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July 29, 2005

**BY ELECTRONIC MAIL, U.S. FIRST CLASS MAIL**

U.S. Nuclear Regulatory Commission  
Office of the Secretary  
Attn: Rulemaking and Adjudications Staff  
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Washington, DC 20555

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August 2, 2005 (12:35pm)

OFFICE OF SECRETARY  
RULEMAKINGS AND  
ADJUDICATIONS STAFF

Re: In the Matter of: Hydro Resources, Inc.  
Docket No: 40-8968-ML

Dear Sir or Madam:

Please find attached for filing Hydro Resources, Inc.'s Response in Opposition to Intervenors' Written Presentation Regarding Air Emissions in the above-captioned matter. Copies of the enclosed have been served on the parties indicated on the enclosed certificate of service. Additionally, please return a file-stamped copy in the self-addressed, postage prepaid envelope attached herewith.

If you have any questions, please feel free to contact me at (202) 496-0780.  
Thank you for your time and consideration in this matter.

Sincerely,



Anthony J. Thompson, Esq.  
Christopher S. Pugsley, Esq.  
Thompson & Simmons, PLLC.  
Counsel of Record to HRI

Enclosures

(hydro resourcesCOVERLETTTER 7-29-05.doc)

Template = SECY-021

SECY-02

UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION  
ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:  
E. Roy Hawkens, Presiding Officer  
Dr. Richard F. Cole, Special Assistant  
Dr. Robin Brett, Special Assistant

In the Matter of:

Hydro Resources, Inc.  
P.O. Box 777  
Crownpoint, NM 87313

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)  
) Docket No.: 40-8968-ML  
)  
) Date: July 29, 2005  
)  
)

**HYDRO RESOURCES, INC.'S RESPONSE IN OPPOSITION TO  
INTERVENORS' WRITTEN PRESENTATION REGARDING  
AIR EMISSIONS**

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NUCLEAR REGULATORY COMMISSION  
ATOMIC SAFETY AND LICENSING BOARD**

**Before Administrative Judges:  
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**HYDRO RESOURCES, INC.'S RESPONSE IN OPPOSITION TO  
INTERVENORS' WRITTEN PRESENTATION REGARDING AIR EMISSIONS**

**I. INTRODUCTION**

Hydro Resources, Inc. (HRI), by its undersigned counsel of record, hereby submits this Response in Opposition to Intervenor's Written Presentation Regarding Air Emissions<sup>1</sup> with respect to HRI's Nuclear Regulatory Commission (NRC) source material license to operate an *in situ leach* (ISL) uranium recovery facility at Church Rock and Crownpoint, New Mexico. For the reasons discussed below, HRI respectfully requests that the Presiding Officer reject each of Intervenor's arguments regarding air emissions at the Church Rock Section 17 uranium recovery site.

**II. BACKGROUND AND PROCEDURAL HISTORY**

HRI applied for an NRC source material license to operate an ISL uranium recovery facility at the Crownpoint Uranium Project (CUP) consisting of the Church

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<sup>1</sup> It is important to note that, pursuant to an agreement between the parties, Intervenor's are permitted to present air emissions arguments for the Church Rock Section 17 site only.

Rock Sections 8 and 17, Unit One, and Crownpoint uranium recovery sites. On November 14, 1994, NRC Staff prepared a draft environmental impact statement (DEIS) and published a notice in the Federal Register detailing its availability. *See* 59 Fed. Reg. 56,557 (November 14, 1994). This Federal Register notice provided potentially affected parties with an opportunity to request a hearing in accordance with 10 CFR § 2.1205. On December 21, 1994, several parties filed hearing requests with NRC, and a Presiding Officer was designated by the Atomic Safety and Licensing Board. *See* 59 Fed. Reg. 66,979 (January 8, 1995). However, the Presiding Officer held all aspects of this proceeding, including final determinations of standing for a hearing, in abeyance until NRC Staff completed its review of HRI's license application and issued its final environmental impact statement (FEIS). On February 29, 1997, NRC Staff issued its FEIS and, on January 5, 1998, NRC Staff approved HRI's license application and granted HRI License No. SUA-1508.

On May 13, 1998, the Presiding Officer permitted several parties, including the Eastern Navajo Dine Against Uranium Mining (ENDAUM), the Southwest Research Information Center (SRIC), and Grace and Marilyn Sam (hereinafter the "Intervenors"), to intervene to challenge HRI's license under NRC's 10 CFR Part 2, Subpart L provisions for "informal hearings." *See In the Matter of Hydro Resources, Inc.* (Crownpoint Uranium Project), LBP-98-9, 47 NRC 261 (May 13, 1998). Additionally, in September of 1997, NRC Staff requested leave to participate as a party in the hearing process in accordance with 10 CFR §§ 2.1213 & 2.1237. During the hearing, the Presiding Officer bifurcated the proceeding to address HRI's four (4) proposed uranium

mining sites separately: (1) Church Rock Section 8; (2) Church Rock Section 17; (3) Unit One; and (4) Crownpoint.

**A. Church Rock Section 17 Air Emissions Area of Concern**

As part of the Subpart L hearing process, Intervenors were required to submit a list of contentions to the Presiding Officer to determine which areas of concern, if any, were germane to this proceeding. The Presiding Officer admitted the following air emissions issues as germane: (1) whether HRI's license application and supporting documentation adequately address air emissions and (2) the effects of radon re-circulating in uranium recovery solutions.

On January 11, 1999, Intervenors submitted their written presentation regarding air emissions for the Church Rock Section 8 uranium recovery site. *See In the Matter of Hydro Resources, Inc.: Eastern Navajo Dine Against Uranium Mining's and Southwest Research and Information Center's Brief Regarding Radioactive Air Emissions at the Crownpoint Project* (January 11, 1999). In response to Intervenors' written presentation, on February 11, 1999, HRI submitted its response in support of its license application. *See In the Matter of Hydro Resources, Inc.: Hydro Resources, Inc.'s Response to ENDAUM's and SRIC's January 11, 1999 Brief Regarding Radioactive Air Emissions at Crownpoint Project* (February 11, 1999). Then, on February 18, 1999, NRC Staff submitted its response to Intervenors' written presentation. *See In the Matter of Hydro Resources, Inc.: NRC Staff's Response to Intervenors' Presentation on Air Emissions Issues* (February 18, 1999).

In response to these written presentations, on March 18, 1999, the Presiding Officer issued an Order in which several questions were posed to all parties regarding

Church Rock Section 8 air emissions issues. *See In the Matter of Hydro Resources, Inc.*, (Questions Concerning Radioactive Air Emissions), LBP-99-15, 49 NRC 261 (March 18, 1999). On May 13, 1999, the Presiding Officer issued LBP-99-19 in which HRI's Church Rock Section 8 license was upheld with respect to air emissions issues. *See In the Matter of Hydro Resources, Inc. (Partial Initial Decision)*, 49 NRC 421 (May 13, 1999). In response to LBP-99-19, Intervenors submitted a Petition for Review to the Commission requesting that the Presiding Officer's decision be reversed. HRI and NRC Staff submitted responses to Intervenors' Petition for Review. On July 10, 2000, after reviewing all parties' filings, the Commission rejected Intervenors' Petitions for Review. *See In the Matter of Hydro Resources, Inc. (Memorandum and Order)*, 52 NRC 1 (July 10, 2000).

On June 14, 2005, Intervenors submitted their written presentation regarding air emissions issues for the Church Rock Section 17 uranium recovery site. In response to Intervenors' air emissions, HRI hereby submits this response and respectfully requests that the Presiding Officer reject each of Intervenors' arguments regarding air emissions for the Church Rock Section 17 uranium recovery site.

### **III. AIR EMISSIONS DECISIONS REGARDING CHURCH ROCK SECTION 8 URANIUM RECOVERY SITE**

#### **A. LBP-99-15: 49 NRC 261 (March 18, 1999)**

In LBP-99-15, the Presiding Officer issued a series of questions to all parties regarding air emissions issues. Prior to listing this series of questions, the Presiding Officer provided a brief discussion of the argument presented by HRI, Intervenors, and NRC Staff regarding air emissions and the legal/regulatory standards applicable to this

proceeding, including dicta regarding “background radiation.” After this discussion, the Presiding Officer presented his questions.

**B. LBP-99-19: 49 NRC 421 (May 13, 1999)**

In LBP-99-19, the Presiding Officer considered Intervenors’ arguments regarding potential air emissions issues at the Church Rock Section 8 uranium recovery site. The Presiding Officer determined that Intervenors’ calculation of off-site doses of radiation from the Church Rock Section 8 uranium recovery site were incorrect. More specifically, the Presiding Officer stated that “I disagree with Intervenors concerning the calculation of off site doses.” 49 NRC at \*11. Thus, based on his analysis, the Presiding Officer concluded that “HRI has demonstrated...that the air borne doses from the proposed operation of the Church Rock site will not exceed regulatory requirements.” *Id.* at \*14.

**C. CLI-00-12: 52 NRC 1 (July 10, 2000)**

In CLI-00-12, the Commission considered three (3) Petitions for Review from Intervenors regarding, *inter alia*, air emissions from the Church Rock Section 8 uranium recovery site. The Commission rejected Intervenors’ claims that the Presiding Officer’s questions regarding air emissions allowed HRI and NRC Staff to cure fatal deficiencies in their license application, FEIS, and written presentations. 52 NRC at \*4. The Commission noted that the Presiding Officer’s questions were a “legitimate effort to obtain clarification or elaboration of assertions in existing pleadings.” *Id.* at \*5. With regard to Intervenors’ other arguments regarding air emissions, the Commission determined that “we see no reason to call for full briefing or for plenary Commission review.” *Id.* at \*4.

**IV. SUMMARY OF EVIDENCE REGARDING AIR EMISSIONS ISSUES AT CHURCH ROCK SECTION 8 URANIUM RECOVERY SITE**

**A. *Hydro Resources, Inc.'s Response to ENDAUM's and SRIC's January 11, 1999 Brief Regarding Radioactive Air Emissions at the Crownpoint Project***

On February 11, 1999, HRI submitted its response to Intervenors' written Presentation regarding air emissions issues for the Church Rock Section 8 uranium recovery site. This response included the text of HRI's written presentation and one attached expert affidavit from Dr. Alan C. Eggleston.

The text of HRI's written presentation addressed each of the arguments presented by Intervenors' with respect to air emissions from ISL uranium recovery operations at the Church Rock Section 8 site. After providing a brief procedural history, HRI first argued that Intervenors misinterpreted the regulatory requirements of 10 CFR Part 20 for radiation dose limits. HRI asserted that Intervenors mischaracterized the definition of "background radiation" and that their "proposed definition of "background radiation" was incorrect.

Next, HRI argued that its assessment of gamma radiation at the Church Rock site was adequate because of Intervenors' mischaracterization of "background radiation," because gamma radiation is not transported by wind, and because Intervenors' failed to demonstrate that a source of gamma radiation from licensed activities will result in potential adverse radiological impacts to members of the public.

HRI also argued that its exposure calculations were correct and satisfied applicable NRC regulations. HRI stated that Intervenors argument that the FEIS' exposure calculations were flawed was baseless because an appropriate interpretation of radon-222 measurements in groundwater was used. Further, Intervenors' assertion that

an uncertainty analysis should have been required was refuted by HRI's expert by stating that source terms for the CUP were similar to other source terms used for ISL uranium recovery projects in the United States. Moreover, the potential impacts of such source terms also were based on a MILDOS analysis, which is a proven model and is often overly conservative. Further, to alleviate concerns about the Gaussian model, HRI agreed to license conditions requiring field verification of model predictions prior to operations.

Finally, HRI stated that gamma radiation was measured prior to the removal of some materials associated with previous mining activities and will be measured prior to the commencement of operations at the Church Rock site. HRI also noted that gamma radiation measurements were not taken at the nearest residence because that residence was not present when early pre-operational baseline studies were conducted. Finally, HRI asserted that gamma radiation from the Church Rock site was part of background and, thus, did not create doses above natural background.

**1. Affidavit of Dr. Alan C. Eggleston**

In support of its written presentation, HRI offered the testimony of Dr. Alan C. Eggleston, which contained his opinion regarding the potential types of air emissions from ISL uranium recovery activities and site-specific analyses for the Church Rock Section 8 site. First, Dr. Eggleston stated that much of the material that contributed to ambient radon levels at the Church Rock site was removed (i.e., pond sediments) and that mine vents and shafts were sealed. New ambient radon levels would be collected pursuant to a license condition and under standard operating procedure (SOP) prior to the commencement of operations.

Next, Dr. Eggleston provided a discussion of the presence of naturally occurring radioactivity in different sections of the United States based on geological features. Dr. Eggleston cited the State of New Mexico as an example of an area where elevated radon-222 levels are present due to geological features and not necessarily as a result of anthropogenic activities such as uranium mining. This statement was supported by ambient radon-222 data from other mining project where uranium could be recovered using ISL techniques. Thus, Dr. Eggleston concluded that the presence of variable, elevated radon-222 levels in areas where uranium can be recovered is the rule rather than the exception.

Next, Dr. Eggleston stated that the proposed boundary receptors for radon measurements in the MILDOS model are sufficient because members of the public will not have access to restricted areas or mining sites. The boundary receptors are important because they *represent* the closest approach permitted to members of the public to the areas in which SOPs for HRI personnel apply, as well as applicable NRC occupational dose limits. These fences will be appropriately labeled to restrict access to members of the public, thus, limiting potential doses from ISL uranium recovery operations. All boundary receptors are listed in the FEIS and are used in the MILDOS calculations.

According to Dr. Eggleston, the assessment of potential gamma exposure to the nearest resident was sufficient because receptors have been designated to monitor the potential dose at that point and pre-operational and operational monitoring of potential exposures are required by license condition. Further, the analysis performed by HRI for the source term was adequate and an uncertainty analysis was not necessary. Given that many source terms at other ISL uranium recovery sites using similar technology resemble

that of the Church Rock site and that the analysis of the source term was performed properly, Dr. Eggleston concluded that HRI's license application satisfied relevant regulatory requirements.

Dr. Eggleston also concluded that HRI's analysis of potential dose from groundwater in the production well-field was adequate. Several protective factors were included in HRI's and the MILDOS model to ensure that outcomes were properly assessed. Such factors include a radon-222 database from Mobil Corporation, no credit for the small diminution of dissolved radon-222 from its starting concentration with introduction of water from outside the ore body during mining or during restoration from removed radium, and the fact that uncertainty hinges on the presence of high concentrations, high possible doses, and discontinuous operations which are not part of CUP operations.

Finally, Dr. Eggleston concluded that the use of MILDOS does not constitute a misrepresentation or distortion of information regarding air emissions at the Church Rock site. Dr. Eggleston stated that MILDOS is a proven model that does not underpredict impacts at ISL uranium recovery facilities.

**B. *Hydro Resources, Inc.'s Response to LBP-99-15 Memorandum and Order (Questions Concerning Radioactive Air Emissions)***

After the Presiding Officer issued LBP-99-15 requesting answers to several questions regarding air emissions, HRI's response included a brief summary of its answers to the Presiding Officer's questions and two (2) attached expert affidavits from Dr. Douglas Chambers and Mr. Mark S. Pelizza.

After presenting a brief synopsis of the legal issues in question, HRI provided a brief summary of its answers to the Presiding Officer's questions. This summary

provided information regarding legal arguments on “background radiation” and the fact that no source, special nuclear or byproduct material *regulated by the Commission* is present at the Church Rock Section 8 site.

**1. Affidavit of Dr. Douglas Chambers**

The affidavit of Dr. Douglas Chambers presented expert testimony in the form of specific written answers to each of the Presiding Officer’s questions. With respect to ambient radon levels in Church Rock, Dr. Chambers stated that natural background for radon is highly variable and that Church Rock radon levels can be expected to be naturally elevated due to the geological formations in the area such as the natural outcrops of the Morrison and Dakota formations. This widely spread mineralization contributes regionally to elevated natural background radon-222 concentrations. Based on this, Dr. Chambers concluded that natural background in the Church Rock area should be in the range of one to two pCi/L, which is consistent with HRI’s measurements.

Dr. Chambers also addressed the presence of gamma radiation at Church Rock and stated that elevated levels of such radiation should not be considered part of the total effective dose equivalent (TEDE) for the CUP. Since gamma radiation levels decrease rapidly with increasing distance from its source and production areas will be fenced to prevent unauthorized access to production areas, Dr. Chambers concluded that gamma should not be considered part of the CUP’s TEDE for members of the public.

With respect to what portion of the TEDE should not be considered “background radiation” and how TEDE should be calculated, Dr. Chambers stated that

assuming a 300 mrem/year natural background level for the Church Rock area, the TEDE from ISL uranium recovery operations should be 0.25% of the natural background dose. Dr. Chambers qualified this statement by noting that a 300 mrem/year natural background level is likely too low for the Church Rock area. Dr. Chambers also stated that the methodology used by NRC Staff in the FEIS to calculate TEDE was appropriate. After discussing NRC Staff's procedures, Dr. Chambers concluded that MILDOS is unlikely to underestimate the TEDE dose and that the contribution to TEDE from ISL uranium recovery operations is inconsequential to natural background at Church Rock.

Dr. Chambers addressed the Presiding Officer's question regarding closest receptors by stating that the FEIS accurately selected the nearest resident as the receptor and that the calculations of a 0.25 mrem/year dose were correct. Further, Dr. Chambers noted that the FEIS also addressed several other receptors for the Church Rock, Unit One, and Crownpoint areas.

Finally, Dr. Chambers concluded that the FEIS properly addressed the potential combined radiological impacts for the CUP and from elevated natural background levels in the area. Dr. Chambers also noted that, in his opinion, elevated levels of radioactivity in the Church Rock area were from natural sources and not man-made or anthropogenic activities.

## **2. Affidavit of Mr. Mark S. Pelizza**

The affidavit of Mr. Mark S. Pelizza presented expert testimony regarding radiation issues associated with the Presiding Officer's questions in LBP-99-15. First, Mr. Pelizza stated that the CUP was specifically designed to restrict access of members

of the public to restricted areas. HRI's license application devotes 62 single spaced pages to its Radiation Safety Program, including a description of how each production site will be restricted. HRI's Consolidated Operations Plan (COP) Rev. 2.0 § 9.13 specifically addresses restricted areas and security measures to prevent unauthorized access.

Mr. Pelizza further stated that Intervenors' complaints that radiation doses within the restricted area should be measured for members of the public are incorrect. Radiation measurements within the restricted area do not apply to members of the public because they will not be permitted access to the restricted areas. Since occupational dose limits are different from those for members of the public, Mr. Pelizza stated that cumulative impacts within the restricted area are not an issue for members of the public.

With respect to monitoring, Mr. Pelizza stated that HRI's radiation monitoring program is outlined in the COP and meets NRC requirements. Further, HRI specifically selected a monitoring station at the nearest residence based on its distance and location in the downwind path of the prevailing wind.

## **V. STANDARD OF REVIEW**

### **A. Scope of Licensing Board Review**

Normally, the Licensing Board is charged with compiling a factual record in a proceeding, analyzing the record, and making a determination based upon the record. The Licensing Board performs the important task of judging factual and legal disputes between parties and has the responsibility for appraising *ab initio* the record developed before it and for formulating the agency's initial decision based on that

appraisal. *See Wisconsin Electric Power Co.* (Point Beach Nuclear Plant, Unit 2), ALAB-78, 5 AEC 319, 322 (1972). A Licensing Board is not required to do independent research or conduct *de novo* review of an application in a contested proceeding, but may rely upon uncontradicted Staff and applicant evidence. *See Consumers Power Co.* (Midland Plant, Units 1 & 2), ALAB-123, 6 AEC 331, 334-35 (1973).

With respect to the jurisdiction of the Licensing Board, a Licensing Board has only the jurisdiction and power which the Commission delegates to it. *See e.g., Public Service Co. of Indiana* (Marble Hill Nuclear Generating Station, Units 1 & 2), ALAB-316, 3 NRC 167 (1976). While the Licensing Board possesses the power to provide initial reviews of license applications in contested proceedings, it does not possess the power to overrule Commission holdings. Where a matter has been considered by the Commission, it may not be reconsidered by a Board. *Virginia Electric & Power Co.* (North Anna Nuclear Power Station, Units 1 & 2), ALAB-584, 11 NRC 451, 463-65 (1980). A Licensing Board for an operating license proceeding is also limited to resolving matters that are raised therein as *legitimate* contentions by the parties or by the Board *sua sponte*. *See e.g., Dairyland Power Cooperative* (LaCrosse Boiling Water Reactor), LBP-88-15, 27 NRC 576, 579 (1988) (emphasis added).

#### **B. Law of the Case Doctrine**

The law of the case doctrine is generally applicable in NRC adjudicatory proceedings. *Safety Light Corp.* (Bloomsburg Site Decontamination), CLI-92-9, 35 NRC 156, 159-160 (1992). As stated by the Presiding Officer in LBP-05-17, the law of the case doctrine “establishes that the decision of an appellate tribunal should ordinarily be followed in all subsequent phases of that case, provided that the particular question in

issue was ‘actually decided or decided by necessary implication.’ *In the Matter of Hydro Resources, Inc.* (Crownpoint Uranium Project), LBP-05-17, (July 20, 2005) quoting *Safety Light Corp.* (Bloomsburg Site Decontamination), CLI-92-09, 35 NRC 156, 159-160 & n.5 (1992). When court decides that a rule of law or a factual determination is applicable in a stage of a proceeding, then that rule or determination is equally applicable in subsequent stages of the proceeding. *Safir v. Dole*, 718 F.2d 475, 480-81 (D.C. Cir. 1983). Law of the case decisions include the court’s explicit decision, as well as those decided by implication. *Williamsburg Wax Museum, Inc. v. Historic Figures, Inc.*, 810 F.2d 243, 249 (D.C. Cir. 1987).

Exceptions to the law of the case doctrine are limited. The law of the case doctrine applies to adjudicatory proceedings “unless the evidence on a subsequent trial was substantially different, controlling authority has since made a contrary decision of the law applicable to such issues, or *the decision was clearly erroneous* and would work a manifest injustice.” See e.g., *Pittsburg & Midway Coal Mining Company v. Watchman*, 52 F.3d 1531 (10<sup>th</sup> Cir. 1995) quoting *United States v. Monsisvais*, 946 F.2d 114, 117 (10<sup>th</sup> Cir. 1991) (emphasis added).

## **VI. ARGUMENT**

### **A. Intervenors’ Argument That Radiation Levels from Section 17 Exceed NRC Regulatory Limits is Without Merit**

Intervenors claim that Church Rock Section 17 ISL uranium recovery operations will result in radioactive air emissions exceeding NRC regulatory limits. These claims are centered on the fundamental premise that HRI and NRC Staff mischaracterize the regulatory definition of “background radiation” and, thus,

miscalculate the total effective dose equivalent (TEDE) for the site. As will be discussed below, Intervenor's arguments are without merit and should be rejected.

**1. The Law of the Case Doctrine Does Not Apply to The Presiding Officer's Dicta in LBP-99-30 and Intervenor's Interpretation of "Background Radiation" is in Error**

Intervenor's written presentation begins with an attempt to extend the law of the case doctrine to the Presiding Officer's dicta in LBP-99-19 regarding the definition of "background radiation" pursuant to 10 CFR Part 20 requirements. Intervenor claims that the Presiding Officer determined what "background radiation" is as a matter of law for this proceeding and that this determination should be used with regard to determining the TEDE for Section 17.

In LBP-99-19, the Presiding Officer "discussed" thoughts on the interpretation of the term "background radiation:"

"Although HRI would apply the phrase "regulated by the Commission" to each of the antecedent nouns, that is not the way English grammar treats subordinate clauses."

*In the Matter of Hydro Resources, Inc.*, LBP-99-19, 1999 NRC LEXIS 60, \*10-11 (May 13, 1999).

However, in spite of these "discussions," issues of "background radiation" were not relevant to the Section 8 site because Intervenor's calculations regarding TEDE were unacceptable to the Presiding Officer:

"Nevertheless, I disagree with Intervenor concerning the calculation of off site doses....The probability that an individual will be present during the worst case scenario is less than 100 percent and it is therefore inappropriate to act as if the individual would definitely be there during a "worst case."

*Id.* at \*11.

Thus, as stated above, the Presiding Officer has not rendered a *final legal opinion* on the issue of what is “background radiation” at the Section 17 site. The “discussion” offered by the Presiding Officer in LBP-99-19, while perhaps grammatically sound and, in any event, is *clearly erroneous*, and, as such, does not warrant invocation of the law of the case doctrine.

The Presiding Officer’s “discussion” and Intervenor’s argument relies on the statement that:

“The normal meaning of this sentence is that “regulated by the Commission” applies *only* to the last noun in the series, “special nuclear materials.” To interpret it otherwise would be to find that the regulation contains a drafting error....”

*Id.* at \*10 (emphasis added).

Intervenor agrees with Judge Bloch’s “discussion” that the clause “regulated by the Commission” applies *only* to special nuclear material and not to source or byproduct material.

This argument is flawed because, as noted above, it assumes that the clause “regulated by the Commission” applies only to special nuclear material. Further, it could be read to assume that there are classes of special nuclear material “not regulated by the Commission.” The second assumption is patently false as there is no *de minimis* quantity of special nuclear material, and there can be no special nuclear material that is *not* regulated by the Commission, because, by definition, special nuclear material does not exist naturally and is created only through an AEA-licensed activity. The first assumption also fails because byproduct material, like special nuclear material, does not exist naturally and is created only by AEA-licensed activities (i.e., uranium milling or processing or materials made radioactive during the production of special nuclear

material) and because there also is no *de minimis* quantity of byproduct material that is not subject to regulation by the Commission.

The first assumption further fails if there are classes of *source material* that are not regulated by the Commission. *Source material* is defined as:

“(1) Uranium or thorium, or any combination of uranium and thorium in any physical or chemical form; or (2) Ores which contain, by weight, one-twentieth of one percent (0.05 percent), or more, of uranium, thorium, or any combination of uranium and thorium.”

42 U.S.C. § 2014(z) (2005).

With this definition in mind, Section 62 of the AEA, as amended, creates a class of *source material* termed “unimportant quantities” and states that “licenses *shall not* be required for quantities of source material which, in the opinion of the Commission, are unimportant.”<sup>2</sup> 42 U.S.C. § 2092 (2005) (emphasis added). Thus, based on the AEA, there is a class of uranium *source material* that is not *licensable* and, thus, not regulated by the Commission. Since there cannot be either byproduct or special nuclear material which is not regulated by the Commission and since there can be uranium source material that is and is not *licensable*, Judge Bloch’s grammatical interpretation is *clearly* erroneous (i.e., the phrase “regulated by the Commission” cannot be read to apply only to special nuclear material).

Since, as stated by Mr. Pelizza, the uranium source material at the Section 17 site is below the 0.05 percent, by weight, threshold for *licensable* source material, no license is required for such uranium *source material*, and this material is not regulated by the

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<sup>2</sup> NRC’s Office of General Counsel has also evaluated the terms of Section 62 and determined that its provisions are *mandatory*. See Letter to H. L. Price, Director, Division of Licensing and Regulation from Neil D. Maiden, Acting General Counsel, Atomic Energy Commission, *Re: Mill Tailings* (December 7, 1960).

Commission. Thus, this material is naturally occurring radioactive material and, as such, any dose therefrom is part of background radiation.

Finally, as discussed below, since the materials located on the surface at Section 17 and in the underground mine workings are the result of *mining*, which NRC does not regulate, this material is mine waste and is part of background radiation at the site. Neither NRC nor its predecessor, the Atomic Energy Commission (AEC), have regulated uranium mining, either at the mine, on ore storage pads at the mine or during transport to a mill facility regardless of the ore grade (i.e., greater than 0.05 percent, by weight) until it reaches the milling facility.<sup>3</sup> Further, since only uranium *milling or processing* (i.e., ISL uranium recovery as “milling underground”)<sup>4</sup> can create 11e.(2) byproduct material and Section 17 activities were limited exclusively to *conventional mining* activities, none of the material on the surface or in the underground mine workings at Section 17 is regulated by the Commission as byproduct material. Thus, Intervenor’s reliance on Judge Bloch’s “discussion” in LBP-99-19 is misguided because his “discussion” regarding byproduct material at Section 17 is *clearly* erroneous. Therefore, the law of the case doctrine should not apply.

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<sup>3</sup> See United States Nuclear Regulatory Commission, *Generic Environmental Impact Statement on Uranium Milling*, NUREG-0706, Volume 1, A-89 (September 1980) (hereinafter “GEIS”) (offering interpretation of NRC regulatory authority over milling as regulating those activities associated with *processing* and finding that uranium ore on a milling site’s ore pad meets the requirements). To the best of HRI’s knowledge, NRC does not regulate mining, ore at a mining site or ore in transport to a uranium milling site. See generally Exhibit A at 16.

<sup>4</sup> See Letter from Malcolm Knapp, Director, Division of Waste Management, NRC, to Anthony Thompson (June 2, 1994).

## 2. Materials at Underground Mines at Section 17 Are Not Byproduct Material and Are Background Radiation

Intervenors contend that materials present in Section 17 underground mine workings are byproduct material, as defined in the AEA, as amended. Intervenors specifically state that “the prior occupant of Section 17 owned and operated an underground uranium mine....[and] the remaining underground ore is ‘tailings’ as defined in 40 CFR § 192.01(m).” Intervenors’ Written Presentation at 17. Further, Intervenors assert that Judge Bloch determined that “the regulatory definition of byproduct material included some of the material left underground or on the surface of the ground at the HRI site because it resulted from the *extraction* of uranium by the previous operator at HRI’s Section 17 site.” *Id.* (emphasis added)

Intervenors’ argument and the Presiding Officer’s “discussion” of the definition of byproduct material are *clearly* erroneous, because Intervenors’ ignore the fact that NRC does not regulate *mining*. In its Generic Environmental Impact Statement on Uranium Milling (GEIS), NRC states that it “has no direct authority over *uranium mining or mine wastes*. GEIS at A-94. The GEIS also discusses NRC’s regulatory authority over uranium *milling* with respect to uranium ore:

“Section 205(a) of the UMTRCA [Uranium Mill Tailings Radiation Control Act of 1978] amends the Atomic Energy Act of 1954 by adding a new Section 84 which states in part that ‘the Commission shall insure that the management of any byproduct material, as defined in section 11e.(2) , is carried out in such a manner as...the Commission deems appropriate to protect public health and safety and the environment from radiological and nonradiological hazards *associated with the processing* and with the possession and transfer of such material...”

GEIS at A-89 (emphasis in original).

Thus, uranium ore at a uranium *mill* is subject to NRC jurisdiction, but uranium ore at a *mining* site or in transport to a uranium *milling* site is not and, to the best of HRI's knowledge, has not been subject to NRC jurisdiction. Thus, materials at Section 17 such as surface ore piles, remnants of surface ore storage pads or windblown ore dust from transport of uranium-bearing ores for uranium recovery at the nearby UNC mill are *mine wastes not* regulated by the Commission and, as such, cannot be byproduct material. If this were not the case, every *conventional* uranium mine in the United States would require an NRC license. Given that NRC does not and has not required such licenses, any argument alleging that byproduct material can be present at *conventional surface or underground mining* sites due to the extraction or removal of uranium-bearing ore by mining is incorrect.

The confusion regarding this issue stems from assuming that *extraction* of uranium ore from a conventional *mine* along with accompanying mine wastes has the same meaning as *extraction* at a uranium *mill* or by ISL uranium recovery. With respect to uranium *milling* or ISL uranium recovery, 11e.(2) byproduct material is defined as:

“the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore *processed* primarily for its source material content.”

42 U.S.C. § 2014(e)(2) (2005).

*Extraction* at a conventional uranium *mill* involves the separation of natural uranium from its host rock (i.e., waste) by chemical processes.<sup>5</sup> After the ore is ground to sand-like consistency, it proceeds in solution through a series of chemical processes that ultimately strip the natural uranium from the waste sands which then go to tailings as

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<sup>5</sup> See generally GEIS § 3.0.

11e.(2) byproduct material. Thus, as stated above, materials at conventional mining sites such as surface ore piles, remnants of ore storage or pads or windblown ore dust from transport of uranium-bearing ore for *milling* or *processing* at current or former conventional uranium *mining* sites cannot be considered 11e.(2) byproduct material. In ISL uranium recovery operations, the uranium is extracted underground by solubilizing and stripping the uranium from the host rock formation using oxygenated lixiviant.

### 3. Ambient Radon at Section 17 Does Not Exceed NRC Regulatory Limits

Intervenors devote a substantial portion of their argument to allegations that HRI and NRC Staff have failed to demonstrate that radon at the Section 17 site will not exceed NRC regulatory limits.<sup>6</sup> Intervenors claim that radiological data in the DEIS demonstrates that radon emissions will exceed 10 CFR Part 20 requirements. Intervenors Written Presentation at 18. This data allegedly supports Intervenors' claims that elevated radiation levels, consistent with recent measurements taken at the Section 17 site, suggests that exposures on leased grazing areas will exceed applicable limits. *Id.* at 19. Finally, Intervenors claim that such elevated radiation levels cannot be attributed to background.<sup>7</sup> *Id.* at 20.

Initially, for purposes of a frame of reference, all humans are exposed to ionizing radiation on a daily basis, termed "natural background," and "natural background doses are highly variable." Affidavit of Dr. Douglas Chambers (Exhibit B) at 4, ¶ 3. "Natural background" radiation in areas where ISL uranium recovery projects are *sited* often

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<sup>6</sup> It is worth noting that, as a technical matter, gamma radiation is not an "air emission" like radon or airborne particulates as it is not transported by wind and, like x-rays, requires direct exposure as a result of proximity to a source. Nevertheless, HRI will provide a discussion of gamma radiation below.

<sup>7</sup> This argument is addressed in Section VI(A)(1 & 2) above.

dwarfs emissions from ISL uranium recovery facilities themselves. Radon emissions from ISL uranium recovery operations present limited radon source terms versus conventional mill tailings piles and “[t]he lack of heavy equipment, haul roads, waste dumps, etc. [at ISL facilities] result in virtually no air quality degradation....” (e.g., airborne particulates). Affidavit of Mr. Mark S. Pelizza (Exhibit A) at 2, ¶ 8. Moreover, since the primary health threat related to radon is due to inhalation of air containing radon daughters and risks associated with such inhalation is based upon long-term cumulative exposure,<sup>8</sup> ISL uranium recovery operations, which are outdoors and separated from the public by fencing, result in a very small contribution (far less than mill tailings piles) to public exposure to radon and do not pose any significant potential risk to public health.

With respect to radon emissions at the CUP, “[r]adon levels in the Church Rock area would be expected to be naturally elevated as a consequence of natural geologic formations which contain elevated levels of radioactivity.” Exhibit B at 5, ¶ 6. Natural mineralization in this area produces elevated concentrations of radon, thus, creating higher “natural background” levels. Thus, as stated by Dr. Chambers, “in addition to normal soils which release radon, the widely spread mineralization will contribute regionally to an elevated ambient natural background concentration of radon-222.” *Id.* at 5, ¶ 7. Therefore, Dr. Chambers concludes that, “given the extensive natural mineralization in the Church Rock area, it is not surprising that natural background radon

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<sup>8</sup> See *In the Matter of Hydro Resources, Inc.: Hydro Resources, Inc.'s Response to ENDAUM's and SRIC's January 11, 1999 Brief Regarding Radioactive Air Emissions at the Crownpoint Project* at 3-4, citing NRCP, *Ionizing Radiation Exposure of the Population of the United States*, Report No. 93 (September 1, 1987) at 12.; Nuclear Energy Agency, *Dosimetry Aspects of Exposure to Radon and Thorium Daughter Products* (September 1983). Radon gas is inhaled and exhaled too rapidly during human breathing to allow for decay from radon daughters.

levels in the area should be in the range of 1 to 2 pCi/L, consistent with the levels measured by HRI.” *Id.* at 6, ¶ 10.

The evaluation of potential radiological impacts (including those from radon) at ISL uranium recovery projects relies on a detailed technical process involving NRC-approved modeling to determine whether proposed projects are adequately protective of public health and safety. The primary model used by NRC and licensees is the MILDOS-AREA computer code. *See Exhibit A* at 3, ¶ 13. This is the model used by HRI to evaluate potential radiological impacts at the CUP. *See id.* at 3, ¶ 14. This model also can factor in the proven effectiveness of radiological effluent control procedures and technologies such as pressurized systems. *See id.* at 9 ¶ 41.

Based on the discussion above, Dr. Chambers concludes that, contrary to Intervenors’ claims, the Section 17 TEDE was properly calculated. Initially, Dr. Chambers notes that NRC Staff’s FEIS assumed *no radon emission controls* when presenting its analysis. Exhibit B at 8, ¶ 16. Even with this assumption,<sup>9</sup> the FEIS, using an NRC-approved MILDOS-AREA assessment, concluded that the nearest receptor would receive “(about) 1.5 percent of the NRC limit. In addition the FEIS (at 4-79) notes that each of the radon daughters were “several orders of magnitude less than the allowable limits” and also noted that “predicted concentrations of airborne radionuclides at other nearby residences were similar to or lower than those at the nearest residence.” *Id.*

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<sup>9</sup> As discussed by Mr. Pelizza, HRI will use a pressurized radiological effluent control system which minimizes or eliminates potential radon exposures to levels lower than facilities not using such a system. *See Exhibit A* at ¶ 36-44.

Intervenors and their affiant allege that radon-222 in complete equilibrium should have been considered in the FEIS analysis. However, Dr. Chambers states that

Intervenors' statement is misguided:

"The ingrowth of radon decay products is not instantaneous. It takes time for radon decay products to grow in....The EPA...notes that while secular (i.e., complete) equilibrium is a theoretical upper limit, "in reality it is not achievable."

*Id.* at 9, ¶ 17.

Dr. Chambers also adds that migrating radon plumes also are unlike Intervenors' characterizations:

"It should also be noted that as the 'plume' of radon moves downwind away from a source, which allows some time for ingrowth of radon decay products, the concentrations of radon in air will also continue to decrease...."<sup>10</sup>

*Id.*

Therefore, based on the discussion above, Intervenors' argument with respect to ambient radon should be rejected.

Further, contrary to Intervenors' contentions, ambient radon measurements have been taken at the Section 17 site as Mr. Pelizza states, "[a] radon station...was placed on the Section 17/8 boundary. There is no significant gap in data."<sup>11</sup> Mr. Pelizza also notes

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<sup>10</sup> Intervenors argument on radon exposure also fails to account for the fact that: "while outdoor radon contributes to levels of radon (daughters) indoors, it is universally understood that the predominant source of people's exposure to radon is from exposure to radon (daughter) levels inside the home primarily originating from the soils beneath the home."

Exhibit B at 9, ¶ 18.

Thus, while Intervenors argue that members of the public standing in one location 100% of the time will result in radon doses exceeding NRC requirements, it is unlikely that significant radon doses will be received by just "standing around outdoors." As EPA has stated, "people need to be occupying a structure and not just standing outdoors" for radon health risks to be applicable. *See* 48 Fed. Reg. 15076, 15083 (April 6, 1983).

<sup>11</sup> Mr. Pelizza also states that, based on natural conditions at the Church Rock sites:

"it is logical to assume that radon levels at Station 8R1 reflect ambient radon from

that Intervenor's contentions regarding DEIS conclusions that ambient radon will exceed NRC limits is unfounded:

"The DEIS...does not say that radon near the Section 17 [boundary] exceeds regulatory limits, rather the DEIS shows mean ambient radon of 2.16 pCi/L. In the Draft EIS the NRC Staff considered these radiation levels at the Church Rock site (including radon) to be a portion of background...In addition, the radon measured and reported in the DEIS is ambient measure of radon and does not measure radon in equilibrium...which is the relevant measurement in 10 CFR 20....Therefore, on its face, the numbers cannot be compared with respect to potential adverse health effects."

Exhibit A at 14, ¶ 65.

Finally, using the information provided in the Affidavit of Salvador Chavez (Exhibit C), Mr. Pelizza concludes that mine shafts at Section 17 do not offer an additional source of radon:

"regardless of how ore remaining underground is defined, the Old Church Rock shafts do not provide a conduit for radon emanation. There were four shafts at this location that have been fully sealed."

*Id.* at 14, ¶ 67; *see also generally* Exhibit C.

Therefore, for the reasons discussed above, Intervenor's argument with respect to ambient radon should be rejected.

#### **4. Section 17 Gamma Radiation Will Not Exceed NRC Regulatory Limits**

As a general proposition, all persons are exposed to ionizing gamma radiation on a daily basis, as a part of "natural background exposure," and "natural background doses are highly variable." Exhibit B at 4, ¶ 3. As stated by Dr. Chambers, NUREG-1501 states that "a 'range of 1 to 10 mSv (100 to 1000 mrem)—a span factor of ten—is typical

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all background sources including geologic outcrops and the small area impacted by waste ore from the old Church Rock mine."  
Exhibit A at 14, ¶ 64.

of the variation in background doses for most United States citizens in a given year.” *Id.* at 4, ¶ 3. Variability is often influenced by natural conditions in different areas of the United States such that “[t]he rate of release will vary with the radium-226 content of the soil or rock and other factors.” *Id.* at 4, ¶ 4.

With respect to their allegation that elevated gamma radiation will cause HRI’s Section 17 site to exceed NRC requirements, Intervenor’s fail to account for the radiological properties of gamma radiation. To evaluate potential exposure to gamma radiation, the strength of the source, the receptor’s proximity to such source, and duration of exposure must be known. Dr. Chambers offers his opinion on potential doses of gamma radiation:

“Gamma radiation dose depends on a number of factors, specifically, the strength of the source, and exposure duration. It is also important to understand that gamma dose [sic] rate *is not affected by wind direction.*”

Exhibit B at 6, ¶ 12 (emphasis added).

Similar to x-rays, gamma radiation is not affected by wind and, therefore, is not an actual “air emission.” Thus, a member of the public, such as Intervenor, must have proximity to a source of gamma radiation and a significant duration of exposure to the thin veneer of waste materials generating gamma radiation at Section 17 before a significant dose could be received from such radiation. Given, as stated by Dr. Chambers, “[l]icensed production areas of Section 17 will be fenced, thus preventing unintentional access by members of the public,” Intervenor are unlikely to be close enough to a gamma source for a sufficient period of time to suffer any adverse impacts. *Id.* at 6, ¶ 11.

Dr. Chambers' conclusions regarding gamma radiation are also espoused by the United States Environmental Protection Agency (EPA). EPA's analysis of gamma radiation closely resembles that of NRC;

“The concentration of gamma radiation from the [tailings] pile...decreases rapidly with distance; at more than a few tenths of a mile from most of the inactive [mill] tailings piles, it is undetectable above normal background....”

*Id.* at 7, ¶ 12 quoting United States Environmental Protection Agency, *Final Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites* (40 CFR 192), Volume 1, (October 1982).

As EPA recognized in the mill tailings pile context, gamma radiation decreases by at least a factor of three from the center to the edge of a waste pile. EPA, *Diffuse NORM-Waste Characterization and Preliminary Assessment* (May, 1993) at D-B-14. For an individual to be exposed to gamma radiation at Section 17 due to HRI's ISL uranium recovery operations at levels above those provided in 10 CFR Part 20, the individual must be proximate to a source (i.e., within the restricted area fence-line). However, as stated above, “[l]icensed production areas of Section 17 will be fenced, thus preventing unintentional access by members of the public.” Exhibit B at 7, ¶ 10.

Proximity to a source of gamma radiation also applies to Intervenor's argument regarding potential exposure to uranium ore dust on former ore haulage roads at Section

17. As stated by Dr. Chambers:

“[i]t is likely that radioactive material (i.e., uranium ore or ore dust) have fallen off trucks hauling mineral ore to the former United Nuclear mill...during transport, especially in areas of sharp...turns. My experience...suggests that such spillage *would be limited mostly to close proximity* to haul roads.”

*Id.* at

Since access to many of these areas may be restricted and members of the public would not be exposed to ambient gamma radiation from such areas for a significant period of time and in close proximity, potential exposures to gamma radiation are negligible.<sup>12</sup>

Intervenors also argue that the gamma dose rate at the nearest residence may exceed NRC limits. But, as stated by Dr. Chambers, Intervenors' argument rests on unreliable conclusions as the gamma radiation source (i.e., a thin veneer of ore dust and waste rock) is not an unusually strong one:

“Mr. Franke ignores data in his own report that contradicts his hypothesis....Figure 6 of Mr. Franke's report shows a gamma survey map (as do later figures of Mr. Franke's 1999 affidavit) which shows a measured gamma exposure rate of 10 uR/h at a location proximate to the King residence, well within the range of natural background gamma radiation considered by HRI, NRC and Melinda Ronca-Battesta.”

*Id.* at 7-8, ¶ 14.

In any event, existing radiation at the Church Rock sites is included in HRI's license application and, in accordance with HRI's NRC license and the COP, radiation will be measured again before operations begin at the site. Any radiation observed at that time will establish background levels against which operational impacts will be measured. *See* SUA-1508, License Conditions 9.8 & 10.30. It is likely that background gamma radiation will be elevated due to the presence of the naturally occurring radioactive materials (i.e., mine waste) noted above. *Id.* It is also likely that the gamma radiation associated with Section 8 is different compared to the Crownpoint site, but such variation is common among prospective ISL sites. *Id.*

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<sup>12</sup> *See also* Dr. Chambers analyses of “narrow” gamma sources at Exhibit B at 6, ¶ 12.

While Intervenors are correct that radiation was not measured at the nearest residence in the early pre-operational baseline studies, they ignore the fact that the residence at issue did not exist at that time. Nevertheless, monitoring of this residence is required under HRI's license. *See* SUA-1508, License Condition 9.8 & 10.30.

Therefore, after considering all air emissions analyses in the FEIS and Intervenors' failure to present evidence that radiation doses will exceed NRC limits, Dr. Chambers concludes that "gamma dose to nearby residents outside of license site [Section] 17 operation are extremely small both on or absolute basis and by comparison to natural background and of no significance." Exhibit B at 10-11, ¶ Overall Opinion. Moreover, Mr. Pelizza notes that Dr. Chambers' analysis of gamma radiation demonstrates that Section 17 gamma radiation will not exceed NRC limits:

"gamma radiation dose requires proximity to the source and mine entrances are sealed and members of the public will be restricted from HRI['s] site so that occupancy factors will be so small an exposure that exceeds the TEDE limits will not be possible."

Exhibit A at 17, ¶ 77.

Therefore, for the reasons described in this Section, Intervenors' argument with respect to gamma radiation should be rejected.

##### **5. Intervenors' Argument That HRI's License Should Be Revoked As a Matter of Policy Should Be Rejected**

Intervenors' written presentation also includes an argument that HRI's license should be revoked for policy reasons. More specifically, Intervenors claim that NRC Staff has shown "disregard for the cumulative impacts of past and concurrent uranium mining on nearby communities." Intervenors' Written Presentation at 22. Intervenors also claim that the grant of HRI's license would "set a bad precedent for communities in

which industries that emit radioactive effluents locate, because these communities would bear a disproportionate radioactive burden.” *Id.* Further, Intervenor’s allege that the passage of the Dine Natural Resources Protection Act (NRPA) prohibits uranium mining and processing on tribal lands and that cannot be ignored from a policy perspective. *Id.*

Intervenor’s argument is unreasonable. HRI cannot be held responsible under its license for the past activities of others in the Church Rock area, most of which were not licensed activities (i.e., uranium mining), but only for its proposed licensed activities. In that regard, NRC Staff’s assessments and analyses for the CUP have been more extensive than those for a multitude of other ISL uranium recovery projects in the United States. To the best of HRI’s knowledge, since 1982, ISL uranium recovery projects have not required an environmental impact statement (EIS) because of its low level of risk and minimal potential for impact to public health and safety. HRI’s CUP required an EIS only because of Bureau of Indian Affairs (BIA) issues but, as a residual benefit, the CUP received one of the most extensive health and safety analyses available to date for an ISL uranium recovery project. NRC Staff’s assessment of radioactive air emissions included the accounting of 19 potential receptors of radiation, monitoring of potential impermissible doses to workers and members of the public, including the nearest downwind residence, and the required measurement of gamma radiation prior to the commencement of operations. This extensive analysis can hardly be considered “disregard” for the Church Rock and Crownpoint communities.

Intervenor’s claim that NRC Staff is ignoring the effects of past uranium mining on communities such as Church Rock. While, to the extent that uranium mining has had some adverse effects on past members of the Navajo community (i.e., primarily

underground miners), no such adverse effects were the result of ISL uranium recovery and, therefore, are irrelevant to the CUP, as proposed. Indeed, as Judge Bloch opined,

“I...find no basis for disturbing the Staff’s FEIS conclusion that it is desirable to initiate a project that creates minimum risks to public health and safety and to the environment and that increases local economic activity.”

50 NRC at \*79.

Further, NRC Staff has imposed appropriate license conditions to ensure that no such adverse effects will be realized. Thus, Intervenor’s claim is without merit.

With respect to the NRPA, as a general proposition, the NRPA and its potential legal or regulatory effects on HRI’s CUP are separate and distinct from the validity of HRI’s NRC license from a health and safety perspective. Questions about the Navajo Nation’s authority to prohibit ISL uranium recovery *do not affect NRC licensing authority*, which preempts regulation of the health and safety aspects of the recovery of source material (i.e., ISL uranium recovery). Thus, the potential legal impacts of the NRPA on HRI’s CUP are not within the scope of issues necessary to determine whether HRI’s license should be upheld.

**B. HRI’s License Application With Respect to Air Emissions at Section 17 Satisfies NRC Regulations**

Intervenor’s also present several arguments regarding portions of HRI’s and NRC Staff’s air emissions analyses and allege that such analyses were inadequate to protect public health and safety. These arguments include allegations regarding the adequacy of analyses for (1) source term data; (2) meteorological data and monitoring; (3) the use of boundary receptors for radiological air emission monitoring; and (4) control of airborne effluents. Each of these arguments is without merit and will be addressed in turn below.

**1. HRI's Source Term Data is Adequately Protective of Public Health and Safety**

Intervenors claim that source term data for the CUP is inadequate and is insufficient to determine TEDE from Section 17. Intervenors' Written Presentation at 25. Specifically, Intervenors claim that no dissolved radon data for Section 17 groundwater is available and the use of Unit One dissolved radon concentrations is impermissible. *Id* Further, Intervenors' claim that airborne releases from liquid waste disposal are not included in the final TEDE calculations for the Church Rock sites.<sup>13</sup> *Id.*

First, the use of Unit 1 dissolved radon data for the Section 17 site evaluation is appropriate. As stated by Mr. Pelizza, Intervenors' argument on this point demonstrates a fundamental lack of knowledge regarding the nature of uranium ore deposits and their potential contribution to radon emissions:

*"Both Section 17 and Unit 1 are redistributed natural uranium ore (roll fronts) of similar grade/thickness, similar width [and] similar age."*

Exhibit A at 4, ¶ 20.

Based on these similarities, Mr. Pelizza determines that the use of Unit 1 data is appropriate:

*"There is no technical reason to assume that radon from concentrations of uranium ore at Section 17 will be significantly different than at Unit 1 unless there is a corresponding difference in the quantity of uranium in the ore."*

*Id.* (emphasis added).

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<sup>13</sup> HRI asserts that Intervenors should not be permitted to raise liquid waste issues under the guise of "air emissions" as that issue has been conceded for the remainder of this litigation. Accordingly, any argument or evidence submitted by Intervenors regarding this issue should be stricken.

At this point, Intervenors attempt to discredit the use of Unit 1 data using their affiant's "12x" theory and claiming that the concentration of uranium in ore at Section 17 is likely to be much greater than that of Unit 1.<sup>14</sup> However, Mr. Pelizza demonstrates that this theory is misguided:

"[F]or Franke's 12x supposition to be remotely possible, the uranium concentration in the ore at Church Rock Section 17 would need to be 12x the uranium ore concentration at Unit 1. *It is not.*"

*Id.*

As noted in Table 1 of Exhibit A, a comparison between the uranium ore concentrations at Section 17 and Unit 1 is a distinction without a difference:

"[T]he ore at Unit 1 is about 75% wider than at Church Rock Section 17 while the grade times thickness 'GT' is 33% higher at Section 17 than at Unit 1. *One is wider, the other has higher GTs—the difference is irrelevant.*"

*Id.*

Further, HRI also presented site-specific dissolved radon data from its parent company, URI, regarding its previous or current ISL uranium recovery projects. *See Exhibit A at 4, ¶ 20.* Based on this data and the analyses provided by HRI, Mr. Pelizza concludes that Intervenors have no substantive basis for their argument:

"These are examples of the radon concentrations found in the water in actual ISL wellfields with similar ore characteristics. These examples do not support Franke's assertion that the Church Rock Section 17 radon may be 12x Unit 1. *Franke presented no samples to support his hypothesis.*"

*Id.* at 5, ¶ 21 (emphasis omitted in part and added in part).

Thus, the use of Unit 1 radon data is appropriate.

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<sup>14</sup> With respect to Intervenors' claim that it is "likely" that dissolved radon is higher at Section 17 due to oxidizing conditions from existing mine shafts, Mr. Pelizza states, "[r]adon forms from radioactive decay of radon-226. Oxidization does not affect the rate of radioactive decay." Exhibit A at 5, ¶22.

In addition, the use of Unit 1 radon data is useful in assessing radon concentrations in water for the entire CUP. As stated by Mr. Pelizza:

“[f]rom a practical perspective, the quality of data a[t] [sic] Unit 1 is not available anywhere in New Mexico because at Unit 1 Mobil Oil drilled a full-scale commercial ISL wellfield with multiple injection and extraction wells providing the sampling points.”

*Id.* at 4, ¶ 18.

Unlike the Church Rock sites where no wellfields, sampling points or other points of reference are available, “[i]f Mobil Oil had not drilled this commercial ISL wellfield, these data would not have been available.” *Id.* When HRI’s license permits, such wellfields, sampling points, and points of reference will be easily obtained and “HRI will collect this level of radon data as wellfields are developed.” Exhibit A at 4, ¶ 18. Thus, it would have been irresponsible not to use Unit 1 radon data for Section 17 analyses because geologic characteristics are similar.

With respect to Intervenors’ argument regarding radon variability in different wells, Mr. Pelizza notes that this argument ignores one of the fundamental premises of ISL uranium recovery:

“[I]t is entirely appropriate to use an *average* value for radon across a wellfield. No single well will be pumped for uranium recovery, rather the wellfield is pumped as a unit. The waters are commingled and the average of these wells is what is circulated through the system.”

*Id.* at 5, ¶ 24 (emphasis in original).

Thus, based on this fundamental premise, Mr. Pelizza concludes that “[t]he *average* radon source term is the only source term that is appropriate.” *Id.* (emphasis in original).

Therefore, HRI’s source term data is adequate to protect public health and safety.

Finally, Intervenor's argument regarding TEDE from land application is without merit. Intervenor's claim that HRI did not satisfy requirements that its dose assessment must include all potential radiological releases from Section 17, including those from land application. Intervenor's Written Presentation at 27. However, as stated by Mr. Pelizza, "HRI has no plan to conduct land application unless there [are] [sic] additional approvals by NRC." Exhibit A at 10, ¶ 46. This statement is supported by the FEIS' requirement that HRI submit a license amendment application before proceeding with a land application program. *Id.* at 11, ¶ 47, quoting FEIS at 4-80. Further, Intervenor's have not provided any evidence "as to how radon will reach any land application areas or why...after treatment a significant amount of radium and uranium would be in the waste water applied to soils. *Id.* at 10-11, ¶ 46. Thus, Intervenor's argument is both unsubstantiated and not ripe for adjudication.

## **2. HRI's Meteorological Data Is Adequately Protective of Public Health and Safety**

Intervenor's allege that HRI's meteorological data and program is insufficient to produce accurate site data for the CUP. Intervenor's allege that HRI "never established a local or on-site meteorological station to obtain site-specific weather data for Section 17." Intervenor's Written Presentation at 28. In addition, Intervenor's claim that HRI's reliance on National Weather Service (NWS) data for Gallup, New Mexico and data from the United Nuclear (UNC) mill facility is impermissible. *Id.* at 28-29.

In response to Intervenor's and their affiant's allegations regarding site-specific weather data, Mr. Pelizza states that, as a general proposition, "NWS [National Weather Service] meteorological data is a necessary input assumption that was used in the Church Rock MILDOS-AREA evaluation that was previously litigated in Phase 1..." Exhibit A

at 5, ¶ 25. Further, Mr. Pelizza also notes that NRC's Standard Review Plan (SRP) for ISL uranium recovery sites endorses this approach:

"NRC's own SRP at § 2.5.1 requires NRC to review '(1) National Weather Service station data, including locations of all National Weather Service stations within an 80-km (50-mi) radius....(2) *On-site meteorological data...if National Weather Service data representative of the site are not available.*'"

*Id.* at 6, ¶ 28 (emphasis added).

Additionally, with respect to Intervenor's claim that NRC's SRP was not satisfied as a representation of long-term conditions at the Church Rock site, Mr. Pelizza states to the contrary:

"[I]n addition to the adequacy of the NWS data to meet SRP guidance criteria...HRI also provided meteorological information from the station that was located at the UNC [United Nuclear] mill some 2-3 miles north of the Church Rock Section 17 location."

"The NWS data and UNC data gave URI representative information *upwind and downwind* of the Section 17 site."

*Id.* at 6, ¶¶ 27-28.

Thus, based on the SRP's recommended approach, existing NWS and UNC data, HRI's meteorological data are adequate to protect public health and safety.

With respect to Intervenor's arguments regarding the Puerco Valley's influence on prevailing winds, Mr. Pelizza asserts that Intervenor's affiant and his conclusions are "illogical." Initially, Intervenor's argument that the topographical features of the Puerco Valley will promote an alteration of the prevailing southwest to northeast winds is misguided:

"The topographic map in Attachment 5 clearly shows that the effect [sic] of the topography in the predominant upwind direction (southwest) of Sections 8 and 17 would be to cause it to move in a northwesterly fashion at Sections 8 and 17, exactly as was found at the weather stations described above."

*Id.* at 6-7, ¶ 29.

Even if topography is assumed to affect the prevailing wind:

“It should be noted that the Church Rock Section 17 location is in an expansive open plain....The Puerco Valley is a broad flat plain which is contiguous from Gallup to the Section 17 site, and in the event that topography does direct prevailing winds, it directs the prevailing wind to the northwest through the area.”

*Id.* at 6, ¶ 30.

Thus, Intervenors’ argument on this issue should be rejected.

### 3. HRI Properly Accounted for Boundary Receptors on Section 17

Intervenors allege that HRI has failed to account for three residences close to and downwind from the Section 17 site. Intervenors’ Written Presentation at 30. Intervenors claim that the receptor labeled “BR-5 S” is likely not Mr. King’s residence and that discrepancies in the receptors accounted for in the FEIS and the actual location of these residences “cannot be overstated.” *Id.* Intervenors’ also claim that this alleged omission from HRI’s only quantitative analysis is grounds for revocation of its NRC license. *Id.* at 31.

Intervenors argument regarding the failure to account for the *exact geographical location* of Mr. King’s or other residences is fundamentally flawed. This argument ignores the fundamental premise of the MILDOS-AREA assessment routinely utilized by NRC:

“the fact that the King Residence is not BR-5 but is NR-1...and not specifically noted on subsequent maps is not significant because the MILDOS-AREA assessment assures that *any person (or any point) within the influence area of the receptor studies will not exceed the TEDE limit.*”

Exhibit A at 7, ¶ 31 (emphasis added).

Based on this “influence area” analysis in the MILDOS-AREA assessment, Mr. Pelizza states that:

“Because the closest downwind resident (i.e., ‘real person’) located at CRR4 and numerous other boundary receptors were included in the FEIS assessment and shown to be at a fraction of regulatory limits, the King location, *which is further than a number of such receptors from the primary source term at Section 8 and oblique to the prevailing wind...* therefore, will also receive exposure that is at a fraction of the regulatory limits.”

*Id.* (emphasis added).

HRI followed applicable guidance when selecting receptors for its MILDOS-AREA assessment. As required in NRC’s SRP § 7.3.1.2.1 and stated in ¶ 32 of Exhibit A, HRI selected receptors that matched each of the requirements, including the “nearest residence in the direction of the prevailing wind.” *Id.* at 7, ¶ 32 (emphasis omitted). Then, when a new residence was constructed closer to the process facility, Mr. Pelizza states that:

“In 1990, residence CRR4 [not the King residence] was constructed on Section 9 ENE [east northeast] of the primary emission source (S) (Attachment 1)...This is the closest resident for the purpose of modeling the dose [sic] to the closest ‘human’ living in the direction of the prevailing wind.”

*Id.* at 8, ¶ 33.

After completing the MILDOS-AREA assessment, which is specifically designed to map the “worst-case scenario,” it was determined that this receptor would receive doses that are a fraction of regulatory limits. *Id.* at 8, ¶¶ 33-34. Thus, Intervenor’s claims that the King residence or other residences in proximity to his would receive doses in excess of regulatory limits is incorrect.

Moreover, Mr. Pelizza notes that “the King homestead is not downwind and the predominant source term to this residence at Section 17 will only be a wellfield.” Exhibit

A at 8, ¶ 34. Even assuming a wind pattern contrary to the prevailing wind pattern and existing NWS and UNC data, the King residence is not the most impacted receptor.

Receptor CRR4 is the most impacted receptor and

“[i]f the impact analysis shows that this receptor is well below limits, surely a receptor, boundary or residence, that is located oblique to the prevailing wind on Section 17 (120 degrees oblique with regard to the Section 8 source term) would also be well below limits.”<sup>15</sup>

*Id.*

Therefore, for the reasons discussed above, the boundary receptors selected by HRI were adequate and, as such, Intervenors’ argument regarding this issue should be rejected.

#### **4. HRI Has Provided Adequate Information Regarding Control of Airborne Effluents**

Finally, Intervenors argue that HRI has not provided sufficient technical information regarding its proposed pressurized radiological effluent control system when engaging in ISL uranium recovery operations. Intervenors’ Written Presentation at 31. Intervenors’ allege that HRI has provided no documentation of the “operational efficiency” of its control system and that the hearing record is “devoid” of information regarding Mr. Pelizza’s proposed “engineering modification” to HRI’s system. *Id.* at 32. Intervenors also allege that NRC Staff has failed to properly evaluate HRI’s proposed system in light of 10 CFR Part 20 requirements. *Id.* at 33.

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<sup>15</sup> This point also is relevant to Intervenors’ failure to consider dose calculations at other receptors shown in the FEIS. As stated by Mr. Pelizza:

“he [Franke] does not address the modeling results at receptors B2 and B3, both of which are far closer to the predominant source...than the King residence yet they are shown to receive a small fraction of the TEDE in FEIS Table 4.18 and the allowable concentration of airborne radon and daughters in FEIS Table 4.24.”

Exhibit A at 8, ¶ 35.

Initially, the viability of the pressurized radiological effluent control system was litigated and approved in Phase 1 of this proceeding regarding Section 8. *See generally* LBP-99-30. Given that there are no site-specific differences between monitoring programs at any of the CUP sites, the law of the case doctrine should apply to Intervenors' arguments on this issue.<sup>16</sup>

If the law of the case doctrine is not applied, HRI still has demonstrated that its pressurized control system is adequately protective of public health and safety. Generally, "HRI has abandoned an upflow IX process design that was initially proposed for the Church Rock site which allowed unrestricted radon release to the atmosphere." Exhibit A at 8, ¶ 39. This new system is evaluated in the FEIS, and it is demonstrated that it "limits radon release significantly as compared to an upflow system even without the additional controls that were described in the FEIS at 2-15."<sup>17</sup> *Id.* Further, additional radon gas will be removed by "removing vent gas (including radon) in an intermediate holding tank using a vacuum pump, compressing the gas and returning it to groundwater on the injection side." *Id.* at 9, ¶ 40. This combination of methodologies will result in potential exposures to radon well below 10 CFR Part 20 limits.

In response to Intervenors' allegations that the lack of documentation in the record, including the FEIS, is "strange," Mr. Pelizza states that "[t]he [F]EIS omitted

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<sup>16</sup> In addition, as stated by Mr. Pelizza:

"[t]he lixiviant that will be processed from Section 17 will be identical to the lixiviant from Section 8 where exposures have been found to be a fraction of NRC limits for all the receptors evaluated....whether the facility receives feedstock from one area or another will not impact the quantity of emissions."

Exhibit A at 9, ¶ 38.

<sup>17</sup> As stated by Mr. Pelizza, it is worth noting that pressurized downflow systems are currently used by URI, Inc. in Texas and are operating as described in Exhibit A at 8-10, ¶¶ 36-44. *Id.*

discussion that distinguished between the two [systems] because it was unnecessary.”<sup>18</sup> Exhibit A at 9, ¶ 41. Further, since Section 17 will have no processing plant, the use of an effluent control system is only relevant to the Section 8 site, which already has been evaluated. *See id.* Moreover, HRI will be required to continuously monitor airborne releases of radon from the system, including the “re-running” of the MILDOS-AREA assessment, to demonstrate compliance with 10 CFR Part 20 requirements. *See id.*; *see also* COP Rev. 2.0, § 5.2.1. This process will not affect any ISL uranium recovery operations at the Section 17 site and it will not alter air emissions from the site.

HRI’s entire proposed effluent control system (i.e., a downflow system) can be observed at URI’s newly commissioned Vasquez ISL uranium recovery site. Based on data collected at the Vasquez site, “there is no measured radon loss through the system.” *Id.* at 10, ¶ 42. Thus, HRI’s proposed effluent control system is practical and protective of public health and safety in the FEIS and in existing ISL uranium recovery operations.

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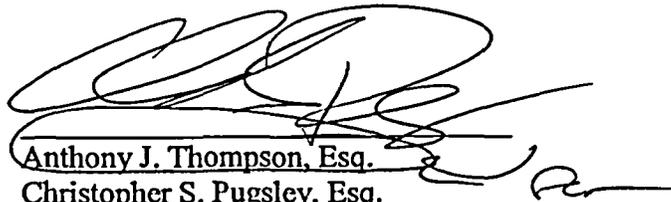
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<sup>18</sup> To paraphrase Mr. Pelizza, any professional experienced in ISL uranium recovery would instantly understand the technical and engineering differences between upflow and downflow systems. *Id.* Thus, an explanation of such differences in the FEIS was unnecessary.

**VII. CONCLUSION**

For the reasons discussed above, HRI respectfully requests that the Presiding Officer reject each of Intervenors' arguments regarding air emissions issues at Section 17.

Respectfully Submitted,



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UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:  
E. Roy Hawkins, Presiding Officer  
Dr. Richard F. Cole, Special Assistant  
Dr. Robin Brett, Special Assistant

In the Matter of: )  
Hydro Resources, Inc. ) Docket No.: 40-8968-ML  
P.O. Box 777 )  
Crownpoint, NM 87313 ) Date: July 29, 2005  
\_\_\_\_\_ )

CERTIFICATE OF SERVICE

THIS IS TO CERTIFY that a copy of the foregoing Hydro Resources, Inc.'s Response in Opposition to Intervenors' Written Presentation Regarding Air Emissions in the above-captioned matter has been served upon the following via electronic mail and U.S. First Class Mail or "expedited service" as indicated by an asterisk on this 29th day of July, 2005.

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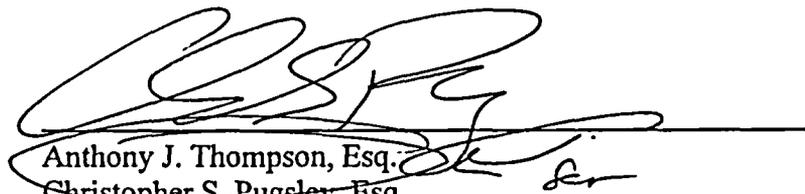
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UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION  
  
ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:  
E. Roy Hawkens, Presiding Officer  
Dr. Richard F. Cole, Special Assistant  
Dr. Robin Brett, Special Assistant

In the Matter of:	)	
	)	
Hydro Resources, Inc.	)	Docket No.: 40-8968-ML
P.O. Box 777	)	
Crownpoint, NM 87313	)	Date: July 29, 2005
	)	

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**HYDRO RESOURCES, INC.'S RESPONSE IN OPPOSITION TO  
INTERVENORS' WRITTEN PRESENTATION REGARDING AIR  
EMISSIONS**

**INDEX OF ATTACHMENTS**

**1. EXHIBIT A: Affidavit of Mr. Mark S. Pelizza**

Exhibit A presents the Affidavit of Mr. Mark S. Pelizza which describes a variety of issues related to potential air emissions at the Church Rock Section 17 site. Mr. Pelizza's affidavit consists of his professional conclusions and several attachments which will be described below. Mr. Pelizza's professional conclusions include discussions of general information regarding *in situ* leach (ISL) uranium recovery and analyses of HRI's and NRC Staff's source term data and applications, meteorological data, boundary receptor selection and application, and descriptions of HRI's proposed pressurized radiological effluent control system. Further, Mr. Pelizza discusses the issue of naturally occurring radioactive materials at Section 17, measurements of radioactive emissions, and NRC's ability to regulate mining.

**A. ATTACHMENT 1: Church Rock Revised Environmental Report (Excerpts)**

Attachment 1 to Exhibit A presents excerpts from the Church Rock Revised Environmental Report cited by Mr. Pelizza in his expert affidavit. References to this Attachment may be found at pages 8, ¶ 33, 12, ¶ 57, 13 ¶ 59, and other locations.

**B. ATTACHMENT 2: Church Rock Map**

Attachment 2 to Exhibit A presents two (2) maps of the Church Rock sites in support of Mr. Pelizza's conclusions regarding radiation measurements and wind direction.

**C. ATTACHMENT 3: NUREG-1569 Excerpts**

Attachment 3 to Exhibit A presents several excerpts from NUREG-1569 entitled *Standard Review Plan for In Situ Leach Uranium Extraction License Applications* in support of Mr. Pelizza's conclusions regarding air emissions measurements and weather data.

**D. ATTACHMENT 4: Meteorological Information from Church Rock Revised Environmental Report**

Attachment 4 to Exhibit A presents additional excerpts from the Church Rock Revised Environmental Report regarding HRI's use of weather data for the Church Rock sites.

**E. ATTACHMENT 5: Annotated Topographic Map of the Church Rock Vicinity**

Attachment 5 to Exhibit A presents a topographic map for the Church Rock area showing the prevailing wind direction described by Mr. Pelizza in his affidavit.

**F. ATTACHMENT 6: Church Rock Section 17 Restoration Action Plan (RAP) Excerpt**

Attachment 6 to Exhibit A presents an excerpt of the Section 17 RAP submitted to and approved by NRC Staff, which was recently endorsed by the Presiding Officer. These sections address Mr. Pelizza's conclusions regarding the types of groundwater restoration to be used by HRI.

**G. ATTACHMENT 7: NUREG-1736 Excerpt**

Attachment 6 to Exhibit A presents excerpts from NUREG-1736 entitled *Consolidated Guidance: 10 CFR Part 20—Standards for Protection Against Radiation* used by Mr. Pelizza to discuss his opinion on the calculation of background radiation for the Section 17 site.

**H. ATTACHMENT 8: Section 17 Surface Use Agreement**

Attachment 8 to Exhibit A presents HRI's surface use agreement for the Section 17 site demonstrating its ability to perform ISL uranium recovery operations at that site.

**I. ATTACHMENT 9: Vasquez Radon Analysis**

Attachment 9 to Exhibit A presents radon analyses from Uranium Resources, Inc.'s Vasquez, Texas ISL uranium recovery project in support of Mr. Pelizza's conclusions regarding the pressurized radon effluent control system.

**J. ATTACHMENT 10: Photograph of the Vasquez Remote IX**

Attachment 10 to Exhibit A presents a photograph of the Vasquez IX unit to further support Mr. Pelizza's conclusions regarding radon effluent control.

**2. EXHIBIT B: Affidavit of Dr. Douglas Chambers (C.V. Attached)**

Exhibit B presents the Affidavit of Dr. Douglas B. Chambers which addresses several issues regarding the radiological properties of radon and gamma radiation at the Section 17 site. Dr. Chambers presents multiple opinions regarding the manner in which members of the public potentially could be exposed to radon or gamma radiation, the analyses performed by several regulatory agencies regarding radon and gamma radiation, and the practical implications of such analyses in light of the naturally occurring radioactive material at Section 17.

**LIST OF ATTACHMENTS INCLUDED IN EXHIBIT B**

**3. EXHIBIT C: Affidavit of Salvador Chavez**

Exhibit C presents the Affidavit of Salvador Chavez which provides brief information regarding the sealing of mine vents and shafts at the Section 17 site. This evidence is offered in refutation of Intervenors' claims regarding such vents and shafts.

**A. ATTACHMENT 1: Professional C.V. Attached**

**B. ATTACHMENT 2: Photographs**

Attachment 2 to Exhibit B presents photographs of Section 17 mine shafts and vents that have been sealed, thus, preventing radon emissions.

**4. MISCELLANEOUS ATTACHMENTS**

HRI is also attaching excerpts from NRC's *Generic Environmental Impact Statement on Uranium Milling* (NUREG-0706) and a letter from the Atomic Energy Commission's Acting General Counsel dated December 7, 1960 cited in HRI's written presentation.

# EXHIBIT A

UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD PANEL

Before Administrative Judge  
E. Roy Hawkins, Presiding Officer  
Dr. Richard F. Cole, Special Assistant  
Dr. Robin Brett, Special Assistant

In the Matter of:	)	
	)	Docket No.: 40-8958-ML
HYDRO RESOURCES, INC.	)	
P.O. Box 777	)	ASLBP No. 95-706-01-ML
Crownpoint, NM 87313	)	
	)	July 28, 2005

**AFFIDAVIT OF MARK S. PELIZZA**

Before me, the undersigned notary on this day appeared Mark S. Pelizza, a person known or identified to me, and who after being duly sworn deposes and says the following in response to the Intervenor's Brief with Respect to Radioactive Air Emissions dated June 13, 2005.

**I. PERSONAL.**

1. My name is MARK S. PELIZZA; I reside at 3217 Breton Drive, Plano, Texas 75025. I am over 21 years of age; I never been convicted of a felony; and, I am fully capable of making this Affidavit.

2. The factual matters set out herein are within my personal knowledge or my corporate knowledge within my official capacity as set out herein. The opinions set out herein are based upon data and analytic techniques reasonably and customarily used by qualified professionals to form opinions and draw scientific and technical inferences for the purposes of important health, safety, environmental and regulatory decisions in the uranium recovery industry.

**II. QUALIFICATIONS.**

3. My Qualifications have been set out in this case in my Affidavit with Respect to Groundwater Protection, Groundwater Restoration and Surety Estimates Dated April 21, 2005.

**III. MATERIALS PREPARED AND REVIEWED.**

4. All the environmental studies and application documents that are required by NRC that culminated in the issuance of the Materials License were prepared with my direct involvement or under my supervision. I served as the technical support manager during Phase 1 and Phase 2 of this licensing hearing held on the CUP. As such I have reviewed all technical presentations and legal briefs. I have had direct involvement in or supervision of the presentations of all technical

experts who have responded in both Phase 1 and Phase 2 of this licensing hearing and as such have reviewed all of the expert submittals, including specifically those of Dr. Douglas B. Chambers and Salvador Chavez.

5. Specifically relevant to this Affidavit I have read the Intervenor's Legal Brief with respect to Radiological Air Emissions for the Churchrock Section 17 site dated June 13, 2005 including the attached Declarations of Melinda Ronca-Battista, Bernd Franke and Larry King.

#### **IV. RECOVERY OF URANIUM BY ISL IN THE UNITED STATES RESULTS IN NEGLEGABLE RADIOACTIVE AIR EMISSIONS.**

6. The *ISL* industry has operated in the United States for over 30 years. I have been directly associated with many of these operations and have knowledge of the environmental impacts of these operations. I know of no adverse offsite radiation impacts ever presenting themselves at any U.S. *ISL* facilities. On this point the Intervenor's concerns are greatly exaggerated.

7. *In situ* recovery results in significantly less surface disturbance than from conventional mines because mine pits, waste dumps, haul roads, and tailings ponds are not needed.

8. The lack of heavy equipment, haul roads, waste dumps, etc., result in virtually no air quality degradation at *in situ* uranium recovery operations.

9. The *in situ* uranium recovery process recirculates native ground water within the ore zone, over and over, until the uranium is depleted; the thus aquifer is not dewatered. Conventional mining (I.e., underground or open pit), however, requires that all water be removed from the ore horizon, and that the surrounding aquifer system, both above and within the ore horizons, be continually drained, or depressurized, during ore recovery operations and radon off gasses from all the water that is discharged. As a result, the *in situ* uranium recovery process consumes significantly less water than open pit or underground mine dewatering and results in far less radon emanation into the environment.

10. Since the solids remain in-place during *in situ* uranium recovery where they naturally occur, as compared to the huge amounts of rock and ore excavated during conventional mining; *in situ* uranium recovery reduces the amount of waste solids to a negligible quantity. This eliminates the need for ore storage pads and waste piles associated with conventional uranium recovery operations and results in minimal surface contamination.

11. In simple terms, *ISL* leaves the waste radioactive materials underground in the formations and form where they have resided naturally.

**V. THE EVALUATION OF RADIOACTIVE AIR EMISSIONS FROM THE PROPOSED CHURCH ROCK URANIUM RECOVERY LOCATIONS SHOWS THAT THE POTENTIAL IMPACT WILL BE INSIGNIFICANT.**

**A. MILDOS MODELING WAS CONDUCTED**

12. HRI used the MILDOS-AREA computer code to analyze the potential impacts of releases of radioactive materials at the CUP (FEIS p. 4-72). NRC evaluated the MILDOS-AREA analysis that was provided in support of the Application and concluded for the Church Rock site: "The calculated exposures and potential concentrations, with emission controls, are a small fraction of the regulatory limits." (FEIS p. 4-83)

13. The MILDOS-AREA computer code is not only acceptable to the NRC (NUREG-1569 p. 7-9), it is the code that has been used at every project that has been Licensed by HRI's sister company in Texas (URI) to analyze the potential impacts of releases of radioactive materials from ISL sites.

14. The MILDOS-AREA computer run that was conducted for the Church Rock site addresses the cumulative activities at both the Section 8 and Section 17 sites. This is significant because all wellfields at both sites will feed to the process facility on the Section 8 site where most of the potential release of radon would be. In other words, the worst case for potential radioactive air emissions is from the Section 8 facility. As shown on the map within Attachment 2, ponds, IX columns, process facilities and restoration equipment will be limited to the Section 8 site. Intervenor's claim that will be addressed in ¶¶B-F below are standard assumptions that were used in the MILDOS-AREA modeling for both Church Rock sites or in the case of ¶G, a general finding of fact with regard to the potential impact of Section 8 operations. These assumptions used in MILDOS-AREA have already been litigated in Phase 1 of this hearing as has the impact of radioactive air emissions from the Section 8 process facility.

15. The Section 8 and Section 17 wellfields feed the process facility at Section 8 in the same way. The Section 8 and Section 17 orbodies are one geologic feature, with virtually identical chemical and radiological properties which are only separated by a property boundary. Therefore, operations at the Section 8 process facility will have the same potential radiological impacts whether it is being fed from wellfields on Section 8 or wellfields on Section 17. The potential impacts from the Section 8 process facility were evaluated in Phase 1 of this Subpart L hearing and they were found to be acceptable. There will be no similar potential impacts from Section 17 operations since there will be no process facility.

**B. THE UNIT 1 RADON SOURCE TERM ASSUMPTION WAS TECHNICALLY SOUND AND SUPERIOR TO USING CALCULATIONS**

16. I concur with Franke (Franke ¶12) that radon will be the largest contributor to radioactive air emissions at the CUP, nevertheless, the contribution of radon will be very small and well below applicable limits. At Section 17 the only potential release of radon will be from trunkline vents.

17. Dissolved radon from the Unit 1 site data provide an excellent source term for the Churchrock evaluation. Intervenor's concerns (Brief B.2, Ronca-Battista ¶37, Franke ¶¶9,11,12, 17, 37) that no radon measurements were obtained from Section 17 and that HRI used Unit 1 data without demonstrating that those data are representative of Section 17 are ill founded. It is totally appropriate to use the Unit 1 data to *estimate* source term from Section 17. This assumption has already been approved for Section 8 during Phase 1 of this subpart L hearing. (LPB99-19 p. 10)

18. From a practical perspective, the quality of data a Unit 1 is not available anywhere in New Mexico because at Unit 1 Mobil Oil drilled a full-scale commercial ISL wellfield with multiple injection and extraction wells providing the sampling points. If Mobil Oil had not drilled this commercial ISL wellfield these data would not have been available. There is no wellfield developed at the Church Rock sites yet to allow for this type of sampling. HRI will collect this level of radon data as wellfields are developed. This phased approach to development and baseline sampling of wellfields was discussed at length in my groundwater affidavit at ¶XV (Pelizza Affidavit Respect to Groundwater Protection, Groundwater Restoration and Surety Estimates Dated March 21, 2005), and noted at the bottom of pages 23-24 of the July 20, 2005 "PARTIAL INITIAL DECISION (Phase II Challenges To In Situ Leach Mining Materials License Regarding Groundwater Protection, Groundwater Restoration, And Surety Estimates)".

19. Radium and radon are a direct consequence of the radioactive decay of uranium. Uranium-238 decays to Thorium-234 decays to Protactinium-91 decays to Uranium-234 decays to Thorium-230 decays to Radium-226 decays to Radon-222. The amount of radium, and therefore radon, are directly dependent upon the amount of uranium in-place. Because of the length of half-lives involved, it takes about a million years for equilibrium to occur. Both before and after equilibrium, ores of equal age will have the same proportional amounts of radium and radon. Simply put, the more uranium present, the more radium and radon there will be for ores of equal age.

20. Both Section 17 and Unit 1 are redistributed natural uranium ore (roll fronts) of similar grade/thickness<sup>1</sup>, similar width (See Table Below) similar age. As described in the preceding paragraph, there is no technical reason to assume that radon from concentrations of uranium ore at Section 17 will be significantly different than at Unit 1 unless there is a corresponding difference in the quantity of uranium in the ore. So, for Franke's 12x supposition to be remotely possible, the uranium concentration in the ore at Church Rock Section 17 would need to be 12X the uranium ore concentration at Unit 1. It is not. The table below, which provides a review of the average width and the GT of the orbodies shows that the ore at Unit 1 is about 75% wider than at Church Rock Section 17 while the grade times thickness "GT" is 33% higher at Section 17 than at Unit 1. One is wider, the other has higher GT's – the difference is irrelevant.

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<sup>1</sup> The convention of grade X thickness (GT) is used in the uranium industry to describe the quality of uranium ore. It is derived by multiplying the average percent uranium of an ore interval by the thickness that ore interval in feet. It is an excellent measure of the overall mineralization of the ore over the interval that will be mined.

Comparison of Ore Properties		
Property	Average Ore Zone Width (ft)	Average Ore U Grade x Thickness
Unit 1	111.5	1.48
Section 17	63.5	1.86

21. Dissolved radon was discussed in my groundwater affidavit at ¶VI.III.B. (Pelizza Affidavit Respect to Groundwater Protection, Groundwater Restoration and Surety Estimates Dated March 21, 2005). There the high radon concentrations in Unit 1 ore were described but data was also presented regarding dissolved radon at non-New Mexico URI sites. These other URI sites have similar ore properties as described in the table above for Unit 1 and Section 17. My affidavit notes that the average radon concentration at the Unit 1 site was 140,677 pCi/l; URI's Vasquez is 280,098 pCi/l; and URI's KVD averaged from 61,336 to 141,275 pCi/l. These are examples of the radon concentrations found in the water in *actual ISL wellfields* with similar ore characteristics. These examples do not support Franke's assertion that the Churchrock Section 17 radon may be 12X Unit 1. Franke presented no samples to support his hypothesis.

22. Franke (Franke ¶12) closes with the opinion that it is "likely" that dissolved radon concentrations are higher at Section 17 than Unit 1 because groundwater has been exposed to oxidizing conditions in the existing UNC underground mine shafts. I know of no reference that suggests that radon dissolution in water is "likely" or even possibly impacted as result of oxidation. Radon forms from radioactive *decay* of <sup>226</sup>Ra. Oxidation does not affect the rate of radioactive decay. Franke should provide a basis for this statement or it should be ignored. Franke ignores the possible effect past mine-dewatering may have had on existing radon gas at Section 17. That area was completely dewatered to allow miners access to the underground mine. All radon gas dissolved in that water discharged to the surface has already been vented to the atmosphere. So, there likely is even less in-situ radon gas at Sec. 17 then there would have been if dewatering had not taken place. Again, there is simply no technical information to support Franke's guesswork.

23. Finally, Franke's (Franke ¶13) theory that the radon value in Section 17 water is 12 times higher than Unit 1 and the 10CFR20 limit standard may be exceeded at Section 17 is completely misleading in that Franke utilizes the radon concentrations in FEIS Table 4.24 for an *unpressurized* upflow IX design. Yet it is stated multiple times, in the FEIS (e.g., pages 2-15, 4-3; 4-74, 4-82, 4-125) that HRI will use a *pressurized* system. As shown in the FEIS Table 4.24, when considering airborne concentrations of radon using a *pressurized* system URI is below the 10CFR20 standard by a factor of 175. Franke completely ignored this in trying to make his case.

24. Franke (Franke ¶14) reports an old concern from his 1999 report that radon variability from well to well was not properly addressed and that only averages were used. While this issue has been dealt with in Phase 1, it is worth noting that it is entirely appropriate to use an *average* value for radon across a wellfield. No single well will be pumped for uranium recovery, rather the wellfield is pumped as a unit. The waters are commingled and the average of these wells is what is circulated through the system. The *average* radon source term is the only source term that is appropriate.

25. In closing, Franke (Franke ¶30) notes that with respect to radon “URI and NRC simply assumed radon data in production well water from the Unit 1 site are representative for Section 17 ignoring the geological differences and previous mining activity that have influenced dissolution in groundwater. Here Franke claims that, among other things, HRI and NRC “ignored the geological differences” yet he has not cited a single geological difference. As noted in ¶19 above, the only story is one of mineralogical similarities not difference and as noted in ¶21, there is no evidence that previous mining influences radon dissolution in water, but it may have influenced radon off-gassing to the atmosphere.

**C. METEOROLOGICAL ASSUMPTIONS ARE BASED ON NRC GUIDANCE, ARE TECHNICALLY SOUND AND INDUSTRY STANDARD**

26. Intervenors concerns (Brief B, Franke ¶¶9, 11, 19, Ronca-Battista ¶37) that National Weather Service (“NWS”) data from Gallup 12 mi. west-southwest are used and that site specific meteorological data are missing are misplaced. NWS meteorological data are necessary input in the Church Rock MILDOS-AREA evaluation that was previously litigated in Phase 1 of this hearing.

27. Franke claims (Franke ¶21) that SRP §2.5.3(3) is not met because “The meteorological data used for assessing impacts are substantiated as being representative of expected long term conditions at and near the site.” But in addition to the adequacy of the NWS data to meet SRP guidance criteria stated in ¶25 above, HRI also provided meteorological information from the station that was located at the UNC mill some 2 – 3 miles north of the Church Rock Section 17 Location. Data from his station lacks the sophistication of NWS data and lacks stability class information needed for the MILDOS study. Examination of this data shows that prevailing winds are, however, consistent with the NWS information. The southwest to northeasterly prevailing wind is supportive of the fact that if anything, the Puerco Valley supports the wind regime that is documented in Gallup.

28. HRI used appropriate meteorological information at the Section 17 location. NRC’s own SRP at § 2.5.1 requires NRC to review “(1) National Weather Service station data, including locations of all National Weather Service stations within an 80-km (50-mi) radius....(2) On-site meteorological data...if National Weather Service data representative of the site are not available.” The NWS station in this case is approximately 12 miles SW of the site. It is the best available data to be used in the MILDOS-AREA modeling that was performed for the project. HRI also evaluated a limited amount of information obtained from the UNC<sup>2</sup> mill two to three miles north of the Section 17 site which supports the NWS information. The NWS data and UNC data give HRI representative information *upwind and downwind* of the Section 17 site.

29. The cursory analysis by Franke (Franke ¶20) that the Rio Puerco valley is more predominantly west to east indicating that the prevailing wind may be more predominantly west to east than southwest to northeast is not borne out by the topography. The topographic map in Attachment 5 clearly shows that the affect of the topography in the predominant upwind direction (southwest) of Sections 8 and 17 would be to cause it to move in a northwesterly

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<sup>2</sup> The UNC data was limited as compared to data developed by the NOAA. It does not cover the time span in years, nor does it provide the detailed information on stability classes that are required input for the MILDOS-AREA code.

fashion at Sections 8 and 17, exactly as was found at the weather stations described above. It should be noted that the Church Rock Section 17 location is in an expansive open plain as shown in the Ronca-Battista Declaration photograph (Attachment 3 Figure 15) of that area. (Also See the photograph in Attachment 5 that is taken from the Section 17 location looking to the Southwest toward Gallup) The Puerco Valley is a broad flat plain which is contiguous from Gallup to the Section 17 site, and in the event that topography does direct prevailing winds, it directs the prevailing wind to the northwest through that area.

30. Franke notes Larry King's observation that he has seen blowing of dust on his land in spring and summer. This is consistent with the wind data that was illustrated in the FEIS (Figure 3.1), where the annual wind rose includes a due westerly wind component, albeit not the predominant component. King's assessment is not quantitative where the NWS data are quantitative. MILDOS-AREA input must be quantitative.

**D. RECEPTOR CHOICES WERE BASED ON NRC GUIDANCE, ARE TECHNICALLY SOUND AND INDUSTRY STANDARD**

31. Intervenors have made a major issue that the potential impacts to 13 People who have lived on the King property were not assessed. (Brief B.3, Franke ¶¶11, 22, Ronca-Battista ¶36) and that real human beings were not considered in the application or FEIS. As stated below, the fact that the King Residence is not BR-5<sup>3</sup> but is NR-1 in Fig 7.3-3 of the 1988 Church Rock ER and not specifically noted on subsequent maps is not significant because the MILDOS-AREA assessment assures that any person (or any point) within the influence area of the receptor studies will not exceed the TEDE limit. Because the closest downwind resident (i.e. "real person") located at CRR4 and numerous other boundary receptors were included in the FEIS assessment and shown to be at a fraction of regulatory limits, the King location, which is further than a number of such receptors from the primary source term at Section 8 and oblique to the prevailing wind (as compared to CRR4), therefore, will also receive exposure that is at a fraction of the regulatory limits.. As found in Phase 1 of this hearing, the receptors chosen for the Church Rock MILDOS-AREA evaluation were properly chosen and demonstrate that locations that are even more susceptible to impact from potential radiation exposure than the King residence receive only a small fraction of the regulatory limits.

32. HRI followed NRC guidance when choosing receptor locations for the MILDOS-AREA model as outlined in SRP § 7.3.1.2.1. "...The staff should then review the estimates of annual total body and organ doses to individuals including (i) at the point of maximum ground level concentration offsite; (ii) at the site boundary in the direction of the prevailing wind,; (iii) at the site boundary nearest the emission source; and (iv) *at the nearest residence in the direction of the prevailing wind.* (Attachment 3)

33. The nearest resident changed in the Church Rock Revised Environmental Report ("CRRER") in 1993 because a new house was built closer to the process facility. The Application that was submitted in 1986 showed the King residence as NR-1. At the time this

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<sup>3</sup> Also See the map in Attachment 2 that shows the location Section 17 wellfields, Section 8 facilities, receptors, prevailing wind, etc.

was the nearest resident albeit not downwind of the Section 8 process facility<sup>4</sup>. In 1990 residence CRR4 was constructed on Section 9 ENE of the primary emission source (S). (Attachment 1) This is the closest resident for the purpose modeling the does to the closest "human" living in the direction of the prevailing wind. It is the same approach used at other CUP locations where the *nearest residence in the direction of the prevailing wind* is chosen as a point on the map for modeling the worst case scenario. The MILDOS-AREA model shows that CRR4 receives exposures that are a fraction of the regulatory limits. See FEIS 4-83 and Table 4.24.

34. As noted in ¶¶29, 30 the King homestead is not downwind and the predominant source term to this residence at Section 17 will only be a wellfield. Even presuming a prevailing wind from the west for arguments sake, the King homestead falls at the southern extent of well field development. The primary potential radon emission source during the operation of the Section 17 wellfields is the processing facility in the SE corner of Section 8. Logically CRR4 is the most potentially impacted individual and CRR4 is the closest individual to the source. If the impact analysis shows that this receptor is well below limits, surely a receptor, boundary or residence, that is located oblique to the prevailing wind on Section 17 (120° oblique with regard to the Section 8 source term) would also be is well below limits.

35. In addition to CRR4 the Church Rock MILDOS-AREA model calculates exposures for numerous boundary receptors at locations to simulate "hypothetical" individuals at different distances and different directions. MILDOS-AREA presumes a 100% occupancy factor at all receptors. Franke however, does not address the dose calculations at other receptors shown in FEIS Figure 4.5. His only concern is that the King Residence may be closer to the Section 17 wellfield than receptor B5, but he does not address the modeling results at receptors B2 and B3, both of which are much closer to the predominant source (S) than the King residence yet they are shown to receive a small fraction of the TEDE in FEIS Table 4.18 and the allowable concentration of airborne radon and daughters in FEIS Table 4.24. (The radon and progeny at B5 also reflect very low concentrations that are below limits.) Given that the King residence is further away and oblique to the prevailing wind as compared to B2 and B3, an exceedance is not feasible.

#### **E. A PRESSURIZED SYSTEM IS BASED ON STANDARD INDUSTRY TECHNOLOGY AND IS A VALID ASSUMPTION**

36. Intervenors claim (Brief B.4, Franke ¶¶10, 11, 23, 27, 28) that there is insufficient documentation for the assertion that radon generated at its Section 8 satellite processing plant will be contained rather than vented. In addition Franke suggests that the modeling based on the release of radon from Sec. 8 is not appropriate because it will be processing pregnant lixiviant from Sec. 17.

37. The adequacy of the pressurized system was evaluated in Phase 1 of the hearing. (LPB99-1 p.4)

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<sup>4</sup> The nearest resident *downwind* at the time was CRR3.

38. The lixiviant that will be processed from Section 17 will be identical to the lixiviant from Section 8 where exposures have been found to be a fraction of NRC limits for all the receptors evaluated. In other words, whether the facility receives feedstock from one area or another will not impact the quantity of emissions.

39. But if this matter is to be considered separately for Section 17, then it must be reemphasized that HRI has abandoned an *upflow* IX process design that was initially proposed for the Church Rock site which allowed unrestricted radon release to the atmosphere. As revised and evaluated in the FEIS, the Church Rock 8 facility will use a *pressurized downflow* system, which limits radon release significantly as compared to an upflow system even without the additional controls that were described in the FEIS at 2-15 et. al. Pressurized downflow ion exchange systems are not unusual and are currently in use at the NRC licensed *ISL* sites in Wyoming and by URI, Inc., HRI's sister company in Texas.

40. In addition HRI plans to remove additional quantities of radon from wastewater by removing vent gas (including radon) in an intermediate holding tank using a vacuum pump, compressing the gas and returning it to the groundwater on the injection side. By weight this gas will be predominantly composed of carbon dioxide and water vapor, with a minor component being the radon gas. (FEIS at 2-15) This is a relatively simple concept so there is no standard design plan per se.

41. Franke (Franke ¶24) calls the lack of documentation in the FEIS strange. I disagree. The FEIS was not meant to be a refresher course on basic engineering fundamentals, and did not present those fundamentals on any topic. A person with understanding of basic engineering or experience in *ISL* technology would instantly recognize the fundamental difference between upflow (unpressurized) IX and downflow (pressurized) IX. (i.e., that under pressure there are no gaseous emissions.) The EIS omitted discussion that distinguished between the two because it was unnecessary. HRI's plan to have an intermediate tank that removes additional quantities of radon from primarily restoration water will result in even more radon removal. This technology only applies to source term reduction at the Section (8) processing facility and has no impact on releases from Section 17 which will have no processing plant. The process will be monitored during operations, HRI will rerun MILDOS-AREA with operational data and HRI will be required to demonstrate compliance with 20 CFR 1302. The plan for demonstrating compliance including monitoring is clearly described in the COP:

"The source term for radon gas (e.g. the quantity of gas that is released to the atmosphere from various locations within the in situ process) can be precisely measured by obtaining simultaneous samples and then conducting same time radon measurements on leach solution from the main trunkline on the pregnant side of the process facility ( $Rn_{pregnant}$ ) and on the main trunkline of the barren side of the process facility ( $Rn_{barren}$ ). The difference in the radon concentration ( $Rn_{pregnant} - Rn_{barren}$ ) has been released to the atmosphere and therefore is the source term which will be entered into MILDOS-AREA (1997) to determine compliance. The radon sampling schedule is stated in Table 9.5-1. Compliance will be demonstrated on an annual basis through modeling using measures radon release information from the previous year." See COP§5.2.1 in Pelizza Affidavit

Respect to Groundwater Protection, Groundwater Restoration and Surety  
Estimates Dated March 21, 2005 Attachment 3.

42. URI, Inc., HRI, Inc.'s sister company in Texas has operated a downflow IX systems at its Kingsville Dome project and the newly commissioned Vasquez ISL facility where similar monitoring as that specified in COP §5.2.1 is conducted. At Vasquez, two parallel pressurized downflow IX trains are in operation and URI obtains extraction side lixiviant samples (pregnant lixiviant) and injection side lixiviant samples (barren lixiviant) and measures radon. The results shown in the Table below (Lab sheets in Attachment 9) show that there is no measured radon loss through the system (Effluent actually measures higher, a physical impossibility that is explained by laboratory error).

URI, Vasquez – Radon in Lixiviant 6-24-05 (pCi/l)		
Location	Extraction (Preg.)	Injection (Barren)
Remote Ion Exchange 1-4	85,500	90,200
Remote Ion Exchange 5-9	62,500	66,000

43. Finally, Franke (Franke ¶26) claims that a pressurized system only allows compliance with 10 CFR 20, Appendix B MCLs because without the pressurized system <sup>218</sup>Po would exceed the relevant. Franke is wrong because HRI will monitor to demonstrate compliance and all CUP IX facilities will be constructed with the pressurized design. Monitoring of Section 8 operations will have been ongoing to demonstrate compliance with 20 CFR 1302 before operations begin in Section 17. The operation of the Section 17 facility will extend the time by which the operation of the Section 8 IX operates but will not alter the emissions from that site at any given point in time. Franke did not address HRI's monitoring described in the COP.

44. Franke closes (Franke ¶29) with the assertion that absent technical justification the License should be revoked or HRI ordered to amend its application to reflect the actual processing system. He is incorrect. As noted in ¶40 above his assertion is unrealistic. A pressurized down flow IX system is not going to have the radon emission that an open up flow IX system has and HRI is committed to conducting operations with down flow IX. Reevaluation based on something that is not planned is not reasonable.

**F. RESTORATION BY LAND APPLICATION IS A INCORRECT ASSUMPTION**

45. Intervenor's (Brief B.1) claim that HRI has failed to include assessment of the TEDE from land application activity. They claim that this is an error because doses to human receptors who actually live on and next to Section 17 could be significant, not only from radon, but from additional deposition of uranium and radium on local soils. They note that while HRI is not required to determine a method of waste disposal until before injection of lixiviant, but after adjudication, doses should be calculated from all releases from Sec. 17 including land application of radioactive wastewater a few feet from Mr. King's residence.

46. As was the case in Phase 1 of this hearing (LPB99-1 p.10), it is Intervenor's who err in this claim because HRI has no plan to conduct land application unless there is additional approvals by NRC. In addition, Intervenor's have not presented any evidence as to how radon

will reach any land application areas or why, contrary to the finding in the FEIS 4-87, after treatment a significant amount of radium or uranium would be in the waste water applied to soils.

47. FEIS at 4-80 states: "HRI did not submit a detailed plan for land application and would need to submit a detailed license amendment in the future to use land application for wastewater. This evaluation is based on the assumptions and information presented by HRI in its general concepts on using land application. An environmental assessment of the license amendment for land application would be completed as part of the licensing process." HRI has not developed any new plan in addition to what has already been stated and evaluated in the FEIS. Moreover, HRI's Restoration Action Plan for the Church Rock Section 17 site does not consider irrigation as a restoration option but rather considers reverse osmosis and brine concentration. Attachment 6. At this time reverse osmosis and brine concentration are HRI planned water disposal options.

48. HRI's license requires that further consideration of land application or irrigation would require a license amendment and supplemental EA.

"Prior to land application of waste water, the licensee shall submit and receive NRC acceptance of a plan outlining how the licensee will monitor constituent buildup in soils resulting from the land application. The plan should identify the constituents resulting from land application that will be monitored, constituent threshold values for discontinuing land application and justification for the values selected." (SUA-1508 License Condition 11.8).

49. Finally, HRI's COP at 43 explains that the land application plan is uncertain with regard to the parcels of land that would be used or even that land application would be chosen at all. The COP commits to providing an application if land application is pursued: "HRI will commit to filing an application with NRC at the time irrigation plans have been finalized. Such an application will contain information on the environmental conditions of the parcel of land to be used."

50. Intervenor's concern for any impact associated with any possible land application plan, therefore, is not ripe, with or without consideration of Mr. King. At this time there is no plan to evaluate a land application option.

#### **G. FEIS EVALUATION SHOWS IMPACTS TO BE FAR BELOW LIMITS**

51. According to the FEIS, "The proposed project would make minor contribution to cumulative impacts in terms of health physics and radiological impacts (Section 4.6)" FEIS 4-124. This finding of fact has been accepted in Phase 1 of the Hearing (LPB99-30 p. 71). The Section 17 wellfields will not cause an incremental or cumulative increase of potential radiological impacts.

52. FEIS Table 4.24 lists the airborne concentrations of radon and daughters at selected receptor locations near the Church Rock satellite facility for both a pressurized system *and* an unpressurized system. In reference to this table, the FEIS at 4-83 concludes: "For the Church Rock analysis, radon emission controls reduce the airborne concentration by approximately a

factor of 10 (see Table 4.24). The resulting values at the nearest residence are approximately 0.5 percent and 7.6 percent of the limit, *with* and *without* the emissions controls, respectively. The calculated exposures and potential concentrations, with emission controls, are a *small fraction of the regulatory limits.*" In other words the FEIS concludes that even without emission controls, at the closest residence the calculated exposures would only be 7.6 percent of the limit.

53. The concern over radiological impacts by HRI's operations is unfounded and based on unreasonable assumptions and speculation. The only radiological air effluent at Church Rock during operations would be radon (FEIS at 4-82). The FEIS describes the MILDOS-AREA evaluation<sup>5</sup> of radiological impacts at various boundary receptor points and the closest *downwind* residence (FEIS Figure 4.5), concluding that: "The calculated exposures and potential concentrations, with emission controls, are a small fraction of the regulatory limit" (FEIS at 4-83), and that: "The proposed project would have negligible effects in terms of health physics and radiological impacts" (FEIS at 4-87).

54. Given the minimal potential incremental radiological impacts of the Church Rock ISL project operations, the consequence of the existing levels of radiation that exist from old mining operations can now be addressed in an appropriate context. Also See Chambers ¶20.

## **VI. BACKGROUND RADIATION WAS ADDRESSED IN THE APPLICATION AND EVALUATED IN THE FEIS.**

### **A. HRI CONDUCTED GAMMA SURVEYS THAT SHOW RADIATION LEVELS INDICATING OLD MINING ACTIVITY**

55. Intervenor's (Ronca-Battista pp. 0-16) describe in detail the QA procedures and methods that were utilized to conduct gamma surveys at the Church Rock Chapter House, at the Springstead area, and at the Church Rock Section 17 property. These surveys were conducted reasonably, moreover, detailed below the surveys provide results that are very similar to those that are included in HRI's Application.

56. Ronca-Battista (Ronca-Battista ¶27) demonstrates that background radiation at the Church Rock Chapter House is 11  $\mu\text{R/hr}$  and at the Springstead Trading Post is 13  $\mu\text{R/hr}$ . These readings are consistent with "background" readings at a short distance from the Old Church Rock mine taken by HRI and included in the Application. HRI utilized the same make and model (Ludlum Model 9) scintillator that was reportedly used by CRUMP. Therefore, based on the same rationale used by Ronca-Battista, locations where readings by HRI are in the 11  $\mu\text{R/hr}$  to 13  $\mu\text{R/hr}$  (+ or - for natural variability) demonstrates that there is no affect of mining there.

57. The results of HRI's gamma survey were presented on a topographic map on Figure 2.9-1 of HRI's on Figure 2.9-1 in the Church Rock Project Revised Environmental Report, March, 1993 ("CRRER"). See Attachment 1. There the readings at the low end of the range were consistent with the Springstead numbers presented by Ronca-Battista. For example within Section 17 sample locations 8S22, 8S23 and 8S24 showed gamma measurements of 12, 10, and

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<sup>5</sup> Which was conducted using the source term, meteorological, and receptor assumptions that were addresses in §V herein.

15  $\mu\text{R/hr}$ <sup>6</sup> respectively. I would note that location 8S23 is also adjacent to the King residences. This would suggest gamma activity at these Section 17 locations is similar to that seen at the Springstead location.

58. Gamma values on Section 8 are higher than on Section 17; ranging from 14 to 30 in the well field area. There has been no previous mining activity on Section 8 but there has been exploration drilling and a uranium orebody was discovered during that drilling activity. Exploration drilling is not regulated by NRC.

59. In addition to gamma surveys results, HRI has presented soil analysis results in the CRRER and included these results in Attachment 1. Uranium and <sup>226</sup>Ra at sample locations 8S22, 8S23 and 8S24 are uniformly low. Samples 8S21, 8S25 and 8S26 show elevated levels of Uranium and <sup>226</sup>Ra but the levels of uranium are below 500 ppm (.05%). I believe that locations 8S21, 8S25 and 8S26 are in the vicinity of old mining activity and locations 8S22, 8S23 and 8S24 have had minimal impact from old mining.

60. Ronca-Battista (Ronca-Battista ¶29) notes higher gamma ( $\mu\text{R/hr}$ ) (mean/max) at mapped locations: 2-1 and 2-2 (21/39); 2-3 and 2.4 (28/180); 2-5 (35/110); 2-6 (34/70) with the highest gamma of 180  $\mu\text{R/hr}$  along SH 556. These levels are consistent with or slightly less than the high gamma levels HRI reported in the CRRER of 350  $\mu\text{R/hr}$ .

61. HRI evaluated the background radiological features in the CRRER, stating in part: "Gamma ranged from 12  $\mu\text{R/hr}$ . to 350  $\mu\text{R/hr}$ . with the higher concentration generally found in association with the previous mining activity." and "As was the case with gamma activity, higher nuclide concentrations are generally found in association with previous mining activity" SRER §2.9.1 §2.9.2 respectively Attachment 1. HRI has represented from the time of the Application that a veneer of ore material and waste rock from the old Church Rock mine is the cause of these anomalous levels of gamma activity. But the impacts of previous mining are only local, and widespread impact on the TEDE to an individual is not supported by the localized nature of the mine residues.

62. There was no uranium mill on the Section 17 property. No ore was processed at this site "primarily" for its source material content so, based on my knowledge of the uranium recovery regulatory regime, there is no 11e.(2) byproduct material at the site. All ore was processed at the UNC mill 2 to 3 miles north of the section 8 site. All residual material is, therefore, ore and scrap rock. The ore contains values for uranium, however, no samples have shown uranium to exceed 500 ppm or .05% uranium by weight – the regulated/licensable level for uranium source material under the Atomic Energy Act ("AEA") and 10CFR40..

#### **B. AMBIENT RADON MEASUREMENTS HAVE BEEN CONDUCTED AT THE SECTION 17 BOUNDARY**

63. Franke (Ronca-Battista ¶37 and Franke ¶16) states that the Application is deficient because it is devoid of airborne radon samples at the fence line; the Section 8/9 data are at least

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<sup>6</sup> HRI reported the readings in the CRRER as mRem/hr. I have reviewed this information and note that the units are  $\mu\text{R/hr}$ .

one order of magnitude above areas not affected by mining; and there is no other source of background radon in rock. A radon station (8R1 on Figure 2.9-1 Attachment 1; also Attachment 2 Church Rock Map shows the location of 8R1) was placed on the Section 17/8 boundary. There is no significant gap in data.

64. I disagree with Franke that there are no other radon sources in the general area. In addition to a contribution from the veneer of ore material from Section 17 there are other radiation sources in the area which will result in radon emanation on a regional basis. As discussed by Dr. Chambers in 1999 (and the Chambers Affidavit 2005 ¶¶ 6, 7) the Church Rock site is situated on the Dakota and Mancos Shale which would contribute to radon in the region. As shown on the USGS Topographic map in Attachment 2, the outcrop of the Dakota and Mancos Shale in the vicinity of the Church Rock site forms a broad band across the region covering thousands of acres, yet as can be seen on HRI's map, Franke Figure 6 in Attachment 1 of this Affidavit, by comparison, any contribution of radionuclides to the environment from the ore pad is relatively small (20 to 30 acres). Therefore, it is logical to assume that radon levels at Station 8R1 reflect ambient radon from all background sources including geologic outcrops and the small area impacted by waste ore from the old Church Rock mine.

65. Intervenor's (Brief IV.A.3) claim the DEIS says ambient levels of radon near Section 17 exceed regulatory limits. The DEIS p.3.2 does not say that radon near the Section 17 exceeds regulatory limits, rather the DEIS shows mean ambient radon of 2.16 pCi/l. In the *Draft* EIS the NRC Staff considered these radiation levels at the Church Rock site (including radon) to be a portion of background. This cannot be a violation of regulatory limits, because background is not included in the regulatory limit. In addition the radon measured and reported in the DEIS is ambient measure of radon and does not measure radon in equilibrium (WL) which is the relevant measurement in 10 CFR 20. (Chambers Affidavit 2005 ¶¶17, 18) Therefore, on its face, the numbers cannot be compared with respect to potential adverse health effects.

66. Intervenor's (Brief IV.A.2.b) argue that the radon emanating from ore remaining underground, through, for example vent holes on Section 17, should be considered byproduct material and included in the source term and TEDE. The argument that the material that is underground is byproduct material is unfounded because the Church Rock workings are a uranium mine not a mill.

67. Moreover, regardless of how ore remaining underground is defined, the Old Church Rock shafts do not provide a conduit for radon emanation. There were four shafts at this location that have been fully sealed. The Affidavit of Mr. Chavez thoroughly describes the method by which these shafts were sealed. (Chavez Affidavit 2005) Therefore Intervenor's concern is without merit because the shafts have been sealed.

### C. MATERIAL ON THE SURFACE OF SECTION 17 IS LOCALIZED

68. Ronca-Battista (Ronca-Battista ¶30 and Franke ¶18) combines the concepts that the gamma outside Section 17 security fence is 5 to 16 times background depending on which background is used and the fact that 13 King Family members live 1,400 feet east and downwind of Sec. 17 and generates a concern. The potential for this concern is flawed, King lives oblique to the prevailing wind when compared to the Sec. 17 site (¶¶29,30 ) and nearly upwind when

compared to the radon source on Section 8 (§33). Next I would note that gamma radiation is local, it does not travel distances and is not dispersed by wind. The King residence is not impacted by gamma radiation from the old mining activity (See discussion of 8S23 in §57) and in any event, King will be restricted from the wellfields by fence (VII.B). (See Chambers Affidavit 2005 §§11-14)

69. Ronca-Battista (Ronca-Battista §32) takes issue with HRI's August 31, 1994 letter to NMMRD that indicates that sludge had been removed from ponds but which does not address radiation levels or indicate that levels had been lessened from Fig. 2.9-1 of the CEER. Although sludge has been removed from the ponds that were on the Section 17 property, Intervenors are correct in that no ore or waste rock veneer has been removed and because this veneer is ore, it still contributes radiation.

70. The August 31, 1994 letter to NMMRD that the Intervenors refer to is clear. The sludge was removed from the pond but there is no indication in that letter that HRI attempted to remove residual ore and waste rock from the mine area because there were no applicable regulatory requirements to do so. That is still the case; the Regulations that have been promulgated in response to the New Mexico Mining Act do not address radiation. Franke's concern that HRI has not conducted more recent gamma surveys of the Section 17 area after the sludge was removed from the ponds is not material because the time span since the Application was submitted will not change background conditions. As I noted above, gamma measurements that were obtained by CRUMP are consistent with those obtained by HRI in the application in 1987 and that current gamma readings result from the residual uranium ore and waste rock.

71. The Section 17 surface will not remain unmitigated forever. It will have to be reclaimed to allow release for unrestricted use *after the ISL activity is completed*. (See FEIS 4.12.4 regarding positive aspects of decommissioning). This could be accomplished by a combination of excavation of any small patches of pre-existing ore material or material from operational spills, if any, and covering areas associated with the old ore pad itself. It would be counterproductive at this time to place a cover on the ore pad, only to dig it up during well field development. During the interim there will be no impact to members of the public because the area will be restricted by fence (See COP§9.13 in Pelizza Affidavit Respect to Groundwater Protection, Groundwater Restoration and Surety Estimates Dated March 21, 2005) and HRI will monitor the unrestricted area according to Section 9.5 of the COP.

72. Ronca-Battista (Ronca-Battista §35) claims that *high levels*<sup>7</sup> of radiation are from residual radioactive materials dispersed by wind from the Section 17 mine site. While some limited dispersal by wind should not be precluded, the localized nature of the anomaly adjacent to the SH556 route would suggest that most of the ore fell out of trucks as they left the mine area and headed for the UNC mill. Ore trucks exited the UNC mine at the location surveyed by CRUMP and described by Ronca-Battista, and there made a hard 90° left turn on SH556 in route to the mill some two to three miles northeast where the ore was milled and uranium extracted. It

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<sup>7</sup> 10CFR20.1003 states "*High radiation area* means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates." The maximum radiation level that has been documented by Ronca-Battista 180 µR/hr. (.000180 rem). Therefore, in the context 10CFR20 the radiation levels at the Church Rock Section 17 site are not "high".

is reasonable to expect that ore bounced and spilled along the roadway from these dump trucks while making the turn and exiting the mine area on to the highway.

#### D. MINING IS NOT REGULATED BY NRC.

73. Ronca-Battista (Ronca-Battista ¶35) claims that residual radioactive materials from the Section 17 mine site are now licensed and the materials are now regulated by the AEA of 1954 and radiation from them must be included in the TEDE for Section 17 because they are not included in the definition of background.

74. It is my experience as part of the uranium industry that there is a clear distinction between regulated and non regulated radioactive materials. Uranium production, depending on the technique, results in the production of rock and sand with various concentrations of uranium during the exploration, mining and milling processes. During the ISL process NRC has determined that the extraction of source material occurs *in situ*, so that regulation of this processing is taken to the subsurface. With conventional mining NRC regulation is not applicable in or at the mine, including ore storage at the mine and during transport to the mill. NRC regulation begins at the mill where the ore is crushed and leached. With any type of uranium recovery, at the exploration stage, drill cuttings are brought to the surface. These cuttings are buried on site in pits (FEIS 4-73) and are not regulated by NRC. Surface mining activities are not been regulated by NRC. While there have been mines that are closely associated with mills (such as the Church Rock) the mining is not regulated by NRC. Milling is regulated by NRC because it is at the mill where the ore is processed "primarily" for its source material content and the waste generated is 11.e(2) byproduct material..

75. At the Church Rock Section 17 location a thin veneer of ore material and waste rock remains on the surface which, because it is composed of rock and some natural uranium and uranium decay products, emits gamma radiation that can be measured by Geiger Counter or Scintillator (¶¶59, 61), but as it is ore material from a mining operation the material was not and is not, licensed AEA material. Moreover, there is no "byproduct" (¶62) or tailings at the Section 17 site. The UNC uranium mill was the facility where all of the "ore" from the Church Rock mine was processed. The Old Church Rock mine on Section 17 was limited to mine workings, ore stockpiles, and treatment of water for surface discharge. The ponds that were used for water treatment contained barium sludge. UNC removed the sludge from these ponds prior to the sale of the property to HRI. Finally there is no licensed or licensable uranium source material at the Section 17 location (¶62 regarding lack of ore 05% by wt. uranium). As such, according to §20.1003 these ores do not qualify as source material.

76. My opinion based on many years in the uranium industry is that there is no source or byproduct material on the Church Rock Section 17. I view this material as naturally occurring background material. This is consistent with the DEIS p. 3-19 which noted that "*Background radiation levels for the Church Rock and Crownpoint areas have probably been slightly elevated by previous mining and exploration activities.*"

**VII. EVEN IF ACTIVITY FROM MINE WASTE WERE INCLUDED IN CALCULATIONS THE TEDE TO THE NEAREST RESIDENT WOULD BE WELL BELOW REGULATORY LIMITS.**

77. Given that mine wastes remain on Section 17, Intervenors jump to the conclusion that these wastes will cause individuals to exceed the TEDE. Franke (Franke ¶15) notes that gamma radiation exceeds local background by 35 times; dose rates are far in excess of the dose rates set in 10CFR §20.1302(2)(ii). Ronca-Battista (Ronca-Battista ¶31) says that the gamma levels *inside* the mine are high enough to produce a dose to an individual with continuous exposure that would exceed 10CFR20 annual dose limit. Intervenors are wrong because gamma radiation dose requires proximity to the source and mine entrances are sealed and members of the public will be restricted from HRI site so that occupancy factors will be so small an exposure that exceeds the TEDE limits will not be possible. In the case of employees who's access is not restricted, employee exposure will be estimated for routine activities based on exposure times and the levels of radiation as determined from routine monitoring. See COP§9.6

78. Additionally in outlining their concern regarding exposure Intervenors (Ronca-Battista ¶36) claim a difference between Sec. 8 and Sec. 17 because there are residences on Sec 17 and not on Section 8 so that exposure to these individuals to source material released from the licensed Section 17 site must be considered in the TEDE for the project. I know of no regulation that correlates property boundaries with exposure. It is the occupancy factors, proximity and other external factors such as prevailing wind for radon that determine exposure. As described in more detail in ¶¶31-34, HRI used the location CRR4 on Section 9 where there is also a residence and the closest downwind resident for determining TEDE.

79. The Intervenors conclude (Brief IV.A.3) that existing levels of radiation at Section 17 from Source and Byproduct material are above regulatory limits, therefore any emissions from HRI operations on Section 17 would cause radiation levels to climb even further above regulatory limits so no additional licensed activity can be permitted. Intervenors are wrong on two counts. First, the Section 17 materials are mine waste and are part of background. Secondly, even if the gamma radiation levels are not considered part of background they would not impact any member of the public because access to the area will be restricted and in the case of proximity to the highway right of way the occupancy factors will be so low that no one will receive an exposure close to the TEDE limit.

**A. CORRECT READING OF NRC'S REGULATIONS ILLUSTRATES THAT GAMMA FROM SECTION 17 WILL NOT CAUSE A VIOLATION OF 20CFR1301.**

80. The regulation in 20CFR1302 provides a licensee with two different methods that are acceptable for showing compliance with the public dose limit of 100 mrem per year. The first method relies on any combination of calculations and measurements of the dose received by a member of the public receiving the highest dose from the licensed activity. These calculations will typically include the measurements of monitoring at the site weighted for exposure based on access restrictions and occupancy factors. The second method relies on showing that two conditions have been met: the concentrations of radioactive materials released to the environment at a fence line, when averaged over a year, do not exceed those listed in Table (2) of Appendix B,

and the external dose that would be received by anyone continuously present anywhere in the unrestricted area is less than 2 mrem in any one hour and less than 50 mrem in a year. Intervenors disregard the first method that is provided for in the regulations.

81. NRC Guidance Document NUREG-1736 addresses 20.1301 DOSE LIMITS FOR INDIVIDUAL MEMBERS OF THE PUBLIC and 20.1302 COMPLIANCE WITH DOSE LIMITS FOR INDIVIDUAL MEMBERS OF THE PUBLIC and provides licensees guidance and examples. In particular NUREG-1736 p. 3-68 (Attachment 7) provides an example of the type of evaluation that a licensee may conduct by way of a combination of calculations and measurements to demonstrate the dose received by the member of the public is below the 100 mrem/y TEDE:

“Although licensed activities may result in radiation levels in a controlled area or in an unrestricted area that exceed 100 millirem in a year, the actual dose to a member of the public likely to be present in the controlled area or unrestricted area may, depending on occupancy, be below the 100 mrem limit. For example, through monitoring, a licensee may identify radiation levels of 320 millirem in a year at a neighboring location, such as an adjoining suite in an office complex. Through discussions with management staff of the neighbor, the licensee determines that the adjoining office is staffed 10 hours a day, five days a week, all year. Thus, the occupancy factor would be 0.3 (50 hours a week times 52 weeks a year divided by 8760 hours in a year). The resulting dose to a likely worker at the neighbor from licensee operations would be 96 millirem. If the neighbor's hours of operation increased; such as adding another work day, the licensee may need to reduce the radiation levels in the neighbor's facility, or refine the occupancy factor by determining that no employee of the neighbor averages more than 50 hours a week throughout the year.”

82. The NUREG-1736 example above is analogous to Church Rock where gamma activity has been documented to exist that would cause an exceedance of TEDE if 100 percent occupancy is assumed. But access to wellfields, will be restricted so only exposure *adjacent to* the restricted area are applicable, because of very low occupancy times and the limited impact from low activity gamma from a thin ore veneer it will be impossible to receive any significant exposure. For example, given Ronca-Battista's highest gamma is 180 microrem/hr along SH 556, on an annual basis it would be impossible for a person to receive a dose of 100 millirem per year because the occupancy is so limited. There is no reason for a person to reside along the side of a state road without any type of shelter, food or sustenance in a barren desert 100% of the time. At most a person may walk by the site, pause, and move on; change a flat tire etc. Residency time is only minutes so significant exposure is not possible. This type of demonstration is adequate for the regulations.

83. So when Intervenors conclude (Franke ¶15, Ronca-Battista¶31) that according to the regulations an individual will exceed the TEDE because of localized conditions at the mine site they are incorrect. Intervenors equate the instantaneous gamma radiation readings at an area to a weighted exposure as described in 10CFR §20.1302(2)(ii) which states: “If an individual were continuously present in an unrestricted area the dose from external sources would not exceed .....05 rem in a year.” But, the Church Rock Section 17 area will be restricted, so with respect to gamma there will be no exposure to the general public. In addition, even if there were

elevated gamma readings at a area where public access is possible (I.e. along the roadside) proper time weighted exposure assumptions must be made to evaluate compliance with 10CFR §20.1302(2)(ii). No individual will live along the side of the road 24h/365d per year because the area is open range. Rather one must evaluate the time a passerby might be exposed. In that case, the time of exposure is short and the exceedance of TEDE from the levels of direct gamma at issue is not a significant concern. Intervenors do not present any information on occupancy factors in the areas that they surveyed to support their hypothesis that the 100 mrem/y TEDE would be exceeded.

## B. THE AREA WILL BE RESTRICTED

84. HRI COP § 9.13 at 142 states:

“HRI will minimize access, and provides accountability for all persons entering the CUP restricted area. Restricted areas will include the CCP, and individual satellites. The restricted area includes the facilities inside the fenced area of the CUP. This will include all buildings, and wellfield patterns, and associated equipment. Access to this area will be through the main gate which will be electronically controlled, and will only be opened by entering a combination into the key pad, or by contacting a HRI employee inside the property on the call box.

All non-employees entering the CUP will be required to log in at the main office after receiving visitor training or, as appropriate for the work they will be performing. The combination to the main gate will be changed at irregular intervals to ensure that the restricted area security is maintained.”

85. Intervenors (Ronca-Battista ¶34, Franke ¶18) observe that an area outside of the Section 17 restricted area fence exceeds baseline of the Church Rock Chapter House. But they fail to demonstrate that the area that *currently* is unfenced around the perimeter of the old UNC Church Rock Mine will not be fenced to restrict access to HRI Section 17 well field. In fact as shown in Attachment 2, the monitor well ring and an expected wellfield area will be fenced on the east side of SH 556. So the area will be restricted.

86. HRI will control the Sec. 17 well fields by a fence and has full discretion as to where this fence will be placed. It would be logical for HRI to fence in the area just outside the monitor well ring. As Shown in the map within Attachment 2 this fencing would protrude slightly on to the land on the east side of SH 556 which would enclose the area shown in the drawing of Ronca-Battista Attachment 8 containing mine waste. This would enclose and restrict the areas affected by past mining from any member of the public.

87. Mr. King would be restricted from access as any other member of the public. HRI's surface use agreement allows unlimited use of the surface for mineral production including fencing to restrict any portion of Section 17. (Attachment 8)

**C. AMBIENT RADON CANNOT BE COMPARED WITH 10CFR20  
BECAUSE IT IS NOT IN EQUILIBRIUM**

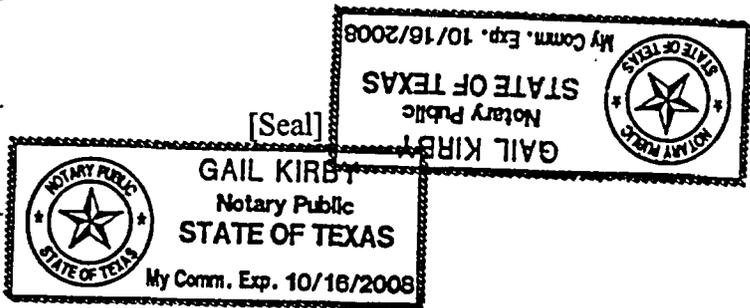
88. Intervenors' concern regarding exposure to ambient radon is misplaced. The 10CFR20 limits for radon are based on radon in equilibrium to its decay products and are expressed in working levels (WL). (FEIS Table 4.19<sup>a</sup>) Radon measured by HRI is ambient, is not in equilibrium, and is expressed as a single element in pCi/l. As described by Dr. Chambers ¶¶17-18, it is incorrect to attempt to describe exposure to ambient radon outdoors as if in growth were allowed to occur.

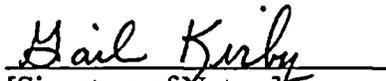
I declare on this 26<sup>th</sup> day of April in Lewisville, Texas, under penalty of perjury that the foregoing is true and correct.

  
Mark S. Pelizza

**ACKNOWLEDGEMENT**

SUBSCRIBED and SWORN TO before me, the undersigned authority, on June 26, 2005 by Mark S. Pelizza.



  
[Signature of Notary]  
Gail Kirby  
Printed/typed name of Notary

Notary public for the State of Texas. My commission expires 10-16-2008

ATTACHMENT 1  
CHURCHROCK PROJECT REVISED ENVIRONMENTAL REPORT -  
MARCH 1993  
SECTION 2.9 FIGURE 2.9-1 AND TABLES

HRI, INC.

CHURCH ROCK PROJECT

REVISED ENVIRONMENTAL REPORT

MARCH, 1993

## **2.9 BACKGROUND RADIOLOGICAL FEATURES**

### **2.9.1 Gamma Radiation**

Gamma measurements were conducted during the survey in the spring of 1987 using a Ludlum scintillator at the ground surface. Figure 2.9-1 shows the gamma activity level in mRem/hr. Gamma ranged from 12 mRem/hr. to 350 mRem/hr. with the higher concentration generally found in association with previous uranium mining activity.

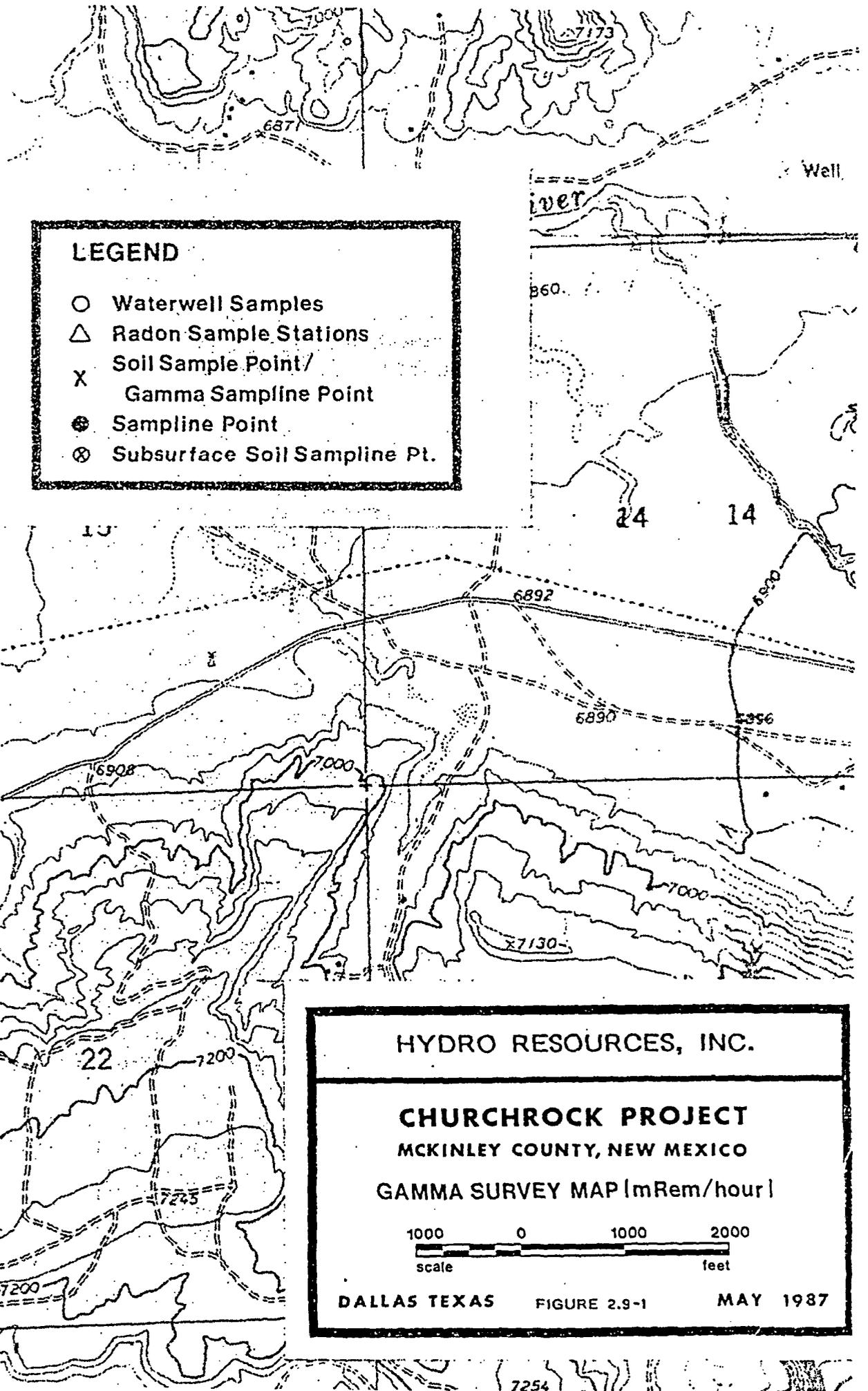
### **2.9.2 Environmental Radionuclide**

Radionuclide concentration in vegetation is covered in Section 2.8.

Environmental radionuclide concentrations in soil were determined by obtaining 26 soil samples in the plant, wellfield and license area and analyzing the soils for U, Ra226, Pb210 and Th230. Sample locations are shown on Figure 2.9-2. The results at this sampling program are within Table 2.9-1. Generally speaking, the four nuclide concentrations are proportional for a given sample. If U is high, then Ra226, Pb210 and Th230 also are high. As was the case with gamma activity, higher nuclide concentrations are generally found in association with previous mining activity. One sample, 8S-16, was anomalously high in nuclide concentration, but not in an area associated with previous mining. This may be a local anomaly, or may be one of many small local occurrences related to exploration activity. HRI will survey more exploration sites before mining to determine if, in fact, many small local areas of high nuclide concentration exist.

Seven sediment samples were obtained...six in the arroyo, which dissect the license area, and one in a pond which was associated with the previous mining activity. Analysis of all creek samples (Table 2.9-2) were revealed similar concentrations of radionuclides and other metals. The pond samples showed higher nuclide concentrations.

Radon measurements began in August using Tract Etch measurement devices. Sample stations were located 100 meters upwind and downwind of the proposed process facility, and at the closest residence downwind. Results of the Radon sampling program are shown on Table 2.9-3. Monthly sampling will continue until one full year of measurements are obtained.



**LEGEND**

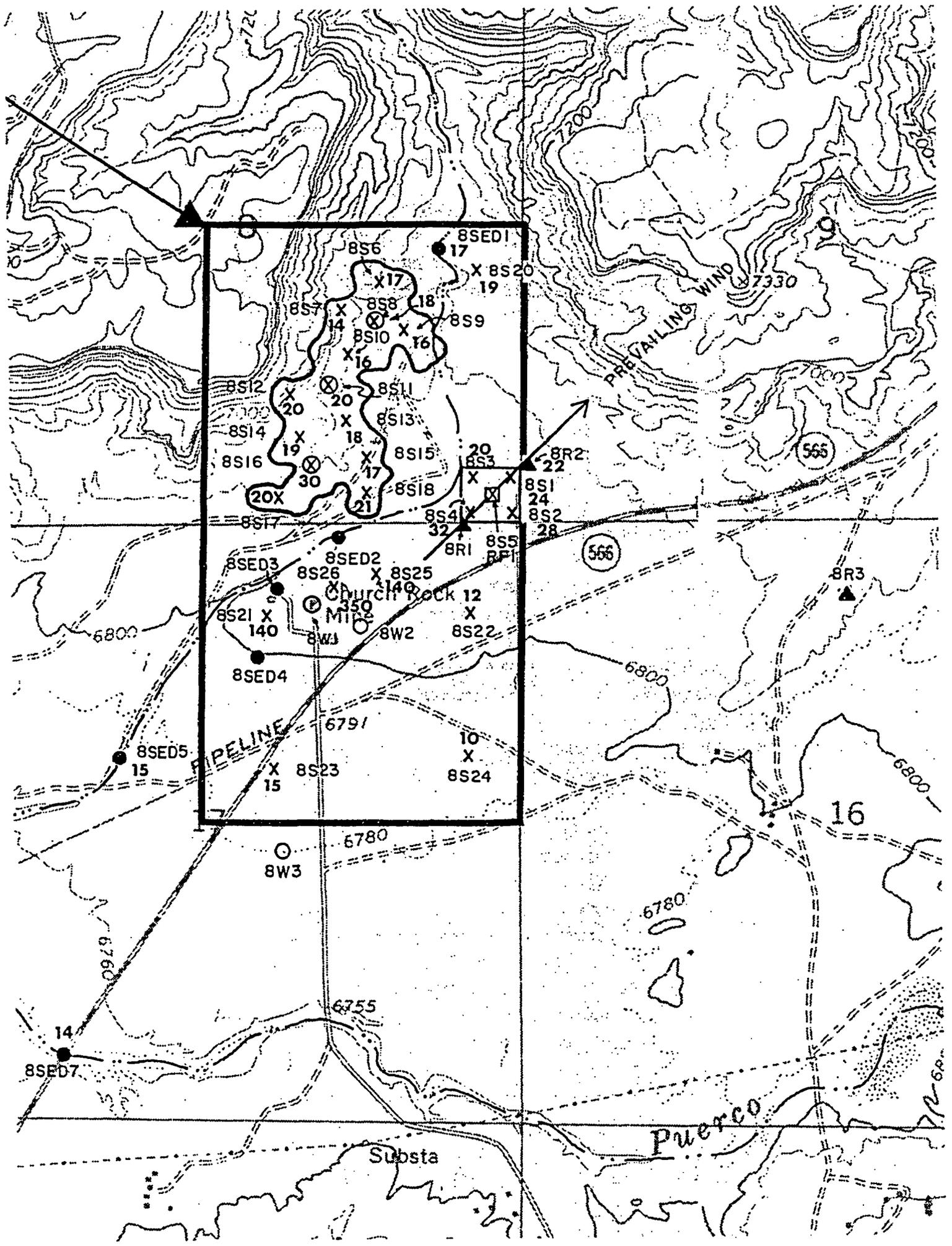
- Waterwell Samples
- △ Radon Sample Stations
- X Soil Sample Point / Gamma Sampline Point
- ⊙ Sampline Point
- ⊗ Subsurface Soil Sampline Pt.

**HYDRO RESOURCES, INC.**

**CHURCHROCK PROJECT**  
**MCKINLEY COUNTY, NEW MEXICO**  
**GAMMA SURVEY MAP (mRem/hour)**

1000 0 1000 2000  
 scale feet

**DALLAS TEXAS FIGURE 2.9-1 MAY 1987**



JORDAN LABORATORIES, INC.  
CHEMISTS AND ENGINEERS  
CORPUS CHRISTI, TEXAS  
SEPTEMBER 21, 1987.

URANIUM RESOURCES, INC.  
SUITE #735, PROMENADE BANK TOWER  
RICHARDSON, TEXAS 75060

## REPORT OF ANALYSIS

IDENTIFICATION	*PH	URANIUM PPM	RADIUM 226 PCI/L	LEAD 210 PCI/L	THORIUM 230 PCI/L
SOIL 8S-1 6-30-87	7.69	5.5	2.4 +/- 0.1	3.6 +/- 0.7	4.5 +/- 0.5
SOIL 8S-2 6-30-87	7.82	13	8.7 +/- 0.3	13 +/- 1	15 +/- 1
SOIL 8S-3 6-30-87	7.91	7.8	3.9 +/- 0.2	6.4 +/- 0.9	8.0 +/- 0.7
SOIL 8S-4 6-30-87	7.97	12	5.7 +/- 0.2	8.9 +/- 1.0	11 +/- 1
SOIL 8S-5 6-30-87	7.83	8.5	4.2 +/- 0.2	5.9 +/- 0.8	9.2 +/- 0.7
SOIL 8S-6 6-30-87	7.84	3.3	1.1 +/- 0.1	1.9 +/- 0.6	2.2 +/- 0.3
SOIL 8S-7 6-30-87	8.07	1.7	0.7 +/- 0.1	0.85 +/- 0.55	1.3 +/- 0.4
SOIL 8S-8 0-12" 6-30-87	7.64	2.9	0.8 +/- 0.1	1.3 +/- 0.6	1.5 +/- 0.3
SOIL 8S-8 12-24" 6-30-87	7.54	2.5	1.3 +/- 0.1	0.99 +/- 0.57	1.7 +/- 0.4
SOIL 8S-8 24-36" 6-30-87	7.66	2.5	1.1 +/- 0.1	1.4 +/- 0.6	2.0 +/- 0.3
SOIL 8S-9 6-30-87	7.86	2.1	0.9 +/- 0.1	2.2 +/- 0.7	1.7 +/- 0.4
SOIL 8S-10 6-30-87	7.76	2.2	0.9 +/- 0.1	1.9 +/- 0.6	1.3 +/- 0.2
SOIL 8S-11 0-12" 6-30-87	4.83	3.7	1.4 +/- 0.1	2.5 +/- 0.6	4.2 +/- 0.5
SOIL 8S-12 6-30-87	7.88	1.6	0.5 +/- 0.1	0.64 +/- 0.49	0.75 +/- 0.20
SOIL 8S-13 6-30-87	7.77	2.7	1.0 +/- 0.1	1.6 +/- 0.6	2.6 +/- 0.4
SOIL 8S-14 6-30-87	6.66	5.3	1.8 +/- 0.1	3.5 +/- 0.7	3.4 +/- 0.4
SOIL 8S-15 6-30-87	7.70	3.1	1.6 +/- 0.1	2.1 +/- 0.6	3.1 +/- 0.5
SOIL 8S-16 7-1-87 12-24"	7.56	56	4.9 +/- 0.2	7.8 +/- 0.9	7.0 +/- 0.5
SOIL 8S-16 6-30-87	7.59	650	49 +/- 1	90 +/- 3	89 +/- 2
SOIL 8S-17 6-30-87	7.94	3.3	1.0 +/- 0.1	1.2 +/- 0.5	1.9 +/- 0.3

JORDAN LABORATORIES, INC.  
 CHEMISTS AND ENGINEERS  
 CORPUS CHRISTI, TEXAS  
 SEPTEMBER 21, 1987

URANIUM RESOURCES, INC.  
 PAGE 2

## REPORT OF ANALYSIS

IDENTIFICATION	*PH	URANIUM PPM	RADIUM 226 PCI/L	LEAD 210 PCI/L	THORIUM 230 PCI/L
SOIL 8S-18 6-30-87	8.06	4.0	1.5 +/- 0.1	2.2 +/- 0.6	2.6 +/- 0.4
SOIL 8S-20 6-30-87	7.85	2.9	1.1 +/- 0.1	1.6 +/- 0.6	1.7 +/- 0.3
SOIL 8S-21 - - - -	8.42	144	48 +/- 1	97 +/- 3	92 +/- 2
SOIL 8S-22 7-1-87	8.00	2.2	1.1 +/- 0.1	1.7 +/- 0.6	1.4 +/- 0.2
SOIL 8S-23 7-1-87	7.93	3.5	1.7 +/- 0.1	2.6 +/- 0.7	3.9 +/- 0.5
SOIL 8S-24 7-1-87	7.92	2.7	1.1 +/- 0.1	1.7 +/- 0.6	1.1 +/- 0.2
SOIL 8S-25 7-1-87	8.08	310	99 +/- 1	241 +/- 4	261 +/- 3
SOIL 8S-26 7-1-87	8.48	420	149 +/- 1	283 +/- 5	242 +/- 3

\*PH DETERMINED ON SATURATED SOIL PASTE.

LAB. NOS. M25-4684 THROUGH M25-4711

RESPECTFULLY SUBMITTED,

CARL F. CROWNOVER

Table 2.9-2  
 BASELINE SEDIMENT ANALYSIS

	8 Sed 1	8 Sed 2	8 Sed 3	8 Sed 4	8 Sed 5	8 Sed 6	8 Sed 7
pH	7.86	7.77	7.97	7.83	8.07	7.86	7.96
Arsenic , ppm	8.8	7.3	18	5.4	5.7	9.8	3.2
Copper , ppm	10	10	11	15	7.0	8.3	6.1
Moly , ppm	4.5	2.4	7.7	2.3	1.8	1.7	1.0
Lead , ppm	11	13	9.4	18	11	11	13
Selenium , ppm	.4	.1	1.4	.8	.1	.1	<.1
Uranium , ppm	2.0	2.4	3.2	140	2.5	4.1	2.4
Ra 226, pci/g	.7	.8	1.1	16	1.2	1.3	.8
Lead 210, pci/g	.51	1.4	1.3	13	1.2	1.8	.94
Thorium, pci/g	.93	1.8	1.3	2	1.7	1.9	1.7

**Table 2.9-3**  
**Churchrock Project**  
**Baseline Radon**

Month	8R1*	8R2*	8R3*
08-05-87 - 09-01-87	1.4	2.9	-
09-01-87 - 09-27-87	7.0	1.2	1.7
09-27-87 - 11-07-87	1.5	1.8	1.8
11-07-87 - 12-08-87	6.3	1.5	11.9
12-08-87 - 01-04-88	2.6	.7	1.0
01-04-88 - 02-12-88	.1	.3	.8
02-12-88 - 03-01-88	2.2	1.8	2.5
03-01-88 - 03-31-88	1.0	.4	1.8
03-31-88 - 05-10-88	4.2	.8	.8
05-10-88 - 05-31-88	.6	.8	.8
05-31-88 - 07-01-88	.3	.7	1.4
07-01-88 - 08-01-88	1.4	1.0	1.8
08-01-88 - 09-01-88	.9	.6	.8
09-01-88 - 10-03-88	13.4	2.1	1.7

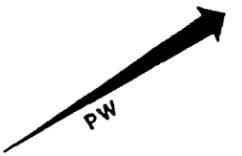
\* All values in pC/l



ATTACHMENT 2  
CHURCHROCK MAP



RESIDENT CRR4



ENTRANCE

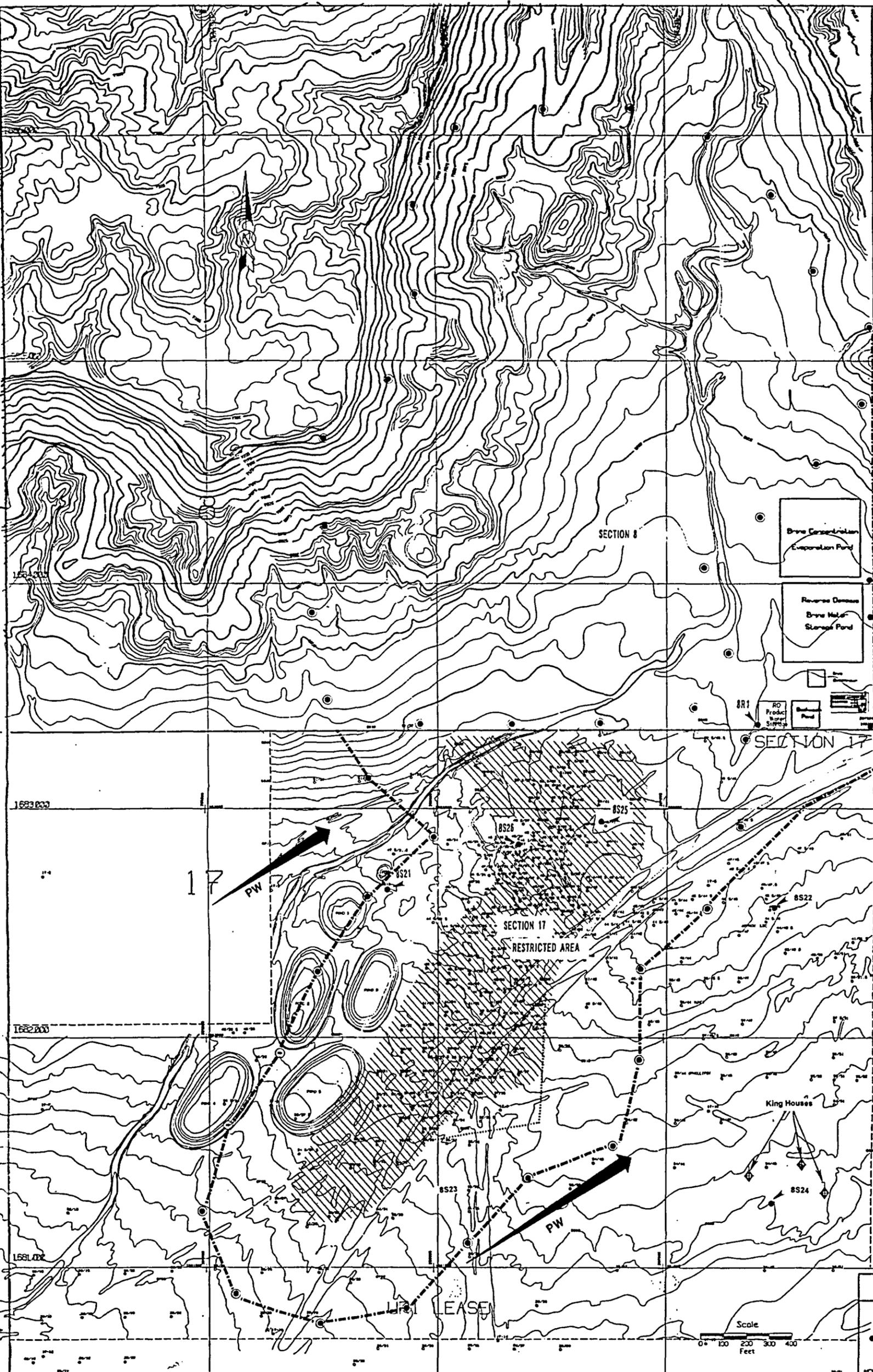
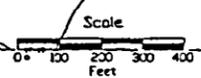
Wellfield

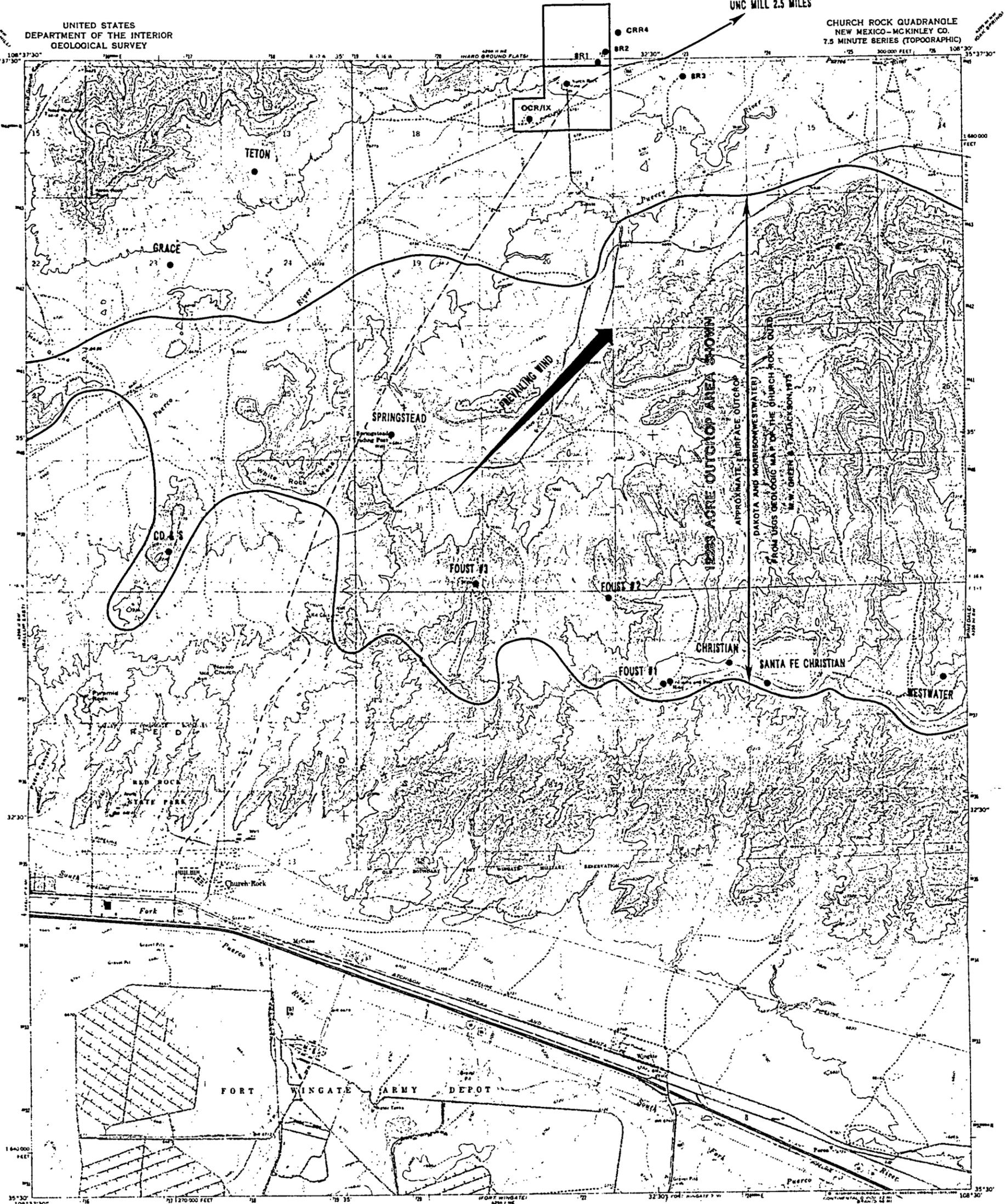
FENCE (APPROXIMATE)

Monitor Well (APPROXIMATE)

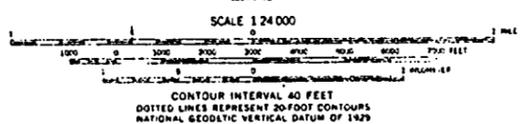
REVISION		
Date	Revision	By
03/24/93	Monitor Wells, Plant Wellfields and Plant Location	WPG
10/2/93	Tire Rack	RAM
10/17/93	Pond Location	WPG
7/21/05	Aspen Pipeline	WPG

**HYDRO RESOURCES, INC**  
 Churchrock Project  
 Plant Location  
 Figure 32-1  
 Sections 8 & 17  
 B5  
 MORTON COUNTY, NEW MEXICO  
 MARCH 1993





Mapped, edited, and published by the Geological Survey  
Control by U.S. and NOS/NOAA  
Topography by photogrammetric methods from aerial  
photographs taken 1962. Field checked 1963.  
Polyconic projection. 1927 North American datum.  
10 000 foot grid based on New Mexico coordinate system, west zone.  
1000-meter Universal Transverse Mercator grid ticks,  
zone 12, shown in blue.  
Fine red dashed lines indicate selected fence lines  
where omitted, land lines have not been established.  
There may be private shadings within the boundaries of the  
National or State reservations shown on this map.  
Reservoirs shown in purple compiled from aerial photographs  
taken 1978 and other source data. This information not  
shown on this map.



ROAD CLASSIFICATION	
Heavy duty	Light duty
Medium duty	Unimproved dirt
Interstate Route	U.S. Route
	State Route

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS  
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092  
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

CHURCH ROCK, N. MEX.  
N3530-W10830/7.5  
1963  
PHOTOREVISED 1979  
DMA 4258-B-88-BERMS 9081

ATTACHMENT 3  
NUREG-1569 P. 7-9; § 2.5.2; 2.5.3, 7.3.1.2.1

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# Standard Review Plan for In Situ Leach Uranium Extraction License Applications

## Final Report

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Date Published: June 2003

Prepared by  
J. Lusher

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Office of Nuclear Material Safety and Safeguards  
U.S. Nuclear Regulatory Commission  
Washington, DC 20555-0001



White House. "Consultation and Coordination with Indian Tribal Governments." Executive Order 13175. *Federal Register*. Vol. 65. pp. 67249 67252. 2000.

## **2.5 Meteorology**

### **2.5.1 Areas of Review**

The staff should review descriptions of the atmospheric diffusion characteristics of the site and its surrounding area based on data collected onsite or at nearby meteorological stations. The data to be reviewed include

- (1) National Weather Service station data, including locations of all National Weather Service stations within an 80-km [50-mi] radius; and available joint frequency distribution data by wind direction, wind speed, stability class, period of record, and height of data measurement
- (2) On-site meteorological data, including locations and heights of instrumentation, descriptions of instrumentation, and joint frequency distribution data, if National Weather Service data representative of the site are not available
- (3) Miscellaneous data, including annual average mixing layer heights, a description of the regional climatology, and total precipitation and evaporation, by month

The staff should also review a discussion of the general climatology including existing air quality, the relationship of the regional meteorological data to the local data, the meteorological impact of the local terrain and large lakes and other bodies of water, and the occurrence of severe weather in the area and its effects. This review should also include data on averages of temperature and humidity.

### **2.5.2 Review Procedures**

The staff should determine whether the application includes sufficient local and regional-scale meteorological information to support estimates of airborne radionuclide transport from the proposed *in situ* leach facility to the surrounding area and for determination of airborne pathway inputs to risk assessment models. This information may include National Weather Service data, on-site monitoring data, or data from local meteorological stations, and any maps or tables that describe meteorological conditions at the site and surrounding area. Section 2.5 of the Standard Format and Content of License Applications, Including Environmental Reports (NRC, 1982) contains a list of acceptable meteorological data requirements.

For license renewals and amendment applications, Appendix A to this standard review plan provides guidance for examining facility operations and the approach that should be used in evaluating amendments and renewal applications.

## Site Characterization

### 2.5.3 Acceptance Criteria

The characterization of the site meteorology is acceptable if it meets the following criteria:

- (1) A description of the general climate of the region and local meteorological conditions is provided, based on appropriate data from National Weather Service, military, or other stations recognized as standard installations.

These data include precipitation, evaporation, and joint-frequency distribution data by wind direction, wind speed, stability class, period of record, and height of data measurement. The average inversion height should also be identified. Data should also be provided on diurnal and monthly averages of temperature and humidity. The locations of all stations used in the data analysis and the height of the data measurement should be included. Data periods should be defined by month and year and cover a sufficient time period to constrain long-term trends and support atmospheric dispersion modeling.

Data from local meteorological weather stations supplemented, if necessary, by data from an on-site monitoring program, are provided.

A minimum of one full year of joint frequency data presented with a joint data recovery of 90 percent or more is provided.

The on-site program should be designed in accordance with Regulatory Guide 3.63, "Onsite Meteorological Measurement Program for Uranium Recovery Facilities—Data Acquisition and Reporting" (NRC, 1988).

- (2) Consideration of relationships between regional weather patterns and local meteorological conditions based on weather station data and the on-site monitoring program, if necessary, is included. The impacts of terrain and nearby bodies of water on local meteorology are assessed, and the occurrence of locally severe weather is described and its impact considered.

Information on anticipated air quality impacts from non-radiological sources, such as vehicle emissions and dust from well field activities, is provided for assessing cumulative impacts.

- (3) The meteorological data used for assessing impacts are substantiated as being representative of expected long-term conditions at and near the site.
- (4) The application contains a description of existing air quality.

The applicant must demonstrate that the radiological and non-radiological air quality impacts caused by *in situ* leach facilities are virtually indistinguishable from background, or information on the likelihood of air pollution is based on U.S. Environmental Protection Agency (EPA) studies. Affected counties within 80 km [50 mi] of the facility are classified according to the National Ambient Air Quality

Standards as being in attainment (below National Ambient Air Quality Standards) or nonattainment (above National Ambient Air Quality Standards status).

- (5) The sources of all meteorological and air quality data are documented in open file reports or other published documents. If data have been generated by the applicant the data documentation should include a description of the investigations and data reduction techniques.

#### 2.5.4 Evaluation Findings

If the staff review as described in this section results in the acceptance of the meteorology, the following conclusions may be presented in the technical evaluation report and in the environmental assessment.

NRC has completed its review of the site characterization information concerned with meteorology at the \_\_\_\_\_ *in situ* leach facility. This review included an evaluation using the review procedures in standard review plan Section 2.5.2 and acceptance criteria outlined in standard review plan Section 2.5.3.

The licensee has acceptably described the site meteorology by providing data from National Weather Service military, or other stations recognized as standard installations located within 80 km [50 mi] of the site, including available joint frequency distribution data on (i) wind direction and speed, (ii) stability class, (iii) period of record, (iv) height of data measurement, and (v) average inversion height. The data cover a sufficient time period to constrain long-term trends and support atmospheric dispersion modeling. The applicant has provided acceptable on-site meteorological data, if necessary, including (i) descriptions of instruments, (ii) locations and heights of instruments, and (iii) joint frequency distributions. The joint-frequency data presented are for a minimum of 1 year, with a joint data recovery of 90 percent or more. Additional data on (i) annual average mixing layer heights, (ii) a description of the regional climate, and (iii) total precipitation and evaporation by month have been provided. The applicant has noted any effect of nearby water bodies or terrain on meteorologic measurements. The applicant has acceptably demonstrated that meteorologic data used for assessing environmental impacts are representative of long-term meteorologic conditions at the site. The applicant report on the existing air quality at the site and nearby is acceptable.

Based on the information provided in the application, and the detailed review conducted of the characterization of meteorology at the \_\_\_\_\_ *in situ* leach facility, the staff concludes that the information is acceptable to allow evaluation of the spread of airborne contamination at the site and development of conceptual and numerical models, and is in compliance with 10 CFR 51.45, which requires a description of the affected environment containing sufficient data to aid the Commission in its conduct of an independent analysis. The characterization also meets the requirements of 10 CFR Part 40, Appendix A, Criterion 7, which requires pre-operational and operational monitoring programs.

## Environmental Effects

anticipated impacts to terrestrial ecology, air quality, surface- and ground-water systems, and land use are environmentally acceptable.

Based on the information provided in the application and the detailed review conducted of the effects of operations on the \_\_\_\_\_ *in situ* leach facility, the staff concludes that the anticipated effects of operations are acceptable and are in compliance with 10 CFR 40.41(c), which requires the applicant to confine source or byproduct material to the location and purposes authorized in the license; and 10 CFR 51.45(c), which requires the applicant to provide sufficient data for the Commission to conduct an independent analysis.

### 7.2.5 Reference

NRC. NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs." Washington, DC: NRC. 2001.

## 7.3 Radiological Effects

### 7.3.1 Exposure Pathways

The staff should review information on the radiological effects of operations on humans, including estimates of the radiological impacts from all exposure pathways. The staff should evaluate descriptions of the plant operations with special attention to the likely pathways for radiation exposure of humans. The staff should review information on accumulation of radioactive material in specific internal compartments and should ensure that both internal and external doses are included in the analysis. This information can be tabulated using the outline provided in Appendix A of the Standard Format and Content Guide (NRC, 1982).

#### 7.3.1.1 *Exposures from Water Pathways*

##### 7.3.1.1.1 Areas of Review

The staff should review the estimates of annual average concentrations of radioactive nuclides in receiving water at the site boundary and at locations where water is consumed or is otherwise used by humans or where it is inhabited by biota of significance to human food chains. The review should include the data presented in support of these estimates, including details of models and assumptions used in supporting calculations of total annual whole body and organ doses to individuals in the off-site population from all receiving water exposure pathways as well as any dilution factors used in these calculations. Additionally, the staff should review estimates of radionuclide concentration in aquatic and terrestrial food chains and associated bioaccumulation factors. The staff should evaluate calculations of internal and external doses. If there are no waterborne effluents from the facility, then these analyses are not needed. Details of models and assumptions used in calculations may be provided in an appendix to the application.

#### 7.3.1.1.2 Review Procedures

The staff should determine whether the concentration estimates at the site boundary meet the regulatory requirements in 10 CFR 20.1302(b)(2)(i) which specifies limits for annual average concentrations of radionuclides in liquid effluents. The staff should also check to ensure that calculations of concentrations have been done for receiving water at locations where water is consumed or is otherwise used by humans or where it is inhabited by biota of significance to human food chains, to meet public dose limits in 10 CFR 20.1301. If the liquid effluent dose is calculated separately from the air pathway dose, the staff should ensure that the results can be summed with the air pathway dose for the total dose comparison to the limit in 10 CFR 20.1301. The staff should also determine whether these estimates are supported by properly interpreted data, calculations, and model results using reasonable assumptions. The staff should review the parameter selections including the justifications provided for important parameters used in the dose calculation. The staff should check the input data for modeling results, to ensure the parameters discussed in the application are the same as those used in the modeling. Code outputs should be spot-checked to ensure that the results are correctly reported in the application. For simple hand calculations, spot calculations can be used to verify that they were done correctly.

For license renewals and amendment applications, Appendix A to this standard review plan provides guidance for examining facility operations and the approach that should be used in evaluating amendments and renewal applications.

#### 7.3.1.1.3 Acceptance Criteria

The exposures from water pathways are acceptable if they meet the following criteria:

- (1) The estimates of individual exposure to radionuclides at the site boundary meet the regulatory requirements in 10 CFR 20.1302(b)(2)(i), which specify limits for annual average concentrations of radioactive nuclides in liquid effluents, or the dose limit in 10 CFR 20.1301.
- (2) Calculations of concentrations of radionuclides in receiving water at locations where water is consumed or is otherwise used by humans or where it is inhabited by biota of significance to human food chains are included in the compliance demonstration for public dose limits in 10 CFR 20.1301.
- (3) For facilities that generate liquid effluents, the relevant exposure pathways are included in a pathway diagram provided by the applicant.
- (4) The conceptual model (scenarios and exposure pathways) is similar to and consistent with the methodology for liquid effluent exposure pathways in Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance With 10 CFR Part 50," Appendix I (NRC, 1977).
- (5) The conceptual model used for calculating the source term and individual exposures (and/or concentrations of radionuclides) from liquid effluents at the facility boundary is

## Environmental Effects

representative of conditions described at the site, as reviewed in Section 2.0 of this standard review plan.

- (6) The parameters used to estimate the source term, environmental concentrations, and exposures are applicable to conditions at the site, as reviewed in Section 2.0 of this standard review plan.

### 7.3.1.1.4 Evaluation Findings

If the staff review, as described in this section, results in the acceptance of the exposure estimates from water pathways, the following conclusions may be presented in the technical evaluation report.

NRC has completed its review of the radiological effects of exposure from water pathways at the \_\_\_\_\_ *in situ* leach facility. This review included an evaluation of the methods that will be used to evaluate radiological effects using the review procedures in standard review plan Section 7.3.1.1.2 and the acceptance criteria outlined in standard review plan Section 7.3.1.1.3.

Applicant estimates of individual exposure to radionuclides from water pathways at the site boundary are acceptable since they are less than the requirements in 10 CFR 20.1302 (b)(2)(i) with regard to annual average concentrations in liquid effluents, or they are less than the dose limit in 10 CFR 20.1301. The applicant has demonstrated that the concentrations of radionuclides in receiving water where it is consumed or otherwise used by humans, or where it is inhabited by biota significant to the human food chain are in compliance with the public dose limits in 10 CFR 20.1301. The applicant has included the relevant pathway diagrams in the application. The applicant has used an acceptable representation of the conditions at the site in the determination of the source term for the model calculations. The applicant has acceptable values for parameters used to estimate the source term, environmental concentrations, and exposures, and the parameters are representative of the \_\_\_\_\_ *in situ* leach site.

Based on the information provided in the application and the detailed review conducted of exposures from water pathways for the \_\_\_\_\_ *in situ* leach facility, the staff concludes that the exposures from water pathways are acceptable and are in compliance with 10 CFR 20.1302(b)(2)(i), which specifies limits for annual average concentrations of radionuclides in liquid effluents and 10 CFR 20.1301, which specifies dose limits for individual members of the public.

### 7.3.1.1.5 References

NRC. Regulatory Guide 3.46, "Standard Format and Content of License Applications, Including Environmental Reports, for *In Situ* Uranium Solution Mining." Washington, DC: NRC, Office of Standards Development. 1982.

———. Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance With 10 CFR Part 50, Appendix I." Washington, DC: NRC, Office of Standards Development. 1977.

### 7.3.1.2 Exposures from Air Pathways

#### 7.3.1.2.1 Areas of Review

The staff should review estimated release rates of airborne radioactivity from facility operations and the atmospheric dispersal of such radioactivity considering applicable meteorological data as reviewed in Section 2.0 of this standard review plan. The staff should then review the estimates of annual total body and organ doses to individuals including (i) at the point of maximum ground level concentration offsite; (ii) at the site boundary in the direction of the prevailing wind; (iii) at the site boundary nearest the emission source; and (iv) at the nearest residence in the direction of the prevailing wind. The applicant can choose to show compliance with a concentration limit or with individual dose limits. Therefore, the staff should initially determine the method of compliance chosen by the applicant and focus the review accordingly. Regardless of which compliance method is chosen, the reviewer should also evaluate an individual dose to the public to verify compliance with the requirements in 10 CFR 20.1301. The staff should review data, models, calculations, and assumptions used in support of these estimates. The review should consider both the source term and exposure pathway components of the calculation and should include deposition of radioactive material on food crops and pasture grass.

#### 7.3.1.2.2 Review Procedures

The staff should determine whether the estimates of annual total body and organ doses to individuals at the point of maximum ground level concentrations offsite; individuals exposed at the site boundary in the direction of prevailing wind; individuals exposed at the site boundary nearest to the sources of emissions; and individuals exposed at the nearest residence in the direction of the prevailing wind, meet the regulatory requirements in 10 CFR 20.1301. The staff should also determine whether these estimates are supported by properly interpreted data, calculations, and model results using reasonable assumptions.

An acceptable computer code that calculates off-site doses to individuals from airborne emissions from *in situ* leach facilities is MILDOS-AREA (Yuan, et al., 1989). This code does not calculate the source term. Therefore, the applicant must provide documentation of the source term calculation that is used as input to MILDOS-AREA (Yuan, et al., 1989), if this code is used. The staff should review the source term equation to ensure that it is an accurate estimation of all significant airborne releases from the facility including, where applicable, yellowcake dust from the dryer stack and radon emissions from processing tank venting and well field releases. If a closed processing loop is used, then radon release from processing is expected to be negligible. If a vacuum dryer is used for yellowcake, then dust emissions from drying may also be assumed to be negligible. The staff should focus attention on the values used for the production flow and the fraction of this flow that is expected to be released during operations. A reasonable estimate of well field radon release is about 25 percent. The staff should also

## Environmental Effects

ensure that the source term calculation accounts for all material released during startup, production, and restoration activities.

The review of the MILDOS-AREA (Yuan, et al., 1989) calculation should focus on the code input provided by the applicant. The applicant should have provided a list of the relevant parameter information that was used. The information from this list should be compared with the input from the code run to ensure that the correct values have been used. Dose results from the code output should be checked against the tabulated results in the application to ensure that the values have been correctly reported. The staff should also evaluate warning messages that the code provides in the output to identify anomalies in the input data or problems with the run. If reported results appear anomalous, the staff may conduct confirmatory analyses using MILDOS-AREA (Yuan, et al., 1989).

For license renewals and amendment applications, Appendix A to this standard review plan provides guidance for examining facility operations and the approach that should be used in evaluating amendments and renewal applications.

### 7.3.1.2.3 Acceptance Criteria

The exposures from air pathways are acceptable if they meet the following criteria:

- (1) The estimates of individual exposure to radionuclides at the site boundary meet the regulatory requirements in 10 CFR 20.1302(b)(2)(i) with regard to annual average concentrations of radionuclides in airborne effluents or the dose limit in 10 CFR 20.1301. The estimates of individual exposure to radionuclides (not including radon) indicate that the ALARA constraint on air emissions in 10 CFR 20.1101(d) will be met.
- (2) Calculations of concentrations of radionuclides in air at locations downwind where residents live or where biota of significance to human food chains exist are included in the compliance demonstration for public dose limits in 10 CFR 20.1301. The estimates of individual exposures to radionuclides (not including radon) indicate that the as low as is reasonably achievable constraint on air emissions, in 10 CFR 20.1101(d), will be met.
- (3) Relevant airborne exposure pathways are included in the pathway diagram provided by the applicant.
- (4) The conceptual model used for calculating the source term and individual exposures (and/or concentrations of radionuclides) from airborne effluents at the facility boundary is representative of conditions described at the site as reviewed in Section 2.0 of this standard review plan. The conceptual model is consistent with the methodologies described in Regulatory Guide 3.51, Sections 1-3, "Calculational Models for Estimating Radiation Doses to Man From Airborne Radioactive Materials Resulting From Uranium Mill Operations" (NRC, 1982). The conceptual model for the MILDOS-AREA code (Yuan, et al., 1989) is one acceptable method for performing these exposure calculations. Other methods are acceptable if the applicant is able to satisfactorily demonstrate that the model includes the criteria discussed above.

- (5) The parameters used to estimate the source term, environmental concentrations, and exposures are applicable to conditions at the site as reviewed in Section 2.0 of this standard review plan. Guidance on source term calculations is available in Regulatory Guide 3.59, Sections 1-3, "Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations" (NRC, 1987). Additionally, an example source term calculation specifically applicable to *in situ* leach facilities is described in Appendix D.

#### 7.3.1.2.4 Evaluation Findings

If the staff review, as described in this section, results in the acceptance of the radiological effects from air pathways, the following conclusions may be presented in the technical evaluation report.

NRC has completed its review of the radiological effects of exposure from air pathways at the \_\_\_\_\_ *in situ* leach facility. This review included an evaluation of the methods that will be used to evaluate radiological effects using the review procedures in standard review plan Section 7.3.1.2.2 and the acceptance criteria outlined in standard review plan Section 7.3.1.2.3.

Applicant demonstrations of individual exposure to radionuclides from air pathways are acceptable since they are less than the limits in 10 CFR 20.1302 (b)(2)(i) with regard to annual average concentrations in airborne effluents or they are less than the dose limit in 10 CFR 20.1301. The applicant has acceptably demonstrated that the concentrations of radionuclides in air at locations where residents live or where biota of significance to human food chains exist are in compliance with the public dose limits in 10 CFR 20.1301 and the as low as is reasonably achievable constraint on air emissions in 10 CFR 20.1101(d). The applicant has included the relevant airborne exposure pathway diagrams in the application. The applicant has used an acceptable representation of the atmospheric conditions at the site in the determination of the source term and individual exposures for model calculations. The applicant has used acceptable values for parameters used to estimate the source term, environmental concentrations, and exposures; and the parameters are representative of the \_\_\_\_\_ *in situ* leach site.

Based on the information provided in the application and the detailed review conducted of exposures from air pathways for the \_\_\_\_\_ *in situ* leach facility, the staff concludes that the exposures from air pathways are acceptable and are in compliance with 10 CFR 20.1302(b)(2)(i), which specifies limits for annual average concentrations of radionuclides in airborne effluents; 10 CFR 20.1301, which specifies dose limits for individual members of the public; and the as low as is reasonably achievable constraint on airborne emissions in 10 CFR 20.1101(d).

#### 7.3.1.2.5 References

NRC. Regulatory Guide 3.59, "Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations." Washington, DC: NRC, Office of Standards Development. 1987.

## Environmental Effects

———. Regulatory Guide 3.51, "Calculational Models for Estimating Radiation Doses to Man From Airborne Radioactive Materials Resulting From Uranium Milling Operations." Washington, DC: NRC, Office of Standards Development. 1982.

Yuan, Y.C., J.H.C. Wang., and A. Zielen. "MILDOS-AREA: An Enhanced Version of MILDOS for Large-Area Sources." Report ANL/ES-161. Argonne, Illinois: Argonne National Laboratory, Energy and Environmental Systems Division. 1989.

### 7.3.1.3 *Exposures from External Radiation*

#### 7.3.1.3.1 Areas of Review

The staff should review estimates of maximum annual external dose that would be received by an individual from direct radiation at the nearest site boundary and in off-site populations. The staff should also review data, models, calculations, and assumptions used in support of these estimates.

#### 7.3.1.3.2 Review Procedures

The staff should determine whether the estimates of maximum annual external dose that would be received by an individual from direct radiation at the nearest site boundary meet the limits specified in 10 CFR 20.1301(a)(2). The staff should also determine whether these estimates are supported by properly interpreted data, calculations, and model results using reasonable assumptions. Staff should confirm that the input parameters used for the external dose calculation are consistent with the information provided in the application. The staff should also confirm that the selected parameter values are representative of conditions at the site as reviewed in Section 2.0 of this standard review plan. Staff should check the source term conceptual model and selected parameter values to ensure that they are appropriate for the site conditions described in the application.

For license renewals and amendment applications, Appendix A to this standard review plan provides guidance for examining facility operations and the approach that should be used in evaluating amendments and renewal applications.

#### 7.3.1.3.3 Acceptance Criteria

The exposures from external radiation are acceptable if they meet the following criteria:

- (1) The estimates of external radiation exposure at the site boundary meet the regulatory limits in 10 CFR 20.1301(a)(2), in accordance with 10 CFR 20.1302(b).
- (2) The applicant provides an exposure pathway diagram that includes the relevant external exposure pathways.
- (3) The model(s) used for calculating the source term, environmental concentrations, and external exposures at the facility boundary are representative of site conditions reviewed in Section 2.0 of this standard review plan.

- (4) The parameters used to estimate the source term, environmental concentrations, and external exposure are applicable to site conditions as reviewed in Section 2.0 of this standard review plan.

#### 7.3.1.3.4 Evaluation Findings

If the staff review, as described in this section, results in the acceptance of the radiological effects of exposures from external radiation, the following conclusions may be presented in the technical evaluation report.

NRC has completed its review of the radiological effects of exposure from external radiation at the \_\_\_\_\_ *in situ* leach facility. This review included an evaluation of the methods that will be used to evaluate radiological effects using the review procedures in standard review plan Section 7.3.1.3.2 and the acceptance criteria outlined in standard review plan Section 7.3.1.3.3.

Applicant demonstration of individual exposure to radionuclides from external radiation is acceptable and meets the limits in 10 CFR 20.1301(a)(2) in accordance with the requirements of 10 CFR 20.1302 (b). The applicant has provided an acceptable exposure pathway diagram that includes all relevant external pathways. The applicant has used an acceptable representation of the external exposures at the site in the determination of the source term, environmental concentrations, and individual exposures for the model calculations. The applicant has used acceptable values for parameters used to estimate the source term, environmental concentrations, and exposures; and the parameters are representative of the \_\_\_\_\_ *in situ* leach site.

Based on the information provided in the application and the detailed review conducted of exposures from external radiation for the \_\_\_\_\_ *in situ* leach facility, the staff concludes that the exposures from external radiation are acceptable and are in compliance with 10 CFR 20.1301(a)(2), which specifies limits for radiation doses in unrestricted areas from external sources in accordance with the methods contained in 10 CFR 20.1302(b).

#### 7.3.1.3.5 References

None.

#### 7.3.1.4 Total Human Exposures

##### 7.3.1.4.1 Areas of Review

The staff should review estimates of the maximum annual dose that could be received via all pathways described above by an individual at the site boundary and at the nearest residence. The staff should also review data, models, calculations, and assumptions used in support of these estimates. Much of this review will already have been completed for the pathway-specific calculations, and the total dose will be the sum of these results.

## Environmental Effects

### 7.3.1.4.2 Review Procedures

The staff should determine whether estimates of the maximum annual dose that could be received via all pathways described above by an individual at the site boundary and at the nearest residence meet regulatory requirements in 10 CFR 20.1301. These calculations can be effectively executed by the MILDOS-AREA code (Yuan, et al., 1989). The staff should also determine whether these estimates are supported by properly interpreted data, calculations, and model results using reasonable assumptions. After the pathway-specific calculations have been reviewed, staff should check to ensure that the doses have been correctly summed to determine the total dose. Also, staff should ensure the population dose is compared with a meaningful reference dose, such as that which is expected for the exposure to the same population from background radiation sources.

For license renewals and amendment applications, Appendix A to this standard review plan provides guidance for examining facility operations and the approach that should be used in evaluating amendments and renewal applications.

### 7.3.1.4.3 Acceptance Criteria

The total human exposure is acceptable if it meets the following criteria:

- (1) The estimates of individual exposure to radionuclides at the site boundary meet the regulatory requirements in 10 CFR 20.1302(b)(2)(i) with regard to annual average concentrations of radioactive nuclides in airborne and liquid effluents or the dose limit in 10 CFR 20.1301.
- (2) Calculations of the maximum individual whole body and organ doses at the site boundary and for the nearest downwind resident and where biota of significance to human food chains exist are included in the compliance demonstration for public dose limits in 10 CFR 20.1301.
- (3) The exposure pathway diagram provided by the applicant includes pathways relevant to all effluents expected from facility operations.
- (4) The models used for calculating the source terms and individual exposures (and/or concentrations of radionuclides) from all effluents at the facility boundary are representative of conditions described at the site as reviewed in Section 2.0 of this standard review plan. The conceptual models are acceptable as described in Sections 7.3.1.1, 7.3.1.2, and 7.3.1.3 of this standard review plan.
- (5) The parameters used to estimate source terms, concentrations, and exposures are representative of conditions described at the site as reviewed in Section 2.0 of this standard review plan.

#### 7.3.1.4.4 Evaluation Findings

If the staff review, as described in this section, results in the acceptance of the radiological effects from total human exposures, the following conclusions may be presented in the technical evaluation report.

NRC has completed its review of the radiological effects of total human exposures at the \_\_\_\_\_ *in situ* leach facility. This review included an evaluation of the methods that will be used to evaluate radiological effects using the review procedures in standard review plan Section 7.3.1.4.2 and the acceptance criteria outlined in standard review plan Section 7.3.1.4.3.

Applicant determination of total human exposure to radionuclides at the site boundary is acceptable since it meets the requirements in 10 CFR 20.1301. The applicant has provided an exposure pathway diagram that includes all relevant external pathways. The applicant has used an acceptable representation of the external exposures at the site in the determination of the source term, environmental concentrations, and individual exposures for the model calculations. The applicant has used acceptable values for parameters used to estimate the source term, environmental concentrations, and exposures; and the parameters are representative of the \_\_\_\_\_ *in situ* leach site.

Based on the information provided in the application and the detailed review conducted of total human exposures for the \_\_\_\_\_ *in situ* leach facility, the staff concludes that the total human exposures are acceptable and are in compliance with 10 CFR 20.1301 which specifies dose limits for individual members of the public.

#### 7.3.1.4.5 Reference

Yuan, Y.C., J.H.C. Wang, and A. Zielen. "MILDOS-AREA: An Enhanced Version of MILDOS for Large-Area Sources." Report ANL/ES-161. Argonne, Illinois: Argonne National Laboratory, Energy and Environmental Systems Division. 1989.

#### 7.3.1.5 Exposures to Flora and Fauna

##### 7.3.1.5.1 Areas of Review

The staff should review estimates of maximum radionuclide concentrations that may be present in important local flora and local and migratory fauna. The staff should also review data, bioaccumulation factors, models, calculations, and assumptions used in support of these estimates.

##### 7.3.1.5.2 Review Procedures

The staff should determine whether estimates of maximum radionuclide concentrations that may be present in important local flora and local and migratory fauna are calculated such that environmental impacts from facility operations can be assessed to address the requirements of 10 CFR Part 51. Particular attention should be paid to impacts to threatened and endangered

## Environmental Effects

species. The staff should also determine whether these estimates are supported by properly interpreted data, reasonable bioaccumulation factors, approved calculations, and model results using reasonable assumptions. Detailed biosphere modeling is not necessary for these calculations. Output from MILDOS-AREA (Yuan, et al., 1989) provides ground level concentrations of radionuclides that can then be converted to plant and animal concentrations by use of simple conversion equations that include deposition, uptake factors, plant interception fractions, and animal consumption rates obtained from the literature. The staff should spot-check parameter values against known sources to ensure that they are within expected ranges. The tabulation of bioaccumulation factors and their sources can be presented in an appendix to the application. Provided these concentrations are protective of human health, they would not be expected to adversely affect native plants and animals (Barntouse, 1995).

For license renewals and amendment applications, Appendix A to this standard review plan provides guidance for examining facility operations and the approach that should be used in evaluating amendments and renewal applications.

### 7.3.1.5.3 Acceptance Criteria

The exposures to flora and fauna are acceptable if they meet the following criterion:

- (1) The model and parameter values used for calculation of concentrations of radionuclides in important local flora and fauna are consistent with generally accepted health physics practice and are applicable to the species identified at the site, as reviewed in Section 2.0 of this standard review plan.

### 7.3.1.5.4 Evaluation Findings

If the staff review, as described in this section, results in the acceptance of the radiological effects from exposures to flora and fauna, the following conclusions may be presented in the technical evaluation report.

NRC has completed its review of the radiological effects of exposures to flora and fauna at the \_\_\_\_\_ *in situ* leach facility. This review included an evaluation of the methods that will be used to evaluate radiological effects using the review procedures in standard review plan Section 7.3.1.5.2 and the acceptance criteria outlined in standard review plan Section 7.3.1.5.3.

The applicant forecasts that the off-site radiological impacts of operation will be minimal. Flora and fauna in the areas surrounding the project site are similar to those onsite and are common in the region. Since calculated human exposures are protective of human health, they would not be expected to adversely affect the native plants and animals, and as such, are acceptable.

Based on the information provided in the application and the detailed review conducted of exposures to flora and fauna for the \_\_\_\_\_ *in situ* leach facility, the staff concludes that the exposures to flora and fauna are acceptable and are in compliance with 10 CFR Part 51 which requires that environmental impacts from facility operations be assessed.

ATTACHMENT 4  
CHURCHROCK PROJECT REVISED ENVIRONMENTAL REPORT -  
MARCH 1993  
METEOROLOGICAL INFORMATION

## 2.5 Meteorology

The site area has an arid to semiarid continental climate with more than 50 percent sunshine throughout the year. On an annual basis, winds are moderate and from the west-southwest. Most precipitation occurs in the late summer with generally dry conditions persisting year-round.

### 2.5.1 Joint Wind Direction Frequency Distribution

The joint frequency distribution is described by wind speed, wind direction, and atmospheric stability. Table 2.5-1 presents the joint frequency distributions and Figures 2.5-1 through 2.5-13 present the monthly windroses based on the National Weather Service (NWS) data for the period from January 1976 to December 1980 at Gallup. These are data which have a joint recovery of 90 percent or more. They show that on an annual basis, most winds are from the west-southwest at approximately seven miles per hour during neutral to stable conditions. Stable conditions (Classes E and F) occur approximately 44 percent of the time at Gallup, indicating limited diffusion potential. Mixing and dispersion take place during unstable conditions (Classes A, B, and C) which occur approximately 23 percent of the time. During the winter season, winds are from the west-southwest, and winds predominate from the west-northwest during the summer.

The on-site data collected by UNC from May 1977 to April 1978 are presented in Tables 2.5-2 through 2.5-4. These data show that winter winds at the site are predominately from the northeast and summer winds are predominately from the southwest. On an annual basis, winds average about five miles per hour and most are from the south-southwest to southwest with an additional component from the northeast. The southwest to northeast direction in which the winds blow is partially a result of funneling through the valley which is also oriented southwest to northeast.

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CHECKED BY JSH

APPROVED BY CGK

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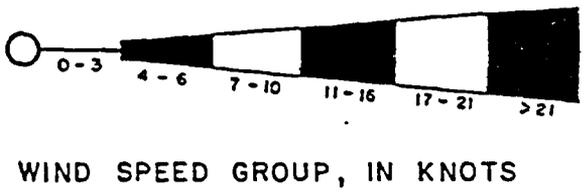
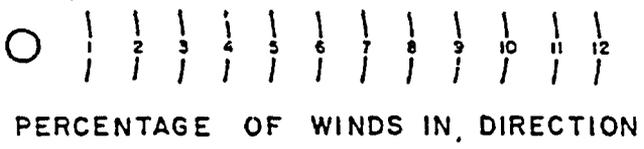
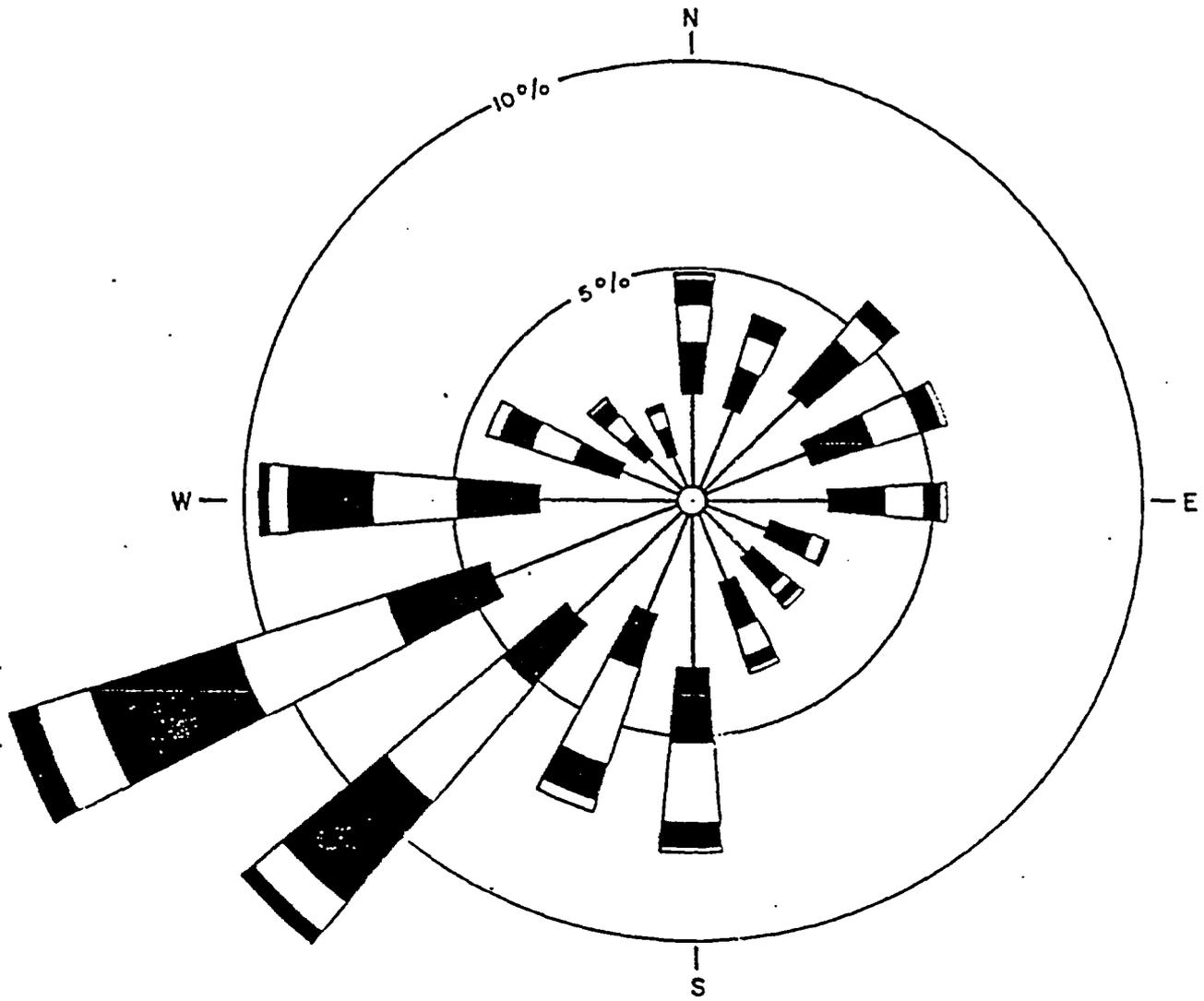


FIGURE 2.5-1  
 WIND ROSE  
 FOR GALLUP, NEW MEXICO  
 AVERAGE ANNUAL CONDITIONS  
 1976 - 1980  
 PREPARED FOR  
 UNC MINING AND MILLING  
 CHURCH ROCK OPERATIONS

Reference: U.S. Dept. of Commerce,  
 NOAA, 1981

Table 2.5-4  
 Percentage Wind Distribution and Speed Distribution  
 United Nuclear Corporation  
 Churchrock  
 May, 1977 - April, 1978<sup>(1)</sup>

Wind Direction	Wind Speed (MPH)						Percentage of Total
	0-3	4-7	8-12	13-18	19-24	Over 24	
N	4.4	3.6	2.6	0.2			10.8
NNE	10.6	1.8	1.5				13.9
NE	14.1	1.4	0.6				16.1
ENE	1.3	0.2	0.1				1.6
ESE	0.6	0.4	0.4				1.8
SE	1.8	1.4	0.6				3.8
SSE	1.1	0.8	0.3	0.2			2.4
S	2.1	2.0	0.8	0.1			5.0
SSW	3.0	5.9	5.2	1.7	0.6	0.4	16.5
SW	2.0	4.6	8.0	1.9	0.4		16.9
WSW	0.8	1.2	1.1	0.1			2.9
W	0.7	1.1	1.0	0.1			2.9
WNW	0.2	0.5	0.4				1.1
NW	0.6	0.8	0.4				1.7
NNW	0.4	0.4	0.3				1.1

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(1) UNC Mining and Milling, 1981

ATTACHMENT 5  
ANNOTATED TOPOGRAPHIC MAP OF THE CHURCH ROCK VICINITY





View looking southwest from the Old Church Rock Mine on Section 17. One of the decommissioned ponds is in the foreground. The expansive Puerco River valley forms the background.

ATTACHMENT 6  
SECTION 17 RAP EXCERPT

July 23, 2001

**Hydro Resources, Inc.**

**CHURCH ROCK SECTION 17  
RESTORATION ACTION PLAN**

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**License No: SUA-1580**

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**July 23, 2001**

## **2. Groundwater Restoration**

### **2.1. Introduction**

In addition to the regulatory guidance provided by NRC, HRI used historic and ongoing company experience with similar groundwater restoration operations in developing its budget model. Groundwater restoration costs are presented as a monthly restoration budget with cumulative total costs. This is an appropriate budget interval because ongoing operational cost such as labor, electricity, reagents, replacement equipment etc. are paid out of cash on a monthly basis. The duration of the restoration cost expenditure was based on the processing and circulation of 9 pore volumes of groundwater as required by license condition 9.5 surety requirement. Surety will be maintained at this level until the number of pore volumes required to restore the ground water quality of a production scale wellfield has been demonstrated as stated in COP Section 10.4.4.

The COP that was submitted in support of the HRI's License contemplated a number of methods for liquid waste treatment and disposal during ground water restoration. The costs that are presented in this budget assume the most conservative liquid waste treatment and disposal option; reverse osmosis treatment ("RO") and brine concentration ("BC"). It is conservative because it is authorized by the current license (other options would require additional licensing steps) and it is the most costly option. If HRI is to pursue one of the other treatment/disposal options described in the COP Revision 2.0 and it is approved in a future licensing action, then HRI will adjust the surety budget accordingly during the annual update review.

RO and BC will be used to treat water during production operations and be used for groundwater restoration conducted in the pilot demonstration and during concurrent restoration that will be ongoing with production activities. Because the cost of restoration equipment such as wellfield pumps, ponds, the RO unit, the BC unit, laboratory equipment, trucks, and field equipment must be incurred for production process operations, they are assumed to be operational capital and are not included as capital requirements in any of the RAP budget lines. NRC will be able to verify the availability of the restoration equipment during routine inspections.

The budget model described in this RAP used 712,913,000 gallons of water to size duration of the restoration program against the projected nominal equipment capacity. Rows 21-42 of the restoration budget is a monthly calculation of water treatment capacity that has been cumulated over the term of restoration and compared with the required nine pore volumes of treated water. It is nominal equipment design capacity that is needed to process the requisite gallorage that justifies the length (and cost) of groundwater restoration operations.

### **2.2. Reverse Osmosis Equipment Description**

Reverse osmosis is a water treatment process whereby the majority of dissolved "ions" are filtered from the wastewater, and concentrated into a smaller concentrated brine volume. The resulting product water typically meets, or exceeds drinking water standards, and during restoration activities, is reinjected back into the wellfield further diluting the underground mining

solutions toward baseline quality. For the purpose of this budget model, the concentrated brine stream, representing 20% of the feed volume will be disposed by brine concentration (a form of distillation).

Osmosis is a natural process that occurs in all living cells. With an appropriate semi-permeable membrane as a barrier to solutions of differing concentrations, naturally occurring osmotic pressure forces pure water from the dilute solution to pass through the membrane, and dilute the more concentrated solution. This process will continue until equilibrium exists between the two solutions.

Reverse osmosis (R.O.) is a reversal of the natural osmotic process. By confining a concentrated solution against a semi permeable membrane, and applying a reverse pressure on the concentrate greater than the naturally occurring osmotic pressure, water will move across the membrane ("product water"), and out of the original concentrate, resulting in an even more concentrated solution ("brine"). The membrane rejects the passage of the majority of the dissolved solids while permitting the passage of water.

Post-mining solutions from a depleted mine area will be treated with an anti-scalent which is the only chemical pretreatment budgeted. The solution may next be bulk-filtered across sand filters to remove all solids greater than 30 microns. Cartridge filters will then filter out the remaining solids greater than 1 micron. The solution at this point is ready for the reverse osmosis process. To achieve reverse osmotic purification, the pretreated solution is pressurized and directed to the first step of a two-stage reverse osmosis process. Approximately 60 percent of the total feed volume will be converted to product water in the first stage. The brine water of the first stage will then act as the feed for the second stage, which yields an overall product to brine ratio of 4:1. The brine generated will be further treated and reduced by brine concentration.

The RO unit was sized to operate at a nominal<sup>9</sup> capacity of 580 gallons per minute. This design rate has been utilized by URI at similar ISL facilities with excellent results. Additionally, the sizing is optimal because it will allow concurrent restoration to proceed at approximately the same rate production wellfields are depleted. (I.e. with mining and restoration going on concurrently restoration and mining will proceed at similar rates).

RO treatment operating and maintenance costs are included within the O & M budget in Attachment E-2-1.

### 2.3. Brine Concentrator Equipment Description

A brine concentrator will be used for final reduction of liquid waste. The RO reject stream will be treated with a vertical tube, falling film vapor compressor evaporator followed by a

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<sup>9</sup> RAP-17's nominal capacity is an estimate. HRI will deal with capacity variances that result from equipment efficiency or downtime by increasing or decreasing the equipment size and possibly adjusting surge capacity. For example, if actual operating results indicate that R.O. equipment downtime is 5% then increasing the equipment design capacity from 580 gpm to 610 gpm would allow the average throughput to remain the same. At this stage it is impossible for HRI to anticipate and adjust for every operational variable that may arise in the future.

steam driven rotary drum dryer to achieve zero liquid discharge (dry solids). The solids will be bulk stored and shipped to an 11.e.2-byproduct facility for disposal.

Brine concentration is a process that can process a waste stream into deionized water and solid slurry. Electrical utilities in the Four Corners area, and paper, and pulp companies have employed this technology for decades to handle their waste streams. The principle behind the process is based on the ideal Carnot cycle where an initial fixed volume of concentrated brine is heated to boiling temperature. The steam vapor created is mechanically compressed; resulting in a secondary steam vapor whose temperature is elevated (15-20 degrees) by the work energy used during compression. Distilled water is condensed from the secondary steam vapor onto internal heat exchangers. The heat loss during condensation is transferred to the circulating brine on the opposite side of the heat exchanger. The brine's temperature is raised, maintaining the internal boiling environment. This source of heat sustains the creation of primary steam used to feed the compressor. The cycle is continuous so long as energy is added at the compressor stage. The electrical power used in compressing, and elevating the temperature of the primary steam vapor produces distilled product water. The resultant hyper-concentrated brine allows solid precipitate in the form of common salts as determined by the solution's limits for solubility. Typically, for each 100 gallons of waste brine treated, 98 gallons of distilled water and 2 gallon of slurry solids are formed.

The BC was sized to accommodate the anticipated brine that the RO will produce.

BC costs are included within the O & M budget in Attachment E-2-1.

#### 2.4. Pore Volumes and Flair

Restoration equipment capacity design coupled with timing of the restoration operations budgeted herein is a function of the quantity of water that will be processed during restoration that is calculated in this RAP by using the pore volume unit of measure. The term "pore volume" (PV) is a term of convenience that has been conceived by the ISL industry to describe the quantity of free water in the pores of a given volume of rock. The units are provided in gallons. PV's provides a unit of reference that a miner can use to describe the amount of circulation that is needed to leach an ore body, or describe the times water must be flowed through a quantity of depleted ore to achieve restoration. PV's provide a way that a miner can take small-scale studies, such as studies in the laboratory, and scale these studies up to field level or to compare pilot scale studies<sup>10</sup> to commercial scale. Hence they provide a miner with an important technique for calculating ISL project economics and restoration costs.

PV's are calculated by determining the three dimensional volume of the rock (that is also the ore zone) and multiplying this number by the percent pore space. HRI used the "ore area" method to determine pore volumes<sup>11</sup>, where the extent of ore of given grade within a mine unit is

<sup>10</sup> I.e. such as the Section 9 Pilot. See FEIS p. 4-37.

<sup>11</sup> Different operators have used different methods to determine the volume of the ore zone. For example, some use the "pattern method" where pattern dimensions are used to determine the area of the ore and then the area is multiplied by screen thickness to determine the volume of rock in the five spot. The pore volume of the five spot is

ATTACHMENT 7  
NUREG-1736 EXCERPT

### 3.20.1301 DOSE LIMITS FOR INDIVIDUAL MEMBERS OF THE PUBLIC

**Statement of Requirement:**

(a) Each licensee shall conduct operations so that:

- (1) The total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem (1 millisievert) in a year, exclusive of the dose contributions from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive material and released in accordance with 10 CFR 35.75, from voluntary participation in medical research programs, and from the licensee's disposal of radioactive material into sanitary sewerage in accordance with 10 CFR 20.2003; and
- (2) The dose in any unrestricted area from external sources, exclusive of the dose contributions from patients administered radioactive material and released in accordance with 10 CFR 35.75, does not exceed 0.002 rem (0.02 millisievert) in any one hour.

(b) If the licensee permits members of the public to have access to controlled areas, the limits for members of the public continue to apply to those individuals.

(c) A licensee or license applicant may apply for prior NRC authorization to operate up to an annual dose limit for an individual member of the public of 0.5 rem (5 mSv). The licensee or license applicant shall include the following information in this application:

- (1) Demonstration of the need for and the expected duration of operations in excess of the limit in Paragraph (a) of this section;
- (2) The licensee's program to assess and control dose within the 0.5 rem (5 mSv) annual limit; and
- (3) The procedures to be followed to maintain the dose as low as is reasonably achievable.

(d) In addition to the requirements of this part, a licensee subject to the provisions of EPA's generally applicable environmental radiation standards in 40 CFR Part 190 shall comply with those standards.

(e) The Commission may impose additional restrictions on radiation levels in unrestricted areas and on the total quantity of radionuclides that a licensee may release in effluents in order to restrict the collective dose.

**Discussion:**

This section specifies the limits for public dose from licensed activities, including dose from transient activities (i.e., dose in any one hour) and cumulative activities over a year, and lists the sources of exposure that are excluded from the public dose limits. The section also provides a mechanism for obtaining NRC's specific approval of a higher annual public dose limit.

## PART 20

### **Statement of Applicability:**

This regulation is applicable to all NRC licensees whose activities may result in exposure to members of the public.

### **Guidance Statement:**

This section addresses two separate dose limits for licensed operations. One limit, 100 mrem, applies to the annual, cumulative dose to individual members of the public from licensed operations. To meet this limit, licensees most often will need to evaluate radiation levels and effluent concentrations within controlled areas of the site and at the boundaries of the facility. The evaluations may conclude that radiological conditions in controlled areas and/or at the boundaries are indistinguishable from background, and no additional monitoring may be necessary. In other cases, licensees may need to use environmental monitors (thermoluminescent dosimeters [TLDs] and air samplers) to assess the conditions.

Although licensed activities may result in radiation levels in a controlled area or in an unrestricted area that exceed 100 millirem in a year, the actual dose to a member of the public likely to be present in the controlled area or unrestricted area may, depending on occupancy, be below the 100 mrem limit. For example, through monitoring, a licensee may identify radiation levels of 320 millirem in a year at a neighboring location, such as an adjoining suite in an office complex. Through discussions with management staff of the neighbor, the licensee determines that the adjoining office is staffed 10 hours a day, five days a week, all year. Thus, the occupancy factor would be 0.3 (50 hours a week times 52 weeks a year divided by 8760 hours in a year). The resulting dose to a likely worker at the neighbor from licensee operations would be 96 millirem. If the neighbor's hours of operation increased; such as adding another work day, the licensee may need to reduce the radiation levels in the neighbor's facility, or refine the occupancy factor by determining that no employee of the neighbor averages more than 50 hours a week throughout the year.

The other limit is 2 millirem in any one hour in any unrestricted area from external sources. This limit is usually associated with transient activities. Such activities may include the use of licensed material in the public domain (e.g., temporary job site activities by radiographers or portable gauge users) and activities near restricted area boundaries at fixed facilities that result in elevated radiation levels in unrestricted areas (e.g., public sidewalks) for short periods of time.

This limit means that doses in unrestricted areas may not exceed 2 millirem in any period of 60 consecutive minutes, regardless of the instantaneous dose rates within that period of time. For example, a licensee's activities may result in an instantaneous dose rate in an unrestricted area of 120 millirem per hour, provided that the dose rate did not exist for more than one minute (1/60th of an hour). This would be allowable as long as the dose rate in the unrestricted area did not exceed background levels for the next 59 minutes, so that the total dose in that hour did not exceed 2 millirem. This limit applies to unrestricted areas, regardless of whether or not exposure occurs to an individual member of the public.

## PART 20

For the purposes of this regulation, public dose does not include contributions from: background radiation, radiation associated with the medical administration of licensed materials to the individual, exposure to individuals administered radioactive material and released in accordance with 10 CFR 35.75, voluntary participation in medical research programs, and the licensee's disposal of radioactive material into sanitary sewerage in accordance with 10 CFR 20.2003.

Public dose does include contributions from radioactive material packages within the licensee's control, such as packages prepared by it for shipment and awaiting pickup by a courier and packages received but not yet opened by the licensee. Once radioactive material packages meeting applicable requirements are shipped by a licensee, are in the possession of a courier, and are on a public thoroughfare outside the confines of the licensee's facility, the public dose limits no longer apply. Once the; radioactive material packages are considered in transit (i.e., on a public thoroughfare outside the confines of the licensee's facility), the requirements in 10 CFR Part 71 and the Department of Transportation's regulations governing hazardous material transport provide adequate protection to members of the public who might be exposed.

The requirements for licensees demonstrating compliance with these public dose limits are contained in 10 CFR 20.1302.

### 3.201302 COMPLIANCE WITH DOSE LIMITS FOR INDIVIDUAL MEMBERS OF THE PUBLIC

#### Statement of Requirement:

#### 10 CFR 20.1302 Compliance with Dose Limits for Individual Members of the Public

(a) The licensee shall make or cause to be made, as appropriate, surveys of radiation levels in unrestricted and controlled areas and radioactive materials in effluents released to unrestricted and controlled areas to demonstrate compliance with the dose limits for individual members of the public in 10 CFR 20.1301.

(b) A licensee shall show compliance with the annual dose limit in 10 CFR 20.1301 by:

- (1) Demonstrating by measurement or calculation that the total effective dose equivalent to the individual likely to receive the highest dose from the licensed operation does not exceed the annual dose limit; or
- (2) Demonstrating that:
  - (i) The annual average concentrations of radioactive material released in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed the values specified in Table 2 of Appendix B to Part 20; and
  - (ii) If an individual were continuously present in an unrestricted area, the dose from external sources would not exceed 0.002 rem (0.02 mSv) in an hour and 0.05 rem (0.5 mSv) in a year.

(c) Upon approval from the Commission, the licensee may adjust the effluent concentration values in Appendix B to Part 20, Table 2, for members of the public, to take into account the actual physical and chemical characteristics of the effluents (e.g., aerosol size distribution, solubility, density, radioactive decay equilibrium, chemical form).

#### Discussion:

This section requires licensees either to take actions or have actions taken on their behalf to ensure that their licensed operations do not result in doses to individual members of the public in excess of the limits specified in 10 CFR 20.1301. The section provides for two principal means of demonstrating compliance with the annual dose limit for members of the public.

#### Statement of Applicability:

NRC licensees.

**Guidance Statement:**

This section provides licensees with two different methods for showing compliance with the public dose limit of 100 mrem in a year. The first method relies on any combination of calculations and measurements of the dose received by the member of the public receiving the highest dose from the licensed activity. That dose may result from any combination of external and internal exposures. The licensee must make an effort to determine who, or what group, receives the highest exposure. Depending on the details of the facility's operation, and the combination of external and internal doses, that person or group may be those living or working closest to the site, those living downwind of the plant, those who frequent the controlled or restricted areas and who may receive non-occupational exposures, or those of a particular age group.

The concentrations of released materials are to be measured at the boundary of the unrestricted area. For many facilities, this means at the point of release to the atmosphere, such as the top of the stack, for airborne releases, and at the point of discharge to a body of water, for liquid releases. For large facilities in which the stack may be some distance from the site boundary and where there are no unrestricted areas within that site boundary, application of the regulation would not normally be at the point of release from the stack. The dose of 2 mrem in any one hour is not a dose rate but a dose in a period of an hour. This allows for short duration bursts of radiation that may produce dose rates much higher than 2 mrem/hr but that, when averaged over an hour, will be less than 2 mrem. Note that when showing compliance with external dose limits, occupancy factors are not permitted. In other words, even though no person is known to be continuously present in the unrestricted area, such a continuously present person must be assumed.

Although this section of the regulations addresses only the requirement to show compliance with the dose limits to members of the public, the regulations elsewhere (10 CFR 20.1101) require that the licensee also make every effort to keep the dose to members of the public as far below the 100 mrem/yr limit as possible. The annual dose from air emissions is also subject to a separate constraint of 10 mrem/yr (10 CFR 20.1101).

ATTACHMENT 8  
SECTION 17 SURFACE USE AGREEMENT



Subject, however, to exceptions and reservations of minerals and rights of entry to prospect for, mine and remove the same and to use so much of the surface of said lands as may be necessary and convenient contained in said deed or deeds of conveyance of the described premises given by Santa Fe Pacific.

Santa Fe Pacific has licensed or leased, or proposes to license or lease, the described premises for the purpose of prospecting for uranium and associated minerals and mining and removing the same.

It is desired at this time to avoid any future dispute as to what surface uses are permissible with respect to the described premises under said rights of entry and surface use, expressed or implied, and as to what uses would or might be considered excessive thereunder, and to provide an equitable consideration to the Land Owner for the right to make such uses.

**AGREEMENT:**

NOW, THEREFORE, it is mutually understood and agreed between the parties hereto as follows:

Section 1. In consideration of the mutual benefits and of the sum of Ten Dollars (\$10.00) paid by Santa Fe Pacific to the Land Owner, receipt whereof is hereby acknowledged, the Land Owner hereby confirms, extends, and grants to Santa Fe Pacific, its lessees, licensees, successors and assigns, the easements and rights to enter upon the described premises and to prospect for, mine, store and remove uranium and associated minerals, using any means or methods of mining, stripping, quarrying, drilling or any other or different process of extraction or development, and to construct, maintain and use upon, within, and over said premises, machinery, tanks, engines, pipe, power and telephone lines, water wells, not including water from Land Owner's wells, roadways, and, without limitation by reason of the foregoing enumeration, any and all other structures, equipment, fixtures, appurtenances, or facilities (all the above being included under the term "facilities") necessary or convenient in prospecting for and developing, producing, storing, transporting and marketing uranium and associated minerals produced from any portion of the described premises.

Section 2. Santa Fe Pacific agrees, so long as it is receiving royalties upon uranium ore production from the described premises, to pay or cause to be paid to the Land Owner the value on the premises of two per cent (2%) of all the uranium ore hereafter produced, saved and marketed therefrom. Said value shall not include any bonuses, development or haulage allowances or other special payment provided for by statute or by regulation or order of any governmental agency. The said two per cent (2%) shall be in lieu of any other payment expressed or implied in deed or deeds of conveyance of the described premises given by Santa Fe Pacific.

Section 3. Nothing herein contained shall be construed as a covenant to mine by Santa Fe Pacific, its lessees or licensees, or as a grant of any mineral right to the Land Owner.

Section 4. The easements, rights and uses herein shall be binding upon the described premises and each and every part thereof, and the present and future owners thereof, and shall continue for the benefit of the present or future owners of the uranium rights in the described premises and each and every part thereof, and their lessees and licensees.

Section 5. Santa Fe Pacific agrees (a) to pay or cause to be paid all damage to the Land Owner's buildings and growing crops caused by the erection or construction of facilities to be used in connection with mining operations; (b) that all pipe lines shall be buried below plow depth where such lines cross cultivated land; and (c) that where there are fences, to construct gates or cattle guards therein where necessary for Santa Fe Pacific, or its licensees or lessees, to cross same, and to keep such gates and cattle guards in repair and gates closed.

Section 6. This agreement and the easements, rights and uses granted herein shall terminate upon the termination of the license or lease; provided, however, that such termination shall not terminate the rights of entry and of surface use expressed or implied in the deed or deeds of conveyance from Santa Fe Pacific.

Section 7. This agreement shall inure to the benefit of, and shall be binding upon the successors and assigns of the parties hereto, including the heirs and personal representatives of the Land Owner, if the latter is an individual or individuals.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the day and year first above written.



SANTA FE PACIFIC RAILROAD COMPANY

By (Sgd) C. F. Mappes

President

ATTEST:

(Sgd) R. C. Schmidt

Assistant Secretary

NAVAJO TRIBE OF INDIANS

By (Sgd) Paul Jones

Chairman, Navajo Tribal Council

(Sgd) J. Maurice McCabe

J. Maurice McCabe  
Executive Secretary  
THE NAVAJO TRIBE

Approved: Mar 9 1959  
Bureau of Indian Affairs

By (Sg) Carthow R. Patrie  
Acting Assistant Area Director

APPROVED AS TO FORM

(Sgd) E. G. Johnson

Solicitor for New Mexico

AES

FORM APPROVED

-3- (Sgd) L. W. Butterfield

General Attorney

ATTACHMENT 9  
VASQUEZ RADON ANALYSIS

JORDAN LABORATORIES, INCORPORATED  
ANALYTICAL & ENVIRONMENTAL CHEMISTS  
CORPUS CHRISTI, TEXAS  
July 18, 2005

URI, INC.  
650 S. Edmonds Lane, Suite 108  
Lewisville, Texas 75067

Report of Analysis

Lab. No.	Identification (Vasquez)	*Radon 222 pci/L
M43-2536	RIX Preg. Lix 1-4 06-24-05	85500 +/- 645
M43-2537	RIX Barren Lix 1-4 06-24-05	90200 +/- 656
M43-2538	RIX Preg. Lix 5-6 06-24-05	62500 +/- 569
M43-2539	RIX Barren Lix 5-6 06-24-05	66000 +/- 591

Analyst: Nixon  
Analysis Date: 06-27-05  
Metod Number: 903.1

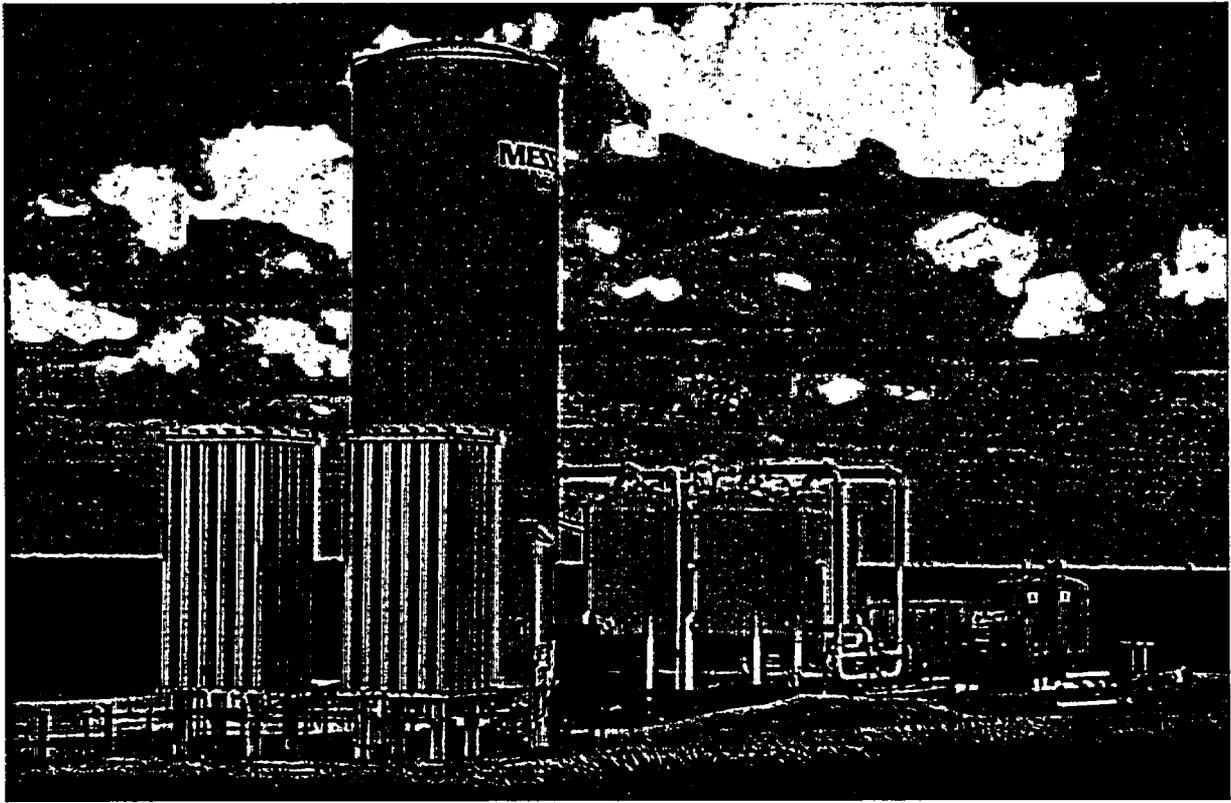
\*Note: Values reflect Radon 222 content at time of sampling.

Respectfully Submitted,



Carl F. Crownover, Pres.

ATTACHMENT 10  
PHOTOGRAPH OF THE VASQUEZ REMOTE IX



The Vasquez remote ion exchange unit. The four buff color tanks are pressurized ion exchange columns. The tall white tank holds oxygen.

# EXHIBIT B

**UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION**

**ATOMIC SAFETY AND LICENSING BOARD PANEL**

Before Administrative Judge  
E. Roy Hawkins, Presiding Officer  
Dr. Richard F. Cole, Special Assistant  
Dr. Robin Brett, Special Assistant

In the Matter of:	)	
	)	
HYDRO RESOURCES, INC.	)	Docket No. 40-8968-ML
2929 Coors Road, Suite 10	)	ASLBP No. 95-706-01-ML
Albuquerque, NM 87120	)	
	)	July 26, 2005

**AFFIDAVIT OF DOUGLAS B. CHAMBERS, Ph.D.  
PERTAINING TO RADIATION**

**A. PERSONAL**

My name is Douglas B. Chambers, Ph.D. The factual matters set out herein are within my personal knowledge.

**B. PROFESSIONAL QUALIFICATIONS**

A detailed summary of my professional qualifications is attached to this Affidavit.

In brief, I have worked in the area of environmental radioactivity, risk assessment, risk management and waste management for more than 30 years on a wide variety of environmental radioactivity projects involving both the nuclear fuel cycle and non-fuel cycle activities in Canada, the United States and internationally.

I have been significantly involved in the development of probabilistic tools for pathways analysis and risk assessment for application to nuclear fuel cycle activities. Such approaches are used to evaluate the effect of uncertainty and are becoming the state-of the-art in such assessments. In addition, I have investigated the effects of uncertainty on epidemiological feasibility and on dose-response relationships. One example of my work in this area was a project for the development of the Uranium Tailings Assessment Program (UTAP) for the Canadian government which embeds source terms, exposure pathways, and dose calculations in a Monte Carlo framework. I continue to be active in this area. In addition, I have applied these methods to the interpretation of epidemiological studies of uranium miners.

I have been active in radiological dose and risk assessment since the mid-1970's when I directed evaluation of the expansion of the Elliot Lake Mines, new uranium processing facilities and nuclear generating stations. I have conducted environmental assessments and radiological dose assessments at all of the uranium mining and milling facilities in Canada, several uranium facilities in the United States, and several uranium facilities in Europe and Africa. For example, I was advisor to the Federal Ministry of Environment in Germany concerning the decommissioning of very large uranium facilities in eastern Germany.

My work in the areas of environmental assessments, radiological dose assessments and risk assessment is recognized internationally and I am a member of numerous professional societies. I was a founding member of the Canadian Radiation Protection Association (CRPA). I became a member of the Canadian Standards Association (CSA) Committee on Environmental Radiation Protection in 1978, and subsequently was chairman to 1989 during which time national standards on environmental pathways analysis and radiological dose estimation were developed. I was a member of the U.S. National Council on Radiation Protection and

Measurements (NCRP) Scientific Committee 85 on the Risk of Lung Cancer from Radon, and have participated on a committee of the Science Advisory Board of the U.S. Environmental Protection Agency (EPA) concerning radon research initiatives. I was appointed to Canada's Atomic Energy Control Board (former) Advisory Committee on Radiological Protection (ACRP) in 1993 and was vice-chairman in 2001. I am a member of the Canadian delegation to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). UNSCEAR has the United Nations mandate for providing the scientific basis for understanding the levels and effects of ionizing radiation. Scientists from thirteen countries, among them the United States, Canada, Great Britain and Japan, participate on the Committee. I am currently UNSCEAR's radon consultant and I am preparing the next UNSCEAR assessment of radon. I was the recipient of the 1997 W.B. Lewis award of the Canadian Nuclear Society for achievements in environmental radioactivity. In February 2002, I was the Morgan lecturer for the Health Physics Society's mid-year symposium in Orlando.

### **C. MATERIALS REVIEWED**

- Final Environmental Impact Statement (FEIS) to Construct and Operate the Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico, USNRC, 1997 (NUREG 1508).
- The report of Bernd Franke attached to his affidavit which in turn formed part of ENDAUMS's and SRICS's January 11, 1999 Radiation Brief.
- Affidavit of Christopher McKenny which is attached to the NRC Staff Briefing dated February 18, 1999.
- Affidavit of Melinda Ronca-Battista dated June 10, 2005 (Appendix K of the June 13, 2005 submission of ENDAUM and SRIC concerning radiological air emissions from Church Rock Section 17.
- Affidavit of Mark S. Pelizza, HRI Resources Inc., dated April 21, 2005 Pertaining to various aspect of Radiation and Radioactivity associated with the Crownpoint Uranium Project.

#### D. EXPERT OPINION

1. This Affidavit provides my opinion on a variety of radiological issues raised by the ENDAUM and SRIC briefs. My affidavit is structured as a series of questions and answers that I believe are relevant to the issue of potential radiological exposure.

##### **Are ambient radon levels in the Church rock area consistent with natural background?**

2. Ionizing radiation is ubiquitous. All of us are exposed to ionizing radiation all the time. The National Council on Radiation Protection and Measurement (NCRP) in Report No. 94 (1987) describes the exposure of people in the United States to natural background radiation. According to the NCRP, the annual average radiation dose to someone living in the United States is about 300 mrem per year [mrem/y] (at 149) [The millirems or mrems measure of radiation dose is in units of total effective dose equivalent or TEDE dose that is referred to by Franke and used by NRC in the Final FEIS (NUREG 1508)].

3. Natural background doses are highly variable. A 1994 NRC report (NUREG 1501) notes that the dose from cosmic radiation in Denver could be about a factor of two higher than the national average. Furthermore, the NRC report (NUREG 1501) states that a "range of 1 to 10 mSv (100 to 1000 mrem) – a span of a factor of ten – is typical of the variation in background doses for most United States citizens in a given year."

4. All soils and rocks release radon-222 to the atmosphere. The rate of release will vary with the radium-226 content of the soil or rock and other factors. Data reported by the NCRP (ibid. at 94) suggests that [average] soils release radium-226 at the rate of about 0.5 pCi [pico curies, a measure of the amount of radioactivity] per square meter per second. For example, an acre of soil containing radon at average levels [of about 1 pCi per gram of soil] would release radon to the air at a rate of about 2000 pCi per second.

5. In 1985, I investigated the natural background levels of radon-222 in the region of Grants, New Mexico. [“Exploratory Analysis of Radon Data from Ambrosia Lake, New Mexico” SENES Consultants, 1986]. Natural sources of radon in the Grants area, as in the Church Rock area, include local soils and outcroppings of naturally elevated mineralization including the Mancos shale, the Morrison formation and the Todelto formation. My analysis indicated that in the Grants area, natural outdoor ambient radon levels are likely to be in the range of 0.5 to 1.5 pCi/L, consistent with the levels measured at Springstead and the Church Rock site and in the expected range of natural variation.

6. Radon levels in the Church Rock area would be expected to be naturally elevated as a consequence of natural geologic formations which contain elevated levels of radioactivity. Likely sources of ambient radon in the Church Rock area are the geologic outcrops of the Morrison and Dakota formations. These formations contain much of the uranium mineralization in the San Juan Basin. (Indeed, Figure 3.8 of the FEIS (NUREG 1508) clearly refers to “Mancos Shale Valley” a clear demonstration of the presence and proximity of this kind of material which contains naturally elevated radioactivity of the same kinds as discussed by Franke). Mineralization occurs throughout the host formation typically with the highest-grade mineable ore found in the smallest areas with increasingly greater areas that contain progressively lower concentrations of uranium

7. Thus, in addition to normal soils which release radon, the widely spread mineralization will contribute regionally to an elevated ambient natural background concentration of radon-222. NCRP Report No 94 (at 95) provides data that indicates the ambient outdoor radon levels typically range from about 0.1 pCi/L to 0.5 pCi/L, with levels in Colorado Springs as high as 1.2 pCi/L.

8. A recent paper by Grasty and Lamarre ("The Annual Effective Dose from Natural Sources of Ionizing Radiation in Canada", Radiation Protection Dosimetry (2004) Vol. 108 No.3 pp. 215-226) reports average summer outdoor radon levels in 17 Canadian cities. The highest outdoor value reported by Grasty and Lamarre was (approximately) 1.5 pCi/L in Winnipeg, an area with no elevated or unusual levels of radioactivity in the soil.

9. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2000, United Nations, New York), which includes representatives from the United States, suggests that world-wide, a nominal outdoor radon level of about 0.27 pCi/L, with a wide range from approximately 0.03 pCi/L to more than 3 pCi/L.

10. Overall, given the extensive natural mineralization in the Church Rock area, it is not surprising that natural background radon levels in the area should be in the range of 1 to 2 pCi/L or greater, consistent with the levels measured by HRI.

**Are elevated gamma radiation levels expected in areas accessible to the public?**

11. Licensed production areas of Section 17 will be fenced, thus preventing unintentional access by members of the public.

12. Gamma radiation dose depends on a number of factors, specifically, the strength of the source, proximity to the source, and exposure duration. It is also important to understand that gamma dose rate is not affected by wind direction. In the present situation, areas along roadways with elevated gamma radiation levels are thought to be spillage from ore trucks during haulage to the mill [Pelizza paragraphs 72 and 83]. Such spillage would provide a "thin" layer of radioactive material which represents a weaker source of radioactivity than a "thicker" source. For example, for uranium-234, a member of the uranium decay chain, a 0.01 m thick source emits gamma radiation at a rate of about 47% of that of a 1 m thick source [Kamboj, De Le Poire

and Yu, 2002; at p. 8-36]. Similarly, Figure 6 of Kamboj, De Le Poire and Yu shows the relative gamma dose rates for 100 m<sup>2</sup> sources of different shapes. The gamma dose rate from a long narrow source of 50 m by 2 m is about 40% of the gamma dose rate from a rectangular source of 10 m by 10 m.

12. The US EPA acknowledges that gamma radiation decreases rapidly with distance from a planar source. In discussing radiation from uranium mill tailings piles (very much larger sources of radiation than an ISL facility) the EPA states that "The concentration of gamma radiation from the pile, however, decreases rapidly with distance; at more than a few tenths of a mile from most of the inactive tailings piles, it is undetectable above normal background." [Draft Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites (40 CFR 192) 1980.

13. It is likely that radioactive materials (i.e. uranium ore or dust) have fallen off trucks hauling mineral ore to the former United Nuclear mill located about 2 miles to the North during transport, especially in areas of sharp (i.e., close to right-angle) turns. My experience with similar situations elsewhere suggests that such spillage would be limited mostly to close proximity to haul roads. In my opinion, this observation is consistent with the data reported by Melinda Ronca-Battista in her affidavit, which indicates (relatively) elevated gamma radiation levels proximate to haulage roadways (e.g., adjacent to SH 556 route for haulage trucks).

14. Mr. Franke [at p.7 of his 1999 report] suggests that the gamma dose rate at the nearest residence may exceed NRC limits. However, Mr. Franke ignores data in his own report that contradicts his hypothesis. For example, Figure 6 of Mr. Franke's report shows a gamma survey map (as do later figures of Mr. Franke's 1999 report) which shows a measured gamma

exposure rate of 10  $\mu$ R/h at a location proximate to the King's residence, well within the range of natural background gamma radiation considered by HRI, NRC and Melinda Ronca-Battista.

**Is the TEDE in the FEIS properly calculated?**

15. In my opinion, the approach used by the NRC in the FEIS was appropriate for estimating the TEDE dose to members of the public. In brief, the NRC procedure involved:

- Estimating the maximum release of radioactivity from the ISL facilities.
- In particular, the approach used in the FEIS to assess radon source terms and the consequent effects of the radon release is consistent with the approach that I would use to assess potential radiological dose from radon. Moreover, I understand that the analysis of radon presented in the FEIS assumes "no-emission controls for radon" (FEIS p. 4-78). HRI's ion exchange columns (IX) will incorporate a pressurized downflow design which will reduce radon emissions by more than a factor of 100 (see Pelizza affidavit, paragraph 22). Thus, the analysis in the FEIS conservatively overestimates the radon release and the consequent doses from radon (and daughter).
- The locations of the possible receptors, especially the nearest resident are, in my opinion, reasonable.
- The MILDOS-AREA code is a well-established code of the U.S. NRC, widely used for this purpose, was then used to evaluate the potential radiation doses to the various receptors. My experience suggests that the use of the MILDOS code is unlikely to underestimate the TEDE dose.
- The predicted doses were compared to regulatory standards and found to represent at most a small percent of the regulatory limit of 100 mrem/y.

16. The FEIS, assuming no radon emission controls, predicted radon-222 levels at the nearest receptor to be (about) 1.5 percent of the NRC limit. In addition, the FEIS (at 4-79) notes that each of the radon daughters were "several orders of magnitude less than the allowable limits". This is an important observation since it is actually the radioactive decay products ("radon daughters") of radon that when inhaled into the lungs result in exposure of the lung (e.g.,

p. G45 of the NRC's Final Generic Impact Statement on Uranium Milling (GEIS, NUREG 0706, 1980). The GEIS also noted that predicted concentrations of airborne radionuclides at other nearby residences were similar to or lower than those at the nearest residence.

17. In his 1999 brief (at p. 17 of the report attached to his brief), Franke suggests that complete equilibrium of radon-222 with its daughters should have been considered in the NRC analysis. This is simply incorrect. The ingrowth of radon decay products is not instantaneous. It takes time for radon decay products to grow in. This is well known. For example, the EPA in their "Technical Support for Amending Standards for Management of Uranium by Product Materials, 40 CFR Part 192 – Subpart D – Background Information Document (EPA 402-R-93-085, 1993) indicates that at the point where radon-222 leaves the (uranium) tailings piles, radon daughters are at zero. The EPA also notes that while secular (i.e., complete) equilibrium is a theoretical upper limit, "in reality it is not achievable". It should also be noted that as the "plume" of radon moves downwind away from a source, which allows some time for ingrowth of radon decay products, the concentrations of radon in air will also continue to decrease.

18. It is also very important to understand that while outdoor radon contributes to levels of radon indoors, that it is universally understood that the predominant source of people's exposure to radon is from exposure to radon daughter levels inside the home primarily originating from the soils beneath the home. Indeed, exposure to radon daughters indoors accounts for about 50% of people exposure from natural sources of radon [e.g., UNSCEAR 200, p. 112, Table 31].

19. Mr. Franke also suggests that due to variability of radon over time, a significant contribution to annual exposure can occur over a short time (at p.10). I agree with the statement

by Mr. McKenny of the NRC (see McKenny's affidavit, p. 5 to 6 attached to the NRC staff brief of February 18, 1999) that "nearly every assumption in this derivation [i.e. Franke's definition] is worst case or nearly impossible, which has lead to an incredibly conservative estimation [by Franke] of impacts".

**How does the TEDE dose from the Church Rock site compare to natural background radiation?**

20. The FEIS report estimated doses [TEDE doses] for maximum releases and simultaneous operation of the Church Rock, Crownpoint and Unit I facilities [at 4-78]. The maximum dose estimated for the nearest resident, assumed to be adjacent to the Crownpoint plant site, less than 0.6 miles away, is reported as 0.76 mrem per year. This is less than 1% of the dose limit of 100 mrems per year. The maximum dose is an even smaller percent of natural background. If we assume a natural background of 200-300 mrem per year, a value which in my opinion is likely too low for the Church Rock area, especially considering the presence of local uranium mineralization, then the TEDE dose from the ISL operations is at most 0.25% of the TEDE dose from natural background, even without consideration of the controls on the radon emissions.

### **Overall Opinion**

For reasons given earlier in this Affidavit, the contribution, if any, to the TEDE doses estimated in the FEIS from regulated source material or byproduct material are inconsequential in comparison to the dose from natural background, and in fact are likely to be much smaller than reported in the FEIS when the greatly reduced radon emissions are taken into account. It is also my opinion that the gamma dose to nearby residents outside of licensed site 17 operation are

I declare on this 26<sup>th</sup> day of July, 2005, at Richmond Hill, Ontario, under penalty of perjury that the foregoing is true and correct.

Douglas B. Chambers

Douglas B. Chambers, Ph.D.  
Vice President,  
Director of Radioactivity and Risk Studies

### ACKNOWLEDGEMENT

SUBSCRIBED and SWORN TO before me, the undersigned authority, on 26<sup>th</sup> July 2005 by Donald M. Gorber.

[Seal]

Donald M. Gorber  
[Signature of Notary]

Donald M. Gorber  
Printed/typed name of Notary

Notary public for the Town of Richmond Hill in the Province of Ontario. My commission expires in December 2005.



Donald Myron Gorber, Notary Public, Regional Municipality of York  
limited to the attestation of instruments and the taking of affidavits  
for SENES Consultants Limited and its subsidiary companies.  
Expires December 8, 2005

# **DOUGLAS B. CHAMBERS, Ph.D.**

## ***Vice-President, Director of Radioactivity and Risk Studies***

### **EDUCATION**

B.Sc. (Honours), Physics, 1968, University of Waterloo  
(University of Waterloo Tuition Scholarship)  
Ph.D., Physics, 1973, McMaster University (National  
Research Council Science Scholarship)  
Two Sessions at the Advanced School for Statistical  
Mechanics and Thermodynamics, University of  
Texas, Austin, 1970 and 1971  
Air Pollution Diffusion, U.S. EPA, Research Triangle  
Park, 1974  
Annual Health Physics Course, Chalk River Nuclear  
Laboratories, 1974  
Observations on Human Populations, School of  
Hygiene, University of Toronto, 1979

### **PROFESSIONAL AFFILIATIONS**

Advisory Committee on Radiation Protection (1993 to  
2002 - committee advised the Canadian Nuclear  
Safety Commission on matters concerning  
radiation protection)  
American Nuclear Society  
Canadian Standards Association, Member of Technical  
Committee on Environmental Radiation Protection  
(1978 to 1994, Chairman 1987 to 1994)  
Canadian Standards Association, Member of Technical  
Committee on Risk Analysis (1989 to present)  
Canadian Radiation Protection Association  
Health Physics Society (U.S.)  
Society for Risk Analysis (U.S.)  
U.S. National Council on Radiation Protection and  
Measurements, Scientific Committee 85 on Risk of  
Lung Cancer from Radon (1991 to date)  
United Nations Scientific Committee on the Effects of  
Atomic Radiation (UNSCEAR), Member 1998 to  
date, Canadian delegation  
Consultant to UNSCEAR for preparation of  
"Sources-to-Effect Assessment of Radon in Homes  
and Workplaces".

### **AWARDS**

1997 W.B. Lewis Award (Canadian Nuclear  
Association) for achievements in environmental  
radioactivity.

2002 Health Physics Society - Morgan Lecturer  
"Perspectives on Radioactive Waste Management in  
Canada. Joint Midyear Meeting. Orlando, February  
2002.

### **EXPERIENCE**

1980 to date - **SENES Consultants Limited**  
Vice-President and Director of Risk and Radioactivity  
Studies. Technical responsibilities include management  
and technical direction of multi-disciplinary studies

including: human health risk assessments; radioactivity  
exposure evaluations; environment impact assessments;  
uncertainty analysis; dose reconstruction and  
epidemiological investigations; environmental  
pathways and dose assessments; air dispersion  
modelling studies of dense/reactive gases; ecological  
risk assessments; mine waste management;  
geochemical modelling assessments; low-level  
radioactive waste management; and risk (cost) - benefit  
analyses. Many of Dr. Chambers' projects involve  
working with the public to design studies and in  
communicating risks to the public at large.

**Radioactivity** - Director or senior health physics  
advisor for numerous studies pertaining to radiation  
protection including: dose reconstruction and  
epidemiologic analyses of both miners and people at  
home exposed to elevated radon concentrations. He has  
evaluated environmental exposures and doses from  
radioactive contaminated sites, decommissioning of  
uranium and thorium facilities; review of thorium  
metabolism data; and uranium biokinetic models;  
development of decommissioning criteria and  
guidelines; assessment of the potential risks from  
naturally occurring radioactivity (NORM); dose  
assessment and the development of health and safety  
practices for uranium mine workers; and the application  
of the ALARA optimization principal.

**Human Health Risk Assessment** - Numerous risk  
assessments including: uranium mining and production  
facilities, radioactive and industrial contaminated sites;  
incineration; municipal wastes and accidental release of  
chlorine from waste water treatment facilities.  
Evaluation of risks from naturally occurring  
radioactivity in phosphogypsum arising from use in  
agriculture and road construction; risks from exposure  
to radon; investigations into harmonization of cancer  
and non-cancer risk; integrating quality of life issues in  
cost-benefit analyses; studies of the effect of  
uncertainty in exposure (dose) on the feasibility of  
epidemiological investigations, pharmacokinetic  
modelling and toxicological assessments of uranium,  
arsenic and other toxins.

**Ecological Risk Assessment** - Dr. Chambers has  
played a key role in the development of ecological risk  
assessment methodologies for mining regions in  
northern Saskatchewan and northern Ontario, and in  
support of decontamination planning for contaminated  
industrial sites. Dr. Chambers recently completed a  
comprehensive ecological risk assessment for marine  
discharge from the La Hague fuel processing facility.  
Dr. Chambers also completed an ecological risk  
assessment for the use of slag from refining operations  
as construction fill. He has directed numerous risk  
assessments for industrial contaminated sites.

**Remedial Actions and Decommissioning** - Directed and participated in numerous decommissioning and remedial action programs for NORM (naturally occurring radioactive material) wastes and low-level radioactive waste (LLRW) management sites, uranium mining facilities in Canada, United States and overseas. Amongst other studies, Dr. Chambers directed conceptual design studies for disposal of LLRW in near-surface facilities and engineered underground caverns. He also directed a regulatory risk assessment of deep geological repository of low and intermediate level waste at the Western Waste Management Facility.

**Facility Risk Assessment** - Dr. Chambers has been involved in numerous facility risk assessments involving petrochemicals, ammonia, uranium hexafluoride, and chlorine amongst others. He has supervised a number of transportation risk studies involving petrochemicals, acids, radioactive waste, sludge and ore slurry. He has also been involved in a health and safety risk analysis for oxygen and nitrogen pipelines. These projects have been conducted across Canada, in the U.S. and internationally.

**Environmental Assessment** - Numerous, assessments including: the preparation of several environmental impact statements for the decommissioning of uranium tailings facilities in Ontario and northern Saskatchewan, the United States and elsewhere; and for siting of new nuclear facilities in Canada and the United States. Dr. Chambers has also contributed to environmental assessments of nuclear power plants, thermal power plants and other industrial and mining facilities both in Canada and internationally.

**Geochemical Modelling and Assessment** - Dr. Chambers has been active in the development and application of geochemical models for evaluation of management options for mine waste rock and tailings. He was a senior scientist in a multi-disciplinary study team assisting the Federal German Environment Ministry with the decommissioning of uranium mining and processing sites in Saxonia and Thüringia. Other assessments include evaluation of alternatives for reducing acid generation of mine waste heaps in South Africa and characterization of releases from uranium mining facilities.

**Northern Experience** - Dr. Chambers has directed or participated in several studies in the north. For example, as part of an evaluation of epidemiology of miners exposed to radon, Dr. Chambers visited two iron ore mines north of the arctic circle in Sweden to evaluate past exposures of miners. Dr. Chambers provided an internal review function for the team of scientists who carried out surveys in the NWT to find pieces of the Cosmos 954 satellite that came down in the NWT. Recently, Dr. Chambers directed a screening level risk assessment for former asbestos mine (Clinton Creek) in the Yukon. Dr. Chambers directed a dose-reconstruction for Deline who worked as ore carriers in support of the Port Radium mine, and directed an

epidemiological feasibility study of the same ore carriers. He is also currently involved in a study of dust emissions and dispersion at a large base metal mine in northern Alaska.

**Air Quality Assessment** - Provided technical direction to atmospheric dispersion studies involving dense/reactive gases such as ammonia, chlorine, anhydrous hydrogen fluoride and  $N_2/O_2$  and uranium hexafluoride releases. Dr. Chambers developed a detailed physical/chemical model for the release, atmospheric transport and deposition of uranium hexafluoride for an accident at a uranium hexafluoride facility in Gore Oklahoma. He has carried out numerous site-specific modelling studies of thermal power stations, numerical air quality modelling for complex terrain, calibration/verification studies, and development of long-range transport models.

#### **1973-1980 - James F. MacLaren Limited**

General Manager, Nuclear Projects Division from 1977 to 1980. Responsible for the development of the firm's capabilities in environmental radioactivity and radiation protection. Project Manager for the Air Environment Division from 1973 to 1977.

Environmental specialist on matters pertaining to the air environment and/or radioactivity for numerous facilities and several environmental impact assessments across Canada and internationally.

Specialist input to the development, implementation and interpretation of results from air quality and meteorological surveys, air dispersion analyses and noise assessments at several types of industrial projects at locations across Canada. Developed a meteorological control system for large oil fired power plant in New Brunswick.

#### **TECHNICAL PAPERS AND PRESENTATIONS**

More than 100 technical papers, reports publications and presentations (list available upon request). He has also presented seminars and workshops on a variety of topics, in Canada, the United States, Europe, South America and Africa.

## List of Annexes

- Annex A Excerpts from *Final Environmental Impact Statement to Construct and Operate the Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico*, United States Nuclear Regulatory Commission (NRC), 1997. (NUREG-1508).
- Annex B Excerpts from *Exposure of the Population in the United States and Canada from Natural Background Radiation*, National Council on Radiation Protection and Measurements (NCRP), 1987. (NCRP Report No. 94).
- Annex C Excerpts from *Background as a Residual Radioactivity Criterion for Decommissioning, Appendix A to the Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for Decommissioning of NRC-Licensed Nuclear Facilities*, United States Nuclear Regulatory Commission (NRC), 1994. (Draft Report, NUREG-1501).
- Annex D *The Annual Effective Dose from Natural Sources of Ionising Radiation in Canada*, R.L. Grasty and J.R. LaMarre, 2004. (Radiation Protection Dosimetry, Vol. 108, No. 3, pages 215-226).
- Annex E Excerpts from *Sources and Effects of Ionizing Radiation*, United Nations Scientific Committee on the Effects of Atomic Radiation, 2000. (UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, Vol. 1: Sources).
- Annex F Excerpts from *Exploratory Analysis of Radon Data from Ambrosia Lake, New Mexico*, SENES Consultants Limited, 1986. (Prepared for the American Mining Congress).
- Annex G Excerpts from *Draft Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites*, United States Environmental Protection Agency (EPA), 1980. (40 CFR 192, EPA 520/4-80-011).
- Annex H Excerpts from *Technical Support for Amending Standards for Management of Uranium Byproduct Materials*, United States Environmental Protection Agency (EPA), 1993. (40 CFR Part 192 – Subpart D, Background Information Document, EPA 402-R-93-085).
- Annex I *External Exposure Model in the Resrad Computer Code*, S. Kamboj, D. LePoire and C. Yu, 2002. (Health Physics, Vol. 82, No. 6, pages 831-839).
- Annex J Excerpts from *Final Generic Environmental Impact Statement on Uranium Milling*, United States Nuclear Regulatory Commission (NRC), 1980 (NUREG-0706, Vol. III, Appendices G-V).

## Annex A

**Excerpts from Final Environmental Impact Statement to Construct and Operate the  
Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico, United  
States Nuclear Regulatory Commission (NRC), 1997 (NUREG-1508)**

NUREG-1508  
BLM-NM-010-95-02  
BLA-TIS-92-001

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# Final Environmental Impact Statement

to Construct and Operate the  
Crowpoint Uranium Solution Mining Project  
Crowpoint, New Mexico

Docket No. 40-3968  
Hydro Resources, Inc.

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U.S. Nuclear Regulatory Commission  
Office of Nuclear Material Safety and Safeguards

In Cooperation With  
U.S. Bureau of Land Management  
Albuquerque District  
U.S. Bureau of Indian Affairs  
Navajo Area Office



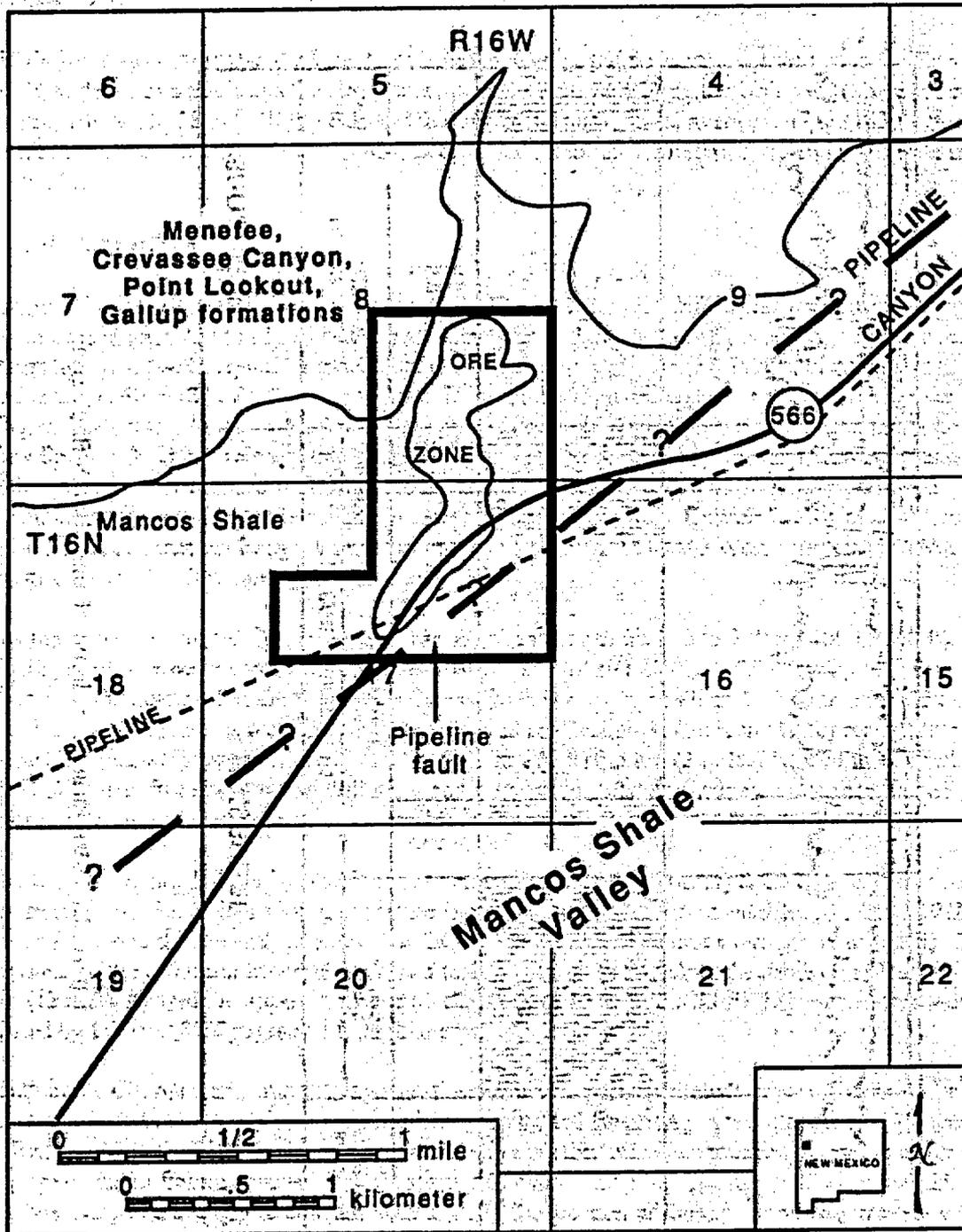


Figure 3.8. Generalized geologic map of the Church Rock site area and the hypothetical Pipeline fault. Sources: Kirk and Zech 1987; Chapman, Wood, and Griswold 1974.

- Yellowcake and 11e(2) by-product waste material, other than samples for research, shall not be transferred from the site without specific prior approval of the NRC in the form of a license amendment. HRI shall maintain permanent record of all transfers made under the provisions of this condition. Transfers of samples for research shall comply with provisions of 10 CFR § 40.22.

In addition to this license condition, NRC staff recommends the following measures to help minimize transportation risk:

- all delivery trucks used to transport project materials (uranium slurry, yellowcake, and process chemicals) should carry the appropriate certifications of safety inspections; and
- all delivery truck drivers should hold appropriate licenses.

#### 4.5.4 Alternative 4 (No Action)

There would be no transportation risk associated with the no-action alternative.

### 4.6 HEALTH PHYSICS AND RADIOLOGICAL IMPACTS

This section describes an analysis of estimated incremental radiological impacts to the environment and the population that would be contributed from the proposed project. The primary radiological impact to the environment in the vicinity of the project results from naturally occurring cosmic and terrestrial radiation and naturally occurring radon-222 and its daughters. The average whole-body dose rate to the population in this part of New Mexico includes a dose of 1.5 mSv/year (150 mrem/year) from cosmic and terrestrial natural background radiation and 0.75 mSv/year (75 mrem/year) from medical procedures, based on national average. Therefore, total background is estimated to be about 2.25 mSv/year (225 mrem/year). Dose estimates and airborne concentrations of radionuclides from the proposed project do not include natural background and are incremental values.

This analysis examines three types of potential exposures to members of the public. During project operations, releases could occur in the form of air releases of particulate and gases. Additionally, HRI would have to dispose of waste materials from the ISL process. After operations, HRI would have to reclaim well fields and facility grounds to allow unrestricted release in the future.

#### 4.6.1 Alternative 1 (The Proposed Action)

Analysis of potential air releases is primarily based on estimated releases of radioactive materials, determined by HRI, using an NRC radiological dose assessment code known as MILDOS-AREA (ANL 1989). HRI ran separate MILDOS-AREA simulations for operations in the Crownpoint and Church Rock areas. The Crownpoint area includes operations at both Unit 1 and Crownpoint facilities. The operations at each of the facilities are similar except that final drying and packaging of natural uranium would take place only at the Crownpoint facility. Detailed analyses of the estimated

radiological impacts of the proposed operations to nearby individuals and the entire population within 80 km (50 miles) of each facility have been performed.

With HRI's proposed action, there would be no radioactive waste material released into surface waters. Although some contaminated water leaked from retention ponds could affect the groundwater system, no significant contribution to dose by water pathways is anticipated. As a control, HRI would perform environmental monitoring to provide early detection of any seepage from retention ponds that might occur and to take appropriate mitigating measures. Solid and sludge waste material would be sent to a licensed disposal site for burial. Wastewater would be disposed of primarily in evaporation ponds after the volume had been reduced by either reverse osmosis or brine concentration. During restoration, land application might be used, due to the much higher volume of wastewater created.

Radiological effects during project construction would include natural background plus remnant radiation stemming from previous mining and milling activities near the Church Rock site. As each well in the mine units is drilled through the Westwater Canyon sandstone, drill cuttings containing uranium ore would be entrained into the drilling mud. The relative volume of uranium in the drilling mud would be minute, and there would be no significant radiological impact to the area. Ore cuttings would be entrained in the wet drilling mud, and would be contained in the mud pits. HRI would allow the pits to dry for a time, and then backfill them with clean soil when the drilling site is reclaimed. In addition, HRI would be required to verify that well fields have been properly reclaimed and meet appropriate requirements before releasing the well field back to unrestricted use.

4.6.1.1 Crownpoint and Unit 1

Air Releases

Source Term. Operations in the immediate vicinity of the town of Crownpoint would occur at both the Crownpoint and Unit 1 sites, each of which would be brought into production on different schedules. Table 4.17 shows the planned schedule of operations at the two facilities. Analysis of radiological effluents was done for the fourth time step, in which the operations are at a maximum at both sites.

Table 4.17. Crownpoint and Unit 1 timeline

Year	Actions
1998-1999	Unit 1—Production flow only Crownpoint—Drying only
2000-2001	Unit 1—Production flow and limited restoration Crownpoint—Production flow only
2002-2014	Full production flow and restoration flow
2015-2018	Restoration flow only

Environmental Consequences, Monitoring, and Mitigation

HRI has determined that the project would have controlled releases from three areas (source terms) within each operation. The source terms are: (1) the resin transfer/process circuit, (2) the process circuit pressure vents, and (3) land application releases. Typical ISL uranium mines have additional source terms, but HRI has proposed various modifications to its operations to remove radon source term locations. Engineering modifications were made to the production and restoration bleed stream to eliminate radon dispersion into the environment from wastewater. In both situations, process bleed and restoration stream waters would be circulated through vented tanks. The off-gas would be captured, compressed, and injected into the lixiviant injection system for reintroduction into the ore zone. The off-gas from the bleed streams would largely consist of carbon dioxide, but would also contain virtually all radon gas dissolved in the lixiviant when it is pumped to the surface.

The release from the resin transfer/process circuit assumes that each ion exchange column would contain 1.323 m<sup>3</sup> (3500 gal) of process water and would be vented three times a day. This value is conservative because each column would actually contain a large volume of resin, and less water. It is further assumed that the water contains a dissolved radon concentration of 4.9 MBq/m<sup>3</sup> (133,000 pCi/L) with a very conservative 100 percent radon evolution rate. This results in a calculated radon release of 68 GBq (1.83 Ci) per year.

The process circuit pressure vents situated on trunk lines would discharge for 2 s every 5 min. With a carrying capacity of 0.25 m<sup>3</sup>/s (4000 gpm) for each trunk line and 20 total vents, the radon released by this system would be approximately 110 GBq/year (2.96 Ci/year). This value is conservative because it assumes that all trunk lines are functioning continuously at the maximum proposed flow rate.

Restoration water would not be open to venting until it arrives at the land application area in Section 12. The source term for modeling was based on equal volumes of water from each of the facilities being disposed of at the land application area. All of the releases are assumed to happen in the center of Section 12. Based on a dissolved radon concentration of 4.9 MBq/m<sup>3</sup> (133,000 pCi/L) and a flow rate of 0.019 m<sup>3</sup>/s (300 gpm), the source term from each facility would be 2.9 TBq (79.35 Ci), or a total of 5.8 TBq (159 Ci), per year. It assumes 100 percent evolution of radon-222 and a high flow rate for restoration water.

Traditionally, open hearth dryers at uranium recovery facilities are a primary source of airborne particulates. The vacuum dryer proposed by HRI is a state-of-the-art, zero-release unit that would result in very minimal particulate emissions from the drying and packaging areas. The proposed drying system would have no vent stack. Additionally, because the ISL production circuit is a wet process, no routine radiological particulate emissions source terms are predicted from other portions of the process circuit. The vacuum dryer is more fully described in Section 2.1.2.1. HRI performed a separate MILDOS-Area calculation of emissions from the drying and packaging areas (HRI 1994). The modeled source term for the dryer at the main process facility was based on data gathered for U-238 at an ISL facility using a similar vacuum dryer in Texas. Using an assumption that the measured value of the lixiviant ratio between Ra-226 and U-238 was constant, the source terms resulted in the following values: U-238, 9.0 kBq/yr (0.243 μCi/yr); Th-230, Ra-226, Pb-210, each 58 Bq/yr (1.56 nCi/yr).

**Population Distribution.** Population census data for 1980, updated to 1990 by projections and field verified, were used in the MILDOS-Area program. Population data for input into the program were determined for persons living within 5 km and 80 km (3 and 50 mi) of the Crownpoint site. HRI determined that approximately 3,600 persons live within 5 km of the Crownpoint process building, and that 76,000 persons live within the 80 km radius. Residences found within lease areas, the nearest residence downwind, and total populations were used in each modeling run to determine compliance with regulatory dose restrictions.

**Meteorological Parameters.** Weather data used in the MILDOS-Area simulations were obtained from U.S. Department of Commerce records maintained for Gallup, New Mexico. Gallup is located about 16 km (10 mi) southwest of the Church Rock site, and 56 km (35 mi) from Crownpoint. Gallup is the nearest active weather station maintaining the complete weather information necessary to run the MILDOS program. More information on meteorology can be found in Section 3.1.1.

**Individual Receptor Locations.** HRI modeled 38 separate receptors for the Crownpoint operational area. The Crownpoint receptors are actual residences or multi-use locations (e.g., churches) near the main processing facility or in the Unit 1 lease area (Figure 4.3). These receptors include nearest residences, nearest downwind residences, population concentrations, and hypothetical facility and well field boundary receptors. HRI would be required to implement a comprehensive environmental monitoring program to determine the annual doses to individuals in unrestricted areas.

**Exposure Pathways.** Potential environmental exposure pathways by which persons could be exposed to radioactive air effluents are presented schematically in Figure 4.4. Estimated dose commitments to humans are based on the proposed facility design and actual characteristics of the site environment. NRC's analysis considers both radioactive particulates and gaseous releases to the atmosphere.

Environmental exposure pathways of concern for airborne effluents from the project include inhaling radioactive materials in the air, particularly radon and its daughters. To a much lesser degree, external exposure would occur from radioactive materials in the air or deposited on ground surfaces, and possibly ingesting contaminated food products (vegetables, milk, and meat) raised locally.

**Regulatory Limits on Exposure for Individuals.** Permissible dosage limits found in 10 CFR Part 20 for individual members of the public are 1 mSv (100 mrem) total effective dose equivalent (TEDE), and 0.02 mSv/hr (2 mrem/hr) from any external sources. Compliance with the annual dose limit to the public (10 CFR § 20.1301) can be shown by calculating the dose to the individual at greatest risk (nearest residence) or compliance with annual concentration levels (10 CFR Part 20, Appendix B) at the site boundary. Two EPA standards apply to this operation. EPA's established average annual dose limits, found in 40 CFR Part 190, *Environmental Radiation Protection Standards for Nuclear Power Operations*, are 0.25 mSv (25 mrem) whole body, 0.75 mSv (75 mrem) to the thyroid, and 0.25 mSv (25 mrem) to any other organ for a member of the public. The other EPA standard, found in (currently suspended) 40 CFR Part 61, Subpart I, *National Emissions Standard for Hazardous Air Pollutants*, is a 0.1 mSv (10 mrem) TEDE limit. The EPA standards exclude radon and its daughters.

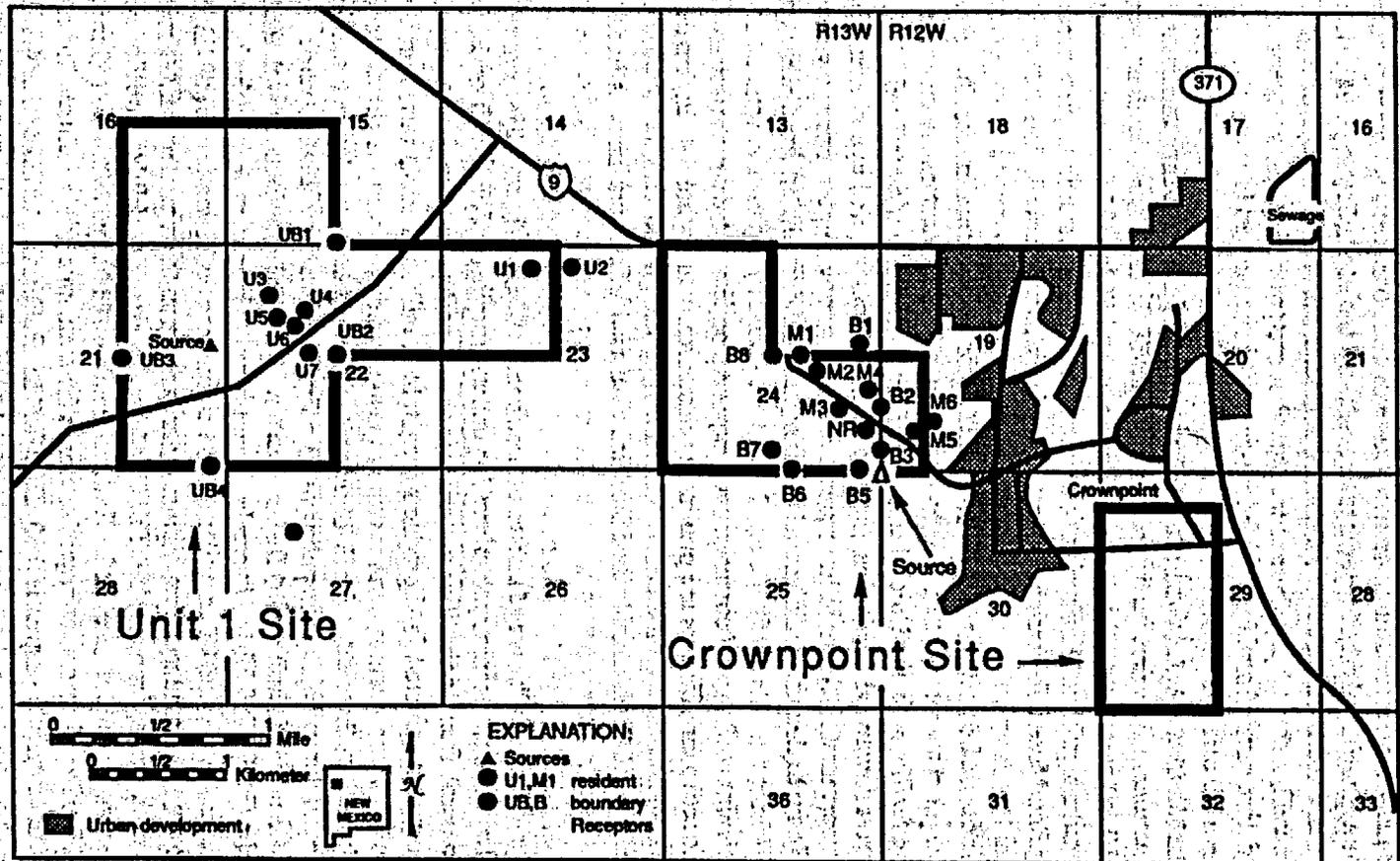


Figure 4.3. Residences and boundary receptors in the Crownpoint and Unit 1 areas.

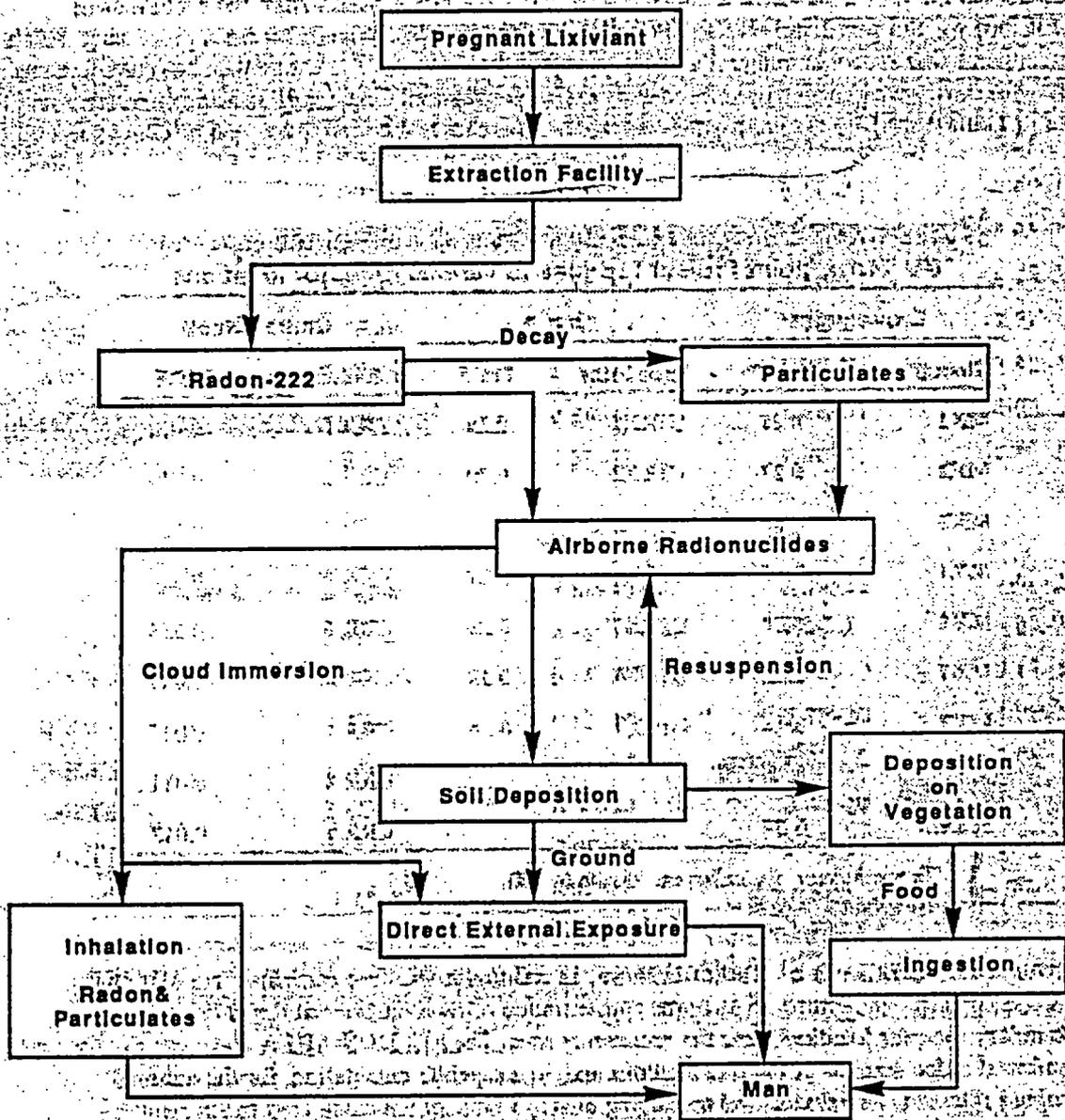


Figure 4.4. Potential exposure pathways for radon-222 and its daughters, escaping the uranium recovery process and wastewater treatment facilities.

*Environmental Consequences, Monitoring, and Mitigation*

**Estimated Doses at Modeled Receptors.** The dose assessment presented here considers doses to infants, which are slightly more sensitive than other age categories. All modeled total annual dose commitments predicted at nearest residences are below the TEDE limits found in NRC regulations. Releases from the Unit 1 site consist only of radon and, thus, are excluded from the evaluation of 40 CFR Part 61, Subpart I and 40 CFR Part 190. Particulate releases from the main processing facility at Crownpoint would be minimal and well below the EPA standards. The estimated dose commitments during periods of simultaneous operations at both Crownpoint and Unit 1 with maximum releases are shown in Table 4.18. (The dose estimates include dose commitment due to radon and its daughters.)

**Table 4.18. Estimated TEDE doses from air effluent releases from the Crownpoint Project facilities to various receptor locations**

Crownpoint		Unit 1		Church Rock	
Receptor	TEDE*	Receptor	TEDE	Receptor	TEDE
MX1	0.21	UIRX1	0.29	CRR 1	0.017
MX2	0.27	UIRX2	0.29	CRR 2	0.019
MX3	0.35	UIRX3	0.27	CRR 3	0.024
MX4	0.46	UIRX4	0.27	CRR 4	0.025
MX5	0.28	UIRX5	0.28	CRR 5	0.055
MX6	0.23	UIRX6	0.28	CRR 6	0.033
MX7	0.14	UIRX7	0.26	CRR 7	0.017
UNK	0.76			CRR 8	0.011
School	0.07			CRR 9	0.012

\*In mrem/year; for mSv/year, divide by 100.

Nearest residence

**Airborne Concentrations of Radionuclides.** In addition to the dose estimates, the MILDOS-AREA code presents the estimated airborne concentration of radionuclides at the various residential and boundary receptor locations near the processing sites. The MILDOS-AREA code was run for both the combined radon sources at the two facilities and, in a separate calculation, for the minimal particulates released from drying and packaging areas. A table of the calculated radon-related concentrations, for the same receptor locations as shown in Table 4.18, is shown in Table 4.19 for Crownpoint and Unit 1.

At Crownpoint, the nearest residence is found adjacent to the plant site, less than 1 km (0.6 mile) away. Projected concentrations of airborne radionuclides there were modeled assuming no emission controls for radon. The resulting values are small percentages of the allowable effluent limits for unrestricted

Table 4.19. Airborne concentrations of radon and daughters at selected receptor locations near the Crownpoint and Unit 1 facilities

Location	Rn-222 (WL) <sup>a</sup>	Pb-210 <sup>b</sup>	Bi-210 <sup>b</sup>	Po-210 <sup>b</sup>
<b>Crownpoint</b>				
MX1	1.55E-05	2.3E-18	5.4E-21	3.4E-25
MX2	1.55E-05	2.3E-18	5.5E-21	3.6E-25
MX3	1.55E-05	2.3E-18	6.1E-21	4.4E-25
MX4	1.5E-05	2.2E-18	6.0E-21	4.4E-25
MX5	1.3E-05	2.1E-18	5.9E-21	4.6E-25
MX6	1.2E-05	2.0E-18	5.7E-21	4.5E-25
MX7	9.8E-06	1.7E-18	4.8E-21	3.8E-25
NR	1.6E-05	2.3E-18	6.4E-21	4.9E-25
School	5.8E-06	1.5E-18	4.9E-21	4.7E-25
<b>Unit 1</b>				
UIRX1	2.5E-05	3.8E-15	8.0E-21	4.6E-25
UIRX2	2.4E-05	3.5E-18	7.0E-21	3.9E-25
UIRX3	2.3E-05	6.6E-18	2.3E-20	2.1E-24
UIRX4	2.3E-05	6.6E-18	2.2E-20	2.0E-24
UIRX5 <sup>c</sup>	2.3E-05	6.6E-18	2.2E-20	2.0E-24
UIRX6	2.4E-05	6.5E-18	2.2E-20	2.0E-24
UIRX7	2.4E-05	6.8E-18	2.3E-20	2.1E-24
Limits <sup>d</sup>	1.1E-3	4E-12	2E-10	7E-12

<sup>a</sup>Units of working levels, which accounts for levels of short half-lived daughter products.

<sup>b</sup>Units of  $\mu\text{Ci/mL}$ ; for  $\text{pCi/m}^3$ , multiply by  $10^{12}$ ; for  $\text{Bq/m}^3$ , multiply by  $3.7 \times 10^{10}$ .

<sup>c</sup>Nearest residence downwind, assuming Gallup wind rose.

<sup>d</sup>Concentration limits in 10 CFR Part 20, Appendix B. Continuous exposure to concentrations at the limit will result in approximately 0.5 mSv (50 mrem) per year.

areas (Table 4.19, receptor NR). Predicted radon-222 values are 1.5 percent of the maximum limit. Each radon daughter modeled was several orders of magnitude less than the allowable limits. For other nearby residences, the projected concentrations of airborne radionuclides were similar to or lower than those at the nearest residence, and therefore, well below the maximum allowable concentrations for unrestricted areas.

0.1 pCi/L  $\left(\frac{1}{100}\right)$   
 $\times 10^{-3} \text{ WL} \times 4.79$

Environmental Consequences, Monitoring, and Mitigation

**Evaluation of Radiological Impacts on the Public.** Calculated annual individual dose commitments are only small fractions of the NRC limits for radiation exposure in unrestricted areas, as specified in 10 CFR Part 20, *Standards for Protection Against Radiation*. Calculated dose commitments to actual receptor locations are also well below limits specified in EPA's standards (40 CFR Part 190 and 40 CFR Part 61, Subpart I). Verification that these regulatory criteria are not exceeded would be provided by the required environmental monitoring program.

**Liquid Waste Disposal**

HRI has proposed two possible ultimate waste disposal techniques for wastewater remaining after volume reduction has been completed: evaporation ponds and land application. The use of evaporation ponds would result in minimal off-site releases under normal operations because of the proposed pressurized system's removing the radon from the circuit and future decontamination and disposal of the pond residues in licensed waste disposal facilities. Land application could result in exposures to individuals, not only during operations but also in the far future, long after operations have ceased. HRI did not submit a detailed plan for land application and would need to submit a detailed license amendment in the future to use land application for wastewater. This evaluation is based on the assumptions and information presented by HRI in its general concepts on using land application. An environmental assessment of the license amendment for land application would be completed as part of the licensing process.

The land application option would only be used for mine wastewater resulting from restoration activities at each of the facilities. Each facility would have a separate irrigation plot of 21 ha (52 acres) on Section 12. Air releases of radon during irrigation were analyzed using MILDOS-AREA with the source term as described above. The potential impacts to a future resident of Section 12 for ground contamination are assessed using the RESRAD code (ANL 1995), which was developed by the U.S. Department of Energy to calculate the risks from residual amounts of radioactivity in the environment.

The treated wastewater would have average constituent values of 37 Bq/m<sup>3</sup> (1 pCi/L) and 1 mg/L for radium and uranium, respectively. HRI estimates that restoration would take 4 pore volumes. Based on this volume flow and the individual irrigation plot area of 21 ha (52 acres), the estimated maximum radionuclide concentrations are shown in Table 4.20. Since the expected accumulation would be sensitive to the amount of water needed for restoration, if the number of pore volumes needed increased, radionuclide concentrations (and calculated doses) would increase similarly, unless HRI used larger irrigation plots to counter the increased volume of water. HRI has additional acreage available in Sections 12 and 17 for irrigation area.

**Table 4.20. Estimated accumulation in land application soils**

Parameter	Unit 1	Crownpoint	Church Rock
Ra-226 (pCi/g)	0.068	0.081	0.061
Uranium (ppm)	16.7	20.0	15.2

## Annex B

Excerpts from Exposure of the Population in the United States and Canada from Natural Background Radiation, National Council on Radiation Protection and Measurements (NCRP), 1987. (NCRP Report No. 94)

NCRP

1987

NCRP REPORT NO. 94

1987

# Exposure of the Population in the United States and Canada from Natural Background Radiation

NCRP

*National Council on Radiation Protection and Measurements*

cross-comparison of these data, it has been conventional to assume that an overall 50 percent equilibrium exists. The equilibrium factor,  $F$ , can be used to calculate an Effective Equilibrium Concentration (EEC) which is the concentration of radon in equilibrium with its decay products that would have the same potential alpha energy emission as the existing concentration mixture. The EEC, in turn, can be converted to WL by dividing by 100.

Such conversions are satisfactory for radiation protection. For the purposes of scientific study, it is better to measure the relevant factors for the existing conditions but this is seldom possible. In this report, EEC and  $F$  are used infrequently but equilibrium factors of  $F = 0.7$  and  $F = 0.4$  are adopted for outdoor and indoor air when necessary.

Another characteristic of the decay products that is of dosimetric significance is the unattached fraction of the products. At any time, some small percentage of the  $^{218}\text{Po}$  and an even smaller percentage of the  $^{214}\text{Pb}$  are not attached to aerosol particles. These unattached products deposit more completely on bronchial surfaces when inhaled, thus enhancing the dose (NCRP, 1984b). The fraction varies with many factors but tends to remain below 10 percent, expressed in terms of the radon concentration. In this report values of eight percent and seven percent are adopted for unattached  $^{218}\text{Po}$  in outdoor and indoor air, respectively.

#### 6.4.2 Outdoor Air

Outdoor radon concentrations depend on the amount of radon exhaled by soil and by the atmospheric factors controlling its upward dispersion. With a half-life of 3.8 days, radon can be transported horizontally over great distances by the wind but vertical movement by diffusion and turbulence tend to dilute the effect of distant sources at the surface.

The exhalation rates from soil have been estimated by Wilkening *et al.* (1975) as  $1.5 \mu\text{Bq}/\text{cm}^2 \cdot \text{s}$  ( $42 \text{ aCi}/\text{cm}^2 \cdot \text{s}$ ) and Birot (1971) as  $1.8 \mu\text{Bq}/\text{cm}^2 \cdot \text{s}$  ( $50 \text{ aCi}/\text{cm}^2 \cdot \text{s}$ ). Using the latter value, Harley (1975) estimated the global radon release to be about 100 EBq/y (2.5 to 3 GCi/y). This value was compared with other sources of radon in NCRP Report No. 78 (NCRP, 1984b). The global release would lead to an atmospheric inventory of about 1.5 EBq (40 MCi). This would give a mean surface radon concentration of the order of  $4 \text{ Bq}/\text{m}^3$  (100 pCi/ $\text{m}^3$ ) in the northern hemisphere, with higher values of perhaps  $8 \text{ Bq}/\text{m}^3$  (200 pCi/ $\text{m}^3$ ) over the continents. Measured values with their geometric standard deviations (GSD) are tabulated in Table 6.1.

TABLE 6.1—Direct measurements of radon-222 in outdoor air.

Location	Number of sites	Radon (Bq/m <sup>3</sup> ) <sup>a</sup>			Reference
		Mean	Median	GSD	
CO, Colorado Springs	5	44			Doyle <i>et al.</i> (1984)
ME, Central	67		17	2.4	Prichard <i>et al.</i> (1983)
NJ, Chester	1 (9-y mean)	8			Fisenne (1987)
NM		9			Wilkening (1959)
NY/NJ	6		7	1.5	George and Breslin (1980)
NY		5			Glauberger and Breslin (1957)
NY		4			Fisenne and Harley (1974)
New York City	1 (4-y mean)	4			Fisenne (1987)
NY	City suburbs	6			George (1975)
		8			
OH, Cincinnati		18			Shlaien (1963)
PA, Pittsburgh	30		11	1.8	Cohen <i>et al.</i> (1984)
SC, Charleston	9	15			Doyle <i>et al.</i> (1984)
TX, Houston	81		8	2.6	Prichard <i>et al.</i> (1983)

<sup>a</sup> 1 Bq = 27 pCi.

The variability with time is best shown by the data of Fisenne (1987) who reported nine years of continuous hourly measurements at Chester, NJ along with four years of data for New York City. An earlier report (Fisenne and Keller, 1985) describes the system used. The diurnal and seasonal variations are shown in Figure 6.1. The hourly data are distributed log-normally for the continuous measurements at this single site and the same is true for a series of measurements at different sites in a single city or general area. Different seasonal patterns are possible, for example a coastal site with strong on-shore winds would show low oceanic concentrations while off-shore winds would show higher continental concentrations (Lockhart, 1962).

There is general agreement that the meteorological factor having the greatest influence on outdoor radon concentrations is atmospheric stability. The diurnal variations reported indicate an early morning peak and a sharp drop in the afternoon. These correlate well with inversion conditions, where the still air at night allows the radon to build up and the turbulence, when the inversion disappears, allows the radon to disperse upward.

### 6.4.3 Indoor Air

There is a large number of limited surveys of indoor radon or decay products in the United States but, as indicated previously, there has

calculations are necessarily incomplete, as measurements of tissue concentrations for radionuclides in the body are limited.

The total effective dose equivalent estimated here as a mean for the United States is 3 mSv/y (300 mrem/y) with the value for Canada being about 2.6 mSv/y (260 mrem/y). This might be compared with the UNSCEAR estimates of 2 mSv/y (1982) and 2.2 mSv/y (1986) for areas of average natural background. The differences are entirely contained in the estimates of effective dose equivalent rate from inhalation of radon decay products. It should be noted that the conversion of dose equivalent in the bronchial epithelium to effective dose equivalent was not part of the ICRP (1977) system and may not be entirely appropriate.

### 9.5 Need for Additional Data

The assessment of dose from natural radioactivity and natural radiation can only be carried out with confidence if the amount and quality of the data are adequate to permit estimation of the mean and distribution of the exposures to the population of interest. In this report, it has been pointed out from time to time that these criteria are not met. Data on exposures to cosmic radiation and external gamma radiation are adequate, but the other sources require additional measurements with satisfactory quality, say an accuracy of 25 percent.

Many of the data that were obtained for other purposes are not satisfactory. For example, regulatory agencies frequently require only pass/fail measurements, where results may be reported only as being less than some arbitrary value. This defect is compounded when surrogate analyses, such as total radium or total alpha activity, are permitted in place of actual radionuclide assays.

While the amount of data on radon decay product exposure in homes is mounting rapidly, the measurements are not all useful for assessment of means and distributions of dose. Many programs are aimed at searching out high values and many of the measurements are not adequate, even at average concentrations in the home. A planned survey by the EPA may help remedy this situation.

Finally, the available data for natural radionuclides in the diet or in the body consist of a few sets of measurements on limited geographical areas made at two or three laboratories. Only  $^{226}\text{Ra}$  has a reasonable coverage. Even this radionuclide requires additional measurements of diet, water, and bone specimens from different areas to determine if water intake is more significant than that from diet.

## Annex C

**Excerpts from Background as a Residual Radioactivity Criterion for Decommissioning, Appendix A to the Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for Decommissioning of NRC-Licensed Nuclear Facilities, United States Nuclear Regulatory Commission (NRC), 1994. (Draft Report, NUREG-1501)**

# Background as a Residual Radioactivity Criterion for Decommissioning

Appendix A to the Generic Environmental  
Impact Statement in Support of Rulemaking on  
Radiological Criteria for Decommissioning of  
NRC-Licensed Nuclear Facilities

Draft Report

**U.S. Nuclear Regulatory Commission**

Office of Nuclear Regulatory Research

A. M. Huffert, R. A. Meck/NRC  
K. M. Miller/EML



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input of man-made radionuclides from fallout after a nuclear weapon test or distant reactor accident, which can increase background levels for a few months to a few decades.

The spatial variation of external radiation is largely related to the makeup of the soil in a locale. The greatest spatial variation in background arises from the differences in levels of radon gas, which can vary from one tenth the national average to more than ten times the average because of differences in the radium concentration in soil. Outdoor gamma radiation levels over sandy soil along a coast may be only one fourth the average for the whole country, whereas it might typically be three times the average in mountainous areas with a high degree of mineralization. Indoor gamma radiation levels vary by about 50 percent because of the use of different construction materials.

Human activities also affect spatial variability of background. Mining and milling have redistributed natural radionuclides, adding to the variation that occurs in some areas. Variations in the dose from internal radionuclides primarily results from differences in the concentration of natural radionuclides in drinking water. A significant fraction of internal dose arises from potassium-40; however, this is relatively constant, whereas the concentration of nuclides such as lead-210 in body tissues has been observed to vary by about a factor three throughout the United States. Cosmic radiation increases by a factor of two between areas above sea level, such as Denver, Colorado, and areas that are at sea level. Variations of a few percent also occur with latitude. On a local scale, cosmic ray levels are lower for residents and workers in tall, massive buildings because of the shielding effects of concrete floors. Measurements inside a building have shown a drop ranging between one to two thirds below that outdoors. Cosmogenic and man-made radionuclide concentrations vary in air and soil, although the overall effect on the total variation in dose from background is quite small.

When considered on a large scale, this widely variable and ubiquitous source of naturally-occurring radiation produces doses to the human population that are, in turn, widely variable as well. The magnitude and variability of radiation doses among a given population is directly proportional to the population's activities and the background level to which the population is exposed. Current estimates of the minimum, maximum, and average dose per year to a United States resident from background are provided in the next section, along with comparisons to worldwide estimates and doses from other sources of radiation.

## 2.4 Estimated Doses From Background

A comprehensive review of background sources and the resultant doses received by the population of the United States has been performed by the National Council on Radiation Protection and Measurements (NCRP, 1987b). Figure 2.8 shows a breakdown of the estimated total effective dose equivalent, with regard to the average contributions from each of the principal sources. Of the rounded total of 3 mSv (300 mrem) per year, two-thirds or 2 mSv (200 mrem) comes from inhaling radionuclides (by and large, the indoor radon decay products). The other radionuclides internal to the body from ingestion and inhalation contribute about 13 percent or 0.4 mSv (40 mrem) of the total dose. External terrestrial (gamma) radiation and cosmic ray components are about equal and together make up about 18 percent or 0.55 mSv (55 mrem) of the total, whereas the annual dose from the cosmogenic radionuclides is very small, on the order of 0.01 mSv (1 mrem) or less than one percent.

### Background Contributions in mSv (mrem)

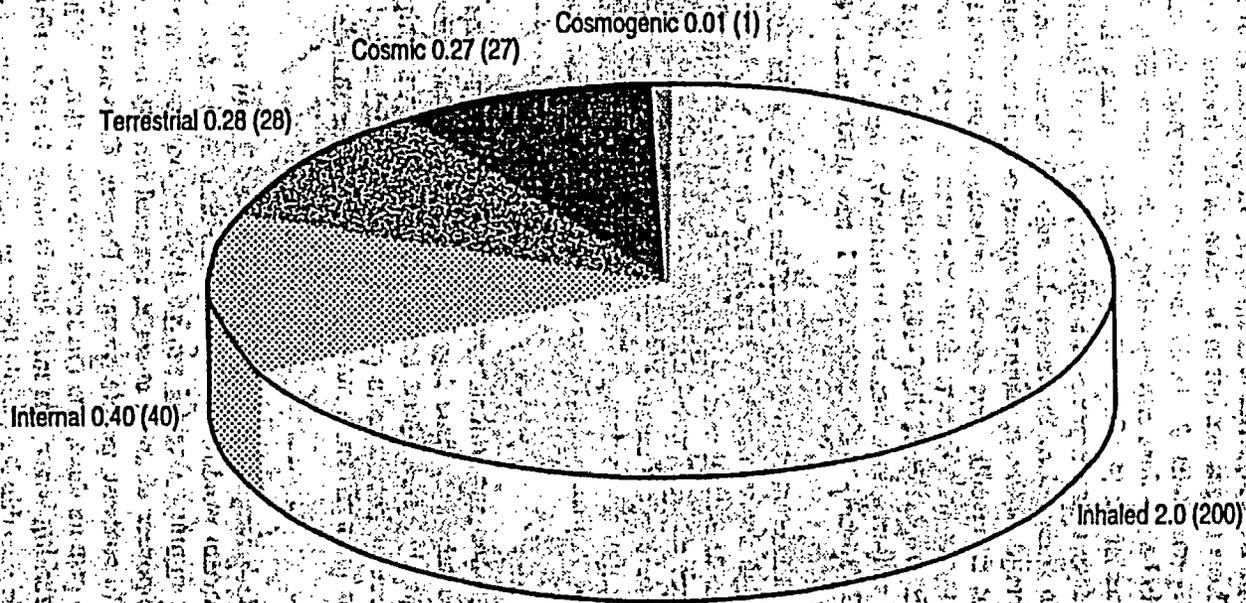


Figure 2.8- The average contribution to the total effective dose equivalent from various sources of background for the United States (NCRP, 1987b)

Given the previous discussion concerning the temporal and spatial background variations, it is imperative to remember that the estimated total dose of 3 mSv (300 mrem) is an annual average, and that the actual dose received by any one individual could be quite different. Figure 2.9 shows the average contributions of the four most significant components in perspective to the estimated typical maximums and minimums. These ranges are not to be taken as the absolute limits, but should indicate the variability generally encountered. In the inhalation category, the maximum of 8 mSv (800 mrem) per year is taken to be the dose corresponding to the current EPA Action Level of 150 Bq of radon per cubic meter of air (4 pCi per liter). Obviously, many United States homes exceed this level; however, indoor radon represents a category of natural radiation that is controllable by remediation. The minimum annual dose for radon, 0.2 mSv (20 mrem), corresponds to a level only one-tenth the national average, which is taken to be typical of well ventilated houses in areas with low radium concentrations in the soil. For internal radiation, about half of the average is taken to be constant, corresponding to the dose from radionuclides such as carbon-14 and potassium-40. The other half of the average internal dose is then varied from one-third to four times the average, based on data for the range of radionuclides measured in human tissues. This yields a minimum of somewhat less than 0.3 mSv (30 mrem) to a maximum of 1 mSv (100 mrem) per year.

The external terrestrial radiation maximum of three times the average is not unusual for areas in the western United States with a high degree of mineralization in the soil, whereas the minimum of one-fourth the average is representative of sandy soil along a coastline. This leads to a range of less than 0.1 mSv (10 mrem) to more than 0.8 mSv (80 mrem) per year for the gamma component. For cosmic radiation, the typical maximum is taken as twice that of the dose at sea level (a resident of Denver), while the minimum is half (a resident of New York City who lives and works in tall buildings). This corresponds to a difference of 0.4 mSv (40 mrem) per year in dose between the extremes for cosmic radiation.

The variability of major background components can average out in many cases so that many people receive similar total doses. Nonetheless, some degree of correlation exists among these components. High gamma levels can be found in mountainous areas, and accordingly, the higher levels of uranium in the soil lead to a larger source of radon gas in the soil, as well as higher concentrations of radionuclides in well water and food grown in those areas. The higher altitude also leads to a higher dose from cosmic rays.

As an example of the typical dose range, consider that people who live in well-ventilated wooden houses on sandy soil near the ocean would receive a minimal dose from radon — one tenth of the United States average — and a minimal external gamma dose — about one-fourth the average. With an internal and cosmic ray component of about average, the total dose to these individuals is only 1 mSv (100 mrem) per year. In contrast, people living in Denver, Colorado, could receive double the cosmic ray dose, triple the gamma dose, and quadruple the radon dose. With a somewhat higher intake of radionuclides from drinking water, the total dose is about 10 mSv (1000 mrem) per year. Although even higher doses are possible for people living in houses with very high radon concentrations, this value could be taken as an upper limit, allowing for extremes associated with unusual situations. Overall, this range of 1 to 10 mSv (100 to 1000 mrem) — a span of a factor of ten — is typical of the variation in background doses for most United States citizens in a given year.

## Annex D

The Annual Effective Dose from Natural Sources of Ionising Radiation in Canada,  
R.L. Grasty and J.R. LaMarre, 2004. (Radiation Protection Dosimetry, Vol. 108,  
No. 3, pages 215-226)

## THE ANNUAL EFFECTIVE DOSE FROM NATURAL SOURCES OF IONISING RADIATION IN CANADA

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A review and analysis of published information combined with the results of recent gamma ray surveys were used to determine the annual effective dose to Canadians from natural sources of radiation. The dose due to external radiation was determined from ground gamma ray surveys carried out in the cities of Toronto, Ottawa, Montreal and Winnipeg and was calculated to be 219  $\mu\text{Sv}$ . A compilation of airborne gamma ray data from Canada and the United States shows that there are large variations in external radiation with the highest annual outdoor level of 1424  $\mu\text{Sv}$  being found in northern Canada.

The annual effective inhalation dose of 926  $\mu\text{Sv}$  from <sup>222</sup>Rn and <sup>220</sup>Rn was calculated from approximately 14,000 measurements across Canada. This value includes a contribution of 128  $\mu\text{Sv}$  from <sup>222</sup>Rn in the outdoor air together with 6  $\mu\text{Sv}$  from long-lived uranium and thorium series radionuclides in dust particles. Based on published information, the annual effective dose due to internal radioactivity is 306  $\mu\text{Sv}$ .

A program developed by the Federal Aviation Administration was used to calculate a population-weighted annual effective dose from cosmic radiation of 318  $\mu\text{Sv}$ . The total population-weighted average annual effective dose to Canadians from all sources of natural background radiation was calculated to be 1769  $\mu\text{Sv}$  but varies significantly from city to city, largely due to differences in the inhalation dose from <sup>222</sup>Rn.

### INTRODUCTION

Humans are exposed to many different sources of ionising radiation, both natural and human-made. The natural component is frequently used as a standard for assessing the impact of human-made radiation such as those produced through the medical use of X-rays and gamma-radiation, as well as from atomic weapon's fallout and nuclear power generation. In order to assess the significance of human-made sources of radiation, the natural background and its variations must be known.

Natural radiation originates from four main sources: radionuclides in the body, inhalation, external terrestrial radiation and cosmic radiation. This natural background radiation can vary considerably depending on such things as the geological environment, type of living accommodation and elevation above sea level. Internal doses arise mainly from the ingestion of potassium-40 (<sup>40</sup>K) and members of the uranium-238 (<sup>238</sup>U) and thorium-232 (<sup>232</sup>Th) series that are present in food and drinking water. The lungs and respiratory tract receive a significant radiation dose due to the inhalation of the radioactive gas radon-222 (<sup>222</sup>Rn) and its progeny present in the air. External sources of terrestrial radiation originate from the natural radioactive elements, principally <sup>40</sup>K and decay products in the <sup>238</sup>U and

<sup>232</sup>Th decay series present in the ground and in building materials. A component of the radiation dose to the human population also arises from high-energy cosmic radiation entering the earth's atmosphere.

In 1984, the Geological Survey of Canada (GSC) published a report showing natural background radiation levels over large areas of Canada<sup>(1)</sup>. The component of natural background radiation due to <sup>40</sup>K, <sup>238</sup>U and <sup>232</sup>Th in the ground and building materials was estimated from published airborne gamma ray survey data flown mostly over unpopulated areas of Canada.

In October 1999, an airborne gamma ray survey was flown over a large populated area near Toronto, Ontario<sup>(2)</sup>. Analyses of the airborne data showed that the urban areas are lower in radioactivity than open areas of parks, forests and farmland. This is because the materials used in the construction of roads, parking lots and buildings are made of low-radioactivity limestone whereas the soils in the rural areas consist of glacial materials with a higher content of radionuclides. The large variation in the radiation dose between the rural and urban areas in the Toronto region, therefore put in doubt the reliability of the earlier airborne gamma ray surveys for estimating the radiation dose from external radiation.

In order to address this problem, in the fall of 2002 Ontario Power Generation initiated a project to carry out gamma ray surveys of the major

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population centres of Toronto, Ottawa, Montreal and Winnipeg using a vehicle-mounted gamma ray spectrometer. The city of Winnipeg was selected as part of the study since it is located in a different geological environment of glacial lake clays compared to the other three cities.

This report is a review and analysis of published information and the results of the gamma ray surveys of the four cities to determine the annual effective dose to Canadians from natural sources of radiation.

## EXTERNAL RADIATION

### The 2002 city surveys

In the fall of 2002, gamma ray surveys were carried out along roads in four cities in Canada to determine the annual external population dose. The justification for using the road survey data to derive the effective dose from external radiation is based on a previous analysis of the indoor-to-outdoor effective dose for the Canadian population<sup>(1)</sup>. In that study, it was determined that the average indoor effective dose was less than 8% higher than the average outdoor dose. Since people spend a percentage of their time outdoors where the annual effective dose is lower than indoors, the annual effective dose both indoors and outdoors closely represents the outdoor dose as measured by the road survey data.

The surveys of the four cities were carried out using an Exploranium GR320 gamma ray spectrometer mounted in a vehicle. Data from a Global Positioning System (GPS) were used for tracking the vehicle route and the data recorded on a laptop computer together with the 256-channel spectrometer data. The surveys were carried out using a large volume  $40.6 \times 40.6 \times 10.2 \text{ cm}^3$  ( $16 \times 16 \times 4 \text{ in.}^3$ ) sodium iodide detector with data being recorded once every 10 s. The sodium iodide detector was mounted in the rear of a station wagon, on the driver's side, so that the spectrometer system was monitoring the radioactivity of the roadbed (Figure 1).

Particular attention was paid to positioning the detector well clear of the fuel tank so that the measurements would not be affected by changing fuel levels. Approximately 600 km of roads were surveyed in each of the four cities over the course of two or more days. The survey route was planned to achieve a relatively uniform coverage of each city. A total of more than 20,000 measurements were made in the four cities.

In carrying out gamma ray spectrometer surveys for geological mapping or uranium exploration, the International Atomic Energy Agency (IAEA) has recommended that field gamma ray measurements be converted to concentrations of potassium,



Figure 1. The system setup in the survey vehicle.

uranium and thorium in the ground<sup>(3)</sup>. These units of concentration are:

- % K (per cent potassium)
- ppm eU (parts per million of equivalent uranium)
- ppm eTh (parts per million of equivalent thorium)

The prefix 'e' (meaning equivalent) is used in reporting the concentration of uranium and thorium to emphasise the indirect detection of uranium and thorium by means of gamma rays emitted by their decay products, bismuth-214 ( $^{214}\text{Bi}$ ) and thallium-208 ( $^{208}\text{Tl}$ ) respectively.

The relationships between the concentrations of potassium, uranium and thorium in soil and the corresponding activities of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  are as follows<sup>(4)</sup>:

$$1\% \text{ K} = 313 \text{ Bq kg}^{-1} \text{ of } ^{40}\text{K} \quad (1)$$

$$1 \text{ ppm eU} = 12.35 \text{ Bq kg}^{-1} \text{ of } ^{238}\text{U} \quad (2)$$

$$1 \text{ ppm eTh} = 4.06 \text{ Bq kg}^{-1} \text{ of } ^{232}\text{Th} \quad (3)$$

The basic calibration procedure for the gamma ray spectrometer system was to compare the potassium, uranium and thorium window count rates over a calibration site with the ground concentrations of potassium, uranium and thorium measured with a calibrated portable gamma ray spectrometer. This is essentially the same procedure recommended by the IAEA for calibrating airborne gamma ray spectrometers<sup>(3)</sup>.

The calibration of the spectrometer survey system made use of a large flat open field. Previous measurements taken with a calibrated portable spectrometer had shown that the site was relatively uniform in potassium, uranium and thorium. Based on the ground concentrations of the site and the count rates in the three windows, the system sensitivities were determined.

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Table 1. Air absorbed dose rate conversion factors at a height of 1 m for potassium, uranium and thorium distributed homogeneously in the ground.

Nuclide	Air absorbed dose rate conversion factors (nGy h <sup>-1</sup> per Bq kg <sup>-1</sup> )
<sup>40</sup> K	4.17 × 10 <sup>-2</sup>
<sup>238</sup> U	4.62 × 10 <sup>-1</sup>
<sup>232</sup> Th	6.04 × 10 <sup>-1</sup>

Table 2. The conversion factors between effective dose and air absorbed dose for potassium, uranium and thorium distributed homogeneously in the ground.

Nuclide	Effective dose conversion factors (Sv. Gy <sup>-1</sup> )
<sup>40</sup> K	0.709
<sup>238</sup> U	0.672
<sup>232</sup> Th	0.695

In processing the gamma ray data, the system background must also be known. This background was determined from measurements taken on a metal bridge over the St. Lawrence River in Montreal. The concentrations of potassium, uranium and thorium in the roadbed were then calculated following the procedures described by the IAEA<sup>(3)</sup>.

Calculation of outdoor external dose

The measured activities of <sup>40</sup>K, <sup>238</sup>U and <sup>232</sup>Th in the ground can be used to determine the air absorbed dose rate 1 m above the ground. The factors to convert the activities to air absorbed dose rates are shown in Table 1. They were taken from data presented by the International Commission on Radiation Units and Measurements<sup>(5)</sup> and were originally calculated by Saito and Jacob<sup>(6)</sup> but published later.

Based on the results in Table 1, the air absorbed dose rate (*D<sub>a</sub>*) in nGy h<sup>-1</sup> is given by:

$$D_a = (4.17 \times 10^{-2} \times ^{40}\text{K}) + (4.62 \times 10^{-1} \times ^{238}\text{U}) + (6.04 \times 10^{-1} \times ^{232}\text{Th}) \quad (4)$$

where <sup>40</sup>K, <sup>238</sup>U and <sup>232</sup>Th are the activities of the radioactive nuclides in the ground and measured in Bq kg<sup>-1</sup>. In Equation 4 it is assumed that <sup>238</sup>U and <sup>232</sup>Th are in equilibrium with their decay products.

The air absorbed dose rate 1 m above the ground can be converted to effective dose using conversion factors presented by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)<sup>(7)</sup>. These conversion factors are shown in Table 2 and were originally calculated by Saito *et al.*<sup>(8)</sup>.

Using the relationships between activity and concentration (Equations 1-3), the annual effective dose *E* in μSv can then be calculated from the potassium, uranium and thorium concentrations of the ground using the following equation:

$$E_a = 81.1 \times K_{\text{ppt}} + 33.6 \times eU_{\text{ppm}} + 14.9 \times eTh_{\text{ppm}} \quad (5)$$

The calibration of the spectrometer to convert the field measurements to ground level concentrations of potassium, uranium and thorium was made on an open field with 2π geometry. In downtown areas with narrow streets and tall buildings, the geometry could be close to 4π. In these situations, the calculated concentrations of potassium, uranium and thorium in the ground will be incorrect. These calculated 'apparent' concentrations would be twice as high as for the 2π case. However, the use of these increased 'apparent' concentrations in Equation 5 for 4π geometry will lead to the correct annual effective dose.

Survey results

Maps of the annual effective dose for the four cities are presented in Figures 2-5. Table 3 shows the average annual dose for the four cities together with statistical information such as the standard deviation of all measurements, the maximum and minimum values and the number of measurements taken. The population of each city from the year 2001 Canadian census was used to calculate a population-weighted average annual dose from external radiation that is also presented in the table.

Roads in Canada typically consist of 20 cm or more of crushed material covered by 5-10 cm of asphalt. Such a thickness of material will produce most of the radiation received by the detector. Table 3 shows that Toronto and Winnipeg have much lower radiation levels than Ottawa and Montreal. This difference can therefore be explained by differences in the radionuclide content of the roadbed. The maps of the cities show sections of road where materials with different levels of radioactivity have been used. In some cases these differences are very large. For instance, the Toronto map (Figure 3) shows an 8-km section of highway at the western end of the city where the radiation levels exceed 600 μSv. This is more than six times greater than many of the roads in the city.

The downtown areas of Ottawa (Figure 4) and, to some extent, Toronto (Figure 3) show increased radiation levels compared to the suburban areas.

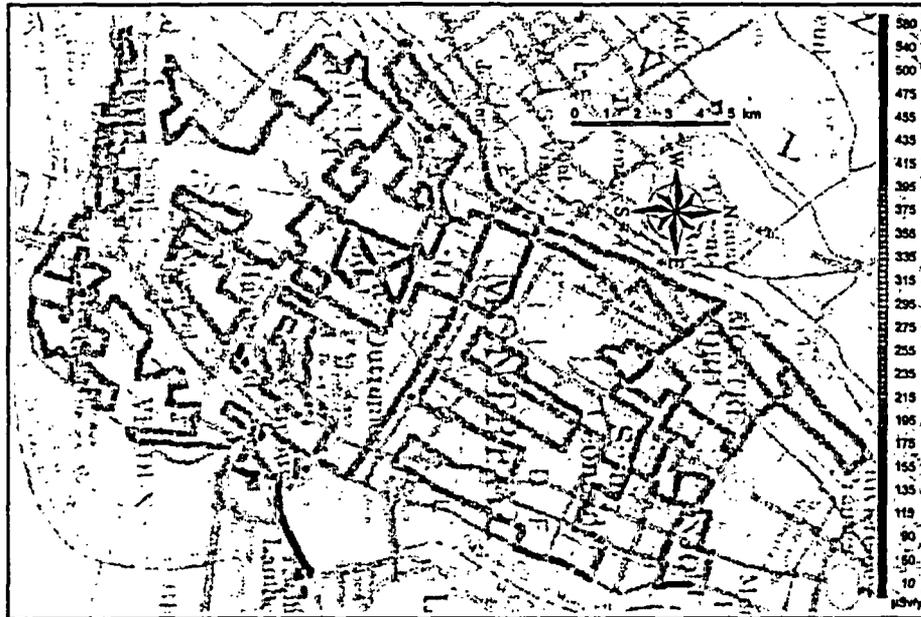


Figure 2. The annual outdoor effective dose ( $\mu\text{Sv}$ ) for Montreal.



Figure 3. The annual outdoor effective dose ( $\mu\text{Sv}$ ) for Toronto.

This is due to geometrical effects since in the downtown area radiation is being received not only from the roadbed beneath the detector but also from tall buildings at the edge of the road. In Ottawa, one of

the localized 'hot-spots' just west of the downtown area arises because the vehicle stopped beneath an underpass. The map of Montreal (Figure 2) shows a stretch of low background radiation over the

#### ANNUAL EFFECTIVE DOSE FROM CANADIAN NATURAL SOURCES

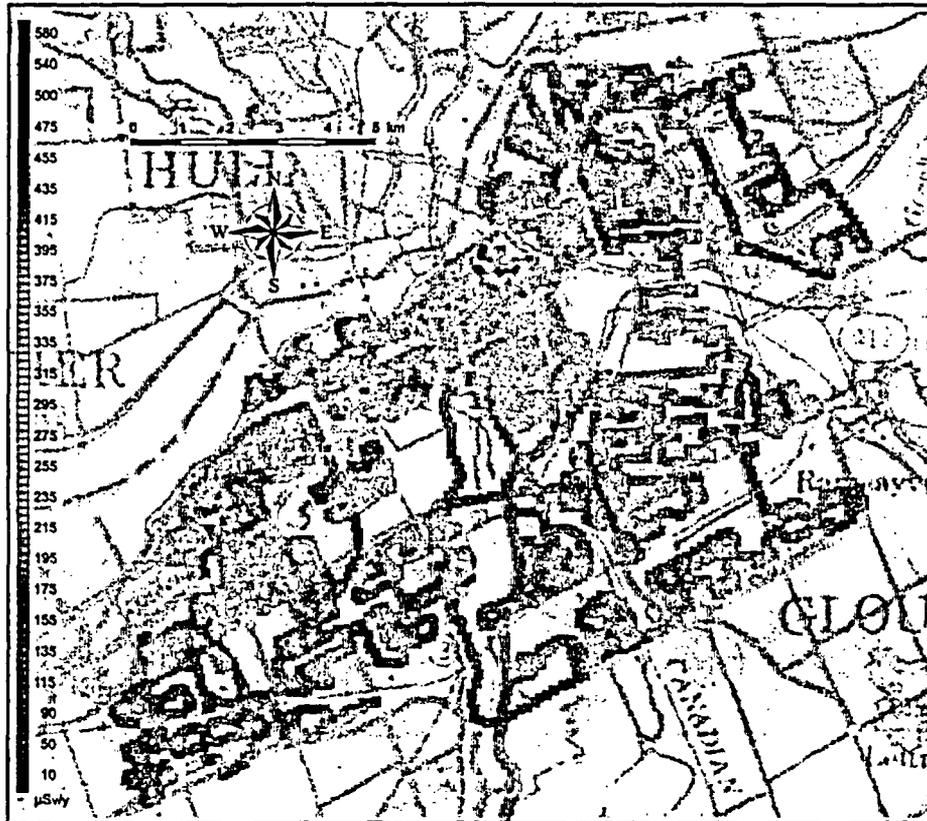


Figure 4. The annual outdoor effective dose ( $\mu\text{Sv}$ ) for Ottawa.

St. Lawrence River. These series of measurements were used to establish the system background.

#### THE CANADA/US RADIOACTIVITY MAP

The Canadian annual external dose of  $219 \mu\text{Sv}$  is considerably lower than the worldwide average of  $480 \mu\text{Sv}$  estimated by UNSCEAR<sup>(7)</sup>. In order to put the Canadian results into perspective, it is useful to study the typical North American ranges in outdoor effective dose due to naturally occurring potassium, uranium and thorium in the ground.

In the period 1975–1983, the United States Department of Energy conducted the National Uranium Resource Evaluation Program<sup>(9)</sup>. This programme included airborne gamma ray surveys of most of the United States. Maps of the potassium, uranium and thorium concentration of the ground were compiled from the digital data<sup>(10)</sup>. In the mid 1970s, a similar programme called the Uranium Reconnaissance Program was carried out in Canada<sup>(11)</sup>.

The GSC has recently combined the US data with those from Canada and produced maps of

the potassium, uranium and thorium concentration of the ground and the outdoor air absorbed dose rate in nano-grays per hour. In order to compare the results of the present study with those from Canada and the United States, the potassium, uranium and thorium concentration data were recompiled to produce a map of the annual outdoor effective dose. The resulting map, shown in Figure 6, represents the average annual effective doses over areas of  $10 \times 10 \text{ km}^2$ .

The map for Canada and the United States shows that there are large variations in annual outdoor effective dose. The difference between the minimum and maximum values represents a variation of more than a factor of 100. In Canada, some of the lowest levels of around  $20\text{--}40 \mu\text{Sv}$  are found in the Athabasca sandstones of northern Saskatchewan, while the highest level of  $1424 \mu\text{Sv}$  is in the Northwest Territories. If this natural level was the result of industry introduced radiation, there would be many places in northern Canada that would exceed the limit of  $1000 \mu\text{Sv}$  ( $1 \text{ mSv}$ ) set by the Canadian Nuclear Safety Commission (CNSC). It should also be noted

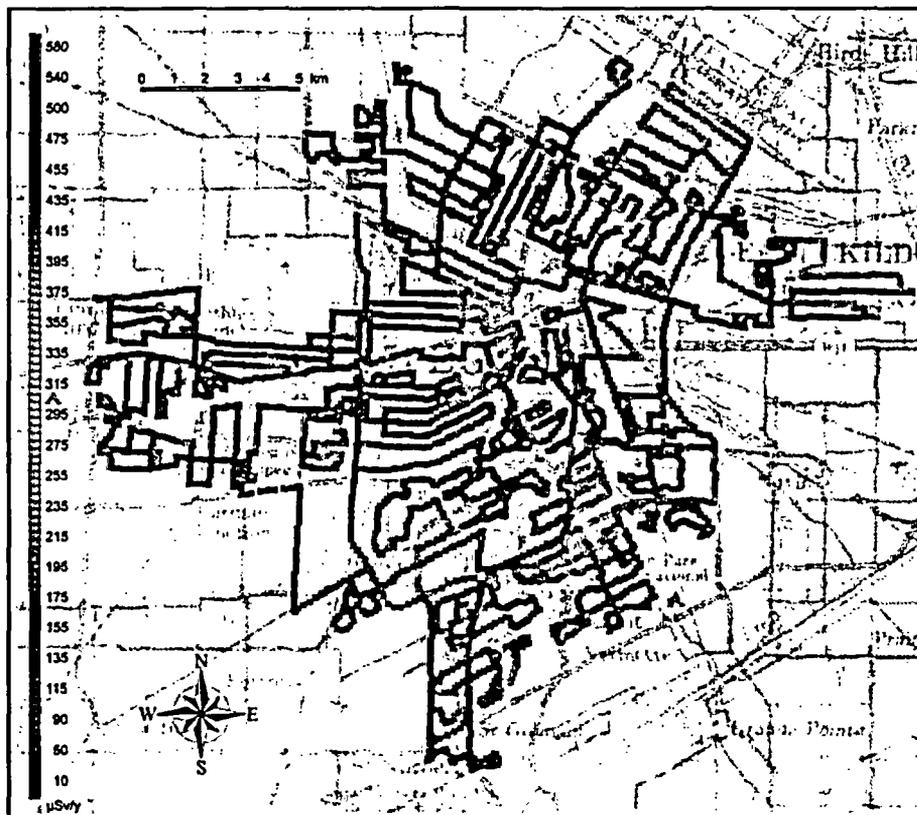


Figure 5. The annual outdoor effective dose ( $\mu\text{Sv}$ ) for Winnipeg.

Table 3. The annual outdoor external dose for four Canadian cities.

City	Population	Annual dose ( $\mu\text{Sv}$ )	Standard deviation ( $\mu\text{Sv}$ )	Min. ( $\mu\text{Sv}$ )	Max. ( $\mu\text{Sv}$ )	Number of samples
Montreal	3,426,350	278	57	81	609	5287
Ottawa	1,063,664	240	43	128	638	5804
Toronto	4,682,897	178	69	56	600	6045
Winnipeg	671,274	176	32	97	423	6787
Population-weighted average		219	59			

that this maximum value of 1424  $\mu\text{Sv}$  represents an average value for a  $10 \times 10 \text{ km}^2$  area but is increased to 2335  $\mu\text{Sv}$  when using the original airborne data that were averaged over areas of  $2 \times 2 \text{ km}^2$ .

#### INHALATION DOSE

##### Indoor $^{222}\text{Rn}$

In the summers of 1977 and 1978, the Radiation Protection Bureau of Health Canada, carried out a total of 9999 measurements of indoor  $^{222}\text{Rn}$

in 14 Canadian cities<sup>(12)</sup>. In subsequent years, measurements were made in an additional five cities<sup>(13)</sup>. The results from the total of approximately 14,000 homes are used to derive an average indoor effective dose from the inhalation of  $^{222}\text{Rn}$ . Table 4 shows the mean  $^{222}\text{Rn}$  progeny concentrations measured in units of Equilibrium Equivalent Concentrations (EEC) of  $^{222}\text{Rn}$  for the 19 cities together with their populations. These populations were used to calculate the population-weighted average EEC  $^{222}\text{Rn}$  concentration, also shown in Table 4.

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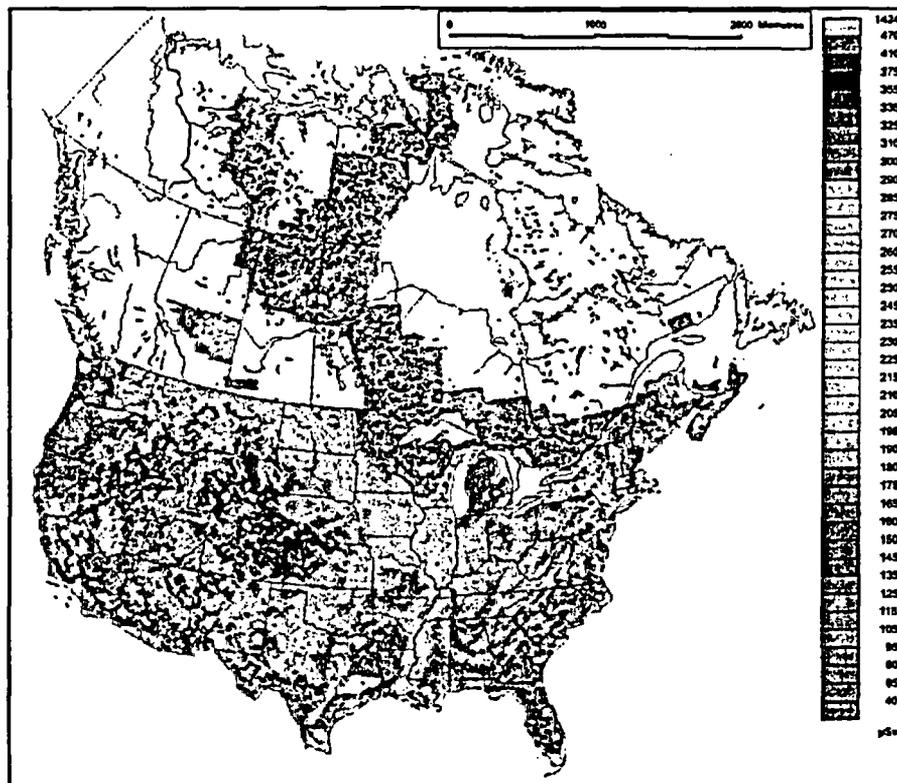


Figure 6. The annual outdoor effective dose ( $\mu\text{Sv}$ ) from external radiation for Canada and the United States.

Table 4. The EEC  $^{222}\text{Rn}$  concentrations in the basements of 19 Canadian cities.

City	Population	EEC $^{222}\text{Rn}$ concentration ( $\text{Bq m}^{-3}$ )
Brandon	39,200	21
Calgary	951,395	10
Charlottetown	32,531	10
Edmonton	937,845	14
Fredericton	46,500	21
Halifax	359,183	22
Montreal	3,426,350	8
Quebec City	682,757	8
Regina	192,800	29
Saskatoon	225,927	19
Sherbrooke	153,811	17
St. John, N.B.	72,500	12
St. Johns, Nfld.	172,918	9
St. Lawrence	101,900	21
Sudbury	155,601	24
Thunder Bay	121,986	15
Toronto	4,682,897	10
Vancouver	1,986,965	4
Winnipeg	671,274	41
Population-weighted average		11.4

In using the Health Canada data to estimate the annual effective dose, several factors must be considered.

- (1) The measurements were taken mostly in the basements and therefore may not be representative of the  $^{222}\text{Rn}$  levels where people spend most of their time at home.
- (2) The measurements represent grab samples taken during the daytime. Due to the diurnal variation in  $^{222}\text{Rn}$  concentrations, the grab measurements may not be representative of the daily average.
- (3) The measurements were taken during the summer. Due to seasonal variation in  $^{222}\text{Rn}$  concentrations in homes, the measurements may not be representative of the yearly average.

However, as reported by the National Council on Radiation Protection and Measurement (NCRP), in computing an annual average these different factors tend to balance each other out<sup>(13)</sup>. In view of the many uncertainties associated with evaluating the annual effective dose from indoor  $^{222}\text{Rn}$ , and to simplify the calculations, we have followed the NCRP procedure and assumed that the summer basement values from the Health Canada study are representative of the annual exposure.

Table 5. The average summer outdoor  $^{222}\text{Rn}$  concentrations for 17 Canadian cities.

City	Population	$^{222}\text{Rn}$ concentration (Bq m $^{-3}$ )
Calgary	951,395	39
Edmonton	937,845	44
Halifax	359,183	9
Montreal	3,426,350	17
Ottawa	1,063,664	16
Quebec City	682,757	13
Regina	192,800	62
Saskatoon	225,927	62
Sherbrooke	153,811	12
St. John NB	72,500	18
St. Johns, Nfld	172,918	10
St. Lawrence	101,900	16
Sudbury	155,601	11
Thunder Bay	121,986	14
Toronto	4,682,897	6
Vancouver	1,986,965	6
Winnipeg	671,274	55
Population-weighted summer average		17.5
Population-weighted annual average		13.5

#### Outdoor $^{222}\text{Rn}$

In order to estimate the annual effective dose from  $^{222}\text{Rn}$ , consideration should be given to  $^{222}\text{Rn}$  in outdoor air. In the summer of 1990, measurements of outdoor  $^{222}\text{Rn}$  were made in 31 communities across Canada<sup>(14)</sup>. Table 5 shows the average  $^{222}\text{Rn}$  levels for 17 major cities that were surveyed, together with their populations from the 2001 Canadian census.

Based on the population figures for the cities, it was calculated that the population-weighted average outdoor summer  $^{222}\text{Rn}$  level was 17.5 Bq m $^{-3}$  (Table 5). However, this average represents the outdoor summer value and must be corrected for seasonal variations since in Canada outdoor  $^{222}\text{Rn}$  concentrations are higher in the summer than they are in the winter.

The seasonal variability of outdoor  $^{222}\text{Rn}$  concentration at Chester, New Jersey over a 9-y period was used to derive a correction factor to convert the summer value of 17.5 Bq m $^{-3}$  to a yearly average<sup>(13)</sup>. This correction factor of 0.77 gives an annual outdoor average  $^{222}\text{Rn}$  concentration of 13.5 Bq m $^{-3}$  ( $0.77 \times 17.5$  Bq m $^{-3}$ ).

#### Calculation of inhalation dose from $^{222}\text{Rn}$

One of the greatest difficulties in estimating the annual dose from natural sources of radiation is in estimating the dose conversion factor for  $^{222}\text{Rn}$ . The range of calculated dose conversion factors for  $^{222}\text{Rn}$  in equilibrium with its progeny varies between

Table 6. The  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  components to annual inhalation dose.

Component	Annual effective dose ( $\mu\text{Sv}$ )
Indoor $^{222}\text{Rn}$	718
Outdoor $^{222}\text{Rn}$	128
Indoor and outdoor $^{220}\text{Rn}$	74
Uranium and thorium series in dust	6
Total	926

6 and 15 nSv per Bq h m $^{-3}$ <sup>(7)</sup>. UNSCEAR have recommended using a dose conversion factor of 9 nSv per Bq h m $^{-3}$ <sup>(7)</sup>. Using this factor and assuming that a person spends 7000 h indoors in a year, the indoor annual effective dose from  $^{222}\text{Rn}$  in equilibrium with its decay products is given by:

$$^{222}\text{Rn}(\mu\text{Sv}) = 11.4 (\text{Bq m}^{-3}) \times 7000 (\text{h}) \\ \times 9 (\text{nSv h}^{-1} \text{ per Bq m}^{-3}) = 718 \mu\text{Sv}$$

UNSCEAR gives an equilibrium factor between  $^{222}\text{Rn}$  and its decay products of 0.6 for outdoor air<sup>(7)</sup>. Assuming a person spends 1760 h outdoors in a year, the annual effective dose from outdoor  $^{222}\text{Rn}$  is given by:

$$^{222}\text{Rn}(\mu\text{Sv}) = 13.5 (\text{Bq m}^{-3}) \times 0.6 \times 1760 (\text{h}) \\ \times 9 (\text{nSv h}^{-1} \text{ per Bq m}^{-3}) = 128 \mu\text{Sv}$$

Together with the indoor value of 718  $\mu\text{Sv}$  this gives a total annual effective dose from  $^{222}\text{Rn}$  of 846  $\mu\text{Sv}$ .

#### Calculation of inhalation dose from thoron

The radioactive gas thoron ( $^{220}\text{Rn}$ ) from the thorium decay series will also contribute a dose to the respiratory tract. However, very few measurements have been made of  $^{220}\text{Rn}$ . It has been estimated that the average worldwide annual effective dose from  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  are 1.15 and 0.10 mSv, respectively<sup>(7)</sup>. Following the UNSCEAR procedure<sup>(7)</sup>, it has been assumed that the ratios of the effective doses from  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  would be similar in Canada. This gives an estimated annual effective dose from  $^{220}\text{Rn}$  of 74  $\mu\text{Sv}$  [ $846 \times (0.10/1.15)$ ].

#### Total inhalation dose

Table 6 shows the indoor  $^{222}\text{Rn}$ , outdoor  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  components to the total population-weighted average annual effective dose due to inhalation. The table also shows a minor component of 6  $\mu\text{Sv}$  due to the inhalation of long-lived uranium and thorium series radionuclides present in dust particles in the air<sup>(7)</sup>.

ANNUAL EFFECTIVE DOSE FROM CANADIAN NATURAL SOURCES

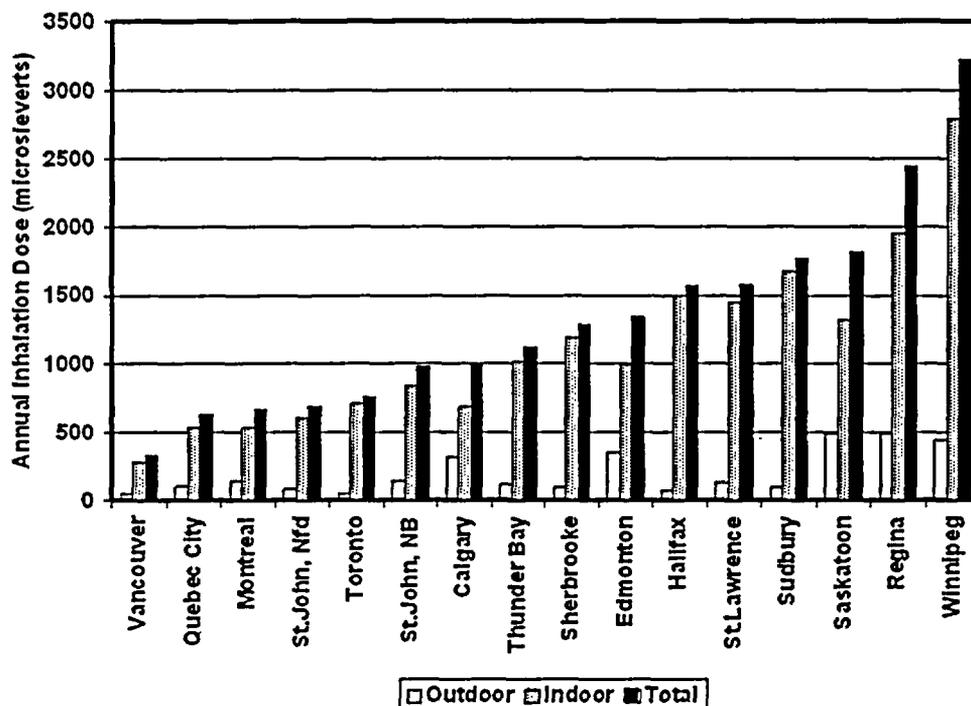


Figure 7. The annual inhalation dose for 16 Canadian cities.

The total inhalation dose varies considerably from city to city across Canada. Figure 7 shows the total annual inhalation dose from  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  for 16 Canadian cities where both indoor and outdoor  $^{222}\text{Rn}$  measurements have been made. This figure shows that the annual inhalation dose for Winnipeg (3225  $\mu\text{Sv}$ ) is almost ten times higher than the value for Vancouver (326  $\mu\text{Sv}$ ) and more than four times the value for Toronto (757  $\mu\text{Sv}$ ). As shown in Table 4, this is primarily due to differences in indoor  $^{222}\text{Rn}$ .

The high indoor  $^{222}\text{Rn}$  levels for Winnipeg and also for Regina and Saskatoon can be attributed to the generally low rainfall in the Prairie Provinces and the associated low moisture content of the ground<sup>(14)</sup>. This low moisture allows  $^{222}\text{Rn}$  to migrate easily through the ground and into homes. In addition, Regina and Winnipeg are situated on glacial lake clays. In summer, these clays dry out and produce fractures that act as  $^{222}\text{Rn}$  pathways through the ground<sup>(14)</sup>.

Large variations were also found in summer outdoor  $^{222}\text{Rn}$  concentrations across Canada with Winnipeg, Regina and Saskatoon being up to 10 times higher than Toronto or Vancouver (Table 5). The high 1990 outdoor values for the Prairies were attributed to the unusually dry summer<sup>(14)</sup>.

COSMIC RADIATION

A large component of the radiation dose to the human population arises from high-energy cosmic radiation entering the earth's atmosphere. A computer program (CARI-6), developed by the Civil Aerospace Medical Institute (CAMI) of the Federal Aviation Administration (FAA) was used to calculate the outdoor cosmic radiation levels for the 21 largest cities in Canada, based on their longitudes, latitudes and elevations above sea level<sup>(15)</sup>. In order to account for variations in cosmic radiation due to the 11-y solar cycle, the values were averaged over four solar cycles starting in 1958. These values ranged from a low of 348  $\mu\text{Sv}$  for Victoria, British Columbia close to sea level, to a high of 556  $\mu\text{Sv}$  for Calgary, Alberta at an elevation of 1048 m. The population-weighted average outdoor annual effective dose for Canada was calculated to be 379  $\mu\text{Sv}$ .

Buildings provide some shielding against cosmic radiation but the shielding factor will depend on the structure and composition of the building materials. UNSCEAR<sup>(7)</sup> has suggested a shielding factor of 0.8 for cosmic radiation. Using this shielding factor and an indoor occupancy factor of 0.8, this corresponds to an annual effective dose of 318  $\mu\text{Sv}$ . The fact that most of the Canadian population lives close to sea



Figure 8. The annual outdoor effective dose ( $\mu\text{Sv}$ ) from cosmic radiation for Canada and the United States.

level explains the lower Canadian dose from cosmic radiation compared to the worldwide average of  $380 \mu\text{Sv}$  reported by UNSCEAR<sup>(7)</sup>.

In order to put the Canadian results into perspective, a map of annual outdoor effective dose has been produced for Canada and the United States (Figure 8). The CARI-6 program was used to produce the map using digital elevation data available on the Internet from the United States Geological Survey (USGS).

The map shows that within Canada and the United States there are large variations in the dose from cosmic radiation. Much of the western part of the map show cosmic radiation levels that are two to three times those in the east. The main factor influencing these variations is the elevation of the ground.

#### INTERNAL EXPOSURE

Naturally occurring radionuclides present in the body give rise to an internal exposure to the body. This internal exposure is principally due to the ingestion of  $^{40}\text{K}$  and members of the  $^{238}\text{U}$  and  $^{232}\text{Th}$  series that are present in food and drinking

Table 7. The annual effective dose from internal sources of radioactivity.

Source	Annual effective dose ( $\mu\text{Sv}$ )
$^{40}\text{K}$	170
Uranium and thorium series	120
$^{14}\text{C}$	10
$^{87}\text{Rb}$	6
Total	306

water. A minor component of internal exposure is also due to carbon-14 ( $^{14}\text{C}$ ) and rubidium-87 ( $^{87}\text{Rb}$ ). The Canadian annual effective internal radiation doses due to radionuclides in the body were obtained from the estimated worldwide averages reported by UNSCEAR in its 1982 and 2000 reports<sup>(7,16)</sup>. These annual effective doses are presented in Table 7 and give a total effective internal dose of  $306 \mu\text{Sv}$ . However, individual values will vary due to the biochemistry of the environment and the radionuclides ingested from foods and drinking water.

## ANNUAL EFFECTIVE DOSE FROM CANADIAN NATURAL SOURCES

### TOTAL ANNUAL EFFECTIVE DOSE

Table 8 shows the four components of the population-weighted average annual effective dose for Canada together with the worldwide values reported by the UNSCEAR<sup>(7)</sup>. It should be noted that the four components in Table 8 are not exactly the same as used by UNSCEAR in its 2000 report. In the 2000 report, the internal dose due to cosmogenic radionuclides was considered part of the dose due to cosmic radiation whereas in the present paper it is considered as part of the internal dose.

The annual doses for Toronto and Winnipeg are shown to illustrate that the total doses received by Canadians depend on where they live. The high annual total effective dose for the Winnipeg population is mainly due to a high inhalation dose.

The average Canadian dose from external radiation is significantly lower than the worldwide average. Since <sup>222</sup>Rn originates from uranium in the soil and building materials, the low Canadian levels in external dose can also explain the low Canadian inhalation dose compared to the worldwide average. The fact that most of the Canadian population lives close to sea level explains the lower Canadian dose from cosmic radiation compared to the worldwide average of 380  $\mu$ Sv.

Estimating the annual dose from inhalation has the greatest uncertainty of the four components. This is partly due to the difficulty in estimating the annual average <sup>222</sup>Rn concentrations from the Health Canada study in which grab samples were taken from basements in the summer. It is also due to the uncertainty in the conversion coefficient between <sup>222</sup>Rn concentration and effective dose.

### CONCLUSIONS

#### External dose

Based on gamma ray surveys of approximately 600 km of roads in the cities of Montreal, Ottawa,

Table 8. The average worldwide effective dose together with those for Canada, Toronto and Winnipeg.

Radiation source	Worldwide average ( $\mu$ Sv)	Canada ( $\mu$ Sv)	Toronto ( $\mu$ Sv)	Winnipeg ( $\mu$ Sv)
Cosmic <sup>1</sup>	380	318	313	315
Internal <sup>2</sup>	306	306	306	306
Inhalation	1256	926	757	3225
External	480	219	178	176
Total	2422	1769	1554	4022

<sup>1</sup>Does not include ingested cosmogenic nuclides. These components are included under internal radiation.

<sup>2</sup>Includes 6  $\mu$ Sv from <sup>87</sup>Rb that was not included in the UNSCEAR (2000) report<sup>(7)</sup> but was included in earlier reports<sup>(15)</sup>.

Toronto and Winnipeg, it was calculated that the average Canadian population-weighted annual external dose from potassium, uranium and thorium in the ground and building materials is 219  $\mu$ Sv.

The external radiation levels for Montreal (278  $\mu$ Sv) and Ottawa (240  $\mu$ Sv) were higher than the values for Toronto (178  $\mu$ Sv) and Winnipeg (176  $\mu$ Sv). Significant variations up to a factor of 6 were found within each city.

A compilation of airborne gamma ray data from Canada and the United States showed that there are large variations in annual outdoor effective dose. Some of the lowest levels of around 20–40  $\mu$ Sv were found in the Athabasca sandstones of northern Saskatchewan, while the highest level of 1424  $\mu$ Sv was found in the Northwest Territories. This value of 1424  $\mu$ Sv exceeds the allowable CNSC limit of 1000  $\mu$ Sv for sources of manmade radiation.

#### Inhalation dose

Based on 14,000 Health Canada measurements of <sup>222</sup>Rn decay products in 19 Canadian cities, the annual inhalation dose is estimated to be 926  $\mu$ Sv. This value includes 718  $\mu$ Sv from <sup>222</sup>Rn in indoor air, 128  $\mu$ Sv from <sup>222</sup>Rn in the outdoor air and a contribution of 74  $\mu$ Sv from <sup>220</sup>Rn (thoron). A small contribution of 6  $\mu$ Sv is also included due to long-lived uranium and thorium series radionuclides present in dust particles.

There are large regional variations in the annual effective dose due to the inhalation of <sup>222</sup>Rn and <sup>220</sup>Rn. The average inhalation dose for Winnipeg of 3225  $\mu$ Sv is almost 10 times the value for Vancouver (326  $\mu$ Sv) and more than four times higher than the value for Toronto (757  $\mu$ Sv).

The high inhalation dose for Winnipeg can be attributed to the generally low rainfall in the Prairie Provinces and the associated low moisture content of the ground. This low moisture content allows <sup>222</sup>Rn to migrate easily through the ground and into homes.

#### Cosmic dose

A computer program developed by the FAA was used to derive an annual effective dose from cosmic radiation of 318  $\mu$ Sv. This value is lower than the worldwide average of 380  $\mu$ Sv since most of the Canadian population lives close to sea level.

#### Internal dose

Data presented by UNSCEAR<sup>(7)</sup> were used to determine the annual effective dose of 306  $\mu$ Sv due to radionuclides in the body. This value includes 170  $\mu$ Sv from <sup>40</sup>K and 120  $\mu$ Sv from the uranium

and thorium series plus a small component of 16  $\mu\text{Sv}$  from  $^{14}\text{C}$  and  $^{87}\text{Rb}$ .

#### Total annual effective dose

The total population-weighted average annual effective dose from natural sources of radiation in Canada is 1769  $\mu\text{Sv}$ . This is significantly lower than the worldwide average of 2422  $\mu\text{Sv}$  reported by UNSCEAR<sup>(7)</sup>.

#### ACKNOWLEDGEMENTS

Gamma-Bob Inc. would like to thank Rob Shives, Peter Holman, John Carson, Ken Ford and John Grant of the Radiation Geophysics Section at the GSC for providing the airborne gamma ray data that was used to produce the map of Canada and the United States. Joe Duval from the United States Geological Survey originally provided the United States data to the GSC. Arthur Scott from the Ontario Ministry of Labour provided valuable assistance with the section on indoor and outdoor radon. Thanks are also due to Malcolm Argyle, Jeff Kertesz and Yves Collins of Sander Geophysics for producing the map of the United States and Canada as well as the maps of the road surveys of Toronto, Ottawa, Montreal and Winnipeg. This project was funded by Ontario Power Generation.

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## Annex E

Excerpts from Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, 2000. (UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, Vol. 1: Sources)

215 4a

# SOURCES AND EFFECTS OF IONIZING RADIATION

United Nations Scientific Committee on the Effects of Atomic Radiation  
UNSCEAR 2000 Report to the General Assembly,  
with Scientific Annexes

VOLUME I: SOURCES



UNITED NATIONS

Solar heating during the daytime tends to induce some turbulence, so that radon is more readily transported upwards and away from the ground. At night and in the early morning hours, atmospheric (temperature) inversion conditions are often found, which tend to trap the radon closer to the ground. This means outdoor radon concentrations can vary diurnally by a factor of as much as ten. There are also seasonal variations related to the effects of precipitation or to changes in prevailing winds [B23]. These effects must be taken into account when interpreting the available measurements, many of which are daytime samples.

121. Recent results of radon measurements outdoors tend to confirm the estimates of typical outdoor  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  concentrations made in the UNSCEAR 1993 Report of  $10 \text{ Bq m}^{-3}$  for each [I14]. There is, however, a wide range of long-term average concentrations of  $^{222}\text{Rn}$ , from approximately 1 to more than  $100 \text{ Bq m}^{-3}$ , with the former perhaps typical of isolated small islands or coastal regions and the latter typical of sites with high radon exhalation over large surrounding areas. Although data are sparse for thoron, considerable variability from place to place would be expected because of thoron's short half-life, which means that the effective surface source, about  $0.1 \text{ km}^2$  [S4], is much smaller than that for  $^{222}\text{Rn}$ , emphasizing the effect of local variations in exhalation rate. Even more important is the fact that thoron's short half-life results in a very steep vertical gradient in its atmospheric concentration at any location. A few measurements show that concentrations a few centimeters above the ground surface and concentrations at a height of 1 m vary by a factor of about 10 [D2, I10, N18]. This gradient would be expected to vary considerably with atmospheric conditions. Thus, pronounced time variations would be expected at any height above the ground at any location. This has obvious implications for estimating thoron exposure outdoors and the outdoor air source term for indoor thoron.

122. Direct measurement of the concentrations of all short-lived decay products of  $^{222}\text{Rn}$  and  $^{220}\text{Rn}$  are difficult and limited. They are estimated from considerations of equilibrium (or disequilibrium) between these nuclides and their respective decay products. An equilibrium factor  $F$  is defined that permits the exposure to be estimated in terms of the potential alpha energy concentration (PAEC) from the measurements of radon gas concentration. This equilibrium factor is defined as the ratio of the actual PAEC to the PAEC that would prevail if all the decay products in each series were in equilibrium with the parent radon. However, it is simpler to evaluate this factor in terms of an equilibrium equivalent radon concentration,  $C_{\text{eq}}$ , in the following manner:

$$F = C_{\text{eq}}/C_{\text{Rn}}$$

$$C_{\text{eq}} = 0.105 C_1 + 0.515 C_2 + 0.380 C_3 \quad (^{222}\text{Rn} \text{ series})$$

$$C_{\text{eq}} = 0.913 C_1 + 0.087 C_2 \quad (^{220}\text{Rn} \text{ series})$$

where the symbols  $C_1$ ,  $C_2$ , and  $C_3$  are the activity concentrations of the decay progeny, namely  $^{218}\text{Po}$ ,  $^{214}\text{Pb}$ , and  $^{214}\text{Bi}$ , respectively, for the  $^{222}\text{Rn}$  series and  $^{218}\text{Pb}$  and  $^{212}\text{Bi}$  ( $C_1$  and  $C_2$ ) for the thoron series. The constants are the fractional

contributions of each decay product to the total potential alpha energy from the decay of unit activity of the gas. In this way, a measured radon concentration can be converted to an equilibrium equivalent concentration (EEC) directly proportional to PAEC. This provides a measure of exposure in terms of the product of concentration and time. The EEC can be converted to the PAEC, when desired, by the relationships  $1 \text{ Bq m}^{-3} = 5.56 \cdot 10^{-6} \text{ mJ m}^{-3} = 0.27 \text{ mWL}$  ( $^{222}\text{Rn}$ ) and  $1 \text{ Bq m}^{-3} = 7.6 \cdot 10^{-5} \text{ mJ m}^{-3} = 3.64 \text{ mWL}$  (thoron). Many measurements have been made of  $^{222}\text{Rn}$  and decay product concentrations, allowing estimates to be made of the magnitude of the equilibrium factor to be estimated in terms of both typical values and range. These were discussed in previous reports of the Committee [U3, U4]. More recent extensive measurements in Europe [R1, W10], the United States [W2], Canada [B12], and Japan [H18, K9] indicate typical outdoor  $^{222}\text{Rn}$  equilibrium factors of between 0.5 and 0.7. These results suggest that a rounded value of 0.6 may be more appropriate for the outdoor environment than the previous estimate of 0.8. There is, of course, a wide range of values from individual measurements, which is understandable given the many environmental factors that influence the various radionuclide activity ratios, including the exhalation rates and atmospheric stability conditions. The range of the equilibrium factor for outdoor radon is from 0.2 to 1.0, indicating a degree of uncertainty in the application of a typical value to derive equilibrium equivalent concentrations.

124. The equilibrium factor approach is more difficult to apply to estimate thoron decay product exposure because, unlike the  $^{222}\text{Rn}$  situation, the concentrations of the gas and the decay products at any particular location, indoors or outdoors, may not be closely related. This is primarily due to the half-lives in the decay series, which produce very different distributions in the atmosphere of the gas and the decay products. A very limited amount of data on thoron decay product concentrations outdoors indicated a typical EEC of the order of  $0.1 \text{ Bq m}^{-3}$  [S4].

(b) Indoors

125. There is a wealth of data available on indoor  $^{222}\text{Rn}$  concentrations, and new information is becoming available on indoor thoron. Substantial compilations of  $^{222}\text{Rn}$  results appeared in the UNSCEAR 1988 and 1993 Reports [U3, U4]. These results are supplemented with recent survey data in Table 24. It is sometimes difficult to evaluate the representativeness of results from published reports. New information will be appearing from many countries in Africa, Asia, and South America, partly as a result of the Coordinated Research Programme on Radon in the Environment, sponsored by the International Atomic Energy Agency (IAEA). This will provide a better understanding of how different climates and housing patterns affect radon exposures. At this stage, it does not appear that the survey results have changed markedly from those contained in the UNSCEAR 1993 Report [U3]. In particular, the values of 40 and  $30 \text{ Bq m}^{-3}$  for the arithmetic and geometric means of the distribution of

CONCLUSIONS

193. Since exposures to natural radiation sources are more significant for the world's population than most exposures to man-made sources, the natural background baseline warrants evaluation in some detail. Efforts should continue to broaden the database used for determining both representative values and extremes in exposures and to improve dosimetric procedures.

194. Because of the wide variations in natural background exposures even within relatively small regions, more efforts will be required to determine the detailed distributions of populations within dose intervals for the various components of exposure. Initial, still limited evaluations of distributions of external exposures outdoors and indoors and of the total exposure have been presented in this Annex. These evaluations seem to reveal patterns that would be expected to be generally valid for other countries and for the world population as a whole. The analysis of distributions will provide an improved basis for deriving worldwide average exposures and their normal and extreme variations.

195. The main uncertainties in the assessment of dose from natural radiation sources arise less from the limited number of measurements than from the complications of the dosimetric considerations. The situation with respect to radon decay products is well known, but similar problems exist for cosmic radiation and ingested radionuclides. For cosmic radiation, more information is needed on exposures to neutrons at all altitudes and latitudes, especially high-energy neutrons and high-Z nuclei at aircraft altitudes, along with critical data or improved models to allow a reasonable estimation of effective doses from these components of the radiation field. For ingested radionuclides, good dosimetric models are available, but the problem is to estimate representative intake amounts

of the radionuclides and associate them with relatively fewer determinations of concentrations in tissues of the body.

196. There are many circumstances in which individuals receive enhanced exposures to natural radiation. Living inside buildings is considered normal in this regard, and flying in airplanes usually involves an insignificant proportion of most people's time. In the past, the Committee has reviewed the exposures caused from the release of natural radionuclides in mineral processing industries, the use of phosphate fertilizers, and the combustion of fossil fuels. These enhanced exposures are usually quite insignificant compared with the normal background exposure from natural sources. This conclusion is still valid, based on a brief review of new information in this Annex.

197. The evaluations in this Annex of exposures from natural radiation sources indicate that the average annual effective dose to the world population is approximately 2.4 mSv, which is the same as the previous estimate of the Committee [U3]. The value of the estimated average exposure should not be taken to be too precise, since broad averaging is involved. For individuals, annual exposures ranging from 1 mSv to two or three times the world average are frequently encountered. It is estimated that about 65% of individuals have exposures between 1 and 3 mSv, about 25% of the population have exposures less than 1 mSv, and 10% have exposures greater than 3 mSv. Although the database continues to expand and characterization of the distributions of populations with respect to the various components of natural background radiation is being improved, the generally assessed exposure levels to which the broad spectrum of the world population is exposed seem reasonably well substantiated.

The Committee's estimate of the average annual effective dose to the world population is based on a wide range of data. The magnitude of the dose is not expected to change significantly.

**Table 31**  
**Average worldwide exposure to natural radiation sources**

Source of exposure	Annual effective dose (mSv)	
	Average	Typical range
Cosmic radiation		
Directly ionizing and photon component	0.28 (0.30)	
Neutron component	0.10 (0.08)	
Cosmogenic radionuclides	0.01 (0.01)	
<b>Total cosmic and cosmogenic</b>	<b>0.39</b>	<b>0.3-1.0<sup>a</sup></b>
External terrestrial radiation		
Outdoors	0.07 (0.07)	
Indoors	0.41 (0.39)	
<b>Total external terrestrial radiation</b>	<b>0.48</b>	<b>0.3-0.6<sup>b</sup></b>
Inhalation exposure		
Uranium and thorium series	0.006 (0.01)	
Radon ( <sup>222</sup> Rn)	1.15 (1.2)	
Thoron ( <sup>220</sup> Rn)	0.10 (0.07)	
<b>Total inhalation exposure</b>	<b>1.26</b>	<b>0.2-10<sup>c</sup></b>
Ingestion exposure		
<sup>40</sup> K	0.17 (0.17)	
Uranium and thorium series	0.12 (0.06)	
<b>Total ingestion exposure</b>	<b>0.29</b>	<b>0.2-0.8<sup>d</sup></b>
<b>Total</b>	<b>2.4</b>	<b>1-10</b>

- a Result of previous assessment [U3] in parentheses.
- b Range from sea level to high ground elevation.
- c Depending on radionuclide composition of soil and building materials.
- d Depending on indoor accumulation of radon gas.
- e Depending on radionuclide composition of foods and drinking water.

Source of exposure	Average	Typical range	Reference
Cosmic radiation			
Directly ionizing and photon component	0.28 (0.30)		
Neutron component	0.10 (0.08)		
Cosmogenic radionuclides	0.01 (0.01)		
<b>Total cosmic and cosmogenic</b>	<b>0.39</b>	<b>0.3-1.0<sup>a</sup></b>	
External terrestrial radiation			
Outdoors	0.07 (0.07)		
Indoors	0.41 (0.39)		
<b>Total external terrestrial radiation</b>	<b>0.48</b>	<b>0.3-0.6<sup>b</sup></b>	
Inhalation exposure			
Uranium and thorium series	0.006 (0.01)		
Radon ( <sup>222</sup> Rn)	1.15 (1.2)		
Thoron ( <sup>220</sup> Rn)	0.10 (0.07)		
<b>Total inhalation exposure</b>	<b>1.26</b>	<b>0.2-10<sup>c</sup></b>	
Ingestion exposure			
<sup>40</sup> K	0.17 (0.17)		
Uranium and thorium series	0.12 (0.06)		
<b>Total ingestion exposure</b>	<b>0.29</b>	<b>0.2-0.8<sup>d</sup></b>	
<b>Total</b>	<b>2.4</b>	<b>1-10</b>	

Average worldwide exposure to natural radiation sources

## Annex F

Excerpts from Exploratory Analysis of Radon Data from Ambrosia Lake, New Mexico, SENES Consultants Limited, 1986.  
(Prepared for the American Mining Congress)

EXPLORATORY ANALYSIS OF  
RADON DATA FROM  
AMBROSIA LAKE, NEW MEXICO

Prepared for the  
American Mining Congress

by  
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May 1986



## SUMMARY

In late August 1985 SENES Consultants Limited were retained by the American Mining Congress to review and analyze radon data from the Ambrosia Lake District in the northwest corner of New Mexico. Underground mining for uranium has been intensive in this area.

The purpose of the study was to analyze the available data and draw suitably-founded scientific conclusions concerning any patterns identified in the radon data. Natural radon sources maintain a background of ambient radon to which uranium mining sources are added. The question of whether an estimate of natural background levels could be obtained from the radon data was a particular focus of the study.

The influence of natural and mining radon sources, the effects of a diurnal pattern in radon and radon daughter levels within the Arroyo del Puerto Valley, the history of mine-vent operation and the monitored radon concentrations were investigated. A March 1985 report by the New Mexico Health and Environment Department on radon levels in New Mexico's uranium mining and milling district was also reviewed. These investigations suggest a range of  $1.00 \text{ pCi L}^{-1}$  to  $1.50 \text{ pCi L}^{-1}$  as an estimate of the natural background radon concentration within the Arroyo del Puerto Valley.

the surface are very poor under inversion conditions.

3. The drainage of cold air downslope is a separate though related phenomenon from the inversion itself.
4. Dispersion modeling is not designed to adequately handle this meteorological phenomenon. Gaussian dispersion coefficients are applicable to larger distances and are least accurate under highly stable or trapped plume conditions. Conditions here are F-stability or worse. Wind velocities are very low so that plume meandering is significant\*.

### 2.3 Natural Radon Sources

Natural radon sources include radon released from local soils as well as radon released from outcroppings of uranium mineralization. The outcroppings include Mancos shale, Morrison formations and Todolito formations.

Figure 2.6 is a geological map of the Ambrosia Lake which shows the surface deposits of radioactive formations which contribute to the radon concentration in the Arroyo del Puerto Valley.

### 2.4 Man-Made Radon Sources (Mine Site Layout)

Figure 2.7 shows the Ambrosia Lake mining area layout. The mine site is located at an elevation of approximately 7000 feet in the Arroyo del Puerto Valley.

Man-made radon sources include all radon released from the mining and milling operations, which include emissions from the mine vents, ore pads, tailings piles and evaporation ponds.

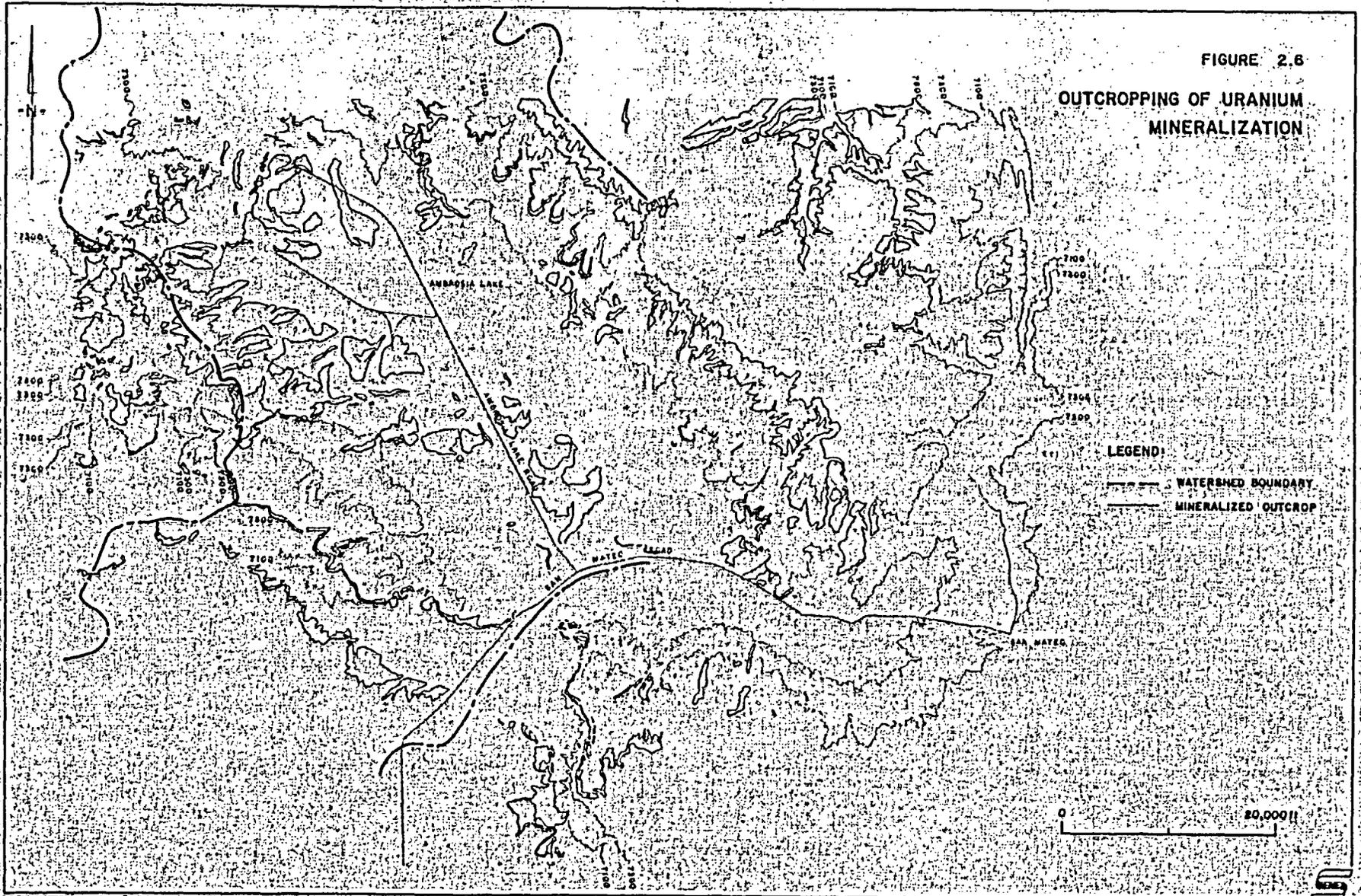
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\* Significant plume meander leads to an averaging in the horizontal crosswind direction and hence a lower concentration than would be predicted using centreline values from a gaussian model.



FIGURE 2.6

OUTCROPPING OF URANIUM  
MINERALIZATION



## 3.0 ANALYSIS OF DATA

### 3.1 Data Base

During the study, considerable radon data and related environmental data (eg. topographical, meteorological and geological data) were provided to SENES. Table 3.1 lists a summary of the data made available to SENES on which the analysis was based.

### 3.2 Presentation of Analysis

#### 3.2.1 Influence of Confounding Sources

Many radon sources contribute to the ambient radon concentration in the Arroyo del Puerto Valley. Confounding sources include all the sources of radon released within the drainage basin of the valley. Natural radon sources include emissions from the surface deposits of Mancos shale, Morrison formations and Todelto formations (Figure 2.6) as well as from the soil. Radon sources that result from the mining and milling operations include emissions from the mine vents, ore pads, tailing piles and evaporation ponds (Figure 2.7). Any analysis of ambient radon data must recognize that all these sources contribute to observed levels. The following discusses the estimated strengths of these various sources.

#### Model for Radon Exhalation from Natural Soils

The rate of radon exhalation from natural materials depend upon the radium concentration and other soil characteristics. The rate of radon exhalation from soil can be predicted by the following equation (NRC, 1980).

$$J = C_{Ra} \rho E \sqrt{\frac{\lambda D}{P}} = C_{Ra} \rho E \sqrt{\lambda k} \quad k = \frac{D}{P} \quad (3.1)$$

## Annex G

Excerpts from Draft Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites, United States Environmental Protection Agency (EPA), 1980. (40 CFR 192, EPA 520/4-80-011)

United States  
Environmental Protection  
Agency

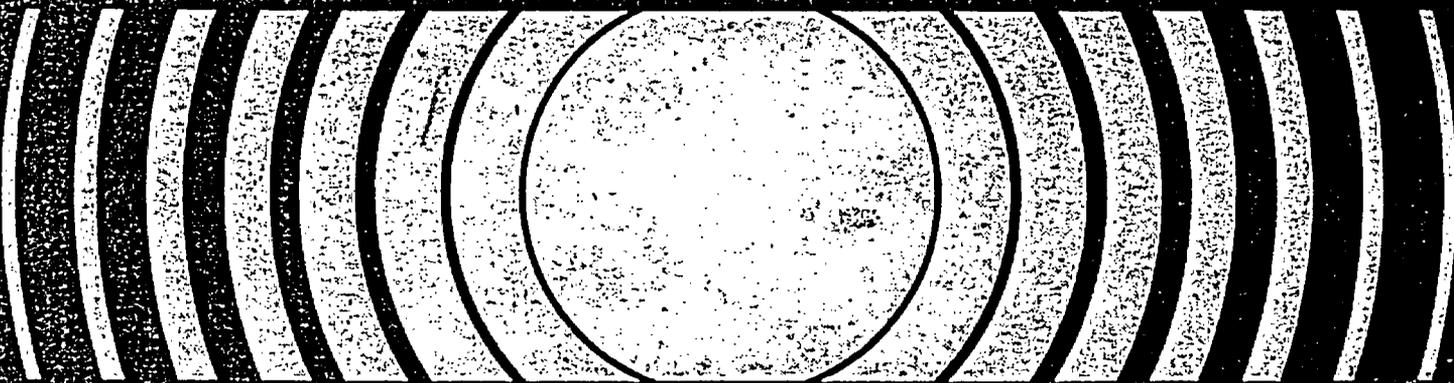
Office of  
Radiation Programs  
Washington DC 20460

  
EPA 520/4-80-011  
December 1980



Radiation

# Draft Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites (40 CFR 192)



this region produces all of its own food. Because this scenario maximizes the dose due to food, it is inappropriate for many of the inactive sites. For tailings near urban areas, with a large number of people living close to the tailings pile, complete dependence on locally supplied food is considerably less likely.

The five sources of exposure in the NRC analysis are shown in Table 4-7. The risk from breathing short half-life radon decay products is more than 10 times greater than the next highest risk, that due to windblown tailings eaten in vegetables and meat. (1) Lead-210 and polonium-210, formed in air following radon decay, are also a source of exposure when deposited on food or breathed. According to the NRC analysis, the risk from each of these pathways equals about one-hundredth of the risk from breathing short half-life radon decay products. Even combined, the total risk from the long half-life radionuclides is much less than the risk from breathing the short half-life radon decay products. Persons living more than 50 miles from an inactive pile would be less heavily exposed and their risk would be considerably below that indicated in Table 4-7.

#### 4.7. Impact from Gamma-Ray Exposure

Many of the radioactive materials in tailings piles are a source of gamma rays. Unlike alpha rays, which must originate within the body to

(1) The NRC analysis for the ingestion pathway is quite conservative because the retention on vegetation assumed for deposited materials (50%), and the transfer of radium from fodder to meat (.003) are larger by a factor of five or more than is usually assumed (EP 78a, MC 79).

TABLE 4-7

Regional Impact from Uranium Mill Tailings

(NRC-GEIS Model Pile and Population)  
Population at Risk--57,300 persons

Number of Cancer  
Deaths Per Year

Inhaled radon decay products	.06(a)
Ingestion of windblown tailings	.004(b)(c)
Inhaled lead-210/polonium-210	.0006(b)
Ingested lead-210/polonium-210	.0006(b)
Inhaled resuspended tailings	.00006(b)

- (a) EPA relative risk estimate based on 2.4 person WL/yr.
- (b) From the computed data for individual radionuclides used to produce the summary tables in the NRC-GEIS (NR-79).
- (c) Particles containing U-238, U-234, Th-234, Th-230, Ra-226, Pb-210, Bi-210; c.f. Fig. 4.1.

become hazardous, gamma rays can penetrate both air and tissue for considerable distances. Near the edge of a pile, the exposure from gamma rays can be many times larger than the background level of gamma rays in uncontaminated areas. The concentration of gamma radiation from the pile, however, decreases rapidly with distance; at more than a few tenths of a mile from most of the inactive tailings piles, it is undetectable above normal background.

Gamma ray exposures to individuals depend on how close to the edge of a pile people live or work. The collective gamma ray dose depends on both the number of people exposed and their average dose. In a few cases individual doses can be approximated from available data, but generally this cannot be done without a variety of information, such as where people live and work and the amount of shielding provided by buildings. Outdoor gamma ray exposures in the vicinity of some tailings piles at inactive sites are summarized in Table 4-8. In several cases, even the nearest residents are far enough from the pile that they receive essentially no excess gamma radiation. At others, a few residents are located close enough to perhaps double the dose from gamma radiation that would occur without the pile. In a few cases, the dose to the nearest resident may be several times normal background levels.

In most of these localities, "normal" background due to penetrating radiation is about 100 mR per year (FB 76-78).<sup>(1)</sup> This radiation exposes

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(1) A milliroentgen (mR), or one one-thousandth of a Roentgen, is a unit of radiation exposure.

## Annex H

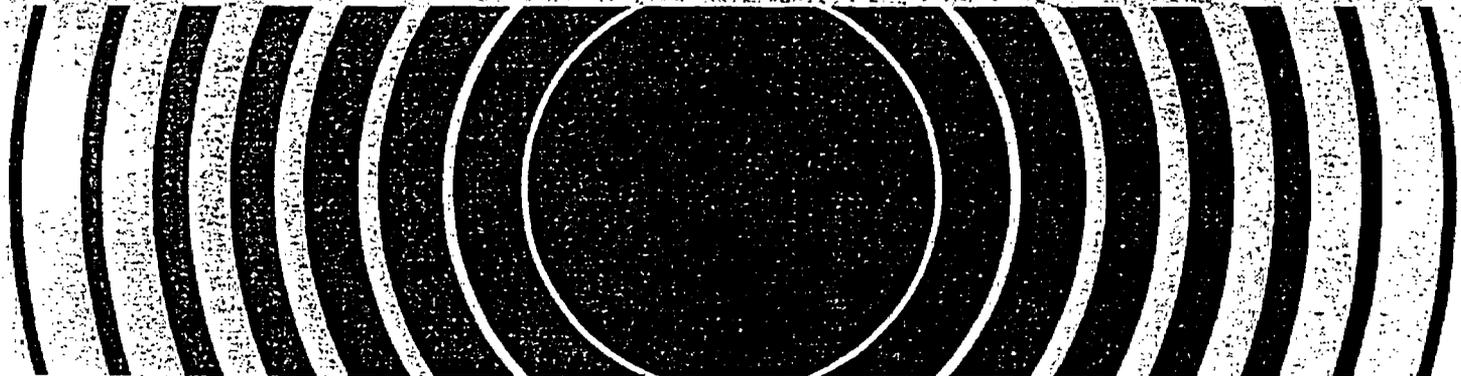
Excerpts from Technical Support for Amending Standards for Management of Uranium Byproduct Materials, United States Environmental Protection Agency (EPA), 1993. (40 CFR Part 192 – Subpart D, Background Information Document, EPA 402-R-93-085)



# Technical Support For Amending Standards For Management Of Uranium Byproduct Materials

## 40 CFR Part 192-Subpart D

### Background Information Document



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#### 4.1.2 Ingrowth of Radon-222 Decay Products

At the point where radon-222 diffuses out of the tailings pile surface, the concentrations of associated radon-222 decay products are zero, because those decay products generated prior to diffusion from the surface are retained in the tailings. As soon as radon-222 is airborne, ingrowth of decay products commences. The quantitative relationship between radon and radon decay products depends on the extent to which radioactive equilibrium is reached. If the rate of formation and disintegration of the decay products suspended in air is exactly equal, a condition of secular equilibrium is reached. Although secular equilibrium is a theoretical upper limit, in reality it is not achievable due to plume depletion of radon daughters by dry and wet deposition and precipitation scavenging.

Human exposure to radon-222 progeny from tailings piles is based on an indoor/outdoor exposure model. The model assumes that the average individual spends about 75 percent of the time indoors and 25 percent outdoors (Mo76; Oa72). Radon-222 and its decay products may enter a structure that is downwind and enhance the normal indoor air concentration.

The specific activity of radon or individual decay product isotopes is commonly quantified in picocuries per liter (pCi/l). However, the specific activity of short-lived radon decay products collectively is also measured in units called working levels (WL). One working level is any concentration of short-life radon-222 progeny having  $1.3 \times 10^5$  MeV per liter of potential alpha energy (FRC67). The relationship between the working level concentration of decay products and the picocurie per liter concentration of radon depends on the degree of equilibrium between radon and radon daughters. At secular equilibrium, one WL is equal to 100 pCi/l of radon-222.

Equation 4-2 defines the relationship between WL and pCi/l in terms of the equilibrium fraction:

$$\text{Equilibrium Fraction} = \frac{[\text{WL}] \times 100}{[\text{pCi/l}]} \quad (\text{Eq. 4-2})$$

The exposure to radon-222 progeny at a site of interest is based on the calculated radon-222 concentration and the calculated radon-222 progeny equilibrium fraction:

$$\begin{array}{l} \text{Radon progeny} \\ \text{concentration} \\ (\text{WL}) \end{array} = \begin{array}{l} \text{Radon} \\ \text{concentration} \\ (\text{pCi/l}) \end{array} \times \begin{array}{l} \text{Radon progeny} \\ \text{equil. fraction} \\ (f_{\text{eff}}) \end{array} \times \begin{array}{l} 1.0 \times 10^{-2} \\ (\text{WL/pCi/l}) \end{array} \quad (\text{Eq. 4-3})$$

## Annex I

External Exposure Model in the Resrad Computer Code, S. Kamboj, D. LePoire  
and C. Yu, 2002. (Health Physics, Vol. 82, No. 6, pages 831-839)

## EXTERNAL EXPOSURE MODEL IN THE RESRAD COMPUTER CODE

S. Kamboj, D. LePoire, and C. Yu\*

**Abstract**—An external exposure model has been developed for the RESRAD computer code that provides flexibility in modeling soil contamination configurations for calculating external doses to exposed individuals. This model is based on the dose coefficients given in the U.S. Environmental Protection Agency's *Federal Guidance Report No. 12* (FGR-12) and the point kernel method. It extends the applicability of FGR-12 data to include the effects of different source geometries, such as cover thickness, source thickness, source area, and shape of contaminated area of a specific site. A depth factor function was developed to express the dependence of the dose on the source thickness. A cover-and-depth factor function, derived from this depth factor function, takes into account the dependence of dose on the thickness of the source region and the thickness of the cover above the source region. To further extend the model for realistic geometries, area and shape factors were derived that depend not only on the lateral extent of the contamination, but also on source thickness, cover thickness, and radionuclides present. Results obtained with the model generally compare well with those from the Monte Carlo N-Particle transport code.

Health Phys. 82(6):831–839; 2002

**Key words:** soil; contamination; environmental; exposure; population; computer calculations

### INTRODUCTION

ESTIMATING THE radiological doses to individuals from external exposure to photons emitted by radionuclides dispersed in the environment is an important aspect of radiological assessment. Many multi-pathway codes compute total effective dose equivalent from radiological contamination in soil. Examples include RESRAD (developed by Argonne National Laboratory for the U.S. Department of Energy; Yu et al. 1993), DandD (developed by Sandia National Laboratory for the U.S. Nuclear Regulatory Commission; Wernig et al. 1999), GENII and GENII-S (developed by Pacific Northwest National Laboratory for DOE; Napier et al. 1988; Leigh et al. 1993), and MEPAS (developed by Pacific Northwest National Laboratory for DOE; Whelan et

al. 1992). The effective dose equivalent (EDE) from external exposure to contaminated soil is calculated primarily by using the dose coefficients, sometimes referred to as dose conversion factors (DCF), for infinite plane or slab sources. Although many studies have been published in the literature on the DCFs for external exposure to photon emitters distributed in the environment (e.g., Beck 1972; O'Brien and Sanna 1976; Kocher 1981; Kramer and Drexler 1982; Kocher and Sjoreen 1985; Jacob et al. 1986; Chen 1991; Eckerman and Ryman 1993), the DCFs published are mainly for infinite plane or slab sources.

The external dose models used in most current codes are either simple, conservative, or do not provide flexibility in accounting for varying physical soil contamination characteristics, such as thickness, area, or configuration. The DandD code, for example, only considers a 15-cm-thick infinite slab of contaminated soil and uses the FGR-12 DCF for a 15-cm-thick slab in the external pathway dose calculations. Thus, this code could underestimate or overestimate the dose, depending on the actual source geometry of the contamination. For example, soil contaminated to an infinite depth with  $^{60}\text{Co}$  would have an effective dose equivalent 20% higher than soil contaminated to a depth of 15 cm with  $^{60}\text{Co}$  (Eckerman and Ryman 1993). The GENII and GENII-S codes allow the user to model two layers of contaminated soil: surface and deep. Surface contamination is contained in the first 15 cm of soil; deep soil contamination may be located at any depth below the first 15 cm. The external model in GENII calculates the external exposure in roentgens per hour by using a modified version of the ISOSHIELD code (Engel et al. 1966) and then converts the results to effective dose equivalent by using the information provided in Kocher (1981). The MEPAS external exposure model converts the soil contamination concentration of any depth to an equivalent average surface soil concentration and then multiplies this value by the dose factor of an infinitely large plane source. This procedure overestimates the external pathway doses. For example, if FGR-12 DCFs were used, the MEPAS external exposure model would overestimate the dose by at least 50% for soil contaminated with  $^{60}\text{Co}$  to a depth of 1 cm. In addition, the MEPAS model does not apply any correction for finite contaminated areas.

The external model discussed here has been incorporated into the RESRAD code to overcome some of these limitations. RESRAD is designed to evaluate the potential radiological doses incurred by an individual who lives at a site with residual radioactivity in soil. The

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code focuses on radioactive contaminant transport in air, water, and biological media to a single receptor. Nine exposure pathways are considered in RESRAD: direct external exposure; inhalation of particulates and radon; and ingestion of plant foods, meat, milk, aquatic foods, water, and soil. The code uses a pathway analysis method in which the relation between radionuclide concentrations in soil and doses to a member of a critical group is expressed as a pathway sum. The RESRAD external exposure model described here provides flexibility in modeling soil contamination configurations (as schematically depicted in Fig. 1) for calculating direct external exposure pathway doses to exposed individuals (Fig. 1).

In 1993, the U.S. Environmental Protection Agency (EPA) published Federal Guidance Report No. 12 (FGR-12) (Eckerman and Ryman 1993), which provided DCFs for exposure to a contaminated ground surface and to soil (density of  $1,600 \text{ kg m}^{-3}$ ) contaminated to thicknesses of 0.01, 0.05, 0.15 m, and to an effectively infinite thickness. Although FGR-12 provides DCFs for some discrete contaminant thicknesses, these values cannot be used for any contaminant thickness, area, or geometry. The RESRAD external exposure model presented in this paper extends the FGR-12 data beyond its limitations of fixed geometry and large area.

In FGR-12, the assumption was made that sources were infinite in lateral extent. In actual situations, soil contamination can have any thickness, shape, cover, or size. For the RESRAD model, a depth factor function was developed on the basis of regression analysis of FGR-12 data to allow expression of DCFs for a continuous range of source thickness. A cover-and-depth factor function was derived from this depth factor function by taking into account the dependence of dose on the thickness of the source region and the thickness of the cover above the source region. To extend the model for finite irregular areas, area-and-shape factors were derived by means of the point kernel method. These factors depend not only on the lateral extent of the contamination, but also on source thickness, cover thickness, and radionuclides (Kamboj et al. 1998). Finally, to evaluate the results of the new model, the doses calculated for different contaminant thicknesses, cover thicknesses, areas, and shapes were compared with Monte

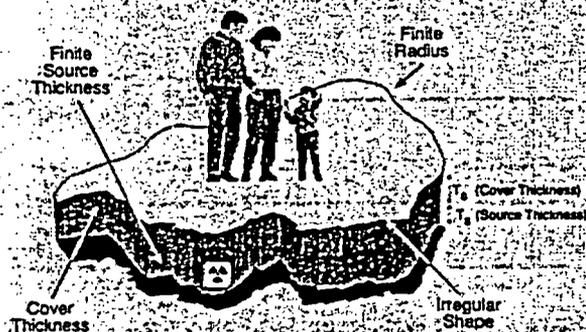


Fig. 1. Exposure geometry of contamination.

Carlo N-Particle (MCNP) transport code computations (Briesmeister 1993).

## METHOD

The dose from external exposure to soils contaminated with a single radionuclide of unit concentration can be written as

$$EDE = DCF \times F_{CD} \times F_A \times F_S \quad (1)$$

where

$EDE$  = effective dose equivalent;

$DCF$  = dose conversion factor (or dose coefficient) for the radionuclide in a uniformly contaminated soil of infinite thickness and lateral extent;

$F_{CD}$  = correction factor for finite thickness and cover (cover-and-depth factor) [when no cover is present,  $F_{CD}$  reduces to  $F_D$ , a correction factor for finite thickness (depth factor)];

$F_A$  = correction factor for finite area (area factor); and

$F_S$  = correction factor for noncircular shape (shape factor).

When the DCF is multiplied by  $F_{CD}$ , the dose equivalent is obtained for a geometry with the given source thickness and cover thickness but an infinite lateral extent.  $F_A$  accounts for the finite radius, but the source is still assumed to be circular;  $F_S$  accounts for irregular source shapes.

### Depth factor

The depth factor ( $F_D$ ) is based on regression analysis of the dose coefficients at different contaminant depths in FGR-12. The following functional form (eqn 2) was chosen because photons are attenuated exponentially with distance within the absorbing media, and multiple distances and photon energies are involved. This functional form could be extended to include more terms, but only limited data were available from FGR-12; therefore, the following functional form with two exponential terms was chosen:

$$F_D = \frac{DCF(T_s = t_s)}{DCF(T_s = \infty)} = 1 - Ae^{-K_A t_s} - Be^{-K_B t_s} \quad (2)$$

where

$DCF(T_s = t_s)$  = FGR-12 DCF at different depths;

$t_s$  = source thickness (m);

$\rho$  = soil bulk density ( $\text{kg m}^{-3}$ );

$A, B$  = fitted parameters (dimensionless); and

$K_A, K_B$  = fitted parameters ( $\text{m} \cdot \text{kg}^{-1}$ ).

The unknown parameters ( $A, B, K_A, K_B$ ) were found via linear regression analysis for the 84 radionuclides available in the RESRAD computer code. It can be easily seen that  $F_D = 1$  when the source is infinitely thick.

Three constraints were used in the regression analysis: (1)  $A + B = 1$  to ensure that the depth factor is zero at

zero source thickness; (2) the parameters were forced to be positive; and (3) the DCF approaches infinitely thin (i.e., ground surface), DCFs reported in FGR-12 as the source thickness approaches zero. The analysis was conducted only for radionuclides with nonzero DCFs (the DCFs for  $^3\text{H}$ ,  $^{41}\text{Ca}$ ,  $^{55}\text{Fe}$ ,  $^{59}\text{Ni}$ ,  $^{63}\text{Ni}$ ,  $^{147}\text{Sm}$ , and  $^{152}\text{Gd}$  were zero).

**Cover-and-depth factor**

The cover-and-depth factor ( $F_{CD}$ ) was derived on the basis of the depth factor function by considering the dependence of dose on the thickness of the source region and the thickness of the cover above the source region:

$$F_{CD} = \frac{D(T_c = t_c, T_s = t_s)}{D(T_c = 0, T_s = \infty)} = Ae^{-K_A t_c} (1 - e^{-K_B t_s}) + Be^{-K_A t_c} (1 - e^{-K_B t_s}) \quad (3)$$

where

- $t_c$  = cover thickness (m);
- $\rho_c$  = cover bulk density ( $\text{kg m}^{-3}$ );
- $t_s$  = source thickness (m);
- $\rho_s$  = source bulk density ( $\text{kg m}^{-3}$ );
- A, B = fitted parameters (dimensionless); and
- $K_A, K_B$  = fitted parameters ( $\text{m}^2 \text{kg}^{-1} \text{y}$ ).

Again, it can be easily seen that  $F_{CD} = 1$  when cover thickness is zero and the source thickness is infinite ( $F_{CD} = A + B = 1$ ).

**Area factor**

The area factor for a circular area,  $a_r$ , was calculated as the ratio of the dose integrals for the geometry being considered (source radius  $r_s$ , thickness  $t_s$ , cover thickness  $t_c$ , and height of the receptor above cover = 1 m) to the infinite slab geometry (Fig. 2):

$$F_A(E, a_r) = \frac{D(R = r_s, T_c = 1\text{m}, T_s = t_s, T_r = t_s)}{D(R = \infty, T_c = 1\text{m}, T_s = t_s, T_r = t_s)} \quad (4)$$

where

$F_A(E, a_r)$  = area factor for photon of energy  $E$ , and

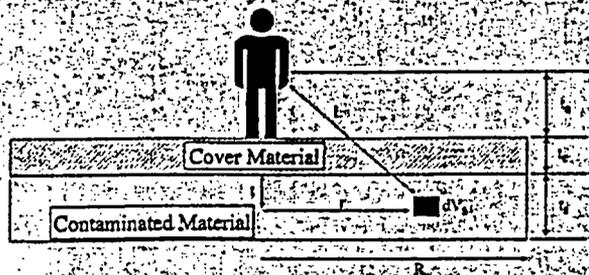


Fig. 2. Cross section of exposure geometry showing element of integration for area factor calculation (contaminated material thickness =  $t_s$ , cover material thickness =  $t_c$ , and receptor distance in air =  $t_r$ ).

$D$  = the dose evaluated by using the point kernel method (Fig. 2).

For a monoenergetic source, a common energy factor in both numerator and denominator of eqn (4) will cancel. The equation for dose after removing this energy factor can be represented by the following function,  $D'$ :

$$D'(r_s, t_c, t_s) = \int_V e^{-\mu_a z} \frac{B(z)}{4\pi r^2} dV_s \quad (5)$$

where

- $\mu_a = \mu_a t_c + \mu_c t_c + \mu_s t_s$
- $r^2 = r_s^2 + (t_c + t_s + t_r)^2$
- $dV_s = 2\pi r t_s dr$
- $t$  = source thickness from the volume element  $dV_s$ ;
- $l$  = receptor distance from the volume element  $dV_s$ ;
- $t_c$  = height of the receptor above cover;
- $\mu_a$  = attenuation coefficient of air;
- $\mu_c$  = attenuation coefficient of the cover material;
- $\mu_s$  = attenuation coefficient of the source material; and
- $B(z)$  = energy absorption buildup factor (Trubey 1991) for length measured in mean free paths,  $z$ .

The area factor (for any specific radionuclide) for a circular area,  $a_r$  (geometry with radius  $r_s$ ),  $F_A^{nucl}(a_r)$ , combines the energy-dependent area factors weighted by their photon yields,  $P_i^{nucl}$ , and dose contributions at the reference point. The photon spectra were obtained from International Commission on Radiological Protection Publication 38 (ICRP 1983).

$$F_A^{nucl}(a_r) = \frac{\sum F_A(E, a_r) P_i^{nucl} D_{slab}(E_i)}{\sum P_i^{nucl} D_{slab}(E_i)} \quad (6)$$

where

$D_{slab}(E_i)$  = dose contribution for energy  $E_i$  from the slab geometry (the values were computed from the FGR-12 values for the monoenergetic source uniformly distributed to an infinite depth).

**Shape factor**

The shape factor,  $F_{sh}$ , was calculated as the ratio of the dose estimates from a noncircular-shaped contaminated area to a reference shape. The reference shape was a fully contaminated, circularly shaped contaminated zone encompassing the given shape, centered at the receptor location. This factor was derived by considering the area factors for a series of concentric circles and the corresponding contamination fractions for the  $nr$  annular regions. The shape factor was obtained by enclosing the irregularly shaped contaminated area in a circle, multiplying the area factor of each annulus by the fraction of

Table 1. Four fitted parameters—A, B, K<sub>1</sub>, and K<sub>2</sub>—to calculate cover-and-depth factor for 84 radionuclides.

Radionuclide	A	B	K <sub>1</sub> (m <sup>2</sup> kg <sup>-1</sup> )	K <sub>2</sub> (m <sup>2</sup> kg <sup>-1</sup> )
<sup>1</sup> H	0.00	0.00	0.00	0.00
<sup>12</sup> C	6.431 × 10 <sup>-1</sup>	3.579 × 10 <sup>-1</sup>	2.940 × 10 <sup>-2</sup>	3.369 × 10 <sup>-1</sup>
<sup>13</sup> C	9.263 × 10 <sup>-1</sup>	7.370 × 10 <sup>-1</sup>	8.740 × 10 <sup>-2</sup>	1.331 × 10 <sup>-1</sup>
<sup>23</sup> Na	9.276 × 10 <sup>-1</sup>	7.240 × 10 <sup>-1</sup>	7.940 × 10 <sup>-2</sup>	1.284 × 10 <sup>-1</sup>
<sup>27</sup> Al	3.405 × 10 <sup>-1</sup>	6.595 × 10 <sup>-1</sup>	3.312 × 10 <sup>-1</sup>	2.846 × 10 <sup>-1</sup>
<sup>32</sup> S	8.885 × 10 <sup>-1</sup>	1.115 × 10 <sup>-1</sup>	1.325 × 10 <sup>-1</sup>	1.886 × 10 <sup>-1</sup>
<sup>35</sup> Cl	7.260 × 10 <sup>-1</sup>	9.274 × 10 <sup>-1</sup>	1.269 × 10 <sup>-1</sup>	7.700 × 10 <sup>-1</sup>
<sup>39</sup> K	0.00	0.00	0.00	0.00
<sup>40</sup> Ca	2.519 × 10 <sup>-1</sup>	7.481 × 10 <sup>-1</sup>	2.743 × 10 <sup>-1</sup>	2.259 × 10 <sup>-1</sup>
<sup>44</sup> Ca	7.290 × 10 <sup>-1</sup>	9.271 × 10 <sup>-1</sup>	1.352 × 10 <sup>-1</sup>	8.530 × 10 <sup>-1</sup>
<sup>52</sup> Cr	8.480 × 10 <sup>-1</sup>	9.152 × 10 <sup>-1</sup>	1.215 × 10 <sup>-1</sup>	8.790 × 10 <sup>-1</sup>
<sup>56</sup> Fe	0.00	0.00	0.00	0.00
<sup>57</sup> Fe	9.276 × 10 <sup>-1</sup>	7.240 × 10 <sup>-1</sup>	8.190 × 10 <sup>-1</sup>	1.374 × 10 <sup>-1</sup>
<sup>59</sup> Co	9.288 × 10 <sup>-1</sup>	7.120 × 10 <sup>-1</sup>	1.604 × 10 <sup>-1</sup>	1.671 × 10 <sup>-1</sup>
<sup>60</sup> Co	9.235 × 10 <sup>-1</sup>	7.650 × 10 <sup>-1</sup>	7.830 × 10 <sup>-1</sup>	1.263 × 10 <sup>-1</sup>
<sup>63</sup> Cu	0.00	0.00	0.00	0.00
<sup>65</sup> Cu	0.00	0.00	0.00	0.00
<sup>66</sup> Zn	9.271 × 10 <sup>-1</sup>	7.290 × 10 <sup>-1</sup>	8.370 × 10 <sup>-1</sup>	1.327 × 10 <sup>-1</sup>
<sup>70</sup> Ge+D	9.270 × 10 <sup>-1</sup>	7.300 × 10 <sup>-1</sup>	9.940 × 10 <sup>-1</sup>	1.412 × 10 <sup>-1</sup>
<sup>74</sup> Se	6.850 × 10 <sup>-1</sup>	9.315 × 10 <sup>-1</sup>	1.552 × 10 <sup>-1</sup>	1.245 × 10 <sup>-1</sup>
<sup>78</sup> Sr	7.210 × 10 <sup>-1</sup>	9.279 × 10 <sup>-1</sup>	1.441 × 10 <sup>-1</sup>	9.990 × 10 <sup>-1</sup>
<sup>82</sup> Sr	8.998 × 10 <sup>-1</sup>	1.002 × 10 <sup>-1</sup>	1.279 × 10 <sup>-1</sup>	1.763 × 10 <sup>-1</sup>
<sup>84</sup> Sr+D	9.074 × 10 <sup>-1</sup>	9.260 × 10 <sup>-1</sup>	1.202 × 10 <sup>-1</sup>	1.699 × 10 <sup>-1</sup>
<sup>86</sup> Nb	9.275 × 10 <sup>-1</sup>	7.250 × 10 <sup>-1</sup>	9.100 × 10 <sup>-1</sup>	1.378 × 10 <sup>-1</sup>
<sup>90</sup> Nb	7.480 × 10 <sup>-1</sup>	9.252 × 10 <sup>-1</sup>	1.363 × 10 <sup>-1</sup>	9.120 × 10 <sup>-1</sup>
<sup>92</sup> Zr+D	9.298 × 10 <sup>-1</sup>	7.020 × 10 <sup>-1</sup>	9.300 × 10 <sup>-1</sup>	1.445 × 10 <sup>-1</sup>
<sup>96</sup> Zr	7.871 × 10 <sup>-1</sup>	2.129 × 10 <sup>-1</sup>	2.106 × 10 <sup>-1</sup>	2.589 × 10 <sup>-1</sup>
<sup>100</sup> Ru	9.271 × 10 <sup>-1</sup>	7.290 × 10 <sup>-1</sup>	9.570 × 10 <sup>-1</sup>	1.409 × 10 <sup>-1</sup>
<sup>102</sup> Ag	9.282 × 10 <sup>-1</sup>	7.180 × 10 <sup>-1</sup>	9.670 × 10 <sup>-1</sup>	1.442 × 10 <sup>-1</sup>
<sup>106</sup> Ag+D	9.261 × 10 <sup>-1</sup>	7.390 × 10 <sup>-1</sup>	8.740 × 10 <sup>-1</sup>	1.339 × 10 <sup>-1</sup>
<sup>108</sup> Cd	6.534 × 10 <sup>-1</sup>	3.466 × 10 <sup>-1</sup>	2.047 × 10 <sup>-1</sup>	4.753 × 10 <sup>-1</sup>
<sup>110</sup> Sn+D	9.272 × 10 <sup>-1</sup>	7.280 × 10 <sup>-1</sup>	1.070 × 10 <sup>-1</sup>	1.652 × 10 <sup>-1</sup>
<sup>114</sup> Sb	1.109 × 10 <sup>-1</sup>	8.891 × 10 <sup>-1</sup>	9.478 × 10 <sup>-1</sup>	7.380 × 10 <sup>-1</sup>
<sup>118</sup> Sb	9.273 × 10 <sup>-1</sup>	7.270 × 10 <sup>-1</sup>	1.005 × 10 <sup>-1</sup>	1.507 × 10 <sup>-1</sup>
<sup>120</sup> Te	7.763 × 10 <sup>-1</sup>	2.237 × 10 <sup>-1</sup>	3.481 × 10 <sup>-1</sup>	3.700 × 10 <sup>-1</sup>
<sup>124</sup> Te	8.540 × 10 <sup>-1</sup>	1.460 × 10 <sup>-1</sup>	3.451 × 10 <sup>-1</sup>	4.422 × 10 <sup>-1</sup>
<sup>128</sup> Te	4.350 × 10 <sup>-1</sup>	5.650 × 10 <sup>-1</sup>	7.137 × 10 <sup>-1</sup>	3.555 × 10 <sup>-1</sup>
<sup>132</sup> Ce	9.266 × 10 <sup>-1</sup>	7.340 × 10 <sup>-1</sup>	9.260 × 10 <sup>-1</sup>	1.379 × 10 <sup>-1</sup>
<sup>136</sup> Ce	7.254 × 10 <sup>-1</sup>	2.746 × 10 <sup>-1</sup>	2.508 × 10 <sup>-1</sup>	3.030 × 10 <sup>-1</sup>
<sup>138</sup> Ce+D	9.281 × 10 <sup>-1</sup>	7.190 × 10 <sup>-1</sup>	9.470 × 10 <sup>-1</sup>	1.411 × 10 <sup>-1</sup>
<sup>140</sup> Ce	9.187 × 10 <sup>-1</sup>	8.130 × 10 <sup>-1</sup>	1.457 × 10 <sup>-1</sup>	1.683 × 10 <sup>-1</sup>
<sup>142</sup> Ce+D	9.116 × 10 <sup>-1</sup>	8.840 × 10 <sup>-1</sup>	9.380 × 10 <sup>-1</sup>	1.411 × 10 <sup>-1</sup>
<sup>144</sup> Pm	7.726 × 10 <sup>-1</sup>	2.274 × 10 <sup>-1</sup>	2.087 × 10 <sup>-1</sup>	2.780 × 10 <sup>-1</sup>
<sup>147</sup> Sm	0.00	0.00	0.00	0.00
<sup>151</sup> Sm	3.310 × 10 <sup>-1</sup>	9.669 × 10 <sup>-1</sup>	8.270 × 10 <sup>-1</sup>	4.926 × 10 <sup>-1</sup>
<sup>153</sup> Eu	9.100 × 10 <sup>-1</sup>	9.000 × 10 <sup>-1</sup>	8.400 × 10 <sup>-1</sup>	1.185 × 10 <sup>-1</sup>
<sup>155</sup> Eu	8.939 × 10 <sup>-1</sup>	1.061 × 10 <sup>-1</sup>	8.250 × 10 <sup>-1</sup>	1.008 × 10 <sup>-1</sup>
<sup>157</sup> Eu	8.569 × 10 <sup>-1</sup>	1.431 × 10 <sup>-1</sup>	1.912 × 10 <sup>-1</sup>	1.486 × 10 <sup>-1</sup>
<sup>159</sup> Gd	0.00	0.00	0.00	0.00
<sup>163</sup> Gd	8.226 × 10 <sup>-1</sup>	1.774 × 10 <sup>-1</sup>	1.986 × 10 <sup>-1</sup>	1.983 × 10 <sup>-1</sup>
<sup>167</sup> Ta	9.233 × 10 <sup>-1</sup>	7.670 × 10 <sup>-1</sup>	8.490 × 10 <sup>-1</sup>	1.337 × 10 <sup>-1</sup>
<sup>171</sup> Ta	9.306 × 10 <sup>-1</sup>	6.940 × 10 <sup>-1</sup>	1.078 × 10 <sup>-1</sup>	1.482 × 10 <sup>-1</sup>
<sup>173</sup> Au	8.772 × 10 <sup>-1</sup>	1.228 × 10 <sup>-1</sup>	2.380 × 10 <sup>-1</sup>	1.880 × 10 <sup>-1</sup>
<sup>175</sup> Pt	8.679 × 10 <sup>-1</sup>	1.321 × 10 <sup>-1</sup>	2.068 × 10 <sup>-1</sup>	1.923 × 10 <sup>-1</sup>
<sup>187</sup> Pb+D	7.502 × 10 <sup>-1</sup>	2.498 × 10 <sup>-1</sup>	1.753 × 10 <sup>-1</sup>	2.200 × 10 <sup>-1</sup>
<sup>189</sup> Po	9.269 × 10 <sup>-1</sup>	7.310 × 10 <sup>-1</sup>	9.040 × 10 <sup>-1</sup>	1.385 × 10 <sup>-1</sup>
<sup>191</sup> Bi	9.246 × 10 <sup>-1</sup>	7.540 × 10 <sup>-1</sup>	8.890 × 10 <sup>-1</sup>	1.350 × 10 <sup>-1</sup>
<sup>193</sup> Ra+D	9.272 × 10 <sup>-1</sup>	7.280 × 10 <sup>-1</sup>	8.350 × 10 <sup>-1</sup>	1.315 × 10 <sup>-1</sup>
<sup>195</sup> Ra+D	9.266 × 10 <sup>-1</sup>	7.340 × 10 <sup>-1</sup>	8.770 × 10 <sup>-1</sup>	1.371 × 10 <sup>-1</sup>
<sup>197</sup> Ac+D	9.229 × 10 <sup>-1</sup>	7.710 × 10 <sup>-1</sup>	1.172 × 10 <sup>-1</sup>	1.512 × 10 <sup>-1</sup>
<sup>199</sup> Th+D	9.277 × 10 <sup>-1</sup>	7.230 × 10 <sup>-1</sup>	7.550 × 10 <sup>-1</sup>	1.261 × 10 <sup>-1</sup>
<sup>201</sup> Th+D	9.130 × 10 <sup>-1</sup>	8.700 × 10 <sup>-1</sup>	1.130 × 10 <sup>-1</sup>	1.491 × 10 <sup>-1</sup>
<sup>203</sup> Th	8.628 × 10 <sup>-1</sup>	1.372 × 10 <sup>-1</sup>	1.871 × 10 <sup>-1</sup>	4.033 × 10 <sup>-1</sup>
<sup>205</sup> Th	8.152 × 10 <sup>-1</sup>	1.848 × 10 <sup>-1</sup>	2.082 × 10 <sup>-1</sup>	5.645 × 10 <sup>-1</sup>
<sup>207</sup> Pu	9.295 × 10 <sup>-1</sup>	7.050 × 10 <sup>-1</sup>	1.163 × 10 <sup>-1</sup>	2.014 × 10 <sup>-1</sup>
<sup>209</sup> U	8.086 × 10 <sup>-1</sup>	1.914 × 10 <sup>-1</sup>	1.754 × 10 <sup>-1</sup>	6.021 × 10 <sup>-1</sup>
<sup>211</sup> U	8.889 × 10 <sup>-1</sup>	1.112 × 10 <sup>-1</sup>	1.394 × 10 <sup>-1</sup>	4.179 × 10 <sup>-1</sup>
<sup>213</sup> U	7.229 × 10 <sup>-1</sup>	2.771 × 10 <sup>-1</sup>	1.937 × 10 <sup>-1</sup>	7.238 × 10 <sup>-1</sup>
<sup>215</sup> U	9.292 × 10 <sup>-1</sup>	7.080 × 10 <sup>-1</sup>	1.383 × 10 <sup>-1</sup>	1.813 × 10 <sup>-1</sup>
<sup>217</sup> U	5.932 × 10 <sup>-1</sup>	4.068 × 10 <sup>-1</sup>	1.980 × 10 <sup>-1</sup>	8.379 × 10 <sup>-1</sup>
<sup>219</sup> U+D	8.590 × 10 <sup>-1</sup>	1.410 × 10 <sup>-1</sup>	9.190 × 10 <sup>-1</sup>	1.111 × 10 <sup>-1</sup>
<sup>221</sup> Np+D	9.255 × 10 <sup>-1</sup>	7.450 × 10 <sup>-1</sup>	8.228 × 10 <sup>-1</sup>	1.671 × 10 <sup>-1</sup>
<sup>223</sup> Pu	2.972 × 10 <sup>-1</sup>	7.028 × 10 <sup>-1</sup>	1.958 × 10 <sup>-1</sup>	9.011 × 10 <sup>-1</sup>
<sup>225</sup> Pu	8.002 × 10 <sup>-1</sup>	1.998 × 10 <sup>-1</sup>	1.348 × 10 <sup>-1</sup>	6.550 × 10 <sup>-1</sup>
<sup>227</sup> Pu	2.972 × 10 <sup>-1</sup>	7.023 × 10 <sup>-1</sup>	2.176 × 10 <sup>-1</sup>	8.997 × 10 <sup>-1</sup>
<sup>231</sup> Pu	9.132 × 10 <sup>-1</sup>	8.680 × 10 <sup>-1</sup>	1.582 × 10 <sup>-1</sup>	2.027 × 10 <sup>-1</sup>
<sup>233</sup> Pu	3.314 × 10 <sup>-1</sup>	6.686 × 10 <sup>-1</sup>	2.109 × 10 <sup>-1</sup>	8.982 × 10 <sup>-1</sup>
<sup>235</sup> Pu	9.259 × 10 <sup>-1</sup>	7.410 × 10 <sup>-1</sup>	9.260 × 10 <sup>-1</sup>	1.431 × 10 <sup>-1</sup>
<sup>237</sup> Am	8.365 × 10 <sup>-1</sup>	1.635 × 10 <sup>-1</sup>	3.130 × 10 <sup>-1</sup>	2.883 × 10 <sup>-1</sup>

Table 1.—(Continued)

Radionuclide	A	B	$K_A$ ( $m^2 kg^{-1}$ )	$K_B$ ( $m^2 kg^{-1}$ )
$^{241}Am+D^*$	$9.098 \times 10^{-1}$	$9.020 \times 10^{-2}$	$1.473 \times 10^{-2}$	$1.642 \times 10^{-1}$
$^{242}Cm$	$9.247 \times 10^{-1}$	$7.530 \times 10^{-2}$	$1.350 \times 10^{-2}$	$1.662 \times 10^{-1}$
$^{243}Cm$	$7.000 \times 10^{-1}$	$9.930 \times 10^{-1}$	$8.461 \times 10^{-1}$	$2.194 \times 10^{-1}$
$^{244}Cm$	$7.333 \times 10^{-1}$	$2.667 \times 10^{-1}$	$1.042 \times 10^0$	$1.215 \times 10^{-1}$
$^{137}Cs$	$6.505 \times 10^{-1}$	$3.495 \times 10^{-1}$	$7.259 \times 10^{-1}$	$0.182 \times 10^{-1}$

\*+D\* means that associated radionuclides with half life less than 1 mo are also included with the principal radionuclide.

the annulus area that was contaminated,  $f_i$ , summing the products, and dividing by the area factor of a circular contaminated zone that was equivalent in area:

$$F_s = \frac{\sum_{i=1}^n f_i [F_A^{nuc}(a_i) - F_A^{nuc}(a_{i-1})]}{F_A^{nuc} \left( \sum_{i=1}^n (a_i - a_{i-1}) f_i \right)} \quad (7)$$

where  $F_A^{nuc}(a)$  is the area factor for circular area  $a$ , of given source thickness and cover thickness.

#### Comparisons with other calculations

Two phases of comparison were performed. In the first phase, the regression analysis was tested against the original data from FGR-12. In the second phase, components of the model ( $F_D$ ,  $F_{CD}$ ,  $F_A$ , and  $F_S$ ) were tested separately, with an independent dose calculation done with the MCNP computer code.

The FGR-12 DCFs at four thicknesses (0.01, 0.05, 0.15 m, and an effectively infinite thickness) were used to calculate  $F_D$ . The  $F_{CD}$  was then derived from  $F_D$  (for example by subtracting the FGR-12 source data for 0.01 m from 0.05 m would give dose for a source thickness of 0.04 m with 0.01 m cover).

The MCNP 4A version of the Monte Carlo N-particle transport code was used to calculate the external EDE at a distance of 1 m from contaminated soil of varying thickness. The gamma energies and their respective abundances were taken from ICRP Publication 38 (ICRP 1983). Flux was calculated at a height of 1 m from the contaminated cylindrical sources, using a point detector next-event estimator. This flux was used to calculate the EDE by using a conversion coefficient (ICRP 1987) between EDE and fluence. For the calculations, rotational symmetry was assumed. Soil and air composition data were taken from FGR-12 (Eckerman and Ryman 1993). A soil density of  $1600 kg m^{-3}$  was assumed. The statistical uncertainty in MCNP calculations was less than 5% at one standard deviation ( $\sigma$ ).

## RESULTS AND DISCUSSION

#### Regression analysis

Table 1 lists the parameter values of A, B,  $K_A$ , and  $K_B$  found by linear regression analysis for the 84 radionuclides in the RESRAD code.

Results obtained from the regression analysis (using the fitted parameters) were compared with the source

FGR-12 data for 84 radionuclides at thicknesses of 0.01, 0.05, and 0.15 m and for an effectively infinite-thick source. Table 2 gives data on the statistical analysis of the results. The analysis was conducted only for radionuclides with nonzero DCFs (the DCFs for  $^3H$ ,  $^{41}Ca$ ,  $^{55}Fe$ ,  $^{59}Ni$ ,  $^{63}Ni$ ,  $^{147}Sm$ , and  $^{152}Gd$  were zero). The statistical analysis provides the average, standard deviation, and maximum deviation by source thickness for 77 radionuclides. For 0.01-m-thick sources, a maximum deviation of 5% was observed for  $^{124}Sb$  and  $^{155}Eu$ . For 0.05-m-thick sources, a maximum deviation of 4% was observed for  $^{238}U$ . For 0.15-m-thick sources, a maximum deviation of 4% was observed for  $^{40}K$ ,  $^{144}Ce$ ,  $^{182}Ta$ , and  $^{228}Th$ . For infinitely thick sources, values were within 1%.

The results of new model dose calculations using cover and depth factors were also compared with the FGR-12 radionuclide-specific dose calculations for  $^{26}Al$ ,  $^{54}Mn$ ,  $^{60}Co$ ,  $^{109}Cd$ , and  $^{137}Cs$  (Table 3). For the FGR-12 calculations, the EDE for a source thickness of 0.04 m with 0.01 m cover, for example, was calculated by subtracting the value for a 0.01-m-thick source from the value for a 0.05-m-thick source. For a cover thickness of 0.01 m, most values from the new model were within 2% of the FGR-12 values; the maximum difference was 5%. For cover thicknesses of 0.05 and 0.15 m, most values were within 10%; the maximum difference was less than 20%.

#### Depth factor

Fig. 3 shows the effect of source thickness for an infinite-extent soil contaminated with different radionuclides of varying gamma energies ( $^{54}Mn$ ,  $^{57}Co$ ,  $^{60}Co$ , and  $^{234}U$ ). The depth factor increases as the average gamma

Table 2. Statistical analysis of the ratio of the dose using depth factor and FGR-12 results.

Item	Source thickness			
	0.01 m	0.05 m	0.15 m	Infinite*
Number of data points	77	77	77	77
Average	1.00	0.998	1.01	0.999
Standard deviation	0.011	0.005	0.014	0.001
Maximum deviation <sup>b</sup>	5%	4%	4%	1%

\*It was assumed that a 1-m-thick source in the model would represent infinite source thickness in FGR-12 for all radionuclides shown in Table 1.

<sup>b</sup>Maximum observed deviations were 5% for  $^{124}Sb$  and  $^{155}Eu$  for 0.01-m source thickness; 4% for  $^{238}U$  for 0.05-m thickness; and 4% for  $^{40}K$ ,  $^{144}Ce$ ,  $^{182}Ta$ , and  $^{228}Th$  for 0.15-m thickness.

Table 3. Ratio of FGR-12 and the external exposure model estimated dose for different source configurations.

Nuclide	Ratio (FGR-12/Model) for different source configuration					
	Cover = 0.01 m			Cover = 0.05 m		Cover = 0.15 m
	Source = 0.04 m	Source = 0.14 m	Source = infinite	Source = 0.10 m	Source = infinite	Source = infinite
<sup>60</sup> Co	1.00	1.05	1.00	1.10	1.00	0.81
<sup>54</sup> Mn	0.99	1.02	1.00	1.06	1.00	0.85
<sup>60</sup> Co	0.98	1.04	1.00	1.09	1.01	0.86
<sup>109</sup> Cd	1.00	0.99	1.00	0.95	1.00	0
<sup>137</sup> Cs	1.00	1.03	1.00	1.06	1.00	0.84

\* The ratio is zero for a <sup>109</sup>Cd source of infinite thickness with 0.15-m-thick cover because the estimated dose for an infinite source with 0.15-m cover is calculated by subtracting the effective dose equivalent value for a 0.15-m-thick source (case 1) from the value for an infinite thick source (case 2). In FGR-12, there is practically no difference in the two cases, and the difference in the doses estimated with the RESRAD model for the two cases is less than 1%.

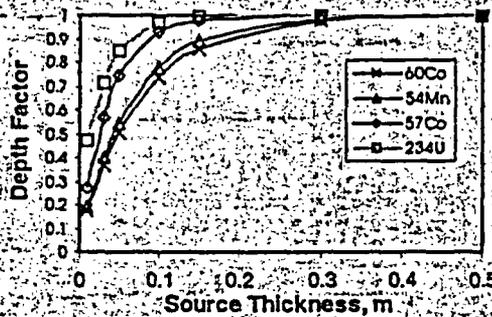


Fig. 3. Depth factor for soil contaminated with different radionuclides.

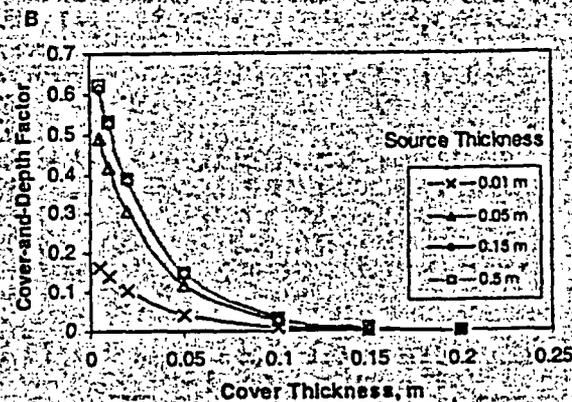
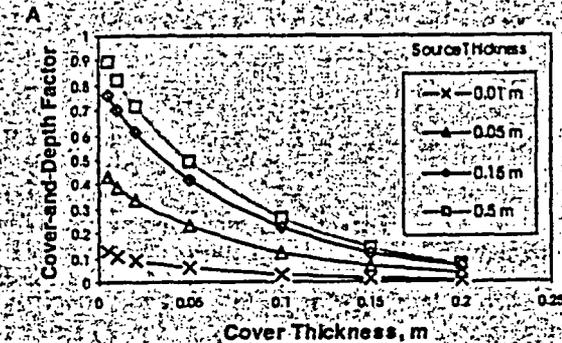
energy emitted by radionuclides decreases and approaches unity as the source thickness increases [For example, a depth factor value of 0.47 for <sup>234</sup>U (gamma energies < 0.1 MeV) compared with 0.18 for <sup>60</sup>Co (gamma energies > 1 MeV) for a soil uniformly contaminated to 0.01-m thickness]. The depth factor is dependent on radionuclide and source thickness.

#### Cover-and-depth factor

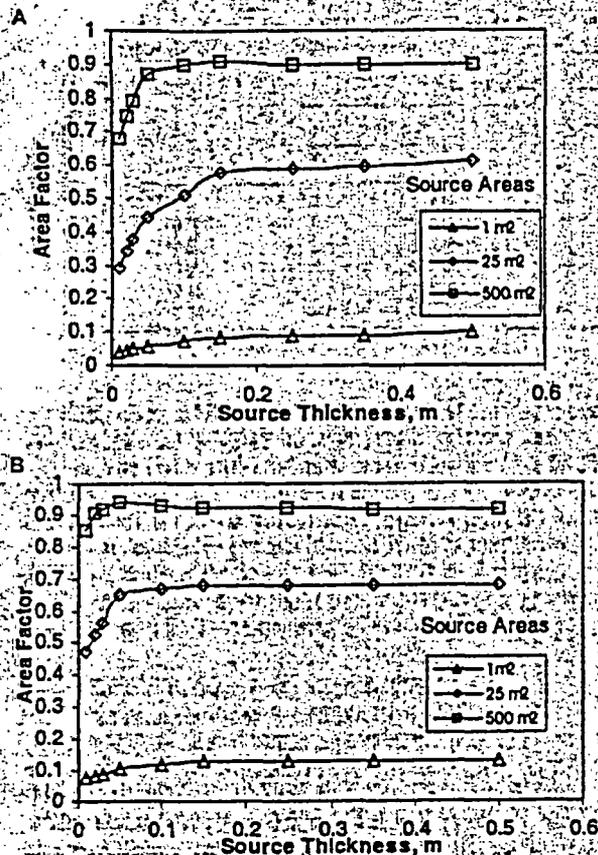
Fig. 4a illustrates the variations of the cover-and-depth factor as the cover thickness changes for different source thicknesses. The source is assumed to be an infinite-lateral-extent soil contaminated with <sup>60</sup>Co. The rate of change in cover-and-depth factors depends on source thickness. The cover-and-depth factors also depend on radionuclides. Fig. 4b shows the cover-and-depth factor for infinite-lateral-extent soil uniformly contaminated with <sup>234</sup>U. The cover-and-depth factor for <sup>234</sup>U decreases sharply with cover thickness compared with high-energy <sup>60</sup>Co and also becomes independent of source thickness beyond a certain thickness. This condition is due to the self absorption of the radiation emitted from the inner layers in the source itself.

#### Area factor

Fig. 5a shows the area factor as the source thickness changes for different contaminated areas. The source is

Fig. 4a. Cover-and-depth factor for different <sup>60</sup>Co source thickness.  
Fig. 4b. Cover-and-depth factor for different <sup>234</sup>U source thickness.

assumed to be soil uniformly contaminated with <sup>60</sup>Co. The area factor changes considerably when the source area is changed. For example, the area factor for a 0.5-m-thick source changes from 0.1 to 0.9 when the source area changes from 1 m<sup>2</sup> to 500 m<sup>2</sup>. The area factor also strongly depends on source thickness. For example, the area factor for a 500-m<sup>2</sup> contaminated area changes from 0.7 to 0.9 when the source thickness increases from 0.01 m to 0.5 m. The area factor also depends on the radionuclides present and thickness of cover. Fig. 5b

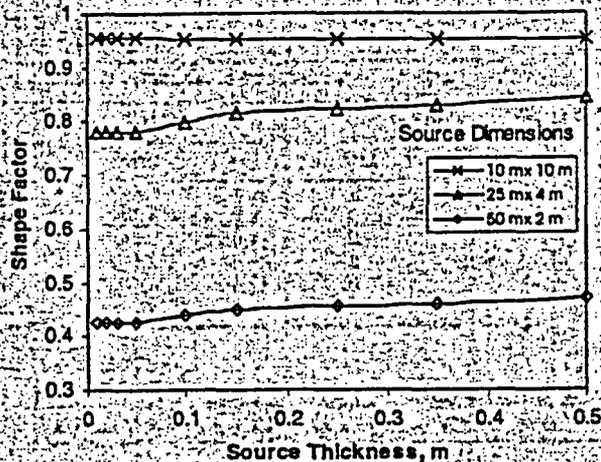
Fig. 5a. Area factor for different  $^{60}\text{Co}$  source areas.Fig. 5b. Area factor for different  $^{238}\text{U}$  source areas.

shows the area factor variations for soil uniformly contaminated with  $^{238}\text{U}$ . The area factor for  $^{238}\text{U}$ , a low-energy gamma emitter, is higher than the area factor for  $^{60}\text{Co}$ , a high-energy gamma emitter. This situation occurs because a smaller area source is equivalent to an infinite area source for a low-energy gamma emitter compared with a high-energy gamma emitter.

The area factor calculated with the RESRAD code was compared with the area factor calculated on the basis of NUREG/CR-3620 (Napier et al. 1984) methodology, and the results for different energies and source configurations are compared in Kamboj et al. (1998).

#### Shape factor

Fig. 6 shows the shape factor dependence on source thickness and different shapes. The source was assumed to be a 100-m<sup>2</sup> area contaminated with  $^{60}\text{Co}$ . Three types of rectangular shapes of different lengths and widths (length = 10 m and width = 10 m; length = 25 m and width = 4 m; and length = 50 m and width = 2 m) but of the same area were compared. The shape factor is close to unity when the shape is square but decreases as

Fig. 6. Shape factor for different shapes of  $^{60}\text{Co}$  source of 100 m<sup>2</sup> area.

the shape becomes elongated. The shape factor changes slightly with source thickness.

#### Depth factor comparison with MCNP

Doses were compared between the MCNP code and the new RESRAD model at different source thickness for soil contaminated with  $^{54}\text{Mn}$  and  $^{60}\text{Co}$  (Table 4). These two radionuclides were chosen because of their relatively simple decay schemes. Source thickness was varied from 0.005 to 1 m. For the depth factor function, the comparison showed that the ratio of new model to MCNP values varied between 1.12 and 0.94; in most cases, differences were less than 7%.

#### Cover-and-depth factor comparison with MCNP

The cover-and-depth factor results were compared with MCNP calculations for  $^{54}\text{Mn}$  and  $^{60}\text{Co}$  at source thicknesses ( $r_s$ ) of 0.01, 0.05, 0.15, and 0.5 m and six cover thicknesses ranging from 0 to 0.25 m (Table 5). In

Table 4. Comparison of dose estimation between MCNP and the model (using depth factor function) for  $^{54}\text{Mn}$  and  $^{60}\text{Co}$ .

Source thickness (m)	Ratio (Model/MCNP) for $^{54}\text{Mn}$ and $^{60}\text{Co}$	
	$^{54}\text{Mn}$	$^{60}\text{Co}$
0.005	1.12	1.11
0.01	1.07	1.07
0.03	1.01	1.00
0.05	1.00	0.99
0.1	1.01	1.02
0.15	1.03	1.03
0.25	0.964	1.00
0.35	0.942	0.976
0.50	0.929	0.968
1.0	0.994	0.994

\* Contaminated cylindrical soil areas of effectively infinite radius with different source thickness.

Table 5. Comparison of dose estimation between MCNP and the model (using cover-and-depth factor function) as a function of cover thickness at different source thickness ( $r_s$ ) for  $^{54}\text{Mn}$  and  $^{60}\text{Co}$ .

Cover (m)	Ratio (Model/MCNP) for four different thicknesses of $^{54}\text{Mn}$ and $^{60}\text{Co}$							
	$r_s = 0.01$ m		$r_s = 0.05$ m		$r_s = 0.15$ m		$r_s = 0.50$ m	
	$^{54}\text{Mn}$	$^{60}\text{Co}$	$^{54}\text{Mn}$	$^{60}\text{Co}$	$^{54}\text{Mn}$	$^{60}\text{Co}$	$^{54}\text{Mn}$	$^{60}\text{Co}$
0.0	1.07	1.07	1.00	0.99	1.03	1.03	0.93	0.97
0.005	0.99	1.02	0.98	0.98	1.00	1.01	0.94	0.98
0.02	0.99	0.99	1.00	1.01	0.96	0.98	0.92	0.89
0.05	1.01	1.06	1.00	1.01	0.92	0.97	0.89	0.85
0.10	0.94	1.01	0.92	0.97	0.85	0.85	0.80	0.75
0.25	0.66	0.70	0.63	0.66	0.62	0.61	0.58	0.50

In general, the results are in good agreement for source thicknesses up to 0.15 m and cover thicknesses up to 0.1 m (i.e., the ratio of new model values to MCNP values is close to unity) (Kamboj et al. 1998). The differences for cover thicknesses greater than 0.1 m and source thicknesses greater than 0.15 m occur because in FGR-12 source thickness was limited to 4.0 mean free paths. Extending the model beyond 4.0 mean free paths would result in large uncertainties.

#### Area factor comparison with MCNP

The area factor was compared with the MCNP code for a few source geometries. Comparisons were done for a cylindrical  $^{60}\text{Co}$  source at nine different radii (1, 2, 3, 5, 10, 20, 30, 50, and 100 m) and at four source thicknesses (0.01, 0.05, 0.15, and 0.5 m). Table 6 gives the ratio of the area factor estimated by the new external model to that associated with the MCNP. A maximum difference of 16% was observed for a thin source with a small radius. As the source thickness or the radius increases, the ratio approaches unity.

#### Shape factor comparison with MCNP

The doses calculated with the model for  $^{60}\text{Co}$  contamination of different source thicknesses for three types of rectangular shapes of different lengths and widths (length = 10 m and width = 10 m; length = 25 m and width = 4 m; and length = 50 m and width = 2 m) were compared with the results from the MCNP code. Table 7 gives the ratio of the dose estimated by the new external

Table 6. Ratio of the area factor estimated for  $^{60}\text{Co}$  source by new model to MCNP values for different radii and thicknesses ( $r_s$ ).

Radius (m)	Ratio (Model/MCNP) for different thicknesses			
	$r_s = 0.01$ m	$r_s = 0.05$ m	$r_s = 0.15$ m	$r_s = 0.5$ m
1	0.85	0.85	0.93	0.91
2	0.84	0.88	0.99	0.98
3	0.84	0.90	1.01	0.98
5	0.85	0.96	1.06	1.01
10	0.88	0.99	1.07	1.01
20	0.93	1.01	1.08	1.00
30	0.94	1.01	1.07	1.00
50	0.98	1.01	1.05	0.99
100	1.00	1.00	1.00	1.00

Table 7. Ratio of the dose estimated by new model to MCNP values for three rectangular shapes of  $^{60}\text{Co}$  contamination.

Source thickness (m)	Ratio (Model/MCNP) for three different rectangular shapes		
	Length = 10 m Width = 10 m	Length = 25 m Width = 4 m	Length = 50 m Width = 2 m
	0.01	0.84	0.89
0.02	0.83	0.87	0.74
0.03	0.84	0.87	0.73
0.05	0.92	0.94	0.78
0.10	0.95	0.97	0.80
0.15	1.01	1.02	0.82
0.25	0.97	0.98	0.78
0.35	0.95	0.96	0.77
0.50	0.94	0.96	0.78
Average	0.92	0.94	0.77

model to that from the MCNP. The average dose ratio for  $^{60}\text{Co}$  sources of different shapes varied from 0.77 to 0.94. The maximum difference (18–27%) was observed for the most elongated source (length = 50 m and width = 2 m).

#### Comparison of results

The doses estimated with MCNP and the depth factor function, when the source thickness varied from 0.005 to 1.0 m for  $^{60}\text{Co}$  and  $^{54}\text{Mn}$ , were within 12%, and in most cases differences were less than 7%. The dose comparison at four FGR-12 source thicknesses showed that for most of the radionuclides, the dose values were within 2%. The cover-and-depth factor was compared with MCNP calculations for  $^{54}\text{Mn}$  and  $^{60}\text{Co}$  and with FGR-12 calculations for  $^{26}\text{Al}$ ,  $^{54}\text{Mn}$ ,  $^{60}\text{Co}$ ,  $^{109}\text{Cd}$ , and  $^{137}\text{Cs}$ . That comparison showed that for small cover thicknesses, most values were within 2% of each other, while for large cover thicknesses (0.05, 0.15 m), most values were within 10%. The area factors of  $^{60}\text{Co}$  sources with varying dimensions (source radii changing from 1 to 100 m and thickness changing from 0.01 to 0.5 m) were compared with MCNP results. Most of the results were within 10% of each other. A maximum difference of 16% was observed for a source with small radius and small thickness.

## CONCLUSION

The new external exposure model discussed here has been incorporated into the RESRAD code (Yu et al. 1993). The model extends the applicability of FGR-12 data to a wider range of source geometries. Parameters extracted from regression analysis of FGR-12 data were used to develop depth and cover factors. The model was further extended by using the point kernel method for area and shape factors. Results from execution of the model show that dose depends on radionuclide, source thickness, source area, cover thickness, and on the actual shape of the contaminated area. The new external model allows the RESRAD code to compute external pathway doses for different contaminant configurations (i.e. different cover thickness, source thickness, and source area and shape). This model has been incorporated into other members of the RESRAD family of codes (Yu 1999), and it can be easily adapted to other multiple pathway codes that calculate external dose due to soil contamination.

**Acknowledgments**—This work was supported by the U.S. Department of Energy, Office of Environmental Policy and Assistance and Office of Environmental Restoration, under Contract W-31-109-Eng-38.

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## **Annex J**

**Excerpts from Final Generic Environmental Impact Statement on Uranium  
Milling, United States Nuclear Regulatory Commission (NRC),  
1980 (NUREG-0706, Vol. III, Appendices G-V).**



Table G-5.2 Inhalation Dose Conversion Factors For Occupational Exposure (mrem/yr per pCi/m<sup>3</sup>)<sup>a</sup>

Yellowcake Dust (Particle Size = 1.0 Microns, Density = 8.9 g/cm <sup>3</sup> )						
Organ	U-238	U-234	U-235	U-238	U-234	U-235
Average Lung	3.57 E+02	4.03 E+02				
Whole Body	3.27	3.73	3.73	3.73	3.73	3.73
Bone	5.53 E+01	6.03 E+01				

Uranium Ore Dust (Particle size = 5.0 Microns, Density = 2.4 g/cm <sup>3</sup> )						
Organ	U-238	U-234	Th-230	Ra-226	Pb-210	Po-210
Average Lung	2.44 E+01	2.77 E+01	4.60 E+02	9.47 E+02	1.10 E+02	6.27 E+01
Whole Body	1.64	1.87	3.37 E+01	1.33 E+01	1.61	2.37 E-01
Bone	2.77 E+01	3.02 E+01	1.20 E+03	1.33 E+02	5.00 E+01	9.63 E-01

<sup>a</sup>The dose conversion factors given are for an occupational exposure of 40 hrs/week; they can be converted to continuous exposure (168 hrs/week) by multiplying by a factor of 3.

where  $C_{aip}$  is the total air concentration of isotope  $i$ , in particle size  $p$ , pCi/m<sup>3</sup>,

$d_j(\text{inh})$  is the resulting inhalation dose to organ  $j$ , mrem/yr,

and

$DCF_{ijp}(\text{inh})$  is the inhalation dose conversion factor for isotope  $i$ , particle size  $p$ , and organ  $j$ , mrem/yr per pCi/m<sup>3</sup>.

## 1.2 Inhalation Dose Conversion Factor for Radon Daughters

The only pathway of radon gas into the body is by inhalation, but it is not readily absorbed or deposited in the lung; thus, the dose from radon to the lung or other body tissue is not of great significance. However, radon decays with a 3.82-day half-life through a series of short-lived daughter products (longest half-life in this chain is 27 minutes) to lead-210 with a 22-year half-life. The short-lived daughters, rather than radon itself, are of primary concern relative to the inhalation pathway.

Even though the dose rate from radon in the atmosphere is small, the dose rate from radon daughters may provide significant exposure (Refs. 4-6). Radon daughters formed in air are rapidly attached to aerosol particles as a result of their rapid diffusion. Rates of attachment are dependent on the concentration of particles in the atmosphere, the ambient humidity (Ref. 2 and 7), and the surface-to-volume ratio of the particles. The observed mean half-life before attachment of a positive ion to atmospheric particles is less than 20 minutes. Since the first daughter product, Po-218, has a radioactive half-life of about three minutes, it is likely to decay to Pb-214 before becoming attached to an aerosol particle. Because of their longer radioactive half-lives, the other radon daughters are more likely to attach to atmospheric aerosols than is Po-218.

Unattached radon daughters are very readily deposited and retained on respiratory surfaces. The dose rate from radon daughters associated with aerosols, as for other particulates, is dependent on the particle's physical characteristics, such as diameter, shape, and density. Also, the ratio of concentrations of radon daughters in the atmosphere to the concentration of radon is related to the mixing and dilution volume. Under equilibrium conditions, the activity of each daughter is equal to the activity of radon. A condition of equilibrium can be approached in a tightly enclosed volume, such as a poorly ventilated room.

In this analysis doses to the critical lung tissue, the bronchial epithelium, from inhalation of short-lived radon daughters are computed on the basis of 100 percent indoor exposure in an adequately ventilated room using a dose conversion factor of 0.625 mrem/yr indoors per pCi/m<sup>3</sup> of Rn-222 in outdoor air. The basis upon which the staff has relied for this dose conversion factor consists of three major component parts as follows:

# EXHIBIT C

UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD PANEL

Before Administrative Judge  
E. Roy Hawkins, Presiding Officer  
Dr. Richard F. Cole, Special Assistant  
Dr. Robin Brett, Special Assistant

In the Matter of: )

HYDRO RESOURCES, INC. )

P.O. Box 777 )

Crownpoint, NM 87313 )

Docket No.: 40-8958-ML

ASLBP No. 95-706-01-ML

July 27, 2005

**AFFIDAVIT OF SALVADOR CHAVEZ**

Before me, the undersigned notary on this day appeared Salvador Chavez, a person known or identified to me, and who after being duly sworn deposes and says the following in response to the Intervenor's Brief with Respect to Radioactive Air Emissions Dated June 13, 2005.

**I. PERSONAL.**

1. My name is Salvador Chavez; I reside at 1001 San Jose Drive, Grants, New Mexico 87020. I am over 21 years of age; I never been convicted of a felony; and, I am fully capable of making this Affidavit.

2. The factual matters set out herein are within my personal knowledge as set out herein.

**II. QUALIFICATIONS.**

3. I hold a High School Diploma from St Francis Seminary in Cincinnati, Ohio and have had additional technical training as specified in my Resume found in Attachment A.

4. I was employed by Hydro Resources, Inc. as an Environmental Coordinator from 11/1988 - 01/2001. My duties in that position are presented in my Resume.

5. While employed at Hydro Resources, I was responsible for sealing the open mineshafts at the Old Church Rock mine on Section 17.

### III. MATERIALS PREPARED AND REVIEWED.

6. I have reviewed the Intervenor's Brief with Respect to Radioactive Air Emissions where they assert that radioactive air emissions are venting from the old mineshafts at Hydro Resources, Inc.'s Section 17 property.

### IV. THE MINE SHAFTS AT THE OLD CHURCHROCK MINE HAVE BEEN SEALED AND SAFEGUARDED.

7. There were four openings into the Section 17 Old Churchrock Mine

- The Main Shaft - 10 foot 6" diameter
- Ventilation and Escape Shaft - 10 foot diameter
- Ventilation Shaft - 44" diameter
- Gravel Hole - 16" diameter Surface casing with 12" diameter gravel casing

8. In October and November of 1994 these openings were sealed under my supervision as described below.

9. **Main Shaft:** A steel platform was manufactured by Western Machine of Milan, NM to contain the cement. The platform was designed to extend one foot into the shaft and was built of 4" steel "I" beams. Five 4" steel "I" beams and six 4" steel "T" beams were placed across the top of the shaft after the platform was in place. A 1/4" steel plate was placed on top of the steel beams. 5/8 inch rebar was placed in two layers to reinforce the concrete. The concrete pour resulted in a two foot thick steel reinforced concrete plug, one foot above the shaft collar and one foot below the surface level. The cement was 3000 psi supplied by Gallup Sand and Gravel of Gallup, NM. A 6" diameter steel pipe with cap was inserted through the cement slab to provide a method of measuring water levels.

10. A 36" steel pipe extending to the south *out* of the shaft was plugged at its entrance with a steel plate and cement.

11. A utility tunnel extending from the shaft to the West was plugged at its entrance with dirt and a two foot thick cement plug. An entrance at the center of this tunnel is sealed with a steel plate welded to the tunnel liner.

12. A photograph of the sealed main shaft is within Attachment 2.

13. **Escape Shaft:** Six 4" steel channels were placed across the top of the shaft, one foot below the collar. A 14 inch steel plate was placed above the steel beams. Four inch "T" steel beams were placed across the shaft above the steel plate. Four inch "I" beams were placed across the top of the shaft at the collar. 5/8 inch reinforcing rebar was placed in three layers. A 3000 psi two foot thick cement plug was poured one foot above and one foot below the shaft collar. A 6 inch steel pipe with cap was inserted through the concrete slab for testing purposes.

A six foot diameter tunnel extending to the north from the shaft was sealed with a steel plate across the tunnel four feet below the surface.

14. A photograph of the sealed ventilation/escape shaft is within Attachment 2.

15. **Vent Shaft:** A 1/8 inch steel plate was welded on top of the casing two feet below the ground level. Six 5/8 inch reinforcing rebar were placed one foot above the steel plate. Five foot diameter steel liner was used to contain the cement pour. The resulting cement plug is two feet above the steel plate and extends one foot below the top of the casing. The top of the cement plug is at ground level and has a six inch steel pipe with cap inserted through it for testing purposes.

16. A photograph of the sealed vent shaft is within Attachment 2.

17. **Gravel Hole:** A steel plate was placed on top of the casing one foot below ground level. A five foot diameter steel tunnel liner was used to contain the concrete pour. The cement plug is five foot in diameter and is sixteen inches thick with 5/8 inch reinforcing rebar and is at ground level. A six inch capped steel pipe was placed through in the slab for testing purposes.

18. No photograph is available of the sealed gravel hole.

**IV. SLUDGE IN THE TREATMENT PONDS AT THE OLD CHURCHROCK MINE HAS BEEN REMOVED.**

19. I monitored and oversaw UNC's removal of the barium chloride sludge from the Sec. 17 ponds. Therefore, to the best of my knowledge all that remains at the Section 17 sight is a veneer of ore material and waste rock.

20. This ends my Affidavit.

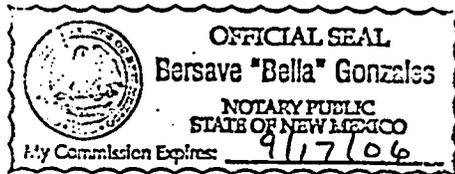
I declare on this 22<sup>st</sup> day of July in Grants, New Mexico, under penalty of perjury that the foregoing is true and correct.

*Salvador Chavez*  
Salvador Chavez

**ACKNOWLEDGEMENT**

SUBSCRIBED and SWORN TO before me, the undersigned authority, on July 22, 2005 by Salvador Chavez.

[Seal]



*Bersave (Bella) Gonzales*  
[Signature of Notary]

*Bersave (Bella) Gonzales*  
Printed/typed name of Notary

Notary public for the State of New Mexico. My commission expires 9/17/06.

Attachment 1  
Resume



maintenance and supervise repairs. Assist with exploration and property evaluations and assessments. Provide information for community and public relations. Conduct tours and make presentations. Ensure the security of the properties and leases. Complete and supply safety and environmental reports for state, federal and tribal agencies. Conduct safety inspections and accompany federal and state inspectors. Complete time sheets, purchase orders, invoices, receiving and shipping documents, including hazardous materials, employee benefits forms and reports for state and federal agencies. Assist with acquiring and maintaining leases and mining claims. Locate, preserve and maintain project records pertaining to ownership, minerals, exploration and reclamation. Gather data for permits and licenses. Submit yearly and monthly budget requests. Was the Radiation Safety Officer and on the transportation accident response team. Responsible for the care and maintenance of 25,000 sq. feet of buildings and two mine sites. Directed the clean up of three mining areas. Supervision 12 years.

**Westinghouse Electric Corp  
Site Superintendent**

**Crownpoint, NM  
01/1984 – 10/1988**

Evaluate, select and advertise surplus equipment (\$8 million) for sale or transfer and arrange dismantling, packing, loading and transportation. Supervise Crownpoint based personnel (7) and contractors. Establish work schedules and maintain 24 hour security. Supply and maintain information on mine site status regarding permits, reserves and leases. Set up and direct preventative maintenance and supervise repairs including contract work. Handle environmental, safety, inspections and employee safety training. Preserve and maintain project records. Was responsible for community relations, conducting tours and making presentations. Completed time sheets, purchase orders, receiving and shipping, employee benefits forms and reports for local, state and federal agencies. Submitted budget requests for yearly operating expenses. (\$500,000). Was responsible for the care of a mine site including buildings (\$1.3 million), equipment (\$8.3 million) and the security of shafts (\$18 million). Supervision /management 4 years.

**Conoco/Wyoming Mineral JV  
Project Supervisor**

**Crownpoint, NM  
07/1980 - 12/1984**

Supervise Crownpoint site personnel (8). Insure the security, maintenance and care of property valued at \$27 million. Supply and maintain data on the mine site status pertaining to permits, reserves and leases. I directed preventative maintenance and repairs and selected contractors and contract work. Completed personnel, safety, and environmental reports for local, state and federal agencies. Accompanied inspectors and conducted site tours. Conducted safety training, public relations and presentations. Submitted budgets and expenditures for yearly operating expenses (\$500,000).

#### **Ventilation Engineer**

Determine ventilation requirements and design the ventilation system for underground mines. Specify and select the main mine fans. Estimate emissions from mine exhausts and review dispersion modeling studies. Determine costs for the ventilation of underground mines. Was acting safety engineer and a member of Conoco's speakers program. Supervision 4 years (management 2 years).

**The Anaconda Company  
Ventilation Engineer**

**Jackpile Mine Laguna NM  
1974 – 07/1980**

Planned supervised and maintained ventilation in existing underground Uranium mines and planned ventilation for future mines. Supervised the control of exposure to radiation and the maintenance of exposure records. Was an instructor in mine emergency training and safety instruction of new employees and kept employees aware of safety requirements. Supplied required records and reports to appropriate state and federal agencies. Supplied assistance and information to the American Mining Congress and the NM Mining Association. Accompanied inspectors and conducted mine tours. Supervision (4 years)

**Kerr McGee Nuclear  
Environmental Tech**

**Ambrosia Lake, NM  
1970 – 1974**

Conducted underground environmental monitoring and sampling to ensure exposure was kept to a minimum. Conducted training in safety. Accompanied mine inspectors. Prepared safety and environmental and safety reports. Estimate future ventilation requirements.

**Magna Oil Corp/ Moki Oil  
Ventilation Tech**

**Ambrosia Lake, NM  
1968 – 1970**

Underground mine ventilation and exposure control. Surveying, drafting, contract payment calculations. Safety training. Directed underground mine ventilation.

**Homestake Sapin Partners  
Operator Class C**

**Grants, NM  
1967 - 1968**

The milling of uranium ore and the extraction, packaging and shipping of uranium.

**US Army  
Medical Lab Sp4**

**Japan, Guam, Korea  
1965 –1967**

Medical lab procedures and testing.

### **Training**

2005 Compensation & Classification, Procurement Procedures Basic  
2004 Civil Rights ADA & Sexual Harassment, Clean Water Act, Cross Section of Stockpiles, Drug and Alcohol Awareness for Supervisors, Employee Development and Appraisal, FMIS Upgrade, Investing In Leadership, Site Manager Change Orders, Contractor Payments and DWR, Stockpile Estimates, Web Focus End User,

- 2003 Compensation and Leave Benefits, Employee Development, FMIS, HMMS, My Smart Force, Nuts and Bolts Employee Management Relations, Introduction to Alternative Dispute Resolution, Accounting, Budgets, Procurement Procedure Overview, Safe and Secure Measures for Front Desk Personnel, The Hiring Process, Time and Attendance, Web Focus End User, Web Focus Customized for Administrators, Workforce Violence Prevention and Mitigation for Supervisors
- 2002 Basic Supervisor Overview, Behavioral Interviewing, Documenting Discipline, Pad Overview, TTCP, Radiological Safety and Theory, Microsoft Word 2000-Level 1, Microsoft Excel 2000-Beginning, Microsoft Outlook 2000-Level 1, Microsoft Access 2000-Beginning
- 2001 Conflict Management, Microsoft 2000 Beginning and Level 1, Smart Force
- 1990 Radiation Safety Officer Training
- 1992 Radiation Safety Officer Training
- 1994 Radiation Safety Officer Training
- 1987 Management Practices
- 1982 Contemporary Supervision

**Professional Affiliations;**

Charter member NM Mine Ventilation Society

Past AIME member

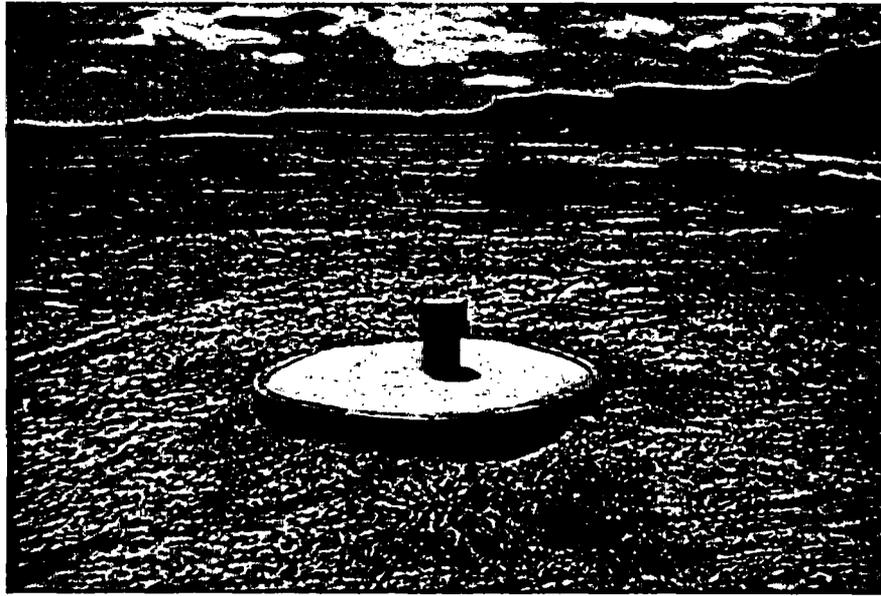
Formerly a member of American Mining Congress Committee on Radiation Exposure Standards

Formerly a member of NM Mining Association on Diesel Exhaust Standards for Underground

Past Director of NM Mining Association

Advisory Committee for The Crownpoint Institute of Technology

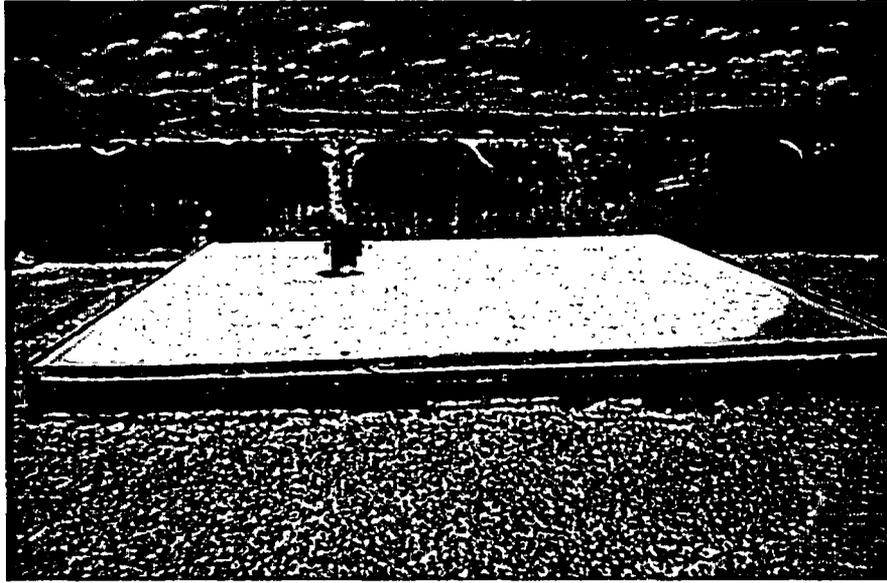
Attachment 2  
Photographs



The Section 17 "Vent Shaft" – sealed with sampling port.



The Section 17 "Escape Shaft" – sealed with sampling port.



The Section 17 "Main Shaft" – sealed with sampling port.

MISCELLANEOUS  
ATTACHMENTS

NUREG-0706  
Vol. I

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# **Final Generic Environmental Impact Statement**

on uranium milling  
Project M-25

Summary and Text

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September 1980

Office of Nuclear Material  
Safety and Safeguards  
U.S. Nuclear Regulatory Commission

REPRODUCED BY  
NATIONAL TECHNICAL  
INFORMATION SERVICE  
U.S. DEPARTMENT OF COMMERCE  
SPRINGFIELD VA 22161

Response: NRC will conform its regulations to those of EPA, as required by the Mill Tailings Act. If EPA establishes the distinction suggested, the NRC would follow suit. It should be pointed out, however, that nothing in the Mill Tailings Act specifically calls for exemption of certain levels of radionuclide content. To the contrary, the Act mandates that radioactive and nonradioactive hazards be regulated.

Comment: In addition to the relevant pre-existing authorities contained in the cited Federal statutes (i.e., the Atomic Energy Act, the Resource Conservation and Recovery Act, the Clean Air Act, and the Federal Water Quality Act), mention also should be made of the applicability of authority contained in the Safe Drinking Water Act and the Toxic Substances Control Act." (41)

Response: Section 13.5.2 of the GEIS has been changed to incorporate this suggestion.

Comment: The proposed regulations should not address ore pads because no uranium milling or ore processing to create source material takes place until ore enters the mill and is processed in the first step of ore grinding. Further, uranium ore on the pad could in no way be considered byproduct material, since it has not been processed. (55)

Response: Section 205.(a) of the UMTRCA amends the Atomic Energy Act of 1954 by adding a new Section 84 which states in part that "the Commission shall insure that the management of any byproduct material, as defined in section 11e.(2), is carried out in such manner as... the Commission deems appropriate to protect the public health and safety and the environment from radiological and nonradiological hazards associated with the processing and with the possession and transfer of such material..." [emphasis added]. The storage of ore on an ore pad prior to milling clearly constitutes an activity associated with processing. Under the language of new Section 84, therefore, it is within NRC's authority to regulate ore pad activities.

Comment: What is the basis for the determination, appearing in the definition of Section 11e.(2) byproduct material, that underground ore bodies depleted by solution extraction techniques do not constitute the tailings or wastes described in Section 11e.(2)? (92, 99)

Response: Although the Mill Tailings Act was primarily directed at the hazards associated with mill tailings from conventional uranium extraction processes, the congressional floor debate on the legislation indicated that there was some concern that in situ operations, though covered by the new Act, should not fall within its requirement that mill tailings and their disposal site be ultimately owned by the Federal or State governments. On the basis of this legislative history and language in the Mill Tailings Act suggesting that the terms "tailings or wastes" are terms of art in the industry referring to discrete materials capable of controlled disposal, the Commission concluded that the Act does not require regulation of the underground ore bodies depleted by solution extraction processes. It has been NRC practice in licensing in situ facilities to require that such sites be returned to baseline conditions; therefore, potential long-term hazards at these sites are eliminated. Surface wastes from in situ operations, however, are sufficiently like those tailings and wastes from conventional milling operations to merit regulation under the Mill Tailings Act. The underlying analysis for this conclusion appears in a memorandum to the U.S. Nuclear Regulatory Commission from Howard K. Shapar, Executive Legal Director, entitled Staff Response to the Commission Request for Further Information Regarding SECY-79-88 "Timing of Certain Requirements of the Uranium Mill Tailings Radiation Control Act of 1978" (May 7, 1979). This document is available in the NRC's Public Document Room.

Comment: NRC should have licensing authority over all DOE owned mill tailings, and NRC should not at any time release its jurisdiction over disposal sites for radioactive wastes. (69, 79)

Response: Under the UMTRCA, the NRC will retain regulatory authority over inactive mill tailings and their disposal sites. Section 83b.(1) of the Atomic Energy Act of 1954, as amended by the UMTRCA, provides that even if the Commission determines that government ownership of a tailings disposal site is not required, "such property and materials shall be maintained pursuant to a license issued by the Commission...." Similarly, Section 84b.(5) provides that the Commission may, pursuant to a license, rule, or order, require the Federal or State agency with custody of tailings and their disposal site to undertake monitoring, maintenance, and emergency measures as may be necessary. Section 84 provides similar authority to the Commission. Thus, it is clear that the UMTRCA requires that the NRC assume and retain regulatory authority over mill tailings that have been disposed of. Criterion 11 of Appendix A to 10 CFR 40 does, in fact, require this.

**Response:** Proposed Appendix A to Part 40 has been amended to require that at active mills, programs meeting the technical and financial criteria shall be developed in connection with license renewal, or proposed programs shall be submitted for review with supporting information within nine months of the effective date of the regulations. Working out the details of an optimum program at any given site is a lengthy, time consuming process. These required reports will be a major first step in this process.

**Comment:** The specific standards which Agreement States must comply with and the penalties for noncompliance should be spelled out in the regulation. (91)

**Response:** Specific technical and financial standards which the Agreement States must use in their uranium mill licensing program are specified in the regulations. Other criteria which they must meet (e.g., procedural requirements, resource levels, etc.) are outlined in the "Guide for Evaluation of State Radiation Control Programs, Rev. 3, Feb. 1, 1980." In the event that the NRC determines that a state's program is not equivalent to the NRC's or does not provide an adequate level of regulatory control, this portion of the agreement could be revoked. A revised set of criteria to be used in evaluating the equivalency of state programs for entering into amendmend agreements in November 1981 has been prepared by the NRC staff.

**Comment:** Since NRC only has control over radioactive elements, the states should be encouraged to pass regulations on uranium milling and mining. (115)

**Response:** The premise of this statement is incorrect. Section 84 of the Atomic Energy Act, as amended by the UMTRCA, states that "The Commission shall insure that the management of any byproduct material, as defined in Section 11e.(2), is carried out in such manner as - (1) the Commission deems appropriate to protect the public health and safety and the environment from radiological and nonradiological hazards associated with the processing and with the possession and transfer of such material...." In light of this and the Congress' desire to eliminate dual jurisdiction (evidenced by the November 1979 amendments to the UMTRCA), NRC considers the most effective arrangement to be one in which either NRC or a state (through an agreement under Section 274) regulates. NRC has no direct authority over uranium mining or mine wastes. Impacts from mining operations are considered on a case-by-case basis, where appropriate, (where it is not possible to distinguish these impacts from those associated with the milling operation). However, as mentioned in Section 1.2, EPA is currently preparing a report, as directed by Congress in Section 114(c) of the Uranium Mill Tailings Radiation Control Act, on the potential health, safety, and environmental hazards of uranium mine wastes.

## 6.9 Technical Issues

### 6.9.1 Siting

**Comment:** Emphasis on consideration of cultural resources should be at the site selection stage rather than at the site preparation stage. (38)

**Response:** The staff agrees. Major site construction should not occur until after a full NEPA review has been completed, as discussed in Section 12.3.10. Such a review would include consideration of cultural resources to the extent appropriate.

**Comment:** The availability of suitable alternative tailings disposal sites should be resolved generically. The NRC should consider requiring location of sites only where tailings can be disposed of below grade safely. Mills should be sited on the basis of safe tailings disposal and not on the nearness of uranium ore. (47, 56)

**Response:** The staff agrees that primary emphasis in the site selection process should be placed on adequate tailings isolation rather than short-term conveniences (see Section 12.3.2). However, the staff does not consider it appropriate or necessary to require full below grade disposal in order to achieve adequate isolation. The general availability of acceptable full below grade disposal sites is not addressed within this document, due to practical considerations; site-specific licensing evaluations routinely consider that matter, however (see Section 12.3.3.2).

**Comment:** The criteria listed in Criterion 4 pertaining to above grade disposal sites only, raise questions as to whether below-grade sites will receive adequate review consideration, particularly because no extensive search for alternative sites is required. (47)

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APPENDIX "E"

OPTIONAL FORM NO. 10  
5010-104

UNITED STATES GOVERNMENT

## Memorandum

TO : H. L. Price, Director  
Division of Licensing and Regulation

FROM : Neil D. Naiden, <sup>7</sup>Acting General Counsel  
<sub>6</sub>

SUBJECT: MILL TAILINGS

DATE: December 7, 1960

This memorandum is in response to your request for the views of this Office as to whether the Commission's regulatory authority and requirements may be applied to mill tailings which contain certain quantities of radium. I understand you have requested this opinion because inquiries have been received as to the regulatory jurisdiction of the Commission over the use of mill tailings for land fill, road building and similar purposes.

In a memorandum to you dated April 15, 1960, a copy of which is attached, we advised you that the exercise of Commission jurisdiction over the transfer of waste tailings by mill licensees to other parties under the circumstances described in that memorandum, for the purpose of assuring that the use of such wastes by the recipients will be consistent with public health and safety, would not be supported by the provisions of the Atomic Energy Act of 1954, as amended, as implemented by the definition of "source material" in Part 40, 10 CFR.

In your present inquiry you have requested that we consider the possibility of amendments to Part 40, 10 CFR, the purpose of which would be to extend the exercise of Commission jurisdiction to the use of mill tailings for the kinds of purposes referred to above. You have advised also that the quantities of uranium and thorium in the tailings do not constitute a hazard to health and safety and are not of significance to the common defense and security; and that any radiological health hazard presented by the tailings is due to the presence of radium and is not affected by the uranium or thorium residues in the tailings.

Source material is defined in § 11 x. of the Act as follows:

"The term 'source material' means (1) uranium, thorium, or any other material which is determined by the Commission pursuant to the provisions of § 61 to

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be source material; or (2) ores containing one or more of the foregoing materials, in such concentration as the Commission may by regulation determine from time to time."

Section 61 of the Act provides:

"Sec. 61. Source Material. - - The Commission may determine from time to time that other material is source material in addition to those specified in the definition of source material. Before making such determination, the Commission must find that such material is essential to the production of special nuclear material and must find that such determination that such material is source material is in the interest of the common defense and security. and the President must have expressly assented in writing to the determination. The Commission's determination, together with the assent of the President, shall be submitted to the Joint Committee and a period of thirty days shall elapse while Congress is in session (in computing such thirty days, there shall be excluded an adjournment of more than three days) before the determination of the Commission may become effective: Provided, however, That the Joint Committee, after having received such determination, may by resolution in writing waive the conditions of or all or any portion of such thirty-day period." (Underscoring added)

You have not advised, and we are not aware, of any reason to believe that radium "is essential to the production of special nuclear material"; or "that the determination that such material is source material is in the interest of the common defense and security." Accordingly, there would not appear to be any basis for amending the definition of source material in § 40.4 (h) of the proposed, revised Part 40 to include "radium" in the definition of source material.

We have also considered the possible argument that the definition of source material in § 11 x. of the Act furnishes a basis for applying the Commission's regulatory authority and requirements

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(such as Part 20) to the mill tailings because the statutory definition of source material appears to specify that uranium and thorium, other than ores, are "source material" without regard to the quantity or concentrations involved. If such an argument were valid, it might then be urged that the Commission should amend § 40.13 (a) of the proposed revised Part 40 to exclude mill tailings containing radium from the exemption contained in that paragraph.\*\*

Such an argument, however, would ignore other provisions of the Atomic Energy Act, and the purpose of the Act as expressed in the Act and its legislative history.

Section 62 of the Act provides that ". . . licenses shall not be required for quantities of source material which, in the opinion of the Commission, are unimportant." The requirements contained in this provision would appear to be mandatory and not permissive.

The quoted provision of § 62 would also appear to require that the exemption from licensing requirements be made whenever the quantity of source material (i. e., uranium or thorium) is unimportant. There does not appear to be any basis for withholding the grant of an exemption for unimportant quantities of uranium or thorium because of the presence of materials which are not

\* Section 40.4 (h) of the proposed, revised Part 40 would revise the regulatory definition of source material so as to make the text of the definition conform somewhat more closely with the text of the statutory definition in § 11.

\*\* Paragraph (a) § 40.13, of the revised, proposed Part 40 provides that:

"(a) Any person is exempt from the regulations in this part and from the requirements for a license set forth in Section 62 of the Act to the extent that such person receives, possesses, uses, transfers, delivers, or imports into or exports from the United States source material in any chemical mixture, compound, solution, or alloy in which the source material is by weight less than 1/20 of 1% (0.05%) of the mixture, compound, solution or alloy."

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themselves within the jurisdiction of the Atomic Energy Commission. Any other conclusion would permit the Commission to extend its regulatory jurisdiction to any materials in existence which contain even microscopic quantities of uranium or thorium.

In its action approving publication of the revised Part 40 for public comment, the Commission found that the quantities of uranium and thorium described in paragraph (u), § 40.15 are unimportant. No circumstances have been brought to our attention which would appear to furnish a basis for modifying that finding.

The foregoing views are consistent with the purposes of the Act, as expressed in the Act, and its legislative history (including the Atomic Energy Act of 1946 and its legislative history). It is a purpose of the Act to regulate the production and use of special nuclear material; the material which special nuclear material is derived (i. e., source material), and radioactive material "yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material" (i. e., "byproduct material"). See e. g., Senate report No. 1211, 79th Cong., 2d sess., pp. 18-19 on the bill which became the Atomic Energy Act of 1946. Nowhere in the Act or in its legislative history is there any suggestion of a purpose to regulate radioactive materials or other sources of ionizing radiation which do not stand in one of the foregoing relationships to special nuclear material.

Commission statements recognize that the Commission's jurisdiction over radiation hazards is limited to radiation hazards arising from source, special nuclear and byproduct materials; and that jurisdiction over radiation hazards from other sources of radiation lies with other agencies of the state or Federal governments. Moreover, in enacting § 274 of the Act, the Congress established a program "for discontinuance of certain of the Commission's regulatory responsibilities with respect to byproduct, source, and special nuclear materials, and the assumption

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thereof by the states." (§ 274 a. (4)) Extension of the Commission's regulatory program to control of radiation hazards from radium in mill tailings would mark the Commission's entry into an area heretofore left to the states and would to this extent be inconsistent with the program and purposes established in § 274.

Attachment:

Memo dtd. April 15, 1960

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### 3. PRODUCTION OF URANIUM

The quantities of uranium projected to be needed and the amount likely to be produced in the United States through the year 2000 are considered in this chapter. In the first part, the quantity of uranium needed for the generation of nuclear power is predicted. The current uranium milling industry is then described in terms of mill capacity, geographic location, and the significance of "unconventional" production sources. This is followed by a more detailed account of the "unconventional" sources, including projections of their contributions to the total uranium supply. An overview of the milling industry to the year 2000 is then given. Descriptions of the more important uranium mining and milling processes are presented in Appendix B.

#### 3.1 THE NEED FOR URANIUM WITHIN THE CONTEXT OF THIS GENERIC STATEMENT

The need for uranium in commercial reactors in the United States is primarily a function of two factors: (1) the installed commercial nuclear reactor capacity, and (2) U.S. uranium enrichment policies. Evaluations of these factors were based on information available from the U.S. Department of Energy (DOE). The sensitivity of cumulative environmental impacts to nuclear power projections, enrichment tails assays, ore grades and other key parameters is discussed in Appendix S. The installed nuclear reactor capacity and uranium enrichment policies are discussed below.

The installation schedule assumed for this document (chosen from many that have been projected) is the DOE Mid-Range projection shown in Table 3.1. This projected growth rate is substantially below prior expectations and results, at least in part, from recent drops in the demand for electricity and increased costs for constructing new nuclear power plants. Approximately 9% of U.S. electricity now is generated by nuclear power. The DOE Mid-Range capacity schedule shown in Table 3.1 is expressed in terms of metric tons of  $U_3O_8$  in yellowcake required annually and cumulatively in Table 3.2. The quantities of  $U_3O_8$  required are based on a "once-through" (throwaway) uranium fuel cycle which does not include recycle of either uranium or plutonium, and a 3-year lead time for yellowcake production (prior to fuel utilization).

A comparison between estimated total requirements for electrical generating capacity and the projected nuclear capacity through the year 2000 is given in Table 3.1. It is shown that nuclear generating plants are expected to furnish from 9% to 20% of the electrical energy supplied during this period. The projections are affected by national policy relative to nuclear power. For example, decisions concerning nuclear reprocessing, the breeder reactor program, spent fuel storage, and nuclear waste disposal are all important factors in determining the economic viability and political acceptability of nuclear power. The availability and economic competitiveness of alternative energy sources such as coal, natural gas, petroleum, and solar energy also influence these projections.

For use in commercial LWRs, the atomic percentage of the fissile nuclide U-235 must be enriched from its natural abundance of 0.71%. The amount of natural uranium required to produce a desired amount of product material of a given enrichment is related to the percentage of U-235 remaining in the enrichment tails, the residual uranium from which some of the U-235 has been removed. The enrichment factors used in converting nuclear fuel requirements into  $U_3O_8$  requirements were based on an enrichment tails assay of 0.20%. The average reload enrichment was taken as 3.0% for the reactor system projected. Enrichment policy changes, such as changing the tails assay or the required delivery time of  $U_3O_8$  to the enrichment plant, will change  $U_3O_8$  requirements. (For example, if the enrichment tails assay were increased to 0.25%, although it would be less costly in terms both of energy and money to do so, the increase in annual  $U_3O_8$  requirements could be 12%.) Perturbations in uranium demand caused by changes in Department of Energy uranium fuel enrichment policies were not factored into the  $U_3O_8$  requirements assumed herein.

Uranium requirements can be filled by other than conventional mining and milling techniques. In addition, uranium can also be imported. The effects of "unconventional" sources are discussed in Section 3.3. The uranium requirements projected in this study are based on the premise that all needs are filled from domestic resources.

An important consideration in this generic study is the comparison of the amounts of raw material ( $U_3O_8$ ) required for the projected reactor schedule (see Table 3.2) to the estimated domestic uranium resources available (Table 3.3). It is shown in Table 3.3 that currently known reserves and probable resources are adequate to support the presumed 180-GWe schedule through the year 2000.

Table 3.1 Comparison of Total and Nuclear Generating Capacity, 1979-2000

Year	Total Generating Capacity, GWe <sup>a</sup>	Nuclear Generating Capacity, GWe <sup>b</sup>			% Nuclear (Mid-Range)
		Low Range	Mid-Range	High Range	
1979	549	49.0	49.0	49.0	8.9
1980	550	53.1	55.3	55.3	11.1
1985	638	86.5	98.3	108.7	17.4
1990	740	121.4	127.7	139.4	17.3
1995	817	137.1	150.9	159.8	18.5
2000	902	160.0	180.0	200.0	20.0

<sup>a</sup>Data shown are from Reference 2. Growth rates used were 3% per year through 1990 and 2% per year thereafter.

<sup>b</sup>Data shown are from Reference 1. Mid-range estimates essentially amount to fulfillment of currently planned nuclear reactor development and have been selected as the basis for estimating uranium demand.

Table 3.2 Requirements for U<sub>3</sub>O<sub>8</sub>, 1979-2000<sup>a</sup>

Year	Generating Capacity, GWe	Required U <sub>3</sub> O <sub>8</sub> Content in Yellowcake Production, 10 <sup>3</sup> MT	
		Annual	Cumulative
1979	49.0	13.4	13.4
1980	55.3	16.5	28.0
1981	61.5	16.0	44.0
1982	72.3	18.2	62.2
1983	79.1	20.6	82.8
1984	86.4	22.1	104.9
1985	98.3	22.9	127.8
1986	111.2	23.2	151.0
1987	119.5	23.6	174.6
1988	123.7	24.7	199.3
1989	125.5	25.3	224.6
1990	127.7	26.2	250.8
1991	133.4	27.5	278.3
1992	136.8	27.9	306.2
1993	141.6	29.0	335.2
1994	148.4	30.1	365.3
1995	150.9	31.2	396.5
1996	156.7	32.2	428.7
1997	162.5	33.3	462.0
1998	168.4	34.4	496.4
1999	174.2	35.5	531.9
2000	180.0	36.5	568.4

<sup>a</sup>DOE Mid-Range nuclear generating capacity estimates are used, from Table 3.1. Conversion from GWe to uranium requirements is based on an average of 185 MT U<sub>3</sub>O<sub>8</sub> in yellowcake required per GWe-year. This is the factor for 3.0% reload enrichment, 0.20% enrichment tails, and an effective average plant capacity factor of 75%. A three-year delay between yellowcake production and fuel utilization is assumed.

Table 3.3 Comparison of U.S. Reactor Requirements and Domestic Resource Availability (in MT  $U_3O_8$  as of January 1978)<sup>a</sup>

Time Period	Reactor Demand	Resource Availability @ \$50/lb <sup>b,c</sup>
1979 to 2000	568,400	
Reserves <sup>d</sup>		890,000
Probable resources		1,395,000
Sum of reserves & probable resources		2,285,000

<sup>a</sup>Based on information presented by D. L. Hetland and W. D. Grundy, at the Grand Junction Office Uranium Industry Seminar, U.S. Dept. of Energy, October 1978, and in "ERDA Makes Preliminary Estimate of Higher Cost Uranium Resources," U.S. Energy Research and Development Administration, Notice 77-105, 22 June 1977, and updated July 1978.

<sup>b</sup>Costs include all those incurred in property exploitation and production except profits and costs of money. Costs are the current ones, and are not intended to project future uranium prices.

<sup>c</sup>\$50/lb is equivalent to \$110/kg.

<sup>d</sup>Does not include  $U_3O_8$  which could be produced as a byproduct of phosphate fertilizer and copper production.

### 3.2 THE CURRENT URANIUM MILLING INDUSTRY

The current conventional uranium extraction and processing industry involves a combination of mining and milling methods that have been developed through experience gained since about 1940. A brief history of this evolution is given in Section 2.1. The mining and milling methods currently used, while capable of general characterization as open pit or underground for mining, and acid or alkaline leach for milling, have evolved into systems usable anywhere in the western United States for sandstone-deposited ores. These ores constitute practically all of the reserves and probable resources identified to date in the United States. In conventional practice, the location of the mill with respect to the mine, the specific process used by the mill, the size of the mill, and the tailings management schemes used are all directly influenced by mining procedures and the chemical and physical characteristics of the ore. Mining and milling operations are discussed in more detail in Chapter 5 and Appendix B.

In this section the current U.S. conventional mill capacity is discussed, the locations of proven and potential uranium reserves are given, and the contribution of "unconventional" processes is considered.

#### 3.2.1 Conventional Mill Capacity in the United States<sup>3,4</sup>

Mill capacities in 1978 ranged from 360 to 6300 MT (400 to 7000 ST) of ore per day, averaging about 1800 MT (2000 ST) per day. On the basis of an average ore grade of 0.10%  $U_3O_8$ , a model mill of 1800 MT/day capacity, as described in Chapter 5, would produce about 580 MT (640 ST) of yellowcake per year at 85% capacity, containing about 520 MT (570 ST) of  $U_3O_8$ . About 80% of the current milling capacity involves the use of the sulfuric acid leach process; the rest involves the use of the basic (carbonate) solution leach process.

At a few mills an additional process--heap leaching--is either being used on a small scale or is being planned. Heap leaching is a technique usually designed to remove unrecovered uranium from low-grade ores or tailings containing less than 0.05%  $U_3O_8$  and is not expected to contribute any major amount towards annual  $U_3O_8$  production. One major heap leach operation, undertaken in 1976, was at Union Carbide's Maybell, Colorado, site, which is remote from any conventional mill.

Heap leaching does not necessarily increase environmental impacts, whether used on existing uranium tailings piles or on low-grade ore transported to the mill for heap leaching. The process might result in slight modification of tailings management procedures because tailings and leached ore could be mixed, rather than separated as in conventional mining and milling; however, operations would still be above the ground and impacts would be essentially unaltered. Heap leaching operations are considered to be part of the conventional milling industry.

The total capacity of conventional mills operating in 1979 was about 43,900 MT (48,200 ST) of ore per day (see Table 3.4). Production of  $U_3O_8$  in 1977 from conventional mills was about 13,000 MT (14,500 ST); 1979 conventional mill  $U_3O_8$  production is estimated to have been about 16,000 MT (17,600 ST) and account for about 90% of total production by all methods.<sup>4</sup> About 14.4 million MT (15.8 million ST) of ore was processed by 21 conventional mills operating in 1979, indicating an average ore grade of about 0.12% and an overall capacity factor of almost 90%.

Average ore grades were about 0.16% in 1977, 0.13% in 1978, and 0.12% in 1979. The average grade of ore processed by conventional milling facilities has been projected to gradually decline to a level of about 0.08% in the 2000.<sup>3</sup> The average ore grade between now and the year 2000 is estimated to be about 0.10% and that figure is used as the basis for subsequent calculations of environmental impacts.

Average mill uranium recovery was about 92% in 1977 and 91% in 1978. The estimated uranium recovery rate for 1979 is between 91% and 92%, despite the decline in average ore grade. Further improvements in extraction efficiency are anticipated as the basic technology evolves, as operators gain experience processing lower ore grades, and as gradual price increases begin to justify the costs of additional equipment or process modifications necessary to enhance recovery.

### 3.2.2 Geographic Locations of Uranium Reserves in the United States

Most of the nation's known uranium resources are located in the West, as shown in Figure 3.1, and all of the 21 conventional uranium mills now operating (Table 3.4) or currently planned for operation are (or will be) west of the Mississippi River. Information is presented in Table 3.4 showing the relative amounts of operating conventional milling capacity in each of the six uranium-producing states and by NURE (National Uranium Resource Evaluation) region.<sup>4-6</sup> The NURE regions were selected principally to allow categorization of uranium reserves on a regional basis. The estimated quantities of the nation's uranium resources are listed by category in Table 3.5. The meanings of the categories are as follows:

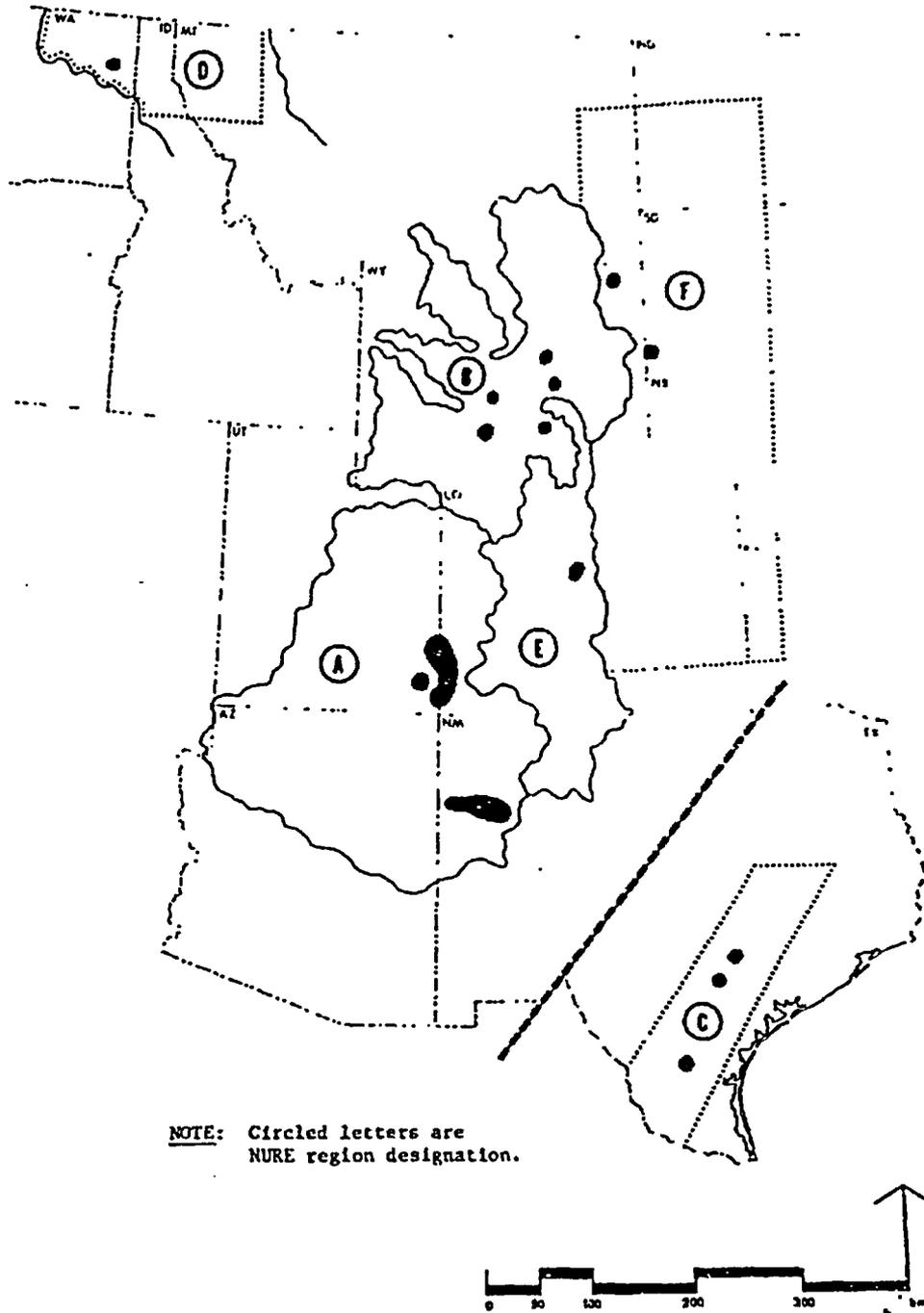
1. Reserves - Uranium which occurs in known ore deposits of such grade, quality, and configuration that it can be economically recovered with currently proven mining and processing technology. Estimates of tonnage and grade are based on specific sample data and measurements of the deposit and on knowledge of the ore body.
2. Potential Resources (three subgroups):
  - a. Probable (potential) resources are located in extensions of established ore trends or in areas demonstrated to contain uranium.
  - b. Possible (potential) resources are located (by estimation) in new deposits in formations or geologic settings similar to production areas elsewhere.
  - c. Speculative (potential) resources are located (by estimation) in new deposits in formations or geologic settings not previously productive.

The above classes are divided in Table 3.6 on the basis of the indicated forward costs, i.e., all costs yet to be incurred by the mining company at the time the estimate is made, except profit and cost of money, and are in the dollars of the year of estimation. The six principal NURE regions had produced 281,000 MT (312,300 ST) of  $U_3O_8$  (as of 1 January 1978) and contain  $2.2 \times 10^6$  MT ( $2.4 \times 10^6$  ST) of  $U_3O_8$  as reserves and probable resources recoverable at \$110/kg (\$50/lb) or less. Uranium requirements are expected to reach 568,000 MT (625,000 ST) of  $U_3O_8$  (70% of the 1978 reserves in the six principal NURE regions) by the year 2000, and production to meet these needs will likely be centered in these six NURE regions. Production and resources are shown by region in Table 3.5.

### 3.2.3 Contribution of Unconventional Processes

Although most uranium production is by the conventional acid or alkaline leaching processes, "unconventional" methods are used for some production. Such methods include solution mining (also known as in situ mining), uranium recovery from mine water, copper dump leach liquor, or wet process phosphoric acid effluents. In each case, the uranium is recovered from solution by ion-exchange or solvent extraction. Production of  $U_3O_8$  by these methods totaled 450 MT (500 ST) in 1976. Production was about 760 MT (850 ST) of  $U_3O_8$  in 1977 and was expected to reach about 1900 MT (2200 ST) in 1978.<sup>7</sup>

Production from solution mining was relatively constant at less than 1% of total uranium production for more than 15 years. This percentage increased to about 3% in 1977 and was expected to be about 7% in 1979. Production by solution mining was expected to be about 1300 MT (1430 ST) in 1979.<sup>4</sup>



**NOTE:** Circled letters are NURE region designation.

Fig. 3.1 Uranium Reserves and Resources in Western United States.

Table 3.4 Conventional U.S. Uranium Mills Operating in 1979<sup>a</sup>

State & Company	Location	Max. Cap., MT ore/day	NURE Region <sup>b</sup>	Process Used
<b>New Mexico</b>				
Anaconda Company	Grants	5,400	A	Acid leach, CCD, solvent extraction
Kerr-McGee Nuclear Corporation	Grants	6,300	A	Acid leach, CCD, solvent extraction
Sohio-Reserve	Cebolleta	1,500	A	Acid leach, CCD, solvent extraction
United Nuclear Corporation	Church Rock	2,700	A	Acid leach, CCD, solvent extraction
United Nuclear-Homestake Partners	Grants	<u>2,700</u>	A	Carbonate leach, caustic precipitation
	TOTAL	18,500		
<b>Wyoming</b>				
Exxon, U.S.A.	Powder River Basin	2,700	B	Acid leach, CCD, solvent extraction
Federal-American Partners	Gas Hills	860	B	Acid leach, eluex
Pathfinder Mines Corporation	Gas Hills	3,500	B	Acid leach, eluex
Pathfinder Mines Corporation	Shirley Basin	1,600	B	Acid leach, CCD, column ion exchange
Petrotonics	Shirley Basin	1,300	B	Acid leach, CCD, solvent extraction
Rocky Mtn. Energy & Mono Power	Powder River Basin	1,800	B	Acid leach, CCD, solvent extraction
Union Carbide Corporation	Natrona County	1,100	B	Acid leach, eluex
Western Nuclear, Inc.	Jeffrey City	<u>1,500</u>	B	Acid leach, eluex
	TOTAL	13,500		
<b>Utah</b>				
Atlas Corporation	Moab	1,350	A	Carbonate leach, resin in pulp & acid leach, solvent extraction
Rio Algom Corporation	La Sal	<u>640</u>	A	Carbonate leach, caustic precipitation
	TOTAL	2,000		
<b>Colorado</b>				
Cotter Corporation	Canon City	1,300	E	Carbonate leach, caustic precipitation
Union Carbide Corporation	Uravan	<u>1,200</u>	A	Acid leach, CCD, column ion exchange
	TOTAL	2,500		
<b>Texas</b>				
Chevron	Panna Maria	2,200	C	Acid leach, CCD, solvent extraction
Conoco & Pioneer Nuclear, Inc.	Falls City	<u>2,900</u>	C	Acid leach, CCD, solvent extraction
	TOTAL	5,100		
<b>Washington</b>				
Dawn Mining Company	Ford	400	D	Acid leach, CCD, column ion exchange
Western Nuclear	Wellpinit	<u>1,800</u>	D	Acid leach, CCD, solvent extraction
	TOTAL	2,200		
<b>GRAND TOTAL</b>		<b>43,900</b>		

<sup>a</sup>Modified from Reference 4.

<sup>b</sup>Region as defined by Figure 3.1 and Table C 5.

Table 3.5 Summary of Uranium Production, Reserves, and Potential Resources by NURE Regions  
(\$50 forward costs as of 1 January 1978)<sup>a</sup>

Region	Past Production ST U <sub>3</sub> O <sub>8</sub>	ST U <sub>3</sub> O <sub>8</sub> <sup>b</sup>			
		Reserves	Potential Resources		
			Probable	Possible	Speculative
(A) Colorado Plateau	216,300	485,200	665,000	815,000	40,000
(B) Wyoming Basins	68,900	264,000	375,000	115,000	30,000
(C) Coastal Plain	10,000	53,900	180,000	95,000	35,000
(D) Northern Rockies		25,400	27,000	63,000	50,000
(E) Colorado and Southern Rockies		25,800	56,000	56,000	41,000
(F) Great Plains	17,100	8,000	27,000	70,000	48,000
Subtotal A,B,C,D,E,F	312,300	862,400	1,330,000	1,214,000	244,000
(G) Basin & Range		25,500	59,000	292,000	76,000
(H) Pacific Coast and Sierra Nevada	<1,000	2,100	4,000	9,000	9,000
(I) Central Lowlands	<1,000	0	ε/	ε/	110,000
(J) Appalachian Highlands	<1,000	0	ε/	ε/	95,000
(K) Columbia Plateaus	<1,000	0	ε/	ε/	31,000
(L) Southern Canadian Shield	0	0	ε/	ε/	ε/
(M) Alaska	<1,000	0	2,000	ε/	ε/
<b>TOTAL</b>	<b>313,100</b>	<b>890,000</b>	<b>1,395,000</b>	<b>1,515,000</b>	<b>565,000</b>

<sup>a</sup>Based on the information derived from:

- (1) D. L. Hetland, "Discussion of the Preliminary NURE Report and Potential Resources," presented at the Grand Junction Office Uranium Industry Seminar, U. S. Dept. of Energy, October 1978.
- (2) D. L. Everhart, "Status of NURE Program," presented at the Grand Junction Office Uranium Industry Seminar, U. S. Dept. of Energy, October 1978.
- (3) "Reserves and Resources of Uranium in the U. S.," supplement to Mineral Resources and the Environment, National Academy of Science, 1975.

<sup>b</sup>Conversion factor: one short ton (ST) = 0.91 metric ton (MT); \$50/lb = \$110/kg.

<sup>c</sup>Resources not estimated because of inadequate knowledge.

Table 3.6 U. S. Uranium Resources<sup>a</sup> (ST U<sub>3</sub>O<sub>8</sub> as of 1 January 1979)

Cost Category, \$/lb U <sub>3</sub> O <sub>8</sub>	Reserves	Potential Resources <sup>b</sup>		
		Probable	Possible	Speculative
Less than \$15	370,000	540,000	490,000	165,000
\$15 - \$30	320,000	475,000	645,000	250,000
\$30 - \$50	200,000	380,000	380,000	150,000
Total	890,000	1,395,000	1,515,000	565,000

<sup>a</sup>Based on information derived from:

- (1) R. J. Meehan, "Uranium Ore Reserves," presented at the Grand Junction Office Uranium Industry Seminar, U. S. Dept. of Energy, October 1977.
- (2) D. L. Everhart, "Status of NURE Program," presented at the Grand Junction Office Uranium Industry Seminar, U. S. Dept. of Energy, October 1977.
- (3) "Reserves and Resources of Uranium in the U. S.," supplement to Mineral Resources and the Environment, National Academy of Science, 1975.
- (4) D. L. Hetland and W. D. Grundy, "Potential Uranium Resources," Resource Division, U. S. Dept. of Energy, Grand Junction, Colorado, October 1978.

<sup>b</sup>The reliabilities of the potential resource estimates decrease from the probable to the speculative class.

Production of uranium from mine water amounts to about 100 tons U<sub>3</sub>O<sub>8</sub> per year. This will increase as more underground wet mines come into production, but the method still is unlikely to account for more than 1% or 2% of domestic uranium production.

During 1979, three companies were producing U<sub>3</sub>O<sub>8</sub> from wet process phosphoric acid, and two other operations should begin production during 1980. Production by this method was about 400 MT (440 ST) in 1979.

Much effort has been expended to determine the amounts of uranium that might be recovered from coal and lignite. Some uranium was recovered from lignite ash in the early 1960s, but that lignite was not a suitable fuel, supplementary fuel being necessary for the conversion to ash, which is necessary before uranium can be extracted. No uranium has been recovered as a byproduct from the ash of coal- or lignite-fired power plants. Ash samples continue to be analyzed for uranium, but to date no ash containing more than 20 ppm U<sub>3</sub>O<sub>8</sub> has been found, and most ash samples contain 1 to 10 ppm U<sub>3</sub>O<sub>8</sub>.

### 3.3 PROSPECTS FOR UNCONVENTIONAL METHODS OF URANIUM PRODUCTION

Principal production methods that could reduce the total conventional milling capacity needed in the future are:

- In situ mining (in-place leaching of ore deposits);
- Production by extraction from "other than uranium" process streams (also called byproduct production);
- Imports and exports.

The potential of these techniques to reduce the number of conventional mills needed and thus reduce mill-associated impacts is summarized in Table 3.7 and examined in more detail below.

#### 3.3.1 In Situ Mining

In situ leaching (solution mining) of uranium is a viable uranium production method that will likely reduce the total conventional milling capacity needed in the future by a significant amount. The method involves (1) the injection of a leach solution (lixiviant) into a subterranean uranium-

Table 3.7 Estimated \$50/lb Uranium Production Capability by Nonconventional Techniques

Year	Production Capability, 10 <sup>3</sup> ST U <sub>3</sub> O <sub>8</sub> per year <sup>a</sup>		
	Solution Mining	Byproduct Recovery	Total Nonconventional
1980	2.5	0.95	3.4
1981	3.3	1.3	4.6
1982	3.9	2.1	6.0
1983	4.6	3.0	7.6
1984	5.4	3.2	8.6
1985	6.1	3.5	9.6
1986	6.6	3.8	10.4
1987	7.4	4.0	11.4
1988	8.6	4.3	12.9
1989	9.7	4.5	14.2
1990	10.3	4.7	15.0
1991	10.6	4.9	15.5
1992	10.7	5.1	15.8
1993	10.6	5.2	15.8
1994	10.5	5.3	15.8
1995	10.4	5.4	15.8
1996	10.4	5.5	15.9
1997	10.4	5.6	16.0
1998	10.2	5.9	16.1
1999	10.1	5.9	16.0
2000	<u>9.9</u>	<u>5.9</u>	<u>15.8</u>
Total	172.2	90.0	262.2

<sup>a</sup>Adapted from data presented in Reference 3.

bearing ore body to dissolve and complex the contained uranium, (2) the mobilization of the uranium complex formed, and (3) the surface recovery of the uranium from the uranium-complex-bearing solution by conventional milling unit operations.

Whereas conventional extraction of minerals may produce significant environmental impacts, the use of solution mining offers the potential advantage of reducing surface disturbance and associated impacts. In situ leaching may also permit economical recovery of currently unrecoverable low-grade uranium deposits, thereby enhancing the nation's uranium reserves.

In this method, an acidic or basic oxidizing leach solution is injected into and withdrawn from the naturally situated ore body via sets of wells. The chemical technology is similar for both acidic and basic leaching. No conventional ore mining, transporting, or grinding operations are needed prior to chemical processing to recover the uranium. Although some solid wastes (primarily calcium salts comobilized with the uranium complex) are generated, large quantities of mill tailings are not produced. For a given production of yellowcake, solid wastes from solution mining are much smaller in volume than tailings from conventional mills. Wastes produced in conventional uranium mining contain essentially all of the associated radium-226 (and its daughter products); on the other hand, less than 5% of the radium (along with the mobilized calcium) from a given ore body is commonly brought to the surface by solution mining techniques. A potential disadvantage of this method of uranium extraction is possible significant deterioration of the groundwater quality; however, groundwater contamination can often be limited by process controls.

Since the technology for in situ solution mining of uranium is still being developed, there are many variations in the process. Further plant and process modifications are likely to be implemented before in situ solution mining can be classified as a conventional mining method. A more detailed description of in situ solution mining is provided in Appendix B.\*

\*The U.S. NRC has been actively following developments in the area of solution mining, and has issued environmental impact statements for two solution mining projects.<sup>9,10</sup> In addition, the NRC has funded a study by Geraghty and Miller, Inc., of possible groundwater contamination.<sup>11</sup>

Direct measurement of the uranium content of the ore body is much more difficult in in situ mining than in conventional mining. For this reason, the efficiency of recovery is more difficult to estimate, but is expected to be less than in conventional mining. Because of these uncertainties, the actual contribution of in situ mining to future uranium production is difficult to predict. The U.S. Department of Energy has projected that in situ production capability could reach 9700 MT (10,700 ST) of  $U_3O_8$  per year by 1991 and hold at about that level through the year 2000 (see Table 3.7).<sup>3</sup>

### 3.3.2 Recovery of Uranium as a Byproduct

Two major sources from which byproduct uranium is being recovered are copper mining leach liquors and wet process phosphoric acid. Of the two, phosphoric acid manufacture (for fertilizer) is receiving the most emphasis. The status of the process development at phosphoric acid plants in Florida is discussed in some detail in Reference 4; a brief summary is presented in the following paragraphs.

The recovery process is based on solvent extraction of uranium from a phosphoric acid stream normally produced at or near the phosphate rock mine. After extraction of the uranium, this phosphoric acid is normally sent to other plants for manufacture of fertilizer. The solvent extraction process is similar to that used in conventional uranium mills, and the  $U_3O_8$  produced is of acceptable quality. Since the uranium is extracted from the phosphoric acid product stream, the amounts of uranium will depend on production rates of the acid, as well as the uranium concentration, and will fluctuate as the market for phosphate-based fertilizer fluctuates. Demand for fertilizer in the world market should increase with demands for increased food production, and this increased demand in turn should result in increased phosphate mining in the United States.

As of 1978 seven companies were in various stages of construction of plants with a total annual production capacity of about 1800 MT (2000 ST). The recovery of uranium from wet-process phosphoric acid is not developing as rapidly as expected, but this process is expected to account for about 2.8% of domestic uranium production in 1979. The best phosphate rock deposits in the United States occur in Florida, and most of the acid from which the uranium will be extracted is manufactured in that state. Wet-process phosphoric acid derived from Florida phosphates contains  $U_3O_8$  in the range of 50 to 200 ppm.

Prediction of the amounts of  $U_3O_8$  which will be recovered from phosphate production is risky, primarily because of the process difficulties involved and dependence of acid availability on the fertilizer markets. Currently,  $U_3O_8$  production is about 400 MT (440 ST) per year but could reach 2700 MT (3000 ST) per year by 1985 and about 4700 MT (5200 ST) by the year 2000 (see Table 3.7).<sup>3</sup>

During the last 15 years, the U.S. Bureau of Mines (Salt Lake City), Kennecott Copper Corporation, and Wyoming Mineral Corporation, a subsidiary of Westinghouse, have extensively tested recovery of uranium from copper dumps, which frequently contain 1 to 12 parts of  $U_3O_8$  per million parts of solution. As a result, Wyoming Mineral Corporation and Kennecott are now operating a 65 MT/yr commercial uranium recovery operation at Bingham Canyon near Salt Lake City. Anaconda and Amax are presently completing a similar size facility to recover uranium at Twin Buttes, south of Tucson, Arizona. In addition, Brush-Wellman has built a uranium recovery circuit into its beryllium mill in Utah to recover 9 to 18 MT of uranium per year as a byproduct.<sup>4</sup>

From the above information it appears feasible to extract uranium as a byproduct in copper milling as well as in other metals industries. However, these extraction techniques are not now as mature as those being applied to recover uranium from phosphoric acid. Together with uranium extraction from mine water, these techniques accounted for about 2% of all U.S. uranium production in 1979.

### 3.3.3 Imports and Exports

Of all of the effects of unconventional sources for  $U_3O_8$  on mill requirements, those of imports and exports are most difficult to assess. The relationship between world and United States prices will affect the United States import/export balance. As shown in Table 3.8, the percent of world production supplied by the United States is estimated to decline slightly by 1985. U.S. government policies regarding enrichment capacity increases, and the nuclear option generally, could dramatically increase or decrease the amounts of  $U_3O_8$  which could or would be exported. For these and other reasons, among which is the complexity of the world markets for uranium, the staff has not attempted to incorporate the effects of net import-export balances into its uranium demand projections. The import-export trade market is extremely volatile and cannot be predicted with any certainty through the year 2000. Therefore, the staff has assumed no net import or export of uranium through the year 2000.

### 3.3.4 Summary of Effects on Mill Requirements Caused by Unconventional Production Sources

As indicated by Table 3.1, potential cumulative unconventional uranium production through the year 2000 is about 239,900 MT (262,000 ST) of  $U_3O_8$ . This is an upper limit estimate, based on

full exploitation of all nonconventional production methods and resources, and represents about 21% of potential cumulative uranium production by all methods.<sup>3</sup> Potential production by all methods through the year 2000 amounts to about 1.14 million MT (1.25 million ST) of  $U_3O_8$ ,<sup>3</sup> almost exactly double the reactor uranium requirements estimated in Table 3.2. Therefore, the staff estimates that actual uranium production by all methods through the year 2000 will be about 50% of potential production. Actual nonconventional uranium production, on an annual basis, is estimated to be 55% of the potential production figures shown in Table 3.7, in order to conservatively account for present trends toward greater proportional utilization of nonconventional methods.

On this basis, Table 3.9 indicates that conventional uranium production requirements through the year 2000 could be satisfied by the equivalent of about 833 years of operation of the model mill described in Chapter 5. On an annual basis, from 23 to 55 model-mill-equivalents would be required to be operating from 1979 to the year 2000. Ore processing capacity available in 1979 totaled 43,900 MT/day, or about 24 model mills of 1800 MT/day capacity. Thus, about 31 new model-mill-equivalents will be needed by the year 2000, not including replacement capacity to make up for potential retirements. In later evaluations, the staff has assumed the retirement of one model-mill-equivalent per year over the period 1980 through the year 2000 (21 model mills retired at the end of the year 2000); this corresponds with an assumed average lifetime of about 20 years for currently operating mills.

#### 3.4 PROJECTED URANIUM MILLING INDUSTRY

Information presented in this section is based on the projections for installation of nuclear power plants shown in Section 3.1 and on the assumption that conventional uranium mills, as described in Section 3.2 and 3.3, will be used to furnish most of the fuel for those power plants. The data presented are intended only to illustrate the need for milling capacity and the concomitant milling impacts resulting from the assumed power projections.

A major determinant of both the ore-processing capacity needed to provide the necessary fuel and of the environmental impacts of milling operations is the quality of the ore (e.g.,  $U_3O_8$  content and chemical composition). This quality establishes the amount of ore that must be processed and the quantity and radioactivity content of the tailings produced. Presently mined ore resources contain from about 0.05% to 0.25%  $U_3O_8$ , and the staff assumes that the range will be similarly broad for the foreseeable future.

The milling techniques currently used, with such minor modifications as increasing the concentration of acid used in leaching or improving resins for concentration of uranium, will likely continue through the year 2000. None of the foreseeable changes in mill processes will drastically affect the number of conventional mills required.

The potential effect of increasing the capacity of individual conventional mills, as from 1800 MT (2000 ST) to 7200 MT (8000 ST) per day, is to lower the relative plant costs. It is common for more than one mine to be developed in an area containing economically recoverable ores. This favors construction of a centrally located mill of sufficiently large capacity to serve several mines within economical transport distance. (See Appendix I for discussion of effect of larger mills on tailings management.)

##### 3.4.1 Current Plans for Increasing U.S. Milling Capacity

In addition to the mills and capacities listed in Table 3.4, other plants are scheduled for probable start-up between 1980 and 1982. These are listed in Table 3.10. There are plans for development of other mills at later dates, but these are considered less definite.

##### 3.4.2 Meeting Projected $U_3O_8$ Requirements

The projected uranium fuel requirements and the translation of these requirements into the number of model mill equivalents are discussed in this section. These mill and ore requirements are based on the reactor installation schedule given in Table 3.2. These requirements and the effect of unconventional processes are shown in Table 3.9.

The staff has assumed that the  $U_3O_8$  content of the ore will remain constant at about 0.10% through the year 2000 and that all mills will operate at 85% of capacity. The average online operating capacities as percentages of stated capacity in 1975, 1976, 1977, and 1978 were, respectively, 83%, 87%, 75%, and 91%. The 1977 value of 75% was lower than the previous years because of poor performance from new mills and older mills which were being expanded to handle more ore. The annual output of  $U_3O_8$  for the conventional standard mill [1800 MT (2000 ST) of ore per day] is 520 MT (570 ST) of  $U_3O_8$  per year, assuming operation at 85% of capacity.

Table 3.8 World Uranium Production Capability (thousands of short tons U<sub>3</sub>O<sub>8</sub>)<sup>a</sup>

Year	U.S. <sup>b</sup>	U.S. % of World	Canada <sup>c</sup>	South & SW Africa <sup>d</sup>	France <sup>e</sup>	Niger <sup>e</sup>	Gabon <sup>e</sup>	Australia <sup>f</sup>	Other Western Nations	Total
1977	15.7	44	7.9	5.0	2.3	1.9	1.0	1.0	1.0	35.8
1978	21.0	42	8.4	11.0	2.9	2.9	1.6	1.0	1.0	49.7
1979	26.1	43	9.1	12.0	3.9	5.2	1.6	1.0	1.5	60.4
1980	29.1	43	10.4	13.2	3.9	5.2	1.6	1.0	2.8	67.2
1981	34.0	43	12.7	14.0	4.0	5.2	1.6	2.5	4.3	78.3
1982	40.3	43	13.3	15.0	4.0	7.8	1.6	6.8	4.3	93.1
1983	41.8	40	14.5	16.5	4.5	7.8	1.6	8.8	7.0	102.5
1984	44.6	40	16.3	16.5	4.5	7.8	1.6	12.4	7.0	110.7
1985	46.8	41	16.3	16.5	4.5	7.8	1.6	14.0	7.0	114.5

<sup>a</sup>Conversion factor: One short ton (ST) = 0.91 metric ton (MT).

<sup>b</sup>ERDA, 1977.

<sup>c</sup>Energy Mines and Resources, Canada, 1977.

<sup>d</sup>Uranium Institute, 1976.

<sup>e</sup>Organization for Economic and Commercial Development (OECD), 1975.

<sup>f</sup>Adapted from Ranger Environmental Inquiry, Second Report, 1977, and Company plans.

Table adapted from R. J. Wright, "Foreign Uranium Developments," presented at the Grand Junction Office Uranium Industry Seminar, U. S. Dept. of Energy, October 1977.

Table 3.9 Conventional Uranium Production Requirements, 1979-2000

Year	Estimated Reactor Requirements, <sup>a</sup> 10 <sup>3</sup> MT U <sub>3</sub> O <sub>8</sub>	Estimated Nonconventional Production, <sup>b</sup> 10 <sup>3</sup> MT U <sub>3</sub> O <sub>8</sub>	Required Conventional Production, 10 <sup>3</sup> MT U <sub>3</sub> O <sub>8</sub>	Model Mill Equivalents Required <sup>c</sup>
1979	13.4	1.5	11.9	22.8
1980	14.6	1.7	12.9	24.7
1981	16.0	2.3	13.7	26.2
1982	18.2	3.0	15.2	29.1
1983	20.6	3.8	16.8	32.1
1984	22.1	4.3	17.8	34.0
1985	22.9	4.8	18.1	34.6
1986	23.2	5.2	18.0	34.6
1987	23.6	5.7	17.9	34.6
1988	24.7	6.5	18.2	34.6
1989	25.3	7.1	18.2	34.5
1990	26.2	7.5	18.7	35.6
1991	27.5	7.8	19.7	37.7
1992	27.9	7.9	20.0	38.2
1993	29.0	7.9	21.1	40.3
1994	30.1	7.9	22.2	42.4
1995	31.2	7.9	23.3	44.6
1996	32.2	8.0	24.2	46.3
1997	33.3	8.0	25.3	48.4
1998	34.4	8.0	26.4	50.5
1999	35.5	8.0	27.5	52.6
2000	36.5	7.9	28.6	54.7
Totals	568.4	132.7	435.7	833.2 <sup>d</sup>

<sup>a</sup>Based on DOE Mid-Range reactor installation schedule in Table 3.2

<sup>b</sup>Assumes 55% of production capability as shown in Table 3.7.

<sup>c</sup>Based on a model mill processing 1800 MT/day of 0.10% ore, with an 85% capacity factor and a 93% extraction efficiency.

<sup>d</sup>A total of 833 model-mill-years are estimated to be necessary to fulfill conventional uranium production requirements through the year 2000.

Table 3.10 Additional Uranium Mills Scheduled for Startup 1980-1982

Company	Mill Location	Year of Startup <sup>a</sup>	Capacity, MT/day
Minerals Exploration Co.	Red Desert, WY	1980	2700
Homestake Mining Co.	Marshall Pass, CO	1980	540
Bokum Resources	Marquez, NM	1980	1800
Energy Fuels Nuclear	Blanding, UT	1980	1800
Plateau Resources, Ltd.	Shootering Canyon, UT	1981	680
Pioneer-Uravan, Inc.	Slick Rock, CO	1981	900
Gulf Minerals Resources	McKinley County, NM	1982	3800

<sup>a</sup>The year of startup for each plant is tentative.

The requirements presented in Table 3.9 do not take into account inventories of  $U_3O_8$  or  $UF_6$  held by the U.S. Department of Energy at enrichment plants nor inventories held by users. The DOE inventories are estimated to be about 26,000 MT (29,000 ST) and the user inventories to be 33,000 MT (36,000 ST). The DOE plans to reduce its inventory to a working level of 4100 MT (4500 ST). The user inventory is expected to increase through 1980 and to decrease steadily thereafter to about 9100 MT (10,000 ST) by 1984. The staff estimates that full use of the inventories through 1985 would have little effect on overall mill requirements through the year 2000.

The Department of Energy has recently changed its policies regarding early delivery of material for enrichment and enrichment tails assay. The NRC staff estimates that without these changes, increased needs for  $U_3O_8$  would have required the equivalent of an additional six to eight standard (1800 MT/day) mills between 1983 and 1990. These additional  $U_3O_8$  requirements that would have been necessitated by continuation of past DOE policies have not been included in the NRC staff's calculation of the number of mills required through the year 2000. For the purpose of these calculations, it has been assumed that the enrichment tails assay would remain at 0.20% U-235 (in the depleted uranium produced) to produce all of the enriched uranium produced through the year 2000.

The estimates shown in Table 3.9 as to the number of equivalent model mills required to be operating do not include provisions for replacement of mills operating in 1979. The average age of the 11 U.S. mills operating in 1979 which had been in operation prior to 1970 was 23 years; the minimum age was 18 years. If the same average age holds through the year 2000, then mills starting up in 1979 or later would not require replacement until past the year 2000. For calculational purposes, the staff has allowed for the retirement of older mills by assuming the retirement of one model mill equivalent per year, from 1980 through the year 2000.

Heap leaching is expected to make some minor contribution to  $U_3O_8$  production at conventional mills. The economic viability of heap leaching will depend on the price of uranium. As the price increases, lower percentages of  $U_3O_8$  in ore will be economically recoverable by conventional means. Exceptions could occur where the cost of transporting the low-grade ore to a conventional mill proves to be prohibitive. Heap leaching will then be practical at existing mills, but new mills will attempt to recover more  $U_3O_8$  by conventional processes. For those reasons, heap leaching will be done only by a small segment of the uranium industry and is not expected to contribute more than 1% to 2% (a maximum of 300 MT) of the U.S. requirements of  $U_3O_8$  per year by the year 2000.

In summary, based upon a reactor schedule of 180 GWe by the year 2000, there will be a need for milling capacity equivalent to about 55 model mills (1800 MT/day (2000 ST/day)) by the year 2000.

### 3.4.3 Geographic Location of Future Conventional Industry

The location of probable resources is shown in Figure 3.1. The potential for expansion of milling activity is greatest in such states as New Mexico, Wyoming, Utah, Colorado, Texas, and Washington, which already are the most active locations of uranium milling and exploration. In Table 3.11, ten states are ranked on the basis of the probable uranium resources contained. The distribution of uranium reserves and probable resources by region and state also is shown in Table 3.12. The number of new mills required between now and the year 2000 within each region and state is estimated on the basis of this distribution and the assumption that mill location will coincide with combined reserve and resource locations. The expected distribution of new model mill equivalents among the states is depicted in Table 3.12.

## 3.5 SUMMARY

Nuclear energy growth projections resulting in a nuclear generating capacity of 180 GWe in the year 2000 were used in estimating U.S. uranium production necessary to meet estimated nuclear fuel needs through the year 2000. Current nuclear energy production requires about 13,400 MT of  $U_3O_8$  per year; these annual  $U_3O_8$  requirements are expected to increase by 170% by the year 2000. Cumulative  $U_3O_8$  requirements over the time period 1979 to 2000 are projected to be about 568,000 MT. It is estimated that conventional milling will produce about 77% of  $U_3O_8$  requirements (about 436,000 MT) out of the total over the time period 1979 to 2000. Based on the assumption that a model mill, operating at 85% capacity, would produce 520 MT of  $U_3O_8$  per year, it would take about 833 model mill years to produce 436,000 MT of  $U_3O_8$ .

Although there is some uncertainty about the growth of the unconventional milling industry, other methods of production, such as in situ mining, byproduct recovery, and imports, are expected to supply over 20% of cumulative  $U_3O_8$  requirements through the end of this century. These projected nuclear fuel needs will necessitate construction and operation of about 53 additional conventional model mills over this time period. These mills would be in addition to the 23 model-mill-equivalents now required, 21 of which are projected to be retired as of the year 2000. Nearly

all of the new mills are expected to be located in the western United States, with over 60% in Wyoming and New Mexico. Projected nuclear generating capacity, annual  $U_3O_8$  requirements, and annual  $U_3O_8$  production from conventional mills are shown in Tables 3.2 and 3.9.

Fulfilling these future energy requirements according to the adopted scenario will generate about  $4.7 \times 10^8$  MT of tailings through the year 2000 by conventional milling; these tailings would be in addition to the  $2.5 \times 10^7$  MT ( $2.8 \times 10^7$  ST) of tailings now at inactive sites, and the  $1.2 \times 10^8$  MT ( $1.4 \times 10^8$  ST) of tailings at currently active mill sites at the end of 1978.

Cumulative impacts due to milling over the time period 1979 to 2000 are addressed in several sections of this document, including: radiological health risks to workers (Sections 6.2.8.2 and 9.2.8.2); radiological health risks to populations (Sections 6.4, 9.3.8 and 12.3); and environmental impacts and resource commitments for the case in which proposed regulatory actions (delineated in Chapter 12) are implemented (Chapter 15). Cumulative impacts are dependent, in part, on the nuclear power projections, enrichment tails assay policies and ore grade assumptions given in this Chapter. The effect of different nuclear power projections, enrichment tails assays, ore grades, and other factors on cumulative impacts is discussed in Appendix S.

Table 3.11 Share of Potential Resources of Uranium in Individual States<sup>a</sup>

State	Share of Probable Resources, <sup>b</sup> %
New Mexico	30
Wyoming	15
Colorado	11
Utah	14
Texas	10
California	2
Arizona	4
South Dakota	1
Nevada	2
Washington	2

<sup>a</sup>From D. L. Hetland, "Potential Resources of Uranium," presented at the Grand Junction Office Uranium Industry Seminar, U. S. Dept. of Energy, October 1978.

<sup>b</sup>Conventional sources only.

Table 3.12 Probable Need for and Distribution of New Conventional Uranium Mills, 1979-2000<sup>a,b</sup>

NURE Region	Reserves & Probable Resources, $10^3$ MT $U_3O_8$	Percentage of U. S. Total in Region	Number of New Model Mill Equivalents 1980-2000	States with Mills in 1978 <sup>c</sup>
A	1150	52	28	New Mexico, Colorado, Utah (Arizona)
B	634	29	15	Wyoming (Montana)
C	234	11	6	Texas (14 other states)
D	52	2	1	Washington (Idaho, Montana)
E	82	4	2	Colorado, New Mexico
F	35	2	1	Wyoming, South Dakota (8 other states)
Total	2192	100	53	

<sup>a</sup>From D. L. Hetland, "Discussion of the Preliminary NURE Report and Potential Resources;" and R. J. Meehan, "Uranium Ore Resources," both presented at the Grand Junction Office Uranium Industry Seminar, U.S. Dept. of Energy, October 1978.

<sup>b</sup>Assumed capacity of 1800 MT/day each.

<sup>c</sup>States in parentheses are in the given NURE region, but had no mills operating in 1978.

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8. J. N. Frank, "Cost Model for Solution Mining of Uranium," presented at the Grand Junction Office Uranium Industry Seminar, U.S. Energy Research and Development Administration, October 1976.
9. "Irigaray Uranium Solution Mining Project - Wyoming Mineral Corporation," U.S. Nuclear Regulatory Commission, NUREG-0481, September 1978.
10. "Highland Uranium Solution Mining Project - Exxon Minerals Corporation," U.S. Nuclear Regulatory Commission, NUREG-0489, November 1978.
11. "Ground-Water Elements of In-Situ Leach Mining," Geraghty and Miller, Inc., for U.S. Nuclear Regulatory Commission, NUREG/CR-0311, August 1978.



UNITED STATES  
NUCLEAR REGULATORY COMMISSION

WASHINGTON, D.C. 20555-0001

JUN 02 1994

Anthony J. Thompson, Esq.  
Shaw, Pittman, Potts & Trowbridge  
2300 N Street, N.W.  
Washington, D.C. 20037

Dear Mr. Thompson:

**SUBJECT: SUGGESTED RECONSIDERATION OF REGULATORY AUTHORITY OVER  
IN-SITU LEACH FACILITY WELLFIELDS**

I am responding to your letter to me of March 10, 1994. In that letter you suggested that the Nuclear Regulatory Commission reconsider its regulatory authority over in-situ leach (IS) facility wellfields. The basis for your position was that contrary to the April 28, 1980, memorandum from the Executive Legal Director (ELD) to the then Chairman Ahearn, you believed NRC lacks jurisdiction over below-ground activities related to licensed IS operations. You also argued that NRC regulation of IS wellfields is unnecessary, duplicative and potentially inconsistent with standards for groundwater protection established by the U.S. Environmental Protection Agency (EPA). Your letter further suggested that if NRC concluded its regulatory rule over wellfields could not be reduced, that the staff consider deferring its authority to States.

Based on its review of your letter, the staff concluded that the legal arguments you presented do not alter the conclusions reached in the 1980 ELD memorandum. Your letter states that NRC is in error in regulating IS wellfields for four reasons. In consultation with our legal counsel, we conclude that the four premises you offered either do not properly convey the concepts promulgated in the regulations with respect to conventional uranium mining and milling, or serve unrelated regulatory purposes. Your four arguments can be briefly addressed as follows:

1. *The underground aspect is mining, which NRC does not regulate.*

The underground aspect is not solely mining. Running lixiviant through an underground ore body is also processing. The Atomic Energy Act of 1954, as amended, gives the NRC authority over source material after its removal from its place of deposit in nature. The dissolution of uranium in the ore body is a removal of uranium from its place of deposit in nature and is also a form of processing equivalent to the acid or base leach in a conventional mill.

2. *The underground ore body is unrefined and unprocessed ore and exempted from licensing.*

After leaching with lixiviant the underground ore body is processed ore.

3. *The ground water involved contains less than 0.05 weight percent of uranium and is exempt from NRC regulation.*

The .05 weight percent unimportant quantity rule in 10 CFR 40.13(a) does not apply to licensed persons. Disposal of waste water by licensees is subject to 10 CFR Part 20, specific license condition, and/or National Pollution Discharge Elimination System (NPDES) permit limits.

4. *The underground aspect does not involve byproduct material.*

Only the depleted underground ore body is excluded from the definition of byproduct material. All other waste is byproduct material and must be disposed of either as an authorized effluent release, or in conventional mill tailings ponds (or the Envirocare licensed facility) pursuant to criterion 2 of 10 CFR Part 40, Appendix A.

Therefore, the staff does not believe there is any basis to alter the staff's understanding of its regulatory jurisdiction over IS wellfields.

With respect to your second suggestion, if the staff finds that a State is implementing a program that is comparable to one the NRC would undertake, the staff could rely on the State's program to also meet NRC's regulatory requirements. This approach would allow the staff to ensure that the necessary oversight was being achieved but still eliminate duplicate regulation. The staff plans to investigate other regulatory programs, administered by the EPA and States, to determine whether these programs accomplish the same objectives as the NRC IS wellfield regulation program, and if so, how they can be used by the staff to fulfill its regulatory obligation. As an initial step, on April 19, 1994, the staff discussed with Wyoming officials that State's program for IS wellfield regulation.

I trust this responds to your concern. If you have further questions, please contact Mike Fliegel at (301) 415-6629.

Sincerely,



Malcolm R. Knapp, Director  
Division of Waste Management  
Office of Nuclear Material Safety  
and Safeguards

cc: States (see attached list)  
In-Situ Licensees (see attached list)  
Wyoming Mining Association  
American Mining Congress