HOUR EMERGENCY TELEPHONE NUMBER:
CHEMTREC (800) 424-9300

BOC Gases
Division of
BOC Canada Limited
5975 Falbourne Street, Unit 2
Mississauga, Ontario L5R 3W6

TELEPHONE NUMBER: (905) 501-1700
24-HOUR EMERGENCY TELEPHONE NUMBER:
(905) 501-0802
EMERGENCY RESPONSE PLAN NO: 20101

PRODUCT NAME: NEON
CHEMICAL NAME: Neon
COMMON NAMES/SYNONYMS: Neon, compressed
TDG (Canada) CLASSIFICATION: 2.2
WHMIS CLASSIFICATION: A

PREPARED BY: Loss Control (908)464-8100/(905)501-1700
PREPARATION DATE: 6/1/95
REVIEW DATES: 6/7/96

2. Composition, Information on Ingredients

INGREDIENT	% VOLUME	PEL-OSHA[1]	TLV-ACGIH[2]	LD_{50} or LC_{50} Route/Species
Neon FORMULA: Ne CAS: 7440-01-9 RTECS #: QP4450000	75.0 to 99.9999	Simple Asphyxiant	Simple Asphyxiant	Not Available
Helium FORMULA: He CAS: 7440-59-7 RTECS #: MH6520000	0 to 25.0	Simple Asphyxiant	Simple Asphyxiant	Not Available

[1] As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)

[2] As stated in the ACGIH 1994-95 Threshold Limit Values for Chemical Substances and Physical Agents

3. Hazards Identification

EMERGENCY OVERVIEW

Simple Asphyxiant - This product does not contain oxygen and may cause asphyxia if released in a confined area. Maintain oxygen levels above 19.5%. Nonflammable.

ROUTE OF ENTRY:

Skin Contact	Skin Absorption	Eye Contact	Inhalation	Ingestion
No	No	No	Yes	No

HEALTH EFFECTS:

Exposure Limits No	Irritant No	Sensitization No
Teratogen No	Reproductive Hazard No	Mutagen No
Synergistic Effects None reported		

Carcinogenicity: -- NTP: No   IARC: No   OSHA: No

EYE EFFECTS:
None known.

SKIN EFFECTS:
None known.

INGESTION EFFECTS:
None known. Ingestion is unlikely as product is gas at room temperature.

INHALATION EFFECTS:
Product is a non-toxic simple asphyxiant. Effects of oxygen deficiency resulting from simple asphyxiants may include: rapid breathing, diminished mental alertness, impaired muscular coordination, faulty judgement, depression of all sensations, emotional instability, and fatigue. As asphyxiation progresses, nausea, vomiting, prostration, and loss of consciousness may result, eventually leading to convulsions, coma, and death.

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

NFPA HAZARD CODES		HMIS HAZARD CODES		RATINGS SYSTEM
Health:	0	Health:	0	0 = No Hazard
Flammability:	0	Flammability:	0	1 = Slight Hazard
Reactivity:	0	Reactivity:	0	2 = Moderate Hazard
				3 = Serious Hazard
				4 = Severe Hazard

4. First Aid Measures

EYES:
None required.

SKIN:
None required.

INGESTION:
None required.

INHALATION:
PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS. Victims should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area, and if breathing has stopped, administer artificial resuscitation and supplemental oxygen. Further treatment should be symptomatic and supportive.

5. Fire Fighting Measures

Conditions of Flammability: Nonflammable		
Flash point: None	Method: Not Applicable	Autoignition Temperature: None
LEL(%): None	UEL(%): None	
Hazardous combustion products: None		
Sensitivity to mechanical shock: None		
Sensitivity to static discharge: None		

FIRE AND EXPLOSION HAZARDS:
None. Nonflammable.

EXTINGUISHING MEDIA:
None required. Use as appropriate for surrounding materials.

6. Accidental Release Measures

Evacuate all personnel from affected area. Use appropriate protective equipment. If leak is in container or container valve, contact the appropriate emergency telephone number listed in Section 1 or call your closest BOC location.

7. Handling and Storage

Electrical classification:
Non-hazardous.

This gas mixture is noncorrosive and may be used with all common structural materials.

Use only in well-ventilated areas. Valve protection caps must remain in place unless container is secured with valve protection outlet piped to use point. Do not drag, slide or roll cylinders. Use a suitable hand truck for cylinder movement. Use a pressure reducing regulator when connecting cylinder to lower pressure (<3000 psig) piping or systems. Do not heat cylinder by any means to increase the discharge rate of product from the cylinder. Use a check valve or trap in the discharge line to prevent hazardous back flow into the cylinder.

Protect cylinders from physical damage. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Do not allow the temperature where cylinders are stored to exceed 125^{o}F (52^{o}C). Cylinders should be stored upright and firmly secured to prevent falling or being knocked over. Use a "first in-first out" inventory system to prevent full cylinders being stored for excessive periods of time.
For additional recommendations, consult Compressed Gas Association Pamphlets P-1, P-14, P-9, and Safety Bulletin SB-2.

Never carry a compressed gas cylinder or a container of a gas in cryogenic liquid form in an enclosed space such as a car trunk, van or station wagon. A leak can result in a fire, explosion, asphyxiation or a toxic exposure.

8. Exposure Controls, Personal Protection

EXPOSURE LIMITS[1]:

INGREDIENT	% VOLUME	PEL-OSHA[2]	TLV-ACGIH[3]	LD_{50} or LC_{50} Route/Species
Neon FORMULA: Ne CAS: 7440-01-9 RTECS #: QP4450000	75.0 to 99.9999	Simple Asphyxiant	Simple Asphyxiant	Not Available
Helium FORMULA: He CAS: 7440-59-7 RTECS #: MH6520000	0 to 25.0	Simple Asphyxiant	Simple Asphyxiant	Not Available

[1] Refer to individual state of provincial regulations, as applicable, for limits which may be more stringent than those listed here.
[2] As stated in 29 CFR 1910, Subpart Z (revised July 1, 1993)
[3] As stated in the ACGIH 1994-1995 Threshold Limit Values for Chemical Substances and Physical Agents.

ENGINEERING CONTROLS:
Local exhaust to prevent accumulation of high concentrations so as to reduce the oxygen level in the air to less than 19.5%.

EYE/FACE PROTECTION:
Safety goggles or glasses as appropriate for the job.

SKIN PROTECTION:
Protective gloves of material appropriate for the job.

RESPIRATORY PROTECTION:
Positive pressure air line with full-face mask and escape bottle or self-contained breathing apparatus should be available for emergency use.

OTHER/GENERAL PROTECTION:
Safety shoes or other footwear as appropriate for the job.

9. Physical and Chemical Properties

PARAMETER	VALUE	UNITS
Physical state (gas, liquid, solid)	: Gas	
Vapor pressure	: Gas, above crit. temp.	
Vapor density at 70 °F, 1 atm (Air = 1).	: 0.70	
Evaporation point	: Not Available	
Boiling point	: -410.9	°F
	: -246.1	°C
Freezing point	: -415.5	°F
	: -248.6	°C
pH	: Not Applicable	
Specific gravity	: Not Available	
Oil/water partition coefficient	: Not Available	
Solubility (H20)	: Negligible	
Odor threshold	: Not Applicable	
Odor and appearance	: Colorless, odorless gas	

10. Stability and Reactivity

STABILITY:
Stable

INCOMPATIBLE MATERIALS:
None

HAZARDOUS POLYMERIZATION:
Does not occur.

11. Toxicological Information

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

No data given in the Registry of Toxic Effects of Chemical Substances (RTECS) or Sax, Dangerous Properties of Industrial Materials, 7th ed.

12. Ecological Information

No data given.

13. Disposal Considerations

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14. Transport Information

PARAMETER	United States DOT	Canada TDG
PROPER SHIPPING NAME:	Neon, compressed	Neon, compressed
HAZARD CLASS:	2.2	2.2
IDENTIFICATION NUMBER:	UN 1065	UN 1065
SHIPPING LABEL:	NONFLAMMABLE GAS	NONFLAMMABLE GAS

15. Regulatory Information

SARA TITLE III NOTIFICATIONS AND INFORMATION

SARA TITLE III - HAZARD CLASSES:
Sudden Release of Pressure Hazard

16. Other Information

Compressed gas cylinders shall not be refilled without the express written permission of the owner. Shipment of a compressed gas cylinder which has not been filled by the owner or with his/her (written) consent is a violation of transportation regulations.

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MSDS
Perfluorodimethylcyclobutane

Material Safety Data Sheet
acc. to OSHA and ANSI
Printing date 05/30/2000Reviewed on 05/05/2000

1 Identification of substance:

Product details:
Trade name: Perfluorodimethylcyclobutane
Stock number: 43036

Manufacturer/Supplier:
Alfa Aesar, A Johnson Matthey Company
Johnson Matthey Catalog Company, Inc.
30 Bond Street
Ward Hill, MA 01835-8099
Emergency Phone: (978) 521-6300
CHEMTREC: (800) 424-9300
Web Site: www.alfa.com

Information department: Health, Safety and Environmental Department

Emergency information:
During normal hours the Health, Safety and Environmental Department. After normal hours call Chemtrec at (800) 424-9300.

2 Composition/Data on components:

Chemical characterization:
Description: (CAS#)
Perfluorodimethylcyclobutane (CAS# 28677-00-1), 100%

Identification number(s):
EINECS Number: 249-145-3

3 Hazards identification

Hazard description: · Not applicable

Information pertaining to particular dangers for man and environment
Not applicable

4 First aid measures

After inhalation
Supply fresh air. If required, provide artificial respiration. Keep patient warm. Seek immediate medical advice.

After skin contact
Immediately wash with water and soap and rinse thoroughly. Seek immediate medical advice.

After eye contact

Rinse opened eye for several minutes under running water. Then consult a doctor.

After swallowing Seek medical treatment.

5 Fire fighting measures

Suitable extinguishing agents
Use carbon dioxide, extinguishing powder or foam. Water may be ineffective but may be used for cooling exposed containers.

Special hazards caused by the material, its products of combustion or resulting gases:
In case of fire, the following can be released:
Carbon monoxide (CO)
Hydrogen fluoride (HF)

Protective equipment:
Wear self-contained respirator. Wear fully protective impervious suit.

6 Accidental release measures

Person-related safety precautions:
Wear protective equipment. Keep unprotected persons away. Ensure adequate ventilation

Measures for environmental protection:
Do not allow material to be released to the environment without proper governmental permits.

Measures for cleaning/collecting:
Absorb with liquid-binding material (sand, diatomite, acid binders, universal binders, sawdust).

Additional information:
See Section 7 for information on safe handling
See Section 8 for information on personal protection equipment.
See Section 13 for disposal information.

7 Handling and storage

Handling
Information for safe handling:
Keep container tightly sealed. Store in cool, dry place in tightly closed containers. No special precautions are necessary if used correctly.

Information about protection against explosions and fires:
The product is not flammable

Storage
Requirements to be met by storerooms and receptacles:
No special requirements.

Information about storage in one common storage facility:

Store away from oxidizing agents.

Further information about storage conditions:
Refrigerate
Keep container tightly sealed.
Store in cool, dry conditions in well sealed containers.

8 Exposure controls and personal protection

Additional information about design of technical systems:
Properly operating chemical fume hood designed for hazardous chemicals and having an average face velocity of at least 100 feet per minute.

Components with limit values that require monitoring at the workplace:
Not required.

Additional information: No data

Personal protective equipment
General protective and hygienic measures
The usual precautionary measures for handling chemicals should be followed. Keep away from foodstuffs, beverages and feed. Remove all soiled and contaminated clothing immediately. Wash hands before breaks and at the end of work.

Breathing equipment:
Use suitable respiratory protective device in case of insufficient ventilation. Use suitable respirator when high concentrations are present.

Protection of hands: Impervious gloves

Eye protection: Safety glasses

Body protection: Protective work clothing.

9 Physical and chemical properties:

Form: Liquid
Color: Colorless
Odor: Nearly odorless

Value/Range		Unit	Method
Melting point/Melting range:	Not determined		
Boiling point/Boiling range:	45	° C	
Sublimation temperature / start:	Not determined		
Flash point:	Not applicable		
Ignition temperature:	Not determined		
Decomposition temperature:	Not determined		

Danger of explosion:
Product does not present an explosion hazard.

Explosion limits:

Lower:	Not determined
Upper:	Not determined

Vapor pressure: Not determined
Density: at 20 ° C 1.62 g/cm3

Solubility in / Miscibility with Water:
Not miscible or difficult to mix

10 Stability and reactivity

Thermal decomposition / conditions to be avoided:
Decomposition will not occur if used and stored according to specifications.

Materials to be avoided: Oxidizing agents

Dangerous reactions No dangerous reactions known

Dangerous products of decomposition:
Carbon monoxide and carbon dioxide
Hydrogen fluoride (HF)

11 Toxicological information

Acute toxicity:

Primary irritant effect:
on the skin: May cause irritation
on the eye: May cause irritation

Sensitization: No sensitizing effects known.

Subacute to chronic toxicity:
Other than potential irritation (see above), no information on illness or injury from acute or chronic exposure to this product is available.

Additional toxicological information:
To the best of our knowledge the acute and chronic toxicity of this substance is not fully known. No classification data on carcinogenic properties of this material is available from the EPA, IARC, NTP, OSHA or ACGIH.

12 Ecological information:

General notes:
Do not allow material to be released to the environment without proper governmental permits.

13 Disposal considerations

Product:
Recommendation
Consult state, local or national regulations for proper disposal.

Uncleaned packagings:
Recommendation:
Disposal must be made according to official regulations.

14 Transport information

Not a hazardous material for transportation.
DOT regulations:
Hazard class: None
Land transport ADR/RID (cross-border)

ADR/RID class: None

Maritime transport IMDG:
IMDG Class: None

Air transport ICAO-TI and IATA-DGR:
ICAO/IATA Class: None

Transport/Additional information:
Not dangerous according to the above specifications.

15 Regulations

Product related hazard informations:
Observe the general safety regulations when handling chemicals

National regulations
This product is not listed in the U.S. Environmental Protection Agency Toxic Substances Control Act Chemical Substance Inventory. Use of this product is restricted to research and development only.

Information about limitation of use:
For use only by technically qualified individuals.

16 Other information:

Employers should use this information only as a supplement to other information gathered by them, and should make independent judgement of suitability of this information to ensure proper use and protect the health and safety of employees. This information is furnished without warranty, and any use of the product not in conformance with this Material Safety Data Sheet, or in combination with any other product or process, is the responsibility of the user.

Department issuing MSDS: Health, Safety and Environmental Department.
Contact: Darrell R. Sanders