Appendix A
Air Quality

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Table of Contents

LIST OF TABLES

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Appendix A
Air Quality

A.1 SITE PREPARATION AND CONSTRUCTION

Air emissions would result from the construction at new SPR sites, the expansion of existing SPR sites, the construction of pipelines in pipeline rights-of-way (ROWs), and the construction of other associated facilities. Air emissions would also result from the operation and maintenance of the SPR sites. The greatest potential for air quality impacts is associated with construction when emission of fugitive particulate matter (PM) would result from large-scale cut-and-fill operations. Other potential impacts that would result from air emissions are related to evaporative non-methane hydrocarbon (NMHC) emissions from the brine ponds associated with cavern development and filling. In addition, construction equipment is generally powered by onsite internal combustion engines, which would emit additional air pollutants, including nitrogen oxides (NOx), PM, carbon monoxide (CO), and NMHC. Emissions that would occur during the site preparation and construction phases are best described in four areas: emissions from off-road equipment used by the work crews, emissions from on-road utility trucks used by the work crews, fugitive dust from construction activity at new buildings, and NMHC emitted during cavern development and filling. This appendix describes how emission estimates in these four areas were developed for this assessment.

In addition to the criteria air pollutants, the construction and operation of the SPR would generate greenhouse gas emissions. Details appear at the end of this appendix on how such emissions were determined for the analysis.

A.2 OFF-ROAD EQUIPMENT EMISSIONS

The NONROAD model (EPA 2002) is the EPA standard method for preparing emissions inventories for mobile sources that are not classified as being related to on-road traffic, railroads, air traffic, or water-going vessels. As such, it is the starting place for quantifying emissions from construction-related equipment. The NONROAD model uses the following general equation to estimate emissions separately for CO, NOx, PM (essentially all of which is PM2.5 from construction sources), and total hydrocarbons (THC), nearly all of which are NMHC[1]:

$$EMS = EF * HP * LF * Act * DF$$

Where:

EMS = estimated emissions
EF = emissions factor in grams per horsepower hours
HP = peak horsepower
LF = load factor (assumed percentage of peak horsepower)
Act = activity in hours of operation per period of operation
DF = deterioration factor

The emissions factor is specific to the equipment type, engine size, and technology type. The technology type for diesel equipment can be “base” (before 1988), “tier 0” (1988 to 1999), or “tier 1” (2000 to 2005). Tier 2 emissions factors could be applied to equipment that satisfies 2006 national standards (or slightly earlier California standards). The technology type for two-stroke gasoline equipment can be “base”

[1] A factor of 0.991 was used for 2-stroke and 0.984 was used for diesel to convert from THC to NMHC.

(before 1997), "phase 1" (1997 to 2001), or "phase 2" (2002 to 2007). Equipment for phases 1 and 2 can have catalytic converters. For this study, all diesel equipment was assumed to be tier 1 and all two-stroke diesel equipment was assumed to be phase 2 without catalytic converters.[2]

The load factor is specific to the equipment type in the NONROAD model regardless of engine size or technology type, and it represents the average fraction of peak horsepower at which the engine is assumed to operate. NONROAD model default values were used in all cases. The deterioration factor was used to estimate increased emissions due to engine age. Conservatively, all equipment was assumed to be fully aged, which can represent different numbers of hours of operation for different equipment types, and the maximum deterioration factor was used.

Using this methodology, it is possible to make a conservative estimate of emissions from off-road equipment if the types of equipment and durations of use are known (see section A.5).

A.3 ON-ROAD UTILITY TRUCKS

Each work crew was assumed to have one truck for every four people. Emissions were estimated assuming that each crew had a gasoline-fueled truck similar to a Ford F-150 Supercab meeting tier 1 emission standards with at least 50,000 miles (80,000 kilometers) of use (between 5 and 10 years old). Such a truck fits into the heavy light-duty truck classification in the heaviest weight category. Table A.3-1 gives the emissions standards for such a truck. Each truck was assumed to be in use for a full 8-hour day traveling a total of 40 miles (64 kilometers) during this period.

Table A.3-1: Emissions from a Single, Fully-Aged (50,000 miles) Crew Truck

	THC	NMHC	CO	NOx	PM
Grams/mile	0.8	0.56	7.3	1.53	0.12
Grams/day	32	22.4	292	61.2	4.8

Source: EPA MOBILE6 Model (EPA, 2003)

A.4 FUGITIVE DUST

Emission rates for fugitive dust were estimated using guidelines outlined in the Western Regional Air Partnership (WRAP) fugitive dust handbook (WRAP 2004). Although these guidelines were developed for use in western states, they assume standard dust mitigation best practices activities of 50% from wetting; therefore, they were deemed applicable but conservative for the Gulf Coast. The WRAP handbook offers several options for selecting factors for PM10 (coarse PM) depending on what information is known. Table A.4-1 shows the possible emission factors and basis for choosing them. However, in addition all roads and earth movement activities are subject to some natural mitigation because of rainfall and other precipitation. To estimate the additional factor for natural mitigation EPA's AP-42 (EPA 2003a) suggests that the PM10 emission factor is multiplied by (365-D)/365, where D is the number of days per year with measurable[3] precipitation. In cities like Jackson, MS, the average value for D is 108 and the additional natural mitigation reduction is 30%. Thus, additional emission reduction through natural mitigation was included specifically for each facility location to account for the more moist Gulf Coast setting.

[2] DOE would require that the construction contractors for SPR expansion must use non-road diesel fueled equipment meeting EPA's Tier 1 or Tier 2 emission standards.

[3] Daily precipitation of 0.01 inch or more.

After PM10 is estimated, the fraction of fugitive dust emitted as PM2.5 is estimated, the most recent WRAP study (MRI 2005) recommends the use of a fractional factor of 0.10 to estimate the PM2.5 portion of the PM10.

For site preparation activities, only the areas of disturbance and approximate durations were known; therefore, the first factor with average conditions was used in the analysis. After completion of soil stabilization and compaction analysis, fugitive dust emissions were estimated for activities involving major earth moving (road building and pipeline construction). In the case of pipeline construction, the second set of factors was used on a per-month basis. The work area was calculated using the easement width multiplied by the length of pipeline laid in a month. The volume of onsite cut-and-fill was calculated assuming a trench 10 feet (3 meters) wide by 5 feet (1.5 meters) deep multiplied by the length of pipeline laid in a month. The volume of earth hauled offsite was assumed to be zero because all earth would be used to refill the trench and cover the pipeline. A pipeline crew with two backhoes was assumed to be capable of digging about 30,000 cubic yards (23,000 cubic meters) of earth per month, and then of refilling the trench after pipe was laid. At this rate, a single crew could be expected to prepare 3 miles (4.8 kilometers) of pipeline trench per month.

Table A.4-1: PM10 Emissions Factors Recommended by the WRAP Handbook

Basis for Emission Factor	Recommended PM10 Emission Factor
Only area and duration known	0.11 ton/acre/month (average conditions) or 0.22 ton/acre/month (average, no mitigation) or 0.43 ton/acre/month (worst-case conditions)
Volume of earth moved known	0.011 ton/acre/month for general construction plus 0.059 ton/1000 yard^3 for onsite cut-fill plus 0.22 ton/1000 yard^3 for offsite cut-fill
Equipment usage known	0.13 pounds/acre/work-hour for general construction plus 49 pounds/scraper-hour for onsite haulage plus 94 pounds/hour for offsite haulage

Source: WRAP, 2004

1 ton/acre = 0.5999 kilograms/meter^2
1 ton/1000 yard^3 = 1.1865 metric tons/1000 meter^3
1 pound/acre = 112 kilograms/kilometers^2
1 pound = 0.45359 kilograms

A.5 SITE DEVELOPMENT

Site preparation can be divided into four sequential phases: clearing and grubbing, rough grading, soil (lime) stabilization, and embankment placement and compaction. Likely equipment needs for these activities are listed in Table A.5-1. All of these activities would be necessary to develop new sites (DOE 1992a, 2-18) and clearing and grubbing activities would be necessary for the entire facility to enable operational surveillance. Existing sites would need elements from each of these activities depending upon existing conditions. Additionally, sites such as Bayou Choctaw, and Chacahoula would only require clearing as they are located in wetlands, but would require other activity phases associated with walkway construction. Results for each of these activities for each facility are given in the body of the report.

Table A.5-1: Typical Equipment Used for Site Preparation at a New SPR Site

Phase	Equipment	Type	HP	Number	% Use
Clearing and grubbing	Chain saw	2-stroke	5	26	50
	Brush cutter	2-stroke	5	26	50
	Chipper	2-stroke	10	4	50
	Backhoe	Diesel	100	8	25
Rough grading	Dozer	Diesel	300	2	100
	Scraper	Diesel	200	2	100
Soil stabilization	Dozer	Diesel	150	4	100
	Grader	Diesel	150	4	100
Embankment compaction	Scraper	Diesel	200	2	100
	Plate compactor	Diesel	5	12	100

HP = Horsepower
% use = the average fraction of time that the equipment is operating during a work day
Source: Clovelly and Chacahoula Cost Estimate (DOE, 2004c; DOE 2004e)

Facility construction would consist of five phases: foundation pouring, building construction, electrical installation, pipe installation, and road construction. These phases could overlap somewhat. Of these activities, only road construction would be expected to result in significant fugitive particulate emissions while they all would produce fuel combustion related emissions. Some of these activities would be unnecessary or relatively brief for expansion sites depending upon existing infrastructure, but all would be necessary at new sites. The equipment that may be used in each phase of facility construction is given in Table A.5-2. Results for each of these activities for each facility are given in the body of the report.

Table A.5-2: Equipment Used for Proposed New SPR Facility Construction

Phase	Equipment	Type	HP	Number	% Use
Foundation pouring	Cement mixer	Diesel	350	2	100
	Roller compactor	Diesel	100	4	50
	Spreader	Diesel	100	4	50
Building construction	50 ton crane	Diesel	170	1	50
	Welder	Diesel	50	12	100
Electrical installation	50 ton crane	Diesel	170	1	25
	12 ton crane	Diesel	40	1	25
	Bucket truck	Diesel	200	1	100
Pipe installation	Excavator	Diesel	240	1	100
Road construction	Dozer	Diesel	200	1	100
	Spreader	Diesel	100	1	100
	Steel roller	Diesel	100	1	30
	Wheel roller	Diesel	100	1	30

HP = Horsepower
% use = the average fraction of time that the equipment is operating during a work day
Source: Clovelly and Chacahoula Cost Estimate (DOE, 2004c; DOE 2004e)

Cavern drilling would require using up to four 500 horsepower diesel-powered boring drills working 24 hours per day. All lead holes (initial holes for cavern development) would be expected to be drilled during facility construction, even if solution mining for some of the caverns would begin at a later date.

New and existing SPR facilities may require extensive pipeline construction for both oil and brine transport. These pipes would range in diameter from 16 to 48 inches (0.4 to 1.2 meters) and are assumed to be buried using a conventional land lay method whereby ditches are excavated with backhoes with the trench dug 5 feet (1.5 meters) deep and 10 feet (3.0 meters) across and then backfilled. This land lay method is conservative for air quality analysis as it requires the most construction equipment and activity, except at locations that are swampy or underwater. Because the majority of pipeline construction would occur offsite, pipeline construction could begin at the start of site preparation and could continue for up to three years, depending upon the site. Equipment likely to be used in pipeline construction is listed in Table A.5-3

Table A.5-3: Equipment Used by a Single Pipeline Construction Crew

Phase	Equipment	Type	HP	Number	% use
Pipeline Construction	Backhoe	Diesel	100	2	100
	12 Ton Mobile Crane	Diesel	40	1	30
	Grader	Diesel	150	1	30

HP = Horsepower
% use = the average fraction of time that the equipment is operating during a work day
Source: Clovelly and Chacahoula Cost Estimate (DOE, 2004c; DOE 2004e)

A.6 CAVERN DEVELOPMENT AND FILLING

During the cavern solution mining process, small amounts of hydrocarbons would be present in the brine pumped out of the caverns and subsequently released into the atmosphere. If it is assumed that these hydrocarbons would be completely volatilized to the atmosphere during the solution mining process, the following equation can be used to estimate atmospheric emissions of NMHC (DOE 1981, appendix C.2):

$$\text{NMHC Emissions} = \text{NMHC in Brine (parts per million} \times 10^{-6}) \times \text{Pumping Rate (barrels per day)} \times (42 \text{ gallons per barrel}) \times \text{Brine Density (pounds per gallon)}$$

Using the assumption that the brine density as measured at the Bryan Mound caverns is fairly constant at the value of 10.0 pounds/gallon (1.2 kilograms/liter) and representative of all SPR caverns, table A.5-1 gives an example NMHC emission rate estimate for 10 cavern facilities each with 10-million barrel (MMB) storage capacity where all caverns are developed simultaneously.

For each new cavern development project, the values in this table were used to predict durations and annual emissions associated with these activities. Durations for solution mining and solution mining/fill activities were estimated by scaling with the peak brine-production rate and maximum added capacity for each site. Annual emissions for these two activities were scaled using only the peak brine-production rate. For the final fill, durations and emissions were scaled using the maximum added capacity only.

Table A.6-1: NMHC Emissions Associated with Cavern Development (100 MMB)

Activity	Duration	Brine Production	Brine NMHC Concentration	Short-Term Emissions (grams/second)	Annual Emissions (tons)
Solution Mining	638 days	1.0 MMBD	0.26 ppm	0.57	19.9
Solution Mining/Fill	539 days	1.0 MMBD	1.0 ppm[a]	2.25	78.2
Final Fill[b]	200 days	0.3 MMBD	2.6 ppm	1.72	32.8

Source: DOE, 1992b

[a] Based on average solubility during solution mining and fill (midpoint) starting from zero based on current cavern development approach; for endpoint used measured data from appendix C.2 (table C.2-1) (DOE, 1981), four of the five measurements >90% full (end of process) and vapor partial fraction of 0.85.
[b] The original tables (table 7.1-1, pg 7-18) in DOE (1992b) reported emission rates of 1.15 g/s and 21.9 ton per year for final fill, but these were found to be in error, and corrected values are shown in this table.

ppm = parts per million
MMBD = million barrels per day

A.7 GREENHOUSE GAS EMISSIONS CALCULATIONS

The most important greenhouse gases (GHG) that would result from activities at the SPR expansion are carbon dioxide (CO_2) and methane (CH_4). The most significant source of GHG emissions are CO_2 emissions associated with combustion sources and CH_4 during cavern solution mining. All combustion engines, including gasoline and diesel, would emit large quantities of CO_2. Emissions of nitrous oxide (N_2O) and CH_4 from gasoline and diesel engines would be much smaller, and therefore, only CO_2 was considered from combustion sources. Solution mining of salt from cavern development would emit trapped CH_4 in addition to the other NMHC discussed in section 3.4. The brine pumped from the caverns also contains some CO_2; however, because CO_2 is soluble in water and the concentrations of CO_2 in the brine are well below equilibrium concentrations found in sea water, the CO_2 would remain in the sea water. Thus, this analysis considers only the CH_4 emissions from cavern solution mining.

Emissions of CO_2 from both spark-ignition and compression-ignition off-road construction equipment was estimated based on assumed fuel consumption rates. EPA's NONROAD model provides a fleet-average fuel consumption rate for diesel as well as two-stroke and four-stroke spark-ignition engines based on technology level and engine size (EPA 2004a, all; EPA 2004b, all). Given these data, the following equation was used to calculate CO_2 emissions:

$$CO_2 = (BSFC*453.6 - HC) *0.87*(44/12)$$

Where:

CO_2 is the CO_2 emission rate for off-road equipment in grams per horsepower hour;

BSFC is the in-use brake-specific adjusted-fleet-average fuel consumption in pounds per horsepower hour;

453.6 is the conversion from pounds (mass) to grams;

HC is hydrocarbon emissions in grams per horsepower hour;

0.87 is the carbon mass fraction of fossil fuels; and

44/12 is the ratio of CO_2 mass-to-carbon mass.

Emission from motor vehicles can be determined in an analogous manner to those from off-road equipment using an assumed fuel consumption rate for gasoline. The CO_2 vehicle emission rate for commuter vehicles can be determined by the following equation:

$$CO_2V= (FUELD*453.6/FE-THC) *0.87*(44/12)$$

Where:

CO_2V is the CO_2 vehicle emission rate in grams per mile;

FUELD is the fuel density of 6.1 pounds per gallon (0.73 kilograms per liter) of gasoline;

FE is the fuel economy of 21 miles per gallon (8.9 kilometers per liter);

THC is the total hydrocarbon emission in grams per mile (from MOBILE6.2);

0.87 is the carbon mass fraction of fossil fuels; and

44/12 is the ratio of CO_2 mass-to-carbon mass.

Total emissions of CO_2 were then calculated based on miles traveled determined from mean driving distance. Local population centers within 50 miles (80 kilometers) of each proposed site were assumed to contribute a share of the workforce proportional to their populations, yielding a population-weighted average commute distance. Conservatively, each worker was assumed to make 250 round trips per year (50 weeks, 5 days per week, no carpooling). Then, using employment information on the total number of workers for each facility, a total CO_2 emission rate was estimated for each facility.

Solution mining of the salt domes would cause emissions of CH_4 to be pumped out with the concentrated brine. A methodology based on several cavern development studies prepared for the 1981 Environmental Impact Statement (DOE 1981), similar to that previously used to determine NMHC emissions, was used to estimate CH_4 emission rates. Equilibrium brine concentrations of CH_4 were calculated based on measurements taken at different stages of cavern development. The vapor partition factor (the ratio of solution escaping to the atmosphere over total solution dissolved from the cavern along with the brine) was assumed to be the same as NMHC as most NMHC emissions were light hydrocarbons (C2–C5 paraffins) (ethane through n-pentane). Throughout all phases emissions were calculated based on the brine removal rate, the concentration of CH_4 in brine, and the vapor partition factor.

Emissions during the initial solution mining were computed from the data of seven Bryan Mound samples studied in 1981 during early stages of cavern and roof development. During the solution mining/fill phase, it was assumed that the concentration of CH_4 in brine varied linearly between the late stages of cavern roof development and the maximum equilibrium concentration in brine. During the final fill, CH_4 was assumed to be at the maximum equilibrium (DOE 1981 p. C.2-9 – C.2-18).

REFERENCES

Midwest Research Institute (MRI). 2005 "Analysis of the Fine Fraction of Particulate Matter in Fugitive Dust" conducted for the Western Governors Association Western Regional Air Partnership (WRAP), MRI Project No. 110397, October, 2005.

United States Department of Energy (DOE). 1981. "Final Supplement to Final Environmental Impact Statements. Strategic Petroleum Reserve: Phase III Development Texoma and Seaway Group Salt Domes (West Hackberry and Bryan Mound Expansion, Big Hill Development): Cameron Parish, Louisiana and Brazoria and Jefferson Counties, Texas." (DOE/EIS-0021,0029).

United States Department of Energy (DOE). 1992. "Draft Environmental Impact Statement on the Expansion of the Strategic Petroleum Reserve, Alabama, Louisiana, Mississippi, Texas." (DOE/EIS-0165-D). Washington, DC.

United States Environmental Protection Agency (EPA). 2002. "User's Guide for the EPA Emissions Model Draft NONRoad 2002." (EPA-454/B-95-003a).

United States Environmental Protection Agency (EPA). August 2003. "User's Guide to MOBILE6.1 and MOBILE6.2: Mobile Source Emission Factor Model." (EPA420-R-03-010).

United States Environmental Protection Agency (EPA). 2004a. "Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression Ignition." (EPA420-P-04-009).

United States Environmental Protection Agency (EPA). 2004b. "Exhaust Emission Factors for Nonroad Engine Modeling – Spark Ignition." (EPA420-P-04-010).

Western Regional Air Partnership (WRAP). 2004. "WRAP Fugitive Dust Handbook." Woodland Hills, CA.