Feasability Analysis: A Comparison of Phosphogysum and Uranium Mill Tailing Waste Unit Designs

Office of Solid Waste
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1. Introduction

This report presents the findings and results of a comparative evaluation of evolving phosphogypsum management practices in Florida and waste unit designs required by the Uranium Mill Tailing Reclamation Act. The purpose of this analysis is to determine the design specifications of large scale mining waste units.

Phosphogypsum and process wastewater are two special wastes from phosphoric acid production using the wet process. In this process, beneficiated phosphate rock is dissolved in phosphoric acid; sulfuric acid is added to this solution and chemically digests the calcium phosphate. The product of this operation is a slurry that consists of the phosphoric acid solution and a suspended solid, calcium sulfate, commonly known as phosphogypsum. The slurry is routed to a filtration operation where the suspended phosphogypsum is separated from the acid solution. The acid isolated during filtration is concentrated through evaporation to produce phosphoric acid. The phosphogypsum is reslurried with process wastewater, and pumped to one or more impoundments located on top of an on-site waste pile known as a gypsum stack. In the impoundment, the gypsum solids are allowed to settle; the liquid (process wastewater) is either directly removed from the settling pond and sent to a nearby cooling pond or indirectly removed after it seeps through the stack and is collected by ditches or ponds that circumscribe the stack. The stack grows as the dikes that form the impoundments at the top are built up with phosphogypsum. The dimensions of gypsum stacks vary between 20 and 260 hectares and 3 to 130 meters in height. Previous EPA studies (U.S. EPA 1990a, 1990b) present a more detailed description of the phosphoric acid industry and its waste management practices. The gypsum stacks and cooling ponds built before the state of Florida enacted new phosphogypsum management regulations in 1993 were unlined and did not have leachate collection systems. Phosphogypsum and process wastewater constituents, such as radium 226, phosphorus, and heavy metals, have been released to ground water at a number of facilities. The new state requirements represent an attempt to mandate environmental protection measures to limit the release of phosphogypsum constituents to the environment, especially ground water.

As part of this research, EPA obtained and reviewed the most recent state and county regulations that affect phosphogypsum management, collected detailed data on new and proposed phosphogypsum stack units from state and county files in Central Florida, and obtained and reviewed the design, construction, and operating standards that apply to uranium mill tailing impoundments. Based on this information, a detailed comparison was conducted of the characteristics of recently built or proposed phosphogypsum management units with the current Florida regulations, as well as with the uranium mill tailings standards.

This report is organized in five sections, including this introduction. The sections are organized as follows:

C Section 2 presents an overview of the most recent state and county regulations that affect phosphogypsum management. In 1993, the Florida Department of Environmental Protection (FDEP) promulgated new management requirements for phosphogypsum stack systems. These standards include requirements for permitting, design, operation, monitoring, and other activities, such as closure, and financial assurance. This section builds upon early study conducted for EPA by its contractor ICF, which is incorporated as an Appendix for reference. The purpose of the report included in Appendix A was to perform a preliminary review of the new modifications of Florida statutory authorities and regulatory programs, related to phosphogypsum and process wastewater from wet process phosphoric acid production facilities. Accordingly, Section 2 updates the earlier work and focuses on new statutory amendments, regulations, guidance, or permitting procedures enacted or published since our previous research was completed.

C Section 3 reviews the design, construction, and operating standards that apply to uranium mill tailings impoundments that are codified at 40 CFR Part 192. These standards are compared and contrasted with current Florida standards for phosphogypsum management units.

Agencies Visited in Florida

, Florida Department of Environmental Protection (FDEP), Tampa
- Phosphogypsum Management Program
- Industrial Wastewater Division

, Environmental Protection Commission of Hillsborough County (HCEPC), Tampa

, Tampa Bay Regional Planning Council, St. Petersburg

, Central Florida Regional Planning Council, Bartow

C Section 4 summarizes publicly available data on new and/or proposed management units in Florida. This section analyzes four new/proposed units, one each at the IMC-Agrico New Wales Chemical Complex, U.S. Agri-Chemicals Ft. Meade Chemical Complex, Cargill Fertilizer Plant City Chemical Complex, and IMC-Agrico Nichols Chemical Complex. Three of these units have received construction permits from the Florida Department of Environmental Protection, and the permit for the fourth one (Plant City) is currently under review. We obtained information on these units through file searches at state, regional, and county offices in Florida.

C Section 5 presents a comparison of the design, construction, and operating characteristics of the four units described in Section 4, with the relevant aspects of the current Florida regulations, as well as with the uranium mill tailings management standards. Differences among the phosphogypsum management units, the state regulations, and the uranium mill tailings standards are highlighted.

2. Florida State and Local Management Requirements for Phosphogypsum Stack Systems

This section focuses on recent Florida regulations that affect phosphogypsum management. In 1993, the Florida Department of Environmental Protection (FDEP) promulgated new management requirements for phosphogypsum stack systems. These standards (Section 17-673.100-900, Florida Administrative Code) include requirements for permitting, design, operation, monitoring, and other activities, such as closure, and financial assurance.

For the construction and operation of a new gypsum stack system, a permit issued by FDEP is required. In addition, the Florida Department of Community Affairs, regional planning agencies (e.g., the Tampa Bay Regional Planning Council and the Central Florida Regional Planning Council) and local government have the authority to require a development of regional impact (DRI) review for new phosphogypsum stack systems to analyze potential environmental and socioeconomic impacts and to propose mitigation measures. The reports submitted by companies proposing new gypsum stack systems, as part of both the permitting and DRI processes, provided the data for the analysis presented in Section 4.

The State and local management requirements for phosphogypsum stack systems were previously reviewed in a document prepared by EPA's contractor, ICF in January 30, 1995. This document has been included, as reference material, in Appendix A. To avoid duplication, this section reflects only the information needed for the comparative analysis provided in later sections. For additional details, the reader is referred to Appendix A.

2.1 The Zone of Discharge

One key concept in the state regulations for phosphogypsum management in Florida is the **Zone of Discharge (ZOD)**. The ZOD is the volume underlying or surrounding the site (phosphogypsum stack or cooling pond) and extending to the base of a specifically designated aquifer or aquifers, within which an opportunity for the treatment, mixture, or dispersion of wastes into receiving ground water is afforded (F.A.C. 17-3.021). For existing stack systems, the zone of discharge usually has been defined to extend horizontally to the property boundary.

According to the 1993 Florida regulations, the dimensions of the ground water vertical and horizontal ZOD are established in the permit for any new stack system. The concept of ZOD is used to define performance standards and location requirements for new stack systems, and variances for closure of existing unlined stack systems. For example, the FDEP permit for the new gypsum stack at Ft. Meade Chemical Complex defines the ZOD as extending horizontally 100 feet from the inside crest of the earthen perimeter dam, and vertically to the base of the shallow water table aquifer. In the case of a modified gypsum stack at the IMC-Agrico Nichols Plant, the ZOD defined in the permit did not change from the previously authorized ZOD for the old stack; it extends horizontally to the property boundary.

The Concept of ZOD in F.A.C. 17-673

Performance Standards. A phosphogypsum stack system shall be designed, constructed, operated, maintained, closed, and monitored throughout its design period to control the movement of waste and waste constituents into the environment so that ground water and surface water quality standards and criteria of Chapters 62-520 and 62-302, F.A.C., will not be violated beyond the applicable zone of discharge specified for the system.

Type of Leachate Control System. The leachate control system shall be designed to prevent leachate from causing violations of water quality standards beyond the approved zone of discharge for the phosphogypsum stack system in accordance with Chapters 62-520 and 62-522, F.A.C.

Location Requirements. Set back distances shall be maintained between the phosphogypsum stack system and the property boundary of sufficient width to allow for location of ground water monitoring wells in a manner that will enable detection of ground water quality changes before contaminant transport to the boundary of the permittee's zone of discharge.

2.2 Factors Influencing the Construction of New Gypsum Stacks

The ultimate height and area of a gypsum stack depend on the configuration of the facility's property and the ability of the native soils to support the load of the stack. These two factors determine the useful life of a gypsum stack. As phosphoric acid facilities continue in operation, eventually their gypsum stacks will reach capacity, and new gypsum stacks will need to be constructed, following the 1993 Florida regulations.

Also, F.A.C. 17-673.650 establishes that no phosphogypsum or process wastewater shall be placed in an unlined phosphogypsum stack system **after March 25, 2001.** Final closure of each unlined system shall be completed no later than five years after it ceases accepting phosphogypsum (i.e., 2006 for operators that dispose gypsum in the stack systems until 2001). Because the DRI and permitting processes may take more than two or three years, and preparation of the gypsum stack components (liners, leachate control system, and water management systems, among others) may take over two years, depending on the stack base area, companies will soon have to make decisions on future actions regarding closure of unlined stacks and construction of new lined ones.

An owner may, however, apply for a variance to the above closure requirement if the owner can demonstrate that the stack system was not causing any violation of FDEP water quality standards on March 25, 1993, and is not reasonably expected to cause any such violation after March 25, 1993. Furthermore, an owner, whose stack system causes a water quality violation after March 25, 1993, may still seek a variance if corrective action can contain seepage from the stack system and further corrective action can bring the ground water at the edge of the ZOD into compliance by March 25, 2001. If ground water quality violations continue past March 25, 1998, a permit application for a new lined stack system will be required to be submitted to FDEP by March 25, 1999. FDEP is currently requesting information from phosphogypsum management facilities on which stacks will be deactivated, and which ones will request an exemption, and if so, under which variance scenario. At the time of preparation of this report, FDEP has not received any variance applications. FDEP has extended the deadline for receiving variance applications until February 28, 1997[1].

Finally, it is important to note that Florida has two major phosphate deposits, the Bone Valley Formation and the Hawthorn Formation. The high-grade, easy-to-process Bone Valley deposit is being depleted rapidly, and the mining industry is moving south/southwest to the Southern Extension of the Bone Valley Formation and the Hawthorn Formation (El-Shall and Bogan, 1994). This migration of the mining industry may introduce a new factor in the planning and construction of new gypsum stacks, as phosphoric acid companies may consider moving the plants to a location closer to the new phosphate rock mines.

2.3 Design Requirements for New Gypsum Stacks

This section describes the key design requirements applicable to new phosphogypsum stack systems, according to F.A.C. 17-673. As explained before, the basic performance standard for a gypsum stack is to not violate ground water and surface water quality standards and criteria beyond the ZOD specified for the system. The requirements of F.A.C. 17-673 are assumed to provide reasonable assurance that this performance standard will be met. If site-specific or situation-specific information indicates otherwise, stricter standards may be imposed. This section presents requirements on the following components of the system: liner, leachate control system, and liquid containment and conveyance systems.

Liners

The regulations allow for two types of liner designs. The synthetic component of the liner is a 60-mil or thicker geomembrane liner with a maximum water vapor transmission rate of 0.24 grams per square meter per day. This liner can either be placed: (1) above a layer of compacted soil at least 18 inches thick, with a maximum hydraulic conductivity of $1x10^{-7}$ cm/sec, or (2) below a layer of mechanically compacted phosphogypsum at least 24 inches thick, with a maximum hydraulic conductivity of $1x10^{-4}$ cm/sec. These two liner design options are shown schematically in Exhibit 2-1.

New gypsum stacks shall be constructed with composite liners and leachate control systems. New cooling ponds shall be constructed with composite liners (F.A.C. 62-673.400). Lined cooling ponds can be constructed on top of an inactive gypsum stack, as long as the pond is designed as part of the closure plan of the gypsum stack. Cooling ponds, as part of the phosphogypsum stack system regulated by F.A.C. 62-673, have similar closure deadlines, i.e., no process wastewater can be placed in an unlined

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[1]Telephone conversation with Robert Vanderslice, Gypsum Management Program, FDEP, 01/13/97.

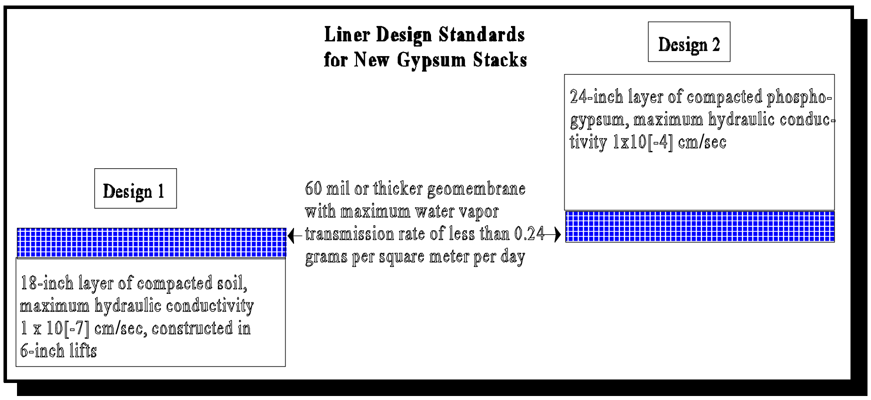
system after March 25, 2001. The variances for gypsum stacks explained in Section 2.2 above also apply to cooling ponds.

<u>Leachate control system</u>

The leachate control system standards include three conditions:

C A perimeter underdrain system designed to stabilize the side slopes of the phosphogypsum stack shall be installed above the geomembrane liner;

C Perimeter drainage conveyance used in the leachate control system shall either consist of covered or uncovered ditches which are lined



continuously with the gypsum stack liner, or of chemically compatible leachate collection pipes; and

C All toe drain or leachate collection systems must be constructed within the lined system.

Exhibit 2-1

<u>Liquid containment and conveyance systems</u>

All liquid containment and conveyance systems associated with phosphogypsum transport, cooling water, and return of process wastewater, shall have composite liners, with the exception of pumped flow systems contained in pipes. In this case, the pipes which cross surface waters must be double contained with chemically compatible materials in a manner that assures that all materials under pumped flow are contained within a lined system in the event of a leak or piping system failure.

2.4 Operating Requirements for New Gypsum Stacks

This section describes the key operating requirements applicable to new phosphogypsum stack systems, according to F.A.C. 17-673.   There are four basic conditions in this regulation:

C The owner or operator shall have a plan for the daily operations of the gypsum stack;

- C A site-specific ground water monitoring system shall be in place, that includes at least one of each of the following types of wells: a well located to determine the background water quality, a downgradient well at the edge of the ZOD, and an intermediate downgradient well within the ZOD (designed to detect the chemical and physical characteristics of the discharge plume). The purpose of this monitoring system is to ensure that the water quality standards for Class G-II ground water are not exceeded at the boundary of the ZOD, in accordance with section 17-520.400 and 17-520.420, F.A.C.;
- C The stack system shall be operated to provide for the collection, control, recycling, and treatment of surface run-off from the site as necessary to meet state water quality standards; and
- C Any leachate emanating from a gypsum stack shall be collected and routed to a cooling pond or surge pond, contained and treated as necessary to meet the applicable state water quality standards.

2.5 New Amendments, Regulations, Guidance, or Permitting Procedures Since 1995

The only new Florida state regulations enacted since 1995 related to new gypsum stacks correspond to ground water protection measures in wellhead protection areas, and air emission permits. In the first case, F.A.C. 62-521.400 prohibits the placement of new phosphogypsum stack systems in wellhead protection areas. In the second case, F.A.C. 62-210.300 exempts from the air permitting requirements of Chapter 62-210, phosphogypsum cooling ponds and inactive phosphogypsum stacks that have been demonstrated to comply with the requirements of 40 CFR Part 61, Subpart R (National Emission Standards for Radon Emissions for Phosphogypsum Stacks - 20 pCi/m^2-s of radon-222 into the air).

The only guidance produced by FDEP since 1995 is related to variance scenarios allowed for operation of unlined gypsum stack systems after March 25, 2001. These variance options are explained above in Section 2.2.

3. Design, Construction, and Operation Requirements for Uranium Mill Tailings Impoundments

Most wastes generated by conventional uranium mills are disposed of in tailings impoundments. Wastes are primarily disposed of in the form of a slurry composed of tailings, gangue (including dissolved base metals), spent beneficiation solutions, and process water bearing carbonate complexes (alkaline leaching) and sulfuric acid (acid leaching), sodium, manganese, and iron. The characteristics of this waste vary greatly, depending on the ore, the beneficiation procedure, and the source of water used (fresh or recycled). The liquid component is usually decanted and recirculated to the crushing/grinding or leaching circuit (U.S. EPA, 1993). The uranium mill tailings are a high volume waste stream that is in some respects analogous to phosphogypsum. The fate of radionuclides is of special interest in uranium mill tailings. Radium-226 and thorium-230 are the principal constituents of concern and are associated with the slime fraction of the tailings.

EPA promulgated final rules in Subpart D of 40 CFR 192 to establish standards for the management of uranium byproduct materials, including tailings or wastes produced by the extraction or concentration of uranium. These standards are the same as those established by EPA for owners and operators of hazardous waste treatment, storage, and disposal (TSD) facilities (40 CFR 264.221). The uranium mill tailings management units also are subject to the ground water protection standards (40 CFR 264.92) and the monitoring requirements (40 CFR 264.98) that were established for TSD facilities, plus specific performance standards for ground water protection, such as a combined radium-226/228 standard of 5 pCi/l, and a gross particle activity standard of 15 pCi/l.

The Nuclear Regulatory Commission (NRC) regulates active uranium milling and inactive uranium mill tailings disposal sites through licenses issued according to the procedures and criteria in 10 CFR 40. The NRC requires the license applicant to file an application at least nine months prior to commencing construction of a plant or facility. Further, the NRC has determined that the issuance of a license to possess and use source material for uranium mills is a major Federal action which significantly affects the environment (10 CFR 51). Therefore, pursuant to the National Environmental Policy Act, an Environmental Impact Statement must be prepared and submitted with the license application. Additionally, under the Atomic Energy Act, DOE has promulgated regulations for leasing public lands controlled by DOE for uranium exploration and mining (10 CFR 760).

3.1 Design Requirements for New Uranium Mill Tailings Management Units

For new surface impoundments regulated by 40 CFR 264.221, on which construction commences after January 29, 1992, the following standards apply:

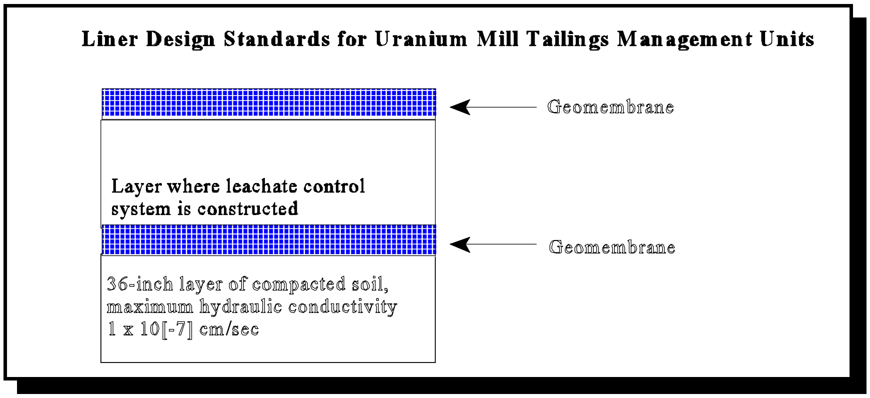
<u>Liners</u>

The liner system must include:

- A top liner designed and constructed of materials (e.g., a geomembrane) to prevent the migration of hazardous constituents into such liner during the active life and post-closure care period; and
- A composite liner, consisting of two components:
  - The *upper component* must be designed and constructed of materials (e.g., a geomembrane) to prevent the migration of hazardous constituents into such liner during the active life and post-closure care period.
  - The *lower component* must be designed and constructed of materials to minimize the migration of hazardous constituents if a breach in the upper component were to occur. The lower component must be constructed of at least 3 feet of compacted soil material with a hydraulic conductivity of no more than $1x10^{-7}$ cm/sec.

Not only does this liner design have one more layer than the design for phosphogypsum management units presented in Section 2.3, but the layer below the bottom geomembrane is thicker (36 inches in this case versus 18 inches for the phosphogypsum unit). Exhibit 3-1 presents a schematic representation of the liner design requirements.

The liner standards do not specify the type of geomembrane to be placed in the top and bottom liners. However, a review of liner configurations



at commercial hazardous waste landfills reported in Neidorf (1995) indicates that these geomembranes are at least 60-mil HDPE, and commonly 80-mil HDPE. The report shows only one exception in the U.S., a landfill with a 40-mil HDPE liner, but with two additional liners of 80-mil and 100-mil.

Exhibit 3-1

Leachate control system

The leachate collection and removal system must be located between the liners, and immediately above the bottom composite liner. This system is also a *leak detection system*, capable of detecting, collecting, and removing leaks of hazardous constituents at the earliest practicable time through all areas of the top liner likely to be exposed to waste or leachate during the active life or post-closure period. The requirements for the leak detection system are:

- Bottom slope of one percent or more;
- Constructed of granular drainage materials with a hydraulic conductivity of $1x10^{-1}$ cm/sec or more, and a thickness of 12 inches or more; *or* constructed of synthetic or geonet drainage materials with a transmissivity of $3x10^{-4}$ m^2sec or more;
- Constructed of materials that are chemically resistant to the waste managed in the impoundment, and of sufficient strength to prevent collapse under pressures exerted by overlying wastes; and
- Designed and operated to minimize clogging during the active life and post-closure care period.

Not only the leachate control system in this case have more stringent design standards than in the case of phosphogypsum management units, so as to collect and remove leakage from the top liner, but it also serves as a *detection system*. While in the phosphogypsum management case, the primary purpose of the system is to routinely convey liquids from within the accumulated waste to a collection point for storage and reinsertion into the production process, in the uranium tailings case any leachate collected above a certain limit constitutes a partial containment system failure and triggers a response action. The operator of the uranium tailings unit must record the amount of liquids removed from each leak detection system sump at least once each week during the active life and closure period. After the final cover is installed, recording frequency can diminish (40 CFR 264.226(d)). The Regional Administrator approves an "action leakage rate" (maximum design flow rate that the leakage detection system can remove without the fluid head on the bottom liner exceeding one foot). The owner or operator of the impoundment must have an approved response action plan to be followed if the action leakage rate is exceeded. Among the actions in this plan, the owner or operator must determine short-term and long-term actions needed to mitigate or stop any leaks.

3.2 Operating Requirements for New Uranium Mill Tailings Management Units

One of the most important operating requirements for new management units regulated by 40 CFR 264 is the ground water protection standard. The owner or operator must comply with conditions specified in the facility permit that are designed to ensure that hazardous constituents listed in 40 CFR 264.93 detected in the ground water from a regulated unit do not exceed the concentration limits specified in 40 CFR 264.94 in the uppermost aquifer underlying the waste management area beyond the *point of compliance*, during the *compliance period*.

The *point of compliance* is defined in the facility permit, and is the point at which the ground water protection standards apply and at which monitoring must be conducted. The point of compliance is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units. The waste management area is the limit projected in the horizontal plane of the area on which waste will be placed during the active life of a regulated unit.

The *period of compliance* is specified in the facility permit, and is the period during which the ground water protection standards apply. The compliance period is the number of years equal to the active life of the waste management area (including any waste management activity prior to permitting, and the closure period).

The ground water monitoring system required by 40 CFR 264.97 must consist of a sufficient number of wells, installed at appropriate locations and depths to yield samples from the uppermost aquifer that: (a) represent the quality of background water that has not been affected by leakage from a regulated unit; (b) represent the quality of ground water passing the point of compliance; and (c) allow for the detection of contamination when hazardous waste or hazardous constituents have migrated from the waste management area to the uppermost aquifer.

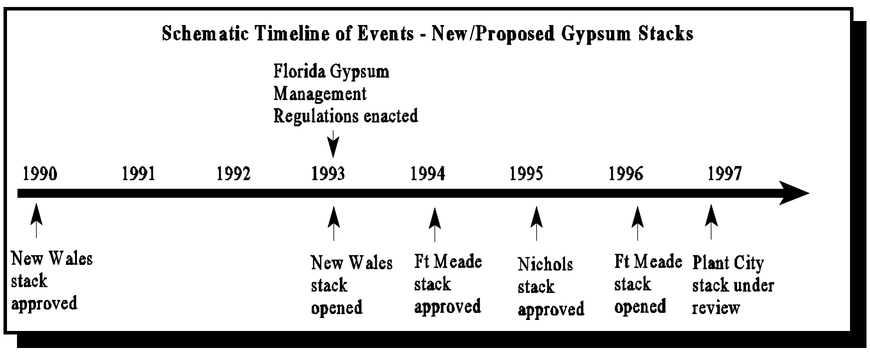
The ground water monitoring system requirements are analogous to the corresponding ones for gypsum stacks, with appropriate differences between the point of compliance in the case of uranium mill tailings and edge of the ZOD for gypsum stacks.

4. New/Proposed Gypsum Management Units in Florida

This section reviews information on four lined phosphogypsum management units that have been built, permitted, or proposed in Florida. Sections 4.1 to 4.4 present a brief description of the facilities where these four gypsum disposal units are or are to be located, including their operations history and need for a new gypsum stack. Each section also presents the current status of the permitting/DRI/construction process for the lined gypsum stack systems. Finally, each section summarizes the design and operation features of each gypsum stack system, including stack configuration/construction plan, liner, leachate control system, slurry wall, ground water monitoring system, expected leakage to ground water (calculated based on stack-specific information such as stack height, gypsum production rate, and useful life, as well as general assumptions presented in the permit application technical reports, such as gypsum permeability at various depths, number and size of liner defects, etc.), air quality sampling, and additional considerations (e.g., sinkhole potential, contingency plans, environmental mitigation measures). Section 5 presents side-by-side comparisons among the actual gypsum stack design and operation features, the 1993 Florida regulations, and the uranium mill tailings management regulations.

Four New/Proposed Lined Gypsum Stacks

- New Wales Chemical Complex, IMC-Agrico, Polk County
- Ft. Meade Chemical Complex, U.S. Agri-Chemicals, Polk County
- Plant City Phosphate Complex, Cargill Fertilizer, Hillsborough County
- Nichols Plant, IMC-Agrico, Polk County



During the last five years, there have been four lined gypsum stack systems in Florida that have been either constructed, permitted, or proposed, as shown in the Exhibit to the right. Exhibit 4-1 presents a schematic timeline of events in the permitting process for these four facilities. The specific process for each facility is described in more detail in the appropriate section. Exhibit 4-1 provides an overview for reference.

Exhibit 4-1

4.1 New Wales Chemical Complex, IMC-Agrico, Polk County

4.1.1 Chemical Complex Description

The facilities at the New Wales Chemical Complex include sulfuric acid plants, phosphoric acid plants, granulated triple superphosphate (TSP) and granulated ammonium phosphate plants, animal feed ingredient plants, and a uranium recovery plant. The phosphoric acid plants use the wet dihydrate process. These plants can produce approximately 1.7 million tons of phosphoric acid per year. Approximately 5 tons of gypsum are generated for each ton of phosphoric acid produced. The gypsum is slurried and transported at approximately 20,000 gpm. (Central Florida Regional Planning Council, 1990)

The old gypsum stack used at the New Wales plant covers a land area on the order of 430 acres. The stack was started in 1975 when the plant was opened. The cooling pond and channels occupy a water surface area of 281 acres (with the main cooling pond accounting for about 247 acres). Approximately 150,000 to 170,000 gpm of process wastewater are recirculated through this cooling pond system to the plant for re-use. A 345-acre clay settling area is used in the non-contact process water circulating system. The old gypsum stack was projected to reach a height of 200 feet above the original land surface by around January, 1992. IMC-Agrico obtained DRI approval in 1990 for a new lined gypsum stack, and shortly thereafter a construction permit from FDEP. Even though the proposed new gypsum stack preceded the 1993 Florida regulations, these were already under discussion, so they were incorporated in the design. The new stack was opened in 1993.

The New Wales plant is underlain by three aquifers. The surficial aquifer averages 31 ft. thick at the site, and the water level naturally lies in this aquifer 4 to 12 feet below the land surface in unaltered areas. The intermediate aquifer is separated from the surficial aquifer by a confining unit with typical thickness of about 125 feet. The intermediate aquifer is about 75 ft. thick, and is underlain by a relatively low permeability “Tampa clay” that ranges in thickness from 9 to 14 feet. Under the Tampa clay is the Floridan aquifer, a 700-foot thick U.S. Drinking Water aquifer. This aquifer is a primary source of drinking water for Central Florida.

Data presented in the DRI report (Central Florida Regional Planning Council, 1990) indicate ground water impacts at the surficial aquifer (up to 800 feet in the horizontal direction from the gypsum stack edge) and the upper portion of the upper confining unit of the intermediate aquifer (i.e., within a depth interval below ground surface of 50 to 70 feet). The impacts in the second case extend to a distance of 2400 feet. The impacts at both aquifers occur within the authorized ZOD.

On June 27, 1994 a site supervisor at the facility noticed a depression within the southwestern quadrant of the old unlined phosphogypsum stack. The depression was approximately 160 ft. in diameter and 180 ft. in depth. Further investigation revealed that the depression was caused by a sinkhole beneath the stack. Remedial actions spanned a period of two years and appeared to have prevented contaminant migration outside the property boundary.

4.1.2 New Gypsum Stack

Stack configuration/Construction plan: The new stack will be built in two phases, with an initial base area of 375 acres in Phase I, to be increased to 670 acres during Phase II. When the Phase I stack reaches a height of approximately 150 feet, the construction of the base and support infrastructure for the Phase II stacking facility is expected to be completed. Both the Phase I and II stacks will be raised to an average height of 200 feet, each providing for gypsum storage needs for 10 to 12 years. The average side slopes will be 2.5H:1.0V.

Liner: The liner of composed by a 60-mil HDPE liner covering the whole base area as well as the upstream slopes of all perimeter earthen starter dikes. The DRI report argues that the 125-foot thick confining unit separating the mined-out area from the major producing zone of the intermediate aquifer will provide secondary protection, as a "natural liner."

Leachate control system: Three concentric rings of perimeter drains were installed over the HDPE liner, beneath the projected slope of the gypsum stack, to reduce the hydraulic head on the liner and improve the stability of the stack. The drains will discharge into the collection ditch surrounding the Phase I stack.

Slurry wall: A soil-bentonite vertical cut-off wall was installed and keyed into the natural confining unit, along the north wall of the new gypsum stack. The goal is to hydrogeologically separate the Phase I gypsum stack from the existing facilities.

Ground water monitoring system: As part of the DRI approval, a network of ground water monitoring wells was installed around the old gypsum stack and cooling pond facility, including 31 wells at six clusters (8 in the surficial aquifer, 19 in the intermediate aquifer, and 4 in the Floridan aquifer). Additionally, as part of the FDEP ground water monitoring plan, five additional wells monitor water quality. Also, the chemical plant has two production wells tapping into the Floridan aquifer system, one of which is monitored. Quarterly monitoring at these wells is performed, unless analysis values indicate values within 10% of the corresponding MCL, in which case the frequency is increased to monthly.

Expected leakage to ground water: The maximum leakage rate to the surficial aquifer beneath the Phase I gypsum stack through the liner (without a tear or breach) is expected to be no greater than 0.3 inches per year (if 2 defects per acre are assumed) and no greater than 0.5 inches per year (if 5 defects per acre are used in the computations). With a total area of 670 acres, an average of no more than 28 acre-ft/year of leakage through the liner may be expected. This leakage is expected to occur during the construction and dewatering (after closure) periods, for a total of 41 years. A tear in the liner with an equivalent area of 100 ft^2 and with the stack at its ultimate height would increase the seepage below the liner by approximately 50 percent.

Air quality sampling: Sampling for fluoride and Radon-222 is done at the existing air monitoring station two miles south from the site. Grass sampling for fluoride is conducted at six sites.

Additional considerations: In the area proposed for construction of the new gypsum stacks, recharge wells were originally installed to dewater the surficial aquifer prior to mining. The recharge wells penetrated the intermediate aquifer and were almost always drilled into the Floridan aquifer, so that the wells could drain the surficial aquifer system into the major producing zone of the aquifers below. Ground water monitoring data has indicated that some recharge wells under the old cooling pond may be leaking and affecting the producing zone of the intermediate aquifer, and possibly the Floridan aquifer. There were a total of 18 wells in the Phase I area that were plugged to a varying extent in the past but which were not abandoned in accordance with current SWFWD (South West Florida Water District) and FDER standards. As part of the gypsum construction, these wells were proposed to be capped by placing a 3-foot thick concrete (and/or soilcrete) pad at the bedrock surface covering the area that encompasses the well location.

The DRI report indicates little potential for sinkhole occurrence in the area, but little supporting field data is presented. As a condition of the Development Order, closure of the old gypsum stack shall commence within 15 years after the start of the operation of the Phase I stack, and shall be completed within 20 years. After the occurrence of the sinkhole in the old gypsum stack, IMC-Agrico agreed to accelerate closure of this stack, and an application was being prepared as of earlier this year.

References: Central Florida Regional Planning Council (1990).

4.2 Ft. Meade Chemical Complex, U.S. Agri-Chemicals, Polk County

4.2.1 Chemical Complex Description

The Ft. Meade Chemical Complex, which began operation in 1961, produced four products: sulfuric acid (1,400,000 tons/year), phosphoric acid (500,000 tons/year), fluosilicic acid (20,000 tons/year), and electric power (197,000 megawatts/year), in 1991. As a by-product of the phosphoric acid production, approximately 2,600,000 tons of gypsum are generated per year (Central Florida Regional Planning Council, 1994).

The old gypsum stack used at the Ft. Meade plant covers a land area on the order of 265 acres. The stack was started in 1961, and was expanded in 1981/982. The cooling pond and channels occupy a water surface area of 97 acres. The clay settling area covers approximately 124 acres. The old gypsum stack was projected to reach capacity around 1995. U.S. Agri-Chemicals obtained DRI and construction permit approvals in 1994 for a new lined gypsum stack. Construction of the new stack was completed in August, 1996.

The Ft. Meade plant also is underlain by the three aquifers common in Central Florida: the surficial, intermediate, and the Floridan aquifer systems, with approximate thickness of 27, 120, and 700 feet, respectively. The Floridan aquifer is a primary source of drinking water for Central Florida. Data presented in the DRI report indicate exceedance of water quality criteria in the surficial aquifer in a number of monitoring wells. Also, levels of radium-226 exceeded water quality standards (5.0 pCi/l) in two wells located in the southwest corner of the unlined gypsum stack, that reach the intermediate (5.9+/-0.4 pCi/l) and Floridan aquifers (8.5+/-0.5 pCi/l), respectively. Gross alpha levels measured in the Floridan well reached 25.5+/-12.9 pCi/l, which exceeds the 15 pCi/l standard. Other water quality parameters measured in wells in the lower two aquifers do not exceed standards (Central Florida Regional Planning Council, 1994).

4.2.2 New Gypsum Stack

Stack configuration/Construction plan: The new gypsum stack will be built in two phases. Phase I, including perimeter embankment, water recirculation system, slurry cutoff wall, and roads will encompass a total area of approximately 160 acres, of which approximately 130 acres will be covered by the gypsum stack. The Phase I gypsum stack will be raised approximately 150 feet above the pre-mining natural ground surface elevation, and it will provide approximately 9 years of storage life at a gypsum production rate of 2.6 million tons per year.

The Phase II gypsum stack and support infrastructure will cover approximately 190 acres. This Phase II stack will initially be raised up to the maximum elevation of the Phase I compartment, and then the combined Phase I and Phase II compartments will be raised together an additional 50 feet. The combined, final configuration will provide a total gypsum storage life in excess of 25 years.

The Phase I stack (and the Phase II stack until it reaches the same height of Phase I) will have overall average side slope of 2.5H:1.0V, that will be constructed by combining steeper slopes with set backs at intermediate elevations. These setbacks will be 20-foot wide benches designed to allow equipment access. When the two gypsum stacks reach the same height, the combined stack area will be raised at a flatter slope of 3H:1V to the final height.

Liner: The entire base of the proposed gypsum stack, as well as the upstream slope of the perimeter dike and process water return ditch will be lined with a 60-mil HDPE liner. The liner base will be comprised of not less than 6 inches of prepared and compacted cast overburden soils. A 24-inch thick compacted gypsum working base, with a maximum hydraulic conductivity of $1x10^{-4}$ cm/sec, will be placed on top of the HDPE liner.

Leachate control system: A system of three underdrains will be placed on top of the HDPE liner beneath the outer slopes of the gypsum stack to draw down the phreatic surface in the gypsum stack and reduce seepage gradients. Gypsum stack seepage collected by the underdrains will discharge into the perimeter ditch.

Slurry wall: A slurry wall will be built along the west and south walls of the new gypsum stack. The slurry wall will be located near the outside toe of the perimeter containment dike of the new stack, and will extend to a total depth of 50 to 60 feet, penetrating not less than 20 to 30 feet into the lower confining clay units beneath the surficial aquifer. The slurry wall will be built with a soil-bentonite mixture having an average coefficient of permeability equal to or less than $1x10^{-7}$ cm/sec.

Ground water monitoring system: The FDEP construction permit for the Phase I gypsum stack requires 10 ground water wells into the surficial aquifer (one background, one upgradient, four compliance, and four monitoring wells). Sampling should be done quarterly. The ZOD shall extend horizontally 100 feet from the inside crest of the earthen perimeter dam, and vertically to the base of the shallow water table aquifer. The DRI approval conditions include monitoring at wells into the intermediate and Floridan aquifers.

Expected leakage to ground water: Assuming an average defect rate of 1 to 2 defects per acre of liner, with an average diameter of 2 mm, the maximum liner leakage rate is projected to be 0.54 inches per year. With a projected total area of 320 acres (phases I and II), a maximum of 14 acre-ft/yr of leakage is projected. The technical report supporting the design calculates the peak incremental impacts at the base of the surficial aquifer beneath the new gypsum stack.

Air quality sampling: Monitoring plan for dust, fluorides, and Radon-222 will be submitted prior to construction of Phase I.

Additional considerations: Thick unbreached deposits of relatively impervious interbedded carbonates and clays in the undifferentiated Peace River and Arcadia formations at the site reduce the potential for sinkhole development and/or sudden subsidence. Deep borings performed in conjunction with the field exploration program did not reveal any major solution features indicative of potential future collapse-type subsidence.

References: Ardaman & Associates (1992, 1996b), Central Florida Regional Planning Council (1994), Florida Department of Environmental Protection (1994).

4.3 Plant City Phosphate Complex, Cargill Fertilizer, Hillsborough County

4.3.1 Phosphate Complex Description

The Plant City Phosphate Complex, which began operations in 1965, currently generates approximately 5.3 million tons of gypsum per year. The old unlined gypsum stack was started in 1965. The stack was later expanded to the current configuration and surrounded by a 129-acre cooling pond and surge pond system. In 1995, Cargill Fertilizer completed construction of a new, composite-lined cooling pond meeting the requirements of Rule 17-673.400, F.A.C. The old gypsum stack is projected to be deactivated in 1999 (CF Industries, 1996).

A new lined gypsum stack, covering 576 acres and planned for construction in three phases, with a useful life of 30 years, was given DRI approval by the Hillsborough County Board of County Commissioners on June, 1996. Its construction permit is currently under review at FDEP.

The Plant City Phosphate Complex is underlain by the surficial and the Floridan aquifers. The surficial aquifer at the site generally consists of a 5- to 15-foot thick layer of sandy deposits. The surficial aquifer at the site is separated from the underlying Floridan aquifer by about 10 to 25 feet of sandy clay. Along the north edge of the site immediately adjacent to the existing stack, the water quality within the surficial aquifer has been adversely affected by seepage from the existing cooling water channel. Other ground water impacts have occurred near a spill site and beneath the existing stack. These impacts resulted in a Consent Order between Cargill Fertilizer and FDEP. An approved Remedial Action Plan calls for the installation of six recovery wells designed to withdraw 1000 gpm of affected ground water from the upper part of the Floridan aquifer downgradient from the old unlined (existing) stack (Ardaman & Associates, 1996c).

4.3.2 Proposed Gypsum Stack

Stack configuration/Construction plan: The proposed construction of the new gypsum stack will proceed in Construction Sequences I, II, and III, with footprint areas of 197, 167, and 158 acres, for a total of 575 acres. The final maximum height will be approximately 250 feet above the surface of the surrounding land. At the final buildout configuration and height, stack expansion will provide approximately 30 years of gypsum storage. Lateral average slopes will be 3H:1V. Although the DRI process approved the three sequences, the construction permit application currently under review is only for Construction Sequence I. One of the recommendations of the DRI committee was to encourage Cargill Fertilizer to minimize the impact of the proposed gypsum stack, either by finding alternative stacking methods that could include placing gypsum on top of the existing stack or placing it in the "notch" between the existing stack and the Construction Sequence I of the new stack. The delay in constructing the later construction sequences could allow time for an alternative use or disposal method to be found for the gypsum.

Liner: For Construction Sequence I, a double geomembrane composite liner has been proposed. The design includes a 60-mil HDPE geomembrane, overlain by a two-foot thick layer of compacted gypsum with permeability no greater than $1x10^{-4}$ cm/sec. This gypsum layer would in turn be overlain by an additional 60-mil HDPE geomembrane. The liner would pass beneath the perimeter return water ditch and be tied into the upstream crest of the perimeter dike, providing full containment within the process water system.

A pressure relief system will be installed in the gypsum between the two geomembranes to relieve any excess hydraulic pressures that may develop between the two liners and to relieve air pressure that may develop beneath the upper of the two liners during initial filling of the area. The relief system will consist of standard width strips of geonet drainage composite installed on approximately 500-foot grid centers beneath the upper of the two geomembranes, and tied to a drain pipe.

Leachate control system: Three concentric underdrains will be built on top of the upper liner beneath the outer slope of the gypsum stack. Each drain will consist of a slotted HDPE collector pipe embedded in a gravel collection zone, which in turn will be completely wrapped in a non-woven geotextile filter fabric and encased in a protective cover of clean, lightly compacted gypsum. Outfall pipes will be provided at discrete intervals to return collected seepage to the perimeter return water ditch.

Slurry wall: Not mentioned in DRI report or construction permit application.

Ground water monitoring system: Cargill Fertilizer proposes in the permit application a combined ground water monitoring plan that includes the plan for the existing operating permit, the remedial action plan based on the existing Consent Order, and eight additional wells for the new stack. The combined program will have 27 Floridan aquifer wells and eight surficial aquifer wells. The proposed plan eliminates sampling for chemical parameters that have never been detectable or significantly elevated either in ground water with known process water contamination or in the process water itself. The plan also proposes to use key indicator parameters that are indicative of pond water seepage.

Expected leakage to ground water: The calculated leakage for a double composite liner is supposed to be less than one-half that calculated for a single geomembrane composite liner. At a height of 100 feet for the gypsum stack, the calculated leakage rate for the double geomembrane liner would be less than 0.006 in/year. There are, however, no detailed analyses of maximum potential leakage rate. This question, among others, has been posed by FDEP to Cargill Fertilizer during the permit review process, in a letter dated October 21, 1996. The information presented in the technical reports is not sufficient to calculate the maximum expected leakage rate through the double liner.

Air quality sampling: Fluoride will be sampled in native vegetation at three sites on a monthly basis, located on the northern and southwest corner of the plant property. Radon will be monitored with five passive detectors.

Additional considerations: Two issues that are analyzed in some detail in the construction permit proposal are sinkhole potential and response actions to a catastrophic occurrence of this type. Cargill Fertilizer did, as part of the field exploratory program, a ground penetrating radar (GPR) survey, with the goal of locating and identifying lateral discontinuities, or anomalies, in the subsurface that could be indicative of ancient karst erosional features, soil voids or raveling conditions. One anomaly was found in the preliminary GPR survey and to better understand its current structure, borings were drilled into it. The area has a loose deep sand layer, with a sandy clay layer below it with apparent low stress. This structure could result in future settlements if loaded with the weight of the new gypsum stack. To minimize the potential for future settlement, the soil within this feature will be pressure grouted using a fine gravel-sand-cement-fly ash grout mixture. The construction permit application submitted by Cargill Fertilizer describes a more comprehensive GPR survey with higher density and additional borings that would take place after permit approval and completion of site clearing operations.

As part of the proposed actions in case of a sinkhole occurrence, Cargill proposed two specific steps: (1) maintain contractual arrangements to install new pumping wells if the existing production wells are not capable of capturing contaminated ground water from a breach anywhere in the liner; and

(2) build the stack with a minimum of three compartments for the ponded area, to reduce the amount of process water that could escape from the system in the case of a sinkhole that extends to the ponded area on top of the stack.

Finally, because the construction of the stack will fill 176 acres of wetlands and 400 acres of uplands, as a mitigation measure, Cargill Fertilizer will (if all three potential mitigation areas are used) create 95 acres of new wetlands, restore 59 acres of wetlands that had been previously destroyed by other land uses, and enhance 576 acres of previously affected wetlands. Also, a 961-acre tract of land owned by the company will be dedicated to environmental protection.

References: Ardaman & Associates (1996c), CF Industries (1996), Florida Department of Environmental Protection (1996), Tampa Bay Regional Planning Council (1996).

4.4 Nichols Plant, IMC-Agrico, Polk County

4.4.1 Plant Description

The Nichols Plant is a phosphate chemical fertilizer manufacturing facility that includes sulfuric acid production, phosphoric acid production, diammonium phosphate production, triple superphosphate production, electric cogeneration facilities, storage and shipping facilities, and a phosphogypsum disposal stack system. At full capacity, the phosphoric acid production at the Nichols Plant is approximately 300,000 tons per year, with a corresponding by-product gypsum generation rate of 1,500,000 tons per year. This gypsum is disposed of in a gypsum stack immediately south of and adjacent to the chemical plant (Ardaman & Associates, 1996a).

The existing gypsum stack complex covers an area of approximately 230 acres, and it includes the following components: (1) a 50-acre at-grade unlined cooling pond; (2) the West Gypsum Field on top of which a 22-acre lined surge pond (West Surge Pond) has been constructed; and (3) the Center Gypsum Field and East Gypsum Field, which are currently being used for active sedimentation of gypsum slurry and/or for process water storage. The gypsum stacks cover an area of 180 acres. The elevations of the Center and East fields are on the order of 240 feet and 195 feet, respectively.

The Nichols Plant is underlain by three aquifers, the surficial, the intermediate, and the Floridan aquifer. The top of the surficial aquifer is the water table which is generally within a few feet of the ground surface and generally follows the topography. The Floridan aquifer consists of more than 1,000 feet of limestone and dolomite, and its top is at a depth of approximately 130 feet below surface. The Nichols Plant has been operating under a FDEP Consent Order signed in September, 1989, to address exceedances of State ground water quality standards at the facility. As a result of the terms contained in the Consent Order, the gypsum stack system is equipped with a Total Perimeter Containment System (TPCS) designed to contain any migration of contaminants off-site. This system includes a hydraulic barrier system comprised of 373 relief wells along the north and east sides, and 316 relief wells along the south and west sides. A soil bentonite cut-off wall and freshwater recharge system have been constructed along the south and west sides as part of the hydraulic barrier system. Ground water collected from the TPCS is currently being pumped into the existing cooling pond. IMC-Agrico was authorized to continue operating the gypsum stack through a plan that included lining the top of the old stack before continuing disposal. The lining would follow the 1993 State regulations, so it is analyzed in this memorandum in Section 4.5, where the construction sequence of the new stack on top of the existing one, is described. The company received a construction permit under a modified plan from FDEP in October, 1995. The completion of proposed construction activities would take approximately four years; construction started in August, 1996 (Ardaman & Associates, 1996a).

4.4.2 Modified Gypsum Stack

Stack configuration/Construction plan: The dual objective and configuration of the modified gypsum stack at the Nichols Plant makes it an interesting case worth mentioning in this memorandum. The goal of IMC-

Agrico's approach is to both cap an existing unlined gypsum stack, using a composite geomembrane liner according to the specifications in Chapter 17-673, F.A.C., and continue building up the stack on top of the liner. In this way, no new land is required (which means no DRI review process), and future gypsum disposal will be performed using a lined stack. The construction sequence is complicated and it will take approximately four years to complete. The construction sequence would proceed as follows:

- Fill the Center Field with gypsum to Elevation 255 feet (NGVD) (approx. 130 feet above ground), to provide borrow material for construction and to accommodate pre-construction settlements prior to placement of the liner;
- Fill the East Field to Elevation 255 feet (NGVD), while: (1) lining the Center Field with 60-mil HDPE, connected to the existing liner in the West Field; (2) preparing the West and Center Fields for gypsum deposition; and (3) lining the bottom and inside slopes of the existing cooling pond with 60-mil HDPE liner;
- Start filling the West and Center Fields while lining the East Field with a 60-mil HDPE liner, connected to the Center Field liner; and
- Combine the three gypsum fields into one lined stack, and fill the new lined stack with gypsum to elevation 350 feet (NGVD) while continuing to use the at-grade newly lined pond for cooling and surge purposes.

This construction sequence requires a variety of additional activities, especially related to the transfer of ponded water, which are described in more detail in the application permit. The average side slopes would be 2.5H:1.0V. The equivalent lined base area and final top area of the combined gypsum stack are on the order of 60 and 20 acres, respectively. The storage volume corresponding to the proposed stack growth geometry above the lined area is on the order of 4,600 acre-feet. Total settlements of the lined area during the life of the stack are expected to add an additional 1,400 acre-feet of useful storage. The useful storage life of the proposed gypsum stack growth is estimated at about 9.2 years.

<u>Liner</u>: The composite liner to be constructed will include a 60-mil HDPE geomembrane liner covered with 24 inches of compacted phosphogypsum. Lining and preparing each field for further gypsum slurry deposition will be undertaken sequentially, as described above. Prior to modifying a given gypsum field, any process water contained in that field will have to be transferred to other existing or previously completed facilities within the gypsum stack system. Each gypsum field will be dewatered and allowed to dry and partially consolidate over a period of 3 to 6 months prior to liner installation.

<u>Leachate control system</u>: Two concentric perimeter stack drains and associated outlets will be installed on top of the bottom liner in each field, beneath the projected slope of the combined gypsum stack.

<u>Slurry wall</u>: Not mentioned in the permit application.

<u>Ground water monitoring system</u>: The construction permit requires quarterly sampling of eight wells in the surficial aquifer (one background and

seven compliance wells), three in the intermediate aquifer (one background and two compliance wells), and one in the Floridan aquifer (currently used for water supply). The ZOD is defined in the permit as extending horizontally to the property boundary.

Expected leakage to ground water: A water balance analysis presented in the technical report of the modified gypsum stack calculates that the hydraulic head associated with the elevated water table in the unlined gypsum fields causes the recharge rate to increase to about 2.5 inches per year, compared to the natural recharge rate of 1.0 inches per year. The 2.5 inches per year over an effective area of approximately 200 acres, when averaged over the 9-year life of the modified gypsum stack, will result in a total of 42 acre-feet per year of downward seepage. This higher rate is due to dewatering of the old unlined stack on top of which the new stack will be built after placement of a liner. The technical reports do not discuss water balance after closure or seepage through the liner, but focuses on dewatering of the closed (existing) layer of the gypsum stack.

Air quality sampling: Not discussed in permit or technical reports.

Additional considerations: One concern with this proposed approach was the differential settlement that would occur in the old gypsum stacks and the stresses it would cause on the new liner on top of them. During a 300-day monitoring period, the settlement of the Center Field dikes ranged from approximately 1.0 to 6.5 feet. The differential settlement was attributed to the fact that the gypsum underlying the mid-portion of the Center Field was deposited relatively recently (i.e., since 1990), while along the east and west edges, the depth of fresh gypsum overlying the West Field and East Field older slopes varies depending on the specific location. This indicates that potentially large long-term differential settlements can be expected beneath the lined combined stack due to variations in the consistency and age of the gypsum. Maximum total settlements of the lined area are predicted to be 17.8 feet, 35.6 feet, and 37.3 feet within the West Field, Center Field, and East Field sections, respectively, during the life of the modified lined stack. Furthermore, the stack is expected to continue to settle beyond the storage life of the stack. Long-term ultimate settlements of up to 29 feet and 44 feet are projected beneath the lined area within the West Field and Center/East Field sections. This will result in a maximum tensile strain in the liner attributed to differential settlements of less than 0.5%, which is within the elastic range for HDPE (a maximum yield strain of 12%). The stack drains have been designed so that they will not span across the boundaries between underlying historical gypsum fields, so as to not be affected by differential settlements.

References: Ardaman & Associates (1996a), Florida Department of Environmental Protection (1995).

5. Summarized Comparison between 1993 Florida Phosphogypsum Management Regulations, New/Proposed Gypsum Stacks in Florida, and Uranium Mill Tailings Management Standards

Table 5-1 presents a summarized comparison of the design, construction, and operating characteristics of the four units described in Section 4, along with the current Florida regulations, and the uranium mill tailings management standards.

There are some trends and differences that can be highlighted from Table 5-1, as follows:

- The 1993 Florida Phosphogypsum Management regulations are less stringent than the uranium mill tailings standards defined in 40 CFR 192 Subpart D in several important respects. First, the uranium tailings standards require a double composite liner with two geomembranes and an underlying layer of 3 feet of compacted soil with minimum hydraulic conductivity of $1x10^{-7}$ cm/sec. The gypsum standards require only one geomembrane and 2 feet of compacted gypsum with minimum hydraulic conductivity of $1x10^{-4}$ cm/sec (or an underlying 18-inch layer of compacted soil with maximum hydraulic conductivity of $1x10^{-7}$ cm/sec, which has not been used in any of the four cases analyzed in Section 4). Second, the uranium tailings standards require a leachate collection system that is also used as detection system. If the measured volume of liquids recovered exceeds a pre-determined action leakage rate, a response action plan is set in motion to mitigate or stop any leaks. In the gypsum case, leakage through the liner is expected and it is actually calculated in the technical reports presented in the permitting process.

- All three gypsum stacks constructed or proposed since the enactment of the 1993 Florida Phosphogypsum Management regulations have followed or exceeded the Florida standards but none of the designs approach the protectiveness of the uranium mill tailings standards.

- The Plant City gypsum stack proposal goes beyond the Florida standards due to the environmental sensitivity of the area (i.e., proximity of a potential future wellhead area) and, quite likely, because of increased public concern in Florida after recent environmental incidents in the phosphoric acid industry.

- A trend that is clearly noticeable in the technical reports presented to support the Florida permit applications is an increasing level of detail and analysis. For example, a new topic that is receiving more attention (both in field work efforts and proposed preventive measures) is sinkhole potential.

- The approach at the Nichols plant of a modified gypsum stack is interesting, as it allows usage of an old stack for the remaining years of its useful life, fulfilling at the same time the 1993 Florida regulation's closure requirements. Furthermore, it is a potential solution for those situations with land availability restrictions; it does not have to go through the DRI process as it does not change the footprint of the original gypsum stack; and the ZOD is not reduced, but remains within a horizontal range to the property boundary.

TABLE 5-1
SUMMARIZED COMPARISON OF FLORIDA GYPSUM MANAGEMENT REGULATIONS, NEW/PROPOSED GYPSUM STACK CHARACTERISTICS AND URANIUM MILL TAILINGS STANDARDS

	Florida 1993 Phosphogypsum Management Regulations 17-673.100-900, F.A.C.	New Wales	Ft. Meade	Plant City	Nichols	Uranium Mill Tailings Management Standards 40 CF 192 Subpart D
Type		New	New	New	Modified	
Status	Enacted 1993	Approved 1990 Opened 1993	Approved 1994 Opened 1996	DRI approved 1996 Construction permit under review	Approved 1995 4-year construction program underway	Enacted 19
Phases/ Gypsum Stack Base Area		2 Phases of 375 acres each	2 Phases of 130 acres and 190 acres	3 Phases of 197, 167, and 158 acres	Lined covered base of old stack 60 acres	
Useful Life		20 to 24 years	25 years	30 years	9.2 years	
Max. Final Height		150 feet Phase I, 200 feet final height	150 feet Phase I, 200 feet final height	250 feet	95 additional feet over old stack height	

	Florida 1993 Phosphogypsum Management Regulations 17-673.100-900, F.A.C.	New Wales	Ft. Meade	Plant City	Nichols	Uranium Mill Tailings Management Standards 40 CF 192 Subpart D
Liner	60-mil or thicker geomembrane liner placed either:(1) above a layer of compacted soil at least 18 inches thick, with a maximum hydraulic conductivity of $1x10^{-7}$ cm/sec, or (2) below a layer of mechanically compacted phosphogypsum at least 24 inches thick, with a maximum hydraulic conductivity of $1x10^{-4}$ cm/sec	60-mil geomembrane	24-inch layer of compacted gypsum, 60-mil geomembrane, 6 inches of prepared and compacted cast overburden soils	60-mil geomembrane, 24-inch layer of compacted gypsum, pressure relief system (geonet drainage), and 60-mil geomembrane	24-inch layer of compacted gypsum, 60-mil geomembrane	Top liner (e. geomembran bottom liner (e. geomembrane), 3 f of compacted s material w maximum hydrau conductivity of 1x1 cm/s
Leachate Collection System	Perimeter underdrain system	Three concentric underdrains discharging to perimeter ditch	Three concentric underdrains discharging to perimeter ditch	Three concentric underdrains discharging to perimeter ditch	Two concentric perimeter underdrains	Granular drain materials with minim hydraulic conductiv $1x10^{-1}$ cm/sec, a minimum thickness inches; or geo drainage materials w minimum transmissiv of $3x10^{-4}$ m^2sec. Syst to be used also **detection syst**
Slurry Wall	Not mentioned specifically	Yes	Yes	Not mentioned in reports	Not mentioned in reports	N

	Florida 1993 Phosphogypsum Management Regulations 17-673.100-900, F.A.C.	New Wales	Ft. Meade	Plant City
Ground Water Monitoring	At least one background well, one well at the edge of ZOD, and intermediate downgradient well within ZOD	8 surficial wells, 19 intermediate wells, 4 Floridan wells	10 surficial wells	8 surficial wells ar 27 Floridan wel
ZOD	To be defined in permit	N/A	Horizontally 100 feet from inside crest of earthen perimeter drain, vertically to base of shallow aquifer	To be determine
Grouting to prevent sinkholes	Not mentioned specifically	No	No	Y

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Appendix A