UNITED STATES

**NUCLEAR REGULATORY COMMISSION**

REGION IV

URANIUM RECOVERY FIELD OFFICE
BOX 25325
DENVER, COLORADO 80225

FEB 03 1987

URFO:GRK
Docket No. 40-8502
License No. SUA-1341
04008502602E

MEMORANDUM FOR: Docket File No. 40-8502

FROM: Gary R. Konwinski, Project Manager
Licensing Branch 1
Uranium Recovery Field Office, Region IV

SUBJECT: ENVIRONMENTAL ASSESSMENT (EA) FOR WESTINGHOUSE ELECTRIC CORPORATION, IRIGARAY PROJECT

Attached is the Environmental Assessment (EA) prepared in support of the renewal of Source Material License SUA-1341 for Westinghouse Electric Corporation, Irigaray Project in Johnson County, Wyoming.

Gary R. Konwinski, Project Manager
Licensing Branch 1
Uranium Recovery Field Office
Region IV

Approved by:
Edward F. Hawkins, Chief
Licensing Branch 1
Uranium Recovery Field Office, Region IV

Attachment: Irigaray Project (EA)

Case Closed: 04008502602E

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40-8502/GRK/87/02/02/0



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ENVIRONMENTAL ASSESSMENT

FOR

WESTINGHOUSE ELECTRIC COMPANY

IRIGARAY SITE

DOCKET NO. 40-8102

CONTENTS

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## 1.0 INTRODUCTION

### 1.1 Background

Westinghouse Electric Company (WEC) applied to the USNRC for renewal of Source Material License SUA-1341. The facility, known as the Irigaray in situ leach project, is a commercial scale uranium recovery venture.

The overall Irigaray site consists of about 131 acres of which 50 acres have been developed into well fields. The site is situated in southeastern Johnson County, Wyoming, approximately 10 miles northeast of Sussex and 43 miles southeast of Buffalo (Figure 1.1.01).

WEC proposes to extract uranium contained in the ore zone. The ore zone is named the Unit One Sandstone which varies from 75 feet to 120 feet in thickness. During the extraction process, an aqueous solution of sodium bicarbonate and an oxidizing agent will be injected through a series of injection wells into well patterns. Each well pattern will consist of a seven-spot configuration. The well patterns are currently installed and divided into nine mining units.

The process plant is currently designed to operate at a maximum capacity of 1600 gpm.

### 1.2 Proposed Action

By letter dated September 28, 1983, WEC submitted an application for timely renewal of Source Material License SUA-1341. Because of site activities, WEC requested by letter dated June 13, 1985, to defer the review of the renewal application. Ultimately, by letter dated October 13, 1985, WEC submitted a complete renewal application for USNRC review.

This Environmental Assessment (EA) discusses the environmental and selected safety aspects of the application proposal. Additional information concerning the safety aspects of the proposed renewal is contained in the accompanying Safety Evaluation Report. The proposed action would be to renew the existing source material license to allow commercial operation of the Irigaray Mine. The license would allow the facility to be operated at 1600 gpm.

## 1.3 Review Scope

### 1.3.1 Federal and State Authorities

Under 10 CFR Part 40, a NRC source material license is required in order to "...receive, possess, use, transfer...any source material..." (i.e., uranium and/or thorium in any form, or ores containing 0.05 percent or more by weight of those substances). In addition, the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) requires persons who conduct uranium source material operations to obtain a byproduct material license to own, use, or possess tailings and wastes generated by the operation (including aboveground wastes from in situ operations). This environmental assessment has been prepared under Title 10, CFR, Part 51. In accordance with 10 CFR Part 51, an EA serves to (a) briefly provide sufficient evidence and analysis for determining whether to prepare an environmental impact statement or a finding of no significant impact, (b) aid the NRC's compliance with NEPA when no environmental impact statement is necessary, and (c) facilitate preparation of an environmental impact statement when one is necessary.

The commercial scale operation of the Irigaray site was previously evaluated in a Final Environmental Statement dated September, 1978 (NUREG-0481). This document and the NUREG evaluate the potential impacts associated with the commercial operation of the Irigaray site. Should the NRC issue a Finding of No Significant Impact, based upon the licensee's application materials and previous operational data, a source material license to commercially operate the Irigaray facility would be issued to WEC.

The Wyoming Department of Environmental Quality (WDEQ) administers and implements the State's rules and regulations. WEC has applied for and received a commercial permit for the site. Due to the operational changes associated with this renewal effort, the WDEQ is currently reviewing an updated WEC application.

### 1.3.2 Basis of USNRC Review

An impact appraisal for the commercial licensing of the Irigaray site has been performed by the USNRC, Uranium Recovery Field Office. This report documents that appraisal. The staff has performed the appraisal of environmental and safety considerations associated with the proposed license renewal in accordance with Title 10, Code of Federal Regulations (10 CFR Part 51, Licensing and Regulatory Policy and Procedures for Environmental Protection).

In conducting this appraisal, the staff considered the following:

- Environmental and operational information submitted by WEC for the research and developmental stages of the project, prior commercial operation of the site,and data collected during the standby status of the facility.

- Additional information submitted in the licensee's application for renewal.

- Information derived from professional papers, journals and text books; USNRC Regulations and Regulatory Guides; as well as other Federal, State and local agencies, and independent consultants.

## 2.0 SITE DESCRIPTION

### 2.1 Location and Land Use

The proposed commercial in situ facility is located in southeastern Johnson County, Wyoming, approximately 10 miles northeast of Sussex and 43 miles southeast of Buffalo (Figure 1.1.01). This will be the authorized place of use for the renewed license. The land at the proposed facility has historically been used for seasonal sheep and cattle grazing. The Irigaray property includes approximately 21,100 acres of leases and claims.

The various research and development phases of the Irigaray facility occupied approximately ten surface acres. Concurrent with the early stages of the site research, well fields were developed and divided into nine mining units. Of these mining units, five (Units 1-5) were partially commercially mined during previous operations. Currently, the facility contains approximately 1300 production and injection wells with an additional 200 monitoring wells. The overall site development covers 131 acres. To assure that potential environmental impacts do not go undetected, the licensee will be required by license condition to perform an environmental evaluation and notify the USNRC prior to any proposed changes to the facility.

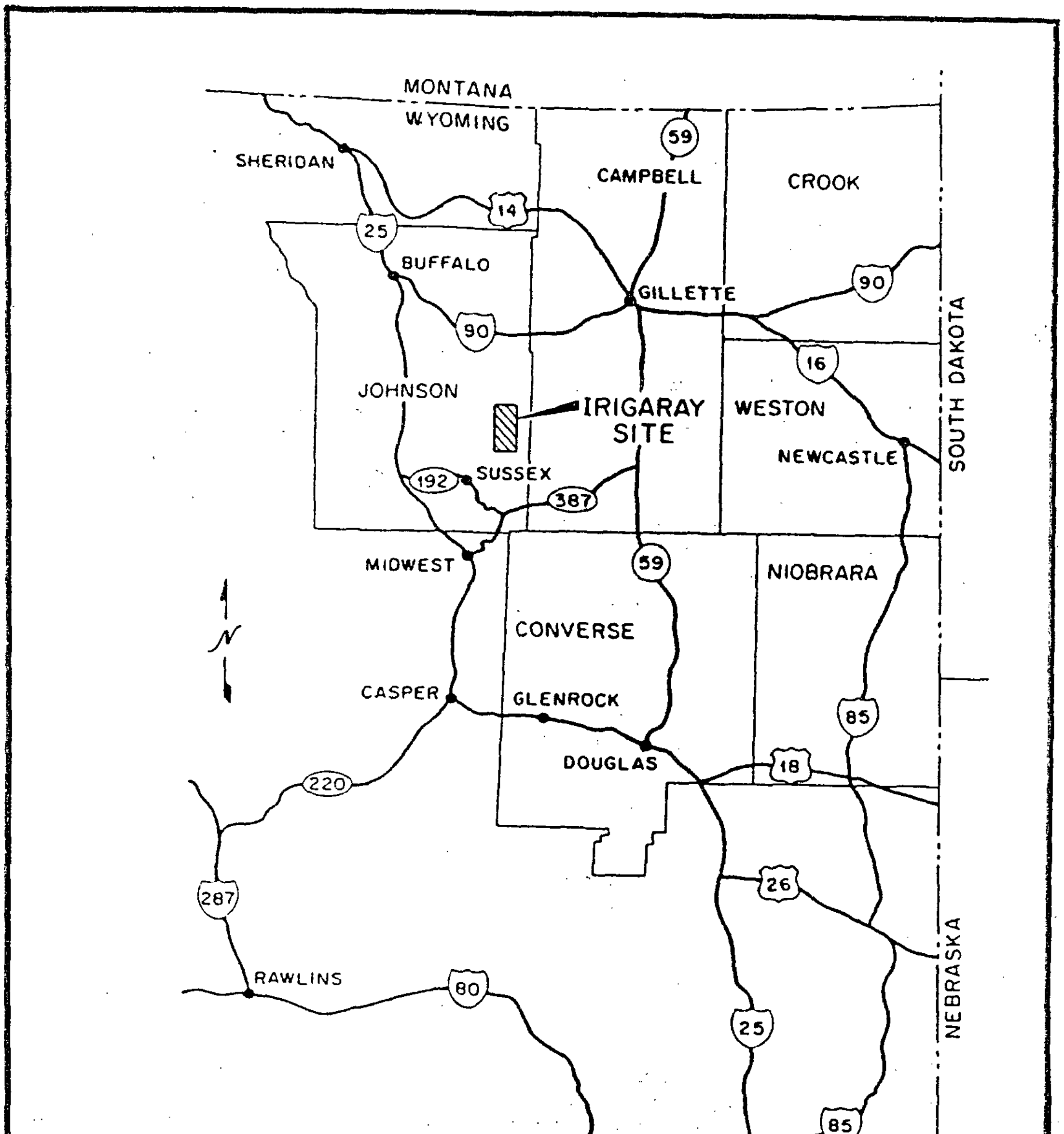


Figure 1.1.01

General Location Map

## 2.2 Geology and Hydrogeology of the Ore Body

### 2.2.1 Geologic and Hydrogeologic Setting

The Irigaray facility is located in the southern portion of the Powder River Basin. The land surface at the site is characterized by gently rolling uplands which have been extensively dissected. The Wasatch Formation is exposed at the ground surface and dips to the west at 1 to 2 degrees. Uranium mineralization occurs in the Upper Irigaray Sandstone. It contains three discontinuous zones which are enriched in uranium. These zones range from 5 to 320 feet in thickness. The sandstone is the result of a fluvial depositional environment which contains at least two periods of downcutting and subsequent filling (Figure 2.2.1-01).

The Upper Irigaray Sandstone is isolated from the underlying strata by a claystone which is approximately 60 feet thick. Overlying units indicate that a marine environment eventually invaded the area, resulting in the deposition of a coal seam, several discontinuous sands and an undifferentiated unit known as the Interburden Unit.

The Upper Irigaray Sandstone is a unit which is continuous over the site. It ranges from 75 to 120 feet in thickness. Overlying confinement was originally thought to be supplied by the claystone unit located stratigraphically above the Upper Irigaray Sandstone and below the coal seam. However, several months of operational data indicated that vertical excursions were taking place. Therefore, the claystone was proven to be a poor confining layer. As explained in subsequent text, a suitable confining layer was eventually found, tested and incorporated into the WEC submittal for license renewal. This zone is called the Interburden unit and lies stratigraphically above the coal zone and the original claystone confining unit.

### 2.2.2 Water Quality and Pump Testing

There are various water qualities at the Irigaray facility, each of which is dependent upon the strata which is being encountered as well as the individual mining unit. Due to these variabilities, the USNRC will require, by license condition, that Two (2) months prior to injection of lixiviant into a mining unit, the licensee submit for review and approval, baseline water quality data for the mining unit. The licensee will further be required by license condition to

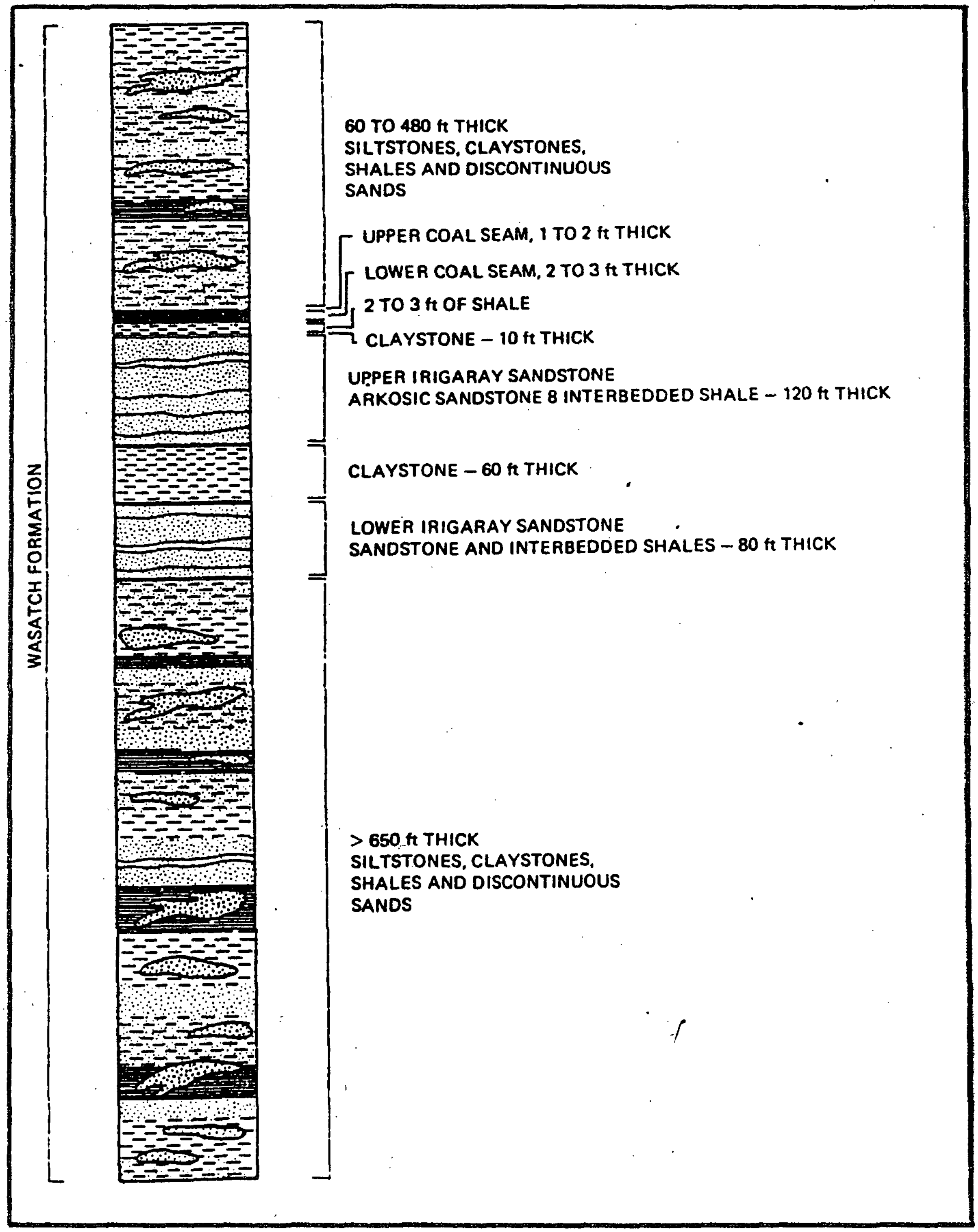


Figure 2.2.1-01

Typical Stratigraphic Section

utilize a representative number of wells from each mining unit for the determination of baseline water quality as well as for subsequent monitoring purposes. Appendix A details the parameters to be sampled.

Aquifer testing at the Irigaray facility during the early stages of commercial operation indicated that confinement was being supplied by the claystone underlying the Upper Irigaray Sandstone and the thin claystone overlying it. It became apparent from ground-water monitoring in the coal zone, which is stratagraphically above the overlying claystone, that vertical excursions were taking place. Due to this, the overlying claystone as well as the coal zone were incorporated into the production zone for restoration purposes. Concurrent with this decision, the NRC, WDEQ and the Irigaray staff reviewed drill logs as well as actual cores to determine if a suitable confining layer existed above the Upper Irigaray Sandstone. A layer which appeared to have adequate confining characteristics was found to lie above the coal zone. It was named the Interburden Unit and became the subject of aquifer testing.

Aquifer testing of the hydraulic characteristics of the Interburden unit, shown on Figure 2.2.1-01 as the unit above the coal zone, was conducted from July 15 to July 23, 1986. These tests indicated that adequate confining characteristics exist in the Interburden Unit as well as in the lower confining strata. Vertical hydraulic conductivities in both of these units were measured and calculated to be in the 10 E-7 cm/sec range. This aquifer test was specifically designed to test the integrity of production units 2 and 3. To be certain that favorable hydraulic characteristics exist throughout the remainder of the production units (4 through 9), as well as any subsequently developed mining units, the staff will include a license condition which will require the licensee to perform periodic aquifer tests.

### 2.2.3 Confinement of the Ore Zone

As has been previously discussed, confinement of the ore zone is accomplished by naturally occurring formations which have very low hydraulic conductivities relative to the mining zone. Confinement below the Upper Irigaray Sandstone has been demonstrated by the underlying claystone. Aquifer testing conducted in this zone indicates that its hydraulic conductivity is 10 E-7 cm/sec. Confinement above the Upper Irigaray Sandstone has recently been demonstrated by the aquifer test run in the Interburden Unit. The results of this test indicate that the hydraulic conductivity in this unit is also in the 10 E-7 cm/sec range.

Lateral confinement is accomplished by pumping of the recovery wells. This procedure maintains a small cone of depression around each production well. To ensure that lixiviant does not travel to areas of the formation where it would be considered to have caused an excursion, the staff will require by license condition that the monitor wells and trend wells be installed and sampled both above and below as well as around the perimeter of the mining units to determine if lixiviant has moved out of the mining units. Additionally, the staff will require that any confirmed excursion have a set of procedures by which corrective actions may be instituted. The results of these corrective actions will be required to be reported to the USNRC for review. To keep excursions at a minimum for the mined areas which have not undergone restoration (the 5I7 and USMT sites), the licensee will be required by license condition to monitor these areas and have appropriate mitigative action limits.

The licensee will also be required during perioda of operational suspension to maintain a minimal one (1) foot of drawdown over the entire well field. This action will keep the lixiviant within the well field area.

## 3.0 PROCESS DESCRIPTION

### 3.1 In Situ Leaching Process

In situ leaching of uranium is a relatively new addition to the list of conventional mining methods currently used to extract uranium. Basically, the in situ leaching method involves: (1) the injection of a leach solution (lixiviant) into a uranium-bearing ore body to oxidize the uranium, (2) the mobilization by complexing the uranium, with a chemical carrier, and (3) surface recovery of the solution bearing the uranium complex via recovery wells. Uranium is then separated from the leach solution by conventional milling unit methods (ion exchange) in a surface facility. The barren solution, which carries some unutilized lixiviant is then returned to the mining zone for additional uranium recovery. This cycle continues until the ore zone is depleted or the uranium is no longer feasible to recover.

There can be many environmental advantages to in situ leaching of uranium. Conventional extraction methods, which usually result in large amounts of spoil and tailings, can produce a significant impact on the environment. However, if hydrogeologic conditions are favorable, the impacts from solution mining are much less. The greatest impact of the in situ leach extraction method is to the ore zone ground-water quality which, in most instances, can be restored to baseline quality, premining quality use, or potential use category. Compared with the conventional uranium mining and milling operations, in situ leaching will also permit economical recovery of currently unrecoverable, deep, low-grade sandstone uranium deposits. The extent to which in situ mining can be conducted is limited in that the ore zone conditions must be suitable for containing and controlling leach solutions during the mining process. The ore body at the Irigaray site, based upon past mining as well as recent testing, appears to exhibit favorable mining characteristics.

## 3.2 The Ore Body

At the Irigaray site, the Upper Irigaray Sandstone contains a roll front uranium deposit which is generally associated with fluvial sandstones. The mineral in the ore is concentrated by uranium-rich, oxidized ground water moving down the hydrologic gradient into a reducing environment. The interface is referred to as the oxidizing front. The physical shape of an ore zone is dependent on the local permeability of the matrix material and its continuity and distribution in the geologic unit. Such ore bodies are prevalent in most of the established uranium mining districts in the western United States. In situ leaching, however, can be conducted only on those ore deposits that meet certain criteria. These generally include: (1) the ore deposit must be located in a saturated zone, (2) the ore deposit must be confined both above and below by low permeability zones, (3) the ore deposit must have adequate permeability, and (4) the ore deposit must be amenable to chemical leaching.

The ore of the Upper Irigaray Sandstone at the Irigaray site appears to have been deposited as described above. Previous operational data confirms that the deposit has the chemical characteristics necessary to allow in situ leaching of uranium. Aquifer pump testing indicates the ore zone is saturated, permeability is adequate, and the ore zone is adequately confined. The ability of the aquitards to confine lixiviant movement to the ore zone and the reaction of the deposit to chemical leaching have been verified during the R&D testing as well as the previous commercial operations. Continued operation of the well field will verify the confining characteristics of the recently tested Interburden Unit.

## 3.3 Well Field Design and Operation

The operation of several test sites at the Irigaray facility, as well as the commercial operation of the mining units 1 through 5, have yielded a considerable amount of data from the ore zone as well as neighboring strata. Due to previous mining operations, approximately 1300 injection and production wells have been installed in a north-south trending valley. An additional 200 monitoring wells have been installed in, above, below and around the mining zone. The overall mining area is divided into nine mining units, each of which consist of at least 20 seven-spot patterns. Generally, the patterns consist of a single centrally located production well with a ring of six injection wells. In places, especially along the perimeter of the mining units, this configuration deviates from this pattern. A representative portion of the well field is shown in Figure 3.3-01. Figure 3.3-02 shows the location of the mining (production) units in relation to the remainder of the facility.

WEC proposes to progressively recover uranium from the individual mine units. Upon completing the mining process in a mining unit, WEC will recirculate lixiviant-rich solution into the next mining unit and begin the ground-water restoration process in the mined-out unit. This process will sustain itself until all mining units have been depleted of uranium. At this time, the licensee will either apply for additional mining authorization or decommission and abandon the site.

The injection and production wells for the most part have open hole completions. The Upper Irigaray Sandstone, in the developed mining units, is generally compentent enough that the well bore will remain open without casing. Due to this completion method, the injection wells are open hole completed over intervals ranging from 5 to 20 feet. Production wells have open hole completions over intervals ranging from 20 to 60 feet.

In addition to the production and injection wells, monitor and trend wells are located laterally along the perimeter of the mining units. These wells will be utilized in collecting water quality data as well as monitoring potential lixiviant movement out of the mining units. Baseline water quality data will be obtained for selective wells. This data will serve as the basis to determine if any unexpected lixiviant movement has taken place. These wells will also be used to monitor the success of any corrective action programs instituted by the licensee.

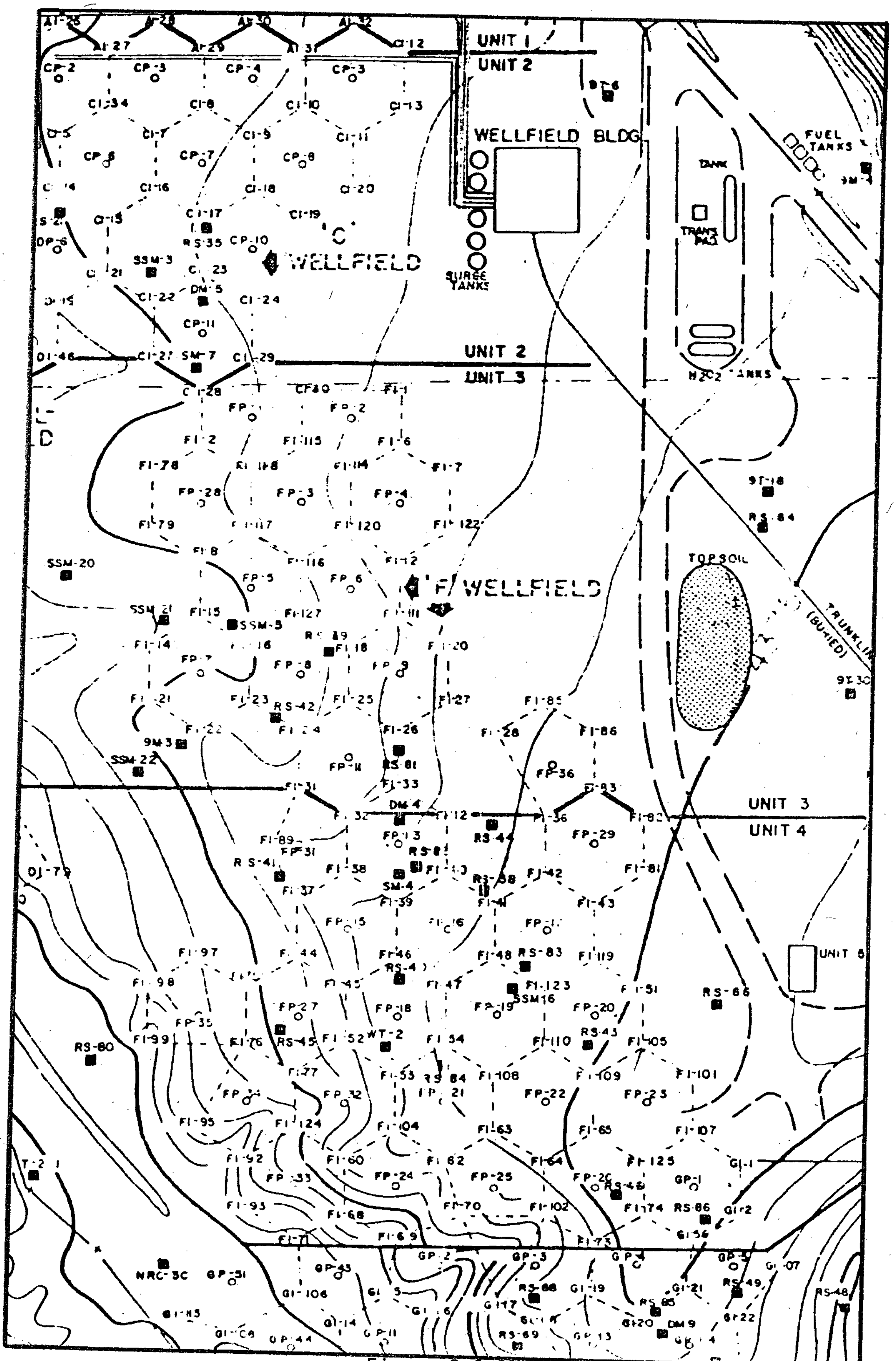


Figure 3.3-01
A representative portion of the well field area

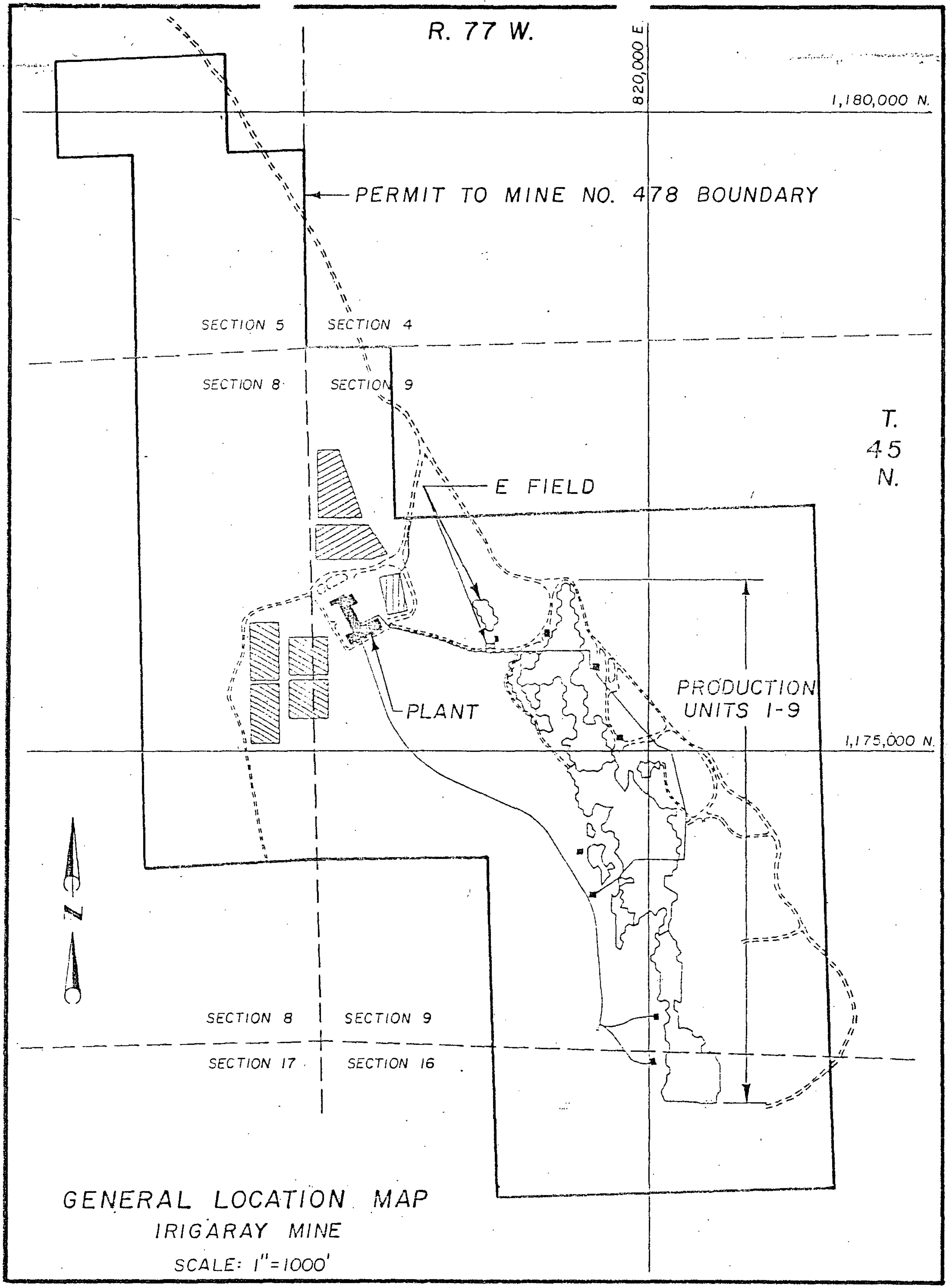
R. 77 W.
820,000 E.
1,180,000 N.
PERMIT TO MINE NO. 478 BOUNDARY
SECTION 5
SECTION 4
SECTION 8
SECTION 9
T.
45
N.
E FIELD
PRODUCTION
UNITS 1-9
PLANT
1,175,000 N.
N
SECTION 8
SECTION 9
SECTION 17
SECTION 16
GENERAL LOCATION MAP
IRIGARAY MINE
SCALE: 1"=1000'

Figure 3.3-02

During operation of the facility, as part of the semiannual reporting requirement, WEC will be required to provide the facility's operating data. All operational data will be reported including flow rates, chemical balance and injection pressures and will be summarized in the semiannual report. The detailed operational data will be maintained on-site and be required to be available for USNRC inspection.

WEC will be required by license condition to verify the integrity of all wells by performing casing integrity tests on the wells put into service. All wells are to be tested at a pressure which simulates the maximum anticipated operating pressure of the well plus a 10 percent factor of safety. If no more than a 10 percent drop in pressure occurs after at least 10 minutes of testing, the well casing will be determined to be mechanically sound. During operation, wellhead pressures shall not exceed the well integrity test pressure. Furthermore, the licensee will be required to retest any well which has undergone cleaning or service in any way which may have damaged the casing. WEC will also be required by license condition to appropriately abandon any well which fails the integrity testing procedure.

3.4 Lixiviant Chemistry

The proposed leach solution or lixiviant to be used for dissolution and recovery of uranium at the Irigaray facility is a sodium bicarbonate solution. Oxidation of the formation will be provided by adding oxygen and/or hydrogen peroxide. Previous mining operations and restoration tests have demonstrated that this lixiviant will recover uranium and while leaving the production zone in such a state that restoration of the affected water will be successful. Due to this, use of any other lixiviant or oxidant will be prohibited by license condition.

A magnesium based lixiviant is also being tested at a neighboring in situ facility. WEC may, based upon the results at this facility, propose to utilize such a lixiviant. Such a process change would require staff review as well as subsequent license amendment.

3.5 Uranium Recovery Process

The uranium recovery process involves three primary steps: (1) uranium adsorption; (2) resin elution; and (3) precipitation of uranium. The following discussion provides more detail.

Uranium solubilized and recovered as a carbonate complex will be produced from the well fields and directed at a flow rate equal to, or less than, the authorized maximum design plant capacity of 1600 gpm to the ion exchange circuit. This circuit consists of resin beads loaded into ion exchange columns. During the solution contact time, the uranium is adsorbed to the resin beads. Following this, the solution leaving the ion exchange unit is refortified with bicarbonate and dissolved oxygen and reinjected into the mining units to repeat the leach cycle.

Upon fully loading the resin with uranium, it is transferred to the elution circuit. During this process, the uranium is stripped from the resin beads with a strong solution of sodium bicarbonate and sodium chloride. This process results in a yellowcake slurry. The slurry enters the liquid/solid separation unit where it is washed and dewatered. The slurry will then be either trucked to a processing facility or dried and packaged on site. A scheamtic flow diagram of the process circuit is shown in Figure 3.5-01.

WEC has indicated that contracts for yellowcake slurry as well as dried product have been signed. Due to this, the process circuit may utilize the drying and packaging units. The drying unit is housed in a controlled area of the mill which is adjacent to the process area. Access to the drying facility is controlled by a change area where employees are required by license condition to monitor themselves for alpha contamination. Furthermore, should an employee fail to successfully alpha monitor, decontamination procedures will be followed prior to exiting the facility.

The exhaust system for the dry/pack area is equipped with a filtration scrubber system. It is designed to have a minimum overall yellowcake particulate removal efficiency of 95 percent. The system consists of a wet Venturi scrubber which captures solids. The solids are then removed to a mesh pad separator section. The cleaned gas exits the top of the separator through an induced draft fan and is discharged to the atmosphere through the stack. Previous operational data indicates that the scrubber meets the 95 percent efficiency rate and that radionuclide releases to the environment are being held to approximately 31 percent of maximum permissible concentrations for restricted areas. Additional data and discussion on the scrubber and atmospheric releases are contained in the accompanying Safety Evaluation Report, as well as in Appendix B of this report.

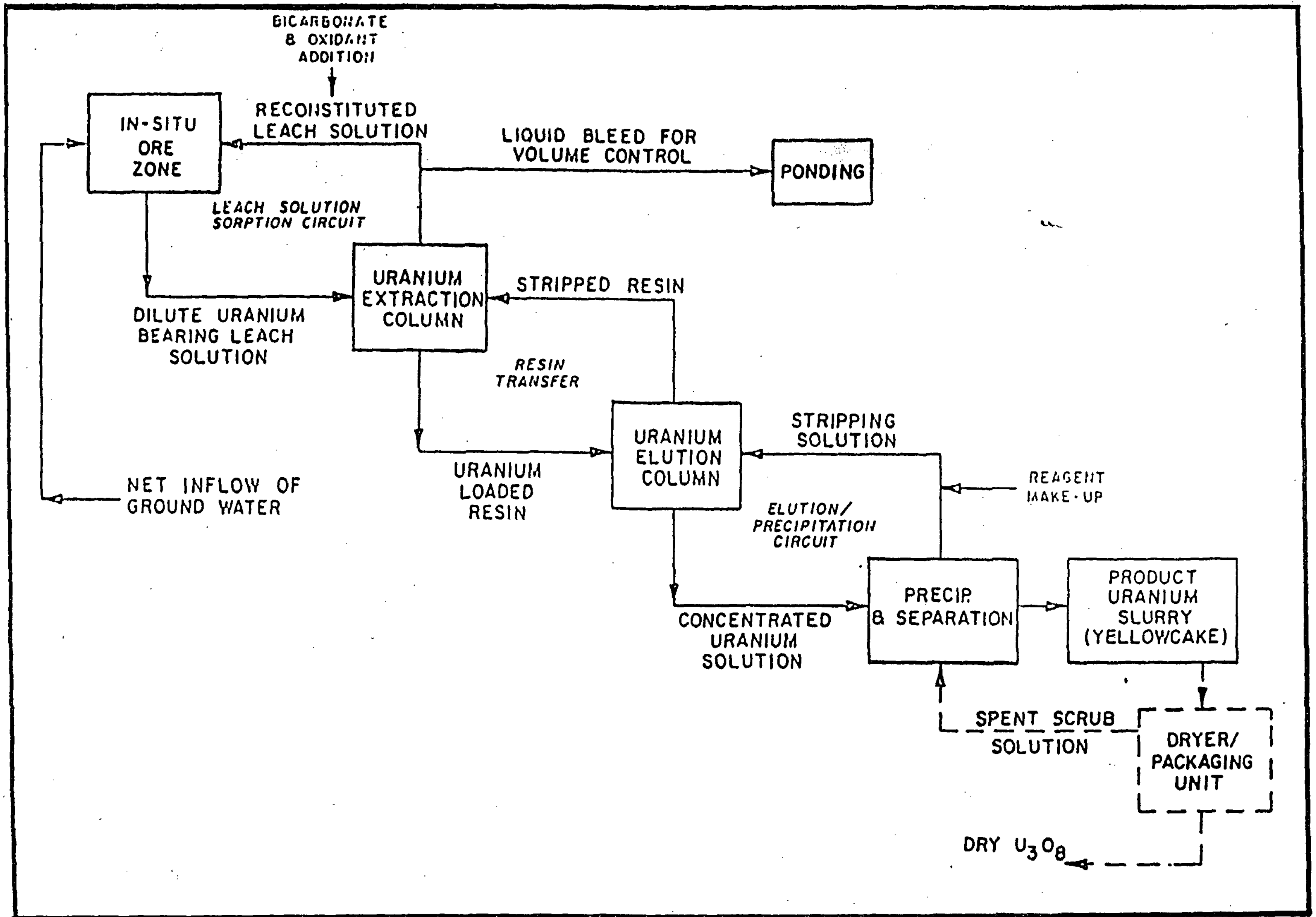
BICARBONATE & OXIDANT ADDITION
IN-SITU ORE ZONE
RECONSTITUTED LEACH SOLUTION
LIQUID BLEED FOR VOLUME CONTROL
PONDING
LEACH SOLUTION SORPTION CIRCUIT
URANIUM EXTRACTION COLUMN
STRIPPED RESIN
DILUTE URANIUM BEARING LEACH SOLUTION
RESIN TRANSFER
URANIUM ELUTION COLUMN
STRIPPING SOLUTION
REAGENT MAKE-UP
NET INFLOW OF GROUND WATER
URANIUM LOADED RESIN
ELUTION/ PRECIPITATION CIRCUIT
PRECIP. & SEPARATION
PRODUCT URANIUM SLURRY (YELLOWCAKE)
CONCENTRATED URANIUM SOLUTION
SPENT SCRUB SOLUTION
DRYER/ PACKAGING UNIT
DRY U3O8

Figure 3.5-01

## 3.6 Description of Process Plant and Support Facilities, Ponds, and Wastes

### 3.6.1 The Process Plant and Support Facilities

The processing equipment (process tanks, ion exchange columns, dry pack area, piping systems and pumps as well as electrical equipment) are all housed in the process building. As mentioned above, the process building is divided into two main areas: the dry/pack area, which has controlled access, and the general process area. All process solution tanks are enclosed in the process building. Those tanks where radon may build up are vented to the atmosphere. Any overflow of liquids from the various process tanks would be controlled via floor drains and process sumps which ultimately return the liquids to the process circuit or the solar evaporation ponds. The process building is vented to allow for three air exchanges per hour. This will ensure that radon released from the process circuit will be discharged to the atmosphere, rather than allowed to build up in the plant.

Additional surface installations consist of fuel storage tanks, the solar evaporation pond system and the office building area. All shower, sink and lavatory effluent wastes will be disposed of in a septic system and ultimately to a leach field. To ensure that contaminated releases to the environment are held to a minimum, the licensee will be required by license condition to return to the process circuit or dispose of all waste solutions with the exception of sanitary wastes, in the solution evaporation ponds.

### 3.6.2 Solar Evaporation Ponds

Currently, seven evaporation ponds exist at the site. These ponds have been utilized during previous operations and have been adequate to handle the bleed volume as well as other aqueous wastes. All of the ponds are rectangluar in shape, earth bermed and lined with 30 mil nylon-reinforced Hypalon. Additionally, four small ponds at the USTM and 5I7 R and D test sites remain. These ponds have been idle for several years and are intermittently utilized to dispose of water solutions when the test sites require pumping. The staff will require by license condition that the licensee submit a mining plan for these sites within one (1) year of license issuance, or a plan for immediate reclamation of the ponds as well as restoration of the test patterns.

Detailed information on each evaporation pond is listed below. The licensee will be required by license condition to maintain the specified freeboard requirements for each evaporation pond. To ensure that any potential leaks do not go undetected and the ponds are maintained according to proper engineering principals, the licensee will be required by license condition to check the evaporation pond leak detection systems as well as the fences and embankments on a daily frequency.

Any waste disposal technique other than the existing waste storage ponds will constitute an amendment to the proposal and therefore require USNRC review and approval.

| POND ID | SIZE | DEPTH (Feet) | FREEBOARD (Feet) | FREEBOARD CAPACITY (Acre/Ft) | TOTAL CAPACITY (Acre/Ft) | EVAPORATIVE CAPACITY (Acre/Ft/Yr) |
|---|---|---|---|---|---|---|
| E | 100x250 | 6 | 2 | 2.7 | 4.4 | 2.73 |
| B | 250x250 | 6 | 2 | 6.3 | 9.9 | 6.03 |
| D | 250x250 | 6 | 2 | 6.3 | 9.9 | 6.02 |
| A | 160x390 | 6 | 2 | 6.3 | 10.0 | 6.12 |
| C | 100x390 | 6 | 2 | 6.3 | 10.0 | 6.12 |
| RA | 100x250 | 20 | 8 | 19.8 | 39.9 | 6.10 |
| RB | 250x250 | 20 | 8 | 19.8 | 39.9 | 6.10 |
| TOTALS | | | | 67.5 | 124.0 | 39.22 |

As previously discussed, the evaporation pond leak detection systems will be checked daily to insure that the pond liner is not leaking. Should the leak detection system have water in it, the water will be required by license condition to be analyzed for chloride, alkalinity, uranium, sulfate and conductivity to determine if the pond is leaking. If a leak is confirmed, the licensee will be required by license condition to institute repairs. Water quality samples taken at the standpipes will continue to be sampled every 7 days or more frequently if conditions warrant during any leak period, and for 2 weeks following repair if any residual liquid is in the standpipes. If the leak is significant and conditions warrant it (i.e., large losses of very poor quality waste water to the subsurface), the NRC may at that time require the installation, pumping and sampling of wells to monitor the situation and recover the fluid. The NRC will be notified immediately if fluid found in the standpipe exceeds Wyoming Drinking Water Standards for any of the parameters.

The licensee will be required to take corrective action in the case of a leak, such as transferring the contents from one pond to another. The previously mentioned freeboard requirements are designed to allow sufficient capacity for the transfer of the contents from one pond to another. Additionally, the licensee will be required to immediately notify the USNRC of any pond failure as well as file a report with the NRC describing the leak and appropriate corrective actions, within 30 days of the event.

### 3.6.3 The Wastes

Liquid waste from the in situ mining operation will primarily consist of the bleed stream (see Figure 3.5-01). The bleed stream will consist of liquids from four components: excursion control, elution water, well cleaning and monitor well wash. Depending upon the mill throughput, the bleed stream will vary from an operational low of approximately 10.6 gpm to a maximum of approximately 22 gpm. The evaporation ponds discussed above have been sized to handle waste volumes in this range.

Solid wastes will also be generated by the mining and milling process. Waste materials such as rags, trash and other solid materials which are contaminated will be treated as byproduct materials, stored in a secure area as required by license condition and disposed of in an authorized mill tailings pond or other NRC-approved disposal area. Waste materials which are not contaminated will be disposed of in a land fill.

Solid residues, as a result of the various bleed streams, will remain in the evaporation ponds until abandonment of the facility. These byproduct materials will then be disposed of in an NRC-approved disposal area.

To ensure that no materials leave the site without proper verification of contamination levels, the licensee will be required to survey all materials to be released. All surveys will be required to be in accordance with the release criteria attached to the source material license.

## 3.7 Ground-Water Restoration, Reclamation and Decommissioning

### 3.7.1 Ground-Water Restoration

Restoration is defined as the returning of affected ground water to its baseline condition or to a condition consistent with its premining use (or potential use) upon completion of leaching activities. Restoration is intended to reduce the concentration of toxic contaminants remaining in the ground water to acceptable levels. The licensee will be required by license condition to meet these minimal restoration goals.

The preferred restoration procedure is restoring mined-out mining units while uranium recovery is proceeding in neighboring mining units. As a mining unit moves into the restoration stage, the first phase of restoration will be a clean water recycle. In this phase, the aquifer will be swept from the edges of the mining zone into the center of the well field by injecting clean water at the edges and pumping the center. The well field water will then be treated by a combination of reverse osmosis and ion exchange. This will result in an 85/15 water split. That is, the evaporation ponds will be utilized to store 15 percent of the water containing the majority of the contaminants, while 85 percent of the water will be returned to the mined aquifer. Due to this split, the volume of waste generated will be proportional to the amount of the mined area that is undergoing restoration.

Previous restoration work in the E-field indicates that the water in the mined zone may have to be recycled and treated up to 15 times to produce water quality meeting restoration criteria. During mining operations, premining baseline water quality generally has its chemical and radionuclide contents elevated many times over. Previous monitoring data indicates that the water quality can be expected to change as shown below.

IRIGARAY E FIELD WATER QUALITY

| | PRE-MINING | POST-MINING | RESTORATION |
|---|---|---|---|
| Alkalinity | 98.6 | 2,909 | 104 |
| Bicarbonate | 74.4 | 3,553 | 100 |
| Chloride | 11.7 | 317 | 11.9 |
| pH (units) | 9.2 | 7.2 | 8.6 |
| Sodium | 117.0 | 1,475 | 124 |
| Sulfate | 185.4 | 75.3 | 192 |
| TDS | 375.1 | 3,764 | 386 |
| Conductivity (umho/cm) | 633.0 | 5,303 | 655 |
| Calcium | 9.5 | 85.3 | 7.8 |
| Magnesium | 1.0 | 21.6 | 0.97 |
| Potassium | 2.5 | 7.0 | 1.5 |
| Silica | 8.7 | 17.0 | 3.9 |
| Barium | <.005 | 0.10 | <.01 |
| Nickel | <.01 | 0.03 | <.01 |
| Selenium | <.002 | 0.24 | <.01 |
| Vanadium | <.05 | 0.48 | <.01 |
| Uranium | 0.03 | 33.5 | 0.04 |
| Ra-226 (pci/l) | 39.6 | 511 | 11.1 |

The restoration work done in the E-Field indicates that the majority of the monitored ground-water parameters can be reduced to baseline concentrations or class-of-use standards. An indepth review completed by the USNRC indicates that $CO_3$, alkalinity, radium and sodium were generally the most difficult parameters to restore to baseline or class-of-use standards in the E-field.

To assure that restoration activities return the ground water to baseline or class-of-use standards, each mining unit will have baseline water quality collected. As a condition of the renewed license, the licensee will be required to determine baseline concentrations as a basis for restoration water quality. Additionally, the licensee will also be required by license condition to restore the ground water to acceptable levels based upon an average of the monitored parameters in each mining unit.

### 3.7.2 Reclamation and Decommissioning

At the completion of all leaching and restoration activities, the licensee will decommission the uranium recovery facilities and reclaim all land affected by leaching operations.

The basic reclamation plan involves disassembly and removal of all plant buildings and ancillary facilities. Pending decontamination procedures and the land owner's desire, some buildings may remain. Concurrent with these activities, the well field area will be ripped, and stockpiled topsoil will be replaced to those areas which had it removed.

Injection, production, monitoring, trend and research wells will be sealed and plugged with concrete from the bottom to within 3 to 4 feet of the surface. The well casings will then be cut off flush with the top of the plug. This leaves a hole of approximately casing diameter, 3 to 4 feet deep, which will be backfilled with adjacent suface materials.

Gravel from well field roads will either be removed and distributed over permanent access roads, used as backfill materials or returned to the private quarry from which it was obtained.

Final slopes of a prepared seed bed will approximate original premining contours. All waste, evaporation and restoration ponds on the site will ultimately be filled, graded and revegetated. Remaining pond residues as well as pond liners will be treated as contaminated materials and disposed of accordingly.

To ensure that well field restoration and abandonment work meets the appropriate requirements for unrestricted release, the licensee will be required by license condition to submit a proposal for a decontamination plan. Additionally, the staff will independently obtain representative soil samples to verify that the licensee has met appropriate closure standards.

The licensee will also be required by license condition to maintain a bond sufficient to cover the estimated well field abandonment, restoration, decontamination and reclamation costs. The bond will be required to be in a form that is acceptable to both the USNRC and the Wyoming Department of Environmental Quality, Land Quality Division.

## 4.0 EVALUATION OF ENVIRONMENTAL IMPACTS

### 4.1 Introduction

In situ leaching of uranium is a relatively new and developing technology. Major human health and environmental concerns with this technique of mining are the potential impacts of mining on ground-water quality, the impacts of potential evaporation pond leakage, radiological impacts and disposal of wastes.

## 4.2 Ground-Water Impacts

### 4.2.1 Excursions

Excursions of contaminated ground water in a well field can be due to improper balances between injection/extraction rates, undetected high permeability strata or geological faults, improperly abandoned exploration drill holes, discontinuity and unsuitability of the confining units to prevent movement of lixiviant out of the ore zone, cracked well casings and faulty well construction and hydrofracturing of the ore zone or surrounding units. There have been numerous excursions at the Irigaray site. The majority of these excursions have been due to improper abandonment of exploration drill holes. In response to this, the licensee instituted a program of locating and plugging abandoned drill holes. Since that effort, the number and frequency of excursions have dwindled.

Additional excursions were noted in wells monitoring the coal zone, a strata overlying the production zone. The causes for these excursions were twofold. First, the upper control limits for the excursion monitoring wells were based upon a limited data base. Further observations of this data base indicated that a true mean was not calculated. Due to this, normal fluctuations were responsible for many of the excursions. The second cause of the coal zone excursions was due to the poor confining characteristics associated with its underlying strata. Subsequent aquifer testing, as discussed in Section 2.2.2, indicates that adequate confinement of the original mining zone did not exist. Therefore, the excursions were to a certain extent, predictable. Based upon the poor confinement, the licensee requested that the coal zone be incorporated into the production zone and that demonstration of confinement be based upon the recently tested Interburden Unit. As previously discussed, the Interburden Unit has proven to be an acceptable confining unit.

### 4.2.2 Evaporation Pond Seepage and Spills

Accidental leaks from the evaporation ponds could, if uncontrolled, contaminate shallow aquifers and locally reduce ground-water quality. The quality control and the maintenance programs associated with the installation of the impermeable synthetic bottom liners in the solar evaporation ponds should eliminate such seepage. Furthermore, if a pond leak were to develop, the monitoring program described in Section 3.6 would allow for early detection and repair of the leak; thereby minimizing the impacts and the quantity of leakage. Previous operational history indicates that no major pond leaks have occurred. However, one evaporation pond routinely gets water in the leak detection system. Laboratory analysis of the fluid indicates that the source of the water is local runoff and subsequent recharge of the unit where the leak detection system is constructed.

Spills from the evaporation ponds resulting from dam failure could result in unacceptable contamination of surface and ground water. However, since pond effluent water levels will be controlled with adequate freeboard requirements, the likelihood of a dam failure is very remote. Furthermore, the monitoring incorporated into this license will provide early warning of embankment fatigue and potential dam failure situations.

### 4.2.3 Restoration of Ground Water

Ground-water restoration will include ground-water removal from the ore zone and any other zones contaminated by lixiviant migration. This may, if necessary, be followed by treatment to remove contaminants from ore zone water, with subsequent reinjection of the treated ground water. Past experience has shown that restoration of ground water to premining conditions is feasible. The staff believes that commercial operation of the Irigaray facility and subsequent ground-water restoration will result in water quality being returned to baseline concentrations or to the premining class-of-use.

## 4.3 Radiological Impacts

### 4.3.1 Introduction

Estimates of radiation doses from the operation and the steps taken by the licensee to minimize doses are considered in this section. Individuals living in the area may be potentially exposed to minor amounts of airborne radionuclides or radioactive material on the land surface or in the ground water.

4.3.2 Offsite Impacts

The release of airborne radioactive particles to the atmosphere from this in situ operation are substantially lower than those occurring at a conventional uranium mining/milling operation since only solutions are brought to the surface during mining and there is a lesser amount of product drying. Radon will be released from leach solutions and vented from the building to the atmosphere. Because these releases will be small, there will be no significant radiological impacts offsite. More specifically, based on the MILDOS computer program and its associated calculated exposures, the effluent limits specified in 10 CFR 20 and 40 CFR 190 will not be exceeded. A considerable discussion on radiological impacts is contained in Appenxix B to this report.

The estimation of radiation doses resulting from operation of the Irigaray facility are based on operational data supplied by WEC. Estimates of doses did, however, assume exposure to contaminated air and ground 100 percent of the time. A similar situation was considered in the food pathway.

The radiological impact of the routine releases of radionuclides was assessed by estimating radiation dose commitments to individuals and a population from the resultant exposure. Since radioactive materials taken into the body by inhalation and ingestion continuously irradiate the body until removed, the estimate of the total dose an individual will receive from 1 year's intake is integrated over 50 years (remaining lifetime of the individual) and is called a dose commitment. All of the internal doses estimated represent 50-year dose commitments. For those materials which have a short radioactive half-life or those, such as uranium, which are eliminated rapidly from the body, essentially all of the dose is received in the year in which the radionuclide enters the body; therefore, the annual dose rate is about the same as the dose commitment.

The primary sources of radiological impact to the environment in the vicinity of the plant are naturally occurring cosmic and terrestrial radiation and naturally occurring radon-222. The average annual total-body dose rate from natural background radiation to the population in the site vicinity is estimated to be about 174 millirems.

The release of radon gas and uranium particulates to the atmosphere are assumed to be the primary mode of environmental contamination. These concentrations are shown below.

Release Rates of Radionuclides from the Irigaray Well Field and Recovery Plant

| | Estimated Releases (Curies/year) | | | | |
|---|---|---|---|---|---|
| Source Description | U-238 | Th-230 | Ra-226 | Pb-210 | Rn-222 |
| Yellowcake Dryer | 1.22E-1 | 6.10E-4 | 1.20E-4 | 1.20E-4 | 0 |
| Well Fields | 0 | 0 | 0 | 0 | 1.55E+3 |
| Evaporation Ponds | 0 | 0 | 0 | 0 | 3.5 E-3 |

#### 4.3.2.1 Dose to Individuals

The estimated radiation dose at a reference point depends on the distance and direction of the point with respect to the source as well as the wind direction. Doses are higher at locations downwind from the plant. As radon is transported offsite, its daughters grow, which potentially results in higher dose commitments farther from the plant.

The maximum annual dose commitments would be received by individuals living at the Reculusa Ranch, the nearest residence to the plant site. The ranch is 6.6 km (4.1 miles) west-southwest of the recovery plant.

The highest organ dose is estimated to be 0.0022 millirem per year to the lung resulting from uranium releases associated with yellowcake drying and packaging and 0.02 millirem per year to the bronchi from radon progeny. Other organ doses and the total body dose are much lower.

These predicted annual individual dose commitments, as shown in Table BB-2 (Appendix B), are only a small fraction of the present NRC dose limits for members of the public, as specified in 10 CFR Part 20, "Standards for Protection against Radiation." A comparison of the predicted annual dose commitments to individuals from operations of the Irigaray project with present NRC limits can be compared with the Environmental Protection Agency's (EPA) Radiation Protection Standard (40 CFR Part 190), see Table BB-2 (Appendix B).

The maximum annual dose commitments are also shown for individuals living in Sussex which is 25.1 km southwest of the facility. The maximum organ dose is estimated to be 0.00037 mrem per year to the lung. Whole body doses averaged 4.3 times less than the doses estimated for the Reculusa Ranch.

#### 4.3.2.2 Dose to the Population

The annual dose commitments from the airborne effluents to the population living within 80 km (50 miles) of the facility are summarized in Table BB-3 (Appendix B). The whole body dose commitment calculated was 0.0015 person-rem/year. The comparable dose from natural background in the same area is 2927 person-rem/year. The highest population organ dose was 0.013 person-rem/year to the bone. This person rem dose is 3.7E-4 percent of the natural background dose to the bone for the area.

All population doses are quite low due to the relative isolation of the project from the nearest residences and, because the population density for the area is very low (only 16,822 persons live within 80 km [50 miles] of the site).

Doses to people living within 80 km and beyond 80 km of the project site are contained in Table BB-4 (Appendix B). These totals are compared to the natural background doses for the respective areas. As can be seen, doses resulting from operation of the Irigaray project are only small fractions of the natural background dose contribution.

Table 3 in Appendix B presents the airborne concentrations of radionuclides at eight restricted area boundary locations, located from 0.05 to 0.071 km from the yellowcake stack. The restricted area air concentrations are compared to the maximum permissible concentrations (MPCs) for each radionuclide. Additionally, the sum of the fractions of MPCs are presented for each location. The staff reviewed the results of modeling the restricted area boundary concentrations based on boundary distances ranging from 0.05 km to 1.5 km from the yellowcake stack. In no case did the sum of the radionuclide concentrations exceed 1 MPC. Therefore, the model indicates an acceptable restricted area boundary exits at 163 feet from the yellowcake stack in any direction.

### 4.3.2.3 Radiological Impact on Biota other than Man

Although no guidelines concerning acceptable limits of radiation exposure have been established for the protection of species other than man, it is generally agreed that the limits for humans are also conservative for other species. Doses from gaseous effluents to terrestrial biota (such as birds and mammals) are quite similar to those calculated for man and arise from the same dispersion pathways and considerations. Because the effluents of the facility will be monitored and maintained within safe radiological protection limits for man, no adverse radiological impact is expected for resident animals.

Additionally, the licensee will conduct an environmental monitoring program that will evaluate the concentrations of radionuclides in the environment that could lead to offsite exposures (See Section 5.2). The staff considers that the environmental monitoring program will be sufficient to evaluate the radiological impact of the in situ leach operations at the Irigaray site.

### 4.3.3 In-Plant Safety

The licensee will establish and conduct an in-plant radiation safety program. The staff, through license conditions, is requiring a program that contains the basic elements required for and found to be effective at, other uranium recovery operations to assure that exposures are kept as low as reasonably achievable (ALARA). The scope of the program has been based upon previous operational data. Due to this, a rather complete understanding of the operation and potential radiation hazards has been developed. Therefore, an in-plant radiation safety program including the following will be required:

- airborne and surface contamination sampling and monitoring;
- personnel exposure monitoring;
- qualified management of the radiation safety program and appropriate training of personnel;
- written radiation protection procedures; and

- periodic audits by individuals meeting certain qualifications and frequent inspections to assure the program is being conducted in a manner consistent with the ALARA philosophy.

The staff considers the program of in-plant safety, as required by license conditions, is sufficient to protect in-plant personnel by keeping radiation exposures as low as reasonably achievable. The staff evaluation of this program and the associated license conditions are contained in the accompanying Safety Evaluation Report.

### 4.4 Waste Disposal

The USNRC has taken the position in its regulations on uranium milling 10 CFR 40, Appendix A, Criterion 2, that the small volume of wastes generated at in situ operations should preferably be disposed of at existing tailings disposal sites or other licensed burial grounds to avoid proliferation of waste sites. The staff will require that the solid wastes generated at the Irigaray site, as described in Section 3.6.3, be disposed of at an existing licensed tailings disposal site.

### 4.5 Surface Discharges

No surface water discharges are currently planned for the Irigaray site. Should the licensee propose to increase the capacity of the facility, additional waste water disposal facilities will be required. Any changes to the process evaluated within this document will require amendment to the source material license.

## 5.0 MONITORING

### 5.1 Ground Water

#### 5.1.1 Water Quality of the Well Fields

At the Irigaray site, approximately 1500 wells have been installed. The majority of these wells are injection and production wells. However, other wells exist which can be utilized in evaluating the well-field performance. The well field has been drilled on a seven-spot configuration. Scattered throughout the various mining units are monitor wells designed to detect vertical migrations of lixiviant. Additionally, trend and monitor wells encircle the mining units. These wells are installed in such a manner to determine if lixiviant is migrating laterally from the production area.

The licensee's proposed monitoring program includes utilization of monitor wells within the well field on a frequency of approximately one well per acre as well as wells on the well field margin. The production zone monitor wells will be monitored every 2 weeks for water level, conductivity, chloride, total alkalinity and sulfate. The wells will be pumped to displace at least one casing volume and the water analysis performed on-site within 48 hours. If these indicator parameters exceed the upper control limits, the injection and production rates will be adjusted as necessary to draw the excursion fluids back into the leach area.

Upper control limits (UCLs) will be set for each well based upon data collected from that well. UCLs for wells monitoring the production zone will be set at a criteria percentage above baseline for total alkalinity, As, $CaCo_3$, conductivity and chloride. Although sulfate concentrations and water levels will be monitored, they will not be utilized as excursion indicators.

As required by license condition, if any two excursion parameters exceed the upper control limits (UCL) or if one excursion parameter exceeds its UCL by 20 percent and is confirmed by analyses of verification samples taken within 48 hours after results of the first analyses are received, an excursion will be declared. Corrective action will be initiated and the USNRC will be notified within 48 hours. The sample frequency for the affected well(s) will be increased to once every 7 days for the nine constituents previously listed, until the excursion parameter value(s) is below the UCL value(s). The UCLs for the monitor wells will be established based on the baseline water quality data for the individual monitor wells.

When a well is on excursion status, the licensee will take corrective measures and be required to notify the USNRC in writing, within seven (7) days of confirming an excursion. The report filed at that time will describe the excursion, corrective actions taken and results of corrective actions. Monthly reports on the condition of the excursion will be filed with the USNRC until the water quality of the affected well(s) stabilizes to acceptable levels. The licensee will be further required by license condition to terminate well field production until such time as the problem is solved if corrective actions have not been effective within a reasonable amount of time (i.e., 2 months since the first excursion verification).

The results of excursion sampling will be summarized and the data reported to the USNRC. The upper control limits (UCLs) for each aquifer and/or well (if there is extreme variability) will be set when all of the water quality data for a particular production unit have been submitted. Seasonal fluctuations in the water quality will be considered to assure that UCLs are set correctly.

To assure that UCLs are appropriately determined, the licensee will be required by license condition to submit background water quality data on each mining unit as well as propose UCLs. A subsequent staff review will then determine if the UCLs are appropriate for inclusion into the license.

5.1.2 Hydrologic Monitoring

Changes in potentiometric levels in the monitor wells and ore zone perimeter monitor wells may be an early indication of an excursion. Water level data collected to date at the Irigaray site indicates that it is a useful parameter for monitoring the performance of the well field. Some caution must however be utilized when evaluating water level data. If the water level in a monitor well rises or falls significantly above or below the natural premining baseline levels, for an extended time period, the change may be indicating inefficiency in adjustment of well field flow rates, insufficient geologic confinement, a potential excursion or a seasonal variation in ground water levels. To determine the actual cause of the water level change, water quality data is extremely valuable.

5.1.3 Evaporation Ponds' Leak Detection Systems

The standpipes at the evaporation ponds will be checked daily for fluid. If sufficient fluid to sample is found, water in the standpipes will be analyzed for parameters indicative of seepage. If the analyses indicate that the pond is leaking, the USNRC will be notified and the pond will be repaired. Furthermore, the licensee will be required to provide a written report to the USNRC within thirty (30) days detailing the cause of the leak and the corrective actions taken.

## 5.2 Environmental Monitoring

The radiological environmental monitoring program proposed by the licensee is outlined below:

| Environmental Element | Sampling Location | Sampling Frequency | Type of Measurement |
|---|---|---|---|
| Surface Water | Surface impoundments and affected drainage | Quarterly | Uranium, Ra-226, Th-230, Pb-210 |
| Air | Air quality monitoring sites | 24-hr sampling at monthly intervals | Particulates, Ra-226, Th-230, Pb-210 |
| Soils, vegetation | At the air quality monitoring sites | Annually | Uranium, Ra-226 Th-230, Pb-210 |

Previous monitoring of these environs at the specified frequency indicates that concentrations of radionuclides in surface water, air, soils and vegetation were generally at or below 10 percent of maximum permissible concentrations. In order to evaluate the project's impact on the environment, these data will be required by license condition to be submitted in a semiannual environmental monitoring report.

## 6.0 ALTERNATIVES

It is the staff's conclusion that the impacts associated with renewal of Source Material License No. SUA-1341 are within the realm of impacts anticipated in the FES. Recognizing these impacts, the staff has available two alternatives with respect to the requested license renewal:

(1) Renew the license with such conditions as are considered necessary or appropriate to protect public health and safety and the environment; or

(2) Deny renewal of the license.

In the safety evaluation report prepared for this action, the staff has reviewed the licensee's proposed action with respect to the criteria for license issuance specified in 10 CFR 40, Section 40.32, and has no basis for denial of the license. Moreover, the environmental impacts described in this document do not warrant denial of the application. For these reasons, license denial is considered an unacceptable alternative, and the staff has determined that no significant impacts that have not previously been addressed in the FES will be associated with the license renewal.

7.0 FINDING OF NO SIGNIFICANT IMPACT

Based on this environmental appraisal, the staff finds that the renewal of Source Material License SUA-1314 for commercial operation of the Irigaray site will not have a significant impact on human health or the environment. The specific reasons for drawing this conclusion are:

- The control and monitoring of the ground water is sufficient for detecting any excursion, either vertical or horizontal;
- The solution evaporation ponds are lined to eliminate seepage of waste solutions; a monitoring system below the liner should detect any leakage which may occur, and license conditions require that corrective action in response to a leak is promptly taken;
- Radiological releases from the uranium extraction operations will be very small (exposures which are small fractions of radiological exposure standards will result) and will be closely monitored to detect any problems;
- All radioactive wastes will be disposed of at an existing, USNRC licensed tailings disposal site; and
- The proposed restoration plan as demonstrated in the E-Field should be sufficient to return the ground water to its premining use (or potential use). On a parameter-by-parameter basis, ground-water quality will be returned to as close to baseline as reasonably achievable.

However, the licensee's submittal for renewal did not address all of the operational and environmental concerns for the site. Therefore, to assure that the impacts listed above are truly representative of renewed commercial operation of the Irigaray site, the staff would recommend that the following license conditions be incorporated into the license renewal:

1. The authorized place of use shall be the licensee's Irigaray project facilities in Johnson, County, Wyoming.
2. The plant throughput shall not exceed 1600 gallons per minute.
3. Release of equipment or packages from the restricted area shall be in accordance with Attachment No. 1 to SUA-1341, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for

Unrestricted Use or Termination of Licenses for Byproduct or Source Materials," dated September, 1984.

4. The results of all effluent and environmental monitoring as described in Section 5.7.7 of the renewal application shall be reported in accordance with 10 CFR 40, Section 40.65, with copies of the report sent to the USNRC, Uranium Recovery Field Office. Additionally, the report shall include operation data such as flow rates, injection pressures, and other pertinent data.

5. All liquid effluents from process buildings and other process waste streams, with the exception of sanitary wastes, shall be returned to the process circuit or discharged to the solution evaporation ponds.

6. The licensee shall submit baseline water quality data for mining units 6 through 9and any subsequent mining units. The data shall be based on wells established in the Unit 1 Sandstone, the deep monitor zone, the mining zone as well as the perimeter trend and monitor wells. All baseline data shall be submitted to the USNRC, Uranium Recovery Field Office, for review and approval. The data shall, at a minimum, consist of five (5) Guideline 8 analyses collected over a period of not less than three (3) months.

7. Mining Units 1 through 9 baseline water quality data shall be established at the following minimal well density for the monitored unit:

| Monitored Unit | Wells per Mining Unit |
|---|---|
| Unit 1 Sandstone | 2 |
| Deep monitor zone | 2 |
| Perimeter trend and monitor wells | 70 percent of installed wells |
| Mining zone | 1/acre |

8. The licensee shall perform, three (3) months prior to lixiviant injection, a aquifer test for USNRC review and approval to characterize the hydraulic properties in mining units 6 through 9. The aquifer test shall be as defined in the "Aquifer-Aquitard Characterization Production Units 2 and 3, Irigaray Mine" submitted by cover letter dated September 4, 1986.

9. The licensee shall submit for USNRC review and approval, two (2) months prior to lixiviant injection, Upper Control Limits (UCLs) for all monitor wells to be utilized for operational monitoring.

If two UCL values are exceeded in a well or if one UCL value is exceeded by 20 percent, the licensee shall take another water sample within twenty-four (24) hours and analyze it for the excursion indicators. If the second sample does not indicate exceedance of the UCLs, a third sample shall be taken within forty-eight (48) hours from the first sample. If neither the second or third indicate exceedance of the UCLs, the first sample shall be considered in error.

If the second or third sample indicates an exceedance of the UCLs, the well in question shall be placed on excursion status. An excursion is confirmed if two or more UCL values are exceeded, or if one UCL value is exceeded by 20 percent or more. Corrective action to mitigate the situation shall be initiated by the licensee when an excursion is confirmed and the USNRC shall be notified by telephone within twenty-four (24) hours and within five (5) days in writing from the time the confirmation sample was taken. Corrective actions shall be continued until the excursion is concluded. In addition to corrective actions, sampling frequency and analysis of excursion status wells shall be performed once every seven (7) days for the excursion indicators. An excursion is considered concluded when the concentrations of excursion indicators are below the concentration levels defining an excursion for three (3) consecutive 1-week samples.

If corrective actions have not been effective within two (2) months of excursion confirmation, the injection of lixiviant shall be terminated in the well field on excursion until the licensee can demonstrate the excursion has been mitigated. Resumption of injection at the well field shall require USNRC approval in the form of a license amendment.

10. A written report shall be submitted to the USNRC, Uranium Recovery Field Office, within two (2) months of excursion confirmation. The report shall describe the excursion event, corrective actions taken and results obtained. If the wells are still on excursion at the time the report is submitted, written progress reports describing the status of the excursion shall be submitted on a quarterly basis until the situation has been mitigated.

11. During periods of operational suspension, the licensee shall maintain at least one (1) foot of drawdown over the entire well field as well as institute corrective actions for any wells on excursion status.

12. The licensee shall conduct mechanical well integrity tests on each injection and production well before the wells are put into service.

The integrity tests shall maintain at least 144 psi for a ten (10) minute period with not more than a ten (10) percent pressure loss.

If any well casing failing the integrity test cannot be repaired, the well shall be plugged and abandoned according to WDEQ standards. The results of the well integrity tests shall be submitted to the USNRC, Uranium Recovery Field Office, for review and approval two (2) months prior to well field operation. Additionally, any injection or production well which has undergone insertion of drill rods or other mechanical equipment shall be retested. Flow rates on each injection and recovery well and manifold pressures on the entire system shall be measured and recorded daily. During well field operations, injection pressures shall not exceed 120 psi.

13. The licensee shall utilize a sodium bicarbonate lixiviant with an oxygen or hydrogen peroxide oxidant. Any variation from this combination shall require a license amendment.

14. Prior to leaving the restricted area boundary, all personnel shall monitor themselves for alpha contamination.

15. The licensee shall, within one (1) year of the issuance of this license, submit a plan for immediate mining of the 5I7 and USMT sites. If the licensee chooses not to mine these sites, they shall restore the ground water, abandon the wells and reclaim the test patterns.

16. Solution evaporation ponds A, B, C, D and E shall have a two (2) foot freeboard requirement. Ponds RA and RB shall have an eight (8) foot freeboard requirement.

    Additionally, the licensee shall, at all times, maintain sufficient reserve capacity in the evaporation pond system to enable the transfer of the contents of a pond to other ponds. In the event of a leak and subsequent transfer of liquid, the freeboard requirements shall be suspended during the repair period.

17. The licensee shall perform and document a daily visual inspection of the evaporation pond embankments, fences and liners, as well as measurements of pond freeboard and checks of the leak detection system. Anytime six (6) inches or more of fluid is detected in the leak detection system standpipes it shall be analyzed for chloride, alkalinity, uranium, sulfate and conductivity. Should analyses indicate that the pond is leaking, the USNRC, Uranium Recovery Field Office, shall be notified by telephone within forty-eight (48) hours of verification and the pond level shall be lowered by transferring

its contents into the other cell. Water quality samples taken at the standpipe shall be analyzed for chloride and conductivity once every seven (7) days during the leak period and once every seven (7) days for at least two (2) weeks following repairs. Additionally, water samples collected at the standpipe shall be analyzed for all seven (7) parameters above at least once per month during the leak period.

A written report shall be filed with the USNRC, Uranium Recovery Field Office, within thirty (30) days of first notifying the USNRC that a leak exists. This report shall include analytical data and describe the mitigative actions and the results of that action.

18. The licensee shall notify the USNRC, Uranium Recovery Field Office, by telephone within forty-eight (48) hours of any failure of an evaporation pond, any break or rupture of any pipeline, or any similar failure of any other fluid or material conduit or storage facility which results in an uncontrolled release of radioactive materials, or of any unusual conditions which if not corrected could lead to such a failure. Such notification shall be followed, within seven (7) days, by submittal of a written report detailing the conditions leading to the failure or potential failure, corrective actions taken and results achieved. This requirement is in addition to the requirements of 10 CFR Part 20.

19. The licensee shall maintain an area within the restricted area boundary for storage of contaminated materials prior to their disposal. All contaminated wastes and evaporation pond residues shall be disposed at a licensed radioactive waste disposal site.

20. At least three (3) months prior to termination of uranium recovery in a mining unit, the licensee shall submit to the USNRC, Uranium Recovery Field Office, in the form of a license amendment, a plan for ground-water restoration and post restoration monitoring. The goal of restoration shall be to return the ground-water quality, on a mining unit average, to baseline concentrations.

21. The licensee shall maintain with the State of Wyoming a surety bond sufficient to cover all costs of restoration, decommissioning and reclamation activities. The bond shall be updated annually, and a copy of the update submitted to the USNRC, Uranium Recovery Field Office, for review and approval.

22. The licensee shall within four (4) months of issuance of this license, submit a proposal for a fenced and posted restricted area boundary which, at a minimum, will be one hundred sixty-three (163) feet from the yellowcake stack.

23. During the period of operational suspension, the licensee shall implement a ground-water monitoring program as follows:

A. Monthly sampling and analysis for chloride, conductivity and total alkalinity from Ore Zone Wells 9T-3, 9T-6, 9T-10, 9T-12, 9T-17, 9T-18, 9T-20, 9T-23 through 9T-26, 9T-32, 9T-34, 9T-36, 9M-15 and HI-53; Coal Zone Wells RS-24, RS-32, RS-50 through RS-52, RS-56, RS-61, RS-62 through RS-64, RS-67, RS-74, RS-75, RS-78 and RS-79; and Unit 1 Sand Wells SSM-1 through SSM-8. Action levels shall be those presented in the licensee's January 19 and May 20, 1982 submittals.

B. Quarterly sampling and analysis for chloride, sulfate and conductivity from 5I7 and USMT Wells M-1 through M-6, NM-3, and M-218 through M-221. Action levels shall be:

| Well No. | Chloride (mg/l) | Conductivity (umho/cm) | Sulfate (mg/l |
|---|---|---|---|
| 517 M-1 | 28 | 804 | 228 |
| 517N M-2 | 16 | 750 | 222 |
| 517 M-3 | 30 | 964 | 274 |
| 517 NM-3 | 16 | 787 | 244 |
| 517 M-4 | 23 | 1018 | 319 |
| 517 M-5 | 16 | 776 | 238 |
| 517 M-6 | 16 | 756 | 236 |
| USMT M-218 | 15 | 760 | 222 |
| USMT M-219 | 15 | 773 | 239 |
| USMT M-220 | 45 | 1428 | 466 |
| USMT M-221 | 29 | 736 | 206 |

C. If action levels are exceeded for chloride or for conductivity and total alkalinity, a verification sample shall be taken within forty-eight (48) hours. If the verification sample exceeds applicable action levels, the licensee, within thirty (30) days, shall develop and implement a plan for mitigation of fluid migration. Results of chemical analyses and records of corrective action procedures shall be submitted to the USNRC, Uranium Recovery Field Office, in the semiannual report.

D. Sample analysis shall be performed utilizing a Quality Assurance Program compatible with USNRC Regulatory Guide 4.15.

Gary R. Konwinski, Project Manager
Licensing Branch 1
Uranium Recovery Field Office
Region IV

Approved by:

Edward F. Hawkins, Chief
Licensing Branch 1
Uranium Recovery Field Office, Region IV

# APPENDIX A

## Water Quality Baseline Determination

Prior to lixiviant injection into a mining unit, the licensee will be required to determine the baseline water quality. This determination shall be based upon five samples collected over a period of not less than 3 months. Baseline determination will include sampling for a Guideline 8 list of parameters which includes the following:

| | |
|---|---|
| Chloride | Sulfate |
| TDS | Ammonia |
| Nitrate/nitrite-N | pH, Lab |
| Conductivity | Aluminum |
| Arsenic | Barium |
| Cadmium | Calcium |
| Chromium | Copper |
| Iron | Lead |
| Magnesium | Manganese |
| Mercury | Nickel |
| Potassium | Selenium |
| Sodium | Vanadium |
| Zinc | Alkalinity |
| Carbonate | Bicarbonate |
| Molybdenum | Ion Balance |
| Radium-226 | Uranium |

# APPENDIX B

Table 3 - Comparison of Predicted Air Concentrations during the Final Year of Operation with 10 CFR 20 Limits for Selected Restricted Area Boundaries

(concentrations were calculated using 0.05 km distances east-west and north-south, although the computer printed distances to the nearest 0.1 km.)

NUMBER 4 NAME=N X= 0.0KM, Y= .1KM, Z= 0.0M, DIST= .1KM, IRTYPE= 0

RESULTS OF MPC CHECK AT THIS LOCATION

| | U-238 | U-234 | TH-230 | RA-226 | RN-222(WL) | PB-210 | BI-210 | PO-210 |
|---|---|---|---|---|---|---|---|---|
| CONC., PCI/M3 | 4.90E-03 | 4.90E-03 | 2.45E-05 | 4.82E-06 | 4.01E-05 | 4.81E-06 | 4.81E-06 | 4.81E-06 |
| MPC, PCI/M3 | 5.00E+00 | 4.00E+00 | 8.00E-02 | 2.00E+00 | 3.33E-02 | 4.00E+00 | 2.00E+02 | 7.00E+00 |
| FRACTION OF MPC | 9.80E-04 | 1.23E-03 | 3.06E-04 | 2.41E-06 | 1.20E-03 | 1.20E-06 | 2.40E-08 | 6.87E-07 |

SUM OF FRACTIONS EQUALS 3.72E-03

TIME STEP NUMBER 1, IN FIVE YEARS DURATION IN YRS IS... 5.0

NUMBER 5 NAME=S X= 0.0KM, Y= -.1KM, Z= 0.0M, DIST= .1KM, IRTYPE= 0

RESULTS OF MPC CHECK AT THIS LOCATION

| | U-238 | U-234 | TH-230 | RA-226 | RN-222(WL) | PB-210 | BI-210 | PO-210 |
|---|---|---|---|---|---|---|---|---|
| CONC., PCI/M3 | 4.57E-03 | 4.57E-03 | 2.28E-05 | 4.49E-06 | 3.16E-05 | 4.48E-06 | 4.48E-06 | 4.48E-06 |
| MPC, PCI/M3 | 5.00E+00 | 4.00E+00 | 8.00E-02 | 2.00E+00 | 3.33E-02 | 4.00E+00 | 2.00E+02 | 7.00E+00 |
| FRACTION OF MPC | 9.14E-04 | 1.14E-03 | 2.86E-04 | 2.25E-06 | 9.50E-04 | 1.12E-06 | 2.24E-08 | 6.40E-07 |

SUM OF FRACTIONS EQUALS 3.30E-03

NUMBER 6 NAME=E X= .1KM, Y= 0.0KM, Z= 0.0M, DIST= .1KM, IRTYPE= 0

RESULTS OF MPC CHECK AT THIS LOCATION

| | U-238 | U-234 | TH-230 | RA-226 | RN-222(WL) | PB-210 | BI-210 | PO-210 |
|---|---|---|---|---|---|---|---|---|
| CONC., PCI/M3 | 2.77E-03 | 2.77E-03 | 1.39E-05 | 2.72E-06 | 3.82E-05 | 2.72E-06 | 2.72E-06 | 2.72E-06 |
| MPC, PCI/M3 | 5.00E+00 | 4.00E+00 | 8.00E-02 | 2.00E+00 | 3.33E-02 | 4.00E+00 | 2.00E+02 | 7.00E+00 |
| FRACTION OF MPC | 5.54E-04 | 6.93E-04 | 1.73E-04 | 1.36E-06 | 1.15E-03 | 6.80E-07 | 1.36E-08 | 3.88E-07 |

SUM OF FRACTIONS EQUALS 2.57E-03

1(b)

TIME STEP NUMBER 1, IN FIVE YEARS DURATION IN YRS IS... 5.0

NUMBER 7 NAME=W X= -.1KM, Y= 0.0KM, Z= 0.0M, DIST= .1KM, IRTYPE= 0

RESULTS OF MPC CHECK AT THIS LOCATION

| | U-238 | U-234 | TH-230 | RA-226 | RN-222(WL) | PB-210 | BI-210 | PO-210 |
|---|---|---|---|---|---|---|---|---|
| CONC., PCI/M3 | 2.67E-03 | 2.67E-03 | 1.33E-05 | 2.62E-06 | 4.27E-05 | 2.62E-06 | 2.62E-06 | 2.62E-06 |
| MPC, PCI/M3 | 5.00E+00 | 4.00E+00 | 8.00E-02 | 2.00E+00 | 3.33E-02 | 4.00E+00 | 2.00E+02 | 7.00E+00 |
| FRACTION OF MPC | 5.33E-04 | 6.66E-04 | 1.67E-04 | 1.31E-06 | 1.28E-03 | 6.54E-07 | 1.31E-08 | 3.74E-07 |

SUM OF FRACTIONS EQUALS 2.65E-03

NUMBER 8 NAME=NE X= .1KM, Y= .1KM, Z= 0.0M, DIST= .1KM, IRTYPE= 0

RESULTS OF MPC CHECK AT THIS LOCATION

| | U-238 | U-234 | TH-230 | RA-226 | RN-222(WL) | PB-210 | BI-210 | PO-210 |
|---|---|---|---|---|---|---|---|---|
| CONC., PCI/M3 | 3.68E-03 | 3.68E-03 | 1.84E-05 | 3.62E-06 | 3.94E-05 | 3.62E-06 | 3.62E-06 | 3.62E-06 |
| MPC, PCI/M3 | 5.00E+00 | 4.00E+00 | 8.00E-02 | 2.00E+00 | 3.33E-02 | 4.00E+00 | 2.00E+02 | 7.00E+00 |
| FRACTION OF MPC | 7.37E-04 | 9.21E-04 | 2.30E-04 | 1.81E-06 | 1.18E-03 | 9.04E-07 | 1.81E-08 | 5.17E-07 |

SUM OF FRACTIONS EQUALS 3.08E-03

1(c)

TIME STEP NUMBER 1, IN FIVE YEARS DURATION IN YRS IS... 5.0

NUMBER 9 NAME=SW X= -.1KM, Y= -.1KM, Z= 0.0M, DIST= .1KM, IRTYPE= 0

RESULTS OF MPC CHECK AT THIS LOCATION

| | U-238 | U-234 | TH-230 | RA-226 | RN-222(WL) | PB-210 | BI-210 | PO-210 |
|---|---|---|---|---|---|---|---|---|
| CONC., PCI/M3 | 1.79E-03 | 1.79E-03 | 8.95E-06 | 1.76E-06 | 2.16E-05 | 1.76E-06 | 1.76E-06 | 1.76E-06 |
| MPC, PCI/M3 | 5.00E+00 | 4.00E+00 | 8.00E-02 | 2.00E+00 | 3.33E-02 | 4.00E+00 | 2.00E+02 | 7.00E+00 |
| FRACTION OF MPC | 3.58E-04 | 4.47E-04 | 1.12E-04 | 8.80E-07 | 6.49E-04 | 4.39E-07 | 8.78E-09 | 2.51E-07 |

SUM OF FRACTIONS EQUALS 1.57E-03

NUMBER 10 NAME=SE X= -.1KM, Y= .1KM, Z= 0.0M, DIST= .1KM, IRTYPE= 0

RESULTS OF MPC CHECK AT THIS LOCATION

| | U-238 | U-234 | TH-230 | RA-226 | RN-222(WL) | PB-210 | BI-210 | PO-210 |
|---|---|---|---|---|---|---|---|---|
| CONC., PCI/M3 | 1.13E-02 | 1.13E-02 | 5.67E-05 | 1.12E-05 | 1.56E-04 | 1.11E-05 | 1.11E-05 | 1.11E-05 |
| MPC, PCI/M3 | 5.00E+00 | 4.00E+00 | 8.00E-02 | 2.00E+00 | 3.33E-02 | 4.00E+00 | 2.00E+02 | 7.00E+00 |
| FRACTION OF MPC | 2.27E-03 | 2.83E-03 | 7.09E-04 | 5.58E-06 | 4.68E-03 | 2.78E-06 | 5.56E-08 | 1.59E-06 |

SUM OF FRACTIONS EQUALS 1.05E-02

1(d)

REGION=IRIGARY IN SITU LEACH    CODE=MILDOS,REVO (7/79)    DATE= 86/12/19.
METSET= IRIGAR    PAGE NO. 20
TIME STEP NUMBER 1, IN FIVE YEARS    DURATION IN YRS IS... 5.0

NUMBER 11 NAME=NW    X= .1KM, Y= -.1KM, Z= 0.0M, DIST= .1KM, IRTYPE= 0

RESULTS OF MPC CHECK AT THIS LOCATION

| | U-238 | U-234 | TH-230 | RA-226 | RN-222(WL) | PB-210 | BI-210 | PO-210 |
|---|---|---|---|---|---|---|---|---|
| CONC., PCI/M3 | 3.42E-03 | 3.42E-03 | 1.71E-05 | 3.37E-06 | 3.84E-05 | 3.36E-06 | 3.36E-06 | 3.36E-06 |
| MPC, PCI/M3 | 5.00E+00 | 4.00E+00 | 8.00E-02 | 2.00E+00 | 3.33E-02 | 4.00E+00 | 2.00E+02 | 7.00E+00 |
| FRACTION OF MPC | 6.85E-04 | 8.56E-04 | 2.14E-04 | 1.68E-06 | 1.15E-03 | 8.40E-07 | 1.68E-08 | 4.80E-07 |

SUM OF FRACTIONS EQUALS 2.91E-03
13.16.20.UCLP, 01, HPLP11C, 1.600KLNS.

1(e)

DETAILED BASIS FOR RADIOLOGICAL ASSESSMENT

The staff's radiological impact assessment is based on site-specific data provided by the applicant (Table B.1) and on the models, data and assumptions discussed in "Calculational Models for Estimating Radioactive Materials Resulting from Uranium Milling Operations" (Regulatory Guide 3.5.1, March 1982).

Table B.1 - Parameters and Conditions Used in the Radiological Assessment of the Solution Mining Project

| Parameter | Value | Units |
|---|---|---|
| Production rate ($U_3O_8$) | 454 | Metric tons/year |
| Average ore grade | 0.12 | Percent |
| Uranium concentration in lixiviant entering plant (average) | 100 | mg/l |
| Average production flow rate | 1600 | gpm |
| Yellowcake stack height | 10.7 | meters |
| Effluent flow rate through stack | 0.967 | $m^3$/second |
| Emission rate ($U_3O_8$) | 431 | kg/year |
| Fraction of release which is Th-230 | 0.005 | |
| Fraction of release which is Pb-210 | 0.001 | |
| Fraction of release which is Ra-222 | 0.001 | |
| Mixing height (annual average) | 538 | meters |
| Plant operating time | 365 | days/year |
| Dryer operating time | 138 | days/year |
| Combined area of small ponds | 0.005 | $km^2$ |
| Ra-226 concentration in first four small ponds | 354 | pCi/l |
| | 47.9 | pCi/l |
| | 4.55 | pCi/l |
| | 6.1 | pCi/l |
| Land use and grazing of cattle | | |
| Hectarage required to graze one animal | 0.66 | ha |
| Fraction of year open to grazing locally | 50 | percent |
| Fraction of stored feed grown locally | 50 | percent |

## B.2 ATMOSPHERIC TRANSPORT

The staff analysis of offsite air concentrations of radioactive materials has been based on two years of meteorological data collected at the uranium mill site in 1979-1980. Modeling the Irigaray site using MILDOS relies totally on meteorological data and a flat terrain is assumed. Doses are representative of the model only and are in no way estimates of real doses likely to be received by the population within 80 km. The collected meteorological data are entered into the MILDOS code as input in the form of a joint frequency distribution by stability class, wind speed group, and direction. The joint frequency data employed by the staff for this analysis are presented in Table B.2.

# TABLE B.2

REGION=IRIGARY IN SITU LEACH CODE=MILDOS,REVO (7/79) DATE= 86/12/19.
METSET= IRIGAR PAGE NO. 2
JOINT FREQUENCY IN PERCENT, DIRECTION INDICATES WH ERE WIND IS FROM FREQWS= .00268, .00307, .00209, .00171, .00052, .00012

| MPH | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STABILITY CLASS 1 | | | | | | | | | | | | | | | | | |
| 1.5 | .0036 | .0033 | .0031 | .0023 | .0020 | .0012 | .0026 | .0019 | .0047 | .0029 | .0048 | .0036 | .0047 | .0034 | .0033 | .0036 | .0510 |
| 5.5 | .0056 | .0033 | .0030 | .0014 | .0005 | .0010 | .0016 | .0024 | .0027 | .0031 | .0036 | .0016 | .0026 | .0013 | .0035 | .0055 | .0427 |
| 10.0 | .0030 | .0013 | .0002 | .0001 | .0001 | .0001 | .0008 | .0007 | .0005 | .0008 | .0015 | .0008 | .0003 | 0.0000 | .0001 | .0010 | .0113 |
| 15.5 | .0020 | 0.0000 | .0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | .0002 | .0001 | 0.0000 | .0001 | .0025 |
| 21.5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 28.0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ALL | .0142 | .0079 | .0064 | .0038 | .0026 | .0023 | .0050 | .0050 | .0079 | .0068 | .0099 | .0060 | .0078 | .0048 | .0069 | .0102 | .1075 |
| STABILITY CLASS 2 | | | | | | | | | | | | | | | | | |
| 1.5 | .0006 | .0007 | .0002 | .0005 | .0008 | .0008 | .0008 | .0012 | .0009 | .0013 | .0020 | .0006 | .0015 | .0009 | .0017 | .0005 | .0150 |
| 5.5 | .0030 | .0014 | .0007 | .0001 | .0007 | .0003 | .0010 | .0015 | .0031 | .0034 | .0028 | .0012 | .0008 | .0014 | .0017 | .0021 | .0252 |
| 10.0 | .0034 | .0016 | .0010 | .0001 | .0003 | .0003 | .0012 | .0012 | .0019 | .0027 | .0019 | .0013 | .0007 | .0007 | .0008 | .0023 | .0214 |
| 15.5 | .0013 | .0005 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | .0001 | 0.0000 | .0003 | .0005 | .0001 | 0.0000 | 0.0000 | .0002 | .0030 |
| 21.5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 28.0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ALL | .0083 | .0042 | .0019 | .0007 | .0018 | .0014 | .0030 | .0039 | .0060 | .0074 | .0070 | .0036 | .0031 | .0030 | .0042 | .0051 | .0646 |
| STABILITY CLASS 3 | | | | | | | | | | | | | | | | | |
| 1.5 | .0005 | .0005 | .0007 | .0003 | .0012 | .0016 | .0015 | .0007 | .0003 | .0007 | .0003 | .0002 | .0006 | .0005 | .0005 | .0009 | .0110 |
| 5.5 | .0014 | .0008 | .0008 | .0001 | .0005 | .0008 | .0013 | .0012 | .0024 | .0043 | .0023 | .0008 | .0014 | .0010 | .0015 | .0014 | .0220 |
| 10.0 | .0065 | .0015 | .0006 | .0008 | .0003 | .0007 | .0015 | .0017 | .0043 | .0027 | .0020 | .0009 | .0008 | .0003 | .0012 | .0041 | .0299 |
| 15.5 | .0035 | .0003 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | .0003 | .0001 | .0002 | .0005 | .0007 | .0008 | .0002 | .0002 | .0002 | .0005 | .0075 |
| 21.5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 28.0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ALL | .0119 | .0031 | .0021 | .0012 | .0020 | .0031 | .0046 | .0037 | .0072 | .0082 | .0053 | .0027 | .0030 | .0020 | .0034 | .0069 | .0704 |
| STABILITY CLASS 4 | | | | | | | | | | | | | | | | | |
| 1.5 | .0014 | .0010 | .0016 | .0007 | .0023 | .0138 | .0087 | .0009 | .0006 | .0001 | .0009 | .0010 | .0022 | .0013 | .0024 | .0014 | .0403 |
| 5.5 | .0061 | .0028 | .0026 | .0008 | .0043 | .0400 | .0205 | .0063 | .0057 | .0069 | .0040 | .0016 | .0017 | .0015 | .0036 | .0067 | .1151 |
| 10.0 | .0129 | .0037 | .0021 | .0020 | .0026 | .0028 | .0083 | .0091 | .0095 | .0088 | .0055 | .0015 | .0014 | .0006 | .0035 | .0105 | .0848 |
| 15.5 | .0162 | .0031 | .0020 | .0014 | .0005 | .0043 | .0123 | .0130 | .0197 | .0246 | .0087 | .0031 | .0049 | .0014 | .0079 | .0262 | .1493 |
| 21.5 | .0049 | .0002 | .0001 | .0001 | 0.0000 | .0012 | .0071 | .0031 | .0052 | .0088 | .0069 | .0015 | .0010 | 0.0000 | .0024 | .0099 | .0524 |
| 28.0 | .0003 | 0.000[illegible] | 0.0000 | 0.0000 | 0.0000 | .0015 | .0035 | .0001 | .0001 | .0006 | .0010 | .0012 | .0005 | 0.0000 | .0005 | .0029 | .0122 |
| ALL | .0418 | .0108 | .0084 | .00[illegible] | [illegible]097 | .0636 | .0604 | .0325 | .0408 | .0498 | .0270 | .0099 | .0117 | .0048 | .0203 | .0576 | .4541 |
| STABILITY CLASS 5 | | | | | | | | | | | | | | | | | |
| 1.5 | .0019 | .0022 | .0009 | .0010 | .0036 | .0121 | .0102 | .0017 | .0015 | .0017 | .0013 | .0005 | .0028 | .0029 | .0021 | .0019 | .0483 |
| 5.5 | .0027 | .0028 | .0008 | .0012 | .0024 | .0180 | .0161 | .0055 | .0033 | .0049 | .0020 | .0020 | .0023 | .0013 | .0034 | .0047 | .0734 |
| 10.0 | .0030 | .0019 | .0016 | .0013 | .0009 | .0037 | .0098 | .0070 | .0066 | .0090 | .0021 | .0007 | .0007 | .0006 | .0020 | .0091 | .0600 |
| 15.5 | .0001 | 0.0000 | .0002 | 0.0000 | 0.0000 | .0001 | .0009 | .0002 | .0010 | .0023 | .0007 | .0001 | .0001 | 0.0000 | .0007 | .0016 | .0080 |
| 21.5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 28.0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ALL | .0077 | .0069 | .0035 | .0035 | .0069 | .0339 | .0370 | .0144 | .0124 | .0179 | .0061 | .0033 | .0059 | .0048 | .0082 | .0173 | .1897 |
| STABILITY CLASS 6 | | | | | | | | | | | | | | | | | |
| 1.5 | .0038 | .0037 | .0028 | .0024 | .0054 | .0143 | .0213 | .0098 | .0054 | .0045 | .0057 | .0035 | .0045 | .0050 | .0049 | .0057 | .1027 |
| 5.5 | .0010 | .0005 | .0003 | .0002 | .0010 | .0040 | .0061 | .0031 | .0024 | .0027 | .0022 | .0008 | .0009 | .0009 | .0010 | .0013 | .0284 |
| 10.0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | .0002 | .0001 | 0.0000 | 0.0000 | .0007 | 0.0000 | .0001 | 0.0000 | 0.0000 | 0.0000 | .0002 | .0013 |
| 15.5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | .0002 | .0001 | 0.0000 | .0003 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | .0001 | .0001 | .0008 |
| 21.5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 28.0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ALL | .0048 | .0042 | .0031 | .0026 | .0064 | .0185 | .0277 | .0130 | .0078 | .0082 | .0079 | .0044 | .0054 | .0059 | .0060 | .0073 | .1332 |
| ALL | .0887 | .0371 | .0254 | .0168 | .0294 | .1228 | .1377 | .0725 | .0821 | .0983 | .0632 | .0299 | .0369 | .0253 | .0490 | .1044 | 1.0195 |

Table B.3 - Physical Characteristics assumed for particulate material releases

| Activity source | Diameter (um) | Density ($g/cm^3$) | Deposition Velocity (cm/s) | AMAD* (um) |
|---|---|---|---|---|
| Crusher dusts | 1.0 | 2.4 | 1.0 | 1.55 |
| Yellowcake dusts | 1.0 | 8.9 | 1.0 | 2.98 |
| Tailings, ore pile | | | | |
| dusts 30% | 5.0 | 2.4 | 1.0 | 7.75 |
| 70% | 35.0 | 2.4 | 8.8 | 54.2 |
| Ingrown radon | | | | |
| daughters | 0 | 1.0 | 0.3 | 0.3 |

*Aerodynamic equivalent diameter, used in calculating inhalation doses.[1]

## B.3 CONCENTRATION IN ENVIRONMENTAL MEDIA

Information provided below describes the methods and data used by the staff to determine the concentrations of radioactive materials in the environmental media of concern in the vicinity of the site. These include concentrations in the air (for inhalation and direct external exposure), on the ground (for direct external exposure), and in meat and vegetables (for ingestion exposure). Concentration values are computed explicitly by the MILDOS code of U-238, Th-230, Ra-226, Rn-222 (air only), and Pb-210. Concentrations of Th-234, Pa-234, and U-234 are assumed to equal that of U-238. Concentrations of Bi-210 and Po-210 are assumed to equal that of Pb-210.

### B.3.1 Air concentrations

Ordinary, direct air concentrations are computed by the MILDOS code for each receptor location from each activity source by particle size (for particulates). Direct air concentrations computed by MILDOS include depletion by deposition (particulates) or the effects of ingrowth and decay in transit (radon and daughters). To compute inhalation doses, the total air concentration of each isotope at each location as a function of particle size, is computed as the sum of the direct air concentration and the resuspended air concentration

$$C_{aip}(t) = C_{aipd} + C_{aipr}(t), \qquad \text{(B-3)}$$

where

$C_{aip}(t)$ = total air concentration of isotope i, particle size p, at time t, pCi/m³;

$C_{aipd}$ = direct air concentration of isotope i, particle size p, for the time constant, pCi/m³;

$C_{aipr}(t)$ = resusupended air concentration of isotope i, particle size p, at time t, pCi/m³.

The resuspended air concentration is computed using a time-dependent resuspension factor, $R_p(t)$, defined by

$$R_p(t) = (1/V_p)10^{-5}\ e^{-\lambda}\ R^{t} \qquad \text{for } t \quad 1.82 \text{ years}$$

$$= (1/V_p)10^{-9} \qquad \text{for } t > 1.83 \text{ year,} \qquad \text{(B-4)}$$

where

$R_p(t)$ = ratio of the resuspended air concentration to the ground concentration, for a ground concentration of age t years, of particle size p, $m^{-1}$;

$V_p$ = deposition velocity of particle size p, cm/s;

R = assumed decay constant of the resuspension factor (equivalent to a 50-d half-life), 5.06 years;

$10^{-5}$ = initial value of the resuspension factor (for particles with a deposition velocity of 1 cm/s), $m^{-1}$;

$10^{-9}$ = terminal value of the resuspension factor (for particles with a deposition velocity of 1 cm/s), $m^{-1}$;

1.82 = time required to reach the terminal resuspension factor, years.

The basic formulation of the above expression for the resuspension factor, the initial and final values, and the assigned decay constant derive from experimental observations.[4] The inverse relationship to deposition velocity eliminates mass balance problems involving resuspension of more than 100% of the initial ground deposition for the 35-um particle size (see Table B.3.). Based on this formulation, the resuspended air concentration is given by

$$C_{aipr}(t) = 0.01\ C_{aipd} \times 10^{-5}\ \frac{1 - \exp[-(\lambda_i^* + \lambda_R)\ (t - a)]}{(\lambda_i^* + \lambda_R)}$$

$$+ 10^{-4}\delta(t) \frac{\exp[-\lambda_i^*(t - a)] - \exp(-\lambda_i^* t)}{\lambda_i^*} (3.156 \times 10^7), \quad \text{(B-5)}$$

where

$a = (t - 1.82)$ if $t > 1.82$, years;

$\delta(t) = 0$ if $t > 1.82$ and is unity otherwise, dimensionless;

$\lambda_i^*$ = effective decay constant for isotope i on soil, year$^{-1}$;

0.01 = deposition velocity for the particle size for which the initial resuspension factor value is $10^{-5}$ per meter, m/s;

$3.156 \times 10^7$ = s/year.

Total air concentrations are computed using Eqs. B-3 and B-5 for all particulate effluents. Radon daughters that grow in from released radon are not depleted because of deposition losses and are therefore not assumed to resuspend.

### B.3.2 Ground concentrations

Radionuclide ground concentrations are computed from the calculated airborne particulate concentrations arising directly from onsite sources (not including air concentrations resulting from resuspension). Resuspended particulate concentrations are not considered for evaluating ground concentrations. The direct deposition rate of radionuclide i is calculated using the following relationship:

$$D_{di} = \sum_p C_{adip} V_p, \quad \text{(B-6)}$$

where

$C_{adip}$ = direct air concentration of radionuclide i, particle size p, $pCi/m^3$;

$D_{di}$ = resulting direct deposition rate of radionuclide i, $pCi/m^2.s$;

$V_p$ = deposition velocity of particle size p, m/s (see ref. 4).

The concentration of radionuclide i on a ground surface resulting from constant deposition at the rate $D_{di}$ over time interval t is obtained from

$$C_{gi}(t) = D_{di} \frac{1 - \exp(-\lambda_i + \lambda_e)t}{\lambda_i + \lambda_e} . \quad \text{(B-7)}$$

where

$C_{gi}(t)$ = ground surface concentration of radionuclide i at time t, pCi/m²;

t = time interval over which deposition has occurred, s;

$\lambda_e$ = assumed rate constant for environmental loss, $s^{-1}$;

$\lambda_i$ = radioactive decay constant[5] for radionuclide i, $s^{-1}$.

The environmental loss constant $\lambda e$ corresponds to an assumed half-time for loss of environmental availability of 50 years.[4] This parameter accounts for downward migration in soil and loss of availability caused by chemical binding. It is assumed to apply to all radionuclides deposited on the ground.

Ground concentrations are explicitly computed only for U-238, Th-230, Ra-226, and Pb-210. For all other radionuclides, the ground concentration is assumed equal to that of the first parent radionuclide for which the ground concentration is explicitly calculated. For lead-210, ingrowth from deposited radium-226 can be significant. The concentration of lead-210 on the ground caused by radium-226 deposition is calculated by the staff using the standard Bateman formulation and assuming that radium-226 decays directly to lead-210. If i = 6 for radium-226 and i = 12 for lead-210 (ref. 1), the following equation is obtained:

$$C_{g12}(pb \leftarrow Ra) = \frac{\lambda_{12} D_{d6}}{\lambda_6^*} \quad \frac{1 - \exp(-\lambda_{12}^* t)}{\lambda_{12}^*} + \frac{\exp(-\lambda_6^* t) - \exp(-\lambda_{12}^* t)}{\lambda_6^* - \lambda_{12}^*} \quad , \qquad (B-8)$$

where

$C_{g12}(Pb \leftarrow Ra)$ = incremental lead-210 ground concentration resulting from radium-226 deposition, pCi/m²;

$\lambda_n^*$ = effective rate constant for loss by radioactive decay and migration of a ground-deposited radionuclide and $= \lambda_n + \lambda_e$, $s^{-1}$.

B.3.3 Vegetation concentrations

Vegetation concentrations are derived from ground concentrations and total deposition rates. Total deposition rates are given by the following summation:

$$D_i = \sum_p C_{aip} V_p , \qquad \text{(B-9)}$$

where $D_i$ is the total deposition rate, including deposition of resuspended activity, of radionuclide i, $pCi/m^2 \cdot s$.

Concentrations of released particulate materials can be environmentally transferred to the edible portions of vegetables or to hay or pasture grass consumed by animals by two mechanisms: direct foliar retention and root uptake. Five categories of vegetation are treated by the staff: edible above ground vegetables, potatoes, other edible below ground vegetables, pasture grass, and hay. Vegetation concentrations are computed using the following equation:

$$C_{vi} = D_i E_r E_v \frac{1 - \exp(-\lambda_w t_v)}{Y_v \lambda_w} + C_{gi}(B_{vi}/P) . \qquad \text{(B-10)}$$

where

$B_{vi}$ = soil-to-plant transfer factor for isotope i, vegetation type v, dimensionless;

$C_{vi}$ = resulting concentration of isotope i, in vegetation v, pCi/kg;

$E_v$ = fraction of foliar deposition reaching edible portions of vegetation v, dimensionless;

$E_r$ = fraction of total deposition retained on plant surfaces, 0.2, dimensionless;

P = assumed areal soil density for surface mixing, 240 $kg/m^2$;

$t_v$ = assumed duration of exposure while growing for vegetation v, s;

$Y_v$ = assumed yield density of vegetation v, $kg/m^2$;

$\lambda_w$ = decay constant accounting for weathering losses (equivalent to a 14-d half-life), $5.73 \times 10^{-7}$ per second.

The value of Ev is assumed to be 1.0 for all above ground vegetation and 0.1 for all below ground vegetables.[6] The value of $t_v$ is taken to be 60 d, except for pasture grass, where a value of 30 d is assumed. The yield density, $Y_v$, is taken to be 2.0 $kg/m^2$, except for pasture grass, where a value of 0.75 $kg/m^2$ is applied. Values of the soil to plant transfer coefficients, $B_{vi}$, are provided in Table B-4.

### B.3.4 Meat and milk concentrations

Radioactive materials can be deposited on grasses, hay, or silage, which are eaten by meat animals, which are, in turn, eaten by man. It has been assumed that meat animals obtain 50% of their feed requirements by open grazing and by eating non-locally grown stored feed for the remaining portion of their feed requirement. The equation used to estimate meat concentrations is

$$C_{bi} = QF_{bi}(0.50C_{pgi} + 0.50C_{hi}), \qquad \text{(B-11)}$$

where

$C_{pgi}$ = concentration of isotope i in pasture grass, pCi/kg;

$C_{hi}$ = concentration of isotope i in hay (or other stored feed), pCi/kg;

$C_{bi}$ = resulting concentration of isotope i in meat, pCi/kg;

$F_{bi}$ = feed-to-meat transfer for isotope i, pCi/kg per pCi/d (see Table A.4);

Q = assumed feed ingestion rate, 50 kg/d;

0.50 = fraction of total annual feed requirement assumed to be satisfied by pasture grass;

0.50 - fraction of total annual feed requirement assumed to be satisfied by locally grown stored feed (hay).

Table B.4 - Environmental transfer coefficients

| Material | U | Th | Ra | Pb |
|---|---|---|---|---|
| Plant/soil, $B_{vi}$ | | | | |
| Edible above ground | 2.5E-3* | 4.2E-3 | 1.4E-2 | 4.0E-3 |
| Potatoes | 2.5E-3 | 4.2E-3 | 3.0E-3 | 4.0E-3 |
| Other below ground | 2.5E-3 | 4.2E-3 | 1.4E-2 | 4.0E-3 |
| Pasture grass | 2.5E-3 | 4.2E-3 | 1.8E-2 | 2.8E-2 |
| Stored feed (hay) | 2.5E-3 | 4.2E-3 | 8.2E-2 | 3.6E-2 |
| Beef/feed, $F_{bi}$, pCi/kg per pCi/d | 3.4E-4 | 2.0E-4 | 5.1E-4 | 7.1E-4 |

*Read as 2.5 x $10^{3}$, or .0025.

Source: U.S. Nuclear Regulatory Commission, "Calculational models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Operations," Report Task RH 802-4, Washington, D.C., May 1979.

The above grazing assumptions are also reflected in the following equation for milk concentrations:

$$C_{mi} = QF_{mi}(0.50C_{pgi} + 0.50C_{hi}), \qquad \text{(B-12)}$$

where

$C_{mi}$ = average concentration of isotope i in milk, pCi/L;

$F_{mi}$ = feed-to-milk activity transfer factor for isotope i, pCi/L per pCi/d ingested (see Table A.4).

## B.4 DOSES TO INDIVIDUALS

Doses to individuals have been calculated for inhalation; external exposure to air and ground concentrations; and ingestion of vegetables, meat, and milk. Internal doses are calculated by the staff, using dose conversion factors that yield the 50-year dose commitment; that is, the entire dose insult received over a period of 50 years following either inhalation or ingestion.[2,7] Annual doses given are the 50-year dose commitments resulting from a one-year exposure period. The one-year exposure period was taken to be the fifth year of mill operation, when environmental concentrations resulting from plant operations are expected to be near their highest level.

### B.4.1 Inhalation doses

Inhalation doses have been computed using air concentrations obtained by Eq. A-3 (resuspended air concentrations are included) for particulate materials and the dose conversion factors presented in Table B.5.

Dose to the bronchial epithelium from radon-222 and short-lived daughters were computed based on the assumption of indoor exposure at 100% occupancy. The dose conversion factor for bronchial epithelium exposure from radon-222 derives as follows:

1. 1 $pCi/m^3$ radon-222 = $5 \times 10^{-6}$ working levels (WL).*
2. Continuous exposure to 1 WL = 25 cumulative working level months (WLM) per year.
3. 1 WLM = 5,000 mrem.[8]

Therefore,

$$(1\ pCi/m^3\ \text{radon-222}) \times 5 \times 10^{-6}\ \frac{WL}{pCi/m^3} \times 25\ \frac{WLM}{WL} \times 5000\ \frac{mrem}{WLM} = 0.625\ \text{mrem},$$

and the radon-222 bronchial epithelium dose conversion factor is taken to be 0.625 millirem per year per $pCi/m^3$.

*One WL concentration is defined as any combination of short-lived radioactive decay products of radon-222 in 1 L of air that will release $1.3 \times 10^5$ MeV of alpha particle energy during radioactive decay to lead-210.

Table B.5 - Inhalation dose conversion factors. Values are given in millirem per year per pCi/m³

| Organ | U-238 | U-234 | U-230 | Ra-226 | Pb-210 | Po-210 |
|---|---|---|---|---|---|---|
| | | | Particle size = 0.3 um | | | |
| Whole body | | | | | 7.46E+0* | 1.29E+0 |
| Bone | | | | | 2.32E+2 | 5.24E+0 |
| Kidney | | | | | 1.93E+2 | 3.87E+1 |
| Liver | | | | | 5.91E+1 | 1.15E-1 |
| Mass average lung | | | | | 6.27E+1 | 2.66E+2 |
| | Particle size = 1.0 um, density = 8.9 g/cm³ | | | | | |
| Whole body | 9.82E+0 | 1.12E+1 | 1.37E+2 | 3.58E+1 | 4.66E+0 | 5.95E+1 |
| Bone | 1.66E+2 | 1.81E+2 | 4.90E+3 | 3.58E+2 | 1.45E+2 | 2.43E+0 |
| Kidney | 3/78E+1 | 4.30E+1 | 1.37E+3 | 1.26E+0 | 1.21E+2 | 1.78E+1 |
| Liver | 0. | 0. | 3.83E+2 | 4.47E-2 | 3.69E-1 | 5.34E+0 |
| Mass average lung | 1.07E-3 | 1.21E+3 | 2.37E+3 | 4.88E+3 | 5.69E+2 | 3.13E+2 |
| | Particle size = 1.0 um, density = 2.4 g/cm³ | | | | | |
| Whole body | 4.32E+0 | 4.92E+0 | 1.66E+2 | 3.09E+1 | 4.36E+0 | 4.71E-1 |
| Bone | 7.92E+1 | 7.95E+1 | 5.95E+3 | 3.09E+2 | 1.35E+2 | 1.92E+0 |
| Kidney | 1.66E+1 | 1.89E+1 | 1.67E+3 | 1.09E+0 | 1.13E+2 | 1.42E+1 |
| Liver | 0. | 0. | 3.43E+2 | 3.87E-2 | 3.45E+1 | 4.22E+0 |
| Mass average lung | 1.58E+2 | 1.80E+2 | 3.22E+3 | 6.61E+3 | 7.72E+3 | 4.20E+2 |
| | | | Particle size = 5.0 um | | | |
| Whole body | 1.16E+0 | 1.32E+0 | 1.01E+2 | 4.00E+1 | 4.84E+0 | 7.10E-1 |
| Bone | 1.96E+1 | 2.14E+1 | 3/60E+3 | 4.00E+2 | 1.50E+2 | 2.89E+0 |
| Kidney | 4.47E+0 | 5.10E+0 | 1.00E+3 | 1.41E+0 | 1.25E+2 | 2.13E+1 |
| Liver | 0. | 0. | 2.07E+2 | 4.97E-2 | 3.83E-1 | 6.36E+0 |
| Mass average lung | 1.24E+3 | 1.42E+3 | 1.38E+3 | 2.84E+3 | 3.30E+2 | 1.88E+2 |
| | | | Particle size = 35.0 um | | | |
| Whole body | 7.92E-1 | 9.02E-1 | 5.77E+1 | 3.90E+1 | 4.43E+0 | 7.28E-1 |
| Bone | 1.34E+1 | 1.46E+1 | 2.07E+3 | 3.90E+2 | 1.38E+2 | 2.96E+0 |
| Kidney | 3.05E+0 | 3.47E+0 | 5.73E+2 | 1.38E+0 | 1.15E+2 | 2.19E+1 |
| Liver | 0. | 0. | 1.19E+2 | 4.85E-2 | 3.51E+1 | 6.52E+0 |
| Mass average lung | 3.33E+2 | 3.80E+2 | 3.71E+2 | 7.64E+2 | 8.79E+1 | 5.75E+1 |

*Read as $7.46 \times 10^0$, or 7.46.

Sources: M. Momeni et al., "Uranium Dispersion and Dosimetry (UDAD) Code," Report ANL/ES-72, NRUEG/CR-0553, Argonne National Laboratory, Chicago, May 1979 and D. R. Kalkwarf, "Solubility Classification of Airborne Products from Uranium Ores and Tailings Piles," Report PNL-2830, NUREG/CR-0530, Pacific

Northwest aboratory, Richland, Wash., Jan. .y 1979.

### B.4.2 External doses

External doses from air and ground concentrations are computed using the dose conversion factors provided in Table B.6.[1] Doses are computed based on 100% occupancy at the particular location. Indoor exposure is assumed to occur 14 h/d at a dose rate of 70% of the outdoor dose rate.

### B.4.3 Ingestion doses

Ingestion doses are computed for vegetables and meat (beef and lamb) on the basis of concentrations obtained using Eqs. B-9 through B-12, ingestion rates given in Table B.7, and dose conversion factors given in Table B.8.[1,4] Vegetable ingestion doses were computed assuming an average 50% activity reduction caused by food preparation.[4] Ingestion doses to children and teenagers were computed but were found to be equal to or less than doses to adults.

Table B.6 - Dose conversion factors for external exposure

| Isotope | Skin | Whole body |
|---|---|---|
| | For air concentration doses, millirem per year per $pCi/m^3$ | |
| U-238 | 1.05E-5* | 1.57E-6 |
| Th-234 | 6.63E-5 | 5.24E-5 |
| Pa(m)-234 | 8.57E-5 | 6.64E-5 |
| U-234 | 1.36E-5 | 2.49E-6 |
| Th-230 | 1.29E-9 | 3.59E-6 |
| Ra-226 | 6.00E-5 | 4.90E-5 |
| Rn-222 | 3.46E-0 | 2.83E-6 |
| Po-218 | 8.18E-7 | 6.34E-7 |
| Pb-214 | 2.06E-3 | 1.67E-3 |
| Bi-214 | 1.36E-2 | 1.16E-2 |
| Po-214 | 9.89E-7 | 7.66E-7 |
| Pb-210 | 4.17E-5 | 1.43E-3 |
| | For ground concentration doses, millirem per year per $pCi/m^2$ | |
| U-238 | 2.13E-6 | 3.17E-7 |
| Th-234 | 2.10E-6 | 1.66E-6 |
| Pa(m)-234 | 1.60E-6 | 1.24E-6 |
| U-234 | 2.60E-6 | 4.78E-7 |
| Th-230 | 2.20E-6 | 6.12E-7 |
| Ra-226 | 1.16E-6 | 9.47E-7 |
| Rn-222 | 6.15E-8 | 5.03E-8 |
| Po-218 | 1.42E-8 | 1.10E-8 |
| Pb-214 | 3.89E-5 | 3.16E-5 |
| Bi-214 | 2.18E-4 | 1.85E-4 |
| Po-214 | 1.72E-8 | 1.33E-8 |
| Pb-210 | 6.65E-6 | 2.27E-6 |

*Read as $1.05 \times 10^{-5}$, or .0000105.

Source: U.S. Nuclear Regulatory Commission, "Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations," Report Task RH 802-4, Washington, D.C., May 1979.

Table B.7 - Assumed food ingestion rates*

| | Infant | Child | Teen | Adult |
|---|---|---|---|---|
| Vegetables, kg/year | - | 48 | 76 | 105 |
| Edible above ground | - | 17 | 29 | 40 |
| Potatoes | - | 27 | 42 | 60 |
| Other below ground | - | 3.4 | 5.0 | 5.0 |
| Meat (beef, fresh pork, and lamb), kg/year | - | 28 | 45 | 78 |
| Milk, L/year | 208 | 208 | 246 | 130 |

*Ingestion rates are averages for typical rural farm households. No allowance is credited for portions of year when locally or homegrown food may not be available.

Source: J. F. Fletcher and W. L. Dotson, "HERMES - A Digital Computer Code for Estimating Regional Radiological Effects from the Nuclear Power Industry," Report HEDL-TME-71-168, Hanford Engineering Development Laboratory, Hanford, Wash., December 1971.

Table B.8 - Ingestion dose conversion factors, values are in millirem/pCi ingested

| Age Group | Organ | U-238 | U-234 | Th-234 | Th-230 | Ra-226 | Pb-210 | Bi-210 | Po-210 |
|---|---|---|---|---|---|---|---|---|---|
| Infant | Whole body | 3.33E-4* | 3.80E-4 | 2.00E-8 | 1.06E-4 | 1.07E-2 | 2.38E-3 | 3.58E-7 | 7.41E-4 |
| | Bone | 4.47E-3 | 4.88E-3 | 6.92E-7 | 3.80E-3 | 9.44E-2 | 5.28E-2 | 4.16E-6 | 3.10E-3 |
| | Liver | 0. | 0. | 3.77E-8 | 1.90E-4 | 4.76E-5 | 1.42E-2 | 2.68E-5 | 5.93E-3 |
| | Kidney | 9.28E-4 | 1.06E-3 | 1.39E-7 | 9.12E-4 | 8.72E-4 | 4.33E-2 | 2.08E-4 | 1.26E-2 |
| Child | Whole body | 1.94E-4 | 2.21E-4 | 9.88E-9 | 9.91E-5 | 9.87E-3 | 2.09E-3 | 1.69E-7 | 3.67E-4 |
| | Bone | 3.27E-3 | 3.57E-3 | 3.42E-7 | 3.55E-3 | 8.76E-2 | 4.75E-2 | 1.97E-6 | 1.52E-3 |
| | Liver | 0. | 0. | 1.51E-8 | 1.78E-4 | 1.84E-5 | 1.22E-2 | 1.02E-5 | 2.43E-3 |
| | Kidney | 5.24E-4 | 5.98E-4 | 8.01E-8 | 8.67E-8 | 4.88E-4 | 3.67E-2 | 1.15E-4 | 7.56E-3 |
| Teenager | Whole body | 6.49E-5 | 7.39E-5 | 3.31E-9 | 6.00E-5 | 5.00E-3 | 7.01E-4 | 5.66E-8 | 1.23E-4 |
| | Bone | 1.09E-3 | 1.19E-3 | 1.14E-7 | 2.16E-3 | 4.09E-2 | 1.81E-2 | 6.59E-7 | 5.09E-4 |
| | Liver | 0. | 0. | 6.68E-9 | 1.23E-4 | 8.13E-6 | 5.44E-3 | 4.51E-6 | 1.07E-3 |
| | Kidney | 2.50E-4 | 2.85E-4 | 3.81E-8 | 5.99E-4 | 2.32E-4 | 1.72E-2 | 5.48E-5 | 3.70E-3 |
| Adult | Whole body | 4.54E-5 | 5.17E-5 | 2.13E-9 | 5.70E-5 | 4.60E-3 | 5.44E-4 | 3.96E-8 | 8.59E-5 |
| | Bone | 7.67E-4 | 8.36E-4 | 8.01E-8 | 2.06E-3 | 4.60E-2 | 1.53E-2 | 4.61E-7 | 3.56E-4 |
| | Liver | 0. | 0. | 4.71E-9 | 1.17E-4 | 5.74E-6 | 4.37E-3 | 3.18E-6 | 7.56E-4 |
| | Kidney | 1.75E-4 | 1.99E-4 | 2.67E-8 | 5.65E-4 | 1.63E-4 | 1.23E-2 | 3.83E-5 | 2.52E-3 |

Isotope columns: U-238 through Po-210.

*Read as $3.33 \times 10^{-4}$ or .000333.

Sources: U.S. Nuclear Regulatory Commission, "Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations," Report Task RH 802-4, Washington, D.C., May 1979, and G. R. Hoenes and J. K. Soldat, "Age-Specific Radiation Dose Conversion Factors for a One-Year Chronic Intake," Report NUREG-0172, Battelle Pacific Northwest Laboratories, Richland, Washington, November 1977.

Table BB-1

Annual Dose Commitments to Individuals in the Vicinity of Irigaray Facility

| Location | Exposure Pathway | Annual Dose Commitment,* mrem/year | | | |
|---|---|---|---|---|---|
| | | Whole Body | Bone | Lung | Bronchial Epithelium |
| Reculusa Ranch | Inhalation+ | #1.89E-5 | 3.39E-4 | 1.90E-3 | 1.92E-2 |
| 6.6 km SW | External Ground | 6.96E-6 | 6.96E-6 | 6.96E-6 | - |
| Nearest resident | External Cloud | 2.83E-4 | 2.83E-4 | 2.83E-4 | - |
| | Meat ingestion§ | 5.16E-7 | 1.02E-5 | 5.16E-7 | - |
| | Vegetable ingestion | 4.35E-6 | 8.00E-5 | 4.35E-6 | - |
| | Milk | 9.36E-7 | 1.57E-5 | 9.36E-7 | |
| Total | | 3.15E-4 | 7.35E-4 | 2.19E-3 | 1.92E-2 |
| Sussex | Inhalation | 4.17E-6 | 9.27E-5 | 2.91E-4 | 4.56E-3 |
| 25.1 km SW | External Ground | 1.56E-6 | 1.56E-6 | 1.56E-6 | - |
| | External Cloud | 7.87E-5 | 7.87E-5 | 7.87E-5 | - |
| | Meat ingestion | 3.49E-7 | 8.29E-6 | 3.49E-7 | - |
| | Vegetable ingestion | 2.02E-6 | 4.62E-5 | 2.02E-6 | - |
| | Milk | 2.14E-7 | 4.21E-6 | 2.14E-7 | |
| Total* | | 8.71E-5 | 2.32E-4 | 3.74E-4 | 4.56E-3 |

*Dose commitments are integrated over a 50-year period from one year of exposure. Occupancy is assumed to be 24 hours/day.

+Doses to the whole body, lungs, and bone are those resulting from the inhalation of particulates of U-238, U-234, Th-230, Ra-226, Pb-210 and Po-210. Doses to the bronchial epithelium are those resulting from the inhalation of radon daughters.

#Read as $1.89 \times 10^{-5}$ or 0.0000189.

§Ingestion impacts result from the assumed consumption of meat from cattle grazed within 1 km of the Irigaray facility.

Table BB-2

Comparison of Annual Dose Commitments to Individuals with EPA Radiation Protection Standards (40 CFR 190)*

| Location | Exposure Pathway | Annual Dose Commitment,* mrem/year Body | Bone | Lung |
|---|---|---|---|---|
| EPA limits (40 CFR 190) | | 25.0 | 25.0 | 25.0 |
| 1. Reculusa Ranch 6.6 km SW Nearest Resident | Inhalation | 1.79E-5 | 3.06E-4 | 1.89E-3 |
| | External | 2.36E-6 | 2.36E-6 | 2.36E-6 |
| | Food Ingestion+ | 4.40E-6 | 7.10E-5 | 4.30E-6 |
| | Total | 2.47E-5 | 3.81E-4 | 1.90E-3 |
| | Fraction of limit | 9.9 E-7 | 1.5 E-5 | 7.6 E-5 |
| 2. Sussex 25.1 km SW | Inhalation | 2.63E-6 | 4.50E-5 | 2.78E-4 |
| | External | 3.48E-7 | 3.48E-7 | 3.48E-7 |
| | Food Ingestion | 6.0 E-6 | 9.8 E-6 | 6.0 E-7 |
| | Total | 8.98E-6 | 5.52E-5 | 2.79E-4 |
| | Fraction of limit | 3.6 E-7 | 2.21E-6 | 1.12E-5 |

*40 CFR Part 190 specifically excludes any dose commitments arising from the release of radon and its daughters.

+Food ingestion impacts result from the assumed consumption of meat from cattle grazed within 1 km of the Irigaray facility.

Table BB-3

Annual 100-year Environmental Dose Commitments to Regional Population within 80-km Radius of the Irigaray Facility

| Exposure Pathway | Annual Environmental Dose Commitments (EDC), person-rem/year | | | |
|---|---|---|---|---|
| | Whole Body | Bone | Lung | Bronchial Epithelium+ |
| Inhalation | #7.231E-5 | 2.053E-3 | 2.055E-3 | 5.371E-2 |
| External ground | 6.541E-5 | 6.541E-5 | 6.541E-5 | - |
| External cloud | 9.478E-4 | 9.478E-4 | 9.478E-4 | - |
| Vegetable ingestion | 4.085E-4 | 8.721E-3 | 4.085E-4 | - |
| Meat ingestion | 2.003E-5 | 4.547E-4 | 2.003E-5 | - |
| Milk ingestion | 1.663E-5 | 3.149E-4 | 1.663E-5 | - |
| TOTAL | 1.531E-3 | 1.256E-2 | 2.513E-3 | 5.371E-2 |
| Estimated population dose from natural background | 2927 | 3516 | 2944 | 9420 |
| Ratio of total EDC to background population dose | 5.2 E-7 | 3.57 E-6 | 1.19 E-6 | 5.7 E-6 |

*Doses to the whole body, lung, and bone are those resulting from the releases of particulates of U-238, U-234, Th-230, Ra-226 and Pb-210.

+Inhalation doses to the bronchial epithelium are those resulting from the inhalation of radon daughters.

#Read as $7.271 \times 10^{-5}$ or 0.00007271.

§Background doses are based on the regional population size of 16,822 and natural background organ doses as follows:

Whole Body - 174 mrem/yr
Bone 209 mrem/yr
Lung - 175 mrem/yr
Bronchial epithelium - 560 mrem/yr

Source: G. L. Montet et al., "Description of United States Uranium Resource Areas, a Supplement to the Generic Environmental Impact Statement on Uranium Milling," Report NUREG/CR-0597, ANL/ES-75, prepared by Argonne National Laboratory for the U.S. Nuclear Regulatory Commission, June 1979. The staff assumes the population dose due to background is equivalent to the general background dose for the Colorado Plateau.

Table BB-4

Total Environmental Dose Commitments (EDC) over
the 5 Operational Years of the Irigaray Facility

| | EDC to each organ, person-rem | | | |
|---|---|---|---|---|
| | Whole Body | Bone | Lung | Bronchial Epithelium |
| EDCs received by population within 80 km of mill | 1.531E-3 | 1.256E-2 | 3.513E-3 | 5.371E-2 |
| EDCs received by population beyond 80 km of mill | 1.417E+3 | 1.931E+4 | 3.219E+2 | 9.052E+3 |
| Total EDCs received by continental population | 1.417E+3 | 1.931E+4 | 3.219E+2 | 9.052E+3 |
| Fraction of background# | 1.08 E-6 | 6.5 E-7 | 1.1 E-5 | 5.93 E-6 |

#Background values estimated on the basis of year 1991, a continental population of 245.5 million persons, each person receiving 100 millirem/year to the whole body, bone and lung, and 500 millirem/year to the bronchial epithelium.

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*Available for purchase from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, D.C.20555, and the National Technical Information Service, Springfield, Virginia 22161.

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