ENVIRONMENTAL ISSUES AT SEQUOYAH FUELS CORPORATION'S URANIUM CONVERSION PLANT NEAR GORE, OKLAHOMA

by

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Preface

This study has been undertaken to provide an independent review of environmental issues of concern at the uranium processing plant near Gore, Oklahoma which is owned and operated by the Sequoyah Fuels Corporation, a subsidiary of General Atomics Corporation. Originally called the Sequoyah Uranium Hexafluoride Plant, the facility was built by Kerr-McGee Corporation, which operated the plant from its beginning in 1970 until 1988, when it was sold to General Atomics. The facility's primary activity is the conversion of uranium oxide into uranium hexafluoride, which, after further processing, is eventually turned into fuel for commercial nuclear power reactors.

During the past two years, the plant has been in the process of license renewal with the U.S. Nuclear Regulatory Commission. During this time, a number of concerns related to environmental issues have drawn renewed attention, including contamination of groundwater, contamination of workers, releases of uranium and other elements to the air and water, and the spreading of a treated raffinate waste stream on the surrounding land as "fertilizer."

The purpose of this study is to evaluate these and related issues and to examine the environmental data which have been collected so far in order to identify new areas of potential concern -- or areas of ongoing concern which have not yet been adequately addressed -- which should be considered by the NRC and the public in the current license renewal process.

This study was conducted by the Institute for Energy and Environmental Research (IEER), a non-profit organization which studies technical aspects of a range environmental and energy issues. The study was done under contract with the Native Americans for a Clean Environment (NACE), an Oklahoma citizen environmental organization concerned about the possible impacts of the Sequoyah Fuels plant on the surrounding environment and public health.

The study could not have been completed without the assistance and consultation, including research and the tracking down of numerous documents and references, provided by Lance Hughes, Director of NACE, and by NACE's attorney, Diane Curran, of the law firm Harmon, Curran, Gallagher, and Spielberg.

We would also like to thank Kirsten Engel, formerly of the Sierra Club Legal Defense Fund and currently professor of environmental law at Tulane University, for first identifying the potential relevance of federal hazardous waste law (RCRA) to the treatment of raffinate waste from the Sequoyah Fuels plant; Dr. David Pimentel, professor of agricultural science at Cornell University, for his assistance in interpreting and evaluating data pertaining to the spread of treated raffinate waste as "fertilizer;" and staffmembers of the U.S. Environmental Protection Agency and the Nuclear Regulatory

Commission, for their assistance in providing documentation and information pertinent to this study.

Those acknowledged here do not necessarily endorse the findings or conclusions of this study, the responsibility for which lies solely with us. We also, of course, take full responsibility for any errors.

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Takoma Park, Maryland
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Executive Summary

Introduction

Sequoyah Fuels Corporation – originally a subsidiary of Kerr-McGee Nuclear Corporation, and, since 1988, of General Atomics – operates a uranium processing plant near Gore, Oklahoma. The principal activity of this facility is the conversion of uranium oxide (U_3O_8), known as "yellowcake," into uranium hexafluoride (UF_6), as part of the process of preparing the uranium for eventual use as fuel in commercial nuclear reactors. The Sequoyah Fuels Corporation also operates a uranium hexafluoride reduction plant at the site, which converts uranium hexafluoride to uranium tetrafluoride (UF_4), as part of the process of producing uranium metal, which is used by the military for bullets, shells, and armor.

The Sequoyah Fuels plant operates under license SUB-1010 from the U.S. Nuclear Regulatory Commission (NRC), and is currently being considered for a 10-year extension of its operating license. This license formally expired in September of 1990 (the plant has operated since that time under an automatic license extension granted for the duration of the NRC's license renewal process). Partly as a result of the license renewal process, as well as a worker contamination incident during an excavation near one of the process buildings in the summer of 1990, this plant has experienced increasing scrutiny from the Nuclear Regulatory Commission, from local citizens, and from the media. This has focused renewed attention on continuing questions about the company's management, especially in relation to environment, safety, and health issues, and about contamination of the plant site and surrounding environment.

These problems (some of which are reviewed in this report) culminated in an NRC order to shut down the plant in October 1991. In mid-April 1992, a phased re-start of the plant was authorized. This study was commissioned by the Native Americans for a Clean Environment as a preliminary review of potential environmental issues that may be relevant to decisions about whether to authorize the requested license extension. The second half of this Executive Summary thus consists of a Summary of Findings which reviews the major findings pertaining to these issues in brief. The body of the report documents these findings and discusses them in greater depth.

The body of the report is organized as follows: first, an overview of uranium processing for the commercial nuclear fuel cycle is presented, with a particular focus on the uranium conversion process, the step in that cycle that is undertaken at facilities like Sequoyah Fuels. Next, Chapter Two gives an overview of the particular operations at Sequoyah Fuels, focusing on plant production processes and waste stream generation and management.

Chapter Three examines in detail environmental concerns pertaining to the treatment and management of the plant's principal waste stream, the raffinate stream. The raffinate stream is a nitrogen-rich liquid which includes the bulk of the metal impurities originally present in the uranium yellowcake (such as arsenic, iron, and vanadium), as well as uranium daughter products (radium and thorium), and the uranium left behind due to processing inefficiencies. Sequoyah Fuels treats this stream to remove much of the heavy metal and radioactive constituents. The treated raffinate is then disposed of by spreading it on the surrounding land as "fertilizer" in the form of ammonium nitrate. Before being treated, this stream may constitute hazardous waste according the federal hazardous waste law known as RCRA, the Resource Conservation and Recovery Act.

Thus, Chapter Three examines whether Sequoyah Fuels, in treating raffinate without a RCRA permit, is in violation of federal hazardous waste laws. We also discuss some of the potential environmental and health problems which might be associated with spreading the treated raffinate on the surrounding land. Finally, some of the issues associated with managing the concentrated sludge which results from raffinate treatment are considered.

Chapter Four reviews the evidence pertaining to uranium contamination of the environment, focussing on three routes: leakage from the production process itself, emission of liquid wastes via a low-volume discharge to the nearby Illinois River, and emissions to the air via plant stacks. Recently released uranium contamination data indicates that Sequoyah Fuels withheld crucial data from its license renewal application, and that as a consequence, the application may contain false statements regarding the environmental monitoring program at the plant.

Finally, Chapter Five reviews several other miscellaneous issues, decommissioning plans for end-of-plant life, and the facility's ability to comply with new NRC regulations regarding radiation protection.

Before proceeding to the main body of the report, however, an overview of the major findings is presented below.

Summary of Findings

Following is a summary of findings and concerns regarding environmental issues at SFC's uranium conversion plant near Gore, Oklahoma that are identified and discussed in this report.

1. Based on a review of the documentation regarding SFC's ammonium nitrate raffinate/fertilizer program, it appears that:

   a) NRC license conditions inadequately regulate the application of the raffinate as "fertilizer." Specifically, the 700 pounds per acre limit on total nitrogen application, and the condition which allows fertilizer application to cause nitrates in groundwater to reach 20 mg/l (as nitrogen) are excessive. In particular, the NRC license condition allowing 20 mg/l of nitrates in groundwater is inconsistent with EPA groundwater protection goals (which are related to EPA's 10 mg/l limit for nitrates in drinking water).

   b) Sequoyah Fuels appears to be staying within the inappropriately high NRC license conditions when average "fertilizer" application rates are considered; however, it is likely that peak nitrogen application rates far exceed even the high rate (700 pounds nitrogen per acre) allowed by the NRC license. In any case, even the average rates are far in excess of those which would be dictated by legitimate agricultural considerations.

      Further, SFC's monitoring system appears to be inadequate to detect problems; such reporting of the fertilizer program as is required is so carelessly and sloppily done as to make definitive conclusions difficult.

   c) It is therefore eminently plausible that the application rates of SFC raffinate may be sufficient to cause the death of vegetation due to nitrogen toxicity in some areas.

   d) Based on the above considerations, nitrate poisoning of cattle (due to high levels of nitrates in water and feed) should be investigated as a possible cause of the death of the large numbers of dead cattle shown in a television news videotape.

2. There is strong evidence that the untreated raffinate constitutes hazardous waste under RCRA, and that by treating this material without a Part B Permit under RCRA, Sequoyah Fuels is in violation of federal hazardous waste law. The untreated raffinate waste appears to qualify as hazardous on two grounds: corrosivity due to pH

less than two, and toxicity due to high levels of arsenic. Evidence for this includes the following:

a) The untreated raffinate waste stream appears to have an HNO_3 molar concentration of around 1, which corresponds to a pH of 0. RCRA regulations classify a waste material as hazardous due to corrosivity if it has a pH of less than two.

b) Materials accounting for arsenic based on average concentrations of constituents in the yellowcake feed indicates that the arsenic concentration in the untreated raffinate waste stream is the range of 40 to 70 mg/l. RCRA regulations classifiy a waste material as hazardous due to toxicity if waste extract contains arsenic in concentrations greater than 5 mg/l.

c) The arsenic levels in groundwater due to the activities of Sequoyah Fuels are so high that in at least one instance (where the concentration is 5.6 mg/l), the groundwater itself would qualify as a hazardous waste under RCRA. In all, 87 of 154 wells tested had measurable arsenic concentrations, with 43 wells containing more than 0.05 mg/l of arsenic -- the maximum allowed groundwater concentration established by EPA under RCRA for facilities which treat, store, or dispose of hazardous waste.

3. SFC releases significant amounts of uranium to the environment as a consequence of routine operations:

- SFC currently releases an average of 80 kilograms (176 pounds) of uranium to the air each year, according to official data. All told, SFC released 1,000 kilograms (2,200 pounds) of uranium to the air during routine operations from 1980 to 1989.

- SFC currently releases an average of 1,500 kilograms (3,300 pounds) of uranium to the Illinois River each year, according to official data for the late 1980s. For the years 1980 to 1990, SFC reported a total discharge to the river of 33,600 kilograms (74,000 pounds) of uranium.

- Anywhere from 30,000 or 40,000 kilograms (66,000 to 88,000 pounds) up to 300,000 kilograms (660,000 pounds) of uranium may have accumulated in settled raffinate sludge from 1980 to 1989.

4. There are uncertainties in data on releases to environment (in particular, air releases) which make some of the above estimates uncertain. At least since 1986, NRC has questioned the accuracy of release estimates from one of the plant's main effluent sources (the HF scrubber). Further, SFC may also have failed to take adequate

account of meteorological patterns, thereby throwing into question the usefulness of offsite air monitoring data, and casting doubt on the validity of its offsite dose assessments.

5. As revealed by investigations undertaken in the wake of the worker contamination incident in August 1990, there is also extensive contamination in the soils and water of the plant site itself. Notable is excess levels of uranium, nitrate, and arsenic. For example:

   - The most extensive contaminant plumes in groundwater appear to consist of nitrates (primarily due to leakage from the process buildings and from the raffinate storage pond 2); some of these plumes extend off the site boundary. Levels in wells onsite range to more than 8,000 mg/l, which is 800 times higher than EPA's drinking water standard. Nitrates in offsite wells at nearby residences have been measured at levels as high as 45 mg/l -- significantly in excess of EPA's 10 mg/l drinking water standard, and in excess of the 20 mg/l reaction level imposed by SFC's license. Sequoyah Fuels claims that the nitrate-contaminated wells offsite are not due to its activities. This claim needs to be independently verified.

   - Uranium in restricted area ground and porewaters ranged up to many millions of micrograms per liter -- far in excess of the NRC's restricted area limit of 1.5 million ug/l. Uranium in unrestricted area ground and porewaters ranged up to 36,600 ug/l (in well MW-10) and 90,708 ug/l (in well MW-33T) -- levels approaching or exceeding the NRC's 45,000 ug/l unrestricted area limits, and far in excess of the 225 ug/l action level imposed by SFC's license.

6. For more than ten years, SFC was collecting data that should have indicated that the area around the process buildings was significantly contaminated. Despite this, SFC failed to report this data to the NRC or to the public, submitting at least three license renewal applications over a period of 10 years which nowhere indicated the possible extent of the contamination. For over ten years, SFC failed to conduct further investigation to determine the extent of contamination indicated by its data, and only did so in 1990 and 1991 after being ordered to do so by the NRC in the wake of a worker contamination incident.

   This situation led the NRC staff to conclude that SFC's "license renewal applications are materially incomplete" and in violation of NRC regulations. However, the staff refused to revoke SFC's operating license, as requested by a joint petition from the Native Americans for a Clean Environment and the Cherokee Nation, saying that "license revocation would be an excessively harsh and unwarranted remedy in this case."

7. Although extensive study of the onsite contamination has now been undertaken by SFC via its contractor, Roberts, Schornick and Associates, there has apparently been no comparably detailed characterization of the extent of contamination offsite, such as that caused by releases through the liquid effluent streams. In 1986, for example, sediments from one stream bed leading to the Illinois River contained uranium ranging up to 760 ug/g, and thorium-230 ranging up to about 350 pCi/g. Natural background levels are normally not more than a few ug/g of uranium or a few pCi/g of thorium-230. Because this stream bed is no longer in use, the concentrations have declined significantly as the radionuclides have gradually been transported to other locations.

8. Sequoyah Fuels recently developed an Action Plan to address some of the contamination issues outlined above. While the plan describes some measures which, if properly implemented, will alleviate some of the uranium contamination, it is too incomplete to evaluate its overall effectiveness in addressing contamination issues. In particular, it does not adequately address the issue of offsite contamination caused by the liquid effluent streams, nor does it adequately address contaminants other than uranium, such as arsenic and nitrates.

9. SFC's current plans for decommissioning the plant at the end of its commercial life are fundamentally inadequate, especially regarding the level of funding assurance. SFC does not appear to know with any certainty the amount of waste to be generated during decomissioning, nor does it have plans on where or how to dispose of it. In spite of this lack of information (upon which decomissioning costs should significantly depend), SFC has submitted a decommissioning cost estimate ($5,364,790) which implies 6-digit precision. It is possible, in our judgement, that decommissioning costs could be significantly greater than this, leaving the burden in the lap of the taxpayer unless General Atomics gives a solid guarantee that it will foot the clean-up bill, and provides financial backing to that commitment.

Chapter One. General Overview of Uranium Processing for the Nuclear Fuel Cycle

A. Nuclear Power and the Nuclear Fuel Cycle

Commercial nuclear electricity in the U.S. is generated from the energy extracted from nuclear reactions involving uranium. Nuclear power thus requires a uranium processing industry to process the needed uranium into an appropriate chemical and physical form so that it may be used as fuel in a reactor. The set of uranium processing activities needed to support nuclear power ranges from the mining of uranium ore from the ground, the refining of the ore at uranium mills, the conversion of uranium to a chemical form which allows it to be "enriched", and the fabrication of the enriched uranium into fuel rods for reactors.

This set of uranium processing activities, along with the operation of the reactor to generate electricity and the subsequent discharge and management of the highly radioactive spent fuel is called the *nuclear fuel cycle*. The nuclear fuel cycle is depicted in Figure 1.

The uranium is first mined, and then refined in a process called "milling." Uranium milling results in a product in the chemical form of uranium oxide (U_3O_8), which is called *yellowcake*. Before it can be fabricated into fuel and used in a typical commercial light-water reactor, however, it must be enriched. Enrichment is the name given to the process by which the amount of the isotope of uranium useful for generating power (uranium-235) is increased relative to the more prevalent uranium-238.[1] Commercial enrichment technologies currently in use require that the uranium be in the chemical form uranium hexafluoride (UF_6).[2] Thus, before being enriched, the uranium oxide must be converted to uranium hexafluoride. This is done at a uranium conversion plant, such as the Sequoyah Fuels facility near Gore, Oklahoma. The conversion process is discussed in greater detail in the section below.

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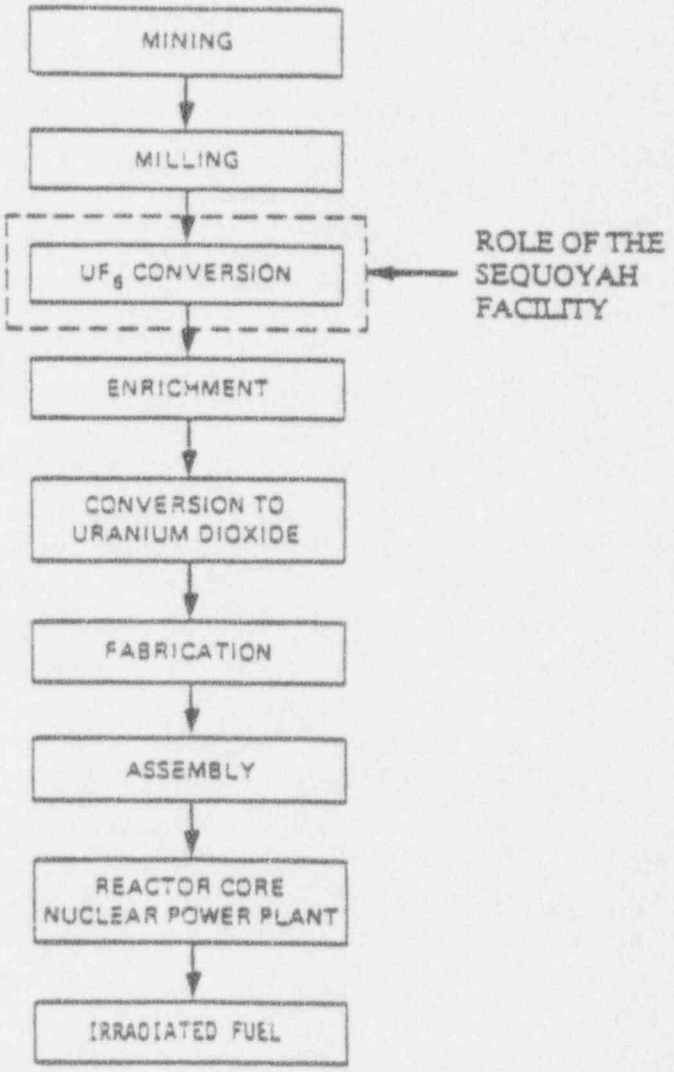
1 Uranium-235 is said to be "fissile" -- meaning that it can be made to support a self-sustaining fission chain reaction (the reaction that is the source of energy in nuclear power). Uranium-238 cannot do this. Natural uranium as it comes out of the ground is almost 99.3 percent U-238, and 0.7 percent U-235. Typical U.S. nuclear power reactors, however, require uranium fuel that has been enriched to the point where it contains several percent (3 percent-4 percent) uranium-235.

2 For uranium enrichment, U.S. plants (in Paducah, Kentucky, and Portsmouth, Ohio) use gas diffusion technology, in which gaseous uranium hexafluoride is made to diffuse through membranes which separate the U-235 from the U-238. A cancelled enrichment plant at Portsmouth (as well as many operating plants in other countries, and a proposed plant in Louisiana) are based on gas centrifuge technology, which also uses uranium hexafluoride. A more advanced laser-based enrichment technology (called AVLIS, or AdVanced Laser Isotope Separation) would not require the uranium to be in the hexafluoride chemical form. This technology is not yet commercial.

Figure 1. The Nuclear Fuel Cycle



After enrichment, the enriched uranium hexafluoride gas is converted into solid uranium oxide (UO_2), which is then compressed and fabricated into fuel pellets. These pellets are loaded into zirconium alloy rods which are then used as fuel for a nuclear reactor. Each of the stages of processing uranium ore into fuel for reactors generates several types of waste: liquid waste, which is often dumped into holding ponds, treated, and allowed to settle; solids, which are incinerated or disposed of in landfills or other disposal sites; and off-gases, which are generally treated to remove some hazardous and radioactive materials and then released to the atmosphere.

B. Uranium Conversion and Uranium Hexafluoride

Worldwide Conversion Capacity

Worldwide, there are relatively few facilities that convert uranium oxide to uranium hexafluoride. Countries known to have conversion facilities include the U.S., Canada, Brazil, France, India, Japan, Pakistan, South Africa, the former Soviet Union, and Britain.[3] The total world capacity for uranium conversion is at least 88,000 metric tons uranium per year (not including the former Soviet Union).[4] Of this, two uranium conversion facilities in the U.S. account for 21,790 metric tons capacity, or about 25 percent. The Allied Corporation conversion plant in Metropolis, Illinois has a capacity of 12,700 metric tons, and the Sequoyah Fuels plant has a capacity of 9,090 metric tons.[5]

Hazards of Uranium Hexafluoride

Uranium hexafluoride is a solid at room temperature, with an appearance similar to rock salt. When heated, however, it turns into a liquid or gas. It is in the gaseous form that it undergoes enrichment.

A major hazard in the uranium conversion process is presented by the handling of uranium hexafluoride, which is highly corrosive and chemically toxic as well as radioactive. When uranium hexafluoride comes into contact with water (such as moisture in the air), it vaporizes and breaks down into hydrofluoric acid (HF), a highly corrosive toxin, and uranyl fluoride (UO_2F_2), a heavy metal uranium compound. There are health hazards posed by each of these. Hydrofluoric acid causes pulmonary edema (excess body fluids in the lungs) and other respiratory damage, skin burns, and irritation. Uranyl fluoride, although posing some radiological hazard, is hazardous primarily because of the chemically toxic effects

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3 Other countries presumed to have conversion facilities include Israel and Argentina.

4 Compiled from DOE 1989, and Spector 1988.

5 *Ibid.*

associated with uranium's characteristics as a heavy metal. Its principal health effects are temporary or permanent kidney damage.[6]

These health effects were seen in the fatal accident which occurred at the Sequoyah Fuels plant on January 14, 1986. On this day, a 14-ton UF_6 cylinder was accidentally overfilled because of a faulty scale. When workers heated the cylinder to re-liquify the UF_6 in order to remove the excess, the expanding UF_6 caused the cylinder to rupture, and essentially all of its estimated 31,000 pounds of UF_6 were released.[7] The material vaporized into a large, dense, white cloud containing hydrofluoric acid and uranyl fluoride. The vapor cloud enveloped the plant and then was carried by the wind past several nearby residences and a major interstate highway (Interstate 40). One worker, who was heating the cylinder when it ruptured, died from pulmonary edema brought on by the inhalation of hydrofluoric acid fumes. All of the 42 workers onsite and approximately 100 others near the plant were hospitalized for treatment and observation, many with respiratory problems and skin burns. Almost all of the exposed plant workers suffered temporary kidney damage from uranium intake, and some may have permanent damage.[8]

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6 U.S. Congress, 1987.

7 U.S. Nuclear Regulatory Commission, *Rupture of Model 48Y UF6 Cylinder and Release of Uranium Hexafluoride* (NUREG-1179), Vol I, pp. 3-12 (1986), as cited in U.S. Congress 1987, p. 8.

8 U.S. Nuclear Regulatory Commission, *Assessment of the Public Health Impact from the Accidental Release of UF6 at the Sequoyah Nuclear Fuels Corporation Facility at Gore, Okla.* (NUREG-1189), as cited in U.S. Congress 1987, pp. 6, 9.

Chapter Two. The Sequoyah Fuels Conversion Plant

A. General Background

Plant Activities

The Sequoyah Fuels Corporation's uranium conversion plant near Gore, Oklahoma (about 150 miles east of Oklahoma City), is one of two such plants in the U.S., and with a capacity of 9,090 metric tons per year of uranium, represents about 42 percent of U.S. conversion capacity. Sequoyah Fuels' operations generate estimated revenues of $35 million per year.[9]

The Sequoyah Fuels Corporation (SFC) is a wholly-owned subsidiary of General Atomics Corporation, a privately-held commercial company involved in research, development and production activities in both nuclear energy and nuclear weapons. Sequoyah Fuels began operations in 1970, and was originally owned and operated by Kerr-McGee corporation; ownership was transferred to General Atomics in 1988.

The principal activity of Sequoyah Fuels is to convert uranium oxide to uranium hexafluoride. In 1987, however, a uranium hexafluoride reduction plant was also licensed. The purpose of the reduction plant is to reduce natural or depleted uranium hexafluoride (UF_6) to uranium tetrafluoride (UF_4).[10]

Current Status

Sequoyah Fuels is currently licensed under NRC Source Material License Number SUB-1010. This license was last renewed on September 20, 1985, but expired on September 30, 1990. Sequoyah Fuels continued to operate after this date under an indefinite license extension automatically granted upon the submission of a timely license renewal application.[11]

However, Sequoyah Fuels has recently encountered increasing scrutiny and criticism regarding poor management practices and environmental contamination. This scrutiny was

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9 Thomas W. Lippman, "Uranium Pollution Probed at Oklahoma Plant," *Washington Post*, p. A1 (4/29/91).

10 The reduction of UF6 to UF4 is one step along the way of converting UF6 to uranium metal. Depleted uranium (the uranium that is left over from the enrichment process and which contains a smaller fraction of U-235 than natural uranium) cannot be used as nuclear fuel, but it is sometimes converted to metal and used for non-nuclear military or weapons applications, such as in constructing tank armor or bullets or artillery shells.

11 Sequoyah Fuels submitted a license renewal application on August 30, 1990 (SFC 1990a). NRC regulations at 10 CFR 40.43(b) provide for such automatic license extension.

sparked by a worker contamination incident in August 1990, about the same time SFC's license renewal application was submitted. At this time, workers in the process of excavating a pit near the solvent extraction (SX) building were discovered to have been working in water contaminated with high levels of uranium. The uranium levels in the water were in the range of 1 to 8 grams per liter. The upper end of this range is over 5 times the general NRC limit for uranium in restricted areas, and 35,000 times the environmental action level specified in SFC's license.[12] It subsequently turned out that SFC had records indicating highly contaminated water in the vicinity of this building (the SX building) which had not previously been reported to NRC.[13]

In the fall of 1990, as a result of the reporting of this environmental contamination data (as well as other historical data on high levels of contamination beneath another building, the main process building[14]) which had previously been withheld from the NRC, the NRC ordered Sequoyah Fuels to conduct a detailed environmental investigation of the site. In response, SFC hired an environmental contractor, Roberts, Schornick & Associates, to conduct a "Facility Environmental Investigation" (FEI) which was completed in July 1991.[15] This investigation showed very high levels of uranium (as well as other contaminants such as nitrate and arsenic) contamination in soil and water. The uranium levels in particular were far higher than any reported in Sequoyah's August 1990 License Renewal or any time up until the worker contamination incident in August 1990. (For further discussion on this point, see Chapter 4, below.)

In October 1991, after months of continuing violations of NRC regulations at the plant, Sequoyah Fuels received an order from the NRC Staff to shut down.[16] The shutdown order also removed Sequoyah's Environmental Manager (Carolyn Couch) from supervisory or managerial responsibilities on the grounds that she "made false statements and withheld information from the NRC."[17] In addition, the NRC Staff noted that "there

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12 NRC 1990b, p. 2; NRC 1990c, pp. 4-5. NRC general limits for water in restricted areas are specified in regulations at 10 CFR 20, Appendix B, Table 1, Column 2. The limit for natural uranium in water is about 1.5 grams uranium per liter. SFC's environmental action level is 225 ug (micrograms) per liter. For more discussion on this worker contamination incident, see Chapter Four, Section B, "Uranium Contamination of Soil and Water from Process Buildings."

13 RSA 1991, Table 78 reports historical internal SFC records on uranium in pore and/or groundwaters near the SX building which date back to 1976 showing very high levels of uranium (up to 1.2 million ug per liter) which were apparently never reported to NRC.

14 NRC 1990c, pp. 11-12.

15 On September 19, 1990, the NRC issued to SFC an Order Modifying License to, among other things, develop a comprehensive Facility Environmental Investigation plan. SFC's contractor, Roberts, Schornick & Associates, issued a Facility Environmental Investigation (FEI) report in July of 1991 (RSA 1991).

16 U.S. Nuclear Regulatory Commission, "Order Modifying License (Effective Immediately) and Demand for Information," EA 91-067 (October 3, 1991). (NRC 1991)

17 NRC 1991, cover letter, p. 1.

are serious questions as to whether the Senior Vice President, the Vice President of Regulatory Affairs and the Health Physics Supervisor, who have not assured that past licensed or safety responsibilities were carried out, can in the future, adequately perform the organizational responsibilities and authorities..."[18]

Taking note of the extensive regulatory violations and failings in health, safety, and environmental protection areas at the plant, the NRC Staff found a "significant management breakdown" within the plant, and observed that

> it appears that a number of deficiencies and weaknesses exist in the Licensees Health & Safety and Environmental programs. These deficiencies include a failure on the part of the Licensee management to fully understand and exercise their licensed responsibilities; poor communication within the SFC organization, particularly between the [Health & Safety] and operations (production) staff; numerous inadequacies with regard to Licensee procedures and failures on the part of SFC employees to comply with SFC procedural requirements and health and safety practices; deficiencies in training and instruction of SFC personnel working in restricted areas; and serious weaknesses in the Licensee's contamination control practices, including failures to exercise basic controls to prevent contamination to the environment and to adequately evaluate contamination. The foregoing deficiencies in the Licensee's Health & Safety and Environmental Programs are significant and adversely impact health and safety.[19]

The NRC Staff ordered Sequoyah Fuels to review plant operating procedures, and submit a re-start plan for approval by the NRC. On April 16, 1992, a phased re-start of the SFC plant began, with the operation of the UF_6 reduction plant.

In parallel with the shut-down order and re-start process, Sequoyah Fuels submitted an Action Plan to NRC in January 1992,[20] developed in response to the findings of the environmental investigation (FEI) conducted by Sequoyah Fuels' contractor, Roberts/Schornick and Associates.

The present report identifies a number of potentially significant environmental issues at the Sequoyah Fuels plant that should be considered as part of the re-licensing process. Some of these issues have also been discussed in the Roberts/Schornick FEI, and touched in Sequoyah Fuels' Action Plan. However, many of these issues have not yet been adequately addressed in either place, or by the NRC. These issues, as covered in this report, include:

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18 *Ibid.*

19 NRC 1991, p. 27.

20 SFC 1992a.

- The possibility that Sequoyah's activities regarding the raffinate waste stream consist of hazardous waste treatment as defined by RCRA regulations, and that without the required Part B permit under RCRA (which SFC lacks), SFC is illegally operating a hazardous waste treatment facility.

- Use of a nitrate-rich raffinate liquid waste stream as a fertilizer on land around the Sequoyah plant. This practice has become a matter of significant controversy. We examine possible problems posed by this practice, focusing in particular on the effects of high nitrate levels on cattle feed and groundwater, and on the inadequacy of NRC limits on nitrate levels (which are inconsistent with more stringent EPA limits).

- Leakage of raffinate from a liquid storage pond on the plant site, and problems associated with the remediation of this pond.

- Uranium releases to the environment through the liquid effluent streams from the plant.

- Uranium and other contaminant releases from leakage in the production process. As outlined above, this issue has been the focus of a detailed investigation by Sequoyah Fuels since the release of information regarding contamination in the fall of 1990.

- False statements in Sequoyah Fuels' license renewal application of August 30, 1990. The information regarding contamination released by Sequoyah Fuels in the Fall of 1990 raises serious questions about the integrity of the license renewal application.

- Releases of uranium to air. Uncertainties about the reliability of measurements mean that official estimates of uranium releases may not be accurate.

- Decommissioning plans. A significant source of environmental concern is the ability of Sequoyah Fuels to clean up the site once the plant has reached the end of its life.

It should be noted that this report does not consider worker safety practices or management defects at the Sequoyah Fuels facility; rather it focuses on the environmental issues raised by the plant. Each of the issues mentioned above will be covered in this report, beginning in Chapter Three. Before addressing these, however, the remainder of this chapter (Chapter Two) will be devoted to an overview of plant processes and waste stream characterization.

B. Plant Processes

Main Plant Production Processes[21]

Conversion of Uranium Yellowcake to Uranium Hexafluoride

The principal activities related to conversion take place in the Main Process Building (MPB), Miscellaneous Digestion Building, and Solvent Extraction (SX) Building. (The layout of the plant site is depicted in Figure 2 on the following page.) The uranium ore concentrate is purified by solvent extraction and converted to UF_6 by successive treatments with heat, hydrogen (H_2), hydrogen fluoride (HF) and fluorine (F). According to SFC, the production flowsheet includes the following six principal steps, which are also illustrated in Figure 3:[22]

1. *Dissolution of yellowcake:* The incoming yellowcake is dissolved in nitric acid, resulting in a highly acidic uranyl nitrate (abbreviated as UNH) solution (which also includes all the non-uranium impurities found in yellowcake).

2. *Extraction and purification of uranium:*

   At the SX building, the UNH solution is contacted with organic solvent containing tri-butylphosphate (TBP), which selectively extracts uranium. The remaining high-acid nitrate (which contains most of the impurities from the original yellowcake, and is referred to as raffinate) is discarded. The washed organic, loaded with uranium, is contacted with low-acid aqueous solution (0.01 molar HNO_3) that strips most of the uranium from the organic phase to the aqueous stream.

   This aqueous product (containing ~70-80 grams uranium per liter) is washed with hexane to prevent any TBP from entering next stage (evaporation) which could lead to explosions.

3. *Conversion of aqueous uranium stream to dry uranium trioxide (UO_3):*

   First, the aqueous uranium solution is concentrated in evaporator to about 450 g U per liter. Evaporator product is then further concentrated to 1,200 g U/l in 3 boildown tanks (which have a total capacity of 225,000 lbs U). Finally, molten UNH product from boildown tanks goes to denitrators (which have a bed temperature of 525° F) where it is converted to UO_3, a "free-flowing material," which is ground to a powder and stored in bins.

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21 As summarized in SFC 1990a and Forsberg 1985.

22 SFC 1990a; supplemented by information from Forsberg 1985, p. 27.

Figure 2 -- Industrial Portion of Sequoyah Fuels Plant Site

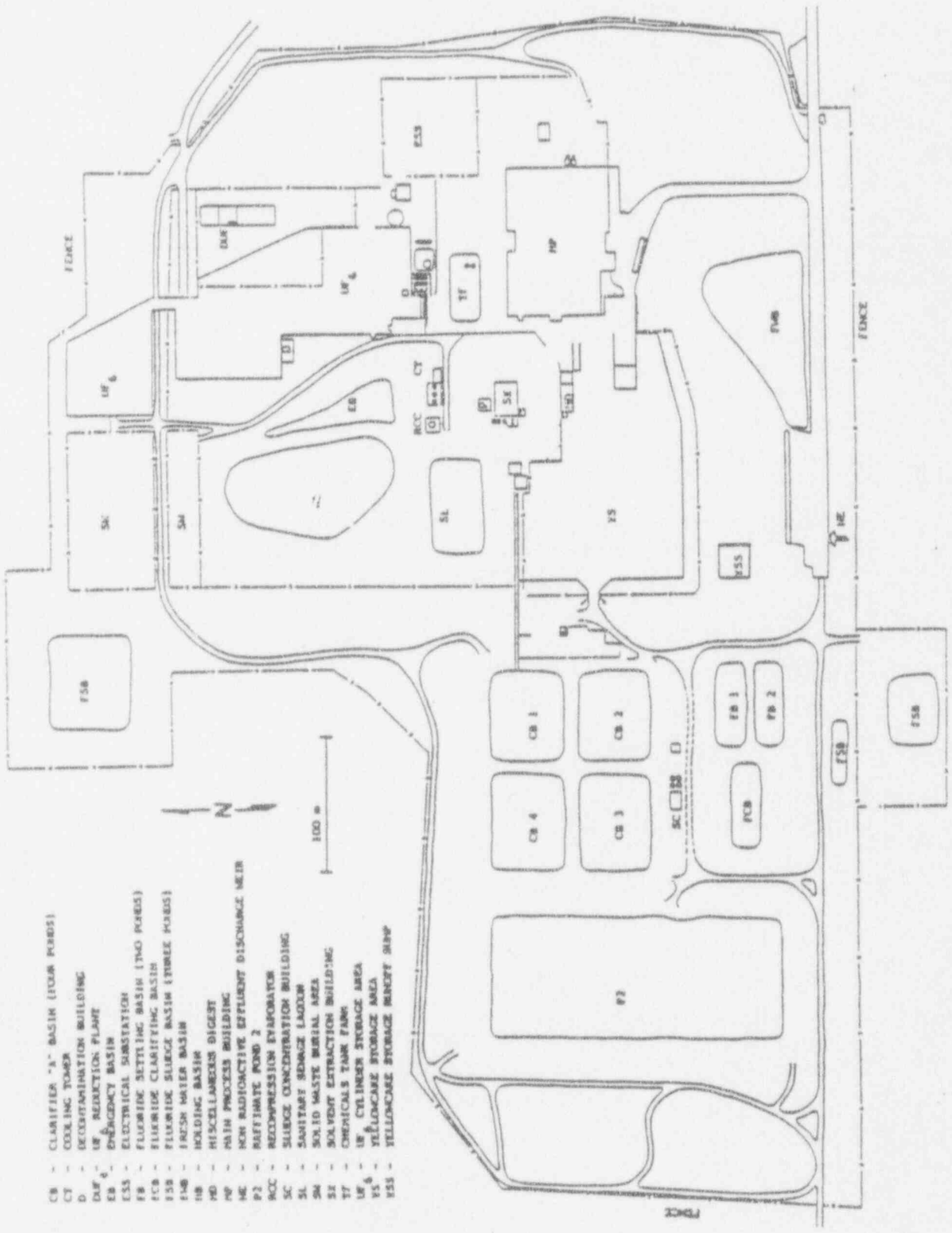
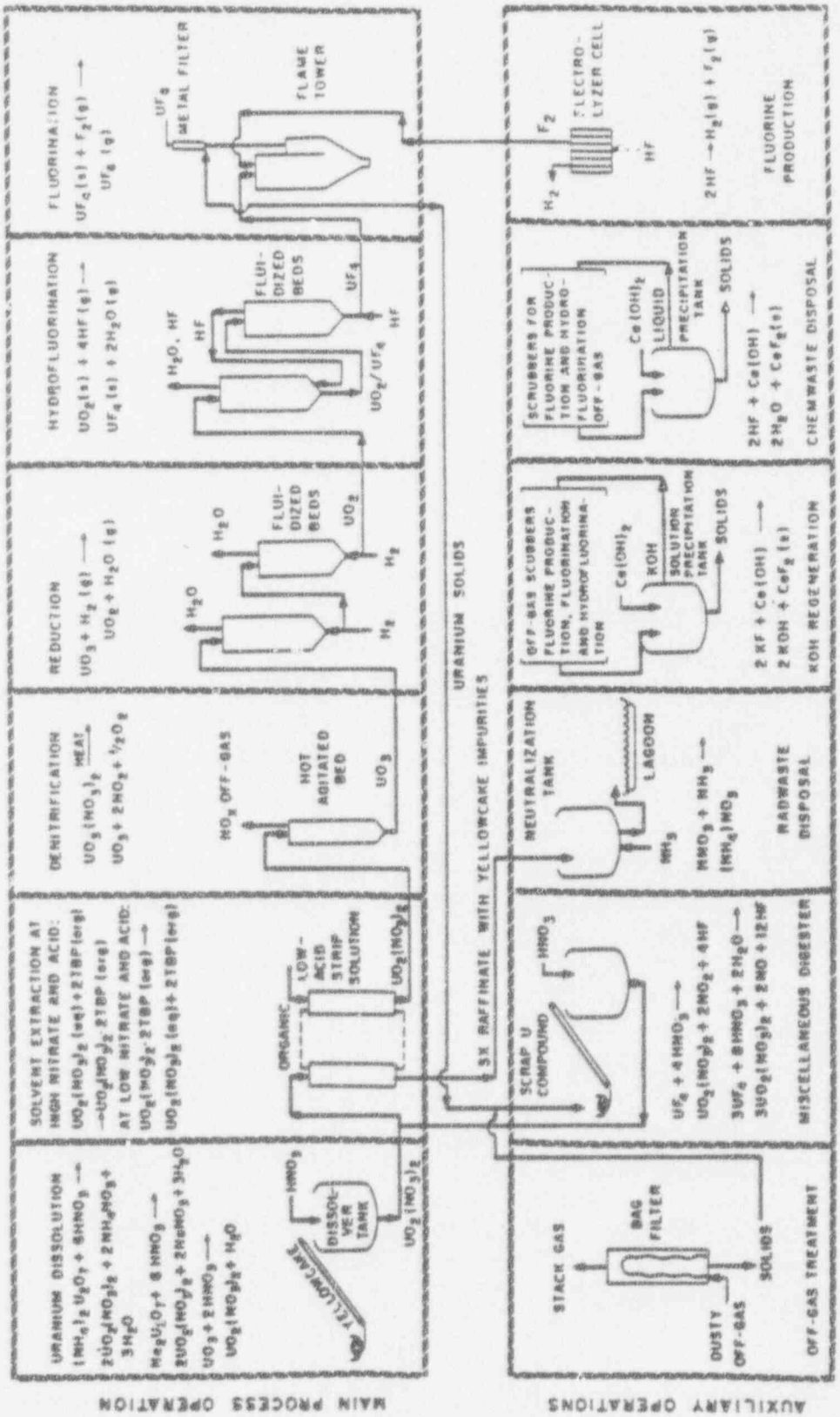


Figure 3 -- Uranium Conversion Flowsheet



4. *Reduction of UO_3 to yield UO_2:* achieved by contact with cracked ammonia (hydrogen and nitrogen), via the following reaction:

$$UO_3 + H_2 \rightarrow UO_2 + H_2O$$

This reaction is exothermic (i.e. heat-generating) and is made to proceed at 1100^{o} F.

5. *Hydrofluorination of UO_2 to UF_4:* UO_2 solids reacted with anhydrous HF gas in fluidized bed to yield UF_4:

$$UO_2 + 4HF \leftrightarrow UF_4 + 2H_2O.$$

This is accomplished with two HF reactors in series in each of two HF lines. Solids enter the first reactor countercurrent to gases, and exit as partially converted solids and gases at ~800^{o} F (425 C). They exit the second reactor at ~900^{o} F (480 C). Waste gas (including some uranium) is exhausted to the air through the HF scrubber.

6. *Fluorination of UF_4 to UF_6:* Solid UF_4 is reacted with F_2 in vertical tower reactors at a wall temperature of 850^{o}F (450 C), to yield UF_6. Essentially all of UF_4 is converted to UF_6 if an excess of fluorine is maintained. The outlet gas stream (containing UF_6, F_2, HF, O_2, and N_2) is cooled and filtered to remove entrained solids. UF_6 is removed as a solid from the cold trap.

(The gas stream from the primary cold-trap is used for secondary fluorination in a clean-up reactor, where it is contacted with an excess of UF_4. Gases discharged from the second cold trap are transferred to an H_2-F_2 burner and then to the HF scrubber in the waste-gas disposal system.)

The solid UF_6 from cold traps is melted and drained by gravity through filters into evacuated cylinders (2 1/2 ton, 10-ton, or 14-ton sizes), where it slowly cools to ambient temperatures (solid). After filling, the cylinders are weighed and transferred to a cylinder storage area in a yard (where they must cool for a 5-day minimum before shipping).

UF6 Reduction to UF4[23]

The second principal process at the Sequoyah Fuels facility is the reduction of uranium hexafluoride (UF_6) to uranium tetrafluoride (UF_4). This process is typically applied to *depleted* UF_6, which is what constitutes the "tails" produced by DOE enrichment

23 SFC 1990a, p. 13-39 to 13-45.

plants as a result of enriching uranium. Reducing UF_6 to UF_4 is one important step in the process of converting uranium hexafluoride into a metal form. (Depleted uranium metal, because of its very high density, is used to make bullets and shells, as well as tank armor, for the military.)

This process takes place at Sequoyah Fuels' UF_6 reduction plant, a separate building north of the Main Process Building. At this plant, UF_6 is chemically reacted with hydrogen to produce UF_4 and anhydrous HF acid. The recovered HF is condensed to liquid and used in the UF_6 conversion plant. The UF_4 product is packaged in 55-gallon drums and shipped elsewhere for further processing.

The reaction is:

$$UF_6 + H_2 \text{ --> } UF_4 + 2HF$$

The UF_6 is received in cylinders as a solid. It is then heated to 220 F, whereupon it becomes a liquid at 75-80 psi. At this point, it is ready to feed UF_6 as vapor to the chemical reactor system (the liquid vaporizes as it leaves the high pressure of the cylinder). As it is fed to the reactor, UF_6 vapor is superheated to 350 F. The hydrogen gas (H_2) is preheated to 1,300 F before being fed to the reactor. The H_2 flow rate is regulated to be about 1.2 times the theoretical quantity needed for compete chemical reaction. The UF_6 and H_2 streams enter a UF_6-H_2 mixer at the top of the reactor and are then discharged into the chemical reactor tube where the reaction takes place. The reactor is controlled to be about 1200 F at the top and 850 F at the bottom. The majority of the reaction occurs at the top of the reactor, and the UF_4 forms as a powdery solid. Pneumatic vibrators are used to shake UF_4 off the reactor walls, which then passes from the bottom of the reactor to a cooling screw conveyor, along with the remaining gaseous reaction products.

The UF_4 powder (sometimes called "green salt") is cooled to about 300 F and discharged from the cooling screw and conveyed to a chute. The off-gases (HF and H_2) are also cooled to about 300 F before they exit from the top of the discharge end of the cooling screw.

The UF_4 powder discharges from the exit chute into a product transfer screw, where it is conveyed to a bucket elevator which drops it through a screen to a blending system feed screw which conveys it to product storage bins.

The off-gases pass through filters to remove entrained dust. The gas is further cooled to condense the HF to liquid (which is then used in processes in the uranium conversion plant). The remaining off-gases are then piped to the UF_6 conversion plant, where they are fed to an H_2 burner to burn the excess H_2, after which they are routed through the HF scrubber to remove remaining HF. According to SFC, the amount of H_2

and other gasses fed to the HF scrubber from the reduction plant constitute only a few percent of the load already presented by the conversion plant effluents.[24]

Subsidiary Support Processes

The principal support process at the SFC plant is the production of fluorine gas which is used in the various reduction and fluorination stages in the plant process. SFC is the country's "largest producer" of fluorine gas, according to its former president.[25]

The fluorine is produced by electrolysis of anhydrous HF in molten electrolyte consisting of potassium fluoride, lithium fluoride, and hydrofluoric acid.[26]

The electrolysis process produces an electrolyte sludge waste which is considered a hazardous waste under RCRA, the Resource Conservation and Recovery Act.[27] The waste is periodically drummed and shipped for disposal to a commercial hazardous waste disposal facility.[28]

C. Waste Streams

Liquid Wastes & Effluents

The processes described in the above section produces two main liquid waste streams: a nitrate stream and a fluoride stream.

1. Nitrate (Raffinate) Stream

The primary liquid waste stream is the solvent extraction raffinate stream (this stream contains 99 percent or more of radioactive waste from such a conversion facility[29]). This liquid is rich in ammonium nitrate that, in the original government conversion plants, was released to nearby waterways. When the first commercial conversion facilities were being built, however, the release of ammonium nitrate directly to water was prohibited because of the chemical toxicity. When Kerr-McGee was building the Sequoyah Fuels

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24 SFC 1990a, p. 13-45.

25 SFC President Reau Graves, as quoted in Thomas W. Lippman, "Uranium Pollution Probed at Oklahoma Plant," *Washington Post*, p. A1 (4/29/91).

26 The HF is electrolytically reduced to H and F by DC electrical current (up to 8,000 amps through 60 cells, averaging 11-volt drop per cell).

27 As required by RCRA, SFC has an EPA generator I.D. number: OKD-051-961-183. (Attachments to Oklahoma 1991.)

28 There are apparently several facilities to which SFC ships hazardous wastes. These include: Chief Supply Corporation near Haskell, OK (EPA ID# OKD 089761290); USPCI Lone Mountain facility, in Waynoka, OK (EPA ID# OKD 065438376); and Technical Environmental Systems, Inc. in La Porte, TX (EPA ID# TXD 982290140). (As identified in Oklahoma 1991.)

29 Forsberg 1985.

facility, it originally planned to use deep-well injection for disposal, and received a license to test for this (and one injection test was conducted), but this method has not been practiced on a routine basis.[30]

To allow the Sequoyah Fuels plant to operate, this raffinate waste was stored in holding ponds as a temporary solution. As a long-term practice, however, it is recognized that there are a number of potential problems associated with pond storage, including:[31]

- The high solubility of ammonium nitrate; this means any leak or spill could quickly allow ammonium nitrate to migrate into ground or surface waters.
- There are strict limits on allowable releases of ammonium nitrate to water because it is a fertilizer and causes algal blooms in surface water.
- Any radionuclides in the ammonium nitrate would be in nitrate form, which means they would be very soluble, facilitating their spread through the environment in the event of a release.
- Ammonium nitrate is hygroscopic, (i.e., it tends to absorb water from the atmosphere) making it unlikely that the waste lagoons will ever dry out totally to allow easy burial or solids handling.

In the absence of a deep well injection method of disposal, Sequoyah Fuels settled on the solution of treating the raffinate waste and spreading it as fertilizer on SFC land surrounding the plant.

This treatment includes the following steps: the washed raffinate from solvent extraction (from step two in the flowsheet described above) is routed to one of the 4 hypalon-lined settling basins (called "clarifier A"), where it is allowed to cool.[32] In the first basin of clarifier A, anhydrous ammonia is added to convert dilute nitric acid to ammonium nitrate and precipitate heavy metals, including uranium and thorium (which are precipitated as heavy metal salts); barium salts are added as the raffinate is transferred to the second and third clarifier basins, where radium precipitates as barium radium sulfate.[33] The liquid from the clarifier basins (now a "high-purity, dilute ammonium nitrate solution," according to SFC) is then pumped to hypalon-lined storage ponds (#3 and #4). According to the NRC, "[t]his waste is not allowed to be discharged to local rivers because of very high nitrogen concentration."[34] Some of this is used as "fertilizer" each year. As of 1985,

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30 Forsberg 1985, p. 27.

31 Forsberg 1985, p. 30.

32 SFC 1990a, p. 13-11; NRC 1985, p. 2-16.

33 SFC 1990a, p. 9-12; SFC 1990a, ER, p. 2-6.

34 NRC 1985, p. 2-16.

however, raffinate production was greater than "fertilizer" spreading, resulting in a continually increasing storage requirement for the treated raffinate.[35]

Before 1979, raffinate was discharged to Ponds #1 and #2. Pond 1 has since been re-built as Clarifier A, and its sludge (containing greater than 20 pCi/g of uranium and thorium) placed in Pond 2. Pond 2, which was discovered in 1974 to be leaking, is no longer in active service for untreated raffinate disposal, and was required to be decommissioned and all sludge removed by NRC license amendment 28 to Sequoyah's license. License amendment 28 authorized construction of a new storage pond.[36]

Details on the characteristics, amounts and management of the nitrate-raffinate waste stream are discussed in Chapter 3, below.

2. Fluoride Stream

The second main liquid waste stream is the "fluoride stream." The fluoride stream consists of dilute HF from the HF scrubber (with some uranium and thorium), HF vaporizer sump, combined with wastes from the fluorine cell rework area and the plant's chemical lab.[37]

These wastes are treated with lime to a pH of 12 to induce formation of CaF_2 precipitates and heavy metal precipitates.

The solution is discharged to the "fluoride sludge pit" where calcium fluoride (CaF_2), lime, and heavy metal precipitates settle out. The pH of the sludge pit is adjusted to be in the range of 6 to 8 with addition of sulfuric acid; the solution is then piped to a clarifying lagoon where additional CaF_2 and $CaSO_4$ settle out. The overflow from this lagoon is combined with treated sanitary waste and lightly contaminated process water in a stilling basin. This is then diluted with fresh water from incoming supply (most of the 1,800-2,800 gallons per minute entering from Tenkiller Ferry reservation goes directly to dilute this waste stream).[38]

This "combination stream" (of the fluoride stream, treated sanitary wastes, process water, and freshwater diluent) is discharged through outfall 001 to the headwaters of Kerr Reservoir. This discharge is permitted under the EPA's NPDES process, and the Oklahoma Water Resources Board; radioactivity levels in this discharge are monitored and reported semi-annually to the NRC.

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35 NRC 1985, p. 2-16.

36 NRC 1985, p. 2-17.

37 SFC 1990a, ER., p. 2-6.

38 NRC 1985, p. 2-13 states that the flow from Tenkiller Reservoir is 2,800 gallons per minute, and (on p. 2-17) that 95 percent of this is used to dilute the fluoride stream. A more recent source (SFC 1990a, ER, p. 2-4) says 1,800 gallons per minute comes from this reservoir.

Details on the total uranium effluent in this stream are discussed in Chapter 4, Section A.

Air Effluents

Off-gas from processes is treated by a hydrogen-fluorine (H_2-F_2) burner and an HF scrubber.

The burner receives gases from a secondary trap in the fluorination process (step 6 in the uranium conversion process described in section B, above), and from fluorine production. The burner is designed to remove fluorides from the gas stream as HF. This results in HF and water vapor. Flue gas from the H_2-F_2 burner enters the HF scrubber system, which also removes uranium hexafluoride from the gas, but with less efficiency.

In addition to receiving the effluent from the H_2-F_2 burner, the HF scrubber receives gases from the hydrofluorination step in the conversion process (step 5 of Section B, above), hydrogen fluoride storage tank vents, HF vaporizer, and a few other miscellaneous sources. Scrubbed gases are discharged to the atmosphere through the main plant stack (150 feet above-grade)[39]. According to Sequoyah Fuels, the HF scrubber exhaust is the primary airborne uranium effluent source, representing 40 percent to 72 percent of the total airborne losses for the facility.[40]

In addition to the main stack, other sources of effluent are NOx emission control exhaust, dust collector exhausts, and "inadvertent process leakage." The main constituents of the gaseous effluent are: uranium, fluorides, and nitrous oxides.[41] All exhaust stacks emitting greater than 10 grams of uranium per month are continuously sampled. A dispersion factor of 1000 is used (to account for distance to fence) before comparing them to the NRC's unrestricted area maximum permissible concentrations (MPCs) in 10 CFR 20.[42]

Sequoyah Fuels maintains 11 environmental air monitoring stations: four fence-line stations, and seven offsite stations, including one at the nearest residence.[43]

Records on amounts of emissions and environmental monitoring levels are covered in Chapter 4, Section D.

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39 SFC 1990a, p. 13-27.

40 NRC Inspection Report 91-07 (6/21/91).

41 SFC 1990a, ER, p. 2-5.

42 SFC 1990a, ER, p. 4-1.

43 SFC 1990a, ER, p. 4-8.

Solid Waste

Compared to the amounts discharged through the fluoride stream and the nitrate stream, the volume of radioactive solid waste generated by Sequoyah Fuels is relative small. The main components of radioactive solid wastes are:[44]

- Raffinate (nitrate) stream settled sludge (uranium, daughter products including thorium-230 and radium-226, and heavy metals). For many years, much of this apparently simply remained at the bottom of the settling ponds. During the course of the remediation of Pond 2, this material was concentrated in a centrifuge and shipped to Quivira uranium mill in New Mexico.
- Fluoride stream settled sludge waste. This apparently remains in the settling basin where deposited by the fluoride liquid waste stream, although some of this apparently was also shipped to the Quivira uranium mill.
- Contaminated equipment and maintenance wastes. Maintenance wastes are packaged to minimize the spread of contamination and stored along with contaminated equipment for later decontamination or disposal.
- Fluorine cell electrolyte sludge. This is neutralized and drummed, and, as mentioned above, periodically shipped to a commercial hazardous waste disposal facility.

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44 SFC 1990a, ER, p. 2-7.

Chapter Three. Environmental Issues: Raffinate Waste

There are a number of potential issues regarding the raffinate (nitrate) waste stream. These include whether the treatment of raffinate to allow it to be spread on agricultural land constitutes the treatment of hazardous wastes under RCRA; issues surrounding the spreading of the treated raffinate as fertilizer; and questions about the handling of the sludge which is left over from the treatment process. These three issues are discussed in the sections below.

A. Raffinate as Hazardous Waste Which Should be RCRA-Regulated

When the raffinate emerges from the solvent extraction phase of the production process (step 2 in the uranium conversion process flowsheet described in Section B of Chapter 2), it is highly acidic (with a pH around zero) and contains significant concentrations of heavy metals (including uranium).[45] It is then treated by the addition of ammonia and barium salts to neutralize the solution, convert it to ammonium nitrate, and precipitate out the heavy metals and radionuclides (this treatment process is briefly described in Section C of Chapter Two, above). After treatment, the resulting ammonium nitrate solution is spread as fertilizer on Sequoyah Fuels land surrounding the plant.

The concentrations of various constituents in the treated raffinate "fertilizer" are listed in Table 1. However, IEER has so far been unable to obtain similar data which would show constituent concentrations in the raffinate *before* treatment.[46] However, our analysis indicates that there are strong grounds to suspect that the untreated raffinate should be classified as a hazardous waste under the federal hazardous waste law known as RCRA (the Resource Conservation and Recovery Act). This is important because if the untreated raffinate *is* hazardous waste, the treatment of this waste would fall under the purview of RCRA, and Sequoyah Fuels would be required to obtain a RCRA Part B

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45 NRC 1985, p. 2-15. One early document refers to the high acidity of this stream: "The contaminants rejected by the solvent extraction system are contained in an aqueous solution approximately 1 molar in nitric acid after removal of excess TBP and hexane." (Kerr-McGee 1973, Attachment p. 1) (1 molar nitric acid implies a pH of roughly 0.)

46 IEER has made numerous unsuccessful requests to the Oklahoma Department of Health (which would be the implementer of RCRA in this instance) and the federal Nuclear Regulatory Commission, as well as extensive searches through public documents. IEER still has an open Freedom of Information Act request to the NRC on this subject. It should be noted that upon initial telephone contact, officials at the Oklahoma Department of Health said that the untreated raffinate had been tested in the past, and found *not* to be hazardous. The table of numbers transmitted to IEER by Oklahoma Department of Health to substantiate this statement contained levels which were non-hazardous, and comparable to those in Table 1 in the text for treated raffinate. However, the table was clearly labeled "Pond 4 *Treated* Raffinate," [italics added] and thus clearly not relevant to the question of *un*treated raffinate. (Personal communication from Bob Robertson, Oklahoma Department of Health Solid Waste Management Service, to Scott Saleska, IEER, September 3, 1991.)

permit to operate a hazardous waste treatment facility.[47] Sequoyah Fuels currently holds no such permit.

Table 1. Concentrations of Constituents in Treated Raffinate ("Fertilizer")

Constituent	Concentration (ppm)
Arsenic	0.70
Barium	0.69
Cadmium	0.03
Cobalt	0.2
Chromium	0.01
Copper	1.95
Iron	0.60
Magnesium	75.65
Mercury	0.0002
Molybdenum	7.67
Nickel	4.83
Lead	0.1
Selenium	0.1
Vanadium	0.03
Zinc	1.14
Uranium	0.002
Nitrogen	16,600
Thorium-230	1.05 pCi/l
Radium-226	0.56 pCi/l

SOURCE: SFC 1991b, Table 1.
NOTE: Analysis of fertilizer applied during first application to SFC land during 1990

There are several strong indications that the untreated raffinate would legally be considered a hazardous waste. First, Oak Ridge National Laboratories has published a report on the amounts and characteristics of waste generated at various stages of the nuclear fuel cycle. The Oak Ridge study reports the chemical composition of generic "raw" raffinate waste for a reference 10,000 ton (9,090 metric ton) conversion plant of the type operated by Sequoyah Fuels: six million gallons per year of raffinate generated, with a HNO_3 molar concentration of 1.26, and containing arsenic at 264 mg/l.[48] This is

47 40 CFR Part 270. (RCRA permit requirements). These requirements state that "treatment, storage, or disposal of hazardous waste by any person who has not applied for or received a RCRA permit is prohibited." (40 CFR 270 section 270.1(b)).

48 Forsberg 1985, p. 31.

hazardous under RCRA due to corrosivity (it is an acid with pH slightly negative).[49] It may also test hazardous due to toxicity as a result of high levels of arsenic.[50]

The concentration of constituents in the raffinate waste, however, is highly dependent on the quality of the uranium yellowcake feed (since these waste constituents originate primarily as impurities in the feed). For this reason, we have used the characteristics of the actual feed to the Sequoyah facility to calculate constituent concentrations. A recent environmental study conducted by a contractor for SFC included information on the average constituent concentrations in yellowcake feed for 1989.[51] Combined with information on the flow of raffinate waste (about 29,500 m^3, or 7.8 million gallons, per year[52]), we estimate an arsenic concentration of about 40-70 mg/l[53] -- significantly lower than the value obtained by the Oak Ridge study for a reference plant, but still many times the toxicity concentration set by RCRA for waste extract.[54]

Another strong indicator that Sequoyah Fuels is handling materials which should be classified as hazardous wastes under RCRA is the significant arsenic contamination in the groundwater at the site. Arsenic has been found in groundwaters at the site at levels as

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49 Material can be classified as hazardous due to several characteristics, two of which are corrosivity and toxicity. Waste is hazardous due to corrosivity if it has a pH of less than 2 or greater than 12.5 (40 CFR 261.22). pH is defined as the negative log of H+ ion concentration; thus, a molar concentration of HNO3 of 1.26 will result in a pH of roughly -0.1 -- far less than 2.0.

50 Waste toxicity is determined by an EP-Toxicity test, which is designed to identify wastes likely to leach hazardous concentrations of toxic substances into groundwater. The test extracts constituents from the waste in a manner intended to simulate the leaching action that occurs in landfills. For example, if the extract from a waste contains 5 mg/l or more of arsenic, the waste is classified as hazardous (RCRA regulations at 40 CFR 261.24.). Under circumstances in which the waste contains less than 0.5% solids, the liquid phase of the waste itself will be treated as the extract. The question of waste toxicity under RCRA thus cannot be determined directly from the waste characterization alone, but relies on the results of the EP-toxicity test. Responsibility for conducting the EP-toxicity test falls on the generator.

51 RSA 1991, Table 4. This table lists arsenic concentration in the yellowcake feed of 240 parts per million.

52 NRC 1985, p. 2-15.

53 Arsenic at 240 parts per million in 9,090 metric tons feed per year implies 2.18 million grams of arsenic. (2.18 million grams per year) / (29.5 million liters raffinate per year) gives 74 milligrams per liter. Conservatively assuming the plant was operating, on average, at only half-capacity would give a lower-bound arsenic concentration of 37 mg/l.

54 Note that in the absence of an EP-toxicity test on this material, this information alone is not sufficient to determine that the waste is toxic. It does, however, provide strong grounds for suspecting that it may be.

high as 5.6 mg/l, an extraordinarily high level for groundwater.[55] This level is so high that the groundwater itself would qualify as a hazardous waste under RCRA.[56]

In all, 87 of 154 wells tested had measurable arsenic concentrations, with 43 wells containing more than 0.05 mg/l of arsenic.[57] These 43 wells all contain arsenic in excess of the maximum allowed concentration (0.05 mg/l) in groundwater established by EPA under RCRA for facilities which treat, store, or dispose of hazardous waste.[58] Thus, it is clear that:

- o there is high concentrations of arsenic in the untreated raffinate,
- o there is sufficient leaking of arsenic into the groundwater to contaminate it far in excess of that which is normally permitted at hazardous waste facilities, even to the point (in at least one instance) where the groundwater itself would qualify as hazardous waste.

Thus, the evidence is strong that Sequoyah Fuels is handling hazardous waste which should be RCRA-regulated.

Further, as noted above, the acidity of the raffinate stream before neutralization is high. This indicates that the untreated raffinate should be considered for classification hazardous on the basis of its corrosivity characteristic alone.

In sum, it appears likely that the raffinate in its pre-treated form should be considered a hazardous waste under RCRA on at least two grounds: high acidity and possibly also due to high levels of arsenic concentration. If so, SFC may be operating illegally since it lacks a permit to treat hazardous waste. (Note: the only other uranium

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55 RSA 1991, p. 234. The peak arsenic concentration (reported as 5.599 mg/l) was measured in monitoring well MW-42 to the southwest of the main process building, and adjacent to the yellowcake storage runoff sump, and near storage pond area.

56 As noted above, an arsenic level of 5 mg/l in waste extract is sufficient to qualify the waste as hazardous by the EP-toxicity test. Thus, with 5.6 mg/l of arsenic, the groundwater itself would qualify as hazardous waste according to this test.

57 RSA 1991, p. 234.

58 RCRA regulations at 40 CFR 264.94 establish groundwater protection limits for various hazardous constituents (these are the same constituents that will qualify a waste as hazardous according to the toxicity characteristic discussed above). These regulations apply to facilities which are licensed as hazardous waste treatment, storage, and disposal facilities, and may be waived if the facility can demonstrate if there is low potential for migration of contaminants. Sequoyah Fuels is not currently licensed as a hazardous waste treatment, storage, or disposal facility.

conversion plant in the country, Allied Chemical's plant in Metropolis, IL, does produce waste which is considered hazardous.[59])

B. The Raffinate "Fertilizer" Program

As reviewed previously, the raffinate waste stream is treated to produce ammonium nitrate solution which is then spread as part of Sequoyah Fuels' "fertilizer" program. The putative agricultural value of this solution is its high content of nitrogen (in the form of nitrate), an important plant nutrient. Various aspects of this program are reviewed in this section.

General Background

Nitrates in Groundwater

Nitrogen is an essential element for all living organisms, and compounds containing nitrogen, such as nitrates (NO_3), are ubiquitous in the environment. At excessive levels, however, nitrogen compounds can be hazardous to ecosystems and to human health. Of particular concern is nitrates in drinking water, which are controlled by EPA regulations at a maximum contaminant level (MCL) of 10 mg/l. Nitrate in drinking water above this level can cause "methemoglobinemia" (also known as "blue baby disease") in infants under six months of age. This is a rare but potentially fatal disease which inhibits the ability of blood to carry oxygen.[60]

Nitrates in groundwater generally are also a serious environmental concern because, once contaminated with nitrates, aquifers are extremely difficult if not impossible to remediate. Consequently, the U.S. EPA has developed an overall strategy towards nitrates in the environment based on the principles of pollution prevention. As put by the EPA strategy, "it is better to release fewer of these nitrogen compounds into the environment and it is better to use practices which minimize the movement of nitrate to surface and ground water than attempt a costly remediation."[61]

Sequoyah Fuels' "Fertilizer" Program

The high nitrogen content (20-25 grams nitrogen per liter, mostly in the form of nitrate)[62] of the treated raffinate waste prevents it from being discharged directly to

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59 Allied Chemical handles wastewater classified as hazardous because of its corrosivity. (Illinois Environmental Protection Agency, Response to Request for Public Records, February 26, 1992, Section D, p. D-1.) It should be noted that the process used for uranium conversion at the Allied Chemical plant in Metropolis is not exactly the same as that employed by Sequoyah Fuels. The characteristic of Allied Chemical's waste are therefore suggestive but not definitive.

60 EPA 1991. pp. 2, 3.

61 EPA 1991, p. 1.

62 SFC 1990b.

surface waters. There have been plans to dispose of this material by underground injection, but these failed to materialize as a routine option. Because nitrogen is an important soil nutrient, the option of spreading the treated raffinate as "fertilizer" on surrounding lands was considered in the early 1970's, if not earlier, although from the beginning it was recognized as potentially controversial by plant officials.[63] The Sequoyah plant began spreading fertilizer as part of an approved testing program in 1973,[64] and continues to do so on a large scale today (although as noted elsewhere, Sequoyah is considering changing this practice).

Sequoyah Fuels's current operating license authorizes the spreading of raffinate as fertilizer subject to certain conditions, including:[65]

- radium-226 content of the raffinate does not exceed 2 pCi/l of solution or 0.1 pCi per gram of nitrogen;
- uranium concentration does not exceed 0.1 mg/l;
- total nitrogen applied to any land in any one year does not exceed 700 pounds per acre;
- nitrate levels in nearby surface and groundwaters (which are to be sampled as part of a regular monitoring program) do not exceed 20 mg/l.

There has been much concern expressed about the possible environmental impact of the spreading of this raffinate as fertilizer, although this concern has focused largely on the radionuclide component. The license conditions above, however, seem to be most egregious in terms of the allowed nitrogen levels. Seven hundred pounds of nitrogen per acre, for example, is an extraordinarily high application rate, far above levels that typically begin to be toxic to most plants, even if it ever applied perfectly evenly. In addition, the NRC-authorized levels of nitrates in groundwater are twice as high as the EPA drinking water standard. This issue of excess nitrogen loading will be discussed further below.

Although Sequoyah Fuels has a regular fertilizer distribution program, in the past this method has not been able to dispose of all the raffinate as fertilizer. As of 1985, for example, there was a gradually increasing inventory of this material in the storage ponds. In 1985, the NRC noted that

> There will be a gradual increase of raffinate and more ponding capacity is needed. The staff believes that it is undesirable for SFC to keep on storing the raffinate in additional ponds without finding a solution for its ultimate disposal. Therefore, the

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63 For example, an attachment to a 1973 letter from Kerr-McGee to the Atomic Energy Commission (the predecessor to NRC) discussing the fertilizer option noted that "[i]n view of the origin of the [raffinate] solution, considerable resistance may be expected without further demonstration of its nondeleterious effects." (Kerr-McGee 1973, Attachment p. 3.)

64 OWRB 1988.

65 SFC 1990a, p. 1-3.

> staff encourages SFC to explore other alternatives for the ultimate disposal of the raffinate, so that it would not be accumulated to an unmanageable situation.[66]

Thus, the need to find something to do with the volume of this material appears to have been a driving incentive behind expanding the "fertilizer" program through the purchase of new lands, and the attempt to get permission to market the raffinate as commercial "fertilizer." Other programs included the building of a new retention pond, programs to reduce the size of the rain catchment area which drains to the ponds, the installation of a spray system to increase evaporation from the ponds. High rainfall is both cited as a problem and reason to spread greater volume as "fertilizer" because of diluted nitrate concentration.[67]

Over the years there has been much expression of citizen concern regarding the spreading of this raffinate waste as fertilizer. Recently, for example, a great deal of attention was generated by the broadcast of a local television news series which showed vegetation which had recently been sprayed with raffinate apparently dying or turning brown; another segment showed large numbers of dead cows (which grazed on Sequoyah land sprayed with raffinate fertilizer) in burial trenches on Sequoyah property (about 30 apparently recently dead cattle can be seen in one burial trench).

With an eye to these concerns, there are two areas we address below: radioactivity levels and nitrate levels.

Radioactivity Levels in SFC "Fertilizer"

The license conditions limit the concentration of radium-226 in the raffinate fertilizer to 2 pCi per liter, and uranium to 0.1 mg/l (or 67 pCi/l). In the fertilizer actually spread (according to SFC reports), the radioactivity of the raffinate is well below these levels: in 1989, radium-226 in fertilizer spread on test plots was at 0.1 pCi per liter or less, and uranium ranged from about 3 to 7 pCi/l.[68] Somewhat higher (although still below the limit) levels (up to 1.05 pCi/l of radium-226) are reported for 1990.[69]

By comparison, natural background levels of these radionuclides was as follows: average levels of radium-226 in groundwater ranges from about 0.1 to 2 pCi/l;[70] uranium in seawater averages about 2 pCi per liter.[71]

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66 NRC 1985, p. 2-17.

67 Letter from Reau Graves (SFC) to Robert Martin (NRC), (6 April 1990).

68 SFC 1990b, Table 1, p. 5.

69 SFC 1991b, Table 1. In 1990, the proportion of radium-226 to nitrogen was about 0.045 pCi per gram of nitrogen.

70 Peak values of background radium-226 can range to about 25 pCi/l. (Eisenbud 1987, p. 133.)

71 Benedict 1981, p. 261.

Thus, if the raffinate spread on test plots is representative of all fertilizer spread, and if the analysis is accurate, the absolute levels of radioactivity based on these two radionuclides are about the same order of magnitude as that found in the environment naturally (though, of course, SFC is adding to these levels by spreading raffinate). It is therefore unlikely, based on the data available from Sequoyah Fuels, and assuming the measurements accurately represent what is being spread, that radionuclide constituents of the treated raffinate are causing readily noticeable short-term effects of the kind being reported on the television news.[72] (It should be noted, however, that there has apparently been no analysis of the fertilizer constituents other than that conducted or contracted by Sequoyah Fuels.)

Nitrate Contamination due to SFC "Fertilizer"

NRC Levels v. EPA Drinking Water Standards

Another area of concern, however, is the level of nitrates in the raffinate and spread as fertilizer. In 1989, the raffinate spread on some test plots contained over 23,000 mg/l of nitrate (measured as nitrogen). Cumulative annual averages of nitrogen spread ranged up to 450 to 550 pounds per acre in 1989 and 1990.[73] These are very high rates of nitrogen application.

EPA drinking water standards (at 40 CFR 141) limit nitrates in drinking water to maximum contaminant limit (MCL) of 10 mg/l (as N). The 20 mg/l level allowed for groundwater by Sequoyah's license with the NRC is twice this. Legally, the EPA standard applies to drinking water sources and underground injection wells, and not necessarily to groundwater generally. However, as reviewed above, it is a policy goal of the EPA to keep nitrate levels in all groundwaters as low as possible. The NRC license conditions permitting 20 mg/l are inconsistent with this goal.

As discussed above, the concern about nitrates in groundwater is a serious one; the drinking water limit is a health-based standard, set to prevent the occurrence of methemoglobinemia ("blue baby" disease). Of particular interest may be the fact that this is also a disease of concern for young cattle, which are more susceptible to nitrate poisoning than most animals. Nitrate drinking water levels of 100 mg/l can be fatal for calves.[74] However, this level may be less if combined with high-nitrate feed. Considering

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72 This conclusion does not extend to more difficult to identify long-term effects. Indeed, according to the commonly used linear hypothesis for the carcinogenic effects of radiation exposure, any level of radiation exposure results in some incremental increase in the risk of cancer.

73 SFC 1990b reports nitrogen application rates in 1989 (Table 2 lists 410 and [illegible] pounds per acre of nitrogen application). Table 2 of SFC 1991 reports nitrogen application rates [illegible] 1990 of 503 and 554 pounds per acre.

74 EPA 1991, p. 3.

the very high levels of nitrogen in the nitrate fertilizer being applied to Sequoyah land, the condition of high-nitrate cattle feed may apply to this case.

Toxic Effects of Excess Nitrogen on Plants

Another concern is the possible toxic effects of high nitrogen levels on plants. Dr. David Pimentel, an agricultural specialist at Cornell and a member of a National Academy of Sciences committee on agriculture,[75] was initially skeptical that nitrogen fertilizer was actually being applied at a rate as high as 400-500 pounds per acre because it would be a waste of money. Upon being informed that it was a waste product, Dr. Pimentel agreed it would be possible, but still noted that it can start to become "toxic" to many plants at a level of 300-400 pounds per acre. (This is because, although nitrogen is a necessary plant nutrient, high levels can cause toxic effects).[76]

A factsheet issued by the Oklahoma State University Division of Agriculture Extension Service lists nutrient requirements for various plants in Oklahoma soils.[77] According to this factsheet, nitrogen requirements for most crops range from 40 or 50 lbs per acre up to 200 - 300 pounds per acre for high yields (200 bushels/acre) of corn. The highest demand crop listed is bermuda grass (which is what Sequoyah Fuels grows). The nitrogen demand for bermuda grass grown to achieve the highest yield goal of 7 tons per acre is listed in the factsheet as 400 pounds per acre (the one ton per acre yield requires 50 pounds nitrogen per acre).[78]

Actual fertilizer application rates should be less than the total nitrogen requirement indicated above, by an amount which depends on the nitrogen content of the soil.[79] However, even the absolute levels of nitrogen requirements listed in the factsheet for the highest yield of bermuda grass (7 tons per acre) are exceeded in some cases at Sequoyah by almost 40 percent.[80]

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75 The Committee on the Role of Alternative Farming Methods in Modern Production Agriculture.

76 Telephone conversation between Scott Saleska, IEER, and David Pimentel, Cornell University, 607-255-2212, (August 20, 1991).

77 G. Johnson, & B. Tucker, OSU Soil Test Calibrations, OSU Extension Facts, No. 2225. One of coauthors of this factsheet -- Billy Tucker -- is SFC's consultant on their "fertilizer" program.

78 We note that even this number appears high. For example, uptake of 400 pounds of nitrogen per acre would result in the production of 6,400 pounds protein per acre in the plant matter. [(400 lbs N/A) / (0.0625 lbs N/lb protein) = 6,400 lbs protein per acre] This is an implausibly high level of protein production per acre.

79 As stated in the OSU Factsheet, "Nitrogen fertilizer rate is calculated by subtracting the soil test nitrogen reported from the nitrogen requirement given in the tables for the desired yield goal." (OSU Factsheet, p. 6.)

80 554 pounds per acre (SFC 1991b, Table 2) exceeds 400 pounds per acre by 154/400 = 38.5%.

In conjunction with the application of ammonium nitrate raffinate, soil, forage, and ground and surface water analyses are regularly reported. Nitrate levels in groundwater in 1989 ranged from 0.1 to 5.5 mg/l. Surface water concentrations of nitrate ranged from 0.1 to 14.4 mg/l.[81] The latter is above EPA drinking water limits, and even the former is apparently higher than EPA staff considers prudent.

The problems discussed above (such as dying vegetation and cattle) may in fact be much more possible than Sequoyah's reported numbers indicate. This is because the numbers reported by Sequoyah (e.g., the nitrogen per acre distribution) are averages over an area. If the workers driving the raffinate application trucks did not spread it evenly over the entire intended area of application, the surface area that did receive the raffinate could easily have received much higher levels of nitrogen, readily achieving toxic levels for the plants affected. Further, if the raffinate tended to puddle temporarily in low areas, or drain into ponds which were drinking sources for the cattle, levels ingested at certain times by cattle could easily exceed the regulatory limits by many fold, without detection by SFC's monitoring system as it currently exists.

Anomalous Fertilizer Data

The data on fertilizer use reported by Sequoyah has a number of apparent inconsistencies and errors which raise questions about its integrity. (See the table below.)

For example, a comparison of pre-season and post-season soil analysis of the 270-North area shows a *decrease* in nitrogen, from 11 and 38 lbs/A (0-6" and 6-12" depth segments, respectively) to 3 and 6 lbs/A.[82] This despite the application of "fertilizer" at a rate of 450 lbs N/acre. Nitrogen content of forage from 270-North was 1400 lbs/A for one sample, and 325 lbs/A for another (Table 10 in SFC report). By comparison, soil nitrogen in 270 South went up. Some of these are indicated in the Table below, including levels of nitrogen in forage samples.

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81 SFC 1990b.

82 SFC 1990b, Table 3 versus Table 5.

1989 Nitrogen Levels (lbs N/acre) (as reported by Sequoyah Fuels)				
Area	Soil Levels[83] pre-season	post-season	"fertilizer" Application[84]	Forage[85]
270-North, 0-6"	11	3	450	1,400 (7/89)
6-12"	38	6		325 (8/89)
270-South, 0-6"	10	72	465	500 (7/89)
6-12"	4	11		2,100 (8/89)

There are several other aspects of these and other measurements in Sequoyah's fertilizer reports that raise questions, and deserve closer scrutiny:

1) Tables showing results of analysis of soil and forage list radionuclide content in units of pCi per *liter*.[86] This is the wrong unit for measuring constituent concentrations in soil or forage. It should be pCi per gram.
2) Some of the levels of nitrogen in forage are far too high to be credible. Average nitrogen uptake in various crops ranges from 15 up to about 300 pounds per acre.[87] Although the upper end of this range is close to some of the levels reported for Sequoyah's forage (e.g. the 325 pounds per acre), the reported levels of 1,400 and 2,100 pounds per acre do not appear to be in accord with agricultural data.[88]
3) Typical nitrogen content (mostly organic) of soils is about 0.15%, or 3,000 lbs/acre in the first 6 inches.[89] However, SFC reports levels of nitrogen which range from only 3 to 72 lbs per acre.[90] SFC's reported levels are thus completely inconsistent as reported. It may be that SFC is measuring only

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83 SFC 1990b, Tables 3 and 5.

84 SFC 1990b, Attachment 1, pp. 11-12.

85 SFC 1990b, Table 10.

86 SFC 1990b, Tables 5, 6, and 10. Heavy metals are listed in units of parts per million, and nitrogen in terms of lbs/A.

87 Fertilizer Institute, *The Fertilizer Handbook*, pp. 18-19 (1982).

88 It is possible that Sequoyah Fuels has incorrectly reported this data. We have found other incorrect listings as, for example, with the incorrect units listed for thorium and radium in soil as pCi/l.

89 *Fertilizer Handbook*, p. 29.

90 SFC 1990b, Tables 3 and 4.

nitrogen in nitrate form. The numbers would make more sense if this were so, but in that case the reported data are mislabeled.[91]

Summary

In sum, based on a preliminary review of the documentation regarding SFC's ammonium nitrate raffinate/fertilizer program, it appears that:

1) NRC license conditions inadequately regulate the application of the raffinate. Specifically, the 700 pounds per acre limit on total nitrogen application, and the condition which allows fertilizer application to cause nitrates in groundwater to reach 20 mg/l are excessive;
2) Sequoyah Fuels, although apparently staying within NRC license conditions for the most part, is applying ammonium nitrate raffinate at average rates far in excess of those which would be dictated by legitimate agricultural considerations;
3) It is possible that peak application rates and nitrate concentrations far exceed even these high values (which are reported as averages). Further, SFC's monitoring system appears to be inadequate to detect such problems; such reporting of the fertilizer program as is required is so carelessly and sloppily done as to make the data suspect and definitive conclusions difficult.
4) It is eminently plausible that the application rates of SFC raffinate are sufficient to cause the toxic effects on vegetation due to an excess of nitrogen.
5) Based on the above considerations, nitrate poisoning of cattle (due to high levels of nitrates in water and feed) should be investigated as a possible cause of the death of the large numbers of dead cattle shown in the television news clip.

Because the spreading of raffinate on agricultural lands results, according to the words of Sequoyah Fuels, in "bad public relations," the company has apparently embarked on a program to alter the handling of the raffinate stream. Sequoyah Fuels has contracted with Ecotek, Inc. to explore the possibility of recovering nitric acid from the raffinate. According to Sequoyah Fuels, this process would result in a sludge waste stream which would be shipped offsite, and a liquid stream whose nitrate content would be low enough to discharge to the river with the existing combination stream.[92]

C. Nitrate Contamination of Groundwater from Plant Processes

In addition to the problem of nitrate contamination due to the spreading of raffinate "fertilizer," there is also a serious nitrate contamination problem from activities at the plant site itself.

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91 Data are reported (SFC 1990b, Tables 3 and 4) under headings labeled "N (lbs/A)." The tables do not indicate that anything other than total nitrogen content is being reported.

92 Sequoyah Fuels Corporation, *Sequoyah Quill*, Vol. III, No. 6 (March 1992).

Nitrate contamination in groundwater on the plant site due to leakage from process buildings and raffinate treatment and storage ponds varies tremendously. Levels reported in Sequoyah Fuels' license renewal application vary from 0.1 mg/l or less, up to more than 8,000 mg/l, with routine levels of thousands of mg/l reported in many wells.[93] More recent data reported by the NRC show nitrate concentrations ranging up to 16,000 mg/l in the underdrain systems beneath the treatment ponds to the west of the process buildings.[94] Such levels are hundreds of times the EPA drinking water standard, with many of them a significant fraction of the level of nitrate in the raffinate itself (20,000 - 25,000 mg/l). This state of affairs is reason for serious concern about nitrate contamination. Unfortunately, given what is known about the leakage from the process buildings and from the raffinate ponds (raffinate pond 2 in particular -- see the section below), it should not be surprising.

Nitrate contamination of groundwater from plant activities is a problem which may also extend to offsite. One of the main areas of nitrate contamination is the area beneath and around the raffinate treatment ponds and clarifier basins immediately to the west of the main process buildings. Although the investigations conducted by SFC's contractor, Roberts, Schornick and Associates, characterized nitrate contamination in the treatment pond area, their data indicate nitrate plumes in groundwater which extend beyond this area. How far offsite these plumes actually extend is not clear, and does not appear to be fully characterized.[95]

Another concern is the set of treated raffinate storage ponds located outside of and to the south of the main plant area. This set of five synthetically-lined ponds (ponds 3E, 3W, 4, 5, and 6) is used to store treated raffinate prior to its being spread as "fertilizer." Although SFC's Environmental Report in its License Application rather casually characterizes the situation in this area by stating that "[t]he concentration of nitrates in the monitor wells are generally low," the data show otherwise.[96] A number of wells in this area show nitrate levels extending to hundreds of milligrams per liter, with a few samples over

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93 Levels of 8200 and 8400 mg/l are reported from monitoring well 2339 in SFC 1990a, Environmental Report, p. B-83. The more recent investigations reported in RSA 1991 also showed high levels of nitrates, which ranged up to 4,210 mg/l in well MW 58A near Pond 2 (RSA 1991, p. 221).

94 NRC Inspection Report 92-02, p. 7 (April 16, 1992).

95 Groundwater plumes are depicted in RSA 1991, Figures 79 and 80. The depiction of these plumes is truncated at the site boundary, but the nitrate levels in the truncated plumes are over 1,000 mg/l in two cases in westward extending plumes, and over 3,000 mg/l in another plume extending to the south.

96 SFC 1992, p. 4-30. This language is unaltered from that originally contained in SFC 1990a, Environmental Report, p. 4-26.

1,000 mg/l.[97] SFC's Environmental Report does acknowledge that "[s]ome of the monitor wells contain elevated nitrate values believed to be the result of ammonium nitrate fertilizer solution applied to this area in the 1970's."[98] This explanation does not appear entirely plausible, considering that at least several of the wells show an increasing trend for nitrate over the last several years. This is further reinforced by more recent data (late 1991) reported by NRC which show, if anything, even higher nitrate concentrations at several of these wells.[99] NRC stated that this trend

> indicates that the current practice of pumping the leak detection systems is not recovering sufficient treated raffinate solution. This lack of recovery is causing a well developed nitrate plume to be developed under the ammonium nitrate storage ponds. During [a] 1987 review, there was no plume that could be accurately defined.... In spite of [SFC's remediation efforts], the data indicates that increasing nitrate concentrations are being measured at an increasing number of wells.[100]

NRC suggested that the source of contamination should be eliminated, but also acknowledged that "the volume of solution in inventory will not allow repairs to be made."[101]

This area does not appear to have been investigated in the SFC-commissioned "Facility Environmental Investigation" (FEI) in as great a detail as that near the raffinate treatment ponds onsite. In the FEI, no nitrate plumes are indicated in this area (that of the treated raffinate storage ponds), and the area was given a low priority for further investigation.

In addition to those areas near the process buildings and around the two sets of storage ponds, there may be additional offsite nitrate contamination. According to the FEI, wells at several offsite residences also contained nitrates in groundwater at excessive levels: 19, 23, and 45 mg/l were reported at three offsite wells.[102] These levels are significantly in excess of the 10 mg/l drinking water standard established by EPA (and two are also in excess of the higher NRC-established environmental action level for Sequoyah Fuels). Sequoyah Fuels' contractor claims, however, that this was not caused by its plant,

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97 For example, many samples from well 2348 are in the hundreds of mg/l, with a peak value of 868 mg/l on 11/20/90. Well 2352 shows only background levels for most of the monitoring period, but nitrate levels jump abruptly to the 300-500 mg/l range starting in late 1990, possibly indicating a new pond leak. Other levels are as follows: #2343, 4.2-1,990 mg/l; #2351, 84-1,068 mg/l; #2354, 2.6-55 mg/l; several other wells in this area also have levels consistently above 10 or 20 mg/l. (SFC 1992, Appendix B.)

98 SFC 1992, p. 4-30.

99 NRC Inspection Report 92-02, p. 8 (April 16, 1992).

100 *Ibid*, pp. 8-9.

101 *Ibid.*

102 RSA 1991, Table 67.

but by animals raised on these properties.[103] This claim needs to be independently verified.

D. Raffinate Sludge and Pond 2 Remediation

The precipitates from treatment of the raffinate settle into sludge on the bottom of the treatment and storage ponds at the Sequoyah site. For 20 years of plant operation, however, much of this sludge simply accumulated at the bottom of the ponds.[104] A typical analysis of sludge constituents and concentrations, as reported by Kerr-McGee in 197[illegible] (and found in several documents since that time) is shown in Table 2. The table also contains reported concentrations of sludge recovered during the decomissioning of pond 2.

The practice of letting sludge accumulate continued even when one of the raffinate ponds (pond 2) was found to be leaking in 1974.[105] Sequoyah responded by establishing an extensive system of monitoring wells around pond 2, but continued to use the leaking clay-lined pond until 1980. Since then, it has not been in regular use,[106] and was in the process of NRC-mandated remediation[107], a process which was recently completed. SFC contracted with the Quivira Mining Company to ship sludges from the raffinate ponds to Quivira's uranium mill in New Mexico. Sequoyah Fuels has indicated that these sludges are being reprocessed for the recovery of uranium,[108] but as discussed below, this is unlikely due to the economics of the uranium market.

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103 RSA 1991.

104 SFC 1991a.

105 Raffinate leakage from pond 2 was discovered through data from an adjacent monitor well in May 1974. (NRC 1985, p. 2-17.)

106 Although on at least one instance (early 1990), the pond was used for overflow from other ponds, a circumstance which arose as a result of high rainfall (see discussion below).

107 NRC 1985, p. 2-17.

108 SFC 1991a, p. 1.

Table 2 -- Selected Constituents of Settled Raffinate Sludge		
Constituent	1977 Sludge Concentrations[109]	Decommissioned Pond 2 Concentrations (1991)[110]
Chemical Species	ppm	ug/g (ppm)
Aluminum	1,500	
Arsenic	120	< 10 - 205
Calcium	1,000	
Chlorine (including Br and I)	50	
Iron	2,500	
Fluoride	10	288 - 30,600
Magnesium (including Mn, Ni, Pb)	600	
Molybdenumn	300	< 5 - 1,694
Nitrate (as N)	7,300	771 - 42,500
Vanadium	200	
Radionuclides	pCi/g	pCi/g
Radium	22	0.9 - 297
Thorium-230	5,060	2.3 - 7,025
Uranium (natural)	<270	4.3 - 1,162 (a)
Net Sludge generation rate:	1.8 million gallons/yr (wet sludge, 68% liquids)	

(a) One document (SFC 1992a) refers to Pond 2 sludge as containing uranium at levels "exceeding 2,000 pCi/g."

Remediation of pond 2, however, went very slowly. For example in April 1990, SFC reported that high rainfall had resulted in exceptionally high levels in the ponds, and that therefore it was transferring raffinate liquid from the full pond 4 to the almost empty Pond 2, resulting in temporary delay of remediation of pond 2.[111] Thus, although Pond 2 was not in active use, Sequoyah Fuels and the NRC apparently did feel free to use it in emergency situations. SFC again reported suspension of remediation of Pond 2 in February 1991, due to the fact that Quivira Mill in New Mexico stopped taking sludges being sent due to some difficulties Quivira was having in obtaining a permit from the EPA related to construction

109 The numbers in this table appear in an attachment to a 1977 letter (Kerr-McGee 1977). These same numbers are reproduced in a table contained in Kerr-McGee c.1980, and again in a 1991 evaluation and inspection report by the Oklahoma State Department of Health on Sequoyah Fuels (Oklahoma 1991). A more recent document (SFC 1992a, p. 38) refers to the level of uranium in the sludge of Pond 2 as "exceeding 2,000 pCi/g," a much higher number.

110 NRC Memo from Gary Konwinski to L.J. Callan, Director, Division of Radiation Safety and Safeguards, "SFC-GORE Soil Samples Results for Pond #2 Decommissioning," (October 21, 1991).

111 Letter from SFC President Reau Graves to NRC Regional Administrator Robert Martin, p. 2, April 6, 1990.

of new mill tailings disposal cells.[112] Sludge shipments resumed later on in the Spring of 1991 when this problem was apparently resolved.

An estimate of total uranium in the sludge can be made from data on sludge composition. Table 2 lists the uranium content of pond sludge as "<270 pCi/gm", and sludge generation rate as 1.8 million gallons per year. A level of uranium in the sludge of 270 pCi/gm implies about 3 metric tons of uranium per year in SFC's raffinate sludge.[113] Another source estimates that the rate of sludge generation is 2.3 million gallons per year, which indicates an upper limit of around 4 metric tons of uranium discharged to raffinate.[114] The same process of estimation gives 17.4 metric tons of accumulated uranium in Pond 2 as of the end of 1979.[115] Presumably the amount in Pond 2 today is much lower due to sludge removal and shipment to Quivira, but since Pond 1 sludges containing greater than 20 pCi/g of uranium, thorium, and decay products were emptied into Pond 2 around 1980,[116] the maximum uranium contained by pond 2 may have been considerably higher.

As the table indicates, a recently reported number indicates uranium levels of over 2,000 pCi per gram. This may not necessarily be inconsistent with the above-reported estimate of "<270 pCi/g," which was first made in 1977 or possibly earlier. Concentration of uranium in the sludge could increase over time if it was subjected to continued loading from ongoing activities, or from remediation. We do not have sufficient data at this time to evaluate the source of this inconsistency reliably. If, however, the 2,000 pCi/gram is more representative of an annual generation rate, the total uranium discharged to raffinate could be substantially higher than the above estimates.

Based on the above estimates, one would expect that total lifetime accumulation to date of uranium in raffinate sludge is in the range of 60 to 80 metric tons (or 440 to 590 metric tons, based on the 2,000 pCi/g sludge content).[117] Calculations based on assumptions in another source, indicate that raffinate releases were likely on the higher

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112 SFC 1991a, p. 1.

113 1.8 million gallons (at a density of the 1.15 g per ml reported in Kerr-McGee 1977) is 7.8 x 10^9 grams. Assuming a uranium concentration of 270 pCi/gram, total annual uranium in sludge = 7.8 x 10^9 grams x 270 pCi/g = 2.1 curies = 2.1 x 1.5 metric tons uranium/curie = 3.15 metric tons uranium.

114 Kerr-McGee c.1980, p.2.

115 Kerr-McGee c.1980, p. 2 indicates a total of 10 million gallons of sludge in Pond 2 in 1979, which equals 4.3 x 10^10 g. Multiplied by 270 pCi U/g gives 11.6 Ci = 17.4 metric tons.

116 NRC 1985, p. 2-17.

117 Annual generation rates of 3 to 4 metric tons gives an accumulated total after 20 years of 60 to 80 metric tons.

side of this range.[118] It must be emphasized that these estimates are very cursory at this point, and should not be given great weight in the absence of more data and analysis.

Presumably this amount (whatever it actually is) is now divided between raffinate sludge, shipments to the Quivira Mill, and any that might have been dumped, disposed of, or leaked somewhere else.

By comparison, Sequoyah's total estimate so far of the amount of uranium contaminating soil from leakage in the process buildings is about 10 metric tons (see below). In any case, since Pond 2 has been known to be leaking since 1974, and this leak is believed to be the source of excedances of the nitrate limits for stormwater runoff from the area of Pond 2,[119] it is also plausible that this pond may be a source of significant additional uranium (or other nuclide contamination).

Incidentally, the above maximum uranium concentration in sludge of 270 pCi/g is equivalent in concentration to that of 0.05% U_3O_8 ore. This is much less uranium than is found in even the lower-grade U.S. ores, which can have uranium concentrations of 0.2% or so. It is therefore highly questionable that this is an economically recoverable amount at current prices. Thus, shipping the sludge to Quivira mill is most likely simply a waste disposal method at this point rather than a recycling of the material, as SFC tends to imply. A sludge concentration of 2000 pCi uranium/gram (or roughly 0.4% uranium) is more likely to be in the range of economic recoverability.

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118 Forsberg 1985, p. 38 implies that 90 percent of the uranium that is lost to waste ends up in the raffinate stream, with most of the remaining 10 percent in the fluoride stream. Our estimate for uranium emissions in the fluoride stream from 1980 to 1990 is 33.5 metric tons (see Chapter Four, Section A, "Uranium in the Fluoride Stream"), implying 33.6*(90%/10%) = 302 metric tons in the raffinate stream just during the years 1980-1990 (which does not include the first ten years of plant operation).

119 SFC, "Surface Water Runoff Compliance Plan," attachment to SFC letter from Scott Knight to Dave Dillon, Oklahoma Water Resources Board Chief (September 11, 1989).

Chapter Four. Uranium Emissions to the Environment

Aside from the raffinate waste stream management and disposal activities discussed in the previous chapter, there are three other main pathways for uranium contamination to reach the environment that we examine here. These are: uranium effluents released through the NPDES-permitted fluoride-combination stream discharged to the Illinois River, uranium leakage from the production process directly into the soil and groundwater, and uranium emissions to air. Each of these are discussed in the sections below. These are followed by a discussion on misrepresentation by Sequoyah Fuels of data relevant to environmental contamination, including an evaluation of statements in Sequoyah Fuels' license renewal application submitted in August of 1990.

A. Uranium Emissions to the River

As mentioned above, there are two principal liquid waste streams. One of them is the raffinate stream, some of which is spread as "fertilizer," as discussed above. The other is a fluoride waste stream, which, after being combined with several other waste miscellaneous streams, is discharged to the Illinois River via Outfall 001. Historically, this outfall has simply been a shallow creek or ditch through which waste water was discharged to the river; currently it is transferred to the border of the property via pipe (called a "combination stream drain"), after which it crosses Army Corp of Engineering property to the river via a ditch. Two permits regulate this "combination stream" discharge: an EPA NPDES permit, and an Oklahoma Water Resources Board (OWRB) permit. In addition, NRC's regulations at 10CFR20 set concentration limits for radionuclide release to the general environment.

Limits set by these permits and regulations:

1.6 mg/l Fluoride
20.0 mg/l nitrate (as N)
2.5 mg/l Ammonia-Nitrogen (as N)
45 mg/l uranium

As interesting as the concentration are the quantities of uranium released by this stream according to official data:

- An average of 4,900 kilograms (10,780 pounds) of uranium per year released 1980-1984. The maximum was 7,000 kilograms (15,400 pounds) in 1982.[120]

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120 NRC 1985, p. 2-19.

- An average of 1,500 kilograms (3,300 pounds) uranium per year released in the years 1985-1989, with a maximum of 1,700 kilograms (37,400 pounds) in 1988.[121] (About 1,575 kg -- 3,465 pounds -- uranium was released in 1990.[122])

As is apparent, the discharge rate has been decreasing over time. Based on the volume discharged, SFC apparently assumes a maximum allowable discharge of about 120,000 kilograms (264,000 pounds) uranium per year.[123] We have not seen data for discharges before 1980, and thus cannot make precise estimates for lifetime discharges, but the total amount of uranium reported discharged in the years 1980-1990 was 33,575 kilograms (almost 74,000 pounds).

Although Outfall 001 is the principal one in use currently, there have been several other outfalls through creeks used in the past to discharge effluents to the river. A report commissioned by the Native Americans for a Clean Environment (NACE) showed uranium contamination in the creek inlets to the Illinois river. The uranium measured in samples of the creek inlets ranged from 24 to 230 pCi per gram.[124] Sequoyah Fuels has also measured high levels of contaminants in sediments in this area. Table 3, below, lists levels of contaminants found in the sediments of old Outfall 005 and in Outfall 001 for 1986 and 1991.

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121 SFC 1990a, Environmental Report, Table 4-3, p. 4-4.

122 SFC President Reau Graves FAX to Bill Beach, NRC (3/13/91).

123 *Ibid.* It should be noted that technically, the allowable discharge is not an absolute limit, but is based on the 10CFR20 Appendix B concentration limit of 45 mg/l. Thus, there is just a limitation on concentration -- which means that the allowable uranium discharge is determined by the overall volume of liquid discharged. For example, assuming a water outflow of 3.55 million gallons per day, as reported in OWRB 1988, would result in an upper limit on U discharge of 225,000 kg/year (495,000 pounds).

124 ES 1988, Table IV. Gross radium was also measured at 1.7 pCi/g.

Table 3 -- 1986 (and 1991 uranium) Sediment Sample Concentrations from discharge Stream Beds[125]

Sample I.D.	Location	Ra-226 (pCi/g) 1986	Th-230 (pCi/g) 1986	U-natural[126] (ug/g) 1986	1991	(Sample I.D.)
Old Outfall 005						
005-00	Fence Line 005	2.22	49	239	4	(SFC-A)
005-03	300' West	1.30	73	255	23	(SFC-B)
005-06	600' West	2.40	354	416	49	(SFC-D)
005-09	900' West	1.6	106	758	220	(SFC-E)
Outfall 001						
001-R	River Sediment	0.92	1.1	29	31[a]	(SFC-H)
001-39	Port Rd. Bridge	1.41	3.6	45	28[b]	(SFC-J)

(a) 1991 sample SFC-H from confluence of 001 and Headwaters (near but not exactly coincident with 1986 river sediment sample 001-R).
(b) 1991 sample SFC-J from inflow of 001 to drainage ditch (near but not precisely coincident with 1986 sample 001-39).

The 1986 uranium levels are very high for offsite contamination -- equal to and in one case (758 ug/g for sample 005-09) exceeding by a factor of almost two the reported concentration (about 400 ug/g) of uranium in the sludge at the bottom of the raffinate ponds (probably the most significant source of uranium effluent from the facility).[127] (For comparison's sake, natural background levels of uranium are on the order of 1 ug/g, and Sequoyah's environmental action level for uranium in soil is about 40 ug/g.) Further, the generally high ratios of uranium to radium-226 indicate clearly that the uranium in the stream bed is not of natural origin, but comes from an artificial source such as Sequoyah Fuels. Radium-226, thorium-230 and natural uranium generally occur in proportions of 1:1:2 in nature. Uranium processed at Sequoyah Fuels, however, has had most of daughter products (including radium-226 and thorium-230) removed during refining processes at a uranium mill.

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125 SFC measurements, as contained in attachment to internal NRC Memo, "SFC-Gore Soil Sample Results," from Gary Konwinsky, Project Manger, to A. Bill Beach, Director, Division of Radiation Safety and Safeguards (August 1991).

126 There is some discrepancy in the source as to which 1991 samplec correspond most closely with the locations for the 1986 samples. For example, some samples are identified in tables by similar labels but appear at disparate locations on the associated map. (For example, 1991 sample SFC-D, containing 49 ug/g of uranium, is labeled as "~900' West 005." However, on the map it coincides most closely with 1986 sample 005-06, which is labeled in its table as "600' West." Where such discrepancies occurred, we used the map as determinant.

127 Raffinate pond sludge was discussed in the previous chapter, where a Kerr-McGee document is cited indicating uranium concentrations of "<270 pCi/g.". Conversion: 270 pCi/g x 1.5 ug/pCi = 405 ug/g.

At up to 354 pCi/g, thorium levels are also high -- several hundred times the natural background level for thorium-230 of about 1 pCi/g.

Samples were taken again in 1991, and as can be seen, the levels of the constituents at all comparable locations in the old 005 outfall declined. Since the 005 outfall is no longer in significant use, this is not especially surprising. (As rainwater continuously transports contaminants to other places, the concentration at a given location will decline unless it is continuously supplied by a source.) As the NRC commented,

> This [decline in radionuclide concentrations] is probably due to a combination of diverting site runoff from the monitored outfalls to the combination stream [Outfall 001], as well as the erosion of resident soils that had accumulated the various radionuclides. Regardless of the reason for these decreases, the radionuclides have been transported to downstream locations and have had their concentrations diluted.[128]

It is interesting to note that two locations that did *not* decrease as substantially in concentration were associated with the Outfall 001 combination stream, which is still in active use, thus providing a continuous source of uranium.

It is important to note that, the few samples cited above notwithstanding, there has apparently been no detailed characterization of the extent of possible contamination caused by the releases through the outfall streams. As pointed out by the NRC, the detailed environmental investigations conducted recently by SFC do not touch on the amount of radionuclides in the area of the outfall streams or their distribution.[129]

The combination stream uranium effluent has apparently been the subject of some concern to the NRC for several years. For example, in 1985, an NRC report stated that "although the release of radioactive liquid waste into the Illinois River complies with 10 CFR 20, the staff is concerned with the transfer of this waste from the plant through a low-flow 5,000 ft. natural drainage course. The accumulation of uranium in the sediment or soil along the combination stream has reached a significant level, therefore, the staff has requested SFC to propose a better method of transference of this waste from the plant to the Illinois River."[130] For this reason, SFC has contained the stream in a drain which pipes the effluent to the edge of the Army Corps of Engineers property, at which point it is discharged to a ditch which takes it the remaining distance to the river.

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128 Internal NRC Memo, "SFC-Gore Soil Sample Results," from Gary Konwinsky, Project Manger, to A. Bill Beach, Director, Division of Radiation Safety and Safeguards, p. 2 (August 1991).

129 Internal NRC Memo, "SFC-Gore Soil Sample Results," from Gary Konwinsky, Project Manger, to A. Bill Beach, Director, Division of Radiation Safety and Safeguards, p. 2 (August 1991).

130 NRC 1985, pp. 2-18, 2-19.

More recently (May 1991), an NRC staff member noted that "Unnecessarily large amounts of [uranium] are discharged from the site [through the combination stream]. This is not consistent with the ALARA principal [sic]. To terminate this situation, some form of alternate water treatment that concentrates the waste product in a manageable sludge and discharges clean water is necessary. SFC should submit a water treatment plan for NRC review and approval."[131]

How many times the NRC will have to raise issues related to uranium effluent before it is acted on to their satisfaction is unclear. SFC uranium emissions do seem to have declined somewhat over the past few years, and SFC officials have responded with concerned rhetoric. In a recent report on uranium emissions to NRC, for example, SFC president Reau Graves stated: "We continue to make good progress in reducing our permitted release of U both in the combination stream and the stack. We plan to include further reduction of these releases in our incentive program again this year. We are and have been committed to ALARA."[132]

In addition, an NRC staffer recently wrote "Rather than wait until the plant closes, SFC plans to address cleanup while the plant is operational.... SFC has taken the necessary steps so that ongoing operations do not regularly contribute to the problem; SFC may have upsets but *routine operations will not contribute.... All* permitted discharges will be treated by the ALARA concept."[133] (emphasis added) This seems to be at odds with what the NRC memo cited above said about the plant's current level of routine releases not being consistent with ALARA.

B. Uranium Contamination of Soil and Water from Process Buildings

Background

Uranium contamination at the Sequoyah facility became a big public issue in the summer of 1990, when workers were discovered to have been working in water contaminated with high levels of uranium. The workers were involved in excavating a pit around buried hexane tanks in the vicinity of the Solvent Extraction (SX) building, and were standing in water which turned out to be contaminated with uranium at levels in the range of 1 to 8 grams per liter.[134] (By comparison, NRC's limits for uranium in restricted areas is about 1.5 grams uranium per liter,[135] and the action level for uranium in water set

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131 NRC Memo from Gary Konwinski, Project Manager, for Bill Beach, Director, "Sequoyah Fuels Environmental Findings" (May 29, 1991).

132 Reau Graves FAX to Bill Beach, NRC (3/13/91).

133 NRC Memo from Merri Horn, "5/23/91 Meeting with SFC and Roberts, Schornick & Associates" (6/13/91).

134 NRC 1990b, p. 2; NRC 1990c, pp. 4-5.

135 Limits in NRC regulations at 10 CFR 20, Appendix B, Table 1, Column 2.

by SFC's license is 225 ug/l -- 35,000 times lower than the 8 gram per liter maximum concentration found in the excavation pit.)

NRC inspections carried out in the wake of this worker contamination incident revealed that SFC had known about the contamination at least two weeks before, but had not reported them -- although an NRC inspector had also been at the site at the time and observed that the water the workers were standing in looked like it might be contaminated, but also apparently did not follow up or press Sequoyah officials further on the matter at that time.[136]

About a month or so after the worker contamination incident at the SX building, SFC reported high levels of uranium (up to 6 grams per liter) in water under a different building, the main process building.[137] This contamination had been brought to SFC management's attention about two weeks earlier, but SFC had delayed notifying the NRC. (NRC regulations require that such information be reported within 24 hours of its discovery.[138]) As it turned out when NRC investigated, the standpipe in the floor of the main process building (in which the contaminated water was found) had actually been in existence since 1976, and SFC personnel were using it to routinely collect contaminated material from water in the ground beneath the building in order to pump it back into the process streams.[139]

NRC concluded that the high level of environmental contamination near the SX building appeared to be the result of the routine dumping of process solutions directly onto the floor, which then drained to a sump.[140] As a result, the floor suffered extensive degradation, which eventually led to "direct hydraulic communication with the underlying aggregate."[141] The floor was completely replaced in 1983-84, and the entire floor re-surfaced in 1988. Process piping was installed in 1986 to eliminate routine discharge of process solution to the floor. NRC concluded that as a result of these steps "[c]ontributions to contamination by current SX processing have been effectively eliminated."[142]

The NRC noted, however, that uranium salts under the SX building "will continue to go into solution and be transported as they come in contact with" precipitation. "The licensee should therefore implement a remediation program that has the ability to remove

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136 NRC 1990b, p. 4.

137 NRC 1990c, pp. 11-12.

138 NRC Regulations at 10 CFR 20.403(b)(4).

139 NRC 1990c, pp. 11-12.

140 Reviewed in NRC 1990b.

141 NRC 1990b, p. 18.

142 NRC 1990b, pp. 6-7.

small volumes of contaminated waters from the aggregate for a period of years."[143] (Sequoyah Fuels issued an Action Plan in January 1992 in response to the uranium contamination issues. This is discussed further below.)

Following preliminary investigations, NRC issued a Demand for Information on November 5, 1990 which found numerous deficiencies in SFC management. These deficiencies included:[144]

- o failure to have an effective site-wide monitoring program;
- o failure to keep contract workers properly informed of workplace hazards (as in the case of the SX Building hexane tank excavation);
- o failure to identify and control the migration of licensed uranium material;
- o failure to report the event to the NRC within 24 hours of its discovery, as required by regulation.

In order to understand the causes of these problems, NRC demanded that SFC investigate both its managerial shortcomings (via an independent outside appraisal), and the extent of environmental contamination, including the potential for offsite migration. The NRC told SFC that this information was "necessary to determine whether to modify, suspend, or revoke your NRC license, and/or whether to renew your license."[145]

Contamination Levels

In response to the NRC's demand, Sequoyah Fuels hired a contractor (Roberts, Schornick & Associates), which has issued a series of reports on the subject of onsite environmental contamination at Sequoyah Fuels. This investigation showed significant environmental contamination in both restricted and non-restricted areas.

Restricted Area Contamination

For example, data from open utility trenches onsite show levels of uranium in ground, pore, and surface waters frequently in the hundreds of thousands of ug/l.[146] (One trench contains water with uranium contamination as high as 1.2 million ug/l.[147]) These levels are far in excess of the 225 ug/l action level in SFC's license, and are comparable to NRC's 10 CFR 20 limits for uranium in water in restricted areas (1.5 million ug/l). Water directly beneath the process buildings was the most contaminated, and ranged up to 9.8

143 NRC 1990b, pp. 19-20.

144 NRC 1990c, p. 21.

145 Letter from Hugh Thompson, Jr., NRC Deputy Executive Director for Nuclear Materials, Safety, Safeguards, and Operations Support, to Reau Graves, Jr., SFC President (November 5, 1990), enclosing NRC 1990c.

146 RSA 1991, Tables 19 and 20.

147 Trench 14, as reported in RSA 1991, Table 19.

million ug/l (in the SX subfloor monitor) and 62 million ug/l (denitration subfloor monitor) -- far in excess the NRC's restricted area limit of 1.5 million ug/l.

Uranium contamination in soil samples often ranged into the thousands of ug/g, substantially in excess of SFC's environmental action level of 40 ug/g set by SFC's license.[148] As reviewed in one of NRC's inspection reports, soil beneath the hexane tank by the SX building contained as much as 388,000 ug of uranium per gram of soil -- a level close to 40% that of pure uranium.[149]

Unrestricted Area Contamination

Uranium contamination in unrestricted areas also appears to be significant, in some cases exceeding not only the 225 ug/l action level contained in SFC's license, but also approaching or exceeding the NRC's 45,000 ug/l limits for natural uranium in unrestricted area. For example, unrestricted groundwater monitoring well MW-10 showed water samples containing up to 36,500 ug/l of uranium.[150] Uranium levels in groundwater monitoring well MW-33T ranged up to 90,708 ug/l[151] -- over twice the NRC unrestricted area limit for natural uranium of 45,000 ug/l.[152] Groundwater samples taken from borehole BH-3, at the southwest corner of the Main Process Building inside the restricted area boundary, but right near the unrestricted area, showed uranium levels as high as 66,650 ug/l.[153]

Total Amount of Onsite Uranium

The total contaminant amounts, as discovered by the these investigations are listed below for the two principal process buildings (the SX building and Main Process Building):

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148 For example, a soil sample from borehole BH-6 (in the unrestricted area) contained 2,289 ug uranium per gram of soil (RSA 1991, Table 29).

149 NRC 1990b, p. 10.

150 RSA 1991, Table 61.

151 RSA 1991, Table 32.

152 This is the peak concentration found upon initial drilling of the well, and may have included insoluble uranium particulates in sediment created during the drilling. Average levels in the groundwater subsequently subsided to lower levels, with an average over time of 9,167 ug/l (RSA 1991, Table 32) -- still a substantial level many thousands of times above background, but not in excess of NRC standards currently in force. (Although it should be noted that even this average level is far in excess of new uranium standards -- of 450 ug/l -- which have been promulgated and are scheduled to become effective in January 1994 -- see discussion in the section in Chapter 5 on "Compliance with the NRC's New Standards for Protection Against Radiation," below.)

153 RSA 1991, Table 74.

Uranium contamination around SX building:[154]

405 kg (water)
5253 kg (soil)

5658 kg total, SX Building

Main Process Building:[155]

3260 kg (under Main Process Building)
728 kg (in soil backfills associated with utility lines)

3988 kg total, Main Process Building

This amounts to 9,646 kilograms (about 21,000 pounds) of uranium (or almost 10 metric tons) contaminating the areas around the process buildings.

SFC Action Plan

On January 10, 1992, Sequoyah Fuels issued an "Action Plan," the purpose of which was to "describe the actions implemented, define the actions to be implemented at the Sequoyah Facility, and provide an implementation schedule."[156] The purpose of such actions, according to Sequoyah Fuels, includes:[157]

- limitation of migration of uranium beyond the restricted area boundary from ground and porewater, and from contaminated soil,
- recovery of uranium from ground and porewater to reduce the uranium content and the possibility of migration,
- limitation of additional contribution to contamination from ongoing operational activities, and,
- ongoing monitoring of the effectiveness of the actions implemented.

The action plan reviews the technical findings of the Roberts/Schornick environmental investigation, and outlines six separate action plans to deal with the issues (these include such plans as a "Geochemical Study Action Plan," a "Groundwater Action Plan," a "Soils Action Plan," etc.). According to Sequoyah Fuels, these action plans should all be implemented by the end of 1993.

154 RSA 1990a, SX Report, p. 21.

155 RSA 1990b, MPB Report, p. iv.

156 SFC 1992a, p. 1.

157 SFC 1992a, p. 2.

The description of planned activities provided is somewhat cursory, so it is difficult to evaluate the likely effectiveness of the plan on remediation of the site. The Action Plan reports a total of about 370 kilograms (a little over 800 pounds) of uranium recovered so far from contaminated groundwater via recovery wells, mostly from beneath the SX building.[158] About 1,400 kilograms (3,100 pounds) of uranium from contaminated soil is also reported to have been recovered via excavation.[159] More of the soil is planned to be excavated under the Soil Action Plan, but what to do with the existing groundwater contamination is more problematic. As the Action Plan notes, "the site characterization information... strongly suggests that in-situ uranium recovery will not be feasible due to the site's geological characteristics."[160]

In the Action Plan, the specific objectives of the Ground Water Action plan include the "Recover uranium from the groundwater system to reduce uranium content in the groundwater."[161] A plan for this is outlined in which uranium recovery wells will be installed which will remove uranium-impacted groundwater from the groundwater system.

The action plan is inconsistent regarding the potential for uranium migration in the groundwater. At one point it states: "there is a mobility potential for uranium as a result of speciation and solubility."[162] A few pages further on, the plan states that "No environmental receptors, including domestic water users, ... are threatened with impact from uranium migration via the groundwater pathway."[163] If the uranium is in the groundwater and is mobile, there must exist some threat of impact from uranium migration. Even if recovery from groundwater is possible, there would be *some* threat of impact since it is highly unlikely that recovery can be complete.

Finally, as stated by the Action Plan, its scope is limited to uranium released or releasable from the site itself. Thus, its scope does not include an evaluation of contamination that is already offsite, nor does it address contamination due to other constituents.

In particular, there has been no careful look at the extent and character of offsite contamination that may have resulted from the releases through the NPDES-permitted combination stream. As mentioned above, SFC has still not undertaken such a detailed assessment of offsite levels of contamination of the scope of the onsite Roberts/Schornick investigation. The Action Plan includes no specific plan to deal with this issue, although it does mention that "a comprehensive soil sampling event along the surface water drainage

158 SFC 1992a, p. 13.

159 SFC 1992a, p. 33.

160 SFC 1992a, p. 6.

161 SFC 1992a, p. 7.

162 SFC 1992a, p. 3.

163 SFC 1992a, p. 8.

paths...was performed in September 1991. Evaluation of this data is not complete. When completed this information will be used to determine further mitigative action if required."[164]

Contamination due to constituents other than uranium may also be significant, and this has so far not been addressed. As discussed in detail, nitrate contamination in particular is widespread and very high (and includes a fully developed nitrate plume from the treated raffinate storage ponds to the south of the main plant area that is not even identified in the FEI or discussed in the action plan). Also, as mentioned in the Section above regarding RCRA issues, there is high levels of arsenic contamination in the groundwater in some places. At levels as high as 5.6 mg/l, arsenic contamination is over 70 times background levels,[165] and is in violation of groundwater limits established by RCRA regulations for hazardous waste management facilities.[166]

In sum, while the Action Plan describes some measures which, if properly implemented, will alleviate some of the uranium contamination, it is too incomplete -- especially on the crucial issue of off-site uranium migration -- to evaluate its overall effectiveness in addressing contamination issues.

C. Uranium Emissions to Air

The principal monitored source of uranium emissions to air is the release of gases discha ged to the atmosphere through the main plant stack (which is about 150 feet above-grade).[167] Other monitored release points include HF off-gas scrubber exhaust, main plant dust collector exhaust, powered roof fans, and other points (there are 12 air effluent monitoring points at the Sequoyah facility).[168] Airborne effluents from the plant are regulated by a total quarterly action level of 30,000 uCi -- about 45 kilograms (100 pounds) per quarter, or 180 kilograms (about 400 pounds) per year -- and by NRC's maximum permissible concentration (MPC) for uranium in air in unrestricted areas (Appendix B of 10 CFR 20), which is 0.005 pCi per liter.[169]

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164 SFC 1992a, p. 32.

165 RSA 1991, p. 234.

166 RCRA regulations at 40 CFR 264.94 establishes 0.05 mg/l as the maximum concentration for arsenic in groundwater for waste management facilities.

167 NRC Inspection Report 91-07 (6/21/91).

168 SFC 1990a, Environmental Report, Table 4-1.

169 SFC reports scrubber effluent uranium releases in terms of effluent concentration, and typically reports releases in the range of 200 to 250 MPC. These MPC values, however, refer to releases at the site boundary, not the stack, and SFC measures the effluent between the HF scrubber and the main stack. SFC assumes a factor of 1,000 dilution due to further mixing in the stack and the air between the stack and the site boundary. (NRC Inspection Report 91-12, p, 3.)

During the first half of the 1980's (1980-1984), Sequoyah reported a total of 594 kilograms (1,307 pounds) of uranium emissions to air, for an average of about 120 kilograms (about 260 pounds) per year.[170] The total emitted apparently declined in the second half of the decade, according to SFC records, with a total emission in the years 1985 through 1989 reported at 394 kilograms (867 pounds) of uranium, or an average of 80 kg (176 pounds) per year.[171] The releases recorded for the first half of 1986 were 18 kg (40 pounds), so this system does not appear to account for the January 1986 accidental explosive release of 31,000 pounds of UF_6 (which was presumably outside, and therefore not released through the plant stack).[172] This also raises the question of possible releases of uranium from other unmonitored sources, including non-point sources.

There are apparently uncertainties about the reliability of measurements of uranium releases through the stack, however. At least since 1986, NRC has questioned the accuracy of the measurements of releases from the HF scrubber.[173] In a recent inspection report, NRC again referred to "questions about the accuracy of the off-gas scrubber monitor."[174] This raises questions about the accuracy of the above reported releases.

In addition to measuring effluents from release points, Sequoyah Fuels also has 11 environmental air monitoring stations which measure ambient air concentrations around the plant. This includes 4 fence-line stations (located at roughly the four cardinal compass directions, north, south, east, and west), in addition to seven offsite, including one at the nearest residence. These can be used as a second check on the environmental impact of air releases. However, NRC has also raised questions about the adequacy of this system as well because Sequoyah Fuels has apparently not taken adequate account of meteorological conditions in evaluating the significance of air monitoring data, at least in relation to specific release times. In discussing excessive releases from the main stack in the summer of 1991, NRC concluded that "as a result [of the lack of evaluation of downwind air movements], site boundary monitor results have been misleading. This was important given that SFC had indications that the air monitor at the HF scrubber may not have been providing accurate data."[175] Without consideration of wind direction and dynamics, it is not possible to adequately evaluate the significance of measurements taken at fixed locations around the plant.

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170 As reported in NRC 1985, p. 2-15.

171 SFC 1990a, Environmental Report, p. 4-2.

172 The low number is probably due to the fact that for most of the first half of the year, the plant was shut down as a result of the accident.

173 NRC Inspection Report 86-14 (January 22, 1987).

174 NRC Inspection Report 91-12 (December 18, 1991). This issue was also discussed in NRC Inspection Reports 92-08 (June 11, 1992) and 92-12 (June 22, 1992).

175 *Ibid.*, p. 5.

The sampler at the nearest residence is apparently used to determine compliance with EPA's 25 millirem radiation dose limits.[176] The highest organ dose reported in SFC's license renewal application due to uranium concentrations at this sampler is 8.2 millirems to the lung in the second quarter of 1987, but all cumulative annual doses reported are below the 25 millirem limit.[177] It should be noted, however, that relying only on dose calculations at the nearest residence is an unacceptable method of determining compliance with EPA's 25 millirem dose standard for the general public. In the absence of meteorological data, there is no *a priori* reason to think that the highest offsite doses will be experienced at the nearest residence, simply because it is nearest. (And apparently, based on the NRC concerns cited above, there *is* an absence of consideration of meteorological data in SFC's monitoring program.) It is possible that much higher doses could be experienced at locations much further than the nearest residence, depending on prevailing winds and atmospheric conditions.

D. Evaluation of Statements Regarding Uranium Contamination in SFC's License Renewal Application

In August of 1990, SFC submitted its license renewal application which listed uranium levels in groundwater in terms of concentration. The license renewal application touts SFC's "extensive groundwater monitoring program," which features monitoring wells located "in areas most susceptible to potential groundwater contamination."[178]

The highest of the measured levels reported in the license application is in well 2301, with levels in thousands of ug/l (the highest is 8909 ug/l).[179] Most levels in other wells in license application do not come close to even these levels.

This is nowhere close to the maximum 8,000,000 ug/l (8 g/l) discovered during the worker contamination incident at the hexane tank excavation (cited above) which occurred just before the license renewal application was submitted. Nor is it close to the levels of tens of thousands of ug/l of uranium reported in ground, pore and surface waters near the process buildings by the Roberts/Schornick environmental reports issued after NRC demanded an environmental investigation.

This seems to indicate that either the data in the 1990 license renewal application was incomplete, or that SFC's monitoring program was so poorly designed prior to the

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176 SFC 1990a, Environmental Report, p. 4-15 cites the results of the dose calculations and notes that they are "well within the annual limit of 25 millirem (40 CFR 190)..."

177 The dose calculation results are reported in Appendix B.1, Environmental Air Data, in SFC 1990a, Environmental Report. The numbers are consistently reported to 5-digit accuracy (e.g. 1.0479 millirem lung dose is reported for the third quarter of 1985), which is not particularly meaningful, since it is unlikely that the calculations are accurate to more than one or two digits.

178 SFC 1990a, Environmental Report, p. 4-22.

179 SFC 1990a, Environmental Report, Appendix B, p. B-27.

hexane tank excavation and the Roberts/Schornick investigation that significant amounts of contamination totally escaped SFC's notice.

The reason for this conflicting set of data is apparent when one examines a map of the location of the monitoring wells of SFC's "extensive groundwater monitoring program." (See Figure 4.[180])

As can be seen in the figure, all of the monitoring wells reported in the license application tend to be near the settling ponds. There were *no* monitoring wells at all located anywhere near the process buildings (for example, there are no wells within 650 feet of the main process building[181]). This was the case despite the fact that SFC, for up to 14 years prior to the submittal of its 1990 license renewal, had been collecting uranium concentration data from water found beneath and near the process buildings.

This data is reported in the 1991 Roberts/Schornick investigation report, and includes water taken from the subfloor process monitor discussed above, and from SX "sand wells" which were located near the SX building. The SX sand wells were used to monitor levels of uranium concentration in water from 1976 through 1989, and showed levels routinely extending to hundreds of thousands of ug/l (the highest level reported was 1.2 million ug/l).[182] As NRC pointed out after this information was finally revealed to it, the sand well data clearly indicate that "uranium concentration had migrated away from the SX building."[183] Yet SFC did nothing to modify its purportedly "extensive groundwater monitoring system" to further investigate the extent of the spreading contamination indicated by the sandwells. Instead, SFC discontinued the sand well monitoring in 1989, and did not even mention the existence of these wells to the NRC or the public, or indicate in the Licence Renewal Application that there was any reason to believe that the process buildings might in any way be contributing to contamination.

In fact, the data from the SX sand wells and the subfloor process monitors were apparently only brought to light as a result of NRC inspections in the wake of the worker contamination incident. Had this investigation not occurred, the NRC might have renewed the plant's license for the requested term of 10 years on the mistaken assumption that SFC's operations were relatively clean and posed little serious risk to the environment.

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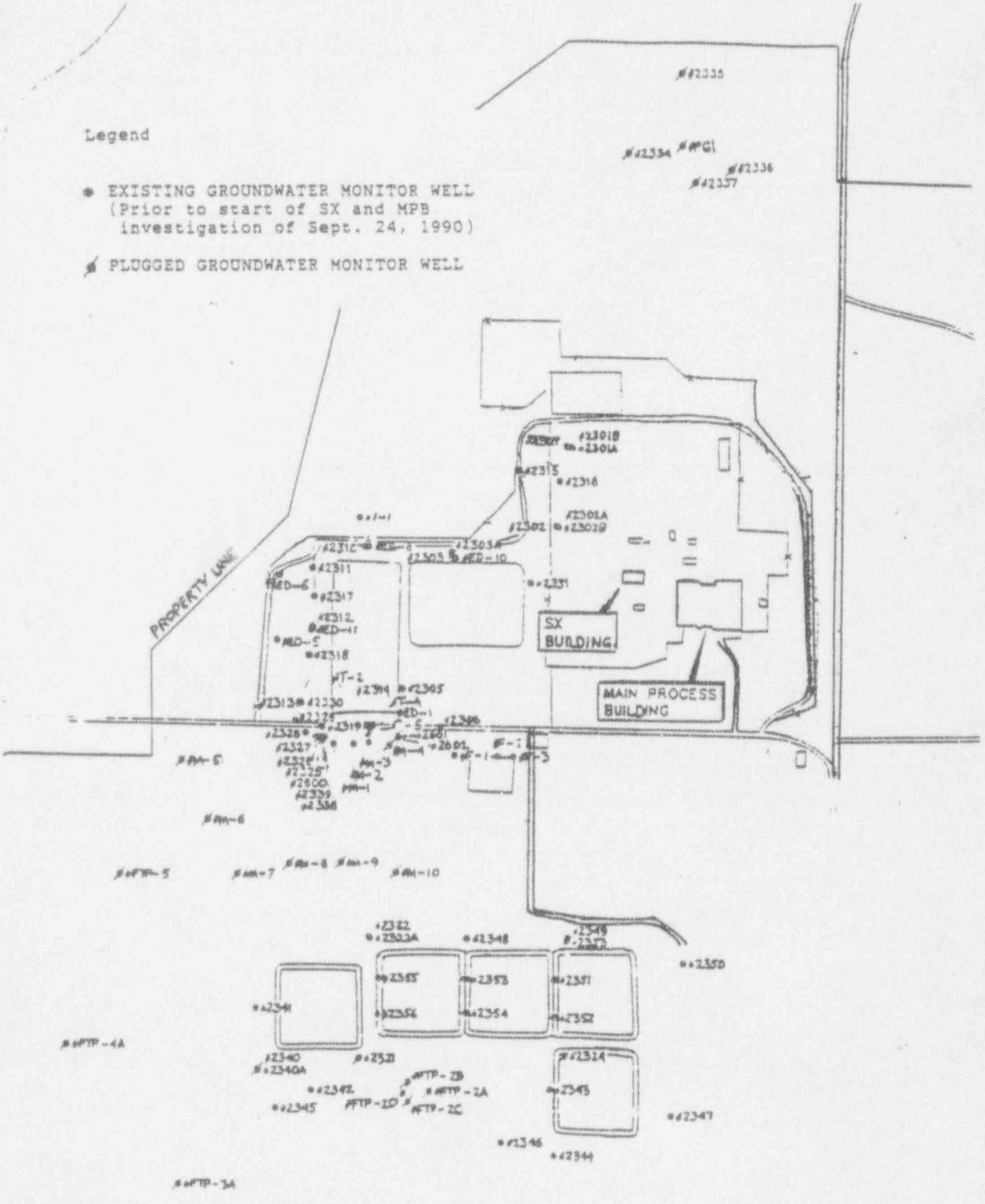
180 Taken from RSA 1991, Volume 4, Drawing Number 22.

181 RSA 1991, p. 262.

182 RSA 1991, Table 78.

183 NRC 1991, p. 17.

Figure 4. Sequoyah Fuels Monitoring Well Locations (before 1990)



Thus, it appears in retrospect that SFC's license renewal application of August 1990 contains materially false statements on at least three grounds:

1. The License Renewal application states that data are reported from "areas most susceptible to potential groundwater contamination," when, in fact, existing data from susceptible areas under and around process buildings were not included.

2. The license application proclaims SFC's "extensive groundwater monitoring program," thus giving every indication that all data relevant to possible groundwater contamination are presented; in fact, crucially relevant data were withheld.

3. The license renewal application indicates that the highest uranium contamination in groundwater was under 10,000 ug/l; in fact, the highest levels of contamination (as shown by the withheld data) were tens to thousands of times higher.

Partly based on these grounds, the Native Americans for a Clean Environment and the Cherokee Nation Tribal Government submitted a petition to the NRC requesting that SFC's license be revoked.[184] As that petition concluded with respect to SFC's handling of environmentally critical data,

> At worst, SFC's misrepresentations are fraudulent, and at best they show gross ignorance and incompetence. In either case, they constitute material false statements and therefore warrant the immediate revocation of SFC's license. In the alternative, SFC should be deemed to have failed to timely file a license renewal application in "proper form," and it should be rejected, thereby nullifying the automatic extension of SFC's license.[185]

In response to this petition, Sequoyah Fuels disputed that the withheld data technically qualified as "groundwater" from a hydrogeological standpoint. SFC argued that the pipes installed in the ground in which high levels of uranium had been monitored extending back into the 1970s were not deep enough "to penetrate the shallowest on-site water-bearing strata."[186] However, Sequoyah Fuels appeared to acknowledge the essential validity of the criticism when it stated that "SFC acknowledges that appropriate consideration of the ... data could have led to the review of the groundwater monitoring

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184 Curran 1991. The Commission referred this petition to the NRC staff according to the provisions of 10 CFR 2.206.

185 Curran 1991, p. 25.

186 SFC, Response to NACE and Cherokee Nation's Emergency Petition, p. 8.

program and the addition of monitoring wells that could directly identify migration of licensed material from the process buildings."[187]

Shortly after NACE and the Cherokee Nation submitted their petition, Sequoyah Fuels submitted to the NRC a revised Environmental Report to replace the one originally submitted as part of Sequoyah Fuels' license renewal application in August of 1990.[188] The new Environmental Report includes a section entitled "Groundwater Monitoring from Wells Installed after September 1990" which discusses the findings of the Roberts/Schornick investigation. This discusses the potential effects on groundwater of operations in the process buildings, and states that "the groundwater monitoring wells which existed prior to September 1990 could not directly monitor such effects." The new Environmental Report also contains an additional section on Other Sampling Information." The section reports on "subsurface water sampling data which do not represent the quality of groundwater at the SFC site." These data, which refer to the SX sand wells and Main Process Building Subfloor Process Monitor, are now included, the report says, "for the purposes of completeness."[189]

On June 8, 1992, the NRC staff issued its decision on the NACE-Cherokee Nation petition. Although the NRC staff concluded that SFC's "license renewal applications are materially incomplete" and in violation of NRC regulations, staff refused to revoke SFC's operating license, saying that "license revocation would be an excessively harsh and unwarranted remedy in this case." Instead, NRC plans to issue a Notice of Violation citing SFC for violating regulations.[190]

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187 *Ibid.*, p. 13.

188 SFC 1992.

189 SFC 1992, pp. 4-32 to 4-34.

190 U.S. NRC, Office of Nuclear Material Safety and Safeguards, Robert M. Bernero, Director, "Director's Decision Under 10 CFR 2.206," June 8, 1992.

Chapter Five. Other Issues

A. Decommissioning

Decommissioning is the process of decontamination and dismantling a plant at the end of its useful life. This is an important question to consider from an environmental perspective because it is at this point that final clean-up of any contamination (including contaminated remnants of the process equipment and buildings) must take place. Lack of planning or faulty assumptions in the planning for decommissioning can result in much greater costs than anticipated.

Decommissioning Assumptions

SFC expects decommissioning to take place later than the year 2000, since "long term contracts are currently in place to produce and deliver uranium hexafluoride beyond the year 2000.... Accordingly, the earliest contemplated decommissioning date would be beyond the ten year term involved in this licensing renewal application."[191]

One SFC document discusses regulatory uncertainties surrounding decommissioning, which make "committing to a plan and a cost estimate at this time a very tentative matter."[192] Uncertainties cited include:

- acceptable levels of residual contamination after cleanup is completed.
- "final disposition of potentially large volumes of materials, soils, sludges, etc., contaminated with very low levels of natural uranium and daughter product activity."

In other words, it appears that SFC does not know how much waste it will have to remove, and even if it did, it would not know where it should be disposed.

SFC notes that wastes from SFC can't be classified as uranium mill tailings (they do not fall under definition of by-product material because, although similar in character, they are not the result of processing "ore"), and therefore concludes that "wastes from a UF6 conversion plant are orphan wastes at any level above background."[193]

SFC determines that material at their plant must be classified as source material. Since NRC regulations (10 CFR 40.13) say that source material in concentrations of less

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191 SFC 1990a, p. 6-1.

192 Letter, SFC (Lee Lacey) to NRC (Charles Haughney) (Aug. 29, 1990), RE: License SUB-1010 Renewal Application. Includes "Decommissioning Program Discussion" attached (p. 1).

193 *Ibid.*, p. 3.

than 0.05% is exempt from licensing, SFC concludes that therefore, waste material containing less than 0.05% uranium (335 pCi/gram) must be exempt from regulation; based on SFC's interpretation of EPA standards for Naturally occurring and Accelerator Produced Materials (NARM), wastes less than 2,000 pCi/g "can be disposed of onsite with appropriate cover" (as long as they are accompanied by an application to NRC in accordance with their regulations at 10 CFR 20.302). Decommissioning plans assume these levels. (Below Regulatory Concern level based on "10 mrem/yr *or higher if demonstrated to be ALARA.*"[194] (emphasis added)

There is a need to examine reasonability of these assumptions. The last statement citing ALARA as an excuse to possibly allow higher exposures is an inversion of the protective intent of ALARA and is disturbing. It may be contrary to regulations.

Decommissioning Cost Estimates

Apparently based on this, SFC estimates total decommissioning costs to be $5,374,790, which appears absurdly low. This despite the fact that "long-term surveillance requirements are unknown at this time." (p. 2) SFC also states that "this estimate assumes a fluorine gas sales business and other businesses will continue beyond the active life of licensed activities and will absorb a major portion of the indirect costs and administrative burden."[195]

SFC expects that combined Federal and state tax returns will be 39% of the total decommissioning expenditure. This, says SFC, reduces expected decommissioning costs to about $3.3 million. (p. 3) The "significant quantities of uranium" cleaned out during the decommissioning process is expected to be equivalent to 64,000 pounds of U_3O_8, thus further reducing costs by $768,000 (value on today's market), leaving approximately $2.5 million.

According to the license renewal application, SFC anticipates receiving approval to sell raffinate "fertilizer" commercialize, and thus, any inventory remaining onsite at the time of decommissioning will be sold. SFC expects at least 30 million gallons will be available for this, at a value of $1.16 million. However, if SFC proceeds with its plans to change the way it disposes of raffinate, it will no longer manufacture fertilizer, and this putative income stream will not be available.

The selling of land is expected to produce up to $5 million, which, according to SFC "could be used to fund the $2.5 million required to complete decommissioning activities." Salvage and warehouse stock we projected to net another $3 to 4 million.[196] Taken literally, all of this seems to imply that decommissioning the Sequoyah plant will generate a

194 *Ibid.*, p. 3,

195 SFC 1990a, Decommissioning Funding Plan, p. 1.

196 *Ibid*, pp. 3-5.

profit of about $4.5 to $5.5 million, $2.1 million of which will come from federal and state tax returns.

In this context, SFC's statement that they will also provide additional financial assurance in the form of a $2.5 million standby letter of credit is made to sound generous. However, our preliminary judgment is that in reality this is likely to be entirely inadequate. If so, it may be that taxpayer money could end up being used if Sequoyah's funds turn out in the end to be inadequate.

B. Compliance with the NRC's New Standards for Protection Against Radiation

Another potential issue for the Sequoyah facility to deal with is new radiation protection standards recently promulgated by the NRC. These are a new version of the longstanding regulations incorporated into the *Code of Federal Regulations* at 10 CFR Part 20.[197] Licensees were originally required to implement these new regulations by January 1, 1993, but this effective date has been moved back to January 1994.[198] The new regulations include a reduction in the allowed level of uranium in water in unrestricted areas from 45,000 ug/l to 450 ug/l – a factor of 100 reduction.[199] Given that the Roberts/Schornick investigation has revealed groundwater contamination levels in the unrestricted area whose average levels range into the thousands of ug/l,[200] this may pose some difficulties to Sequoyah Fuels' ability to comply with the stricter new levels that are ten times more stringent than the actual levels currently found in some parts of the unrestricted area.

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197 The revised version of 10 CFR 20 was published in May of 1991 (NRC 1991a).

198 "De Planque, Five Months on the Job, Shedding 'Freshman' Commissioner Label," *Inside NRC*, p. 3 (May 4, 1992).

199 Revised 10 CFR 20, Appendix B, Table 2, Column 2.

200 For example, monitoring well MW-10, in the unrestricted area near the southwest corner of the Main Process Building, exhibited uranium concentration levels that were typically in the range of 10,000 to 30,000 ug/l (RSA 1991, Table 61). Monitoring well MW-33T, also in the unrestricted area, averaged was found to contain average uranium contamination levels of 7,875 ug/l (RSA 1991, Table 32).

Glossary

ALARA: Abbreviation for "As Low As Reasonably Achievable." A policy established by U.S. radiation protection guidlelines as another layer of protection in addition to specific standards. The idea of this policy is that a facility should always strive (as long as the expense does not become too large) to keep doses and emissions as low as practically possible, even if they are already below what the specific standards require.

Atomic weight: The nominal atomic weight of an isotope of an element is given by the sum of the number of neutrons and protons in its nucleus. The atomic weight is used to identify different isotopes of the same element: for example, uranium-238 and uranium-235 are two isotopes of uranium with atomic weights 238, and 235, respectively. See also "isotope."

Curies: A curie (abbreviated as "Ci") is a measure of radioactivity of a substance equalling 37 billion disintegrations per second. this is the traditional measure of radioactivity, and is based on the number of disintegrations per second undergone by 1 gram of pure radium-226.

Gram: Basic metric unit of mass. One gram is equal to 0.0022 pounds, or 0.0352 ounces (in other words, it take about 28 grams to make an ounce, and about 455 grams to make a pound).

Isotope: Elements have one or more variants called isotopes. Different isotopes of the same element have the same number of protons in the nucleus (and hence the same chemical properties), but a different number of neutrons, and therefore different weights. For example, uranium-238 and uranium-235 are two different isotopes of uranium: they each have 93 protons in their nuclei (this is what makes them both uranium), but uranium-238 has 238-93 = 145 neutrons, while uranium-235 has 142 neutrons. In general, some isotopes are radioactive, while others are not. Many isotopes occur naturally, while a very large number have been created artificially due to nuclear reactions. The various radioactive isotopes of an element have different half-lives.

Kilogram: A metric unit of mass measure consisting of 1,000 grams. One kilogram is equal to 2.2 pounds.

Metric ton: A metric unit of mass measure consisting of 1,000 kilograms (one million grams). One metric ton is equal to 2,200 pounds, or 1.1 short tons.

mg/l: Abbreviation standing for *milligrams per liter*. Often used to measure contaminant levels in a given volume of material, mg/l typically refers to the number of milligrams (thousandths of a gram) dispersed in a liter of liquid, such as water. (In water, a mg/l is approximately equal to one part-per-million, or "ppm.") Another unit used to measure lower contaminant levels in a given volume is ug/l (micrograms of contaminant per liter of water), which is a thousand times smaller than mg/l. Similar units used to measure contaminant level per unit mass of matter are: mg/g (milligrams contaminant per gram of material), and ug/g (micrograms of contaminant per gram of material). For a discussion of measuring radioactive contaminants, see pCi/l and pCi/g.

Milli-: Prefix used with such units as grams, curies, and other units to indicate one-thousandth part of the unit. For example, *milligram* (abreviated "mg") or *millicurie* (abbreviated "mCi").

Micro-: Prefix used with grams, curies and other units to indicate one-millionth part of the unit. For example, *microgram* (abbreviated "ug" or "μg") is one millionth of a gram, and *microcurie* (abbreviated "uCi" or "μCi") is one millionth of a curie.

Neutron: An elementary particle that is electrically neutral. Together with protons, it forms the nucleus of an element (except the normal hydrogen nucleus, which consists only of a single proton).

NPDES: Abbreviation for "National Pollutant Discharge Elimination System" -- a system for regulating pollutant discharges in accordance with the Federal Water Pollution Control Act. For example, Sequoyah Fuels Corporation has NPDES permit regulating its discharges to the Illinois river.

pCi/l: Abbreviation for *picocuries per liter*. Used to measure radioactivity levels in a given volume of matter, pCi/l often refers to the amount of radioactivity dispersed in a liter of liquid, such as water. A larger unit for measuring radioactivity level per unit volume is uCi/l (microcuries per liter). One uCi/l equals one million (1,000,000) pCi/l.

pCi/g: Abbreviation for *picocuries per gram*. Used to measure radioactivity levels in a given mass of material, pCi/g often refers to the amount of radioactivity dispersed in a gram of solid matter, such as soil. For measuring non-radioactive contaminants, units such as mg/g (milligrams per gram) are typically used.

Pico-: Prefix used with grams, curies and other units to indicate one-trillionth part of the unit. For example, *picocurie* (abbreviated pCi), means one-trillionth of a curie of radioactivity. The prefix "pico-" indicates that the unit is a million times smaller than the same unit with the prefix "micro-".

Proton: An elementary particle with a positive electrical charge, weighing slightly less than a neutron. Protons and neutrons make up the nuclei of elements. The number of protons in the nucleus of an atom is its atomic number; it is this number which determines what element the nucleus is. For example, a nucleus with atomic number 93 has 93 protons in it, and is therefore by definition a uranium nucleus.

RCRA: An abbreviation for "Resource Conservation and Recovery Act," the primary federal law regulating hazardous waste management and disposal.

ug, uCi: Abbreviations for *microgram* (one-millionth of a gram), and *microcurie* (one-millionth of a curie). The letter "u" here is symbolic of the greek letter *mu*, usually written "μ" -- which is the equivalent of "m" in the greek alphabet. Wherever they are used as prefixes, "u" and "μ" usually mean "micro-."

ug and uCi (or μg and μCi) are often combined with other units to measure trace levels of contaminants in material. For example, ug/l, ug/g, uCi/l could be used to measure micrograms of contaminant per liter of water, micrograms of contaminant per gram of soil, and microcuries of radioactive material per liter of water, respectively.

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August 28, 1986 Attachment 6

James G. Randolph
Steve Emerson
Bill Utnage
Peter Nickles
Barbara Hoffman
Joe Young
Paulette Wackerly
Ken Roseman
Ed Still
Billy Tucker
Carol Couch

Attached is a copy of the certification by the Oklahoma Department of Agriculture of our "Nitrogen Fertilizer Solution" as a commercial fertilizer.

We need to define our strategy as soon as possible for using this certification. I suggest that we approach the OWRB to discuss the withdrawal of the portion of our permit application which relates to the fertilizer. We may also wish to advise the Muskogee DA of this development to see if this would change his position. We may wish to advise Bill Crow of NRC to explore reduction of NRC requirements.

Copy to
TOM.
J Horner
B Bailey
Sent copies 8-28

JCB:jlm

JOE YOUNG
8-28-86

J. CLEMENT BURDICK, III