Prepared For:

Western Nuclear, Inc.
Sherwood Project
Wellpinit, Washington

SHERWOOD TAILING RECLAMATION PLAN

RESPONSES TO NRC COMMENTS

VOLUME 2 OF 2
APPENDICES J THROUGH N

Prepared By:

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June 2000

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DIVISION OF RADIATION PROTECTION

June 29, 2000

SMI #03-317

Mr. Gary Robertson
Washington Department of Health
Division of Radiation Protection
P.O. Box 47827
7171 Cleanwater Lane, Building 5
Olympia, Washington 98504-7827

Subject: Responses to NRC Staff Comments (Dated May 19, 2000) on the Termination Finding of the Western Nuclear, Inc.'s Sherwood Uranium Mill License Submitted by the Washington State Department of Health

Dear Gary:

As you requested, we have reviewed the letter you received from the NRC dated May 19, 2000, (NRC, 2000) that submitted 20 questions regarding the reclamation of the Sherwood tailings impoundment. We have prepared responses to the 20 questions, as well as a subsequent verbal question you received during a meeting with the NRC. The responses that are presented below incorporate previous information that was submitted to your agency over the last 6 years. In many cases, several questions can be grouped and answered with one response. The following presents the NRC questions followed by our response:

NRC Q1: ***Please provide further information and justification to confirm that the formation of sand boils was considered, and that resulting damage could be accommodated by the design.***

NRC Q3: ***Please provide additional information and documentation to confirm that an appropriate PGA, including amplification, if necessary, was considered in the stability and liquefaction analyses.***

NRC Q4: ***Please provide additional information and documentation to support your conclusion regarding the potential for recharge of the tailings. If there is potential for ponding water to infiltrate and recharge the tailings, please provide additional information and documentation to confirm that an increased likelihood of liquefaction of a wet embankment was considered.***

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NRC Q10: ***Please provide additional information on this subject (Geologic and Seismologic Characterization) sufficient to understand the subsequent brief discussion of site stability.***

NRC Q12: ***Please provide additional information and discussion related to specific local bedrock features, especially discontinuities such as faults and fractures, for consideration in seismotectonic hazard analyses.***

NRC Q13: ***Please provide additional information and discussion of WDOH's findings related to its review of key references and the geologic map of Coulee Dam Vicinity (Waggoner report, 1990, Ref. 4) The TER points out a large discordance in the structural trends at the site. Waggoner indicates north-south; Shepherd Miller, Inc. (Reclamation Plan, 1994, Ref. 5) indicates east-west. Please provide further discussion and clarification of the significance of this discordance in WDOH's determination that all applicable standards and regulations have been met.***

NRC Q15: ***Please provide additional information and discussion of WDOH's evaluation of earthquake sources (such as capable faults) and earthquake hazards for the site. The information should include discussion of seismic design basis (maximum credible earthquake or reasonable alternative basis) for the engineering structures and WDOH's evaluation of liquefaction potential.***

The preceding 7 questions all relate to seismic stability of the reclaimed site. Western Nuclear Inc. (WNI) performed a number of analyses starting in 1994 to address the seismicity of the region and designed and constructed the reclamation facility to be stable under the seismic forces for the 1,000-year-design life of the reclaimed facility. The following chronology describes the analyses that were performed:

A comprehensive regional and local geologic evaluation was conducted. This evaluation identified key geologic structures both regionally and locally that provided a basis for understanding current site conditions as well as the expected future seismic activity. This evaluation is included in Attachment C to Appendix P of the 1994 Reclamation Plan (WNI, 1994) and is included in this report as Appendix A. This information gives the general geologic setting of the region and also includes site-specific geological features. Additionally, a separate report (prepared by R.L. Volpe & Associates, Inc., 1994) included in Attachment C of Appendix L of the 1994 Reclamation Plan (WNI, 1994) presents a geologic evaluation more closely focused on the seismicity of the region. This report is included as Appendix B to this report.

Based on the background geologic information, an evaluation of the seismic forces that should be used in the design of the reclamation system was made. This evaluation is also included in the report attached as Appendix B to this submittal.

The seismic forces that were assigned to the site were then used in the design and evaluation of the reclamation system. Specifically, the stability of the embankment outslope was evaluated under seismic loading conditions. This evaluation was included in Appendix N of the 1994 Reclamation Plan (WNI, 1994) and is included as Appendix C to this report.

The performance of the reclamation cover system under seismic loading was also evaluated. The performance of the homogenous cover system was evaluated relative to sand boils, rafting, and settlement. This evaluation used a much more conservative seismic loading condition than the one presented in Appendix B of this submittal. The seismic loading conditions used in the cover evaluation assumed a peak ground acceleration of 0.15 g (which is considerably greater than would be expected during the 1,000-year-design life as documented in Appendix B of this submittal). This seismic scenario was thought to represent a very conservative upper bound of the anticipated earthquake loading and would, therefore, give very conservative seismic stability results. The determination of the larger seismic loading conditions was included in Appendix 3 of the Revegetation Reclamation System Evaluation Report (WNI, 1995) and is included in Appendix D of this submittal. The results of the evaluation were also included in Appendix 3 of the Revegetation Reclamation System Evaluation Report (WNI, 1995) and are also included in Appendix D of this report. The results consist of the original submittal dated May 5, 1994, and a subsequent submittal dated September 13, 1995, that responded to questions from Gerald LaVassar of the Washington Department of Ecology – Dam Safety Section.

In summary, the results of the evaluations clearly show that a conservative design earthquake event was determined using all information that was available at the time of the original study, and that the performance evaluation of the reclamation system would not be adversely impacted by the design seismic event. Specifically, the embankment outslope would be stable under the anticipated maximum earthquake loading during the 1,000-year-design life. Additionally, the cover of the reclaimed impoundment would perform successfully under earthquake loading much larger than would be expected during the design life. The cover was evaluated and found to possess adequate factors of safety relative to rafting, settlement, and the formation of sand boils.

NRC Q2: ***Please provide additional information and documentation to confirm that the embankment stability under saturated conditions was considered.***

The stability of the reclaimed embankment was evaluated in Appendix N of the 1994 Reclamation Plan (WNI, 1994). This evaluation is attached as Appendix C of this submittal. As can be seen, the evaluation clearly shows that the reclaimed embankment will be stable. The evaluation assumed that there would be no phreatic surface in the embankment since the embankment is separated from the tailings by an impermeable liner, the embankment is constructed of a free draining material that would drain faster than water could seep from the tailings if the liner were to fail, and that the depth to water (or a low permeable layer) is over 150 feet that would require saturation before a phreatic surface could form.

However, the original design report for the tailings dam (D'Appolonia, 1977) assumed that a fully formed phreatic surface would exist in their evaluation of the stability of the tailings dam. Figure 7 from the D'Appolonia report is included in Appendix C and clearly shows that the tailings dam was stable under static and psuedostatic loading with saturated conditions in the embankment. Given that the embankment outslope has been flattened from 2.75:1 (h:v) to 5:1 (h:v), and the embankment is 45 feet shorter than originally designed, the embankment stability has a factor of safety much greater than required even if the embankment material were to become saturated (which, as stated above, could not occur).

NRC Q5: ***Please provide additional information and documentation to confirm whether this dam will be classified as a dam under the Federal Guidelines for Dam Safety and the National Dam Safety Program Act.***

The former tailings dam at the Sherwood Site has been reclaimed. The stability of the outslope and the reclamation cover over the tailings was evaluated under a wide range of static and seismic conditions, as described in this report. The evaluation of the reclamation system indicates that the tailings will remain isolated and contained under all scenarios for the 1,000-year-design period.

The tailings dam was operated and maintained under the Washington Department of Ecology – Dam Safety Office (WDOE-DSO) from the construction of the dam through the reclamation of the dam. In a letter dated December 15, 1997, (WDOE, 1997) the WDOE-DSO confirmed that the "provisions of the Dam Safety Section's reclamation requirements have been satisfied, and the project is hereby classified as reclaimed." In a recent letter dated June 23, 2000 (WDOE, 2000), the WDOE-DSO remained steadfast in its opinion that the engineering assessment of the reclaimed impounding structure is valid and that the reclaimed barrier represents "a practical scheme to provide a high likelihood of the structure safely impounding the process waste for the thousand-year design-life assuming little, if any, maintenance." Copies of both the December 15, 1997 and the June 23, 2000 letters are included in Appendix E of this submittal.

Jerald LaVassar of the WDOE-DSO met with representatives of the NRC, DOE, FERC, WDOH, and WNI at the site on June 21, 2000. In his letter of June 23, 2000, (WDOE, 2000) Mr. LaVassar states the WDOE-DSO views that "the reclaimed impounding barrier is a dam" and "is considered a jurisdictional dam under the provisions of Washington Administrative Code (WAC) 173-175-020." The practical consequences of such classifications are that the barrier would be inspected on a 6- to 8-year interval or in the event of an extreme storm or earthquake. There would be no cost for periodic inspections and report of findings. On the jurisdictional issue, the letter states that "The project would be removed from our jurisdiction in the event a Federal Agency assumes ownership of the project, . . ."

The DOE is the proposed long-term custodian of the site under a Long Term Surveillance Plan to be approved by the NRC. The DOE has negotiated an Access and Maintenance Agreement with the Spokane Tribe of Indians. The land, including the reclaimed barrier, remains Tribal land and the DOE has access for inspections and maintenance required by UMTRCA. Inasmuch as DOE will have no legal rights of ownership, it seems that the WDOE-DSO will likely retain jurisdiction of the reclaimed barrier under the relevant provisions of the WAC.

The current WDOH licensee, WNI, takes the position that, without agreeing or disagreeing with the technical and legal conclusion that the barrier is a dam, the fact that the WDOE-DSO retains jurisdiction presents no impediment to achieving site closure and license termination by August 2000 as presently scheduled by the NRC. The Long Term Surveillance Plan can incorporate a provision for periodic inspection and reports by the WDOE-DSO. In the remote instance that a deficiency be found with the integrity of the barrier, the DOE's obligation for necessary repairs would be no greater than that already imposed by UMTRCA for the containment and stabilization of by-product material. The DOE would be exposed to no greater responsibility or liability than it otherwise would have. The WDOE-DSO jurisdiction just provides another layer of institutional control.

Inasmuch as it would appear unlikely that a federal agency would assume ownership of sovereign Indian property, it is unnecessary to undertake a FERC review for it to determine whether the impounding barrier is a dam. That determination has already been made by the WDOE-DSO having jurisdiction. Additional federal review would seem to be duplicitous, unnecessary, and jurisdictionally problematic.

NRC Q6: ***Please provide additional information and discussion of rock durability test results that supports WDOH's final approval of the quarry for riprap source.***

NRC Q7: ***Please provide additional information and justification of the representativeness of the 3 samples on which durability estimates were based. Based on field photos, the samples tested do not appear to be representative of the rocks used and could have led to underestimation of rock durability.***

NRC Q8: ***Please provide additional information and justification of the acceptability of the rock that has already been placed to function for the performance period of 1000 years and at least 200 years, given that some areas have degraded. The objective is to get a more realistic basis for projected performance of the rocks than can be gotten from more pristine samples from quarry walls.***

NRC Q9: ***Please provide further information and analyses that demonstrate that large areas of non-quartz monzonite rock or poor quality quartz monzonite rock have not been placed in the rock cover, particularly in the diversion channel.***

NRC Q21: ***(This question was added during a May 24, 2000, meeting in Spokane, Washington, and is paraphrased from the conversation.) Please provide information that standing water or freeze/thaw effects on weathering of rock (riprap) has been considered during WDOH review of rock durability and longevity in relation to millsite performance in meeting 10 CFR 40 Appendix A criteria.***

Questions 6 through 9 and 21 all relate to the durability of the rock used as erosion protection for the site. A brief discussion of the sampling and analyses of the rock along with references of previously submitted material is provided that demonstrates that the riprap that was used meets the requirement of the reclamation plan that were developed in accordance with NRC guidance on rock durability.

An initial evaluation of the available on and near-site rock sources was conducted in 1994 and documented in Appendix B of the 1994 Reclamation Plan (WNI, 1994). This is included as Appendix F to this submittal. This report indicated that the on-site basalt rock would be acceptable for use as riprap for any application, and the quartz monzonite material was marginal. The testing and evaluation were conducted using NRC guidance (NRC, 1990). The evaluation consisted of petrographic analyses as well as physical durability testing.

After the initial testing, another source of on-site quartz monzonite material was identified that appeared to have better durability qualities than the originally sampled locations. Subsequent petrographic and physical durability samples were obtained and tested. The results of the testing indicated that the quartz monzonite material from the new area that ultimately became the quarry would be acceptable. The results of the testing was included in the Construction Completion Report (WNI, 1997) and is attached as Appendix G to this submittal.

Included in Appendix H are the field logs of WDOH personnel that are relevant to the durability of the quartz monzonite from the quarry. These field logs were originally included in Appendix Z of the Construction Completion Report (WNI, 1997). Specifically the field log dated March 11, 1996, written by Dorothy Stoffel, WDOH geologist, documents her visual observation of the proposed quarry area. Her observations are consistent with the determination that the quartz monzonite in the quarry area is durable. Subsequent observations made by WDOH confirm that the quartz monzonite material appeared durable as the quarrying operation continued.

After the initial testing that indicated the quartz monzonite area would be acceptable for use as rock protection, durability tests were conducted on samples taken that represent every 10,000 cubic yards of rock produced. The samples were taken from the quarry after the area was blasted and before the material was crushed and processed. The rock samples were taken by AGRA Earth and Environmental technicians. The samples were taken to be representative of the area blasted, and every effort was taken to not bias the samples based on visual differences in the material (personal communications with Jay Martin, AGRA Earth and Environment, June 16, 2000). Documentation of the sample locations and results of the durability testing were submitted in the Construction Completion Report and are included in Appendix G of this submittal.

The results of the durability testing clearly indicate two key pieces of information. First, all of the rock meets or exceeds the minimum durability requirements of the NRC guidance with the exception of one sample which scored 79 instead of 80. The rock that was represented by this one test result was oversized by 1 percent over the design requirement as required by the NRC guidance. The second key point is that the durability of the quartz monzonite material was very uniform. The material scored from 79 to 81 which indicates that the source was very uniform. That combined with the random nature of the sampling procedures clearly shows that the samples were representative of the quarry.

It should be noted that the basalt material that was also used as riprap scored much higher than the quartz monzonite (durability rating of 90 percent). This indicates that the basalt is more durable than the quartz monzonite, which is counter to the implication made in Question 9.

The guidance provided by NRC gives minimum durability ranking for rock to be used in various conditions. Specifically, rock that is located in areas that could be frequently saturated should have a score of at least 80 percent or be oversized. Since all of the durability requirements for the riprap on site were for the most restrictive conditions (i.e., areas that could be frequently saturated), all of the rock that was placed meets the guidance requirements for rock that might be in standing water and subjected to freeze/thaw events.

There is no indication that any significant amount of rock that would not meet the NRC guidance for durability is concentrated in any particular area. As stated above, the random nature of the sample selection along with the consistent values that were obtained from the durability testing clearly indicates that the rock is uniform and meets the durability requirements as outlined in NRC guidance.

The information discussed above and attached to this document clearly shows that the rock that was used for erosion protection meets the requirements of the approved reclamation plan that were developed using NRC guidance. However, it is also important to note that the conservative nature of the design would not necessarily require that rock be used for erosion protection at all. This is especially true after vegetation becomes established in areas that received riprap.

Much of the diversion channel and all of the swale outlet was excavated into quartz monzonite bedrock. This underlying material will be resistant to erosion if riprap would not have been placed in these areas. Further, analyses show that erosional velocities will not occur in the diversion channel after vegetation has become established. An evaluation was performed to determine the necessary size of the diversion channel after vegetation becomes established. This evaluation shows that the maximum velocities in the channel overbank would range from 0.3 to 1.5 ft/sec and the maximum velocity in the channel would range from 0.9 to 4.9 ft/sec, which is less than 5 ft/sec that the NRC STP on erosional stability recommends as the maximum velocity for grass lined channels. These analyses were included in the Responses to WDOH Comments on the December 1994 Tailing Reclamation Plan (WNI, 1995) dated August 1995 and included in this report as Appendix I. While similar calculations were not performed for the swale outlet and the embankment outslope, similar results would be anticipated.

In summary, the sampling, testing, and analyses of the riprap material were in accordance with NRC guidance. Further, the results of the testing indicate that the rock is acceptable for use as erosion protection for reclamation of uranium mill tailings. Finally, the conservative nature of the reclamation design shows that rock protection is likely not necessary at the site, especially after vegetation becomes established.

NRC Q11: ***Please provide additional information and discussion of WDOH's findings on its review of the key reference materials relevant to site stability analysis.***

NRC Q14: ***Please provide additional information, technical discussion and/or summaries of operative surface processes, including but not limited to mass movements, stream erosion/deposition potential at the site that supports a finding that there are not potential processes which would lead to impoundment instability.***

These two questions relate to the overall geologic or geomorphic stability of the site. The discussion of the geological setting (Appendix A to this submittal) provides a good framework from which to understand the geologic and geomorphic conditions at the site.

The geologic setting of the area is very stable and is expected to remain so for many thousands of years. The geologic stability of the area is provided by the Loon Lake Granite Pluton. This massive geologic formation underlies the entire area and would prevent any significant geomorphic instability.

Sandy alluvial deposits overlie the granitic pluton in the area of the tailings impoundment. This sandy alluvial material varies in depths from a few feet to approximately 200 feet at the toe of the embankment outslope. This material provides an excellent base on which the tailings impoundment was founded. The unsaturated granular nature of the alluvial material precludes any settlement concerns, and the geotechnical stability of the foundation is more than sufficient to support the reclaimed impoundment.

The slopes around the reclaimed tailings impoundment are gently sloping and there is no evidence of landslides or other mass movement. There is very little evidence of surface erosion in the undisturbed surrounding areas. The lack of erosion is due to the gently sloping surfaces, the high infiltration rate of the sandy alluvial material, and the mature vegetation community. Confluences were designed and constructed to convey water from the drainage basin above the reclaimed impoundment in an erosionally stable manner. This, combined with the relatively small total water shed area, contributes to stable hydraulic conditions.

In conclusion, the geomorphic and geologic conditions at the site are conducive to the long-term stabilization of the reclaimed tailings impoundment.

NRC Q16: ***Please provide documentation demonstrating that the review and acceptance, if appropriate, of licensee submitted information pertaining to the impacts to groundwater caused by potential releases of liquids from the disposal cell, given credible failure scenarios of the engineering design components of the disposal cell. This information should not be limited to synthetic liner failure and over-***

topping from water buildup, but include any other credible scenario that could cause release of liquids.

There are no credible failure scenarios that could release water from the impoundment into the groundwater system other than overtopping. That scenario, along with the worst-case bounding scenario of liner failure was evaluated to determine the expected and the worst-case bounding scenario impact of liquids in the impoundment on groundwater. Even under the worst-case condition of complete liner failure, groundwater at the point of compliance would meet site standards. A complete description of the groundwater conditions at the site and the modeled prediction of future concentrations are included in the Groundwater Technical Integration Report (WNI, 1995) which is attached as Appendix J. As this document shows, groundwater will remain protected under the worst-case scenario and would, therefore, remain protected for any other scenario.

NRC Q17: ***Please provide discussion of results of confirmatory soil samples and radiation surveys (including highest, lowest and average values, and data comparisons between WNI and WDOH results) that indicates that the subject site has been cleaned up to the State standards (including uranium and thorium limits) for both surface and subsurface soil.***

A comprehensive radiological program was conducted at the site to determine areas with residual radioactive contamination greater than applicable standards and to verify that those areas had been remediated. The Radiological Verification Completion Report – Executive Summary (Volume 1 of 11) and Report (Volume 2 of 11) (WNI, 1996) summarize the program and are included as Appendix K.

A total of approximately 375,000 cubic yards of material was excavated from the mill area and around the tailings impoundment and placed in the impoundment. A total of 4,968 gamma surveys and 1,320 soil samples were taken to verify that the areas outside of the impoundment could be released for unrestricted use. The program included standards for radium, uranium, and thorium. A summary of the laboratory test results is presented on Figures ES-7 (radium), ES-8 (thorium), and ES-9 (uranium) in Appendix K. Tables 14, 15, and 16 from the main report, attached as Appendix K, present the comparison between WNI and WDOH laboratory test results.

As can be seen, the results of the gamma surveys and the laboratory analyses clearly show that all areas have residual radioactive contamination well below the regulatory limits with the vast majority of the areas at background levels. Additionally, the WDOH laboratory results confirm that all areas have been cleaned up to applicable limits.

NRC Q18: ***Please provide information on the cleanup criteria used for remaining structures, if any, to demonstrate compliance with the State's equivalent of 10 CFR 40.42(k)(2).***

A water tank and a pump house exist on the former millsite area. The building and the water tank were surveyed for surface contamination. All contaminated materials were removed and buried in the tailing impoundment. This information was documented in the Mill Decommissioning Completion Report (WNI, 1997) and is attached as Appendix L.

NRC Q19: ***Please provide information and discussion of the evaluation of the site's compliance with the State's equivalent of 10 CFR 40 Appendix A criteria 6 (2) and (5), concerning the overall gamma radiation level and radioactivity content of the cover material.***

After the cover was placed, radon measurements were taken in accordance with Appendix A criterion 6 (2). The results of this testing were submitted to WDOH on December 16, 1996 (attached to this report as Appendix M). The results of the testing indicated an average radon emanation rate of 0.51 pCi/m2sec which is well below 20 pCi/m2sec specified in criterion 6.

All cover material was obtained from borrow sources around the tailings impoundment. All of this material was used for cover only after the areas were determined to meet the radiological cleanup criteria as discussed above (see Appendix K). The cover material was obtained from near surface soils and had background levels of radionuclides. The background levels are approximately 1 pCi/g for radium-226 and thorium-230 and 2 pCi/g for natural uranium. Appendix K presents a complete summary of the background values for the near surface soils that were used for the cover.

NRC Q20: ***Please provide additional information to support your basis that WNI's remedial work was performed according to the approved plans and specifications.***

In August 1999, WDOH submitted 12 questions resulting from field inspections of the reclaimed site. These questions were address as part of the Request for License Termination (WNI, 1999). The applicable portions of this report are attached as Appendix N.

As documented in Appendix N, all areas identified by WDOH were addressed. Some of the issues were addressed by submittal of information that demonstrated that no additional work was necessary, and that the elements of the reclamation system were performing as designed. Remedial reclamation work was performed to address the remaining areas. Appendix N presents a discussion of each question, the design of the remedial efforts (for elements that required a design effort), the activities that were performed, and the site stability inspection that was performed by an independent third party engineer (Sheila Pachernegg) that confirmed that the remedial efforts were successfully completed. In addition to WNI's efforts, WDOH performed site inspections of the remedial efforts during the construction process. Their inspections concluded that the required remedial effort was performed as required.

We trust that these responses will assist you in responding to the NRC. Should you need any additional assistance, please let us know.

REFERENCES

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Sincerely,

SHEPHERD MILLER, INC.

Louis L. Miller by HMR

Louis L. Miller, P.E.
Vice President

LLM:hmr
Enclosures

Prepared For:

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SHERWOOD PROJECT
GROUND WATER PROTECTION PLAN
TECHNICAL INTEGRATION REPORT

Prepared By:

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DECEMBER 1995

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1.0 INTRODUCTION

This report presents an integrated summary of the contents of the Ground Water Protection Plan (Appendix P) to the December 1994 Western Nuclear Inc. (WNI) Sherwood Project Tailing Reclamation Plan (12/94 TRP; SMI, December 1994) and data included in the Sherwood Project Revegetation Reclamation System Evaluation (SMI, September, 1995). As part of WNI's efforts to reclaim the uranium mining and milling operations at the Sherwood Project, a Tailing Reclamation Plan has been developed. Appendix P to the 12/94 TRP is the Ground Water Protection Plan (GWPP) which has been developed to ensure that the tailing impoundment reclamation is compatible with all appropriate and applicable State of Washington and federal regulations for the protection of the ground water system. Appendix P presents the results of several investigative studies, the analyses of the data developed from these studies, and the ground water monitoring program developed for the prompt detection of leakage of the tailing impoundment, should it ever occur.

The technical approach employed for development of the GWPP consisted of studying the existing physical and chemical conditions both within the tailing impoundment and in the surrounding environment. The results of these studies were then used to evaluate the potential contaminants and their concentrations in the tailing impoundment, to evaluate different reclamation alternatives, to determine how the contaminants would be transported in the environment and what impact they might have were they to enter the ground water system, and ultimately, to design an effective leak detection monitoring program.

Studies of the surrounding environment were performed to better understand the existing hydrologic and chemical characteristics of the existing baseline conditions prior to final closure of the tailing impoundment. These data provided insight into where the ground water occurs, how fast and in what direction it is flowing, and the chemistry of the existing ground water. In addition, these data helped create the framework for evaluating potential impacts to the ground water system.

Studies of the tailing impoundment were performed to better understand the hydrologic and chemical characteristics of the tailing impoundment itself. These data provided insight into the tailing chemical composition, the tailing pore water chemistry, and how the tailing pore water might be removed from the tailing. In addition, the tailing impoundment studies allowed determination of which constituents of regulatory concern are present in the tailing impoundment and in what concentration they exist. These data were used as input to tailing dewatering feasibility analyses and evaluations of potential long-term impacts to the ground water system if tailing pore water were to escape the impoundment. Tailing dewatering was considered as a possible reclamation alternative but, as described in the following sections, was discarded due to the net negative effects on ground water protection.

Predictive modeling of possible impacts from potential tailing pore water release, using the data developed from the studies and analyses mentioned above, provided a basis for evaluating the tailing impoundment reclamation design and the development of an effective leak detection monitoring program. All of the operational and reclamation design elements instituted for the protection of the ground water and the leak detection monitoring program constitute the ground water protection plan.

Appendix P to the 12/94 TRP included four principal phases of work:

1) a geologic investigation,
2) a tailing impoundment investigation,
3) a basin hydrologic evaluation, and
4) a ground water protection evaluation.

The data from these principal phases of work were used to: 1) develop the geologic framework for evaluating ground water protection, 2) evaluate the pros and cons of tailing dewatering as a potential reclamation option, 3) develop the potential contaminant source concentrations of the tailing pore water, and 4) develop an appropriate ground water monitoring program for the prompt detection of leakage.

Analyses presented in Appendix P to the December 1994 TRP were based on the assumption that a conventional compacted clay-sand cover would comprise the final surface reclamation cover. However, a 12.6 feet thick uncompacted, soil cover was selected based on the results of the Sherwood Project Revegetation Reclamation System Evaluation (SMI; September, 1995 and 11/28/95 WDOH Amendment No. 22 to Radioactive Materials License WN-I0133-1). This modified reclamation cover design effectively mitigates factors including biointrusion, freeze-thaw, seismicity, and settlement that affect the long-term performance of the reclamation cover. Infiltration estimates are much less for the thick, uncompacted soil reclamation cover than was assumed for the ground water model presented in Appendix P (12/94 TRP). Therefore, the calculated infiltration of precipitation through the conventional compacted clay-sand cover, presented in Appendix P (12/94 TRP), would constitute a worst-case, upper bound estimate of potential impact to the ground water system. As described in the following sections, potential impacts to ground water, as modeled with the highly conservative Appendix P (12/94 TRP) assumptions involving a conventional compacted clay-sand cover, would maintain water quality below regulatory ground water quality standards at the point of compliance. Therefore, the potential impacts to ground water associated with the 12.6 feet thick uncompacted soil cover would remain less than those modeled in Appendix P (12/94 TRP) and would continue to protect ground water quality for the 1000-year reclamation design life.

2.0 GEOLOGIC INVESTIGATION

The geologic investigation was designed to better understand the geologic framework in which the tailing impoundment is situated. By understanding the types of geologic materials present, their relationships to each other, and the structures that exist within the individual geologic units, it was possible to more accurately evaluate the relationship between the tailing impoundment and the associated hydrologic and ground water system.

The geologic investigation consisted of four tasks:

1) a geologic literature review,
2) a field geologic mapping study,
3) a borehole geophysical study, and
4) a seismic study.

2.1 Review of Geologic Literature

The review of existing geologic literature for the Sherwood Project area provided insight into the regional geologic framework and provided a basis for a more detailed field geologic mapping study of the tailing impoundment area. This literature review indicated that the region is underlain by crystalline igneous rocks. Structural deformation, including folding and faulting of the crystalline bedrock, has locally preserved some slightly younger volcanic and clastic materials in down-thrown fault blocks. Subsequent periods of volcanic activity, after the period of structural deformation, have deposited layers of ash and basalt flows. More recent glacial events have eroded the surfaces of these older rocks and deposited thick layers of sand, silt, and gravel over the eroded bedrock surface. Although no structures are identified which intersect the immediate tailing impoundment area itself, several faults have been identified in the area surrounding the Sherwood Project. The result of the geologic history of the Sherwood Project is a topography of gently rolling sandy hills formed by the gradual erosion of the glacial sedimentary deposits. Beneath the glacial sedimentary deposits lies the igneous bedrock and, in some areas, older sedimentary rocks and volcanic rocks preserved in down-thrown fault blocks from previous events of structural deformation. The structural deformation that created these faults has been inactive for many millions of years.

2.2 Field Mapping Study

In order to obtain more site-specific geologic data at a level of detail greater than could be derived from the geologic literature, a field geologic mapping study was initiated to supplement the geologic reconnaissance performed by Western Nuclear Inc. (WNI) during the past 16 years (see Section 3.1 and Attachment C.2 to Appendix P of the 12/94 TRP). This mapping study was designed to evaluate the existing surface geologic conditions and their potential influence on the ground water system for the tailing impoundment drainage basin. The purpose of this mapping study included the establishment of baseline geologic conditions and the selection of areas for future seismic and surface geophysical investigation. More than 100 rock outcrops were identified: lithologic, textural, and structural features were noted and recorded at 97 different outcrops. Strikes and dips of joints, slickensided surfaces, faults, and fractures were measured.

The site topography is primarily controlled by the bedrock, which typically outcrops at topographic highs, and the glacial sediments which cover the majority of the tailing impoundment area and create a setting of rounded and gently sloping hills. The surface drainage, in which the tailing impoundment is constructed, flows to the south. Although field mapping identified various igneous lithologies and textures, no correlation between lithology and mechanical behavior (i.e. fracturing, jointing) or structural control, which may influence ground water flow, was observed. In addition, several faults and several dominant orientations of jointing and fracturing were identified in and around the tailing impoundment area. However, no continuous or large scale faults, joints or fractures that could influence the gross scale hydrology of the area were observed.

2.3 Borehole Geophysical Study

The borehole geophysical study was performed on selected wells at the tailing impoundment area to supplement the surface geologic mapping and to observe the nature of ground water flow in the open-hole portions of the wells. This study was performed using a down-hole video camera and a natural gamma probe. The down-hole camera was used both to video the inside of selected wells to check the well construction and to observe the flow of water into the wells. The observation of water flowing into the well after it had been bailed dry aided in understanding the way ground water flow occurs in the conductive bedrock. The natural gamma probe allowed confirmation of the geologic logs of older wells by detecting the difference in natural gamma radiation between the bedrock and the overlying glacial sediments. The results of this study indicated that the original geologic and well construction logs from the wells are accurate. In addition, the ground water recharging in to the wells was observed to flow very slowly and only in a few discrete fractures, although many other adjacent fractures were dry and provided no ground water flow. This indicates that fractures in the upper bedrock are discontinuous and not all hydraulically connected.

2.4 Seismic Study

The seismic study of the tailing impoundment area was performed to map the bedrock surface and to delineate subsurface structures which may influence ground water flow. This task provided a more detailed picture of the subsurface geology and its potential influence on the tailing impoundment and the drainage basin hydrologic system. The seismic survey included more than five miles of geophysical traverses consisting of five seismic reflection survey lines totaling 9,570 feet in length and five seismic refraction lines totaling over 17,000 feet in length.

The results of the survey confirmed the surface mapping results, the data developed from borehole logs, and provided information for the placement of the new monitoring wells MW-8, MW-9, and MW-10. The seismic survey showed that the bedrock surface underneath the tailing impoundment creates a southward draining basin. The basin edges correspond to the high outcrops identified during the field mapping. The bedrock occurs near or at the surface on the basin edges and becomes more deeply buried toward the center of the drainage basin and toward the south of the drainage. Bedrock depths are the greatest at the point of compliance below the tailing dam where the glacial sand cover is over 200 feet thick. This drainage basin drains to the south through a narrow, steep-sided valley in the bedrock surface directly below the tailing dam. The installation of wells MW-8, MW-9, and MW-10 provided a check on the seismic study results and confirmed the location of bedrock. The wells were placed in the lowest point in the basin drainage. Though a few zones of low seismic velocity were observed in the seismic refraction lines to the east of the impoundment, no structures which could influence ground water flow or provide alternate ground water flow paths were identified and it was not possible to correlate these few low velocity zones with surface structures observed during field mapping.

2.5 Summary

The result of the geologic investigation revealed that the tailing impoundment is located in a drainage basin in which both surface water and ground water flow toward the south. The bedrock surface which defines the lower portion of the subsurface drainage approximately mirrors the surface topography. No significant structures in the bedrock, such as faults or large continuous fractures, were identified from surface mapping or seismic survey of the area. Observation of ground water recharge to wells bailed dry indicate that the fractures which do exist are discontinuous, not uniformly hydraulically connected, and have limited capacity to carry ground water flow. These data provided the physical framework for evaluating the performance of the impoundment reclamation design, the transport of potential contaminants in the ground water system should they leak from the impoundment, and the development of an effective ground water protection plan.

3.0 TAILING IMPOUNDMENT INVESTIGATION

The Sherwood tailing impoundment contains approximately 100,000,000 cubic feet of submerged tailing material (see Attachment D.1 of Appendix P to the 12/94 TRP). The impoundment contains approximately 9,900,000 cubic feet (74,052,000 gallons) of drainable water (see Attachments D.2 and D.3 of Appendix P to the 12/94 TRP). A 30-mil (0.030 inch thick) B.F. Goodrich Hypalon® liner currently underlies the tailing, thereby isolating and containing all tailing fluid within the tailing impoundment. The tailing impoundment investigation was performed to: 1) identify the constituents of regulatory concern within the tailing impoundment which might potentially impact the ground water system should the impoundment leak; and 2) to evaluate dewatering of the tailing as a potential reclamation alternative.

The tailing impoundment investigation consisted of five principal tasks:

1) tailing material sampling and analysis;
2) tailing impoundment pumping testing and pilot dewatering study;
3) evaluation of tailing impoundment water quality;
4) tailing dewatering feasibility analysis; and

5) evaluation of long-term impacts to the environment from the potential release of tailing pore water.

The results developed from these analyses provide the basis for evaluating tailing dewatering as a possible reclamation alternative. In addition, these data are considered in the evaluation of the tailing impoundment reclamation design success for the protection of ground water, and the development of an effective ground water protection plan.

The objectives of these tasks were to address the following:

1) model the tailing stratigraphy;
2) develop representative hydraulic properties of the individual tailing strata;
3) model and evaluate potential dewatering of the tailing, both by pumping as a reclamation alternative and by potential failure of the liner;
4) characterize the tailing pore water quality for both dewatered and fully saturated conditions;
5) evaluate whether dewatering the tailing would constitute a beneficial reclamation alternative; and
6) evaluate the potential impacts to the ground water system should tailing pore water escape the impoundment.

3.1 Tailing Material Sample Collection and Analysis

The tailing material sampling and analyses were performed in order to characterize the tailing for modeling of tailing dewatering through pumping or drainage due to potential liner failure. The data developed from these analyses are presented in Appendix A and Appendix P to the 12/94 TRP. These data were used in the tailing dewatering feasibility analysis and in the development of the ground water protection plan.

Detailed study of tailing stratigraphy was performed using boring log data to characterize the stratigraphic control on tailing pore water flow. The distribution of tailing sands and slimes in the impoundment was found to be very complex with individual tailing layers thinly bedded and discontinuous. This complexity defies development of small scale stratigraphy for the entire impoundment. However, identification of large scale stratification of the tailing is possible. The lower 15 to 25 feet of the impoundment consist mostly of low permeability slime and sandy slime. The upper 50 to 60 feet consist mostly of sands and slimy sand with some sandy slimes and relatively few slimes (see Section 4.1 and Attachment D.4 of Appendix P to the 12/94 TRP).

Representative hydraulic properties of the tailing were developed to model the dewatering of the tailing materials. This was accomplished by collecting tailing samples from over 1,000 feet of continuous borings within the tailing and developing an empirical relationship between tailing material grain size and tailing permeability. To develop this empirical relationship, the percent of tailing material passing the #200 sieve size was related to 36 laboratory falling head permeability tests (see Attachments D.5 and D.6 to Appendix P of the 12/94 TRP). This relationship was then applied to the average percent of each tailing material type found in the tailing profile. Weighted average vertical and horizontal permeability values were then determined for the two principal tailing layers identified in the tailing stratigraphic characterization described above. Average horizontal permeabilities of 9.6×10^{-5} cm/s and 2.6×10^{-5} cm/s were determined for the upper and lower tailing layers, respectively. Average vertical permeabilities of 1.8×10^{-5} cm/s and 4.2×10^{-6} cm/s were determined for the upper and lower tailing layers, respectively (see Attachment D.6 to Appendix P of the 12/94 TRP). These values were incorporated into the tailing dewatering feasibility analysis and evaluation of potential long-term impacts to the environment.

3.2 Pumping Test and Pilot Dewatering Program

Two field scale tests were performed in the tailing impoundment to develop additional hydrologic data for consideration in the dewatering feasibility analysis and evaluation of potential long-term impacts to the environment. These tests consisted of a pumping test and a pilot dewatering program. The pumping test in the tailing material was performed to provide a field scale check on laboratory permeability tests and to determine the tailing residual saturation values, i.e., how much water remains in the tailing, from gravity drainage due to pumping or potential liner failure. The pilot dewatering program was performed to evaluate the practical aspects of full scale tailing dewatering, such as costs, maintenance, and achievable pumping rates, as a potential reclamation alternative.

The pumping test, performed over a 147 hour period and including eight observation wells and one pumping well, was analyzed for permeability using the method developed by Nueman (1975) and for specific yield using the method developed by Remsahoye and Lang (1961). An average specific yield of 0.1 for the tailing profile and a permeability value of 1.4×10^{-5} cm/s were determined from the pumping test (see Attachments D.2 and D.8 to Appendix P of the 12/94 TRP). These data were incorporated into the tailing dewatering feasibility analysis and evaluation of potential long-term impacts to the environment.

The pilot dewatering program consisted of continuously pumping nine 2-inch diameter wells, installed in a square grid pattern on 60 feet centers in the deepest portion of the impoundment, for a period of approximately seven months. The data collected from this program included pumping rate, water depth, pump frequency changes, maintenance, and downtime (see Section 4.2 and Attachment D.9 of Appendix P to the 12/94 TRP). It was determined from this pilot dewatering program that partial dewatering of the tailing could be achieved. However, the formation of precipitates on pump impellers and flow meters reduced the pumping efficiency, thus causing long-term (longer than two months) pumping rates to average 2.38 gpm. Regular maintenance of five hours per week for each pumping well and the support of approximately two full time staff to maintain each group of approximately 10 wells would be required to support an effective dewatering program. The data developed from this pilot program were incorporated in the tailing dewatering feasibility analysis discussed below.

3.3 Tailing Impoundment Water Quality

Tailing pore water quality was evaluated in two phases: evaluation of existing pore water quality and evaluation of the evolution of tailing pore water quality resulting from a hypothetical worst-case scenario that assumed tailing desaturation and oxidation. Existing tailing pore water quality was determined by direct sampling of the tailing pore water from a well installed in the deepest portion of the impoundment and screened over the full length of the saturated tailing. This water sample was analyzed for all constituents listed in 40 CFR 264 Appendix IX. The results of this sample analysis indicated that the tailing pore water pH is near neutral (approximately 6.5) due to the addition of lime to the tailing at the time of discharge to the impoundment, the tailing are in a reduced state (Eh $<$ 100 mv), and the overall tailing pore water quality is very good. The tailing water contained no volatile or semi volatile organic compounds, herbicides, pesticides, or PCB's. The constituents of regulatory concern (WAC 246-252) identified within the impoundment above drinking water standards were arsenic, nickel, thallium, uranium, radium-226, and radium-228.

The second phase of tailing pore water quality evaluation consisted of geochemical testing of the tailing using static acid-base accounting procedures, column tests, and computer modeling of the geochemical system. These tests provided insight into the evolution of the tailing and tailing pore water system were the tailing were to become oxidized. Tailing might become oxidized if sufficient access to oxygen were available. The acid-base accounting test procedure, one method used in this study, indicated that the tailing have the potential to create acidic conditions. The net neutralizing potential (NNP) of the tailing was found to be -2.4 tons $CaCO_3$/Kt to -4.0 tons $CaCO_3$/Kt. The neutralizing potential (NP):acid producing (AP) ratio was found to be 0.20 to 0.50 (see Section 4.3.2 of Appendix P to the 12/94 TRP). NNP values of less than 20 tons $CaCO_3$/Kt and NP:AP ratios of less than 3 indicate that the tailing material has the potential to create acidic conditions.

These column tests, a second test method used in this study, were performed on three columns, each filled with representative compacted tailing samples. Two of the columns were inoculated with the acidophilic bacteria Thiobacillus ferrooxidans which accelerate the oxidation of ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}). The columns were saturated with deionized water, allowed to drain for 24 hours, and were then aerated with water saturated air. The columns were aerated for 10 weeks, flushed six times with deionized water, aerated again for an additional 10 weeks, and flushed six times again. Effluent samples from the 10 and 20 week flushings were analyzed for pH, 10 metals (As, Ba, Cd, Cr, Fe, Mg, Mo, Ni, Pb, and Se), 2 anions (SO_4, Cl), and the radionuclides uranium and radium-226. During the 20 week tests, the pH of the columns decreased to a low of 3.6. The constituents Cd, Ni, radium-226 and uranium all showed ten-fold increases over exiting concentrations in the tailing pore water while the remaining constituents evaluated either showed evidence of early rinse out behavior and/or were not affected by the oxidation reactions or lower pH conditions (see Section 4.3.2 of Appendix P to the 12/94 TRP)

Geochemical modeling of tailing water was conducted to determine if the column testing (Section 4.3.2.2 of Appendix P to the 12/94 TRP) realistically represented oxidation that would occur with the limited available oxygen. It was assumed that dewatering of the tailing might allow the influx of a limited amount of oxygen which would then be available for reaction with the tailing material. With pumping, air would enter vertically through the well bore and laterally through the well screens.

The geochemical code PHREEQE (Parkhurst et al., 1980) was used to model the chemistry of the column leachates and the tailing pore water. Geochemical modeling steps were designed to: 1) calculate the mineral equilibria of the column leachates and tailing pore water and 2) model the effect of the introduction of oxygen to the tailing-tailing pore water system. The goal of the first step was to determine which tailing minerals were in equilibrium with respect to the tailing pore water. The goal of the second step was to determine: 1) if the column tests realistically represented the oxidation during dewatering of the tailing impoundment and 2) the effect of the addition of oxygen in smaller proportions than used in the column testing on the residual tailing pore water quality.

The geochemical models produced initial values in close agreement with observed values of the tailing water. Therefore, the models were considered to adequately represent the tailing pore water system and could be used to model the impact of the incremental addition of oxygen to the residual tailing pore water as a result of active tailing dewatering.

With the addition of incremental oxygen concentrations, the models showed that as the concentrations of incremental oxygen increase, the pE increases and the pH generally decreases. An increase of pE and a decrease of pH would be coupled with a substantial increase in concentrations of dissolved uranium and dissolved nickel. Assuming that air would fill the open pore space created during dewatering of the tailing and that the resulting available oxygen would be completely consumed, then dissolved uranium and nickel concentrations might be expected to increase by up to four orders of magnitude.

Both the column tests and the three modeled pore water scenarios confirmed that the tailing pore water quality would degrade with the addition of air because of oxidation of the tailing materials. Comparison of the column tests with the geochemical modeling showed that the column tests contain similar or lower concentrations of uranium and nickel than predicted by the model. The degradation of the residual tailing pore water quality predicted by geochemical modeling exceeded the quality observed in the column tests by one to two orders of magnitude.

These test results confirm that the tailing have the potential to produce acidic conditions if allowed to oxidize. In addition, certain constituents have the potential to increase in concentration by at least one order of magnitude over existing tailing pore water concentrations. Dewatering would, therefore, significantly degrade tailing water quality and increase potential adverse impact to the ground water system. These data provided input to the tailing dewatering feasibility analysis, evaluation of long-term impacts to the environment, and development of the ground water protection plan.

3.5 Dewatering Feasibility Analysis

Tailing dewatering was considered as a potential reclamation alternative. The dewatering feasibility analysis integrated the results of the field and laboratory tests on tailing and tailing pore water, and incorporated those results to a computer model to evaluate tailing dewatering. The results of these analyses were evaluated to determine if tailing dewatering would be both feasible and achievable and beneficial to the protection of ground water.

The technical approach used for the dewatering feasibility analysis consisted of developing a conceptual dewatering system of pumping wells and trench drains and modeling the removal of the tailing pore water by applying the hydrologic properties and stratigraphy developed from the earlier phases of the tailing impoundment investigation. In addition, long-term potential impacts to the environment for both the dewatered and non-dewatered scenarios were modeled. The results of the modeling were then reviewed and considered with other factors, such as the amount of removable water, the time for dewatering, the cost of dewatering, and the effect of dewatering on the tailing pore water quality, to determine the net benefit of this reclamation alternative for the protection of ground water.

The conceptual dewatering design was created using data developed from the pilot dewatering program, the pumping test, and tailing sample analyses. The dewatering model used the 3-D, finite difference, computer flow model MODFLOW (McDonald and Harbaugh, 1988). The model results indicated that that only partial dewatering of the tailing impoundment might be achievable. Over the first six years of dewatering approximately half of the drainable water (36,000,000 gallons) could potentially be removed at an estimated present worth cost of $8,330,000. After six years the removal rate would be so small that continued pumping would no longer be productive. Additionally, as a result of infiltration through the cover, the impoundment would refill in a short period of time after pumping ceases. Chemical loading of nickel, radium-226, and uranium was found to be ten times greater for the dewatering option than the non-dewatering alternative.

In summary, it was determined that, although a portion of the water in the impoundment could be removed as a part of a very expensive, long-term dewatering program, the impoundment would refill in a short time period after pumping is discontinued. More importantly, column test and modeling results indicated that the introduction of oxygen as a result of pumping would dramatically degrade water quality in the impoundment. Therefore, a dewatering program would not only have little positive impact, since the impoundment would refill very quickly. Rather, dewatering would have a dramatic negative impact since the impoundment water quality would be significantly degraded.

On this basis, tailing dewatering was considered detrimental for the protection of ground water and was discarded as a potential reclamation alternative.

4.0 BASIN HYDROLOGIC EVALUATION

The basin hydrologic evaluation was performed to characterize the physical parameters which control ground water occurrence, flow, and the potential transport of contaminants. The data from this evaluation, combined with the results of the geologic investigation and the tailing impoundment investigation described above, provided the technical basis for the development of the Sherwood Project Ground Water Protection Plan (GWPP). This evaluation included a review of the existing ground water monitoring system, identification of the hydrostratigraphic units in which ground water was found to occur, estimates of ground water flow rates, and an evaluation of recharge to the drainage basin.

4.1 Ground Water Monitoring System

The Tailing Impoundment drainage basin consists of approximately 730 acres of gently rolling hills with mostly sandy soil cover underlain by igneous bedrock. The basin, which is surrounded on the north, east, and west sides by high bedrock, drains to the south. The hydrologic conditions and ground water quality of the basin have been monitored by a series of 10 monitoring wells installed both in the alluvium and in the underlying bedrock. MW-2a, and MW-3a were situated upgradient from the tailing impoundment and constitute background monitoring locations. Wells MW-4, MW-5, MW-6, MW-8, MW-9, and MW-10 were located near the toe of the tailing impoundment dam and constitute downgradient monitoring locations (see Section 5.1 of Appendix to the 12/94 TRP).

4.2 Ground Water Occurrence and Flow Rates

Data from aquifer tests performed on selected wells and analysis of the well boring logs indicated that the ground water occurs in two hydrostratigraphic units: the alluvium, which lies on top of the bedrock surface, and the conductive bedrock. The second hydrostratigraphic unit, the conductive bedrock, includes the weathered bedrock and the upper portion the unweathered or competent bedrock. Core logs and packer aquifer test data in the weathered zone and upper portions of the unweathered bedrock, indicated that a zone of conductive bedrock with relatively uniform hydraulic conductivity exists to a depth of approximately 50 feet from the top of the bedrock surface (see Section 5.2.2 of Appendix P to the 12/94 TRP). This conductive bedrock zone is formed by a network of small joints and fractures in both the weathered bedrock and portions of the unweathered bedrock. The hydrologic data indicated that the bedrock has no significant hydraulic conductivity at depths greater than 50 feet below the top of the bedrock surface. The alluvium has an average permeability of 1.4×10^{-2} cm/s. The conductive bedrock has an average permeability of 1.5×10^{-5} cm/s.

Ground water in these two hydro-stratigraphic units flows to the south through a narrow bedrock valley located approximately 200 feet beneath the toe of the impoundment dam. Flow in the conductive bedrock zone would occur at a much slower rate due to the lower hydraulic conductivity of this bedrock unit. Well MW-4, which is screened in the conductive bedrock zone, and MW-10, which is screened in the alluvium, monitor these two hydro-stratigraphic units at the point of compliance (POC) and provide prompt detection of any leakage from the impoundment.

Ground water flow rates were estimated for both hydrostratigraphic units by integrating seismic data developed from the geologic investigation (Section 3.0 of Appendix P to the 12/94 TRP), ground water elevation data from the monitoring wells

(WNI Sherwood Project Annual Environmental Monitoring Program Report, 1994), and hydrologic properties of the hydrostratigraphic units developed from aquifer tests (Section 5.2.2 of Appendix P to the 12/94 TRP). The thickness of each hydrostratigraphic unit was determined from water levels using the monitoring wells and the location of the alluvial and bedrock materials from seismic data. Flow gradients were based on the difference in observed water levels between monitoring locations and were modeled to be approximately equal to the slope of the bedrock surface. Simple application of Darcy's Law ($Q = KiA$) for saturated flow in porous medium allowed calculation of the flow rate in each hydrostratigraphic unit. The average ground water flow rate in the alluvium was determined to be 218 gallons per minute (gpm). The average ground water flow rate in the conductive bedrock was determined to be 1.5 gpm. Therefore, overall ground water flow out of the tailing impoundment drainage basin was calculated to be approximately 220 gpm.

4.3 Basin Recharge

The ground water flow rates from the tailing impoundment drainage basin were checked by calculating the amount of ground water recharge to the basin from infiltrating precipitation. This was accomplished by using the Hydrologic Evaluation of Landfill Performance (HELP) computer model (Schroeder, 1988) and site specific climatological data to estimate infiltration through the seven soil types identified within the drainage basin. It was determined from these analyses that approximately 160 to 190 gpm of precipitation is estimated to recharge the basin ground water system. The calculated ground water flow rate from the drainage basin closely agreed with the calculated recharge rate. This indicated that the basin hydrologic model, consisting of two hydrostratigraphic units with average hydrologic properties, reasonably models the hydrologic system, accounts for all the basin ground water flow, and indicates that significant alternate ground water flow paths from the drainage basin do not exist.

All of the studies, sampling and analyses, and modeling efforts performed in the geologic investigation, and basin hydrologic evaluation were designed to create the framework and technical basis for development of an effective leak detection monitoring program to promptly detect leakage, and to evaluate potential long-term ground water impacts.

5.0 GROUND WATER PROTECTION EVALUATION

The development of the leak detection monitoring program required a review of the tailing impoundment operational and reclamation design elements, evaluation of the reclamation design success using a predictive ground water transport model, and development of the specific leak detection monitoring program. Ground water protection was initiated during milling and tailing impoundment design, construction, and operation, and has continued through reclamation.

The performance of the ground water protection measures instituted during the various phases of the Sherwood project were evaluated using a predictive ground water flow and contaminant transport model to determine if a worst-case tailing impoundment leakage scenario could cause the water quality at the point of compliance to exceed regulatory standards. The development of the leak detection monitoring program required review of the existing ground water monitoring system and ground water quality database to determine background ground water quality values.

5.1 Operational and Reclamation Design Elements

Operational design of the tailing impoundment included lining the tailing impoundment with a 30 mil HYPALON™ geosynthetic membrane and adding lime to the mill tailing before deposition in the impoundment. The impoundment was lined to prevent leakage of tailing pore water and contamination of the ground water system. Lime was added to the tailing to maintain a neutral pH environment and to minimize the leaching of metal species from the tailing into the tailing fluid. These design elements have achieved the objective of ground water protection. No leakage of tailing pore water through the impoundment liner has been observed, the existing tailing fluid pH is approximately 6.5, and metals concentrations in the tailing fluid have been effectively minimized. These factors have significantly reduced the source concentrations and the potential for leakage of the tailing pore water to the ground water system.

Surface reclamation design of the tailing impoundment would include the placement of a 12.6 feet thick soil cover on the impoundment (see November 28, 1995, WDOH Amendment No.22 to Radioactive Materials License WN-I0133-1) revegetating the soil cover (See Sherwood Project Revegetation Reclamation System Evaluation; September 15, 1995), maintaining a favorable geochemical environment within the tailing, and enlarging the diversion channel system which circumscribes the impoundment. A thick uncompacted soil reclamation cover design replaced the conventional compacted clay-sand cover design modeled in Appendix P (12/94 TRP). However, the modeling of the conventional reclamation cover design provided highly conservative overestimates of potential ground water impacts and, therefore, would still be acceptable for purposes of ground water protection. The thick uncompacted soil reclamation cover, in conjunction with the revegetation of the reclamation cover, would limit the amount of precipitation and oxygen which may enter the tailing. This would maintain the tailing in a saturated and reduced condition while limiting the potential introduction of oxygen even if the tailing were to partially drain.

The tailing, which are presently in a reduced state, will remain saturated and reduced due to limited access to oxygen. The thick cover design helps maintain the reduced conditions in the tailing by decreasing the introduction of oxygen to the system. Microbial activity that will occur in the upper portion of the revegetated cover will consume much of the oxygen that enters the cover. In addition, the tailing will be saturated or have a high residual water content.

These factors will maintain the reduced conditions within the tailing. Should the tailing drain due to massive liner failure, the oxygen in the air which would fill the drained pores would tend to change the redox state of the tailing to an oxidizing condition. However, this oxidation front would not penetrate to significant depths within the tailing. Oxygen diffusion rates through the drained tailing would be very slow due to two primary factors. First, the high residual moisture content of the tailing after gravity drainage would reduce the volume of continuous pores through which oxygen could diffuse, thereby limiting potential oxidation. Layers of slimes within the tailing pile would essentially stop further vertical penetration of the oxidation front into the tailing profile due to their extremely high residual saturation moisture contents. Second, the oxygen in the air filling the drained pores would be rapidly consumed near the surface of the tailing were air to enter the tailing. Therefore, even if the tailing were to drain, air entering the little available drained pore space at depth would not necessarily receive oxygen as it would be consumed near the tailing surface where the air would enter the tailing. This would slow oxidation front movement downward through the tailing even with gravity drainage. The synthetic membrane liner which surrounds the lower and lateral surfaces of the impoundment will preclude the flux of oxygen into the tailing through these surfaces.

5.2 Evaluation With Integrated Site Model

Tailing impoundment design element effectiveness for ground water protection was evaluated using predictive ground water modeling which estimated the long-term impacts resulting from potential release of tailing impoundment fluid. This model was called the Integrated Site Model (ISM). The ISM employed the computer program SOLUTE (version 3.0; Beljin and Heijde 1993) to model contaminant transport in the ground water system below the tailing impoundment. The ISM combined the physical framework developed during the site geologic investigation, the source concentrations and leakage rate data developed in the tailing impoundment investigation, and hydrostratigraphic unit geometry and hydrologic properties developed during the basin hydrologic evaluation to predict ground water quality. This predictive model was used to evaluate the tailing impoundment, operational and reclamation design element performance relative to ground water protection. In addition, the ISM was used to predict potential long-term impacts to the environment from potential liner leakage.

The subroutine SLUG2D within the computer program SOLUTE was used to develop and calibrate the ISM. The ISM calibration consisted of modeling a February 4, 1984 excursion of approximately 100,000 gallons of tailing fluid of which 20,000 to 80,000 gallons were pumped back into the impoundment and 20,000 to 80,000 gallons infiltrated into the ground water system (see Attachment F.1 of Appendix P to the 12/94 TRP). This excursion was detected in the downgradient monitoring well MW-4. ISM model input included the known concentration of tailing fluid, the known volume of fluid input to the ground water system, hydraulic properties and the geometry of the hydrostratigraphic unit through which the fluid was transported, and the known concentrations observed in the down-gradient monitoring well MW-4. The concentration of the tailing fluid modeled in the excursion was represented by the existing tailing fluid concentrations as determined from hazardous constituent analyses presented in Section 4.3.1 of Appendix P to the 12/94 TRP. The rate of leakage equaled the rate of infiltration through the final soil cover, 10.25 gpm, as calculated in Attachment D.17 to Appendix P of the December 1994 TRP. This scenario requires an impoundment liner failure equivalent to 2,700 square feet or 100 individual leakage areas 27 square feet each, essentially requiring a large portion of the liner to suddenly "disappear". The Sherwood Project Revegetation Reclamation System Evaluation (SMI, September, 1995) concluded that much less net infiltration would pass through the thick soil reclamation cover and, therefore, the estimate of 10.25 gpm net infiltration is conservative. The ISM calibration consisted of varying the dispersivity values in the model for each constituent until the modeled concentrations matched the concentrations observed in well MW-4.

The results of the ISM calibration indicated that the dispersivity values required to model the transport of the excursion solution to well MW-4 would be within the range of typical dispersivity values observed for alluvial material. Only transport of the excursion fluid in the alluvium was modeled because tailing fluid which might escape the impoundment would travel primarily in the alluvial hydrostratigraphic unit with very little migration into the less permeable conductive bedrock unit. In addition, 99% of the air flow occurs in the alluvial hydrostatic unit. The ISM, therefore, was calibrated when it was determined that the ISM accurately modeled the excursion, using the average hydrologic properties developed in the basin hydrologic evaluation, and that the dispersivity values were within the normal range of dispersivity values for alluvium.

For all hypothetical ground water impact scenarios, the ISM model predicted that long-term, steady-state hazardous constituent concentrations at the down-gradient wells for a worst-case leakage scenario would remain below regulatory limits. Therefore, Appendix P (12/94 TRP) calculations demonstrated that both the operational and the December 1994 TRP reclamation design elements, including the use of conventional compacted clay-sand reclamation cover, would effectively continue to protect ground water quality. A 12.6 feet thick, uncompacted final reclamation cover (SMI; September 15, 1995) would allow less infiltration than assumed for the conventional compacted clay reclamation cover system. The Appendix P (12/94 TRP) ISM modeling that assumed a conventional reclamation cover design provided very conservative, upper bound overestimates of potential ground water impacts and, therefore, would remain acceptable for the purpose of evaluating ground water protection given the replacement of the conventional compacted clay reclamation cover with a 12 foot thick, uncompacted solid reclamation cover.

5.3 Ground Water Monitoring System and Data Base

The existing ground water monitoring system and the associated ground water quality database were evaluated in order to develop background ground water quality values for constituents of regulatory interest and to provide a basis for leak detection and compliance monitoring criteria. Ground water data collection began in April, 1978. There are 10 monitoring wells at which monitoring has been conducted: wells MW-1A, MW-2, MW-2A, MW-3, MW-4, MW-5, MW-6, MW-8, MW-9, and MW-10. Analyses were performed for the following constituents:

Ca	SO_4	U	TDS
Mg	Cl	Ra-226	pH
Na	CO_3	Th-230	
K	HCO_3		
	Alkalinity		

The Sherwood Project 1993 Annual Environmental Monitoring Report (WNI 1994) presented a summary of all the historical ground water monitoring data for the study area.

The verified database (see Attachment F.3 of Appendix P to the 12/94 TRP) was used to develop statistical control charts for the constituents chloride, sulfate, uranium, combined radium-226/228, and arsenic. These control charts are a statistical tool used to monitor the statistical variation of water quality data and to identify anomalous values. The control charts illustrate the ground water data for a given constituent from all the ground water sampling locations, the mean of the data, the upper control limit (UCL), and the lower control limit (LCL). The control limits represent the 99 percent confidence intervals for the population of data. Any value above the UCL or below the LCL would have a 99 percent confidence that the data point would lie outside the historical range of values for that constituent.

Supplemental sampling of all ground water monitoring wells for the hazardous constituents radium 228, arsenic, nickel, and thallium was initiated in January of 1994 (WNI Sherwood Project Annual Environmental Monitoring Program Report, 1995). These hazardous constituents (WAC 246-252) were identified in the tailing pore water at concentrations above drinking water standards during the tailing impoundment investigation (Section 4.3 of Appendix P to the 12/94 TRP) and a minimum of one year of data was required to create a background water quality database and control charts for these constituents.

The UCL defines background ground water concentrations for specific constituents and will be employed in two ways. First, the UCL for chloride will be used as the criterion for determining prompt detection of leakage. Any confirmed value exceeding the UCL background, would have 99 percent confidence of exceeding the historical range of values for that constituent. Second, the UCL is considered as part of the criteria for initiating the compliance monitoring program. The UCLs for all of the compliance monitoring constituents (Section 6.3.6 of Appendix P to the 12/94 TRP) will be compared to the promulgated ground water quality standards. The larger of the two values will be used as the criterion for determining whether corrective action is required. For constituents whose standard is background, as in the case of uranium, the site background UCL for that hazardous constituent will be used as the standard. The UCL values and regulatory standards are summarized in the attached Table 1.

The results of the ground water protection evaluation complete the evaluation of the Sherwood Project tailing impoundment facility that allows development of a leak detection monitoring program. The leak detection monitoring program provides an effective method of monitoring the ground water system for the prompt detection of potential tailing impoundment leakage.

5.5 Proposed Leak Detection Monitoring Program

The leak detection monitoring program was developed by considering all of the data developed from the geologic investigation, tailing impoundment investigation, basin hydrologic evaluation, and the ground water protection evaluation. The leak detection monitoring program would include monitoring locations, monitoring constituents, and evaluation procedures which provide for the prompt detection and reporting of anomalous ground water concentrations and potential leakage. Leak detection monitoring would be instituted in two phases: monitoring during final reclamation construction activities and monitoring after completion of construction and prior to license termination.

The proposed leak detection monitoring program for reclamation construction would include monthly water level measurement of upgradient monitoring wells MW-1a, MW-2, MW-2a, MW-3 and down gradient monitoring wells MW-4 and MW-10. In addition, quarterly ground water quality samples would be collected from each of these monitoring wells and analyzed for the following parameters:

Static Water Level	pH	K	Na
Total Dissolved Solids	SO_4	Ni	Mg
Natural dissolved uranium	Cl	Ca	

The proposed leak detection monitoring program for the time period following final reclamation construction and prior to license termination would consist of quarterly static water level measurement and ground water quality sampling of upgradient well MW-2A and down-gradient wells MW-4 and MW-10 for the constituents chloride, sulfate, and nickel.

Well MW-2A was installed and constructed in accordance with State of Washington Department of Ecology standards to provide long-term upgradient water quality data for the tailing impoundment drainage basin. Sampling of Wells MW-4 and MW-10 would provide leak detection monitoring for the tailing impoundment drainage basin. These are the only sampling locations and constituents necessary for prompt detection of leakage. Monitoring Well MW-4 proved to be an effective monitoring location by the detection of various excursions of tailing fluid during milling operations. Monitoring Well MW-10, which screens the alluvium in the deepest portion of the subsurface drainage down-gradient of the impoundment, was proposed as an additional monitoring location for the prompt detection of leakage. Leak detection monitoring would continue until the Sherwood Project Radioactive Materials License has been terminated or the proposed action criteria have been exceeded.

The November 7, 1995 WDOH amendment No.21 to radioactive material license WN-I0133-1 approved the casing extension of well MW-4 to allow the reclamation regrading of the tailing impoundment dam outslope. The November 28, 1995 amendment No. 22 to radioactive material license WN-I0133-1 approved the abandonment of monitoring wells MW-5, MW-6, MW-7 (a dry well never used for monitoring), MW-8, and MW-9. It is anticipated that a reduction in the ground water monitoring program will be approved following completion of reclamation construction which will include the abandonment of wells MW-1a and MW-3.

Selection of leakage monitoring constituents was limited by the relatively good quality of water in the impoundment. Few constituents were present in the impoundment at high concentrations that could be transported without significant retardation. Chloride was proposed as a leak detection monitoring constituent because it is the most conservatively transported constituent, exhibiting no retardation. Therefore, it would be the first constituent to arrive at the point of compliance should leakage occur. Chloride was present in the impoundment at relatively high concentrations (approximately 291 mg/l) and was present in the ground water only at low concentrations (approximately 6 mg/l). In addition, there were no natural sources known to provide chloride to the ground water system.

Sulfate was proposed as a leak detection monitoring constituent due to the high concentration in the impoundment (approximately 6,195 mg/l) and relatively low background concentration (approximately 17 mg/l). The high source concentration and relatively conservative transport made sulfate an appropriate indicator parameter.

Nickel was selected as one of the metals that was present in the impoundment which would exhibit relatively conservative transport in the environment. Due to the operational design elements (i.e.: liming of tailing and maintaining of reduced conditions) few metals were present at measurable concentrations. The radionuclides radium and uranium were not selected as leak detection monitoring constituents because of their relatively slow rates of transport due to retardation, and natural occurrence in the background ground water.

Any anomalies in static water levels or constituent concentrations identified during reclamation construction will be promptly reported to the Washington State Department of Health (WDOH). Any anomalous static water levels or leak detection monitoring constituents detected above their respective control chart upper control limits (UCL) for closure will be promptly reported to WDOH.

If any leak detection monitoring constituents are anomalous or are detected above their UCLs, the laboratory QA/QC data and analyses will be rechecked. If laboratory QA/QC data indicate uncertainty regarding the analytical accuracy of the data, the sample will be reanalyzed. If all laboratory QA/QC data and procedures support the reported constituent concentration(s), a confirmation sampling round of the monitoring wells will be performed. If confirmation sampling indicates that constituent concentrations are below the UCLs, normal leak detection monitoring will continue. If this sampling confirms chloride concentrations above the UCL, an intermediate monitoring phase will begin.

The intermediate monitoring will consist of weekly monitoring of well static water levels, electrical conductivity (EC), and pH as well as monthly ground water quality sampling and analysis for the three leak detection monitoring constituents chloride, sulfate, and nickel. The data from the intermediate monitoring phase will be reported on a regular basis to the WDOH. These procedures will apply for leak detection monitoring during the reclamation construction period and the period following closure. The decision to proceed to compliance monitoring or to return to normal leak detection monitoring will be made based on the specific conditions during the intermediate monitoring phase.

Compliance monitoring will consist of quarterly monitoring for the following parameters:

Static Water Level	pH	K	Na	Tl
Total Dissolved Solids	SO4	Ni	Mg	Ra-226
Natural dissolved uranium	Cl	Ca	As	Ra-228

If compliance monitoring indicates that any of the applicable ground water regulatory standards for hazardous constituents have been exceeded, or in the absence of regulatory standards the constituent UCLs (see Table 1), a corrective action plan will be developed according to the provisions of WAC 246-252-030 Criterion 5 (m) based on the specific conditions at that time.

These procedures and decision pathways provide for prompt detection and reporting of leakage from the Sherwood Project tailing impoundment, both during reclamation construction and prior to license termination.

Table 1 Summary of Leak Detection and Compliance Monitoring Ground Water Standards

Constituent	Ground Water Standards	
	Regulatory Standard	**Baseline**
Chloride	None	6.2 mg/l
Sulfate	None	21.5 mg/l
Uranium	None	128 pCi/l
Radium-226 + Radium-228	[1]5 pCi/l	6.4 pCi/l
Arsenic	[1]0.05 mg/l	0.003 mg/l
Nickel	[2]0.1 mg/l	[3]<0.05 mg/l
Thallium	[2]0.002	[3]<0.001 mg/l

Note:

1 Washington Administrative Code, chapter 246-252: radiation protection-uranium and/or thorium milling; Section 030: criteria related to disposition of mill tailings or waste maximum values for ground water protection.

2 US Environmental Protection Agency, 10 Code of Federal Regulations 40 (CFR), Section 141.62; maximum contaminant levels (MCL's) for inorganic contaminants.

3 Baseline water quality determined as the upper control limit value.

4 The reported values are the lower limits of detection. These constituents have not been detected above the lower limits of laboratory detection.

RESPONSE TO
WASHINGTON DEPARTMENT OF HEALTH
LETTER DATED NOVEMBER 6, 1995

Please find attached the responses to November 6, 1995 WDOH comments regarding the December 1994 Appendix P of the WNI Sherwood Project Tailing Reclamation Plan. Responses to all comments are provided in this transmittal and are addressed on a comment by comment basis.

QUESTION 1:

Appendix P, page 6.2, states that the tailings are presently in a reduced state. Please provide information that supports this conclusion. Have chemical analyses been conducted on the solids that establish the chemistry of the sulfur minerals present in the tailings? Is there evidence that indicates presence of iron as Fe+2 versus Fe+3?

Question 1a:

Appendix P, page 6.2, states that the tailings are presently in a reduced state. Please provide information that supports this conclusion.

Response to question 1a:

The assertion that the tailing are presently in a reduced state is supported by chemical and observational evidence.

The primary mechanism for the production of acidic conditions found in the interstitial waters of uranium mill tailing is the oxidation of pyrite. In the presence of moisture and oxygen, pyrite is oxidized producing H^+ and SO_4^{2-}. The acidic condition produced could further leach other trace metals and radionuclides. Both oxygen and water play an important role in the production of acidic conditions. If oxygen is excluded from the system and the system remains reduced, the reaction will not occur, acid will not be produced, and the potential for metals and radionuclide mobilities will remain dramatically reduced.

The high phreatic surface in the tailing prevents the downward migration of oxygen into the system. Since oxygen plays an important role in the oxidation of pyrite, the absence of oxygen will prevent the pyrite from reacting and thus forming acidic conditions. This can be demonstrated by evaluating the oxidation/reduction (redox) state of the tailing below the water table. The redox state of the interstitial waters was evaluated in two ways: (1) visual observation of water samples collected from wells completed in the tailing and (2) observation of the mineral phases present in the tailing solids.

(1) Water samples were collected from wells completed in the tailing. The water was clear when brought to the surface at a near neutral pH. Within minutes the water turned red with a subsequent drop in pH. This would indication that the iron in the water was ferrous and upon exposure to the atmosphere, oxidized to ferric iron with the subsequent precipitin of iron hydroxide.

(2) Samples of the tailing solids were collected. Two samples of the slimes and two samples of the sands were sent to the laboratory for X-ray diffraction and scanning electron microprobe analysis. Pyrite was found in all of the tested samples. The pyrite was free of oxide coatings which indicates a reduced condition. Other iron mineral phases such as goethite and ferrihydrite were not found in any of the samples. The

presence of pyrite and the absence of goethite and ferrihydrite indicates that the system is reduced.

Geochemical modeling was performed using the chemical composition of the interstitial waters in conjunction with the solid phase assemblage found in the tailing. The results of the water analysis were input into MINTEQA2 with various Eh values at the measure pH For each Eh value, MINTEQA2 predicted a range of iron and sulfide minerals that could theoretically be present. At Eh values greater than 0 mv, ferrihydrite ($Fe(OH)_3$) would be present and above -100 mv, goethite ((FeO(OH) would be present. Both X-ray diffraction and scanning electron microprobe examination of the tailing material did not detect the present of either of these minerals. Therefore, the tailing are reduced with an Eh of less than -100 mv.

In addition, the pH of the tailing pore water is approximately 6.5. This neutral pH indicates that acidic conditions associated with the oxidation of the tailing have not developed and supports the conclusion that the tailing are in a reduced state.

Visual observations of the tailing during exploration of the tailing profile with auger borings and open trenching indicate that the tailing are dark gray in color at depths greater than a few feet below the tailing surface but above the phreatic surface. This gray color indicates that the iron bearing minerals (e.g.: pyrite) have not oxidized, that anaerobic conditions are present, and that the tailing are presently in a reduced state. At this time, the vast majority of the tailing are saturated and reduced with the exception of the upper few feet of tailing. Only a portion of this upper few feet of tailing are partially oxidized. The remainder of the unsaturated tailing are still in a reduced condition as evidenced by the dark gray color of the tailing described above.

Once the cover materials are placed, the unsaturated tailing will rapidly (within one season) return to saturated conditions due to infiltration (see Revegetated Reclamation System Evaluation, Sherwood Project, September, 1995). When the upper portion of the tailing becomes re-saturated, the water quality in the pores of this upper layer will re-equilibrate with the bulk tailing water quality and reduced conditions will be promptly re-established. Oxygen diffusion into the tailing will be essentially eliminated by organic and microbial consumption of oxygen in the reclamation cover (see response to question 2a) and saturation of the tailing pore spaces, thus minimizing the potential for future oxidation. Annual precipitation cycles will introduce sufficient moisture into the final reclamation cover to maintain all the tailing in a saturated condition for a portion of each year, even for extreme climatic conditions approaching desertification. Were the tailing under the 12.6 feet thick reclamation cover to become unsaturated the high residual moisture contents of the reclamation cover materials and tailing would significantly inhibit the diffusion of oxygen in to the tailing, limiting the potential for tailing oxidation. In addition, modeling of the cover system indicates that there are no mechanisms for export of the water in the upper portion of the tailing to the environment outside the lined impoundment (see Revegetated Reclamation System Evaluation, Sherwood Project, September, 1995).

<u>Question 1b:</u>

Have chemical analyses been conducted on the solids that establish the chemistry of the sulfur minerals present in the tailings?

<u>Response to question 1b:</u>

Pyrite (FeS_2), sphalerite (ZnS), Galena (PbS) have been identified within the tailing solids by X-ray diffraction and scanning electron microprobe analyses. These data are presented in Attachment G to Appendix A of the December 1994 TRP which is included with this transmittal.

Question 1c:

Is there evidence that indicates presence of iron as Fe+2 versus Fe+3?

Response to question 1c:

Both observational and experimental evidence exist which indicate that iron in the tailing impoundment exists in the Fe^{2+} state. Water samples collected from wells completed in the tailing were clear when brought to the surface at a near neutral pH. Within minutes the water turned red with a subsequent drop in pH. This would indicate that the iron in the water was ferrous (Fe^{2+}) and upon exposure to the atmosphere, oxidized to ferric (Fe^{3+}) iron with the subsequent precipitation of ferrihydrite ($Fe(OH)_3$). In addition, the tailing have been observed to be dark gray in color one to two feet below the surface and above the phreatic surface. This indicates that oxidation of the iron bearing minerals in the tailing has not occurred and that iron is still in the reduced Fe^{2+} state.

The Geochemical modeling discussed in response to question 1a predicted the presence of ferrihydrite ($Fe(OH)_3$) in the tailing solids at Eh values above 0 mv (oxidizing conditions) and goethite ((FeO(OH) at Eh values above -100 mv (slightly reduced conditions). X-ray diffraction and scanning electron microprobe analysis of the tailing solids, presented in Attachment G to Appendix A of the December 1994 TRP, failed to detect the presence of these minerals, thus indicating that the Eh of the tailing is below -100 mv (reduced). The Fe^{2+} oxidation state is the only form in which iron is stable at the Eh and pH regime in which the tailing presently exist.

QUESTION 2:

How does the proposed thick cover help to keep the tailings reduced? Information that describes the redox potential trend at depth could provide additional justification for the utilization of the thick cover design. Explain how the redox state of the tailings will be affected if the liner fails, and the pore water drains, and if the vegetative cover pulls moisture from the tailings. What is the water holding capacity of the tailings, and what is the likely mobility of oxygen under these conditions? Is it likely that oxygen diffusion will occur from the sides or bottom of the impoundment? How will these conditions affect the previous ground water modeling for water quality impacts?

Question 2a:

How does the proposed thick cover help to keep the tailings reduced? Information that describes the redox potential trend at depth could provide additional justification for the utilization of the thick cover design.

Response to question 2a:

(1) The proposed thick cover maintains reducing conditions in the tailings by **minimizing oxygen diffusion** into the tailings. The general equation that describes gaseous diffusion in soils is a combination of Fick's law and the conservation of mass equation. This algorithm accounts for both the diffusive pathways present in the soil and the amount of oxygen that may be produced or consumed along the diffusive pathway. For steady-state oxygen diffusion ($\partial C/\partial t = 0$):

$$\partial^2 C/\partial^2 t + S/D = 0 \qquad [1]$$

where C = gas concentration; S represents the production or removal rate per unit volume for either carbon dioxide (positive) or oxygen (negative) and *D* is the coefficient of diffusion for the gas through the soil (Marshall and Holmes, 1979). The solution to this equation is given by:

$$C = C_0 + (S/D)(Lx - x^2/2)) \qquad [2]$$

where L is an assumed boundary impermeable to the passage of oxygen at the water table, x is distance, and C_0 is the concentration of oxygen in the free atmosphere, at the soil surface. Equation [2] clearly shows that for a uniform removal rate (S), the reduction in oxygen, as given by $C - C_0$, is proportional to 1/D. The value of *D* in turn depends on the air-filled porosity, therefore oxygen concentrations in a wet soil are typically much less than those in a dry soil; the diffusion coefficient for oxygen in water is approximately 10,000 times smaller for water than air (Grable, 1966; Brady, 1990). Thus, when the tailing are wetted, the infiltrating water displaces much of the soil air and provides a resistance to oxygen diffusion. This resistance minimizes the replenishment of soil oxygen (from that atmosphere) which has been removed by plant root and microbial respiration (discussed in (2) below). Although the atmosphere contains approximately 21% oxygen, oxygen concentrations may drop to levels near zero in the lower horizons of wet soils (Brady, 1990). Because the soil cover is very thick, and the tailings will be saturated or exhibit a high residual water content, reducing conditions will be maintained in the tailings.

(2) The proposed thick cover also maintains reducing conditions in the tailings by **maximizing oxygen removal** within the soil cover. It has been well-established that the decomposition of organic matter in soils occurs via the microbial oxidation of organic

carbon to carbon dioxide, coupled with the reduction of oxygen to water (e.g., Alexander, 1977; Bohn et al., 1985; Tate, 1987; Brady, 1990). Fresh plant matter and other forms of soil organic matter are the primary electron donors in the soil. When oxygen is available, it is used as the primary electron acceptor:

$$CH_2O(s) + O_2(g) = CO_2(g) + H_2O(l) + energy \qquad [3]$$

In addition to oxygen consumption by organic matter decomposition, plant root respiration also consumes oxygen and releases carbon dioxide. Oxygen demands are significantly multiplied in vegetated versus non-vegetated soils (Brady, 1990). Thus, the reduction in oxygen, as given by $C - C_0$, varies directly with the removal rate (S) (see Equation [2] above). The decrease in soil oxygen concentrations as affected by values of S is presented by Marshall and Holmes (1979).

In summary, reducing conditions will be maintained in the tailings as a result of the thick soil cover. The thickness and moisture content will minimize oxygen diffusion into the tailings, and the organic matter supplied to the soil through the establishment of vegetation will maximize oxygen removal. Thus, diffusional constraints, coupled with high oxygen demands, will result in the use of progressively weaker electron acceptors by the soil microorganisms (e.g., nitrate, manganese, and ferrous iron). The result is a reduction in the measured redox potential (Eh) in the soil and/or tailings material (Bohn et al., 1985; Sposito, 1989).

Oxygen concentrations of 2% have been measured at depths as shallow as 0.3 feet on the revegetated Nordic uranium mill tailings in Ontario (Dave et al., 1985). In addition, measured Eh values as low as 0.20 V have been recorded at the 12 foot depth in the Nordic tailings (Cherry et al., 1980), indicating that the oxygen supply has been depleted to the point that organic matter decomposition is being coupled with secondary electron acceptors. In other areas of the world, increases in carbon dioxide concentrations have been correlated with decreases in oxygen concentrations in waste rock dumps, such as at the Rum Jungle mine site in Australia (Ritchie, 1994).

<u>**Question 2b:**</u>

Explain how the redox state of the tailings will be affected if the liner fails, and the pore water drains, and if the vegetative cover pulls moisture from the tailings.

<u>**Response to question 2b:**</u>

While no reclamation system can guarantee that some oxygen could not enter the tailing and cause some change to the redox state of the tailing, the reclamation system and the material properties of the tailing materials at the Sherwood project minimize this potential.

It is very unlikely, if not impossible, for the tailing to become unsaturated. First, there is no mechanism that could cause the liner to fail. As stated in Appendix P of the December 1994 TRP, not only would there have to be failure from some unknown mechanism, but also that failure would have to be massive for the flux rate out the bottom of the liner to exceed the estimated natural infiltration through the cover.

Vegetation will not cause the tailing to become significantly desaturated. Only a very small percentage of the total root mass of only one plant species (Ponderosa Pine) has the potential to reach the tailing. If this were to occur, the maximum depth of the roots into the tailing would be only a few feet and certainly not deep enough to desaturate a significant portion of the tailing.

In the unlikely (impossible) event that the tailing were to become unsaturated, there are several mechanisms that will minimize the available oxygen that could enter the tailing. First, the characteristics of the cover will act to minimize the amount of oxygen that could reach the tailing (as describe in response #2a, above). Second, the water holding characteristics of the tailing (as describe in response #2c, below) will further minimize oxygen mobility.

In conclusion, it is highly unlikely, if not impossible, for the tailing to become unsaturated. If, however, the tailing were to become unsaturated, the characteristics of the cover and the tailing material would serve to minimize the oxygen availability to the tailing. Therefore, the tailing will remain reduced under all foreseeable scenarios.

Question 2c:

What is the water holding capacity of the tailings, and what is the likely mobility of the oxygen under these conditions?

Response to question 2c:

Attachment D.14 to Appendix P of the December 1994 TRP estimates an average tailing porosity (n) of 0.55, an average apparent specific yield (S_{ya}) of 0.1, and a field capacity, or specific retention (S_r), of 0.45. The S_r of the tailing was assumed to equal the porosity (n) minus the apparent specific yield (0.55-0.1) or 0.45. The S_r value of 0.45 represents an estimated tailing moisture content after gravity drainage. These data indicate that the majority of the tailing pores would retain over 80 percent of the pore water after gravity drainage (S_r divided by n, 0.45/0.55 x 100 = 81.8 percent).

As discussed in Response to Question 2a (above), oxygen diffusion in wet tailing is greatly restricted due to the low rates of diffusion of oxygen through water compared to air. The rate of diffusion is proportional to the diffusion coefficient (D) through the soil (Marshall and Holmes, 1979; Hillel, 1982):

$$D = (b)\ (E_a)\ (D_o) \qquad [4]$$

where b = an empirical impedance factor = 0.66, E_a = air-filled porosity, and D_o = diffusion coefficient for oxygen through air = $2.26 \times 10^{-5}\ m^2\ s^{-1}$.

The tailing material in the Sherwood impoundment consist of a heterogeneous mixture of interbedded sands, slimy sands, sandy slimes and slimes (see Appendix A of the December 1994 TRP). The slimes , sandy slimes and slimy sands all have water holding capacities that would cause the material to remain stable with very high, almost saturated, residual water contents if the tailing were to drain. Because of the interbedded nature of the tailing material, the slimy sands, sandy slimes and slimes materials will form a barrier to downward oxygen movement in the highly unlikely event that the tailing were to drain.

<u>Question 2d:</u>

Is it likely that oxygen diffusion will occur from the sides or bottom of the impoundment?

Response to question 2d:

Oxygen diffusion through the sides or bottom of the impoundment is not likely for several reasons. First, the sides and bottom of the impoundment are lined with the Hypalon liner and as discussed above, there is no mechanism that could cause the liner to fail. Additionally, the same mechanisms that will reduce the amount of oxygen that could pass through the cover will occur in the naturally vegetated areas around the impoundment. Third, the layered nature of the tailing and the fact that there is no mechanism to allow the tailing to drain will further minimize the potential that the oxygen could enter the tailing through the sides or bottom of the impoundment.

Question 2e:

How will these conditions affect the previous ground water modeling for water quality impacts?

Response to question 2e:

The ground water modeling assumed that the tailing would remain reduced. As discussed above, the reclamation cover system, the properties of the tailing and the fact that there is no mechanism that could cause the tailing to desaturate will all contribute to maintaining the tailing in a reduced state. Therefore, the assumptions used in the groundwater model to predict long-term groundwater impacts and the results are valid and sound.

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QUESTION 3.

Additional information is needed that describes the tailings material that was used in the columns for the leaching test. What was the origin of the material? Was the material composited prior to placement into the columns? Describe the test methodology.

Response to question 3:

The materials used in the column tests described in Section 4.3.2 of Appendix P to the December 1994 TRP were recovered from the nine-spot borings advanced in the tailing impoundment as part of the tailing impoundment investigation. The tailing encountered in the nine-spot borings are representative and characteristic of the tailing in the entire impoundment.

The nine-spot borings were continuously sampled using 3-inch O.D. lined split spoon samplers, each sample was logged, and the material classified. The relative proportions of each material type from all the nine-spot borings were determined and representative intervals of each material type were composited. The composited individual material types were then mixed in proportions equal to those encountered in the nine-spot borings. These composited samples were well mixed and placed in three columns using 4-inch lifts. Each lift was compacted by dropping and 8-cm-diameter, 2-kg weight 10 times from a height of 10 cm (ASTM D4874-89). Each lift surface was scarified with a steel bar to ensure a homogeneous connection with the next lift of sample material.

Two of the columns, Column 1 and Column 2, measured 4.5 inches in diameter and 26 inches long. The third column, Column 3, measured 4 inches in diameter and 26 inches in length. Approximately 7 kilograms of representative tailing were placed in each column. Before placement in the columns, the tailing material placed in the Columns 1 and 2 was inoculated with approximately 100 milliliters (ml) of a solution containing Thiobacillus ferrooxidans, an acidophilic bacteria which greatly accelerates the oxidation of ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}) and promotes rapid decrease of pH. The columns were then filled from the bottom with deionized water and allowed to drain for 24 hours. After draining, the columns were connected to an air system which forced water-saturated air through the columns from the bottom.

The columns were flushed with deionized water after 10 weeks by allowing water to flow into the bottom of each column until the water appeared at the top surface of the material. The water was then drained from the bottom of each column and collected and analyzed for pH, sulfate (SO_4), iron (Fe), arsenic (As), barium (Ba), cadmium (Cd), chloride (Cl), chromium (Cr), magnesium (Mg), nickel (Ni), lead (Pb), selenium (Se), molybdenum (Mo), natural uranium (U-natural) and Radium-226 (Ra). Each column was rinsed six successive times and effluent water samples collected for each rinsing. Analyses were performed on all six water rinsings for each column at the end of the first 10-week period. After the six rinsings, the columns were permeated with water-saturated air for another 10 weeks and then six additional rinsings were performed on each column. Effluent water samples were collected for analysis from the first, third, and sixth rinsing at the end of this 20-week period. The results of these analyses are presented in Tables 4.14 and 4.15 of Appendix P to the December 1994 TRP.

The column test results represent a conservative estimate of tailing geochemical evolution with oxidation, although the influence of tailing stratification was not modeled. The representative proportions of each tailing type in composited samples used in the column tests minimized potential bias of grain size fraction on the leaching results.

QUESTION 4:

What is the behavior of sulfate over time during the column tests? Does behavior suggest that column results are kinetically limited?

Response to question 4:

Average sulfate concentrations for each respective rinsing decreased slightly from the 10 week to 20 week flushing. In addition, sulfate concentrations decreased between individual rinsings for both the 10 week flushing series and the 20 week flushing series. However, the results from this test, which was designed to determine if the tailing had the potential to produce acidic conditions if oxidized, do not allow conclusive determination of the kinetic limitations, if any, on the behavior of sulfate.

QUESTION 5:

Please provide justification for the use of 50 feet thickness for the conductive bedrock zone. The text should make it clear that the conductive bedrock zone does NOT equate to the weathered bedrock.

Response to question 5:

The bedrock profile below the tailing impoundment consists of an upper layer of weathered bedrock which grades downward into unweathered bedrock. Hydraulic testing of the full range of bedrock, from highly weathered to unweathered, indicates that the bedrock possesses measurable hydraulic conductivity regardless of the degree of weathering. Therefore, the term "conductive bedrock" has been applied to the portion of the bedrock profile which has measurable hydraulic conductivity. The zone of conductive bedrock may include weathered and unweathered bedrock. Page P.E-37 in Attachment E.3 of Appendix P to the December 1994 TRP incorrectly states that 12 hydraulic conductivity values were evaluated to characterize the flow conditions within the bedrock. Replacement pages for P.E-37 and P.E-38 have been included with this transmittal. Eighteen tests of the bedrock hydraulic conductivity were performed at the Sherwood Project site in order to characterize the hydraulic properties of the bedrock (US Dept. of the Interior, 1975; D'Appolonia, 1977; SMI, this document). Of these 18 tests, 14 were found to be valid measurements of the bedrock hydraulic properties (see Table E.3.3 of Attachment E.3 to Appendix P of the December 1994 TRP). These data, presented in Table E.3.3 and attached hereto, were developed from packer tests and pumping tests in the bedrock over bore holes of 2 to 37.5 feet in length and at depths ranging from 6 feet to 54.5 feet below the top of the weathered bedrock. Four of the original 18 tests were not included due to excessive packer leakage.

Four of the original 18 tests were conducted at depths extending greater than 50 feet below the top of weathered bedrock. These test were performed in two borings, TH-16 and TH-20 (D'Appolonia, 1977). The two tests from boring TH-20 were not included in the evaluation due to excessive packer leakage. The first test from boring TH-16 which extended from 32 to 54.5 feet below the top of weathered bedrock, indicated the this interval has no measurable hydraulic conductivity. The second test from boring TH-16 which extended from 27 to 54.5 feet below top of weathered bedrock indicated that this interval has a hydraulic conductivity of 1.3×10^{-5} cm/s. The increase in measured hydraulic conductivity was therefore developed in the discrete zone between 27 and 32 feet below the top of the weathered bedrock surface.

No data exist to indicate that the bedrock below 50 feet from the top of weathered bedrock has any significant hydraulic conductivity. Therefore, the saturated thickness of the conductive bedrock hydrostratigraphic unit was assumed to be 50 feet.

In addition, it is known that fractures in igneous rocks tend to close at depth due to vertical and lateral stresses of the overlying rock (Freeze and Cherry, 1979). Based on these data, a conductive bedrock thickness of 50 feet was selected as a conservative estimate of the thickness of this hydrostratigraphic unit. This is a conservative assumption in that it leads to conservative estimates of bedrock flow capacity for calculating the basin water balance.

A sensitivity analysis was performed to evaluate the significance of the conductive bedrock thickness on the flow rate through this unit. It was determined that were a conductive bedrock unit thickness of 60 feet to have been used, the calculated flow rate through the unit would have increased by approximately 20 percent. The overall calculated ground water flow rate is not sensitive to the conductive bedrock thickness, however, since one percent of the overall calculated ground water flow is in the conductive bedrock and the other 99 percent is in the alluvium. Therefore, changes to the thickness of the conductive bedrock unit do not significantly impact the overall calculated ground water flow quantities.

QUESTION 6:

Please present results of the baseline water quality testing that has been completed for the new monitoring wells. This information will allow for completion and establishment of the baseline testing standards, and revision of Tables 6.2 and 6.3.

Response to question 6:

Baseline ground water quality data from the new monitoring wells MW-8, MW-9, and MW-10 for 1994 have been submitted in the WNI Sherwood Project Annual Environmental Monitoring Program Report, January through December, 1994. Test results through August of 1995 from all existing ground water monitoring locations for the constituents chloride (Cl), sulfate (SO_4), Uranium (U), Radium-226 and Radium-228 (combined), arsenic (As), nickel (Ni), and thallium (Tl) have been compiled and the relevant statistical control charts developed.

No control charts were developed for the constituents nickel and thallium. Thallium has never been observed at concentrations above detection the limits. The detection limit for the period 6/29/94 through 3/29/95 was 0.01 mg/l. The detection limit for the period 4/20/95 through present has been 0.001 mg/l. Based on these data it is concluded that the background concentration of thallium in the ground water is below both the detection limit of 0.001 mg/l and the regulatory limit (USEPA Code 10 40 CFR) of 0.002 mg/l.

Nickel has been observed above detection limits (0.05 mg/l) two time since 9/29/93 when analysis of water samples for this constituent began, once at 0.12 mg/l in MW-3 (4/19/94) and once at 0.51 mg/l in MW-6 (4/19/94). These detections are only two points of over 75 data collected for this constituent to date. Therefore, nickel is considered to be at or below the detection limit of 0.05 mg/l and the regulatory limit (USEPA Code 10 40 CFR) of 0.1 mg/l.

The control charts for arsenic and combined radium-226/228 were developed using the detection limit value for analyses reported as below the detection limit. The upper control limits for arsenic and combined radium-226/228 are 0.003 mg/l and 6.4 pCi/l, respectively.

The upper control limits for the constituents chloride, sulfate, and uranium have been adjusted to reflect the updated database which includes the results of the supplemental ground water monitoring. These changes are reflected in Tables 6.2 and 6.3. The constituent radium-226 as an individual constituent has been dropped as it has no specific regulatory requirement and is included with radium-228 as a combined constituent.

These data establish the appropriate regulatory standards for evaluation of ground water quality data at the Sherwood Project. Updated versions of Tables 6.2 and 6.3 from Appendix P and control charts for the constituents listed above are included in this transmittal.

QUESTION 7:

Figure C.2.1 should be revised to include the following: a notation that complete fracture data are presented in Table C.2-1; a notation that strikes and dips on the figure are only representative and that there are other structures with strike and dip measurements that have been recorded; and delineated areas that were identified on the seismic profiles as areas where Low Velocity Zones were encountered.

Response to question 7:

The revisions requested to Figure C.2.1 of Appendix P to the December 1994 TRP have been made and a revised figure is included with this transmittal.

QUESTION 8:

Please present generalized cross-sections showing the relationship between the hydrostratigraphic units, monitoring well static water levels, bottom profile of the tailing impoundment, and bottom profile of the solution holding pond.

Response to Question 8:

Three figures are included in this transmittal. Two figures are generalized cross sections illustrating the above mentioned features. The third drawing illustrates the cross section locations.

QUESTION 9:

The contour intervals on Figure 3.4 indicate a level of detail that is not supported by the seismic information. Elimination of the 20-foot contour interval on the figure could better represent the bedrock surface. It should be noted that the bedrock contours in the vicinity of seismic line F were based on outcrops. (Seismic line F could not be interpreted.) The text could also be enhanced by documenting that the new downgradient monitoring wells were installed. This is significant, considering the need to have good control at the Point of Compliance downgradient from the tailings impoundment.

<u>Question 9a:</u>

The contour intervals on Figure 3.4 indicate a level of detail that is not supported by the seismic information. Elimination of the 20-foot contour interval on the figure could better represent the bedrock surface. It should be noted that the bedrock contours in the vicinity of seismic line F were based on outcrops. (Seismic line F could not be interpreted.)

<u>Response to question 9a:</u>

The 20-foot contour intervals have been removed from Figures 3.4 and C.4.2 of Appendix P to the December 1994 TRP as requested and replacement figures are included with this transmittal. A note has been added to revised Figures 3.4 and C.4.2 noting that, due to insufficient resolution of the seismic data in these areas, the bedrock contours in the vicinity of seismic line F were based on outcrops

<u>Question 9b:</u>

The text could also be enhanced by documenting that the new downgradient monitoring wells were installed. This is significant, considering the need to have good control at the Point of Compliance downgradient from the tailings impoundment.

<u>Response to question 9b:</u>

Section 3.4 of Appendix P to the December 1994 TRP states "....borehole data from Well MW-8 confirms that the deeper, weak reflectors coincide with the bedrock surface." In addition, Drawing 13 of Attachment C.5 to Appendix P of the December 1994 TRP illustrates the relationship between the seismic data from seismic lines A, B and J, and the geologic data developed from the drilling and installation of wells MW-8, MW-9, and MW-10. These seismic data, which were verified during the April

1993 installation of these new monitoring wells, provide excellent control of the geologic and hydrologic conditions at the point of compliance.

The text in Appendix P to the December 1994 TRP have not been modified to elaborate this fact. However, the information discussed above has been presented more completely in the Technical Integration Report attached with this transmittal (see response to question 13).

QUESTION 10:

Figure 15 of the seismic profiles is incorrect. The SE and NW appear to be reversed and should be corrected.

Response to question 10:

The orientation of the seismic section on Figure 15 (Attachment C.5 to Appendix P of the December 1994 TRP) is reversed. As discussed during a September 28 and 29, 1995 meeting with WDOH, no correction will be made to the figure and this transmittal will document this fact.

QUESTION 11:

A computation error needs to be corrected on page E-14, in converting ft/min to cm/sec. Please clarify in the text, page E-14 that pump test data from wells 8 and 10 were not used in the integrated site model. The physical constraints of the aquifer prohibit an adequate stress test of the aquifer and the drawdown may only represent dewatering of the borehole. Therefore, data from previously performed packer tests were used in the integrated site model.

Response to question 11:

Page P.E-14 of Appendix P to the December 1994 TRP has been corrected and an updated replacement page is included with this transmittal. In addition, a replacement page for page P.E-41 of Appendix P to the December 1994 TRP is included to reflect the modification. Note that the average, maximum, and minimum hydraulic conductivity values are not altered by this correction.

The text on page P.E-14 of Appendix P to the December 1994 TRP has been expanded to document that the data from pumping tests on wells MW-8 and MW-10 were not included in the calculation of average, maximum, and minimum hydraulic conductivity values for the two hydrostratigraphic units modeled. It was not possible to apply sufficient hydraulic stress the hydrostratigraphic units to adequately characterize their hydraulic properties. The text in this response clarifies the basis for development of hydraulic conductivity values use in the site ground water modeling. A copy of the modified page P.E-14 is included in this transmittal.

QUESTION 12:

The text associated with the long-term limitations of yield in any dewatering program could be enhanced. A description of the lenticular, discontinuous coarse-grained layers that are limited in aerial extent, and bounded by fine-grained layers in the tailings impoundment, indicate that the effectiveness of long-term pumping, associated with dewatering, would probably diminish over time as "negative boundaries" are encountered. This information should be included at page 4-12 and in the new Executive Summary.

Response to question 12:

Long-term pumping of the impoundment is impractical due to the discontinuous nature of the coarse grained tailing material. The source of the water removed during the initial pumping phase would be primarily from the lenticular, coarse grained layers in contact with the pumping well screens. Initial pumping rates from these lenses would be relatively high and suitable for dewatering. However, these discontinuous coarse grained lenses drain after a relatively short period of time due to their finite and discontinuous nature. Once drained, flow to the pumping wells will be dominated by the layers of fine grained tailing. These fine grained layers have been shown to exhibit very low permeability along with quite large water retention characteristics (i.e. low apparent specific yield). Coarse grained lenses not in direct contact with the pumping well screens are isolated from other coarse grained layers and the pumping well screens by the fine grained layers. The water retained in these isolated coarse grained lenses must flow through the fine grained layers in order to drain. Therefore, long term pumping rates will be significantly lower and not suitable to tailing dewatering. In addition, the percentage of coarse grained material in the tailing is not representative of the water easily available for removal by pumping due to the isolation of significant portions of the coarse grained materials by fined grained tailing layers.

This more detailed description has been included into the Technical Integration Report. Page P.4-12 and the executive summary to Appendix P has also been updated to include this point. Updated replacement pages P.4-12 and P.1-6 are included with this transmittal.

QUESTION 13:

The information presented in Appendix P represents a very comprehensive approach to evaluating the ground water underlying the area. The information could be effectively summarized in a new document, a Technical Integration Report document, that would be more readable for the non-hydrogeologist and provide a road map/guide to relevant topics found in appendices other than Appendix P. The Technical Integration Report document could also provide the additional information requested in the items listed above.

Response to question 13:

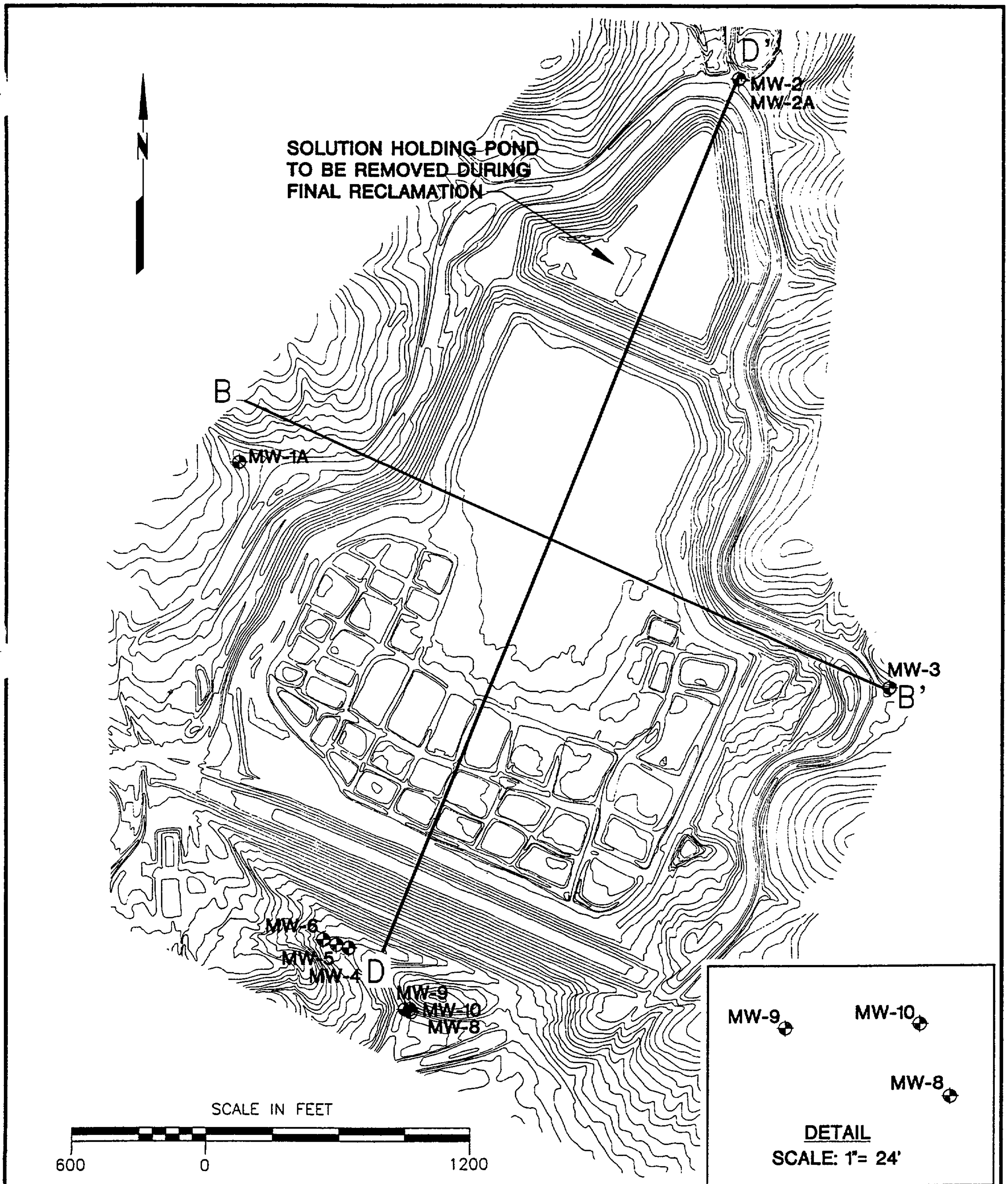
A Technical Integration Report (TIR) to the Sherwood Project Ground Water Protection Plan is included with this transmittal. The TIR attempts to more clearly relate the technical approach that was adopted for the ground water protection evaluation, the methods used, and the rational for these methods. A step-by-step description of the objectives and goals, tasks and methods, and results and their significance are presented, with attention to the needs of the non-technical reader. This document includes the information requested in the WDOH letter of November 6, 1995.

QUESTION 14:

The text associated with ground water monitoring should be revised to reflect additions and modifications to the ground water monitoring program that have been developed since December 1994 (i.e., addition of intermediate phase of ground water monitoring between leak detection monitoring and compliance monitoring).

Response to question 14:

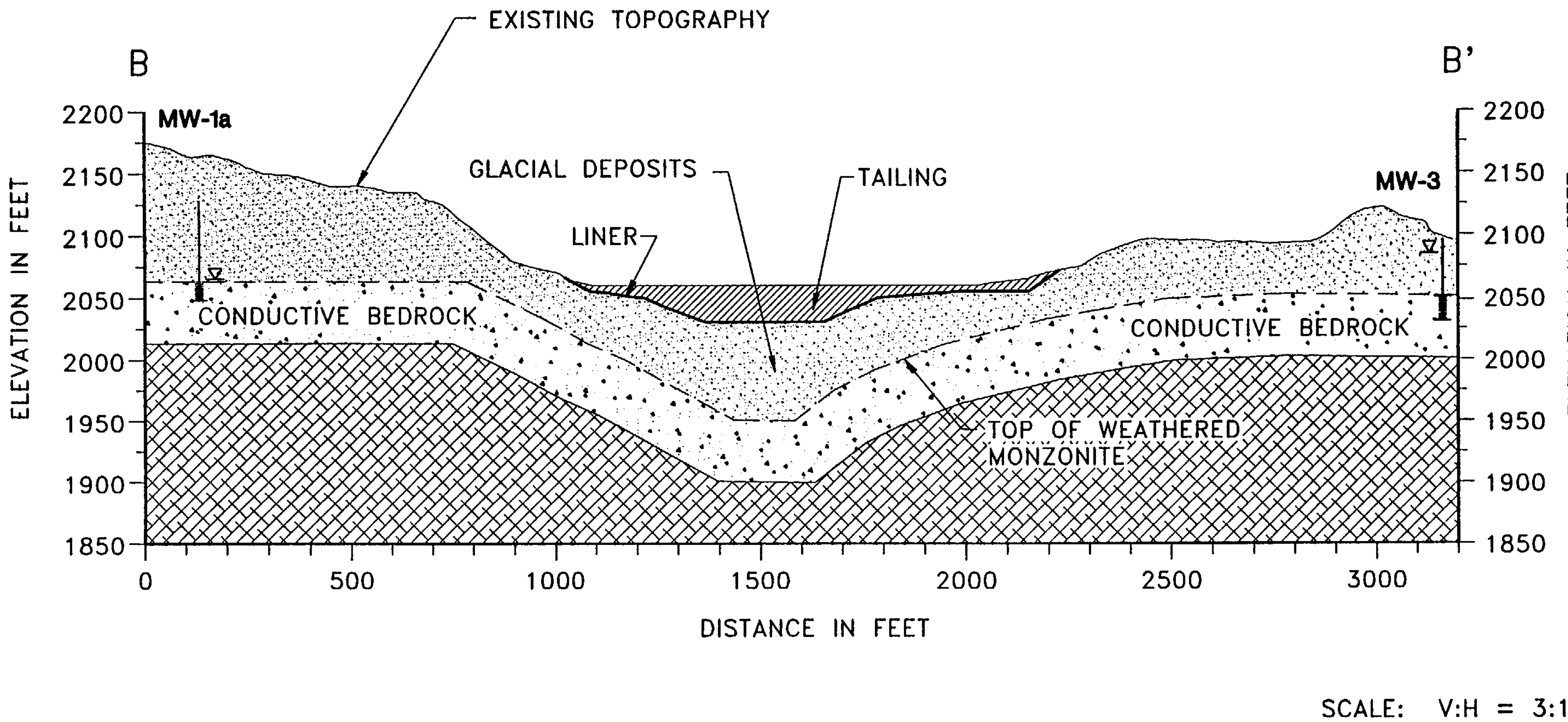
The changes to the leak detection monitoring program for construction and closure developed since December, 1994 have been addressed in the Technical Integration Report which is included with this transmittal.



SMI
SHEPHERD MILLER, INC.

FIGURE 1
CROSS-SECTION AND WELL LOCATIONS

Date:	DEC. 1995
Project:	317
File:	CROS-WEL

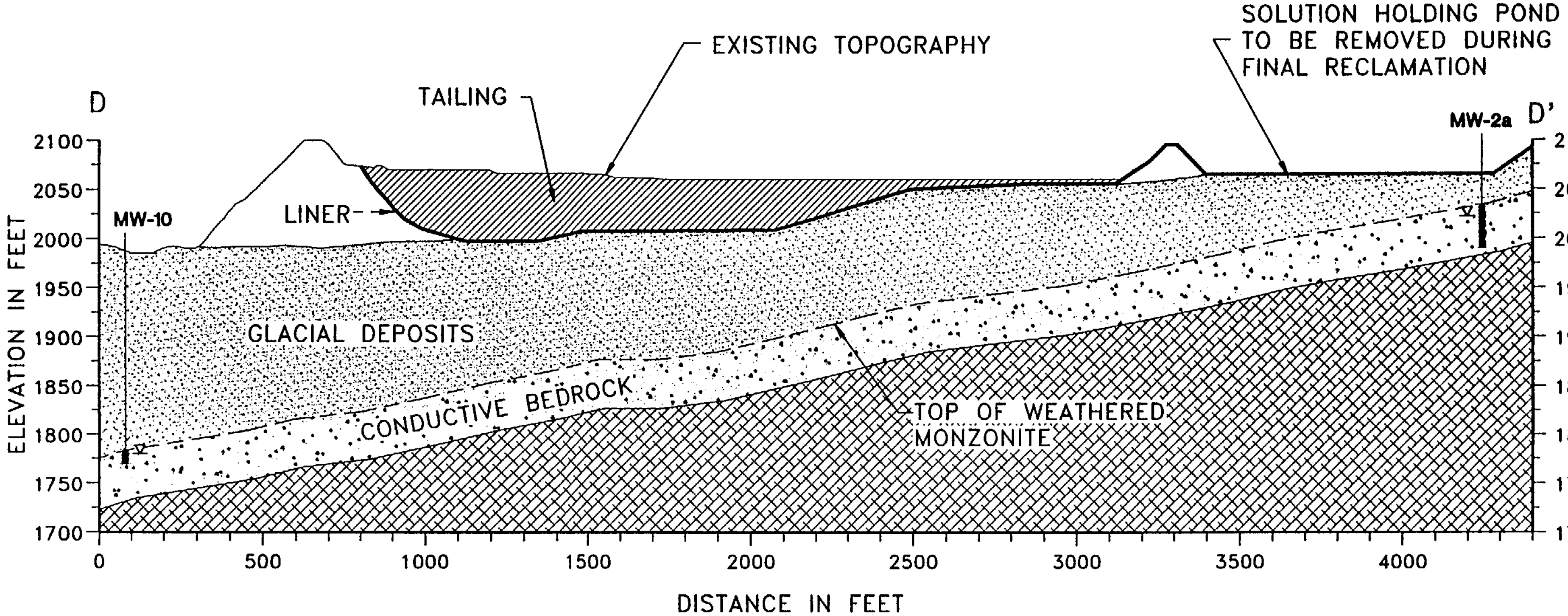


NOTE: WATER LEVELS ARE BASED ON AVERAGE 1994 DATA.

SMI
SHEPHERD MILLER, INC.

FIGURE 2
CROSS SECTION
B–B'

Date:	DEC. 1995
Project:	317
File:	XSECT–B1



SCALE: V:H = 3:1

NOTE: WATER LEVELS ARE BASED ON AVERAGE 1994 DATA.

SMI
SHEPHERD MILLER, INC.

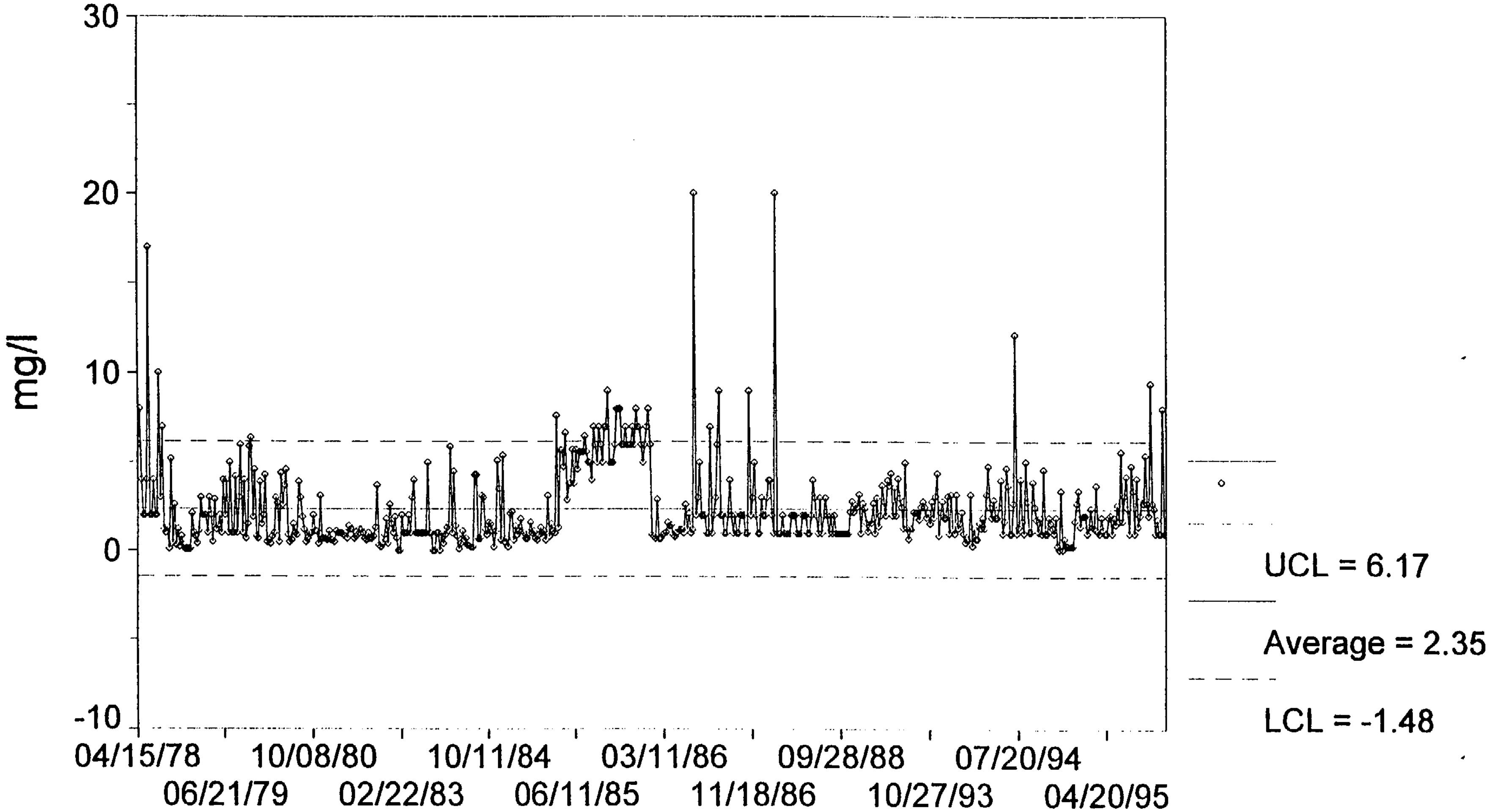
FIGURE 3
CROSS SECTION
D–D'

Date:	DEC. 1995
Project:	317
File:	XSECT-D1

Sherwood Historical Data

Ground Water

Monitor Wells No.: 1A, 2, 2A, 3, 4, 5, 6, 8, 9, 10



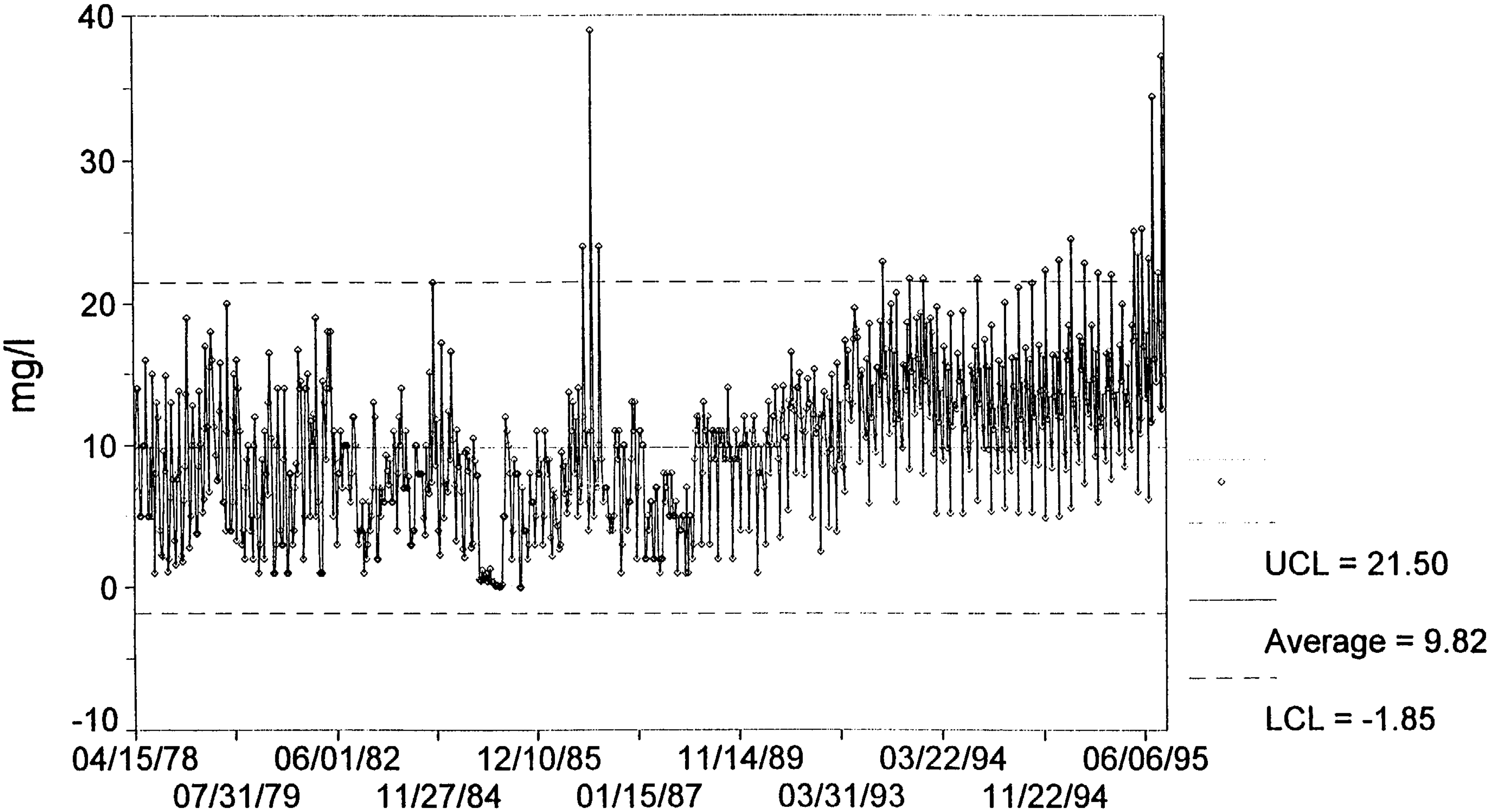
Sigma Level: 3

Cl

Sherwood Historical Data

Ground Water

Monitor Wells No.: 1A, 2, 2A, 3, 4, 5, 6, 8, 9, 10



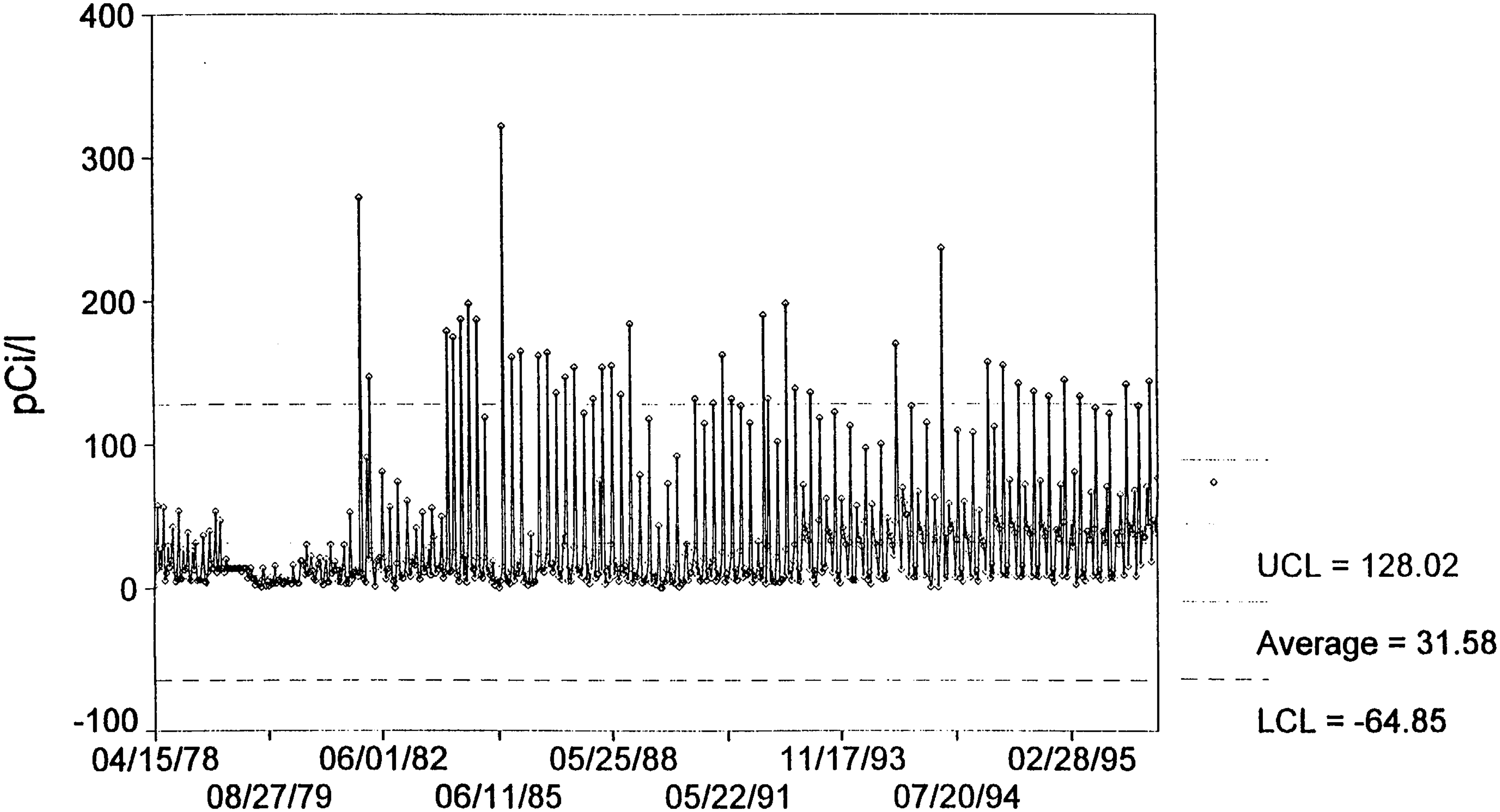
Sigma Level: 3

SO4

Sherwood Historical Data

Ground Water

Monitor Wells No.: 1A, 2, 2A, 3, 4, 5, 6, 8, 9, 10



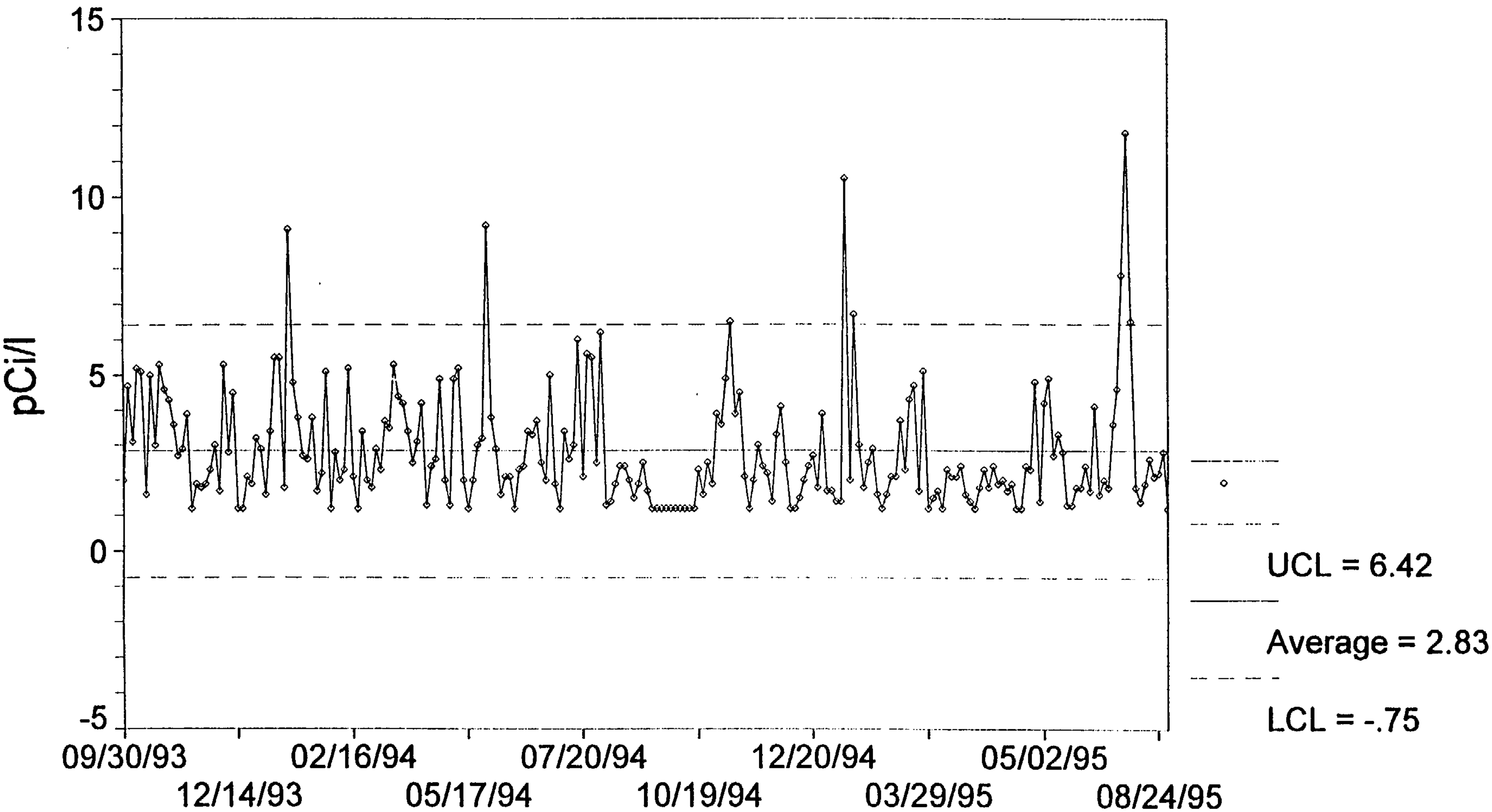
Sigma level: 3

U

Sherwood Historical Data

Ground Water

Monitor Wells No.: 1A, 2, 2A, 3, 4, 5, 6, 8, 9, 10



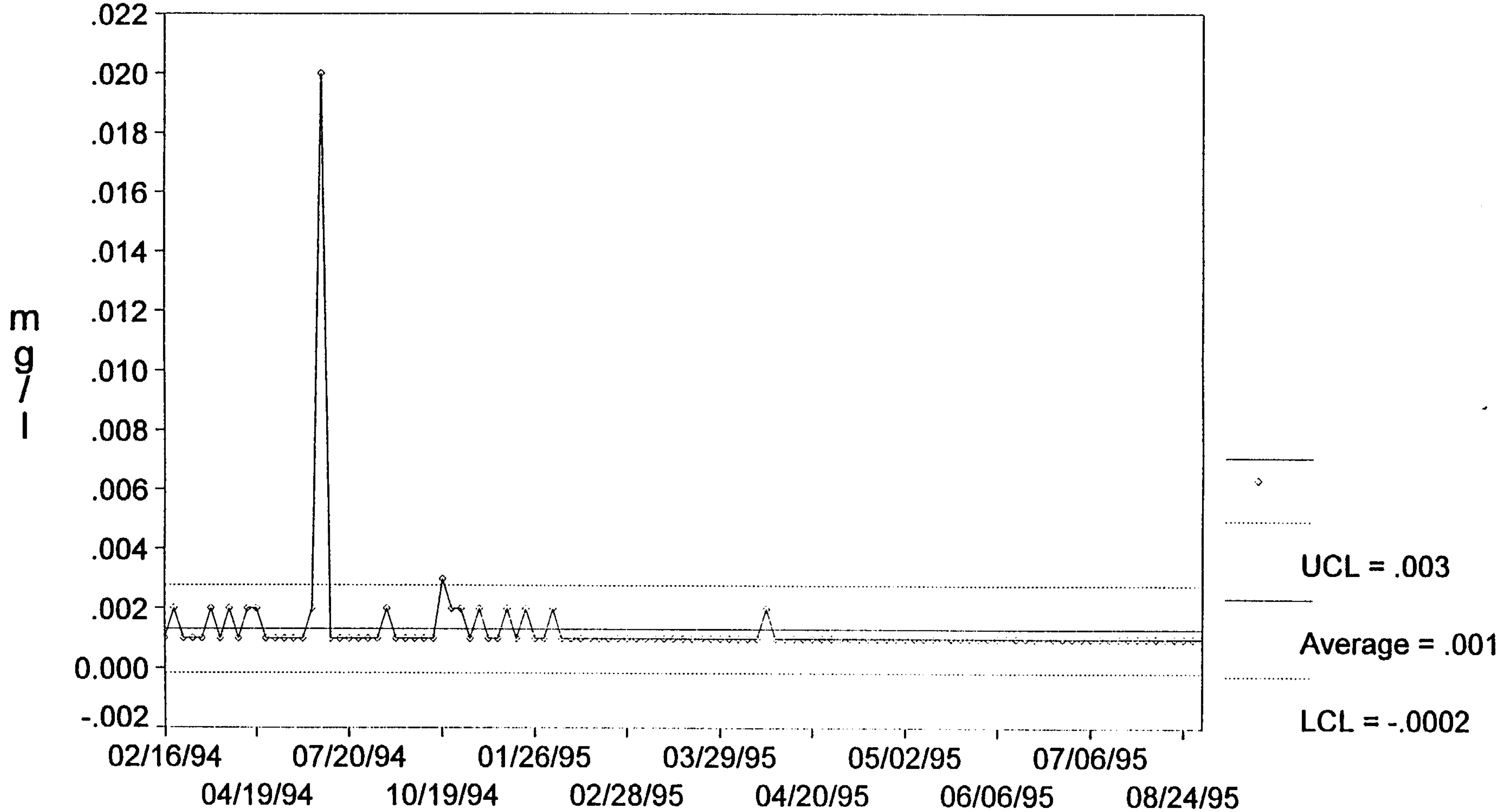
Sigma level: 3

Ra-226 + Ra-228

Sherwood Historical Data

Ground Water

Monitor Wells No.: 1A, 2, 2A, 3, 4, 5, 6, 8, 9, 10



Sigma Level: 3

As

ATTACHMENT G
GEOCHEMICAL ANALYSES

Accu-Labs Research, Inc.

3 Table Mountain Drive , Golden, Colorado 80403-1650
3) 277-9514 FAX (303) 277-9512

Sherwood Water (Tailing) Samples
Project #307

ANALYSIS REPORT
DATE: 11/26/91 PAGE 1

TOM SHEPHERD
SHEPHERD MILLER, INC
1136 E. STUART,
SUITE 2040
FORT COLLINS, CO 80525

Lab Job Number: 2021-40526-3
Date Samples Received: 11/06/91
Customer PO Number: (none)

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2021-40526-3-1	2021-40526-3-2	2021-40526-3-3
Sponsor Designation -	T-4	T-7	T-8
Date Collected -	10/24/91	10/24/91	10/24/91
Determinations in mg/L unless noted			
Cadmium - dissolved	<0.005	<0.005	<0.005
Calcium - dissolved	510	450	460
Chromium - dissolved	0.006	<0.005	<0.005
Copper - dissolved	<0.005	<0.005	<0.005
Iron - dissolved	46	82	130
Magnesium - dissolved	240	470	390
Manganese - dissolved	12	17	18
Molybdenum - dissolved	0.96	1.0	1.1
Nickel - dissolved	<0.01	<0.01	0.04
Potassium - dissolved	56	95	65
Silica-ICP - dissolved	9.0	12	9.8
Silver - dissolved	<0.005	<0.005	<0.005
Sodium - dissolved	160	260	300
Zinc - dissolved	0.026	0.062	0.10
Alkalinity, Total (as CaCO3 to pH 4.5)	120	40	25
pH (pH Units)	6.7	5.9	5.7
Arsenic - dissolved	0.048	0.095	0.043
Lead - dissolved	<0.005	<0.005	<0.005
Nitrate (as N)	0.38	0.29	0.13
Chloride	240	360	400
Sulfate (as SO4)	2,900	4,800	3,700

By: Eyda Hergenreder
Eyda Hergenreder
Water Laboratory Supervisor

EH/ep

RECEIVED ... 8 1992

Accu-Labs Research, Inc.

'63 Table Mountain Drive Golden, Colorado 80403-1650
.03) 277-9514 FAX (303) 277-9512

ANALYSIS REPORT

DATE: 01/06/92 PAGE 1

TOM SHEPHERD
SHEPHERD MILLER, INC
1600 SPECHT POINT DRIVE
SUITE F
FORT COLLINS, CO 80525

Lab Job Number: 2021-40526-3
Date Samples Received: 11/06/91
Customer PO Number: (none)

These samples to be disposed of 30 days after the date of this report.

ALR Designation -	2021-40526-3-1	2021-40526-3-2	2021-40526-3-3
Sponsor Designation -	T-4	T-7	T-8
Date Collected -	10/24/91	10/24/91	10/24/91
Determinations in pCi/L unless noted			
Radium-226 - dissolved	52 ± 1 *	45 ± 1 *	87 ± 2 *
Radium-228 - dissolved	2.9 ± 1.0 *	2.6 ± 0.9 *	3.2 ± 0.7 *
Thorium-230 - dissolved	0.0 ± 0.1 *	0.1 ± 0.1 *	0.2 ± 0.4 *
Uranium - dissolved (mg/L)	0.36	0.12	0.16

* Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

By: Bud Summers
Radiochemistry Supervisor

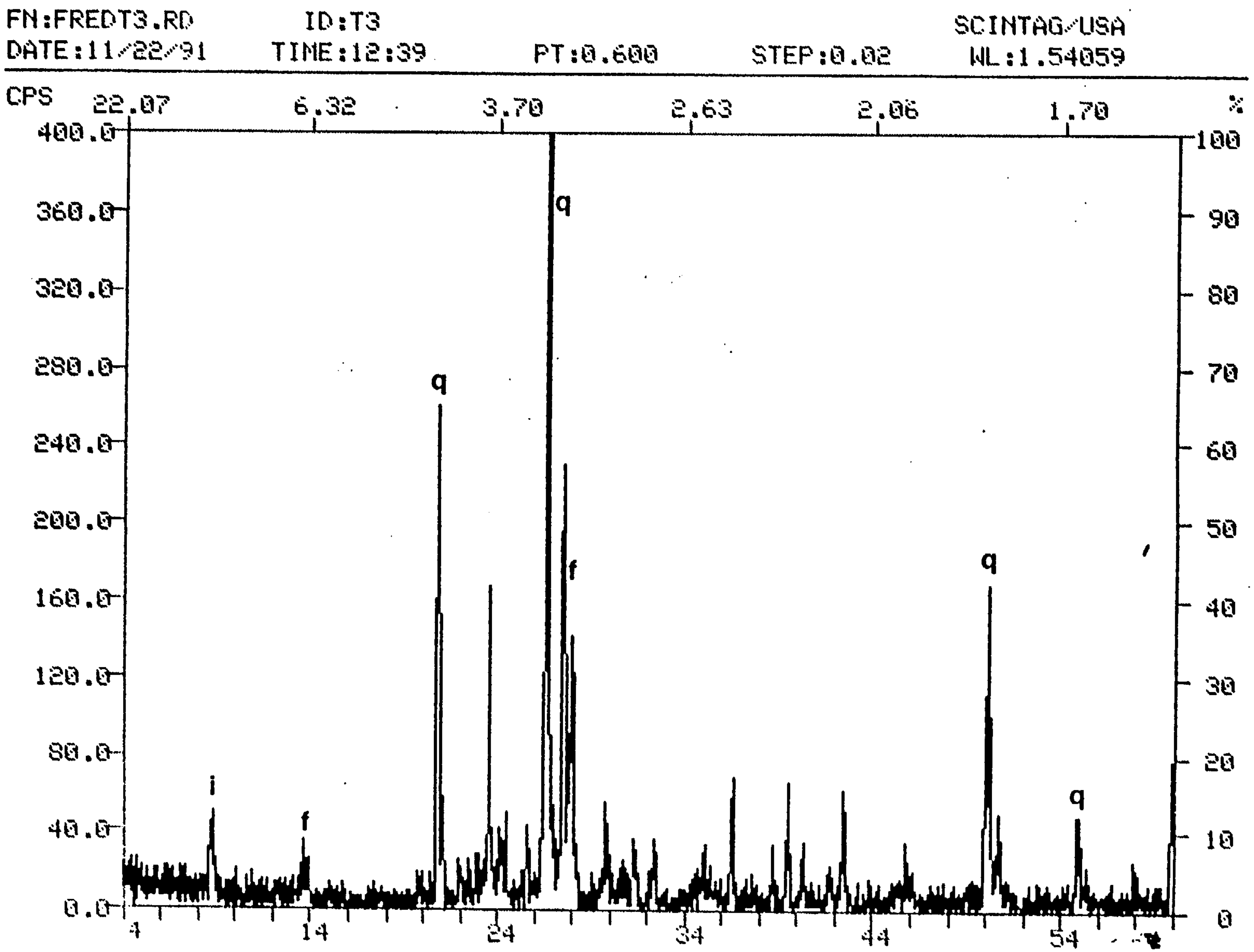
BS/dh

REPORT ON XRD ANALYSES OF MILL TAILING SAMPLES T-3, T-5, T-7, AND T-8.

Sample T-3 contains, in the order of their abundance, quartz, feldspar (anorthite ?), and a small amount of illite (Figure 1). Sample T-8 contains quartz (q), feldspar (f), illite (i), gypsum (g) and kaolinite (k) (Figure 2). Sample T-5 contains quartz, feldspar, illite, gypsum, kaolinite and smectite (s) (Figure 3). The clay fraction was separated from T-5 and mounted by use of a water slurry onto a ceramic slide. The sample was ran through the XRD air dried and then glycolated (Figure 5). The clay fraction from T-5 contains, in the order of abundance, quartz, gypsum, kaolinite, feldspar, illite and smectite. Sample T-7 contains quartz, gypsum, feldspar, illite, , kaolinite and an unidentified clay mineral (Figure 4). The clay fraction was separated from T-7 and analyzed in the same manner as T-5. The clay fraction of T-7 contains gypsum, quartz, feldspar, kaolinite, illite and smectite (Figure 6).

The illite seen in all samples could also be sericite or finely divided muscovite. A knowledge of the original ore would help resolve this problem. The gypsum seen in samples T-5, T-7 and T-8 appears to be clay sized particles. This coupled with the fact that the diffraction pattern of the samples best matched synthetic gypsum suggests that the gypsum precipitated from the reaction of lime and a pyritic ore.

FIG. 1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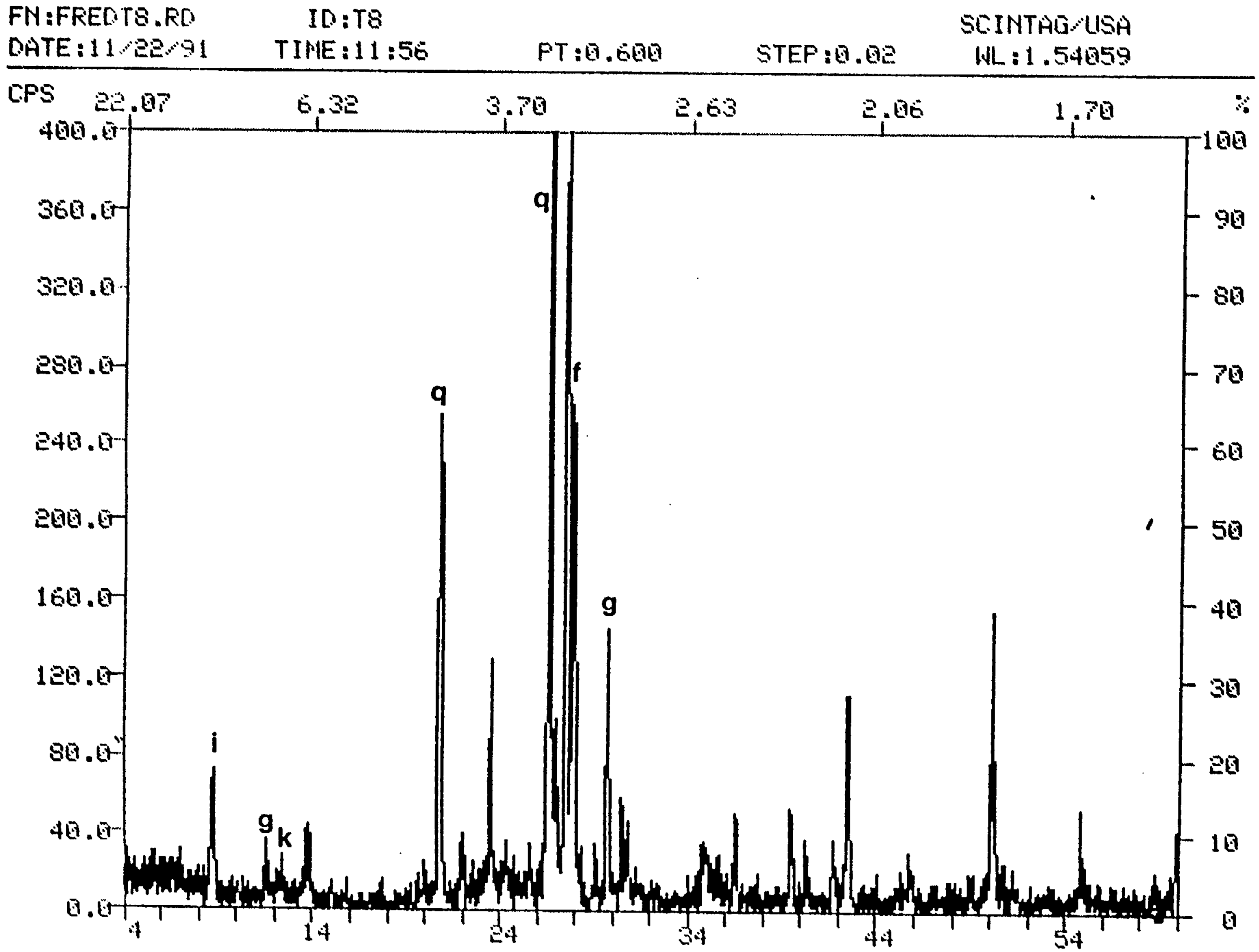
CPS
22.07
6.32
3.70
2.63
2.06
1.70
%
400.0
360.0
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
100
90
80
70
60
50
40
30
20
10
0
4
14
24
34
44
54
q
q
q
q
f
f
i

FIG. 2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1.70
%
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360.0
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
100
90
80
70
60
50
40
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4
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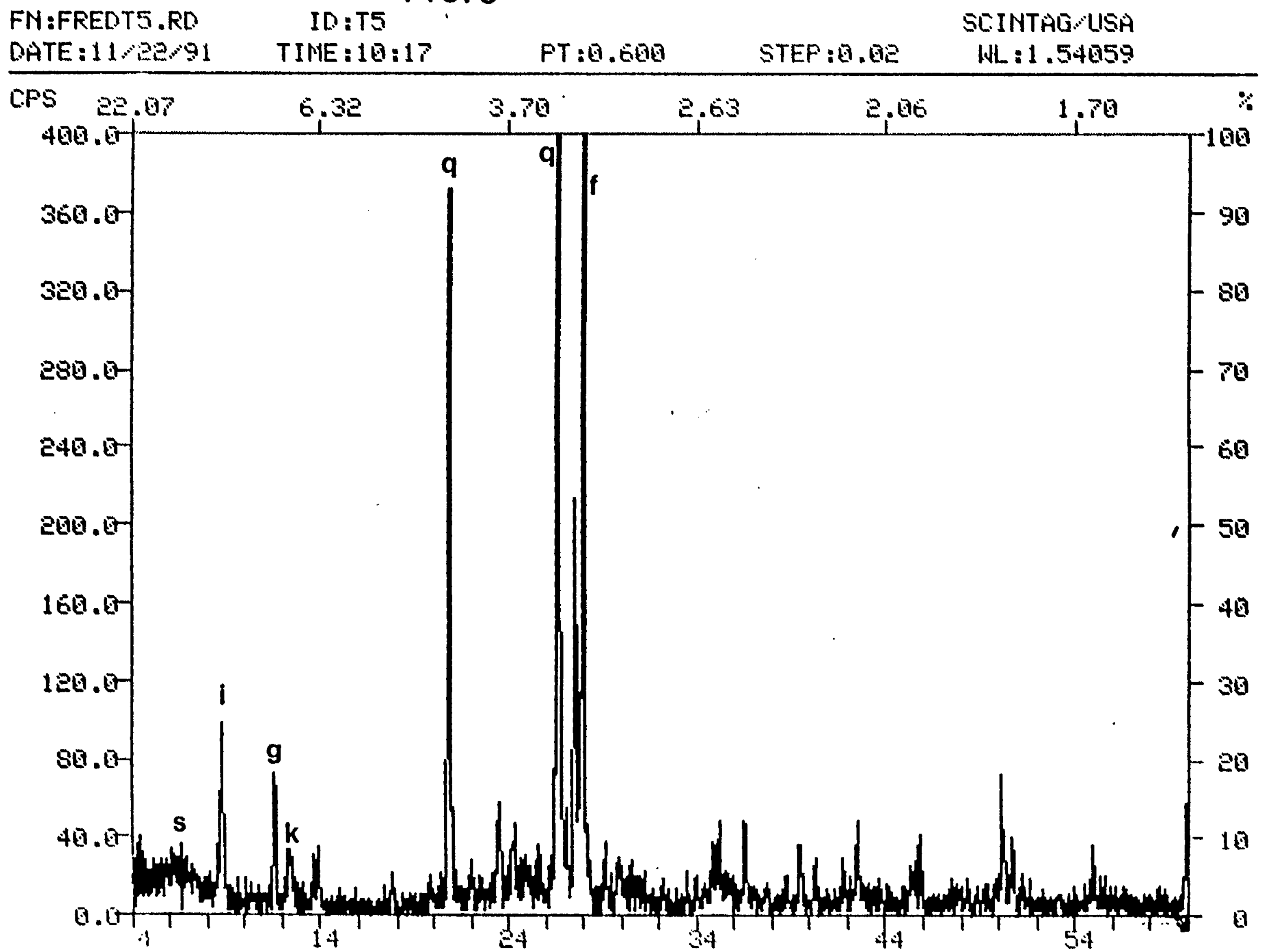
i
g
k
q
q
f
g

FIG. 3



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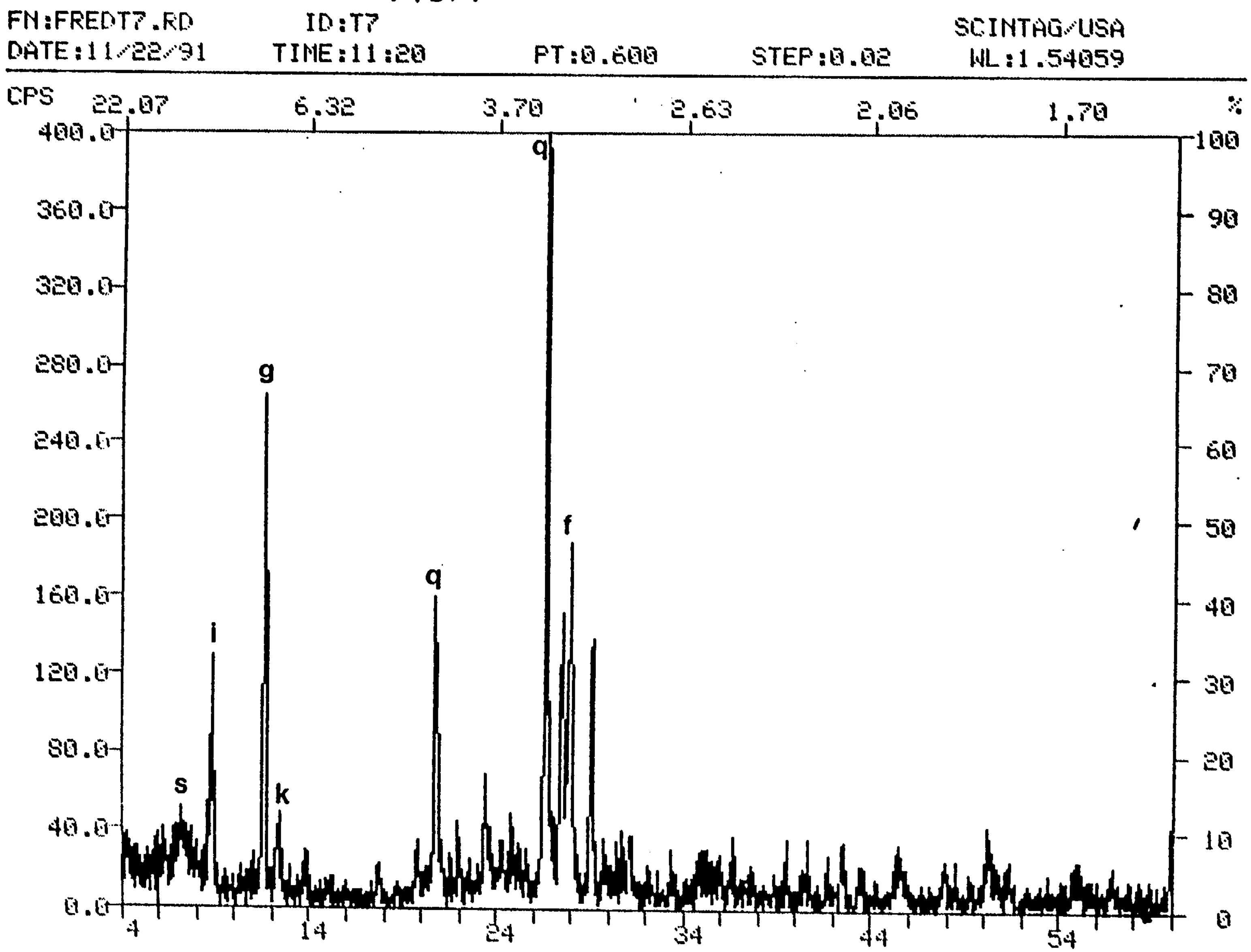
3.70
2.63
2.06
1.70
%
400.0
360.0
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
100
90
80
70
60
50
40
30
20
10
0
4
14
24
34
44
54
q
q
f
i
g
s
k

FIG.4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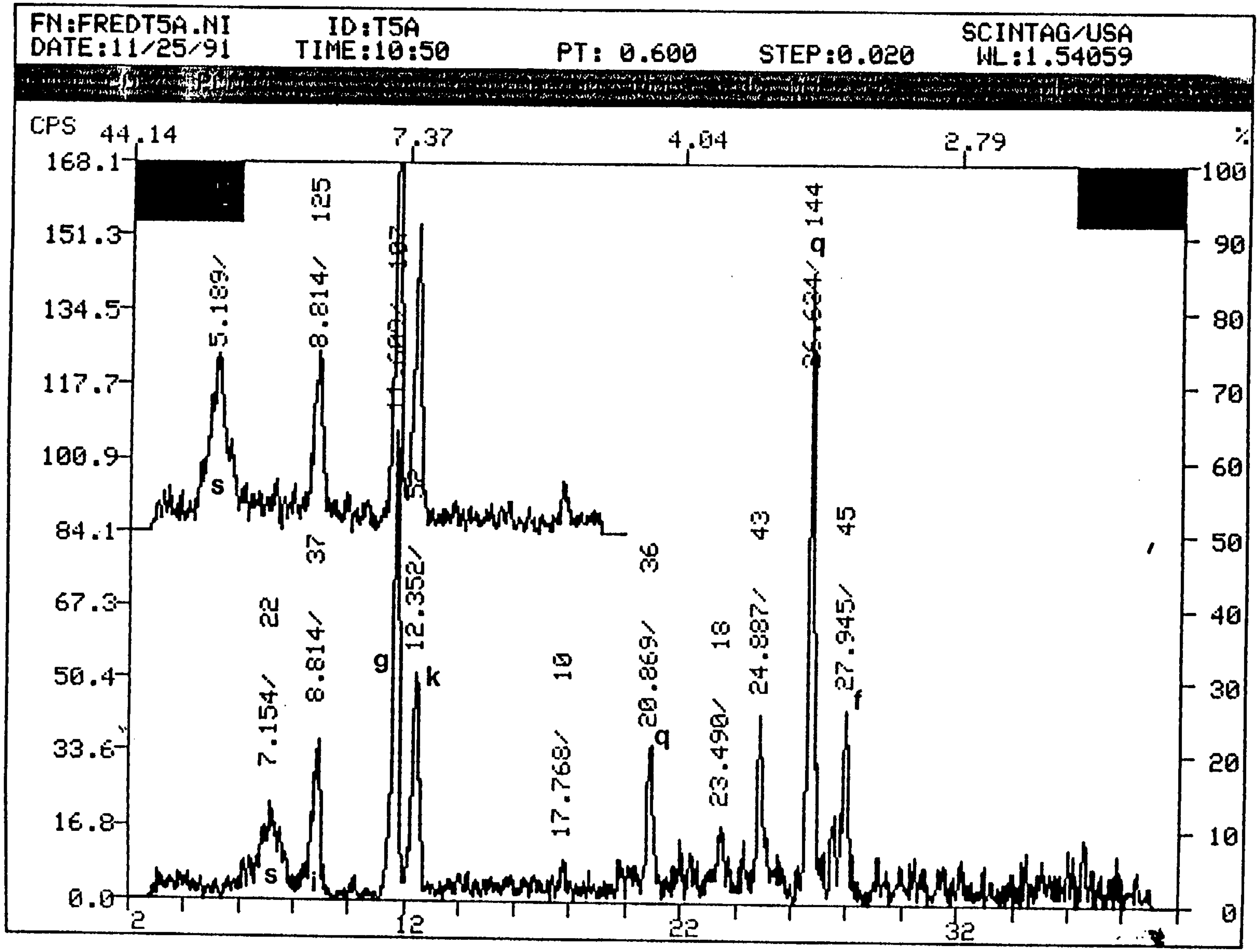
CPS
22.07
6.32
3.70
2.63
2.06
1.70
%
400.0
360.0
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
100
90
80
70
60
50
40
30
20
10
0
4
14
24
34
44
54
s
i
g
k
q
q
f

FIG. 5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WL:1.54059
CPS
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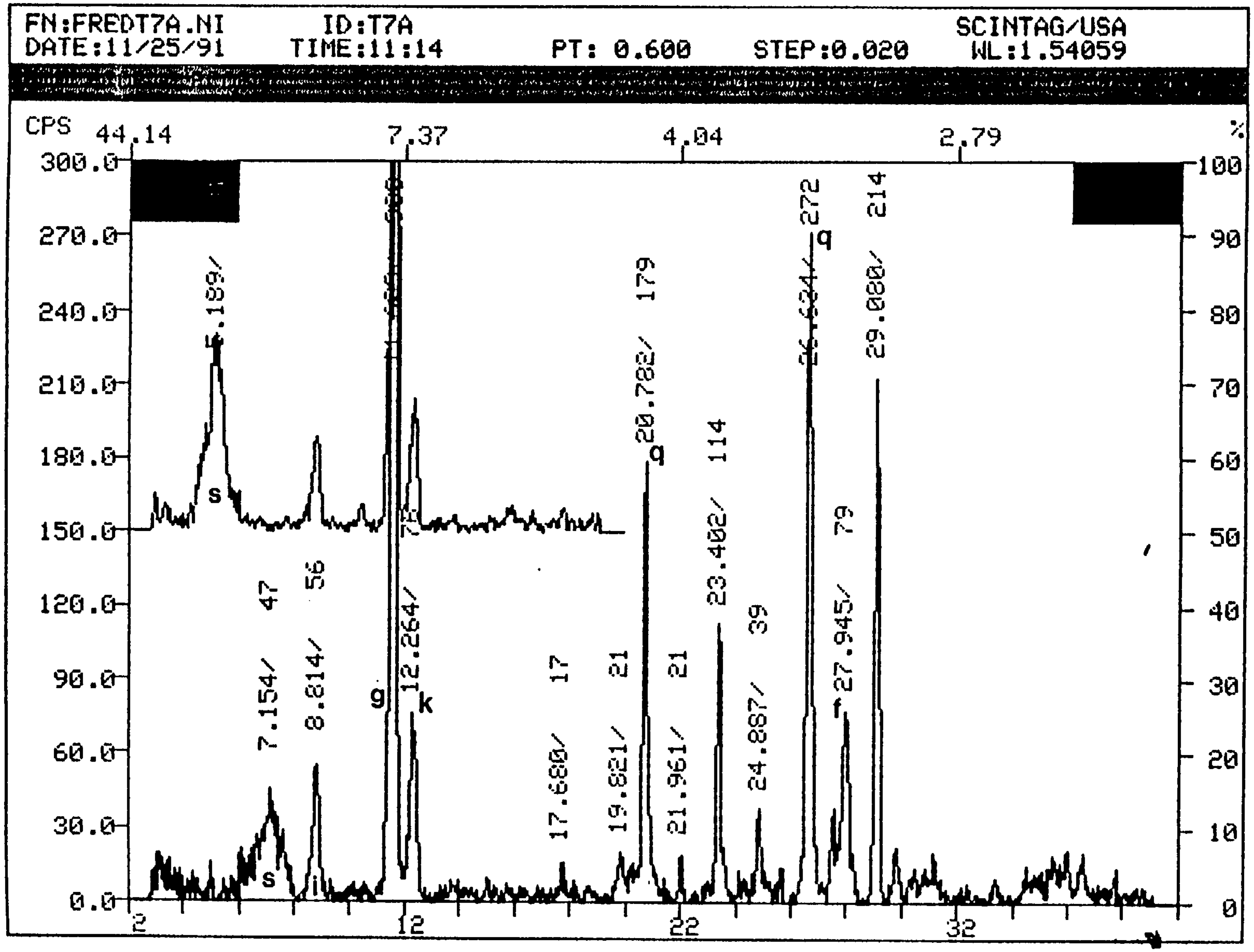
8.814/ 125
12.352/
26.634/ 144
7.154/ 22
8.814/ 37
17.768/ 10
20.869/ 36
23.490/ 18
24.887/ 43
27.945/ 45

FIG. 6



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4.04
2.79
%
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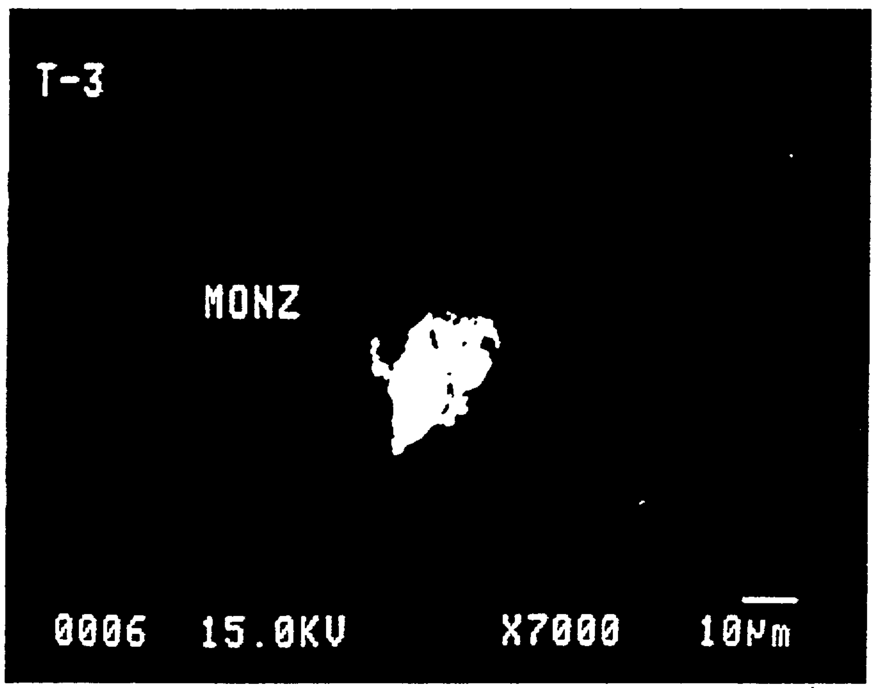
270.0
240.0
210.0
180.0
150.0
120.0
90.0
60.0
30.0
0.0
100
90
80
70
60
50
40
30
20
10
0
2
12
22
32
s
7.154/ 47
8.814/ 56
g
12.264/
k
17.680/ 17
19.821/ 21
20.782/ 179
q
21.961/ 21
23.402/ 114
24.887/ 39
272
q
27.945/ 79
f
29.080/ 214

Sample T-3

In addition to the dominant minerals detected by XRD the following mineral phases were identified by electron microscopy; magnetite, ilmenite, biotite,sphalerite, chalcopyrite and pyrite. U-Th phases found in this sample include small, 1-40 micron, anhedral to subhedral grains of monazite, zircon, betafite, and thorofrancorsite. Monazite and zircon are the dominant U-Th phases.

PHOTO 1. Backscatter photomicrograph from sample T-3 of anhedral monazite.



Sample T-5

This sample in addition to the phases identified by XRD contains; galena, pyrite and sphalerite. The U-Th phases found in this sample include: zircon, cheralite, and thorofrancorsite.

PHOTO 2.. Backscatter photomicrograph of thorofrancorsite from sample T-5.

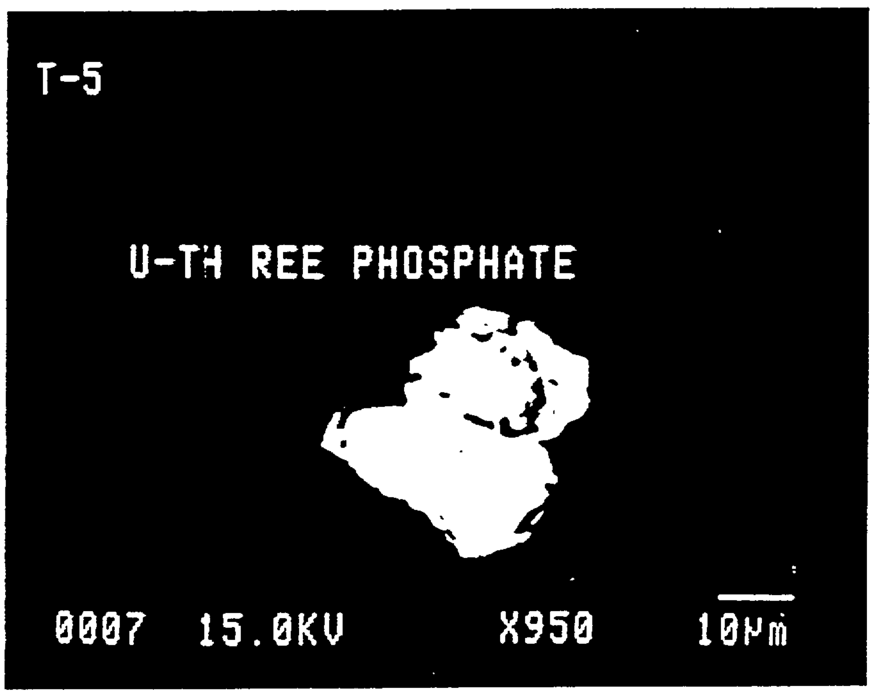
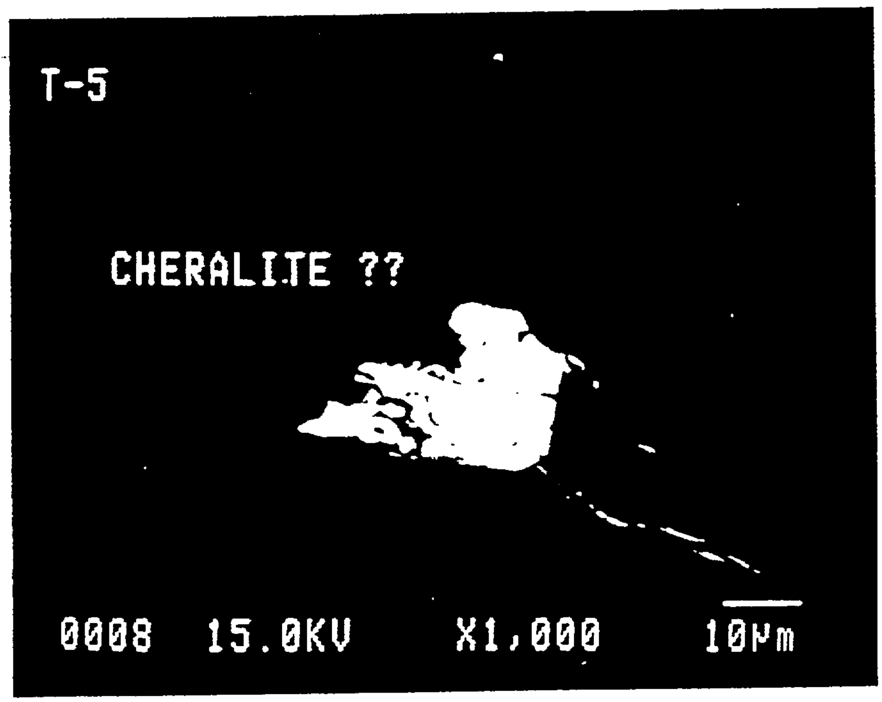


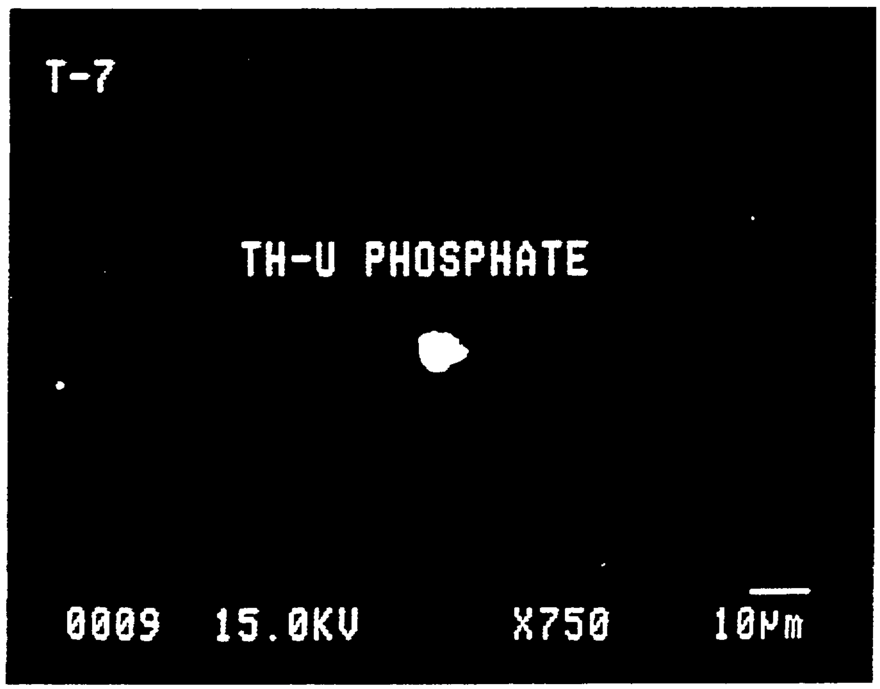
PHOTO 3. Backscatter photomicrograph of cheralite from sample T-5.



Sample T-7

This sample contains galena, sphalerite, pyrite and barite in addition to those identified by XRD. U-Th phase identified in this sample is thorofrancorsite.

PHOTO 4. Backscatter photomicrograph of thorofrancorsite in sample T-7.



Sample T-8

In addition to the phases identified by XRD this sample contains; ilmenite, magnetite, biotite, apatite, and pyrite. U-Th minerals identified include: zircon, uraninite, thorogummite, and thorofrancorsite.

PHOTO 5. Photomicrograph of small, 6 micron, uraninite grain in sample T-8.

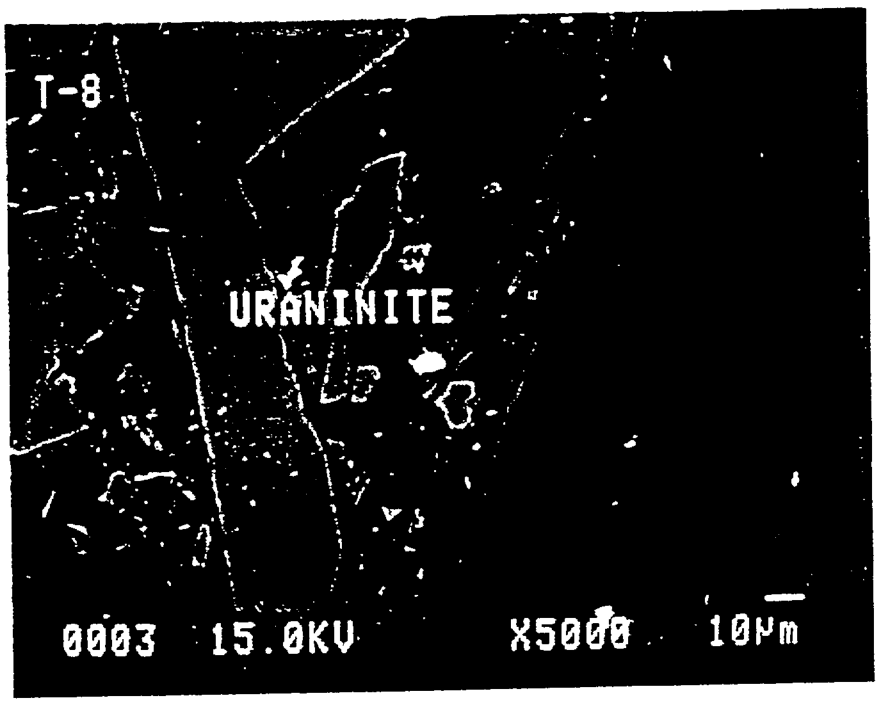
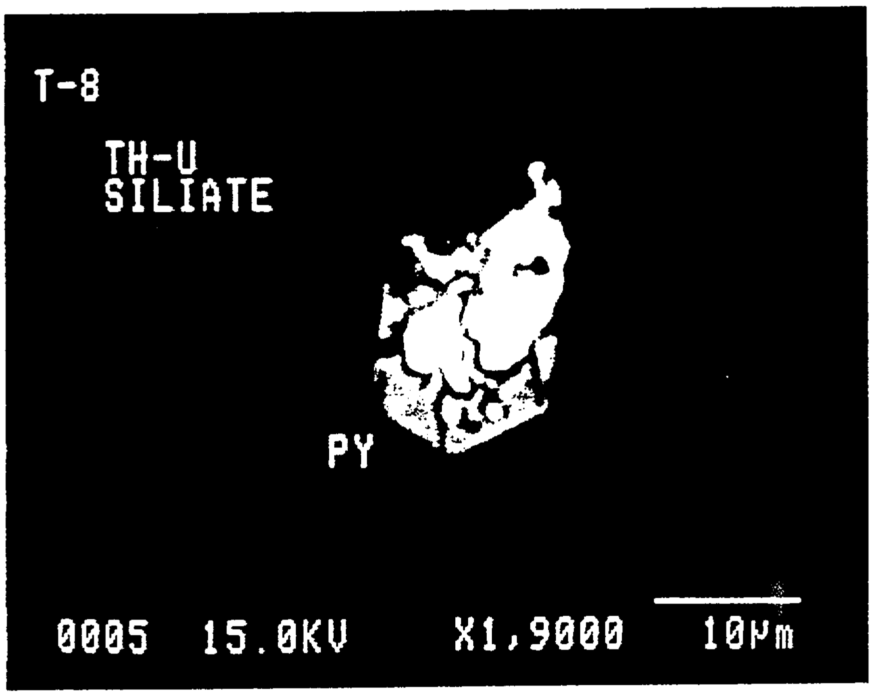
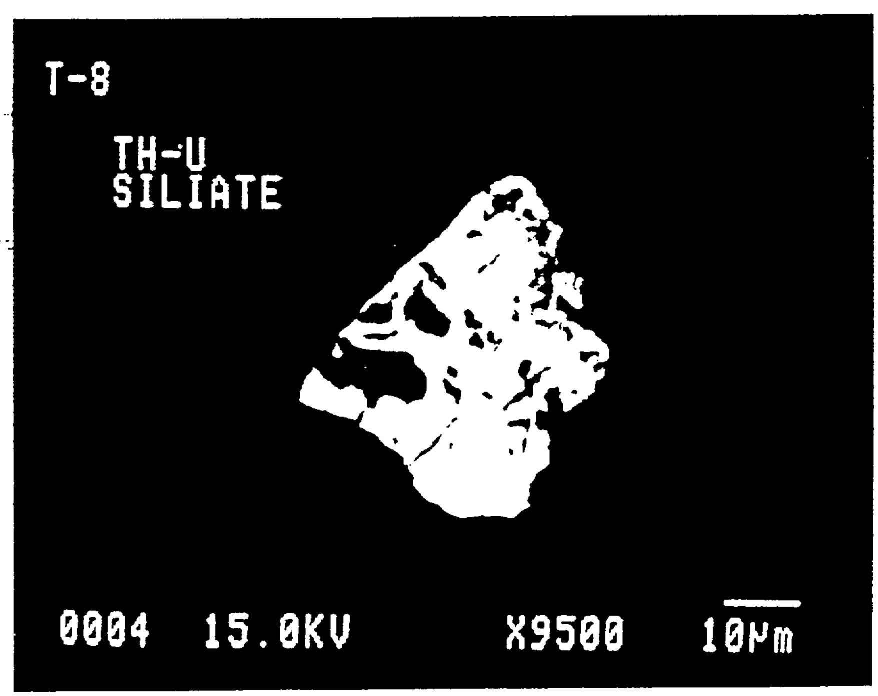
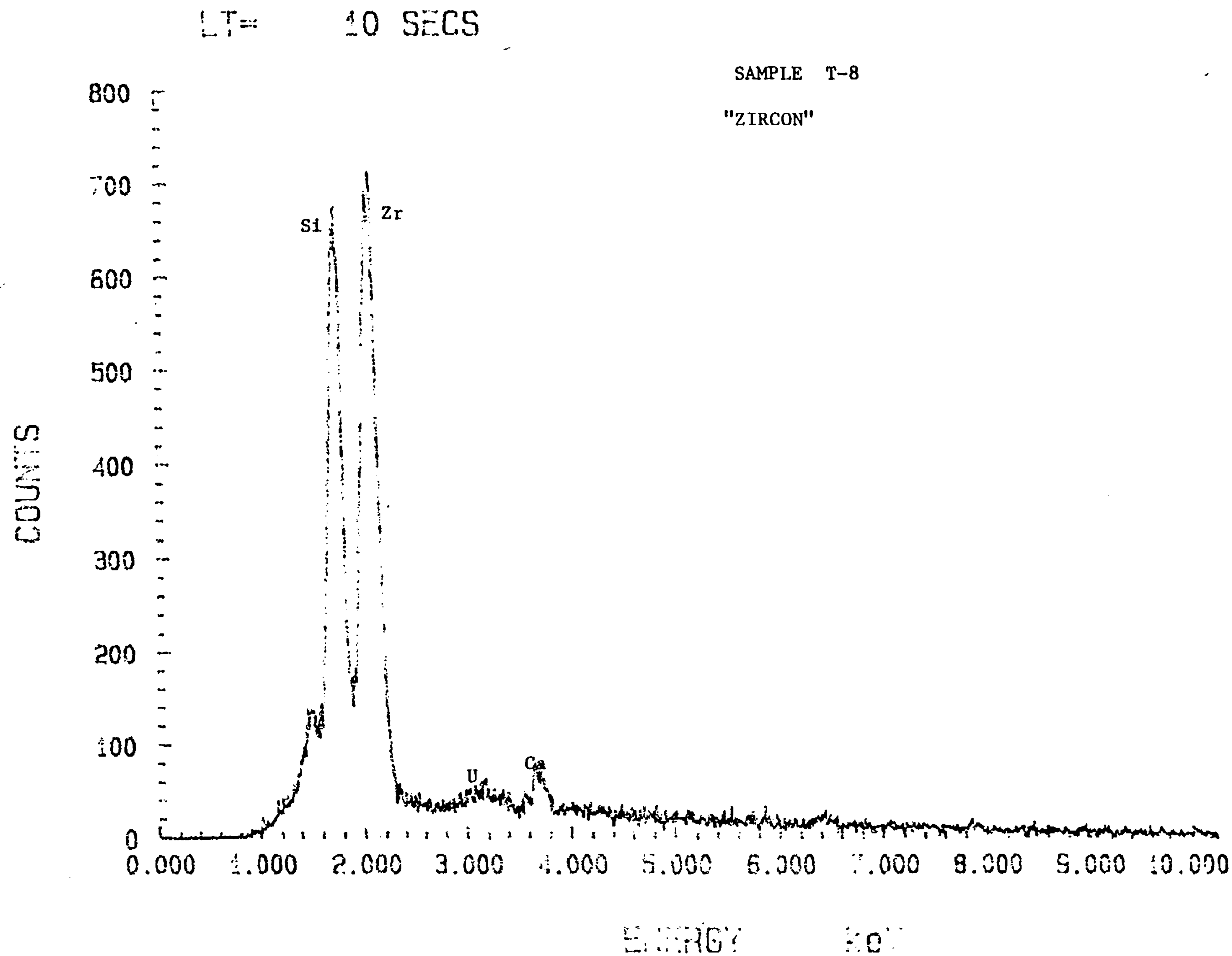


PHOTO 6. Photomicrographs of thorogummite grains; A) on pyrite, and B) a large, 40 micron subhedral grain both from sample T-8.



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SAMPLE T-8
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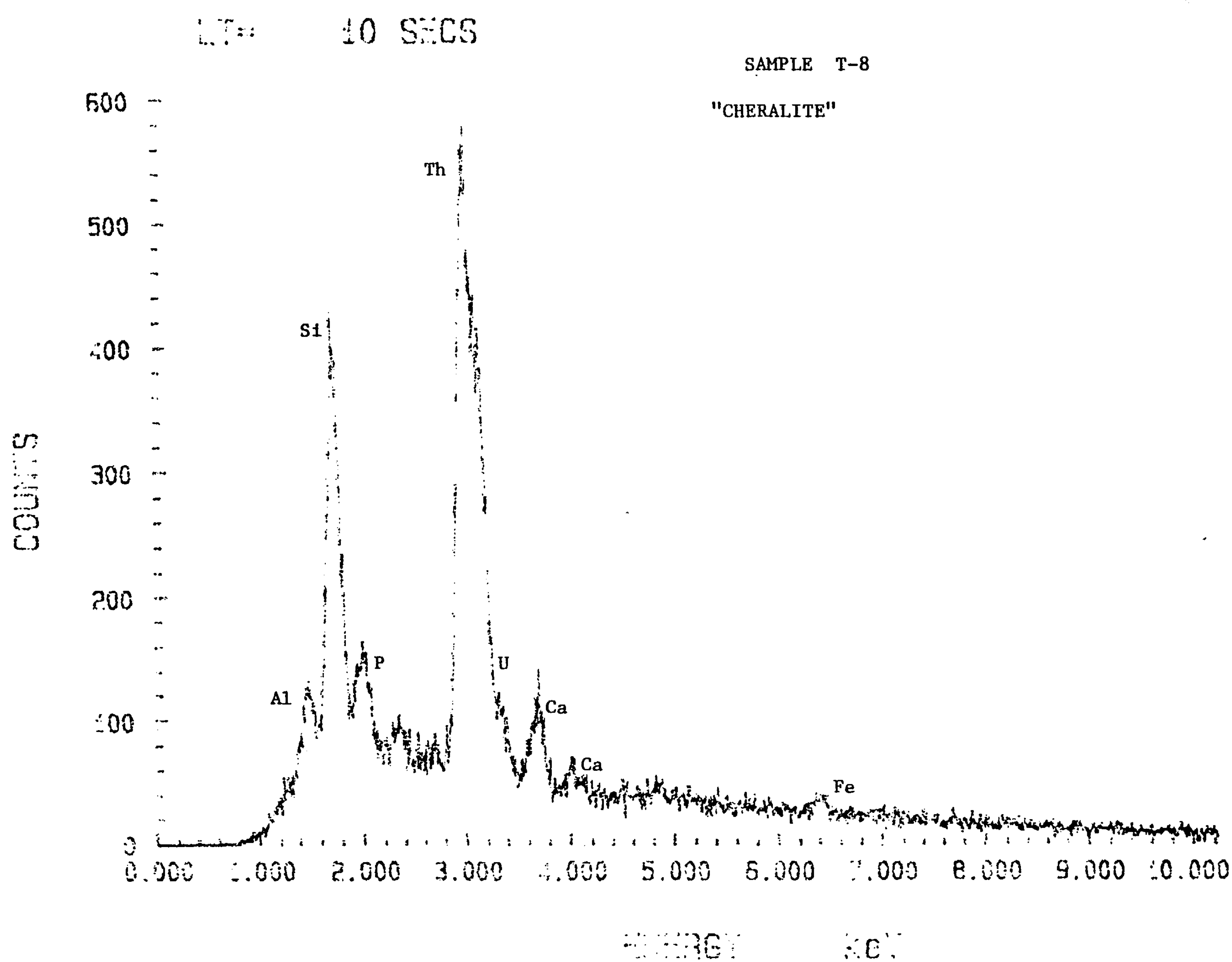
COUNTS
800
700
600
500
400
300
200
100
0
Si
Zr
U
Ca
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000


10 SECS
SAMPLE T-8
"CHERALITE"
COUNTS
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500
400
300
200
100
0
Th
Si
P
U
Al
Ca
Ca
Fe
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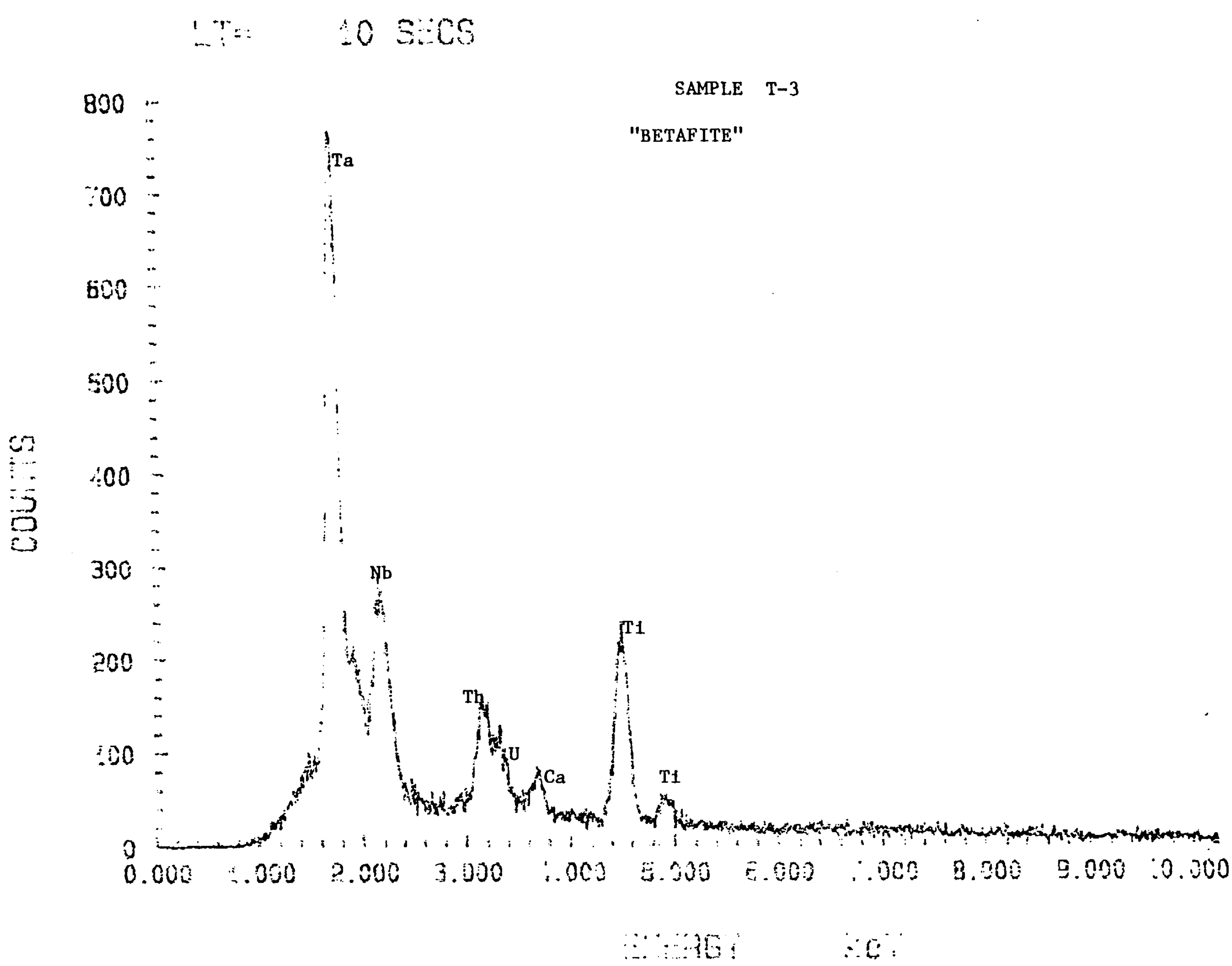
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000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SAMPLE T-3
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COUNTS
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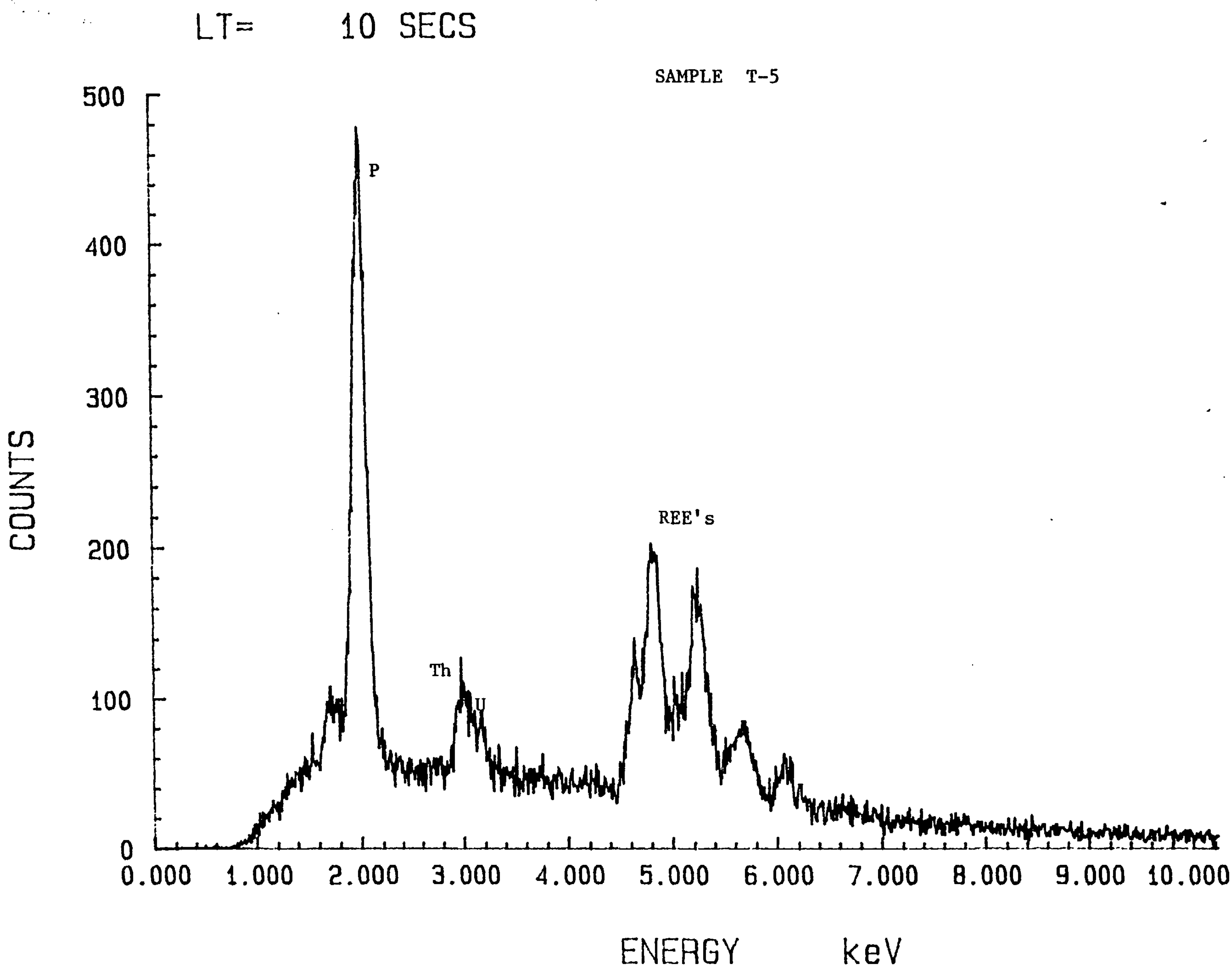
700
600
500
400
300
200
100
0
Ta
Nb
Th
U
Ca
Ti
Ti
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000
ENERGY KEV



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SAMPLE T-5
COUNTS
ENERGY keV
P
Th
U
REE's
0
100
200
300
400
500
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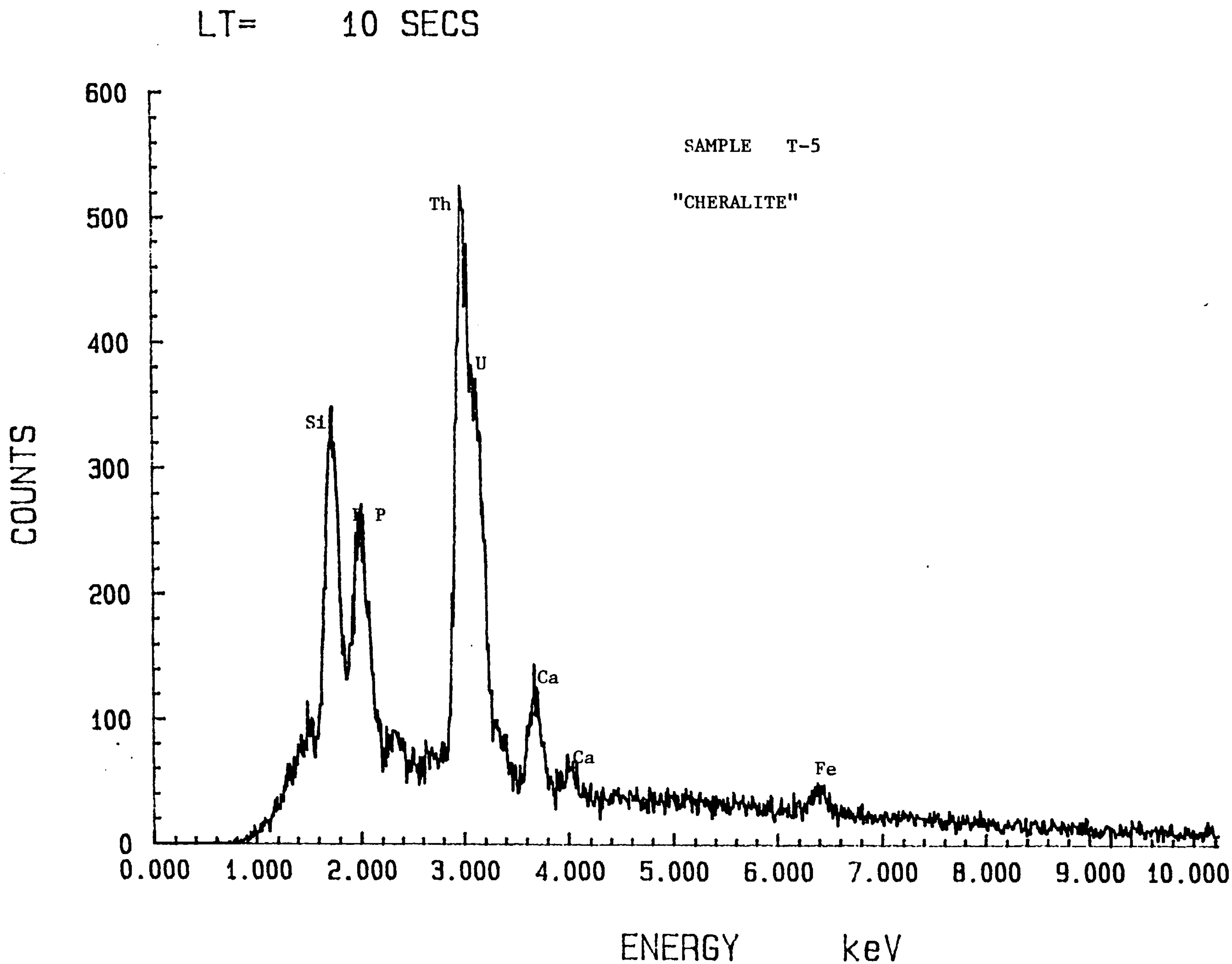
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000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500
400
300
200
100
0
Th
U
Si
P
Ca
Ca
Fe
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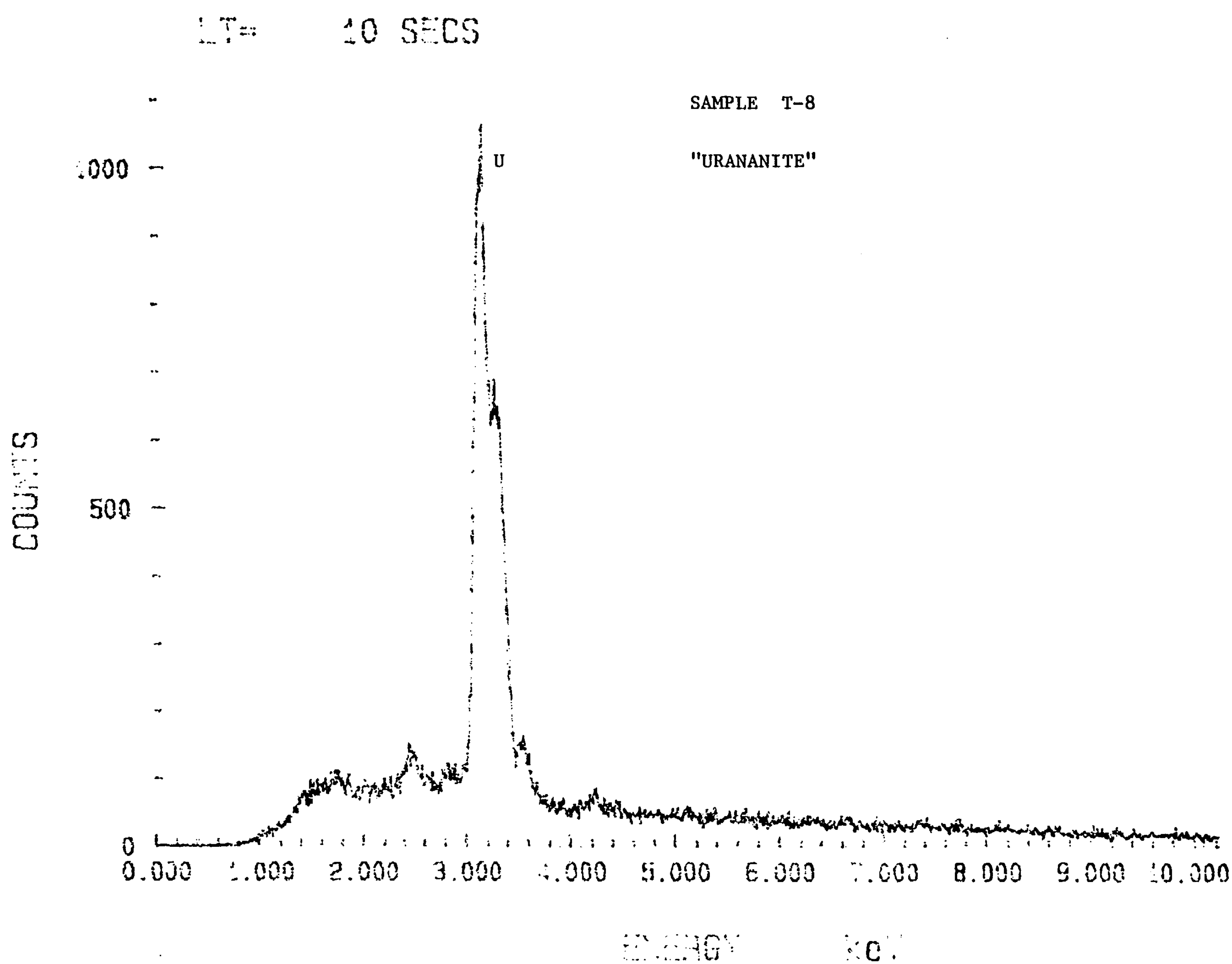
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000
ENERGY keV



LT= 10 SECS
SAMPLE T-8
"URANANITE"
U
COUNTS
1000
500
0
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000
ENERGY KEV

REVISION No.1 REPLACEMENT PAGES TO APPENDIX P OF THE DECEMBER 1994 WESTERN NUCLEAR INC. SHERWOOD PROJECT TAILING RECLAMATION PLAN

WESTERN NUCLEAR, INC.
SHERWOOD PROJECT

DECEMBER 1995 REVISION #9 TO DECEMBER 1994
GROUND WATER PROTECTION PLAN
(APPENDIX P TO DECEMBER 1994 TAILING RECLAMATION PLAN)

Replacement Pages:

	Original 12/94 Pages	Revision #1 12/95 Pages
Table of Contents		Table of Contents
Expanded Attachment List	P-ix	P-ix
Expanded Attachment List	P-x	P-x
Text modified	P.1-6	P.1-6
Text modified	P.3-8	P.3-8
Removed contours	Fig. 3.4	Fig. 3.4
Additional text	-	P.4-12a
Text modified	P.4-27	P.4-27
Table 5.1 modified	P.5-10	P.5-10
Table 5.2	P.5-11	P.5-11
Left blank due to revisions to Table 5.2	P.5-12	P.5-12
Table 6.2 finalized	P.6-19	P.6-19
Table 6.3 finalized	P.6-20	P.6-20
Figure C.2.1 modified	Fig C.2.1	Fig C.2.1
Figure C.4.2 removed contours	Fig. C.4.2	Fig. C.4.2
Table D6.3	P.D-104a	P.D-104a
Text modified	P.E-14	P.E-14
Text modified	P.E-37	P.E-37
Text modified	P.E-38	P.E-38
Text modified	-	P.E-38a
Table E,3.2 corrected	P.E-41	P.E-41
Table E.3.3	P.E-42	P.E-42
Left blank due to revisions to Table E.3.3	P.E-43	P.E-43
Table F.2.2 corrected	P.F-18	P.F-18
Well construction info sheet MW-2A	Att. E.1	Att. E.1
Well construction info sheet MW-3	Att. E.1	Att. E.1
Well construction info sheet MW-8	Att. E.1	Att. E.1
Well construction info sheet MW-9	Att. E.1	Att. E.1
Well construction info sheet MW-10	Att. E.1	Att. E.1

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LIST OF FIGURES (CONTINUED)

LIST OF ATTACHMENTS

LIST OF ATTACHMENTS (CONTINUED)

Tailing dewatering was rejected as a potential closure option based on results of a pilot dewatering study, laboratory testing of the tailing material, geochemical modeling of the tailing-tailing fluid system, and cost-benefit evaluation. Dewatering was found to degrade tailing fluid quality due to the introduction of oxygen into the tailing which would cause a decrease in tailing fluid pH and would increase hazardous constituent concentrations by one to three orders of magnitude. In addition, it was determined that long-term pumping rates were ineffective for the removal of tailing pore water, less than 50 percent of the drainable water (35.9 million gallons) could be removed at an approximate cost of 8.3 million dollars, and that the impoundment would refill, due to infiltration through the final soil cover, in approximately nine years.

This investigation established that the operation and reclamation design elements, coupled with the proposed monitoring programs, ensure both prompt detection of leakage and compliance with ground water standards for the worst-case potential impact scenario considered for the 1000 year design life.
In summary:

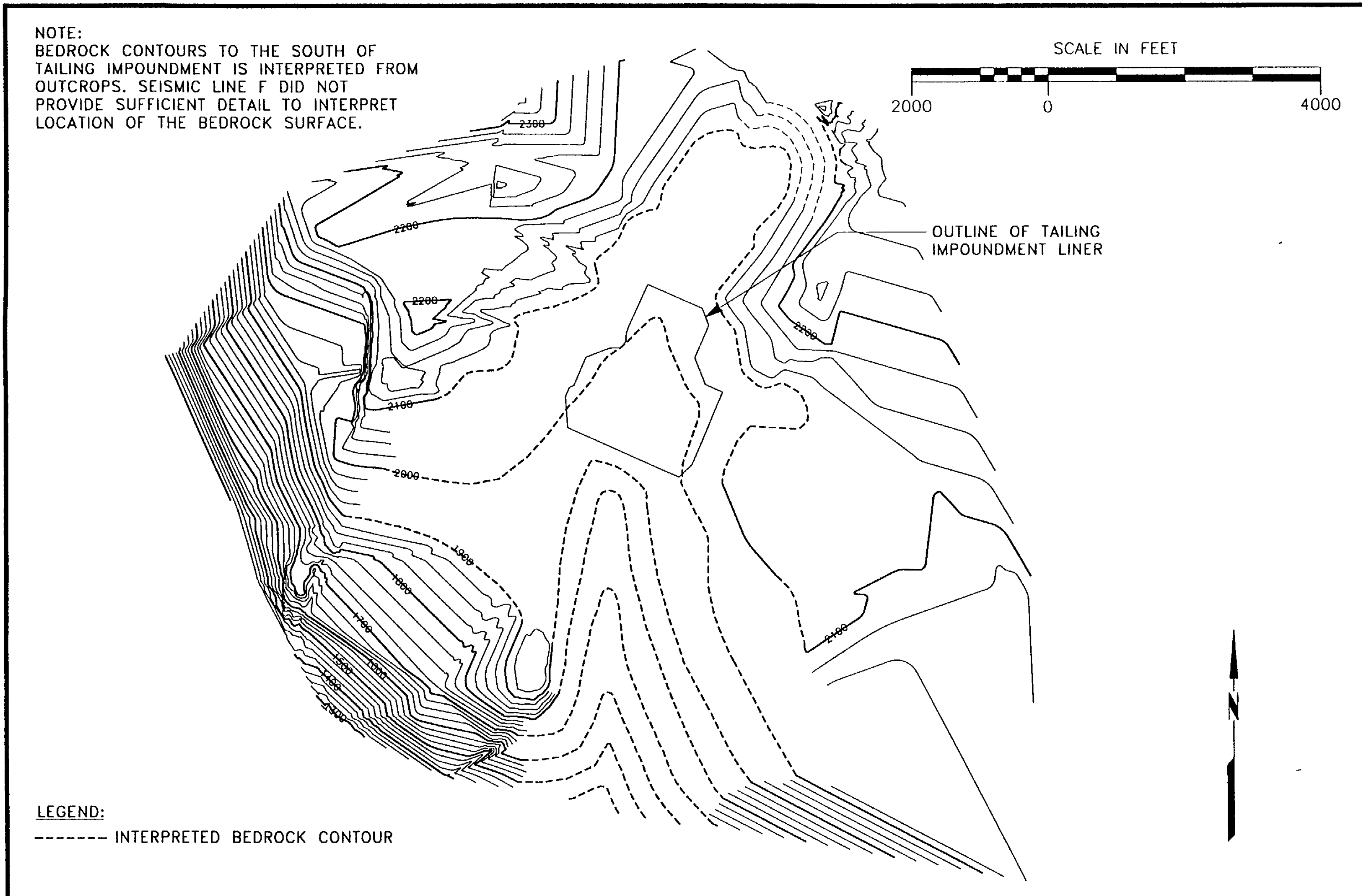
- The hazardous constituents arsenic, nickel, thallium, radium 226, radium 228, and uranium have been identified in the tailing fluid at concentrations above state or federal ground water standards or background ground water concentrations.
- Approximately 9,900,000 cubic feet (74,000,000 gallons) of tailing fluid are drainable from the tailing.
- Dewatering analysis indicates that approximately 35,900,000 gallons of tailing fluid could possibly be remove by pumping 79 wells for six years at a cost of approximately $8,330,000. Additional pumping would not produce significant gains on impoundment dewatering due to infiltration

bedrock material densities. The alteration of the bedrock may be due to locally intense weathering or may be due to structural deformation such as jointing or faulting. The nature of the alteration cannot be determined from these data. No correlation of LVZ's between refraction lines could be made based on these data (see Figure C.2.1).

Geologic conditions at the study site were not conducive to the collection of seismic reflection data. Reflections from subsurface units were often absent or weak. Numerical models of three layered systems were performed to better understand why reflections were absent in many profile sections and to aid in interpretation of first arrival seismic wave data. It was determined from these models that interference from ground roll and wide angle refractions frequently masked reflection patterns from the bedrock and deep alluvium.

Data from reflection line A presented the best reflection profile and confirmed the bedrock surface below the impoundment dam as an incised valley with Monitoring Wells MW-4, MW-5, and MW-6 located on the western slope of the valley. Data from line B presented few strong reflecting surfaces. However, borehole data from Well MW-8 confirms that the deeper, weak reflectors coincide with the bedrock surface. Data from line B was used to locate Monitoring Wells MW-8, MW-9, and MW-10 in the lowest point of the bedrock drainage surface. Data from lines A and B indicate that the bottom of the bedrock valley has a northwest/southeast orientation at this location.

No reflection surfaces could be developed from lines F and G due to interference from ground roll and wide angle refractions. The first arrival refraction data was used to estimate depth to the bedrock surface from line G. The bedrock surface along line G ranges between 25 and 100 feet below the ground surface. The bedrock surface could not be identified at any location along line F from either first arrival refraction



SMI
SHEPHERD MILLER, INC.

FIGURE 3.4
INTERPRETED BEDROCK SURFACE CONTOUR

Date:	REV.1; DEC. 1995
Project:	317\31\SEIS
File:	41-BED

Long-term pumping of the impoundment will be partially controlled by the discontinuous nature of the coarse grained tailing material. The source of the water removed during the initial pumping phase would be primarily from the lenticular, coarse grained layers in contact wiht the pumping well screens. Initial pumping rates from these lenses would be relataively hihg and suitable for dewatering. However, these discontinuous coarse grained lenses will become drained after a relatively short period of time due to their finite and discontinuous nature. Once drained, flow to the pumping wells will be dominated by the layers of fine grained tailing. These fine grained layers have been shown to exhibit very low permeabililty along with quite large water retention characteristics (i.e., low apparent specific yield). Coarse grained lenses not in direct contact wiht the pumping well screens are isolated from other coarse grained layer and the pumping well screens by the fine grained layers. The water retained in these isolated coarse grained lenses must flow through the fine grained layeres in order to drain. Therefore, long term pumping rates will be significantly lower and not suitable to tailing dewatering. In adition, the percentage of coarse grained material in the tailing is not representative of the water easily available for removal by pumping due to the isolation of significant portions of the coarse grained materials by fine grained tailing layers.

steps were designed to (1) calculate the mineral equilibria of the column leachates and tailing pore water and (2) model the effect of the introduction of small proportions of oxygen to the tailing pore water. The goal of the first step was to determine which tailing minerals were in equilibrium with respect to the tailing pore water ~~and whether these minerals were dissolving, precipitating, or saturated with respect to the column leachates.~~. This would allow determination of which minerals are dissolving, precipitating, or saturated with respect to the column leachates. The goal of the second step was to determine if the column tests realistically represented the oxidation during dewatering of the tailing impoundment and the effect of the addition of oxygen in smaller proportions on the residual tailing pore water quality.

4.3.3.1 Column leachates

Three column leachate analyses from the first rinse after 20 weeks were chosen for geochemical modeling. A temperature of 20 degrees Celsius and an elevated pE of 10 were used because column tests were conducted at room temperature and open to the atmosphere (see Section 4.3.2.2).

4.3.3.2 Tailing pore water

The existing tailing water quality data, field-measured pH (6.48), and field temperature (13.9°C) were used in the geochemical modeling. A relatively low pE of -2 was used in modeling, which was estimated from Garrels and Christ (1965, Figure 11.2) for the corresponding pH in an environment isolated from the atmosphere, which is representative of the present tailing conditions.

Table 5.1 Field Permeability Tests of Alluvial Material

Bore Number	Depth (ft)	Test Type	K (cm/s)	Soil Description	Data Source
MW-10	224.0-235.0	Recovery	~~1.1E-04~~ 2.1E-03	alluvium	SMI
TH-17	21.0	CH	1.2E-01	sand, silt lens	D'Appolonia
TH-17	21.0	FH	1.1E-02	sand, silt lens	D'Appolonia
TH-17	85.0	FH	8.0E-03	silt lens	D'Appolonia
TH-18	28.0	FH	7.2E-04	silt lens	D'Appolonia
TH-18	55.5	FH	8.1E-03	silty sand	D'Appolonia
TH-19	13.5	FH	6.6E-03	silty sand	D'Appolonia
3	9.5	FH	8.7E-03	fine sand	Dames & Moore
2	30.0	FH	1.5E-02	fine sand	Dames & Moore
3	30.0	FH	2.6E-02	fine-to-medium sand	Dames & Moore
4	14.5	FH	1.4E-04	fine sand w/ silt layer	Dames & Moore
4	29.5	FH	5.2E-03	fine sand	Dames & Moore
7	15.0	FH	3.5E-04	fine-to-medium sand w/ silt layer	Dames & Moore
8	30.0	FH	5.9E-03	fine sand	Dames & Moore
11	30.0	FH	7.1E-04	silty fine-to-medium sand	Dames & Moore
12	10.0	FH	5.6E-03	fine sand	Dames & Moore
12	30.0	FH	1.4E-02	fine sand	Dames & Moore
15	10.0	FH	6.4E-04	silty fine-to-medium sand	Dames & Moore
15	30.0	FH	1.6E-02	fine sand	Dames & Moore
14	10.0	FH	9.7E-03	fine sand	Dames & Moore
14	30.0	FH	3.6E-02	fine-to-medium sand	Dames & Moore
Maximum K: 1.2×10^{-1} (2.4×10^{-1} ft/min) Minimum K: 1.4×10^{-4} (2.8×10^{-4} ft/min) Average K: 1.4×10^{-2} (2.8×10^{-2} ft/min)					

Notes: CH = constant head, FH = falling head

Table 5.2 Field Permeability Tests of Bedrock Material

Bore Number	Test Depth Range (ft)	Test Depth Below Rock Surface (ft.)	Test Type	K (cm/s)	Soil Description	Data Source
MW-8†	237.0-288.0	-2.0 - 49.0	Recovery	1.1E-04	weathered bedrock / alluvium	SMI
TH-20†	38.5	28.5 -30.5	CH	2.4E-02	highly weathered coarse to medium quartz monzonite-friable & jointed	D'Appolonia
TH-20†	72.5-84	62.5 -74	Packer (6)	5.8E-05 *	"	D'Appolonia
TH-20†	60-84	50 - 74	Packer (6)	4.8E-05 *	"	D'Appolonia
TH-16	85-102.5	37 - 54.5	Packer (4)	0.0	highly weathered quartz monzonite-friable & highly jointed	D'Appolonia
TH-16	75-102.5	27 102.5	Packer	1.3E-05	"	D'Appolonia
TH-19	85.5-88.25	26.5 -29.25	Packer	0.0	highly jointed & weathered quartz monzonite	D'Appolonia
TH-19	82.5-85.5	23.5 -26.5	Packer	2.6E-05	"	D'Appolonia
TH-19	80.5-85.5	21.5 - 26.5	Packer	2.7E-05	"	D'Appolonia
TH-19	75-85.5	16 -26.5	Packer	3.3E-05	"	D'Appolonia
TH-19	70-85.5	11 - 26.5	Packer	6.3E-06	"	D'Appolonia
TH-19	65-85.5	6 - 26.5	Packer	7.0E-06	"	D'Applonia
5	1779.8-1760.5	11.2 - 30.5	Packer	1.9E-07	slightly weathered quartz monozonite	Dames & Moore
5	1774.8-1760.5	16.2 -30.5	Packer	1.9E-07	"	Dames & Moore
5	1775.3-1745.8	15.7 - 45.2	Packer	19E-07	"	Dames & Moore
7	1948.6-1934.1	9.4 - 23.9	Packer	1.3E-05	quartz monozonite; grades to moderately weathered	Dames & Moore
7	1948.0-1910.5	10.0 - 47.5	Packer	8.4E-06	quartz monozonite; moderately to highly weathered	Dames & Moore
11	2001.4-1981.9	11.1 -30.6	Packer	4.3E-06	quartz monozonite; grades to slightly weathered	Dames & Moore
Minimum K: 1.9×10^{-7} (3.7×10^{-7} ft/min) Minimum K: 3.3×10^{-5} (6.5×10^{-5} ft/min) Average K: 1.5×10^{-5} (3.0×10^{-5} ft/min)						

Notes: CH = Constant Head
† not included in maximum, minimum or average calculation due to excessive packer leakage.
* data is probably invalid due to packer leakage.
Numbers in () indicate the number of tests.

Dames & Moore tests list elevations rather than depths.

THIS PAGE INTENTIONALLY LEFT BLANK DUE TO REVISIONS TO TABLE 5.2

Table 6.2 Summary of Ground Water Quality Values for Integrated Site Model

Parameter	Uranium	Arsenic	Chloride	Sulfate	Nickel
Concentration of Released Fluid† (mg/l)	0.231	0.36	291	6,195	0.12
Overtopping Scenario:					
Mass Released (Kg/day) @ 10.25 gpm	0.009	0.013	11.4	242.3	0.004
Predicted Concentration Increase (mg/l)	0.002	0.003	2.28	25.8	0.0008
Predicted Concentration at POC (mg/l)	~~[1]0.049~~ [1]0.019	~~[2]To Be Determined~~ [1]0.006	~~[1]4.25~~ [1]8.48	~~[2]To Be Determined~~ [1]47.3	~~[2]To Be Determined~~ [1]0.0508
Leakage Scenario:					
Mass Released (Kg/day) @ 10.25 gpm	0.013	0.020	16.3	346.1	0.007
Predicted Concentration Increase (mg/l)	0.011	0.013	11.1	181.5	0.004
Predicted Concentration at POC (mg/l)	~~[1]0.058~~ 0.203	~~[2]To Be Determined~~ [1]0.016	~~[1]13.07~~ [1]17.30	~~[2]To Be Determined~~ [1]203.0	~~[2]To Be Determined~~ [1]0.054

Note: † Based on hazardous constituent analysis of tailing fluid. Appropriate standards for these parameters are presented in Table 6.3.

~~1 These values represent predicted increase in concentration added to the larger of the average constituent concentrations observed in down-gradient wells MW-4 and MW-10, as presented in the WNI Sherwood Project Annual 1993 Environmental Monitoring Program Report (WNI 1994).~~

1 These values represent the predicted increase in constituent concentration added to the upper control limit of or the detection limit of the constituent.

~~2 The predicted concentration at the point of compliance (POC) will be determined once supplemental ground water monitoring is completed and control charts are developed for these constituents.~~

Table 6.3 Summary of Leak Detection and Compliance Monitoring Ground water Standards

Constituent	Concentration In Impoundment	Ground Water Standards	
		Regulatory Standard	Upper Control Limit
Chloride	291 mg/l	None	6.2 mg/l
Sulfate	6,195 mg/l	None	21.5 mg/l
Uranium	0.231 mg/l (154 pCi/l)	None	128 pCi/l
~~Radium-226~~	~~54 ± 2.5 pCi/l~~	~~None~~	~~[3]9.7 pCi/l~~
Radium-226 + Radium-228	60.6 ± 2.9 pCi/l	[1]5 pCi/l	~~[4]To Be Developed~~ 6.4 pCi/l
Arsenic	0.36 mg/l (dissolved)	[1]0.05 mg/l	~~[4]To Be Developed~~ 0.003 mg/l
Nickel	0.12 mg/l (dissolved)	[2]0.1 mg/l	~~[4]To Be Developed~~ [3]<0.05 mg/l
Thallium	0.004 mg/l (dissolved)	[2]0.002	~~[4]To Be Developed~~ [3]<0.001 mg/l

Note:

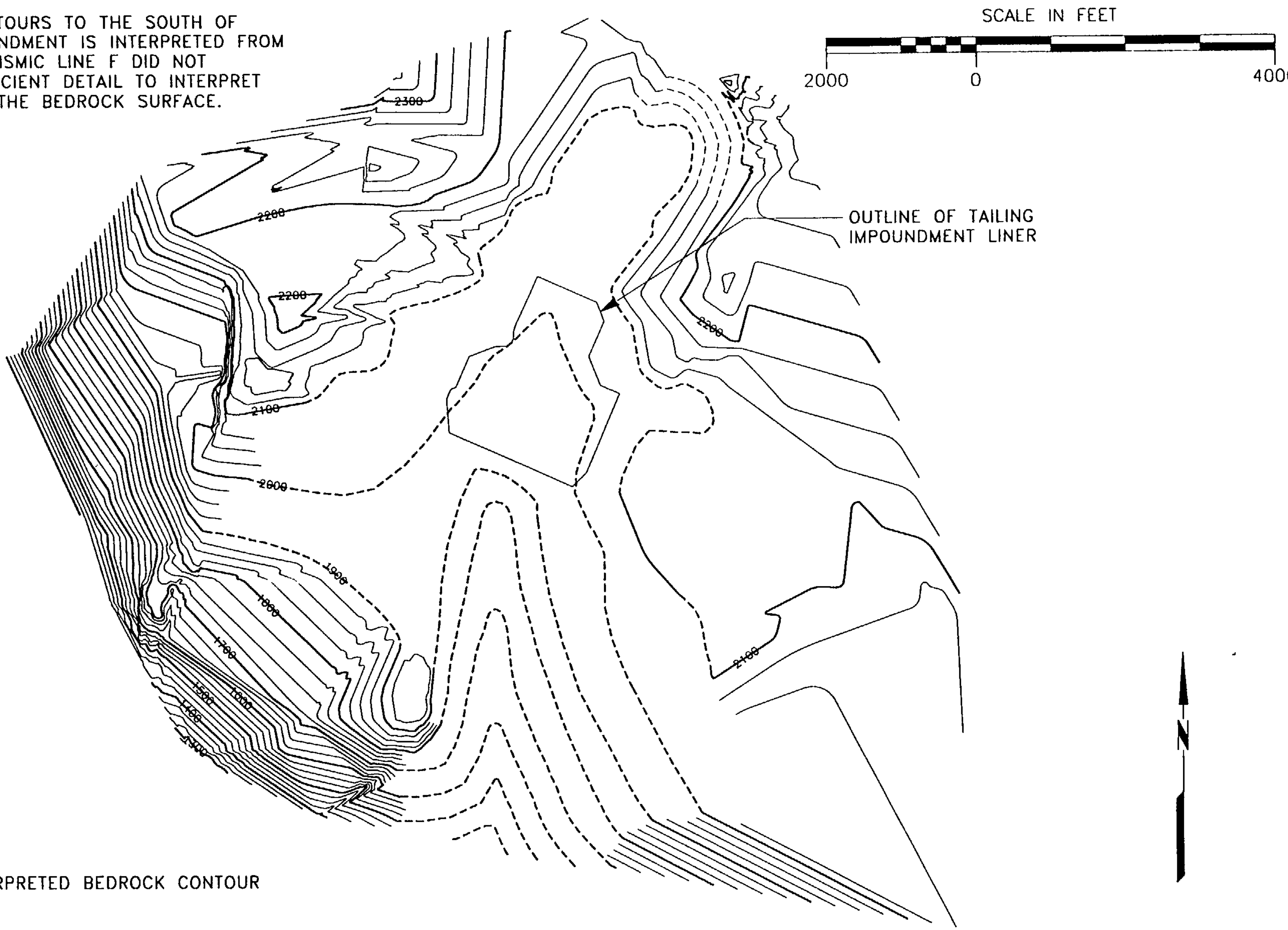
1 Washington Administrative Code, chapter 246-252: radiation protection-uranium and/or thorium milling; Section 030: criteria related to disposition of mill tailings or waste maximum values for ground water protection.

2 US Environmental Protection Agency, 10 Code of Federal Regulations 40 (CFR), Section 141.62; maximum contaminant levels (MCL's) for inorganic contaminants.

3 ~~These values are based on the corrected background data base. The control charts from which these values were developed, will be finalized following completion of supplemental ground water monitoring.~~ The reported values are the lower limits of detection. These constituents have not been detected above the lower limits of laboratory detection.

4 ~~The control charts used to develop the upper control limits for these values will be created once the supplemental ground water monitoring is completed.~~

NOTE:
BEDROCK CONTOURS TO THE SOUTH OF TAILING IMPOUNDMENT IS INTERPRETED FROM OUTCROPS. SEISMIC LINE F DID NOT PROVIDE SUFFICIENT DETAIL TO INTERPRET LOCATION OF THE BEDROCK SURFACE.



LEGEND:

------- INTERPRETED BEDROCK CONTOUR

SMI
SHEPHERD MILLER, INC.

FIGURE C.4.2
INTERPRETED BEDROCK
SURFACE CONTOUR

Date:	REV.1; DEC. 1995
Project:	317\31\SEIS
File:	41-BED

Table D.6-3. Calculation of Average KH and KV for Top and Bottom Layer of Tailing Material.

KH = Horizontal Hydraulic Conductivity; KV = Vertical Hydraulic Concuctivity

H values adjusted to represent the depth from the surface to the liner

Well	SAND (ft)	K-sand (cm/s)	SLIMY SAND (ft)	K-sl sand (cm/s)	SANDY SLIME (ft)	K-sa slime (cm/s)	SLIME (ft)	K-slime (cm/s)	TOTAL (ft)	KH (avg) (cm/s)	KV (avg) (cm/s)
1A											
top layer	30.2	2.53E-04	23.5	3.01E-05	5.5	1.12E-05	2.7	1.80E-06	61.9	1.36E-04	2.14E-05
bot. layer	1.8	2.53E-04	3.1	3.01E-05	8.4	1.12E-05	2.6	1.80E-06	15.9	4.07E-05	6.90E-06
2A											
top layer	9.5	2.53E-04	35.9	3.01E-05	5.5	1.12E-05	3.4	1.80E-06	54.3	6.54E-05	1.50E-05
bot. layer	2.4	2.53E-04	7.1	3.01E-05	0.0	1.12E-05	11.4	1.80E-06	20.9	4.03E-05	3.18E-06
3A											
top layer	9.0	2.53E-04	36.7	3.01E-05	2.8	1.12E-05	5.7	1.80E-06	54.2	6.32E-05	1.16E-05
bot. layer	0.0	2.53E-04	2.2	3.01E-05	1.0	1.12E-05	17.5	1.80E-06	20.7	5.26E-06	2.09E-06
1B											
top layer	34.1	2.53E-04	19.2	3.01E-05	7.6	1.12E-05	0.4	1.80E-06	61.3	1.52E-04	3.66E-05
bot. layer	1.7	2.53E-04	4.0	3.01E-05	7.8	1.12E-05	2.3	1.80E-06	15.8	4.06E-05	7.47E-06
2B											
top layer	10.2	2.53E-04	35.7	3.01E-05	2.8	1.12E-05	1.6	1.80E-06	50.3	7.33E-05	2.13E-05
bot. layer	1.4	2.53E-04	4.2	3.01E-05	7.8	1.12E-05	11.9	1.80E-06	25.3	2.33E-05	3.39E-06
3B											
top layer	11.4	2.53E-04	36.3	3.01E-05	4.0	1.12E-05	4.0	1.80E-06	55.7	7.23E-05	1.45E-05
bot. layer	2.2	2.53E-04	4.1	3.01E-05	2.6	1.12E-05	10.3	1.80E-06	19.2	3.79E-05	3.15E-06
1C											
top layer	27.6	2.53E-04	22.2	3.01E-05	7.2	1.12E-05	4.1	1.80E-06	61.1	1.27E-04	1.62E-05
bot. layer	0.0	2.53E-04	7.1	3.01E-05	3.5	1.12E-05	3.8	1.80E-06	14.4	1.80E-05	5.41E-06
2C											
top layer	18.2	2.53E-04	24.4	3.01E-05	5.3	1.12E-05	7.6	1.80E-06	55.5	9.75E-05	9.95E-06
bot. layer	0.9	2.53E-04	2.5	3.01E-05	4.8	1.12E-05	11.9	1.80E-06	20.1	1.88E-05	2.82E-06
3C											
top layer	13.6	2.53E-04	37.2	3.01E-05	3.6	1.12E-05	2.5	1.80E-06	56.9	8.09E-05	1.90E-05
bot. layer	0.0	2.53E-04	0.2	3.01E-05	10.7	1.12E-05	6.7	1.80E-06	17.6	7.84E-06	3.76E-06
T-1	2.6	2.53E-04	13.8	3.01E-05	3.6	1.12E-05	2.5	1.80E-06	22.5	4.97E-05	1.03E-05
T-2	8.1	2.53E-04	11.3	3.01E-05	0.0	1.12E-05	15.5	1.80E-06	34.9	6.93E-05	3.87E-06
T-3	17.0	2.53E-04	13.1	3.01E-05	7.4	1.12E-05	8.8	1.80E-06	46.3	1.04E-04	7.65E-06
T-4	38.9	2.53E-04	7.9	3.01E-05	11.5	1.12E-05	16.9	1.80E-06	75.2	1.36E-04	6.94E-06
T-5	35.5	2.53E-04	10.9	3.01E-05	4.6	1.12E-05	9.0	1.80E-06	60.0	1.56E-04	1.01E-05
T-6	17.2	2.53E-04	0.0	3.01E-05	0.0	1.12E-05	1.4	1.80E-06	18.6	2.34E-04	2.20E-05
T-7	34.3	2.53E-04	6.2	3.01E-05	13.8	1.12E-05	18.6	1.80E-06	72.9	1.24E-04	6.12E-06
T-8	3.8	2.53E-04	25.1	3.01E-05	7.2	1.12E-05	23.9	1.80E-06	60.0	3.07E-05	4.06E-06
T-9	11.2	2.53E-04	6.5	3.01E-05	0.0	1.12E-05	0.0	1.80E-06	17.7	1.71E-04	6.80E-05
T-10	7.0	2.53E-04	17.3	3.01E-05	0.0	1.12E-05	0.0	1.80E-06	24.3	9.43E-05	4.03E-05

WELL	KH (avg) values (cm/s) top layer		bottom layer	
1A	1.36E-04		4.07E-05	
2A	6.54E-05	MIN.	4.03E-05	MIN.
3A	6.32E-05	6.32E-05	5.26E-06	5.26E-06
1B	1.52E-04	MAX	4.06E-05	MAX
2B	7.33E-05	1.52E-04	2.33E-05	4.07E-05
3B	7.23E-05	AVG	3.79E-05	AVG
1C	1.27E-04	9.63E-05	1.80E-05	2.59E-05
2C	9.75E-05		1.88E-05	
3C	8.09E-05		7.84E-06	
T-1	7.84E-06			
T-2	4.97E-05			
T-3	6.93E-05			
T-4	1.04E-04			
T-5	1.36E-04			
T-6	1.56E-04			
T-7	2.34E-04			
T-8	1.24E-04			
T-9	3.07E-05			
T-10	1.71E-04			

	KV (avg) values (cm/s) top layer		bottom layer	
1A	2.14E-05		6.90E-06	
2A	1.50E-05	MIN.	3.18E-06	MIN.
3A	1.16E-05	9.95E-06	2.09E-06	2.09E-06
1B	3.66E-05	MAX	7.47E-06	MAX
2B	2.13E-05	3.66E-05	3.39E-06	7.47E-06
3B	1.45E-05	AVG	3.15E-06	AVG
1C	1.62E-05	1.84E-05	5.41E-06	4.24E-06
2C	9.95E-06		2.82E-06	
3C	1.90E-05		3.76E-06	
T-1	3.76E-06			
T-2	1.03E-05			
T-3	3.87E-06			
T-4	7.65E-06			
T-5	6.94E-06			
T-6	1.01E-05			
T-7	2.20E-05			
T-8	6.12E-06			
T-9	4.06E-06			
T-10	6.80E-05			

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Hydraulic conductivity (k) values for both tests were derived from the transmissivity values according to the following equation:

$$k = \frac{T}{b}$$

where b is equal to the saturated thickness of the hydrostratigraphic unit being evaluated. The test for MW-8 was assumed to primarily evaluate the conductive bedrock zone and was assigned a saturated thickness of 50 feet based on 1993 water level data. The test for MW-10 evaluated the alluvium and was assigned a saturated thickness of 10 feet based on 1993 water level data.

~~Alluvium (MW-10):~~	~~$k = 1.8 \times 10^{-4}$ ft/min (9.1×10^{-5} cm/s)~~
~~Conductive bedrock (MW-8):~~	~~$k = 2.1 \times 10^{-3}$ ft/min (1.1×10^{-4} cm/s)~~
Alluvium (MW-10):	$k = 4.2 \times 10^{-3}$ ft/min (2.1×10^{-3} cm/s)
Conductive bedrock (MW-8):	$k = 1.8 \times 10^{-4}$ ft/min (9.1×10^{-5} cm/s)

However, these data were not included in the estimation of hydrostratigraphic unit hydraulic properties (see Attachement E.3) because it was not possible to apply sufficient stress to the hydrostratigraphic units to reasonably charaterize the hydraulic properies due to the low recharge rates of these wells.

REFERENCES

McWhorter, David B., and Sunada Daniel K., 1977, Ground-Water Hydrology and Hydraulics, Water Res. Publications, Fort Collins, Co.

Alluvium

The ground water flow gradient was assumed to equal the slope of the bed rock surface for the area 300 feet directly upgradient of the POC. The gradient was estimated to be 0.3.

The cross-sectional area of flow in the alluvium was estimated using AutoCAD and was based on the low water level data for the year 1993 and the geologic cross section described above. The estimated area of flow is 3,500 square feet.

Twenty one hydraulic conductivity values of alluvial materials from previous sources (US Dept. of the Interior, 1975; D'Appolonia, 1977), summarized in Table E.3.2, were evaluated including the results of the aquifer test presented in Section 5.2.2 and Attachment E.2 of this report. Maximum, minimum and average hydraulic conductivity values were used to estimate the range in possible flow rate values, which are summarized in Table E.3.1.

Conductive Bedrock Material

The flow in the conductive bedrock material is treated as a distinct flow system from flow in the alluvium. This is confirmed by the difference in heads between the alluvial and bedrock systems and the difference in observed hydraulic conductivity values for the two media.

~~Twelve hydraulic conductivity values of bedrock material from previous sources (US Dept. of the Interior, 1975; D'Appolonia, 1977 were evaluated. These data, presented in Table E.3.3, were developed form packer tests in the bedrock over bore hole lenghts of 2 to 37.5 feet in lenght and at depths of 6 to 74 feet below the top of weathered bedrock. No tests at depths greater than 50 feet below the top of~~

~~weathered bedrock were observed to have any measureable hydraulic conductivity, possibly because lithostatic loading of the overlying geologic materials closes any fractures that may be present. Therefore, the saturated thickness of the conductive bedrock material was assumed to be 50 feet.~~

Eighteen hydraulic conductivity values of bedrock material from previous sources (US Dept. of the Interior, 1975; D'Appolonia, 1977) were evaluated. These data, presented in Table E.3.3, were developed from packer tests in the bedrock over bore holes of 2 to 37.5 feet in length and at depths of 6 to 74 feet below the top of weathered bedrock. No tests at depths greater than 50 feet below the top of weathered bedrock were observed to have any measurable hydraulic conductivity, possibly because lithostatic loading of the overlying geologic materials closes any fractures that may be present. Therefore, the saturated thickness of the conductive bedrock material was assumed to be 50 feet.

The cross-sectional area of flow in the bedrock was estimated using AutoCAD and was based on the low water level data for the year 1993 in wells MW-4 and MW-9 and the geologic cross section presented in Figure E.3.1. The estimated area of flow is 22,540 square feet.

Maximum, minimum and average hydraulic conductivity values were used to estimate the range in possible flow rate values for the bedrock zone. These flow rates are summarized in Table E.3.1. A single anomalous value of 2.4×10^{-2} cm/s was recorded by D'Appolonia (1977) for a two (2) foot interval in the weathered bedrock. This value was not included in the maximum or average value calculations because it is considered to be an anomalous outlier. In addition, there exists a discrepancy between the reported depth below top of bedrock at which this test was performed and the boring log. Therefore, this data point was not used.

Table E.3.2 Field Permeability Tests of Alluvial Material

Bore Number	Depth (ft)	Test Type	K (cm/s)	Soil Description	Data Source
MW-10	224.0-235.0	Recovery	~~1.1E-04~~ 2.1E-03	alluvium	SMI
TH-17	21.0	CH	1.2E-01	sand, silt lens	D'Appolonia
TH-17	21.0	FH	1.1E-02	sand, silt lens	D'Appolonia
TH-17	85.0	FH	8.0E-03	silt lens	D'Appolonia
TH-18	28.0	FH	7.2E-04	silt lens	D'Appolonia
TH-18	55.5	FH	8.1E-03	silty sand	D'Appolonia
TH-19	13.5	FH	6.6E-03	silty sand	D'Appolonia
3	9.5	FH	8.7E-03	fine sand	Dames & Moore
2	30.0	FH	1.5E-02	fine sand	Dames & Moore
3	30.0	FH	2.6E-02	fine-to-medium sand	Dames & Moore
4	14.5	FH	1.4E-04	fine sand w/ silt layer	Dames & Moore
4	29.5	FH	5.2E-03	fine sand	Dames & Moore
7	15.0	FH	3.5E-04	fine-to-medium sand w/ silt layer	Dames & Moore
8	30.0	FH	5.9E-03	fine sand	Dames & Moore
11	30.0	FH	7.1E-04	silty fine-to-medium sand	Dames & Moore
12	10.0	FH	5.6E-03	fine sand	Dames & Moore
12	30.0	FH	1.4E-02	fine sand	Dames & Moore
15	10.0	FH	6.4E-04	silty fine-to-medium sand	Dames & Moore
15	30.0	FH	1.6E-02	fine sand	Dames & Moore
14	10.0	FH	9.7E-03	fine sand	Dames & Moore
14	30.0	FH	3.6E-02	fine-to-medium sand	Dames & Moore
Maximum K: 1.2×10^{-1} (2.4×10^{-1} ft/min) Minimum K: 1.4×10^{-4} (2.8×10^{-4} ft/min) Average K: 1.4×10^{-2} (2.8×10^{-2} ft/min)					

Notes: CH = constant head, FH = falling head

Table E.3.3 Field Permeability Tests of Bedrock Material

Bore Number	Test Depth Range (ft)	Test Depth Below Rock Surface (ft.)	Test Type	K (cm/s)	Soil Description	Data Source
MW-8†	237.0-288.0	2.0 - 49.0	Recovery	1.1E-04	weathered bedrock / alluvium	SMI
TH-20†	38.5	28.5 -30.5	CH	2.4E-02	highly weathered coarse to medium quartz monzonite-friable & jointed	D'Appolonia
TH-20†	72.5-84	62.5 -74	Packer (6)	5.8E-05 *	"	D'Appolonia
TH-20†	60-84	50 - 74	Packer (6)	4.8E-05 *	"	D'Appolonia
TH-16	85-102.5	37 - 54.5	Packer (4)	0.0	highly weathered quartz monzonite-friable & highly jointed	D'Appolonia
TH-16	75-102.5	27 102.5	Packer	1.3E-05	"	D'Appolonia
TH-19	85.5-88.25	26.5 -29.25	Packer	0.0	highly jointed & weathered quartz monzonite	D'Appolonia
TH-19	82.5-85.5	23.5 -26.5	Packer	2.6E-05	"	D'Appolonia
TH-19	80.5-85.5	21.5 - 26.5	Packer	2.7E-05	"	D'Appolonia
TH-19	75-85.5	16 -26.5	Packer	3.3E-05	"	D'Appolonia
TH-19	70-85.5	11 - 26.5	Packer	6.3E-06	"	D'Appolonia
TH-19	65-85.5	6 - 26.5	Packer	7.0E-06	"	D'Applonia
5	1779.8-1760.5	11.2 - 30.5	Packer	1.9E-07	slightly weathered quartz monozonite	Dames & Moore
5	1774.8-1760.5	16.2 -30.5	Packer	1.9E-07	"	Dames & Moore
5	1775.3-1745.8	15.7 - 45.2	Packer	19E-07	"	Dames & Moore
7	1948.6-1934.1	9.4 - 23.9	Packer	1.3E-05	quartz monozonite; grades to moderately weathered	Dames & Moore
7	1948.0-1910.5	10.0 - 47.5	Packer	8.4E-06	quartz monozonite; moderately to highly weathered	Dames & Moore
11	2001.4-1981.9	11.1 -30.6	Packer	4.3E-06	quartz monozonite; grades to slightly weathered	Dames & Moore

Minimum K: 1.9×10^{-7} (3.7×10^{-7} ft/min)

Minimum K: 3.3×10^{-5} (6.5×10^{-5} ft/min)

Average K: 1.5×10^{-5} (3.0×10^{-5} ft/min)

Notes: CH = Constant Head
† not included in maximum, minimum or average calculation due to excessive packer leakage.
* data is probably invalid due to packer leakage.
Numbers in () indicate the number of tests.

Dames & Moore tests list elevations rather than depths.

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Table F.2.1 Summary of Integrated Site Model Input: Gradient Hydrologic Data

Segment	Seepage Velocity (m/day)	Gradient (m/m)
1	0.55	0.045
2	1.94	0.158
3	3.69	0.301
	Avg: 2.06	Avg: 0.168

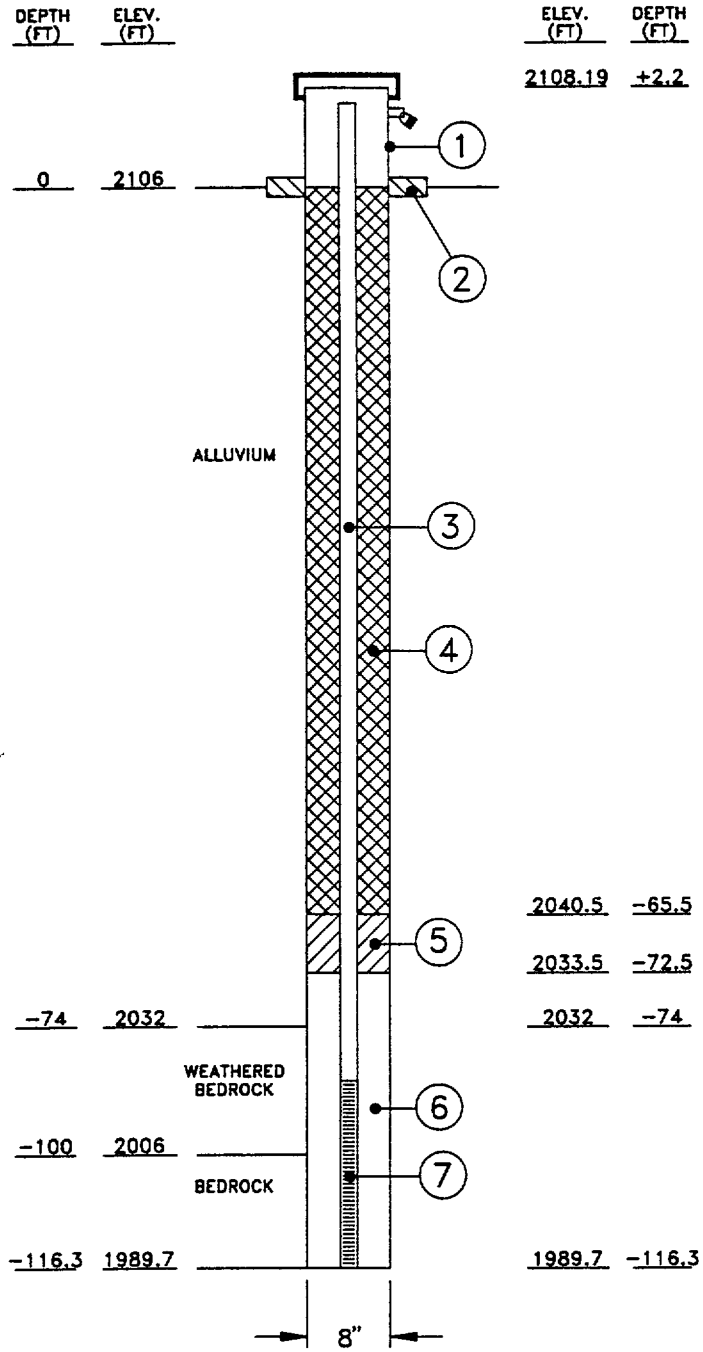
Table F.2.2 Summary of Predicted Concentrations Down-gradient of the Tailing Impoundment.

Parameter	Uranium	Arsenic	Chloride	Sulfate	Nickel
Concentration of Released Fluid† (mg/l)	0.231	0.36	291	6,195	0.12
Overtopping Scenario:					
Mass Released (Kg/day) @ 10.25 gpm	0.009	0.013	11.4	242.3	0.004
Predicted Concentration Increase (mg/l)	0.002	0.003	2.28	25.8	0.0008
Predicted Concentration at POC (mg/l)	[1]0.019	[1]0.006	[1]8.48	[1]47.3	[1]0.0508
Leakage Scenario:					
Mass Released (Kg/day) @ 10.25 gpm	0.013	0.020	16.3	346.1	0.007
Predicted Concentration Increase (mg/l)	0.011	0.013	11.1	181.5	0.004
Predicted Concentration at POC (mg/l)	[1]0.203	[1]0.016	[1]17.30	[1]203.0	[1]0.054

Note: † Based on hazardous constituent analysis of tailing fluid. Appropriate standards for these parameters are presented in Table 6.3.

1 These values represent the predicted increase in constituent concentration added to the upper control limit of or the detection limit of the constituent.

MONITORING WELL CONSTRUCTION INFORMATION SHEET



Client WESTERN NUCLEAR, INC.
Job Number #317 SHERWOOD
Boring/Well Number MW-2a
Date 3/9 - 3/10/93
Location N: 334,039.48 E: 2,670,595.50
Drilling Co. RUEN DRILLING
Drilling Method AIR ROTARY CASING ADVANCE
Driller WILL HAYES
Completed 3/15 - 3/16/93
Logged By KIT COHAN / SMI

Materials:

1. Protective casing type: STEEL
2. Surface seal type: CEMENT
   Dimensions: 6'x 6'x 2'
3. Riser pipe: Type SCH 40 PVC
   Length 76.2'
   ID 2"
4. Backfill Type: NEAT CEMENT GROUT
5. Seal: BENTONITE
6. Filter Pack: 10-20 SILICA SAND
7. Well Screen: Type SCH 40 PVC
   Length 40' (0.4' END CAP)
   ID 2"
   Slotsize 0.020"

Pump Intake: Depth 116.25 El. 1991.94
Pump Type: GRUNDFOS REDI FLO2
Pump Riser Pipe: PVC HOSE

NOTES:

*Depth of pump intake based on maximum measured drawdown during pumping.

*All Elevations Relative to MSL.

NOT TO SCALE

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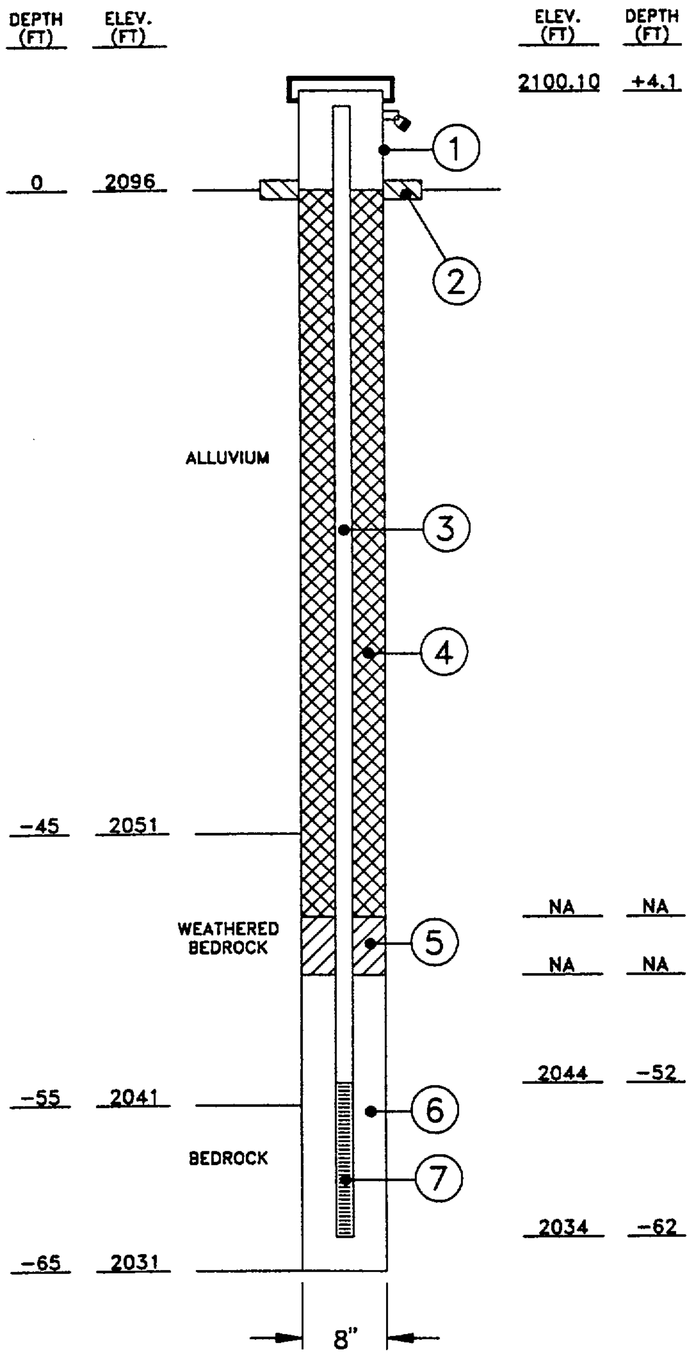
317\TASK31\WELLMW2A.DWG

MONITORING WELL CONSTRUCTION INFORMATION SHEET



Client WESTERN NUCLEAR, INC.
Job Number #317 SHERWOOD
Boring/Well Number MW-3
Date 4/13/78
Location N: 331,336.5 E: 2,671,496.1
Drilling Co. CTL THOMPSON / DRAVO, 1978
Drilling Method PERCUSSION DRILLING
Driller NA
Completed NA
Logged By D. FISCHER

Materials:

(1) Protective casing type: STEEL
(2) Surface seal type: CONCRETE
Dimensions: --
(3) Riser pipe: Type PVC
Length 56.1
ID 2"
(4) Backfill Type: NEAT CEMENT GROUT
(5) Seal: BENTONITE
(6) Filter Pack: 10-20 SILICA SAND
(7) Well Screen: Type SCH 40 PVC
Length 10'
ID 2"
Slotsize 0.020"
Pump Intake: Depth 61.60 El. 2038.50
Pump Type: GRUNDFOS REDI FLO2
Pump Riser Pipe: PVC HOSE

NOTES:
*Pump Intake Depth From TOC.
*All Elevations Relative to MSL

NOT TO SCALE

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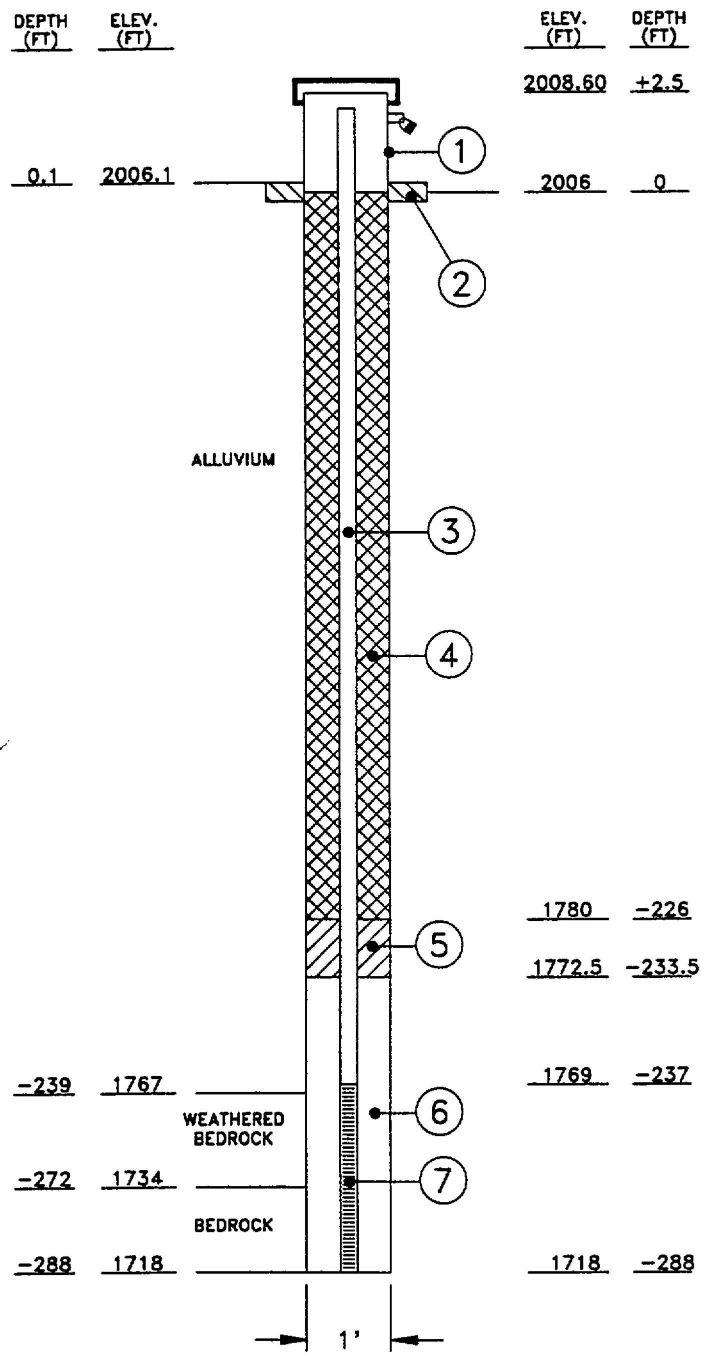
SHEPHERD MILLER, INC.

317\TASK31\WELLMW3.DWG

MONITORING WELL CONSTRUCTION INFORMATION SHEET



Client WESTERN NUCLEAR, INC.
Job Number #317 SHERWOOD
Boring/Well Number MW-8
Date 2/24 - 3/3/93
Location N: 329,866.5 E: 2,669,059.6
Drilling Co. RUEN DRILLING
Drilling Method AIR ROTARY CASING ADVANCE
Driller WILL HAYES
Completed 3/4 - 3/7/94
Logged By KIT COHAN / SMI

Materials:

(1) Protective casing type: STEEL
(2) Surface seal type: CEMENT
Dimensions: 6'x 6'x 2'
(3) Riser pipe: Type SCH 80 PVC
Length 239.5'
ID 5"
(4) Backfill Type: NEAT CEMENT GROUT
(5) Seal: BENTONITE
(6) Filter Pack: 10-20 SILICA SAND
(7) Well Screen: Type SCH 80 PVC
Length 50' (1' END CAP)
ID 5"
Slotsize 0.020"
Pump Intake: Depth 289.35 El. 1719.25
Pump Type: GRUNDFOS 10S10-15 1hp
Pump Riser Pipe: 1" ID SCH. 40 PVC

NOTES:

*Depth of pump intake based on maximum measured drawdown during pumping.

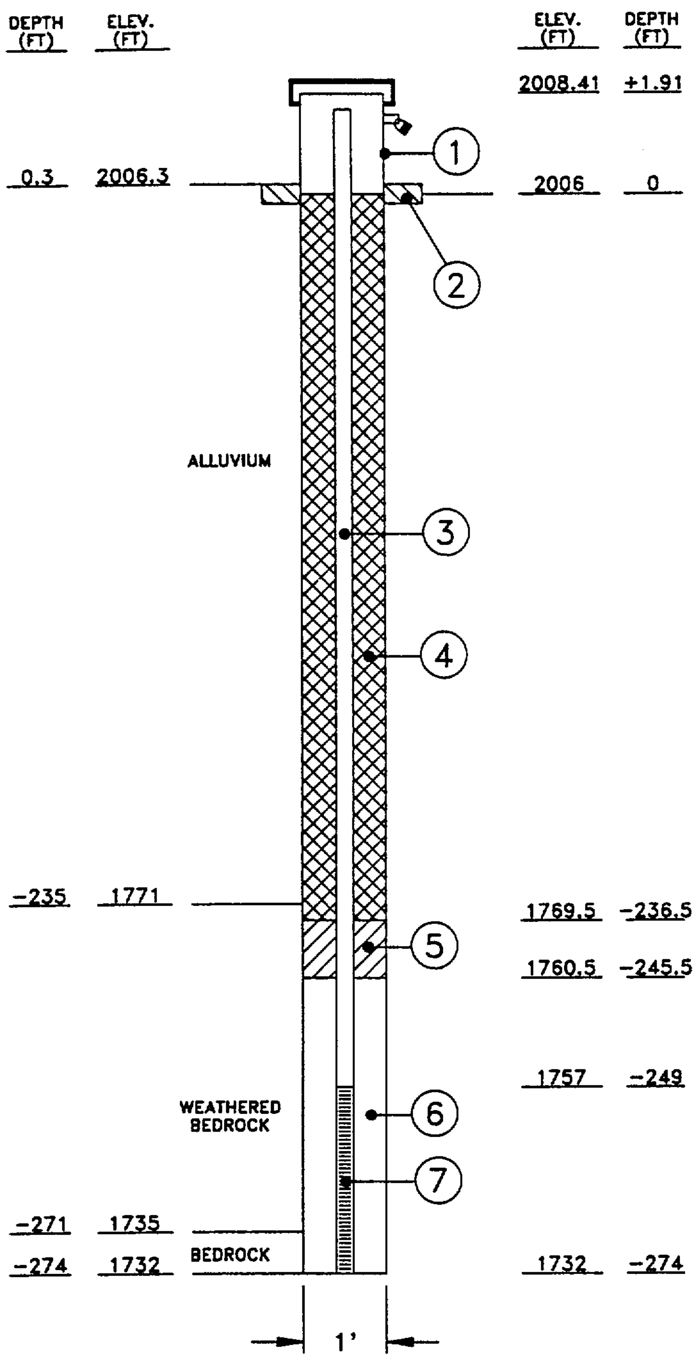
*All Elevations Relative to MSL.

NOT TO SCALE

SMI
SHEPHERD MILLER, INC.

317\TASK31\WELLMW8.DWG

MONITORING WELL CONSTRUCTION INFORMATION SHEET



Client WESTERN NUCLEAR, INC.
Job Number #317 SHERWOOD
Boring/Well Number MW-9
Date 3/17 - 3/26/93
Location N: 329,879.07 E: 2,669,030.05
Drilling Co. RUEN DRILLING
Drilling Method AIR ROTARY CASING ADVANCE
Driller WILL HAYES
Completed 3/30 - 4/1/93
Logged By KIT COHAN / SMI

Materials:

1. Protective casing type: STEEL
2. Surface seal type: CEMENT
   Dimensions: 6'x 6'x 2'
3. Riser pipe: Type SCH 80 PVC
   Length 250.9'
   ID 5"
4. Backfill Type: NEAT CEMENT GROUT
5. Seal: BENTONITE
6. Filter Pack: 10-20 SILICA SAND
7. Well Screen: Type SCH 80 PVC
   Length 20' (1' ENDCAP)
   ID 5"
   Slotsize 0.020"

Pump Intake: Depth 271.30 El. 1737.11
Pump Type: GRUNDFOS 10S10-15 1hp
Pump Riser Pipe: 1" ID SCH. 40 PVC

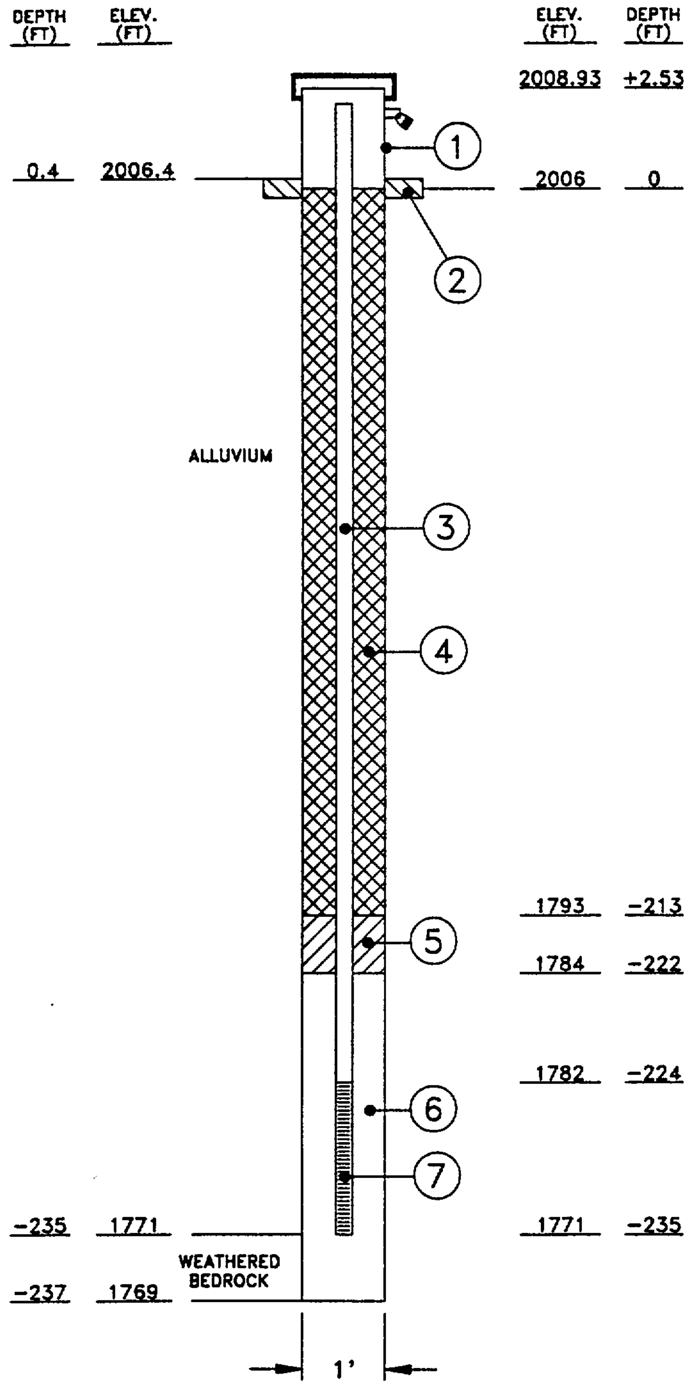
NOTES:
*Depth of pump intake based on maximum measured drawdown during pumping.
*All Elevations Relative to MSL.

NOT TO SCALE

SMI
SHEPHERD MILLER, INC.

317\TASK31\WELLMW9.DWG

MONITORING WELL CONSTRUCTION INFORMATION SHEET



Client WESTERN NUCLEAR, INC.
Job Number #317 SHERWOOD
Boring/Well Number MW-10
Date 4/2 - 4/4/93
Location N: 329,879.8 E: 2,669,054.2
Drilling Co. RUEN DRILLING
Drilling Method AIR ROTARY CASING ADVANCE
Driller WILL HAYES
Completed 4/5 - 4/6/93
Logged By KIT COHAN / SMI

Materials:

(1) Protective casing type: STEEL
(2) Surface seal type: CEMENT
Dimensions: 6'x 6'x 2'
(3) Riser pipe: Type SCH 80 PVC
Length 226.5'
ID 5"
(4) Backfill Type: NEAT CEMENT GROUT
(5) Seal: BENTONITE
(6) Filter Pack: 10-20 SILICA SAND
(7) Well Screen: Type SCH 80 PVC
Length 10' (1' END CAP)
ID 5"
Slotsize 0.020"
Pump Intake: Depth 237.40 El. 1771.53
Pump Type: GRUNDFOS 10S10-15 1hp
Pump Riser Pipe: 1" ID SCH. 40 PVC

NOTES:

*Depth of pump intake based on maximum measured drawdown during pumping.

*All Elevations Relative to MSL.

NOT TO SCALE

SMI
SHEPHERD MILLER, INC.

317\TASK31\WELLMW10.DWG

Prepared For:

WESTERN NUCLEAR, INC.
Wellpinit, Washington

SHERWOOD PROJECT RADIOLOGICAL VERIFICATION COMPLETION REPORT

Volume 1 of 11

EXECUTIVE SUMMARY

Prepared By:

SHEPHERD MILLER, INC.
3801 Automation Way, Suite 100
Fort Collins, Colorado 80525

JULY 1996

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EXECUTIVE SUMMARY

The following report presents the results of the Sherwood Project Radiological Verification Program. These results demonstrate that all areas of the Western Nuclear, Inc. (WNI) Sherwood Site, which could have been contaminated with byproduct material during milling, have been identified and decontaminated and may now be released for unrestricted use. The Radiological Verification Program (WNI, 1994 et seq.), as implemented, ensured compliance with the applicable regulatory limits, reduced residual radioactive materials in soils to levels which were ALARA, and verified all potentially affected areas associated with milling operations, with the exception of the tailing impoundment, are suitable for release for unrestricted use. Drawing ES.1 provides a schematic of the Sherwood Site and demonstrates that all grids are within the release criteria.

The Radiological Verification Program was developed based on the results of the Sherwood Project correlation and scoping studies conducted during the summer of 1993. The program addressed verification of site soils relative to compliance with applicable regulatory limits for ^{226}Ra, ^{230}Th and U (^{238}U+^{234}U). The results of the correlation program were presented in the Sherwood Project Radiological Verification Program Report (WNI,1994 et seq.). On March 22, 1995, via Amendment No. 19 to the WNI Radioactive Materials License Number WN-I0133-1, the Washington Department of Health (WDOH) approved the Sherwood Radiological Verification Program.

History

From November 1971 to October 1972, WNI operated a pilot metallurgical testing plant licensed by the Washington Department of Social and Health Services (DSHS). On October 31, 1972, DSHS terminated the radioactive materials license for the pilot plant, and the heap leach material associated with the pilot plant was subsequently processed through the mill circuit during the 1978 startup of the Sherwood Mill. The pilot plant area was cleaned up in late 1994 during mill demolition.

As a result of the successful pilot plant metallurgical testing during 1971 and 1972, Western Nuclear, Inc. designed and began commercial scale production with the Sherwood Mill. The mill was licensed by the DSHS, now the Washington Department of Health (WDOH). The Sherwood Mill operated from April 1978 to 1984.

The Sherwood Mill was decommissioned during the winter of 1992/1993, and the administration building and warehouse were decommissioned during the winter of 1994/1995. All debris which could not be released for unrestricted use was placed in the Sherwood Tailing Impoundment. Additionally, all underground conduits, (water, steam, and electrical), within the mill area were excavated and disposed of with the exception of the main water line which supplies fresh water to the mine truck shop. One major section of this remaining line (approximately 100 meters) was excavated in the summer of 1996 due to suspected residual radioactive materials within fill material around the line. Following excavation of the surrounding and bedding soils, the line was reconstructed.

The only structures which remain within the former mill area are the pump house, used to distribute fresh water from Lake Roosevelt, and the associated water storage tank. Following mill demolition, the exterior siding and insulation were removed from the pump house. All insulation was disposed of in the tailing impoundment. The metal siding, pump equipment, interior piping, and the water storage tank were then surveyed and found to be below the regulatory limit for unrestricted release. New insulation was subsequently installed and the original metal siding was reattached.

Radiological cleanup and verification of the Sherwood Site soils commenced in 1995 and continued through the summer of 1996. This report presents the findings of the radiological verification effort which supports the conclusion that Sherwood Site soils have been successfully cleaned up and are suitable for release for unrestricted use.

Gamma-Radium Correlation

The purpose of the correlation study conducted during the summer of 1993 was to investigate and develop methods and procedures for conducting external gamma radiation measurement surveys to document radiological compliance by determining a correlation between the average ^{226}Ra content in the soils of 10m x 10m regulatory compliance grids, and the corresponding external gamma radiation exposure rate measurements from those grids. As discussed in the Radiological Verification Program Report (WNI, 1994 et seq.), WNI successfully demonstrated that such correlations existed, and based on these correlations, established gamma survey action levels corresponding to the applicable regulatory limit for ^{226}Ra (see discussion below).

Radiological Standards

The Sherwood Radiological Verification Program was developed to fully comply with the requirements of WAC-246-252 which states that, on a 100 square meter basis, the average soil concentrations of residual ^{226}Ra, as the result of byproduct material, must not exceed background levels of ^{226}Ra by more than:

1. 5 pCi/g averaged over the first 15 cm below the surface; and
2. 15 pCi/g averaged over 15 cm thick layers more than 15 cm below the surface.

Although ^{230}Th contamination is not directly addressed by the standard, it was recognized that if ^{230}Th was out of equilibrium with ^{226}Ra, and present at sufficiently high concentrations, ingrowth of ^{226}Ra from ^{230}Th, over the 1000 year reclamation design life, could result in ^{226}Ra concentrations that would exceed the standard. Because ^{230}Th cannot be detected by gamma measurement surveying, the plan contained provisions, discussed below, for using either elevated ^{226}Ra as an indicator of elevated ^{230}Th or laboratory analysis for the ^{230}Th isotope.

During the course of final verification it was determined that, based on evolving NRC guidance, a uranium standard should be added to the Sherwood Radiological Verification Program. The verification plan was amended via WDOH letter dated April 4, 1996, and random sampling for uranium was conducted, with an emphasis on areas where elevated uranium values might have been expected. The results of the uranium sampling effort indicated that two isolated areas exhibited elevated U (^{238}U+^{234}U) concentrations. Soils in these areas were subsequently cleaned and resampled until the U concentration was below the applicable regulatory limit.

Association Issues and Development of the Radiological Verification Program

The correlation/scoping program of 1993 demonstrated that an "association" between elevated levels of ^{226}Ra and ^{230}Th existed around the tailing impoundment and in certain areas of the mill site; that is, no elevated levels of ^{230}Th were present without corresponding elevated levels of ^{226}Ra. Based on this knowledge, the WDOH approved use of external gamma radiation detection methods for verification of ^{226}Ra (which can be detected by external gamma measurements), and the use of ^{226}Ra as a surrogate indicator of ^{230}Th concentrations (which cannot be detected by external gamma measurements) provided that random confirmatory soil samples be taken, on a percentage basis, to demonstrate that residual concentrations of ^{226}Ra and ^{230}Th were within the applicable regulatory limits.

Figures ES.1 through ES.4 show the prediction intervals derived from the 1993 correlation superimposed against representative 1995 verification data on grids which were both gamma surveyed and soil sampled for confirmation purposes. These figures demonstrate the validity of utilizing gamma detection instrumentation to verify compliance with the applicable limits for ^{226}Ra. Further, out of approximately 300 regulatory compliance grids which were gamma surveyed and then confirmed via soil sampling and laboratory analyses for radionuclide concentrations, in only two instances did use of the association fail to identify elevated ^{230}Th using ^{226}Ra as a surrogate indicator. In both cases, the grids in question were situated immediately adjacent to areas known to have no association (described below) and, therefore, the grids in question as well as peripheral grids were reclassified as areas with no association, and were subsequently verified by 100% soil sampling (see discussion below).

The correlation/scoping program revealed that no radionuclide association between ^{226}Ra and ^{230}Th existed for the soils in either of the liquid deposition drainages (the claricone spill or the barium chloride pond and drainage) or the mill process area. This lack of association is considered attributable to the chemical composition or the depositional nature of the contaminants. Therefore, since elevated ^{230}Th concentrations in these areas were not necessarily associated with elevated ^{226}Ra concentrations, gamma detection methods could not be utilized in these areas. These areas of non-association were delineated and verification of radiological compliance was accomplished via soil sampling in 100% of the regulatory compliance grids within the areas.

Final Verification

Prior to initiation of the final verification program in the spring of 1995, an initial cleanup was conducted in the mill area, resulting in the excavation and initial removal of 70,000 cubic yards of soil which was placed in the tailing impoundment. When final verification began in March 1995, soil cleanup was conducted concurrently with verification activities, and approximately 305,000 cubic yards of additional soil were removed to the tailing impoundment. All contaminated soils were placed beneath the final reclamation cover.

In order to assess compliance on a 100 square meter basis, approximately 4000 10m x 10m grids were established for gamma surveying in all areas surrounding the tailing impoundment and in portions of the mill site where an association between ^{226}Ra and ^{230}Th had been previously demonstrated to exist. These grids are shown on Figure ES.5. Upon initial measurements, 95% of all grids were below the applicable regulatory standards for ^{226}Ra with 85% of all grids at essentially background levels (less than 2 pCi ^{226}Ra/g, see Drawing ES.2). All grids with gamma readings indicative of ^{226}Ra values greater than 5 pCi/g above background were cleaned and resurveyed until the readings indicated that the grids had been successfully remediated to residual radioactivity concentrations less than 5 pCi ^{226}Ra/g above background. In addition to the cleanup required to meet the standards, 10% of the grids that displayed the highest (yet passing) initial gamma survey results were further excavated to reduce soil concentrations to levels which were ALARA.

In the mill process area and the two liquid deposition areas (barium chloride drainage and claricone spill area) no association was found between ^{226}Ra and ^{230}Th. Therefore, as shown on Figure ES.5, approximately 800 10m x 10m regulatory compliance grids were established and verification was conducted by soil sample analyses exclusively. In addition, approximately 300 soil samples were collected from the 4000 gamma survey grids to confirm the gamma-radium correlation. Of the total 1100 grids from which soil samples were taken, 95% of the grids showed residual radionuclide concentrations below the applicable regulatory limits when sampled for the first time, and 60% of the total showed residual radionuclide concentrations at essentially background (see Drawing ES.2). All grids that were in excess of the limits for ^{226}Ra, or ^{230}Th were excavated and resampled until results indicated radionuclide concentrations were below the applicable limits. In addition to the cleanup required to comply with the standards, 35% of the passing grids were further excavated to reduce residual radionuclide concentrations in soils to levels that were ALARA. The histograms provided in Figures ES.7 and ES.8 demonstrate graphically that the residual radionuclide concentrations in most grids are now within the regulatory limits for ^{226}Ra and ^{230}Th, and, furthermore, that the residual radionuclide concentrations in all soils have been reduced to essentially background levels.

After it had been demonstrated that site soils contained acceptable residual concentrations of ^{226}Ra and ^{230}Th, approximately 200 grids (20% of all soil sample grids and 10% of confirmation sample grids) were sampled for U (^{238}U+^{234}U). Upon initial analyses, approximately 95% of these grids were below the WDOH guideline. In the remaining grids, additional soil was removed and the grids were resampled until U concentrations were reduced to less than the applicable limit. Figure ES.9 graphically demonstrates that existing soil concentrations for U are below the applicable guideline, and that the majority of the grids contain residual radionuclide concentrations at essentially background levels.

Finally, in order to bring total radiological closure to the Sherwood Site, soil samples were collected at 500 meter intervals along the main roads between the mill area and the main gate, and between the mill area and the lower pump house located on the shore of Lake Roosevelt. The locations of these samples are shown on Figure ES.6. The result of the sample analyses indicated that all grids contained residual radionuclide concentrations at essentially background levels.

By the conclusion of the Sherwood Radiological Verification Program a total of 4968 gamma surveys, and 1320 soil samples were taken, and approximately 375,000 cubic yards of soil had been excavated and placed in the tailing impoundment beneath the final tailing reclamation cover. As depicted in Drawing ES.1 and Figures ES.7, ES.8 and ES.9, all residual radionuclide concentrations are below the applicable regulatory limits, therefore, all areas, with the exception of the tailing impoundment, are suitable for release for unrestricted use.

The Sherwood Radiological Completion Report

The following volumes of this report contain the details of the Sherwood Radiological Verification Program including the following:

- specific regulatory limits for each radionuclide;
- background radionuclide concentrations;
- the methods and procedures used to conduct radiological verification;
- definition of radiological verification areas;
- all data collected to demonstrate radiological compliance with regulatory limits;
- external gamma radiation survey instrumentation used;
- data management and data reduction methods; and
- QA/QC of laboratory analyses and external gamma radiation measurements.

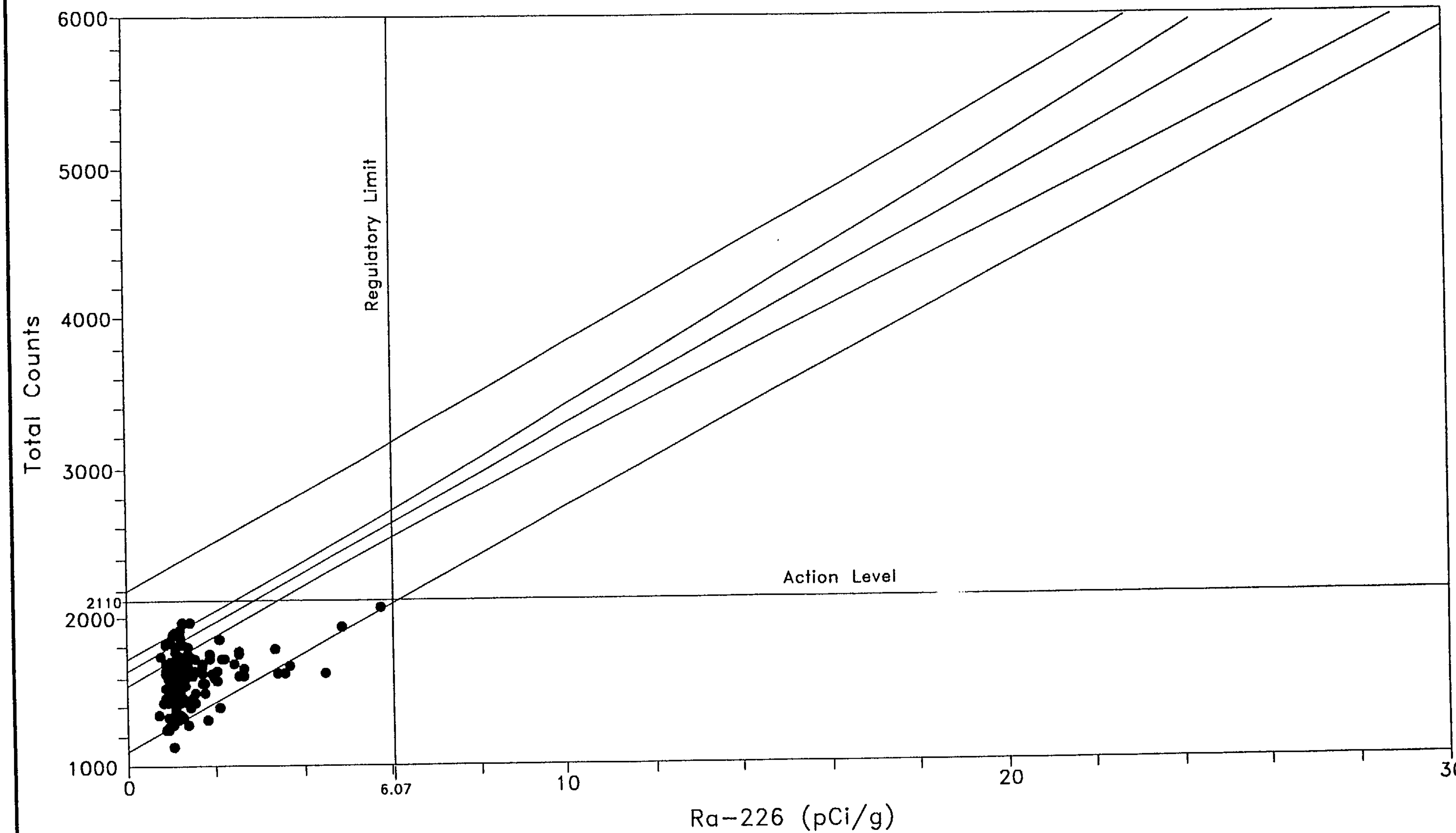
Additionally, the report addresses modifications to the initially approved Sherwood Radiological Verification Program Report (WNI, 1994 et seq.) which, during the course of verification activities, were identified as necessary. Some of these changes such as the following were minor, and in full accordance with the approved plan:

- reclassification of soil types;
- reclassification of radiological area designation; and
- addition of grids to encompass unexpected areas of contamination.

Other modifications, also addressed in this report, were of a more substantial nature and were submitted for WDOH approval. These included the following:

- exclusion of grids identified to be on mine overburden piles;
- exclusion of grids identified to be backfilled with mine overburden;
- exclusion of grids beneath the pump house and water storage tank;
- provisional approval to proceed with construction activities in designated areas; and
- provisional approval to backfill the barium chloride drainage and evaporation pond area.

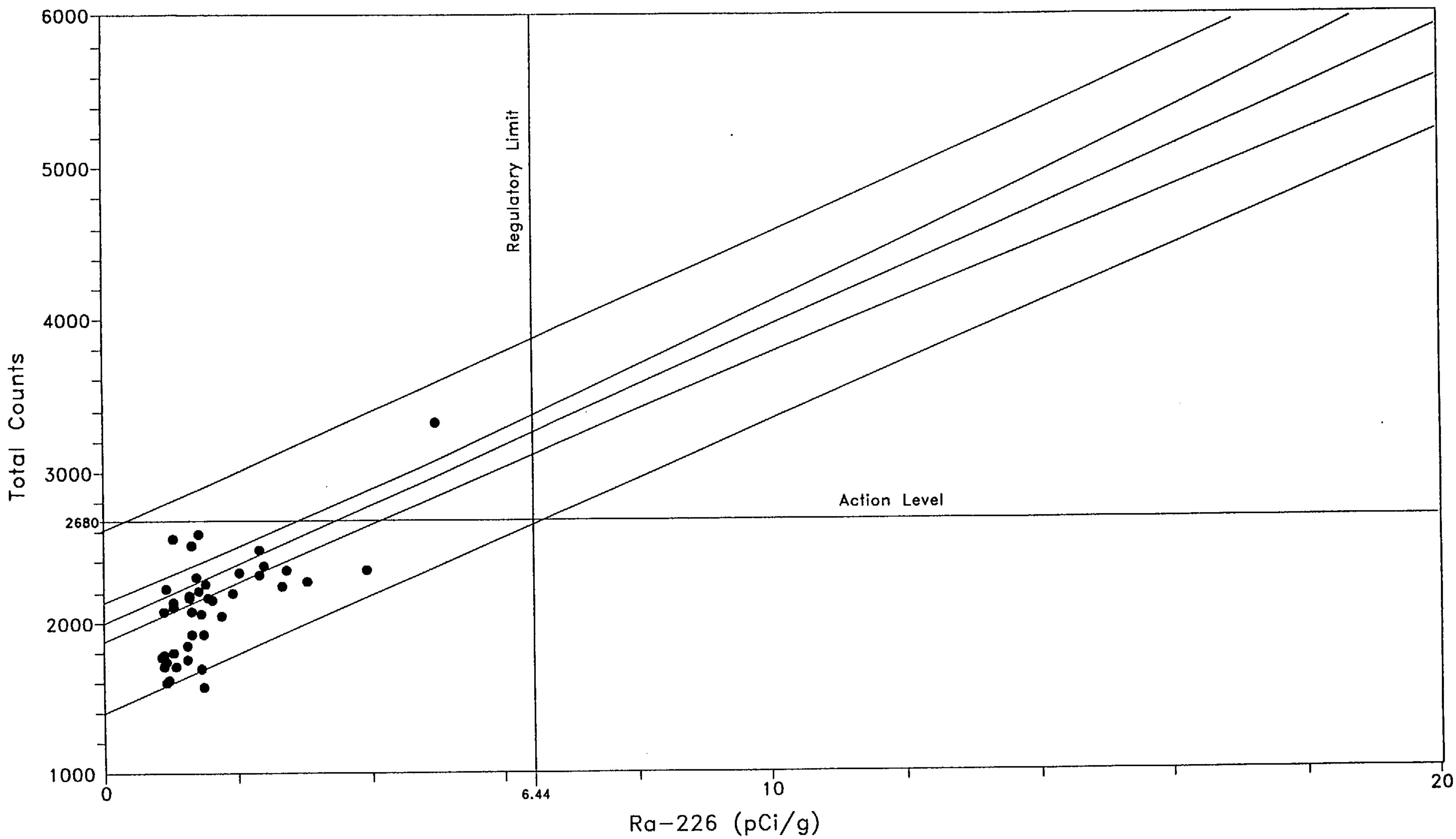
A narrative describing the previously mentioned aspects of the Sherwood Radiological Verification Program is provided in the main text, and all supporting data and documentation is provided in the appendices which follow the main text.



SHEPHERD MILLER INCORPORATED

FIGURE ES.1
150 SECOND INTEGRATED COUNT FOR SAND/FLOAT
GRIDS IN WHICH SOIL SAMPLES WERE TAKEN

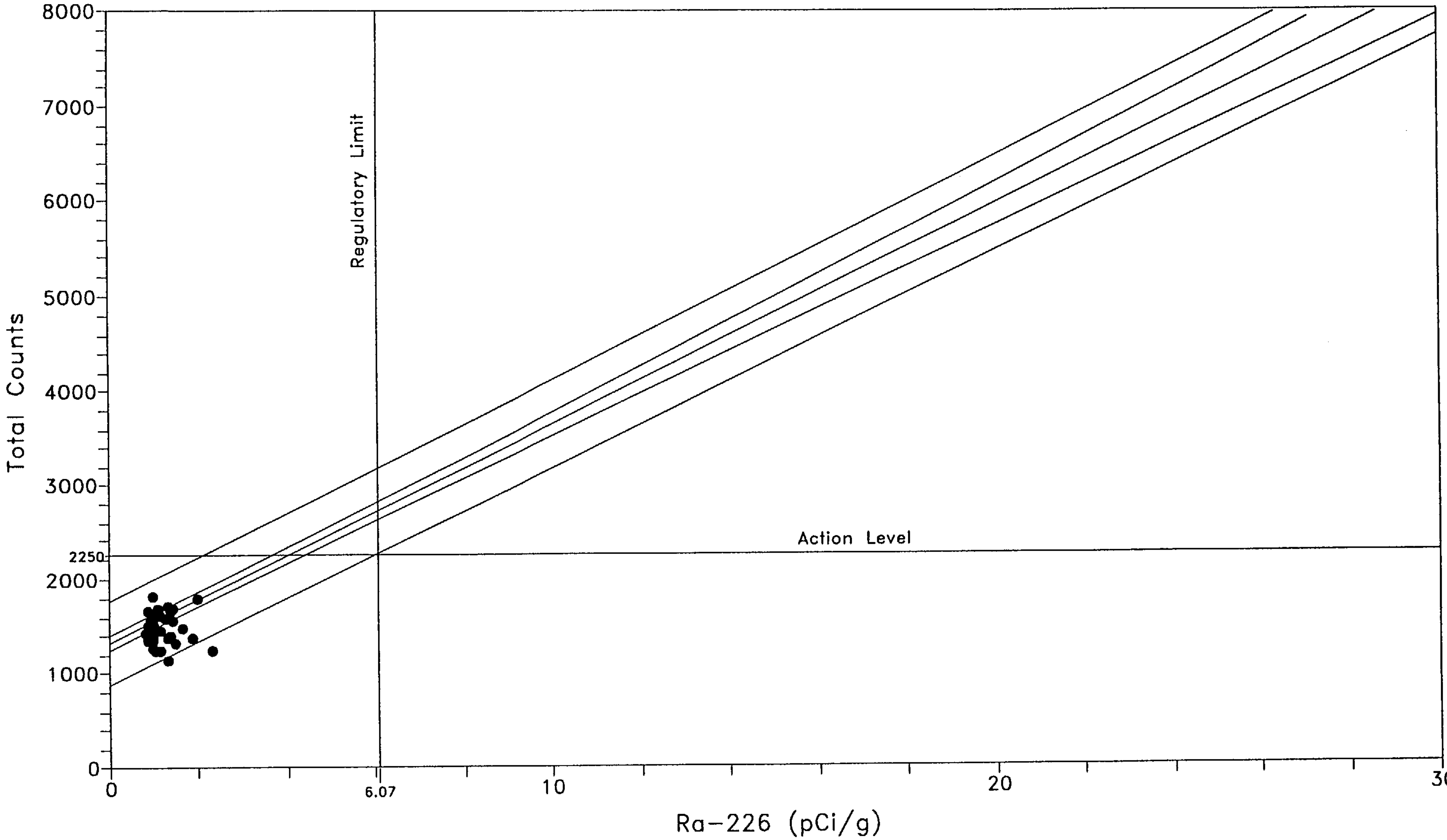
Date:	JULY 1996
Project:	09-353
File:	150-SF



SHEPHERD MILLER
INCORPORATED

FIGURE ES.2
150 SECOND INTEGRATED COUNT FOR WEATHERED QUARTZ
GRIDS IN WHICH SOIL SAMPLES WERE TAKEN

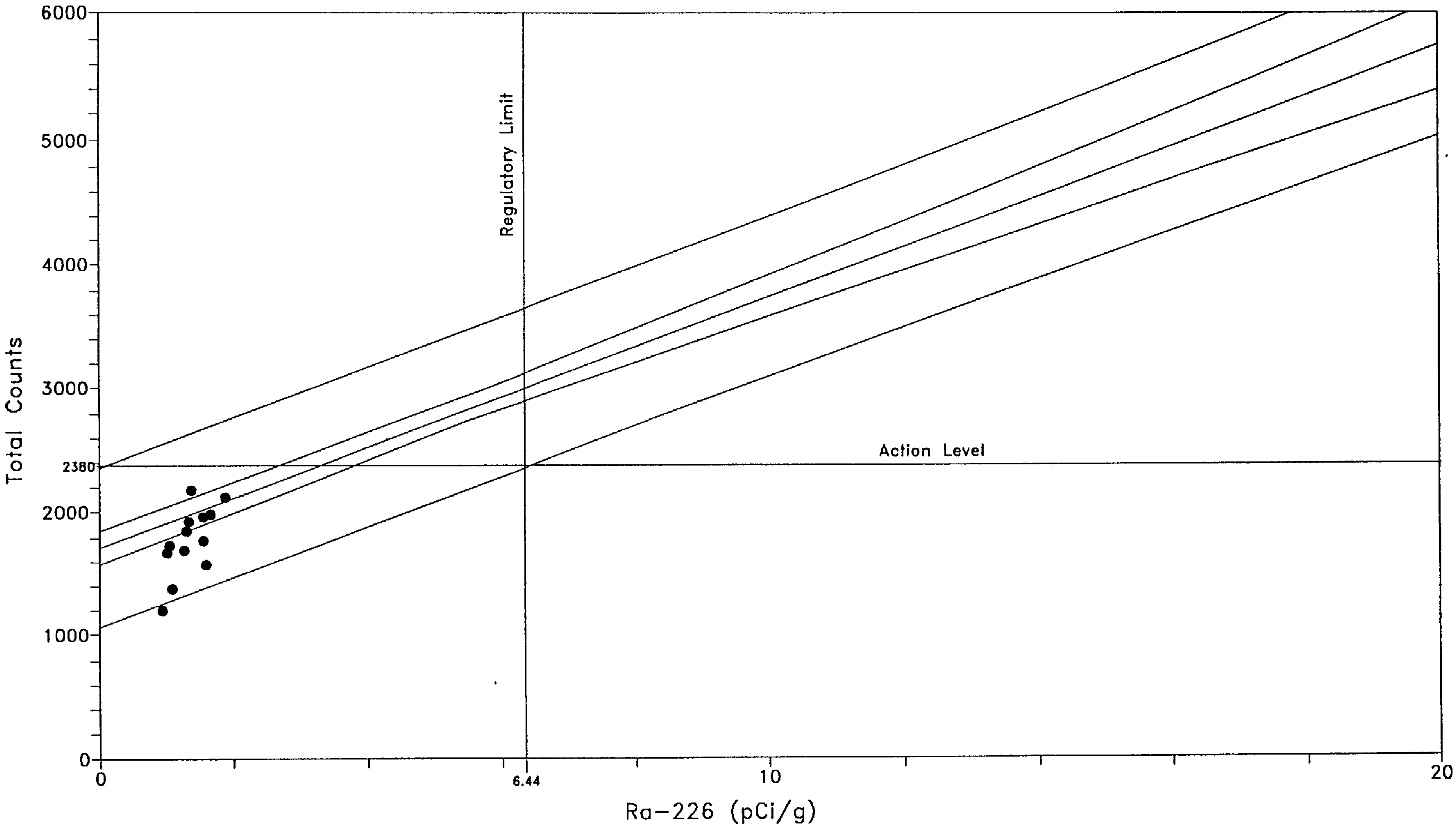
Date:	JULY 1996
Project:	09-353
File:	150-Q



SHEPHERD MILLER INCORPORATED

FIGURE ES.3
120 SECOND COMPOSITE COUNT FOR SAND/FLOAT GRIDS IN WHICH SOIL SAMPLES WERE TAKEN

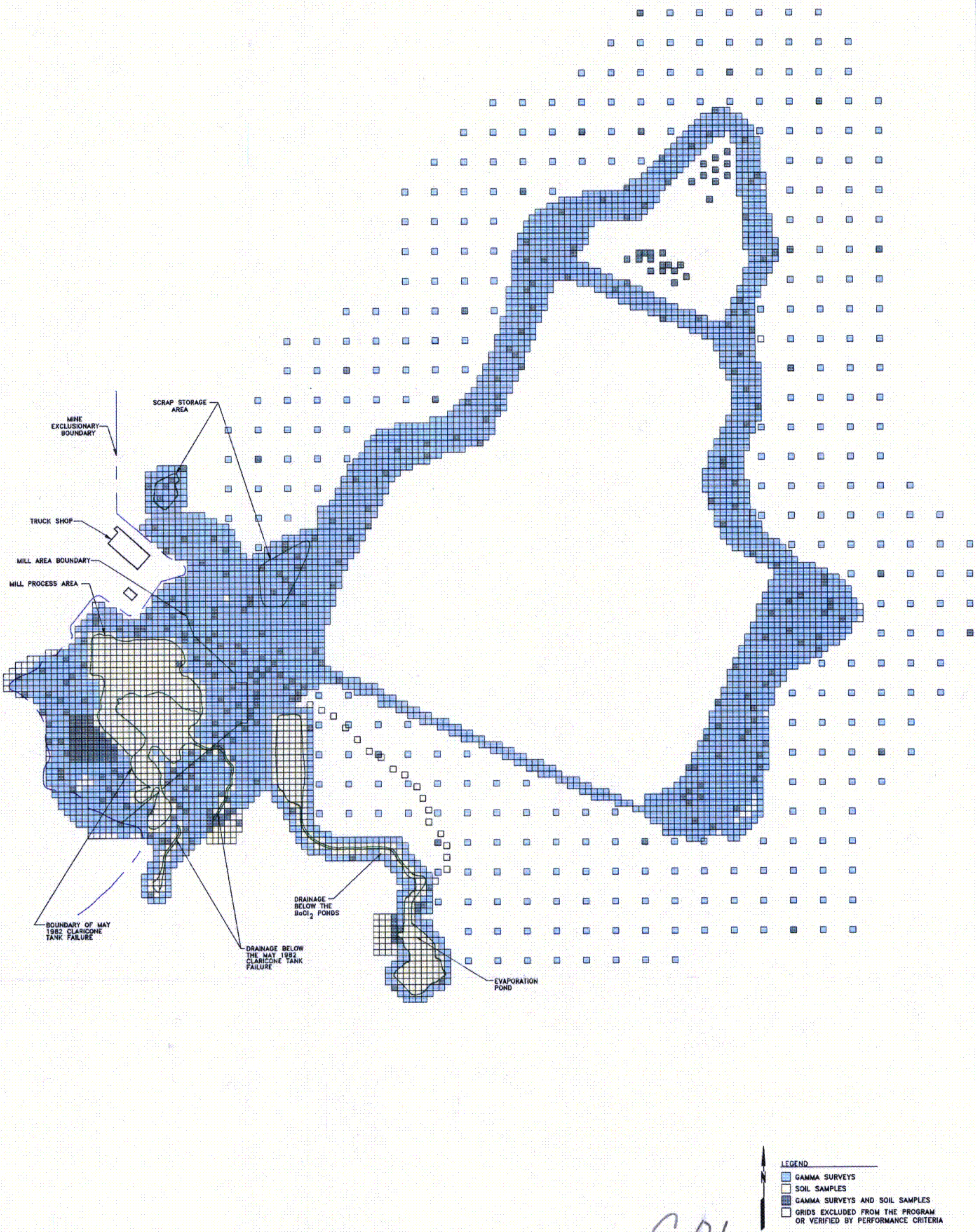
Date:	JULY 1996
Project:	09-353
File:	120-SF



SHEPHERD MILLER INCORPORATED

FIGURE ES.4
120 SECOND COMPOSITE COUNT FOR WEATHERED QUARTZ GRIDS IN WHICH SOIL SAMPLES WERE TAKEN

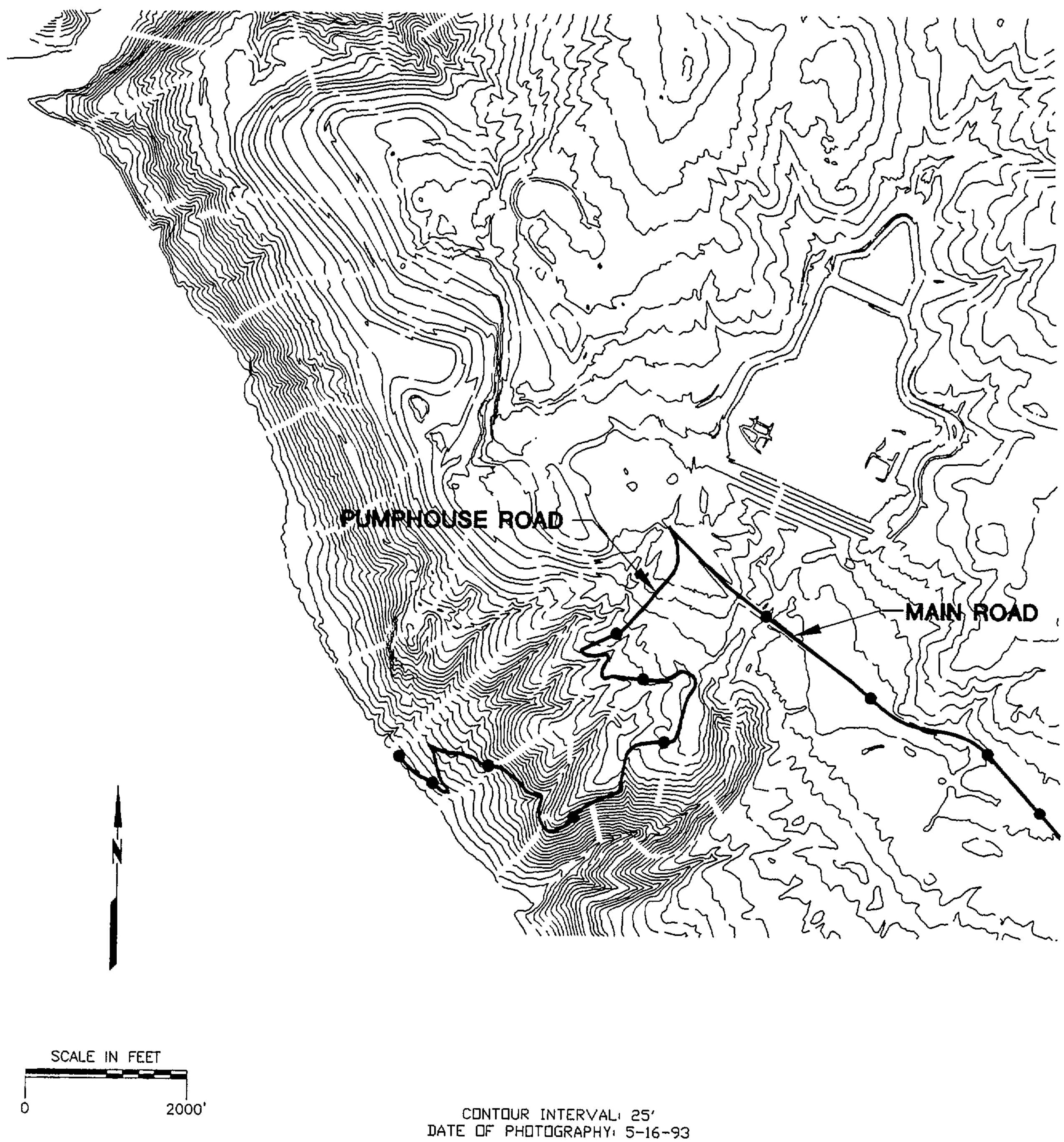
Date:	JULY 1996
Project:	09-353
File:	120-Q



SHEPHERD MILLER INCORPORATED

FIGURE ES.5
RADIOLOGICAL VERIFICATION SOIL SAMPLES AND GAMMA SURVEYS

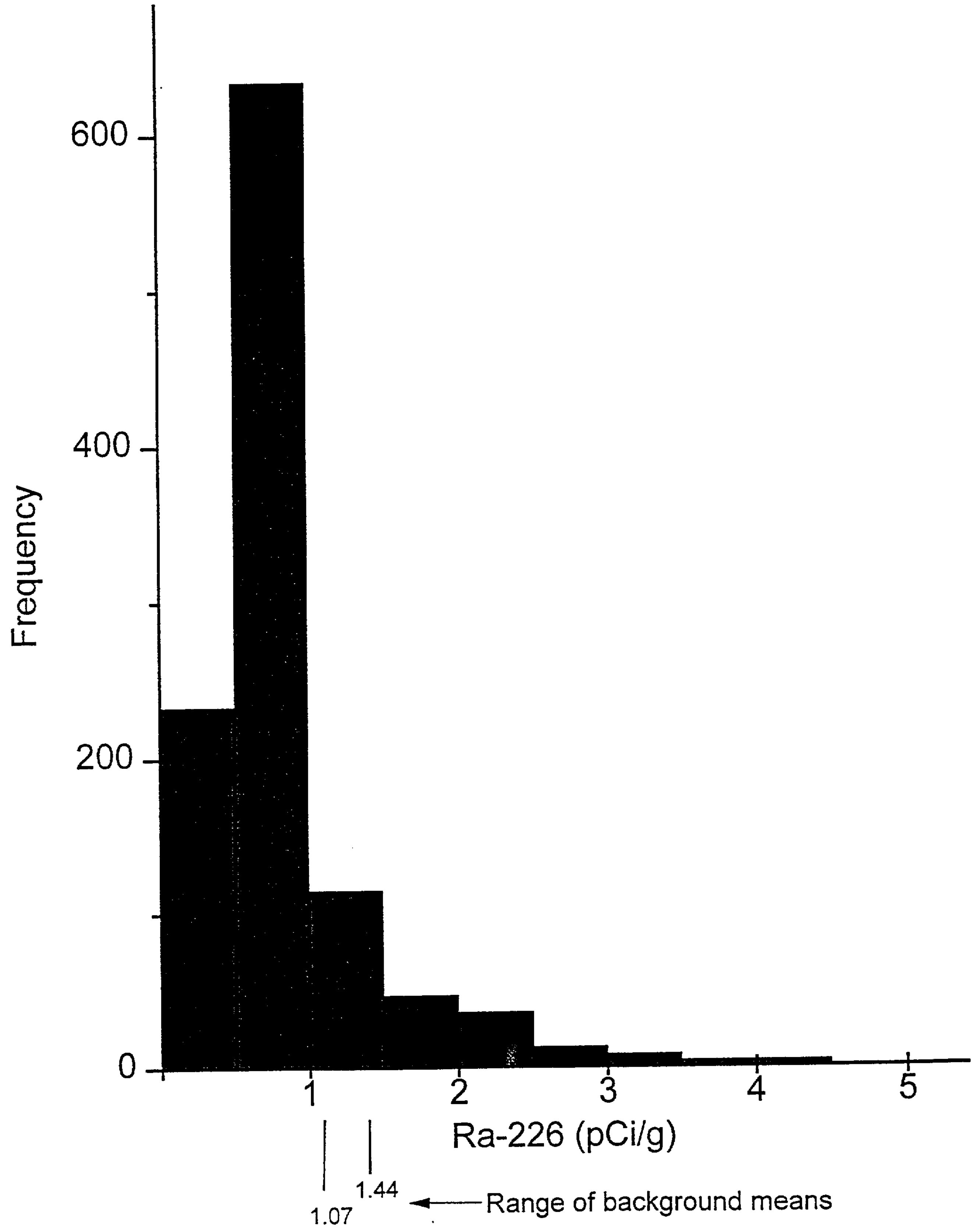
Date: JULY 1996
Project: 09-353
File: FINAL\VER-SURV



SHEPHERD MILLER
INCORPORATED

FIGURE ES.6
ANCILLARY AREAS

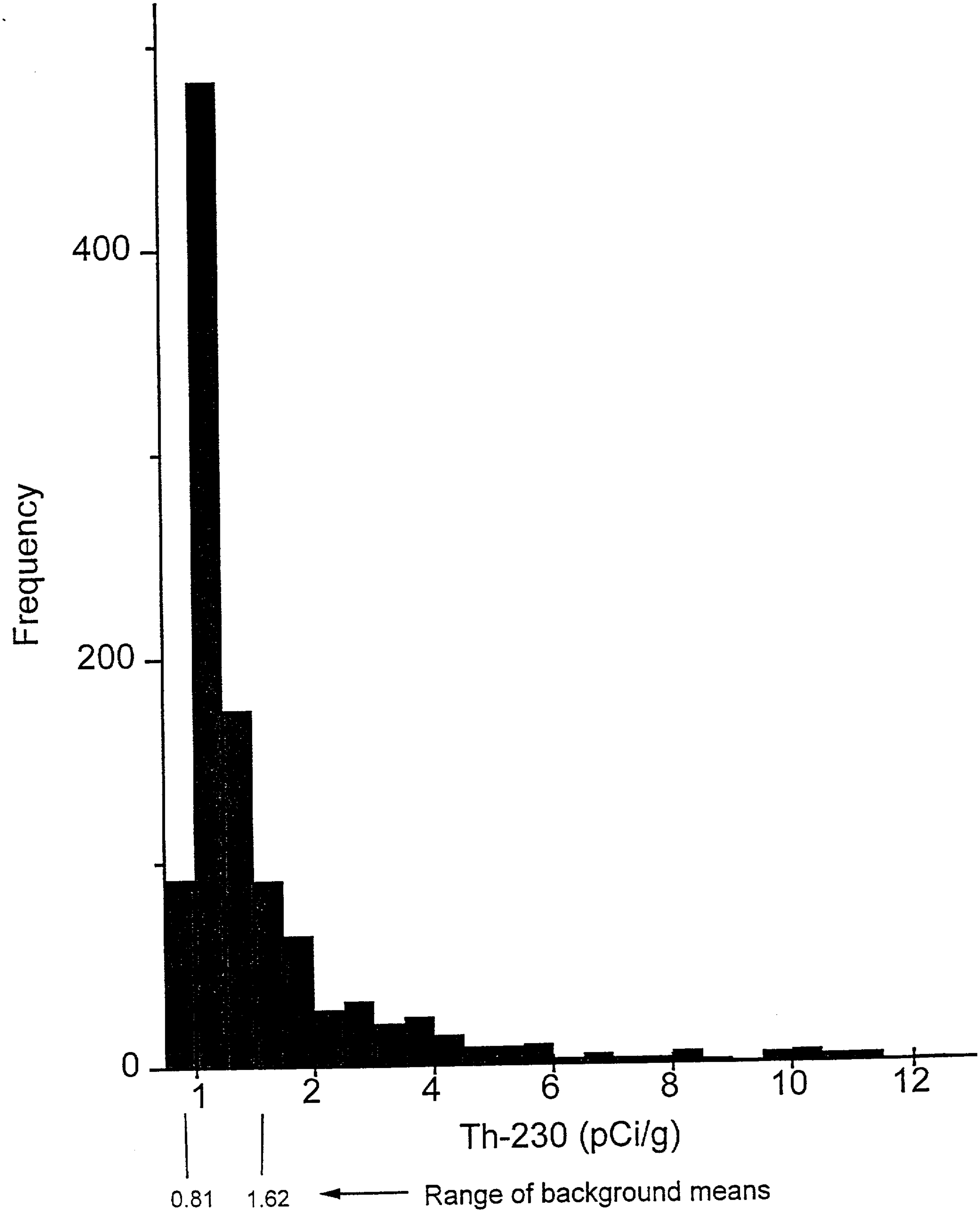
Date:	JULY 1996
Project:	09-353/FINAL
File:	FIGH-2



SHEPHERD MILLER INCORPORATED

FIGURE ES.7
Ra-226 HISTOGRAM

Date:	JULY 1996
Project:	09-353
File:	SURVEYS



SHEPHERD MILLER INCORPORATED

FIGURE ES.8
Th-230 HISTOGRAM

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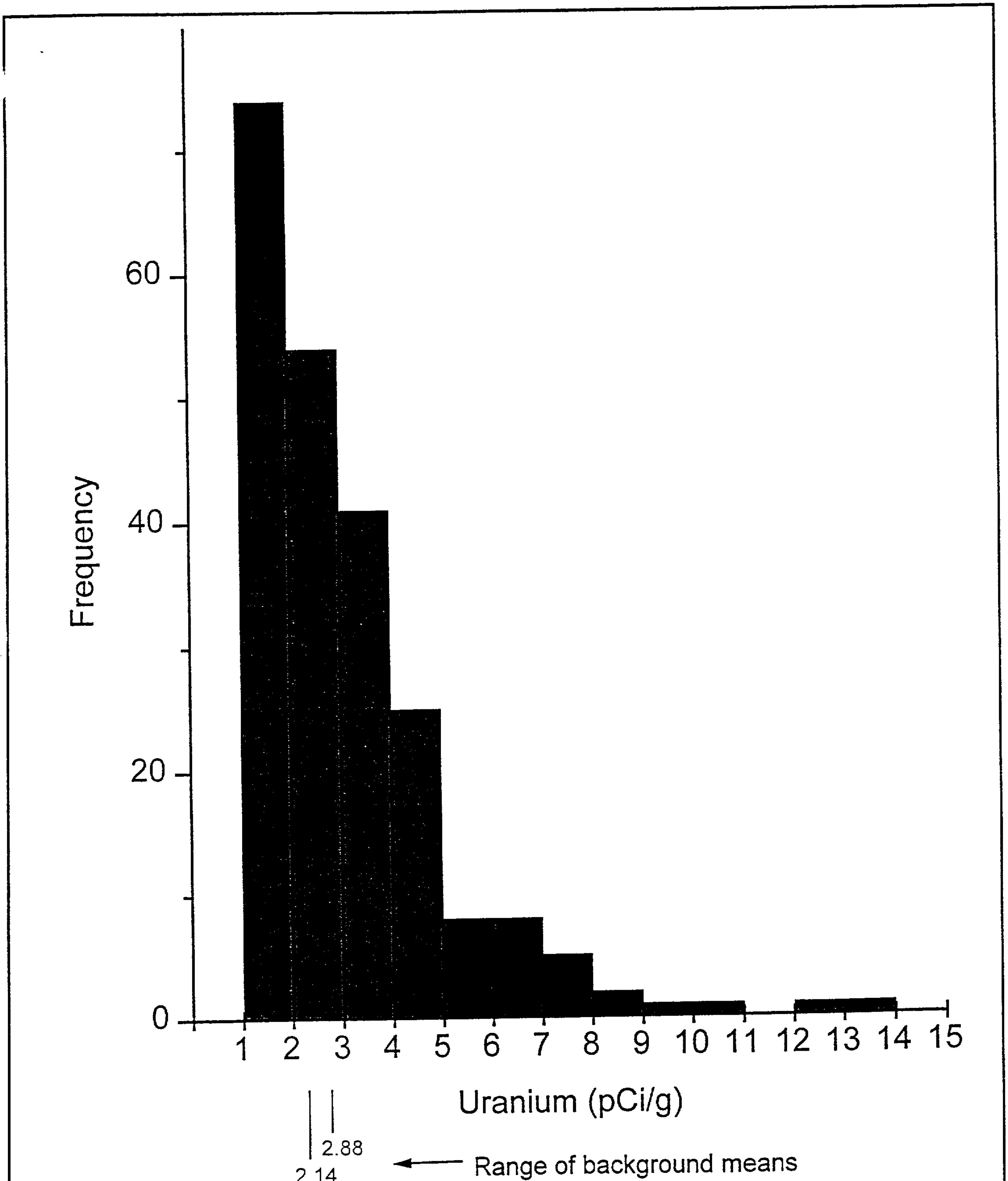
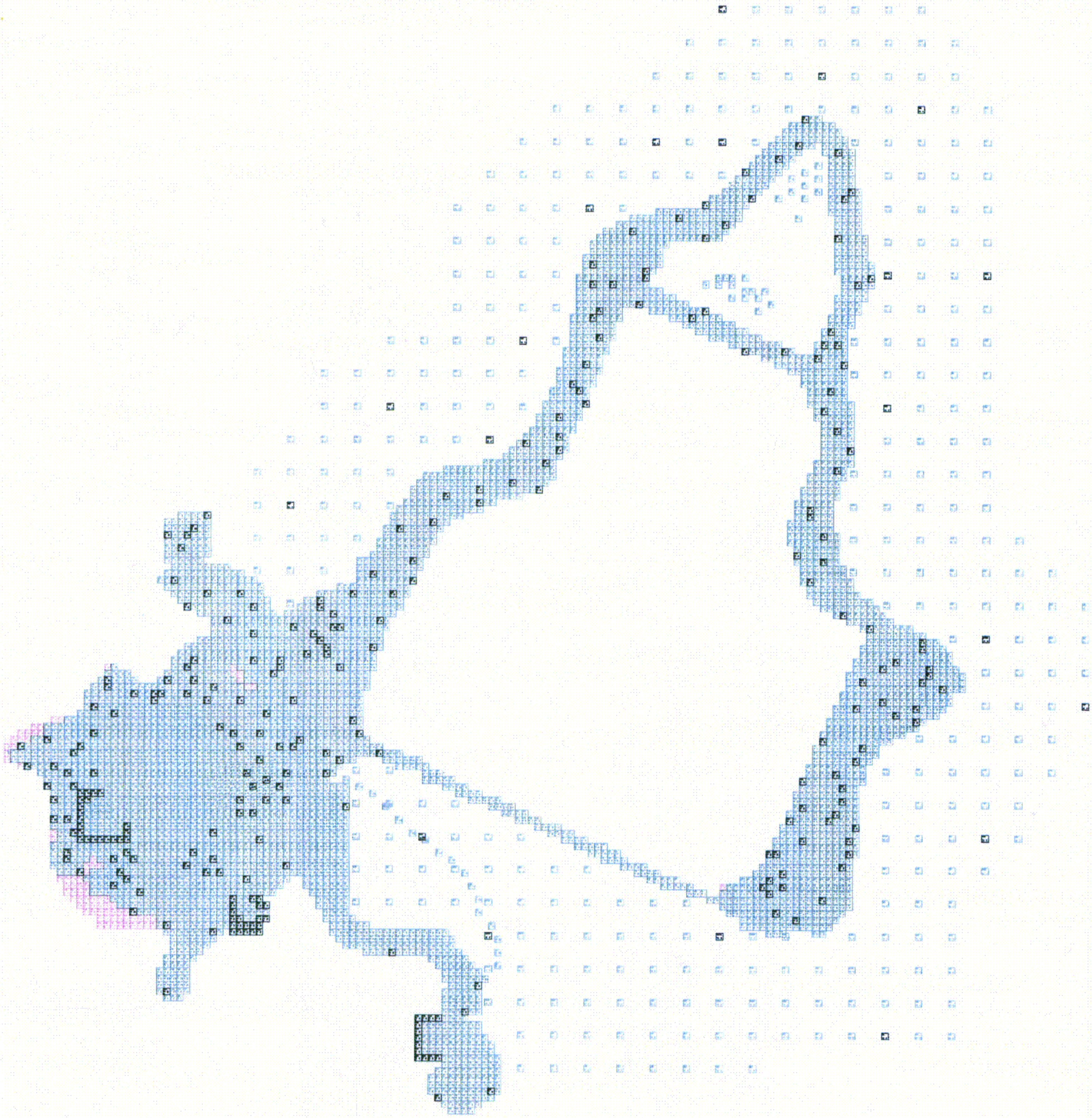
Project:	09-353
File:	SURVEYS



SHEPHERD MILLER INCORPORATED

FIGURE ES.9
URANIUM HISTOGRAM

Date:	JULY 1996
Project:	09-353
File:	SURVEYS



C02

LEGEND
- VERIFIED BY GAMMA SURVEY OR SOIL SAMPLE ANALYSIS
- VALIDATED (VERIFIED BY GAMMA SURVEY AND CONFIRMED BY SOIL SAMPLE ANALYSIS)
- EXCLUSIONARY (ELIMINATED FROM PROGRAM)

REVISIONS	DESCRIPTION	BY	CHKD.	APPROVED	DATE

REFERENCES	DRAWING NO.	DRAWING TITLE

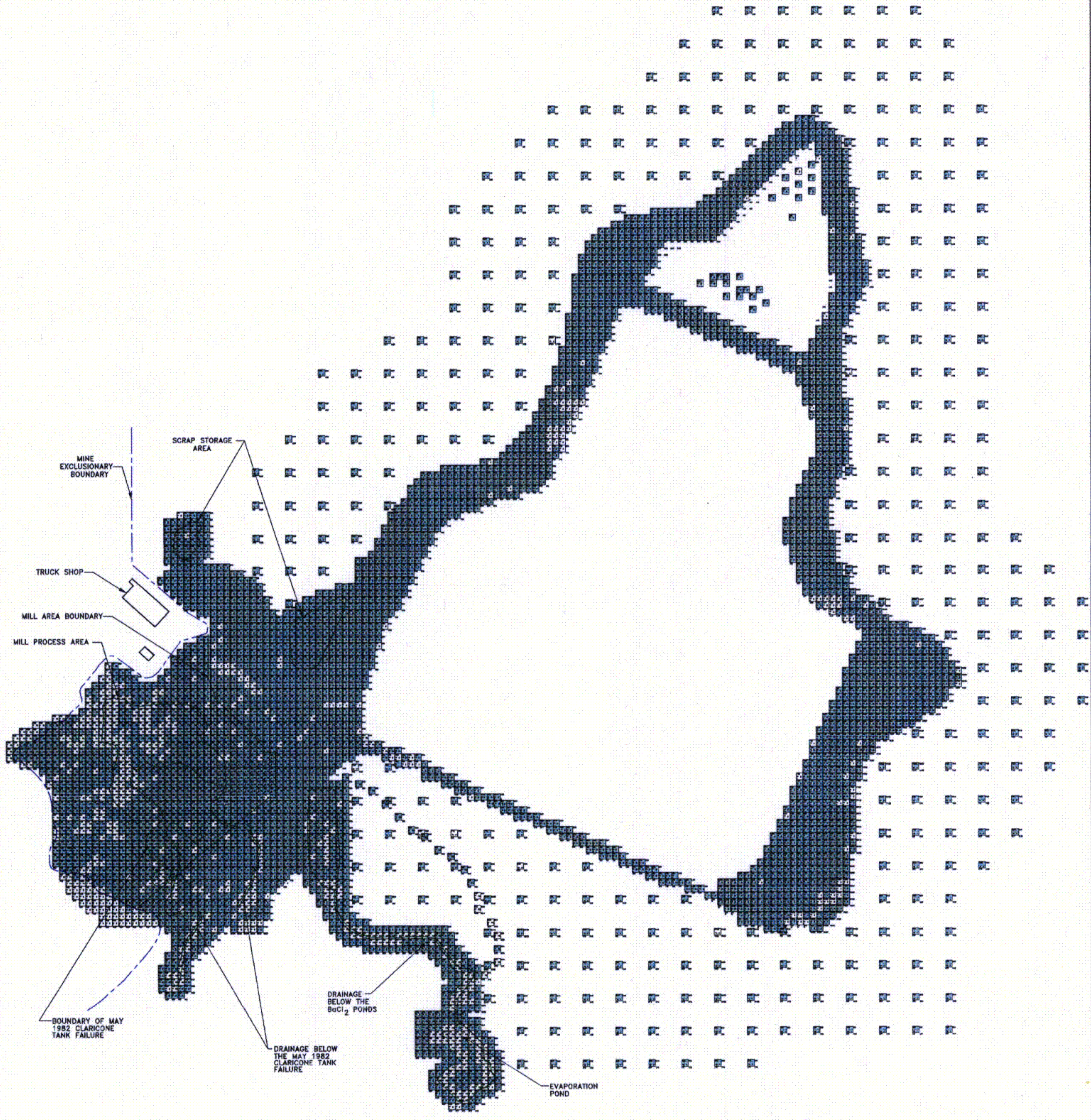
DESIGNERS	ENGINEERING RECORD	BY	DATE

PREPARED BY
SHEPHERD MILLER INCORPORATED

PREPARED FOR
WESTERN NUCLEAR INC.

TITLE
DRAWING ES.1
CURRENT GRID STATUS

09-353	JULY 1998	ES.1	△
NOT TO SCALE	FINAL\C0S		



NOTE, BACKGROUND DEFINED AS:

GAMMA SURVEYS
INTEGRATED GAMMA < 1900 COUNTS PER 150 SECONDS (SAND/FLOAT SOILS)
INTEGRATED GAMMA < 2300 COUNTS PER 150 SECONDS (WEATHERED QUARTZ MONZONITE)
COMPOSITE GAMMA < 1700 COUNTS PER 120 SECONDS (SAND/FLOAT SOILS)
COMPOSITE GAMMA < 2000 COUNTS PER 120 SECONDS (WEATHERED QUARTZ MONZONITE)

SOIL SAMPLES
ANALYTIC RESULT < 2pCi/g ^{226}Ra and 2pCi/g ^{230}Th

LEGEND
GRIDS AT ESSENTIALLY BACKGROUND

C03

NO.	DESCRIPTION	BY	CHKD.	APPROVED	DATE

REVISIONS

DRAWING NO.	DRAWING TITLE

REFERENCES

ENGINEERING RECORD	BY	DATE

DESIGNERS

PREPARED BY
SHEPHERD MILLER INCORPORATED

PREPARED FOR
WESTERN NUCLEAR INC.

TITLE
DRAWING ES.2
GRIDS AT ESSENTIALLY BACKGROUND

PROJECT 09-353 | DATE JULY 1996 | ES.2
SCALE NOT TO SCALE | FINAL\BCK

Prepared For:

WESTERN NUCLEAR, INC.
Wellpinit, Washington

SHERWOOD PROJECT RADIOLOGICAL VERIFICATION COMPLETION REPORT

Volume 2 of 11

REPORT

Prepared By:

SHEPHERD MILLER, INC.
3801 Automation Way, Suite 100
Fort Collins, Colorado 80525

JULY 1996

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(continued)

APPENDICES

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1.0 INTRODUCTION

In October 1994, Western Nuclear, Inc., (WNI) submitted to the Washington Department of Health (WDOH) the report titled *Sherwood Project Radiological Verification Program* (WNI, 1994 et seq.). The report presented the radiological cleanup and verification plan that, following WDOH approval via Amendment 19 to WN-I0133-1 (dated March 22, 1990), was implemented to verify that the residual radionuclide concentrations in all soils within the Sherwood Site that could have been contaminated with byproduct material during milling (with the exception of the tailing impoundment) were below applicable regulatory limits and could be released for unrestricted use. The report also presented a detailed discussion of the relevant history of the site, historical radiological data, and the technical issues that were evaluated to develop the verification program.

This completion report presents the findings of the WDOH-approved radiological verification program and includes the results of all external gamma radiation surveys, soil sample analyses, and all associated supporting documentation, such as laboratory quality control results and instrument calibration/performance checks. Also included in this report is a log describing WDOH-approved revisions to the October 1994 program that were prompted by site-specific conditions.

The results of the verification program and the associated data, provided in Appendix C, show that most areas are at background concentrations, as can be seen in Executive Summary Drawing ES.2. None of the areas currently contain residual radioactive concentrations in excess of the regulatory limits, as depicted in Executive Summary Drawing ES.1, and very few areas approach the regulatory limits, as can be seen in Executive Summary Figures ES.5, ES.6, and ES.7.

The data contained in this report are sufficient to support the conclusion that residual radionuclide concentrations in all areas of the Sherwood Site, excepting the area of the reclaimed tailing impoundment, are below regulatory limits and can therefore be released for unrestricted use.

2.0 REVIEW OF RADIOLOGICAL VERIFICATION PROGRAM

This section presents an overview of the radiological verification program and discusses the verification criteria, the methods and procedures used for verification, and the key program elements, which are subsequently detailed in the remainder of this report. A comprehensive discussion regarding design and validation of the verification program described in this report can be found in the *Sherwood Project Radiological Verification Program* submittal of October 1994 (WNI, 1994 et seq.).

2.1 Background Radionuclide Concentrations

As discussed in Section 2.2, standards for unrestricted release of lands potentially contaminated with byproduct material as a result of milling operations are given in terms of acceptable residual radionuclide concentrations above background. Therefore, in order to demonstrate compliance with the applicable standards, it was necessary to perform a comprehensive characterization of the background soils at the Sherwood Site. The results of the background characterization program indicated that the site consisted of three soil types. Appendix C to the *Sherwood Project Radiological Verification Program* (WNI, 1994 et seq.) provides a detailed discussion regarding the characteristics of the three soil types and their associated background radionuclide concentrations. The sand and float soil types exhibit background ^{226}Ra concentrations of approximately 1.07 pCi/g, while the weathered quartz monzonite soil type exhibits a background ^{226}Ra concentration of approximately 1.44 pCi/g. Relevant findings of the background characterization study that were applicable to the final radiological verification program are:

Background Sample Population Means:

SOIL TYPE	Ra-226 (pCi/g)	$^{238}U + ^{234}U$ (1) (pCi/g)
Sand/Float	1.07	2.14
Weathered Quartz Monzonite	1.44	2.88

(1) For reasons discussed in the WNI submittal to WDOH dated February 7, 1996; uranium was added to the list of constituents of interest subsequent to the initial characterization. Therefore, laboratory data are not available and the background concentrations were accepted by WDOH (via WDOH Amendment # 25, 4/11/96) as the equilibrium value based on laboratory-measured ^{226}Ra concentrations.
(2) As discussed in Appendix C to the Sherwood Radiological Verification Program (WNI, 1994), the soils were characterized for ^{230}Th. However the limits for ^{230}Th, as discussed in Section 2.2.1 of this report, are calculated using total ^{230}Th concentrations. Therefore, ^{230}Th background concentrations were never used.

2.2 Radiological Verification Criteria

The radionuclides of interest for cleanup of byproduct material at the Sherwood Site are ^{226}Ra, ^{230}Th, ^{238}U, and ^{234}U. The compliance limits for these radionuclides are given in Section 2.2.1. Integral to all cleanup efforts is the Washington Administrative Code WAC-246-220-007 mandate to implement as low as reasonably achievable (ALARA) principles in meeting verification criteria. Section 2.2.2 presents WNI's methods for implementing ALARA principles at the Sherwood Site.

2.2.1 Compliance Limits

Radium-226

The verification plan was developed to be in full compliance with the requirements of WAC-246-252, which states that, on a 100-square-meter basis, the average concentrations of residual ^{226}Ra, as the result of byproduct material, must not exceed background levels of ^{226}Ra by more than:

1. 5 pCi/g averaged over the first 15 cm below the surface; and

2. 15 pCi/g averaged over 15 cm thick layers more than 15 cm below the surface.

Thorium-230

Although ^{230}Th limits are not directly addressed by WAC-246-252, ^{230}Th was addressed in the Sherwood Project Radiological Verification Program since it is possible that elevated levels of ^{230}Th (i.e., ^{230}Th not in secular equilibrium with its daughter product ^{226}Ra) could decay to ^{226}Ra, thus producing concentrations above the regulatory limits during the 1,000-year design life given sufficiently elevated initial ^{230}Th concentrations.

The allowable activity of ^{230}Th, based on the maximum ingrowth of ^{226}Ra at 1,000 years, is a function of the initial ^{226}Ra concentration at time = 0 (the present). Therefore, the ^{230}Th activity level was determined by comparing the actual ^{230}Th concentrations to the maximum allowable concentrations of ^{230}Th, such that after 1,000 years, ^{226}Ra concentrations would not exceed 5 pCi/g above background in the top 15 cm or 15 pCi/g above background in 15-cm-thick layers below the top 15 cm of soil. This determination was accomplished using the following ingrowth relationship:

$$A_{(Th,0)} = \frac{A_{(Ra,t)} - A_{(Ra,0)} e^{-\lambda t}}{1 - e^{-\lambda t}}$$

Where:

$A_{(Th,0)}$ = reported activity of ^{230}Th at time = 0 plus the analytic counting uncertainty at the 95% confidence limit;

$A_{(Ra,0)}$ = reported activity of ^{226}Ra at time = 0 plus the analytic counting uncertainty at the 95% confidence limit;

$A_{(Ra,t)}$ = the standard limit of 5 or 15 pCi/g above background;

t = time = 1000 years; and

λ = the decay constant for ^{226}Ra = 4.32E-4 yrs^{-1}.

As discussed in Section 2.1, it was determined that the Sherwood Site is composed of three soil types. The sand and float soil types exhibit background ^{226}Ra concentrations of approximately 1.07 pCi/g, while the weathered quartz monzonite soil type exhibits a background ^{226}Ra concentration of approximately 1.44 pCi/g. Based on these background concentrations, application of the preceding ingrowth relationship was used to determine the following:

- For surface soils (top 15 cm), the limits for ^{230}Th activity levels in sand/float soils range from 15.3 pCi/g at background ^{226}Ra concentrations to 6.07 pCi/g at ^{226}Ra concentrations of 5 pCi/g above background.

- For soils below the top 15 cm, the limits for ^{230}Th activity levels in sand/float soils range from 43.8 pCi/g at background ^{226}Ra concentrations to 16.07 pCi/g at ^{226}Ra concentrations of 15 pCi/g above background.

- For surface soils (top 15 cm), the limits for ^{230}Th activity levels in weathered quartz monzonite soils range from 15.7 pCi/g at background ^{226}Ra concentrations to 6.44 pCi/g at ^{226}Ra concentrations of 5 pCi/g above background.

- For soils below the top 15 cm, the limits for ^{230}Th in weathered quartz monzonite soils range from 44.2 pCi/g at background ^{226}Ra concentrations to 16.44 pCi/g at ^{226}Ra concentrations of 15 pCi/g above background.

Uranium-238 and -234

In April 1995, verification procedures were revised to address a guideline value for uranium which, for surface soils in the top 15 cm, is given by the following equation:

$$\frac{A_{(Ra,t)} - A_{(Ra,Bg)}}{5} + \frac{(A_{(U)} - A_{(U,Bg)}) - 10}{20} \leq 1$$

where:

$A_{(Ra,t)}$ = ^{226}Ra activity at t=0 or t=1000 years (whichever results in the highest activity), accounting for ^{226}Ra ingrowth;

$A_{(Ra,Bg)}$ = background ^{226}Ra activity (1.07 for sand/float or 1.44 for weathered quartz monzonite);

$A_{(U)}$ = activity ^{238}U + activity ^{234}U plus the associated analytic counting uncertainties at the 95% confidence limit; and

$A_{(U,Bg)}$ = background ^{238}U activity + background ^{234}U activity (2.14 for sand/float or 2.88 for weathered quartz monzonite).

When the above-background concentration of uranium is 10 pCi/g or less, the above equation reduces to:

$$\frac{A_{(Ra,t)} - A_{(Ra,Bg)}}{5} \leq 1$$

corresponding to the 5 pCi/g ^{226}Ra limit for surface soils discussed above.

The uranium (^{238}U + ^{234}U) limit for subsurface soils (i.e., below the top 15 cm of soil) is 30 pCi/g above background regardless of the ^{226}Ra activity value, which can vary from background to 15 pCi/g above background.

2.2.2 Soil Cleanup to ALARA

As discussed below, significant effort was given throughout the cleanup and verification programs to implement the ALARA philosophy.

Soils cleanup

Prior to initiation of the final verification program in the spring of 1995, an initial cleanup was conducted in the mill area, resulting in the excavation and removal of 70,000 cubic yards of soil from areas where it was believed that elevated residual radioactivity might exist. When final verification began in March, 1995, soil cleanup was conducted concurrently with verification activities. Areas identified to be above the action limits during verification were excavated (repeatedly if necessary) until gamma readings or soil samples verified that residual radioactivity was reduced to levels below the applicable regulatory limits. Standard procedure for excavating areas identified as requiring cleanup was to over-excavate several feet of material in an effort to lower residual radionuclide concentrations to levels which were ALARA rather than excavation of just surface soil to meet the regulatory limits. By the conclusion of the verification program, an additional 305,000 cubic yards of soil were removed, for a total of 375,000 cubic yards, which were placed below the final cover of the Sherwood Tailing Impoundment.

Establishment of gamma survey action levels

In areas where the presence of ^{226}Ra was indicative of the relative concentrations of ^{230}Th, external gamma surveying was used. The action levels employed during surveying were conservatively set on 90% prediction intervals. A prediction interval of 90% means that 90% of the population is bounded within the interval. Therefore, any single measurement will fall within the 90% prediction interval 90% of the time. In contrast, a 90% confidence limit indicates that there is a 90% probability that the *mean* of the population (the regression line) will be within the confidence limits. As such, prediction intervals must be much wider than confidence limits to accommodate the variability within a population, since confidence intervals must only be wide enough to accommodate the variability that defines the best fit line representing the mean. Therefore, the use of prediction limits to predict compliance of any individual grid based on a single gamma reading is not only more appropriate, but much more conservative than the use of confidence limits.

A 95% limit is often applied to statistical evaluations. Use of 95% limits implies that making an error 5% of the time is acceptable. Of the acceptable 5% error, 2.5% of the time the error will be on the high side of the distribution, and 2.5% of the time the error will be on the low side of the distribution.

In designing the Sherwood verification program, it was recognized that erring on the high side (i.e., a false positive reading, where a grid appears to be dirty by gamma surveying when the actual radionuclide concentration is within the limit) is of no consequence. That is, from a compliance standpoint, false positives lead to the cleanup of soils which are already clean. Therefore, the only error of concern is an error on the low side (i.e., a false negative reading where a grid appears to be clean by gamma surveys when the actual radionuclide concentration is above the limit). Given that the only error of concern is an error on the low side and the typically acceptable error rate is 5%, 90% prediction limits were used. That is, only 5% of the population could represent an error of consequence.

Action level reduction

In an effort to further pursue the ALARA philosophy, gamma survey action limits and soil sample action limits were reduced during cleanup. The conservative gamma survey action limits were reduced by a value of 15% during cleanup, and grids having soil sample results in excess of approximately 2.5 to 3 pCi/g ^{226}Ra or ^{230}Th activity were cleaned and resampled. Although these grids were already within the approved gamma survey action limits or below the regulatory limit for laboratory determined radionuclide concentrations, these efforts were made to reduce the soil concentrations even further so they would approach background levels.

Uranium concentrations

Once residual radioactivity in the soils was believed to be ALARA relative to ^{226}Ra and ^{230}Th concentrations, the issue of uranium was addressed. After initial uranium analyses, all grids identified to contain activity levels over 10 pCi/g of uranium (^{238}U + ^{234}U) were cleaned and resampled.

WNI conducted cleanup using these conservative methods throughout the fall of 1995, until the tailing reclamation construction schedule dictated that interim cover placement be completed. Drawings 1 and 2 provide a schematic of the Sherwood site showing the number of gamma surveys and soil samples taken from each grid, which is representative of the number of times a grid was re-excavated.

The results of the verification program as described in this report, as well as the efforts made toward over-excavation and reduced action limits, demonstrate that most areas are at essentially background concentrations (as depicted in Executive Summary Drawing ES.2) and that ALARA was achieved during soil cleanup.

2.3 Methods and Procedures

Two primary methods of verification were employed to demonstrate that soils were within regulatory limits and could be released for unrestricted use. The methods were: (1) external gamma radiation measurements using both field surveying and laboratory gamma counting of soil sample composites, and (2) laboratory analysis of soil samples. The procedures are summarized below.

2.3.1 Gamma Radiation Measurements

Two types of gamma radiation measurements were used: (1) the integrated survey, which was performed in the field by walking throughout each regulatory compliance grid, and (2) the composite survey, performed by gamma counting a soil sample composite. The design of the gamma surveying techniques and specific operating procedures for conducting the surveys is discussed in Appendix H to the *Sherwood Radiological Verification Program* (WNI, 1994 et seq.).

Integrated Method

The integrated counting method consisted of a timed scaler count that was performed as a technician walked over a 10m x 10m regulatory compliance grid during a 150-second counting period. The scaler count was initiated at one corner of the grid and the technician walked over the grid until the count time expired. The gamma detection probe was shielded using the 1.75-inch-thick, 3-inch-high lead shield that was mounted on a backpack frame. Following each grid count, the grid identification and the total gamma count were electronically stored in the data logger and subsequently transferred to an on-site computer for storage.

The action level for cleanup and verification surveys was determined by the gamma-radium correlation study described in Appendix G to the *Sherwood Project Radiological Verification Program* (WNI, 1994 et seq.). From the correlation study, it was determined that action levels of 2,110 counts per 150 seconds for sand and float soils, and 2,680 counts per 150 seconds for weathered quartz monzonite soils, were appropriate. These action limits were based on the number of counts corresponding to an activity level of 5 pCi/g above background at the lower 90% prediction limit of the gamma-radium correlation.

Composite Method

The second technique used was a soil composite count. The composite method was used as an alternative to the integrated counting method in areas of high shine or in grids that were too steep or the terrain too varied to perform an integrated count. The method was performed by taking a measurement of external gamma radiation on a composite soil sample taken from a 10m x 10m regulatory compliance grid. This procedure was performed by placing the gamma detection probe, shielded with a 3-inch-high, 1.75-inch-thick lead shield, on the surface of the composite soil sample in a 5-gallon bucket.

Gamma-radium correlations were developed using two gamma detection instruments which were distinguished by the instrument serial numbers. Tests comparing readings of the two detector systems indicated that the variability between the systems was less than 10%; however, one system consistently provided lower gamma readings. In order to improve the gamma-radium correlation results for the soil composite counts by eliminating detector variability, a system-specific correlation was performed by counting each archived composite sample with each instrument. The rationale for this procedure was that, while it would not be practical to perform integrated count verification surveys with a single instrument, due to the large number of grids to be surveyed, it might be practical to perform soil composite counts with dedicated instruments, since this method would only be used in a limited number of cases.

From the correlation study, it was determined that action levels of 2,050 counts per 120 seconds for sand and float soils, and 2,100 counts per 120 seconds for weathered quartz monzonite soils, were appropriate for the Serial #98616 instrument. Similarly, action levels of 2,250 counts per 120 seconds for sand and float soils, and 2,380 counts per 120 seconds for weathered quartz monzonite soils, were appropriate for the Serial #98631 instrument. Like the integrated counting method, the action limits were based on the number of counts corresponding to an activity level of 5 pCi/g above background at the lower 90% prediction limit of the gamma-radium correlations.

2.3.2 Soil Sampling

The second method of soil verification consisted of laboratory analyses of soil samples. Samples of the soil within a 10m x 10m regulatory compliance grid were collected by compositing individual core samples taken from the top 15 cm of soil within a grid.

Within any grid, the number of cores needed to adequately represent the mean radionuclide concentrations was determined by the sample adequacy study described in Appendix E to the *Sherwood Radiological Verification Program* (WNI, 1994 et seq.). The results of the study indicated that the number of cores required was dependent on the soil type. Specifically, the number of composite cores required for sand, float, and weathered quartz monzonite were determined to be 9, 15, and 12, respectively.

Verification soil samples were collected using 3-inch-diameter, 6-inch-deep hand augers to obtain each surface soil core. The appropriate number of cores, depending on the soil type, were obtained from a grid and composited in 5-gallon buckets. Each bucket was labeled with the grid identification number from which the sample was obtained, and the buckets were sealed. Following sampling, sample buckets were collected and transported to the sample preparation area. Sample preparation consisted of mixing each sample thoroughly using a commercial-type cement mixer, after which, the sample was split with a riffle splitter to a sample size of 500 to 1000 g, packaged, and shipped to the laboratory for analyses.

Soil samples were analyzed by Yankee Atomic Environmental Laboratory. When analyses for ^{226}Ra and ^{230}Th indicated that residual concentrations were within the applicable regulatory limits, approximately 100 soil samples were analyzed isotopically for uranium, as discussed in Section 2.6.

2.4 Definition of Areas

The initial premise of the design of the Sherwood Radiological Verification Program was that an association between elevated levels of ^{226}Ra and ^{230}Th would exist for all soils potentially contaminated by residual radioactive materials resulting from milling operations. That is, ^{230}Th would be present at elevated concentrations only if ^{226}Ra was also present at elevated concentrations. If such an association actually exists, cleanup and verification of ^{226}Ra (which can be detected by external gamma radiation measurements) would be sufficient to assure cleanup of ^{230}Th (which cannot be detected by gamma survey methods).

However, during the initial site scoping activities in 1993, it was determined that isolated areas existed where an association could not be demonstrated. As a result, the final verification plan contained provisions for verification using soil sampling exclusively in those areas where no association between ^{226}Ra and ^{230}Th existed.

Radiological scoping and correlation studies were performed at the Sherwood Site in 1993. As a result of those studies and for the purposes of cleanup and verification, the Sherwood Site was subdivided into area classifications according to the probability and nature of contamination. Survey and sampling efforts were concentrated toward areas where original site scoping studies indicated that the greatest potential of contamination would exist.

The areas were delineated as follows:

- Areas where there was a high probability of contamination or where contamination was known to exist were classified as Primary areas.
- Primary areas were further divided into Primary-1 and Primary-2 classifications reflecting whether or not an association could be demonstrated.
- Secondary, Tertiary, and Ancillary areas, like Primary-1 areas, were defined as areas where associations were demonstrated but which have decreasing probabilities of contamination. That is, Primary-1 areas have a higher probability of contamination than do Secondary areas. Likewise, Secondary areas have a higher probability of contamination than do Tertiary areas, etc.

As discussed below, the significance of the probability and nature of contamination relate directly to the amount of effort expended in verifying an area for compliance purposes.

Primary-1 Areas

Primary-1 (P1) areas were defined as areas of known or suspected contamination where scoping studies had demonstrated that an association exists between elevated levels of ^{226}Ra and elevated levels of ^{230}Th. Therefore, P1 areas were cleaned up and verified using gamma measurement techniques. These areas, shown in Figure 1, are as follows:

1. Mill area;
2. Tailing discharge line route;
3. Haul road; and
4. Scrap storage areas.

Cleanup and verification procedures in P1 areas were carried out on a 10m x 10m grid basis. First, P1 grids were gamma surveyed. If, based on the gamma survey results, contamination was identified, the grids were cleaned and resurveyed. This procedure was repeated until the gamma survey results indicated the grid was clean or until compliance with one of the performance criteria, described in Section 2.5, was satisfied.

Following gamma surveying, soil from 10% of all P1 grids was sampled and analyzed for ^{226}Ra and ^{230}Th. The purpose of the soil sampling was to confirm that the gamma survey techniques resulted in cleanup of all contaminated materials. The selection of grids to be soil sampled was based on two criteria: (1) even spatial distribution across the contaminated area and (2) high gamma readings. The purpose of selecting grids with the highest gamma readings was to maximize the potential of identifying false negatives (i.e., grids with acceptable gamma readings but with actual radionuclide concentrations that exceed the soil concentration standards).

Primary-2 Areas

Primary-2 (P2) areas were defined as areas of known or suspected contamination where, due to the nature of the contamination, no association between elevated levels of ^{226}Ra and ^{230}Th could be established. Therefore, P2 areas could not be cleaned up or verified by gamma surveying techniques. These areas, shown in Figure 1, are as follows:

1. Mill process area;
2. The area of and the drainage below the claricone tank failure;
3. Barium chloride ponds and the drainage below them; and
4. Evaporation pond.

Since an association between elevated levels of ^{226}Ra and ^{230}Th could not be demonstrated, cleanup and verification of P2 areas was accomplished with soil sample analyses exclusively. Verification procedures in P2 areas were carried out on a 10m x 10m grid basis, and all samples were analyzed by YAEL for ^{226}Ra and ^{230}Th.

Secondary Areas

Secondary (S) areas were defined as areas which were not believed to be contaminated, but where the possibility of contamination existed. Further, secondary areas were defined as areas where no contaminated soil excavation occurred. If, during verification of a secondary grid, it was determined that contamination existed, the grid was reclassified as a Primary-1 area for cleanup and subsequent verification. Secondary areas were also defined as areas where an association existed between elevated levels of ^{226}Ra and elevated levels of ^{230}Th.

Therefore, cleanup of S areas could be verified using gamma measurement techniques. These areas, shown in Figure 1, are as follows:

1. The zone between the mill area and the scrap storage areas;
2. The zone between the mill area and the tailing impoundment;
3. The zone between the mill area and the barium chloride ponds;
4. Tailing impoundment margins; and
5. A 10-meter (1 grid) buffer zone outside all Primary areas (with the exception of grids that would fall outside the exclusionary mine boundary along the western and northwestern sides of the mill area).

   NOTE: The tailing impoundment margins were classified as secondary areas based on the Scoping Study results of 51 soil sample analyses (see Appendix G of the *Sherwood Project Radiological Verification Report* (WNI, 1994 et seq.), which indicated that no contamination existed in these areas. Furthermore, these correlation soil sample analyses indicated that the tailing margin soils did not exhibit radionuclide concentrations above background levels.

Verification of secondary areas was carried out on a 10m x 10m grid basis. First, S grids were gamma surveyed. If, based on the gamma survey results, contamination was identified, the grid was reclassified as a Primary area for subsequent cleanup and verification.

Following gamma surveying, soil from 5% of all S grids was sampled and analyzed for ^{226}Ra and ^{230}Th. Similar to Primary areas, the purpose of the soil sampling was to confirm that the gamma measurement techniques resulted in cleanup of all contaminated materials; therefore, selection of grids to be soil sampled was based on the same criteria described for Primary 1 areas.

Tertiary Areas

Tertiary (T) areas were defined as areas: (1) that have a low probability of contamination and no evidence to indicate that contamination existed, and (2) where no contaminated soil excavation occurred. If contamination was identified during verification of tertiary grid(s), the grid(s) were reclassified as a Primary-1 area for cleanup and subsequent verification. Tertiary areas were also defined as areas where an association existed between elevated levels of ^{226}Ra and elevated levels of ^{230}Th. Therefore, T areas could be verified using gamma surveying techniques. These areas, shown in Figure 1, are as follows:

1. The region inside the existing tailing impoundment diversion channels;
2. A zone extending 100m beyond the tailing impoundment diversion channels; and
3. The region south of the downstream crest of the tailing impoundment embankment.

Since tertiary areas are zones having a low probability of contamination, these areas were gridded and tested on the basis of larger areas, as discussed in NUREG/CR-5849. Tertiary areas were gridded into 50m x 50m areas, as shown in Figure 1, and testing was conducted within a 10m x 10m grid situated at the intersection points of tertiary grid lines.

If, based on the gamma survey results, contamination was identified, the grid was reclassified as a Primary area for subsequent cleanup and verification.

Following gamma surveying, soil from 5% of all T grids was sampled and analyzed for ^{226}Ra and ^{230}Th. Similar to Primary and secondary areas, the purpose of the soil samples was to confirm that the gamma survey techniques resulted in cleanup of all contaminated materials; therefore, selection of grids to be soil sampled was based on the same criteria described for Primary-1 areas.

Ancillary Areas

Ancillary (A) areas were defined as areas for which the probability of contamination is too low to qualify as tertiary areas. However, some documentation of radiological compliance was obtained. Further, ancillary areas were defined as areas where no contaminated soil excavation occurred.

Ancillary areas are as follows:

1. The shoulders of the main road between the mill area and the main gate; and
2. The shoulders of the road between the mill area and the lower pump house.

Ancillary areas were sampled at a frequency of one sample, consisting of a composite from both shoulders of the roads, taken at 500m intervals. Sampling locations for ancillary areas are shown in Figure 2.

2.5 Compliance by Demonstrated Performance

Three performance-based evaluation criteria were developed to be used in lieu of gamma measurements or soil sampling. These criteria address material beneath the ground water table, soil with naturally elevated ^{226}Ra or ^{230}Th background concentrations, and mine overburden material which may have been used as random fill during early site preparation prior to radioactive materials licensing for uranium milling. In all cases, if the performance-based criteria were met, the compliance grid(s) in question were determined to be clean. These criteria are described below.

Criterion 1

The first criterion was that no samples or measurements would be taken in grids with soils that were beneath the ground water table. Radon will not diffuse through saturated materials, and the difficulty associated with excavating and sampling beneath the ground water table makes sampling or removing material neither feasible nor necessary.

Criterion 2

The second performance criterion addressed elevated background concentrations of ^{226}Ra or ^{230}Th in mine overburden that may have been used as fill during site construction and prior to milling operations. It is known that contamination from milling operations would originate from the ground surface. Since ^{226}Ra and ^{230}Th are readily adsorbed in soil, contamination from milling operations will be at the greatest concentrations near the surface and will decrease with depth. If concentrations of ^{226}Ra and ^{230}Th remain constant or increase with depth, the source of the elevated concentrations must be either naturally elevated conditions or mine overburden, rather than contamination from milling operations (11e2 material). Although performance testing was developed in order to account for this possibility, this criterion was never applied during the verification program.

Criterion 3

The third performance criterion addressed elevated background radionuclide concentrations in bedrock material which became exposed during excavation. There is evidence, as discussed in the Sherwood Project Radiological Program (WNI, 1994 et seq.), which indicates that due to the primary and secondary mineralization processes which resulted in formation of the ore body, there is a high variability in background radionuclide concentrations in the quartz monzonite bedrock material at the Sherwood Site. Therefore, regardless of external gamma exposure rate or measured radionuclide concentration, bedrock material was considered to exhibit background radionuclide concentrations. When bedrock was exposed in a cleanup excavation, efforts were made to remove loose material on the bedrock surface, but no excavation of bedrock was made.

2.6 Uranium Analyses

Following initial cleanup and sample analyses, approximately 100 soil samples were analyzed isotopically for uranium. Uranium analyses were conducted only after soil analyses demonstrated that an area was in compliance for ^{226}Ra and ^{230}Th. This approach optimized resources since, if a grid failed for either ^{226}Ra or ^{230}Th, the ^{238}U +^{234}U concentration would be irrelevant because the grid would have to be cleaned regardless of the ^{238}U +^{234}U concentration. Via Amendment 25 to WN-I0133-1 (dated April 11, 1995), WDOH approved this procedure.

The sampling frequencies for uranium were designed to be consistent with the overall radiological verification program philosophy which, as described in Section 2.4, was to concentrate sampling efforts in areas where the greatest potential for contamination existed.

The sampling frequencies, therefore, were as follows:

1. 20% of all P2 claricone spill grids;
2. 10% of all mill process area and $BaCl_2$ drainage/evaporation pond grids; and
3. 5% of all soil confirmation grids.

Note that the area affected by the claricone tank spill was flooded with approximately 39,000 gallons of solution with high uranium concentrations. Therefore, this area was the most likely to exhibit elevated uranium concentrations. As a result of sampling 5% of the confirmation grids, an isolated and previously undetected area was identified in the mill area where uranium was out of equilibrium with its daughter products. It was determined that this area was the likely site of a heap leach pilot plant operated during 1971 and 1972, whose license was terminated by the State of Washington in 1972. This area was subsequently defined and cleaned to the applicable standards using 100% soil sampling.

2.7 Verification Program Results

The following sections of this report provide the verification data obtained to demonstrate that the Sherwood Site has been cleaned to comply with all applicable radiological regulatory limits and can therefore be released for unrestricted use. The report has been subdivided into sections which address each key portion of the data set, as follows:

3.0. Instrumentation

This section provides details regarding the instrumentation used for gamma surveys, including: instrument selection and description, calibration, control charts, and correction factors.

4.0. Data Management and Results

This section describes how verification data were generated and how the data were reduced to a format that could be used for cleanup management and documentation of final verification.

5.0. Quality Assurance/Quality Control of Soil Sample Analyses

The QA/QC of laboratory soil sample analyses was performed in two ways: (1) all laboratory analyses were monitored on a continuous basis using a performance-based QA/QC procedure, and (2) approximately 100 samples were split between WNI's laboratory and WDOH's laboratory for comparative purposes.

6.0 Quality Assurance/Quality Control of Gamma Measurements

The QA/QC of gamma surveys was performed by WDOH in July 1995 and July 1996. The WDOH conducted gamma surveys in a total of 129 randomly selected gamma survey grids.

7.0. Verification Plan Modifications

This section addresses unexpected results encountered during final verification and describes how these situations were resolved.

8.0. Conclusions

This section presents the conclusion that all areas, with the exception of the reclaimed tailing impoundment, contain residual radionuclide concentrations that are below regulatory limits and, therefore, these areas can be released for unrestricted use.

3.0 INSTRUMENTATION

This section presents a discussion of the relevant factors pertaining to instrument selection and calibration, data collection, and data interpretation. Portions of this section are summaries of the instrumentation program as discussed in the *Sherwood Project Mill Decommissioning Plan* (WNI, 1994 et seq.). In addition, Sections 3.2, 3.5, and 3.6 provide details that were not part of the original Sherwood Radiological Verification Plan.

3.1 Instrument Selection and Description

Many types of equipment are available for measuring external gamma radiation. These range from complex multichannel analyzers (MCA) to simple μR meters. The available measurement techniques also range considerably, from an operator-dependent evaluation of the audio signal on a μR meter to a comprehensive gamma spectral evaluation using an MCA.

There were several criteria evaluated to determine the type of equipment that would be utilized. These criteria were:

1. Measurements should be quantitative and operator independent;
2. Readings should be real time so that they could be used to direct clean up activities;
3. Variation within each gamma measurement should be minimized;
4. Equipment should be portable; and
5. Equipment and procedures should provide a simple and readily reproducible method that is time- and cost-effective relative to soil sampling and laboratory analyses.

Based on these criteria and available information, the chosen gamma measurement system consisted of a Ludlum Model 2350 data logger in conjunction with a Ludlum Model 44-10 high energy gamma detector.

Based on the results of the correlation program (WNI, 1994 et seq.), it was determined that the optimum counting time for conducting the gamma measurement methods was 150 seconds for the integrated counting technique and 120 seconds for the composite soil sample counting technique.

3.2 Instrument Configuration

The Ludlum Model 2350 data logger measures radioactive decay with a pulse height analysis circuit. When gamma photons interact with the NaI(Tl) crystal of the detector, the energy deposited in the crystal by the interaction is converted into an electrical signal which is proportional to the amount of energy deposited in the crystal.

The instruments were configured by setting a lower discriminator, or threshold at 20.4 millivolts (mV), meaning that the instrument would only count pulses above 20.4 mV. The upper discriminator is determined by the window setting. The window setting used was 3.3 mV, meaning that the instrument would detect only those pulses between the lower discriminator and a level 3.3 mV above the threshold (23.7 mV). The instruments were then calibrated by adjusting the high voltage supplied to the detector to maximize the number of counts obtained while counting a cesium-137 (^{137}Cs) check source. By setting the threshold and window parameters at 20.4 mV and 3.3 mV, respectively, and adjusting the high voltage so that pulses produced by interaction of the 662 kiloelectron volt (keV) ^{137}Cs gamma photons fell within the window, the pulse height analysis circuit was configured so that 0.1 mV signals from the detector corresponded to 3 kiloelectron volt (keV) of energy deposited in the detector.

Performance checks and field gamma (walkaround) surveys were performed using an open window and a threshold of mV 18.4, or 552 keV. The threshold of 552 keV was selected because it is below the lowest energy gamma photon emitted from bismuth-214 (^{214}Bi) (609 keV) and above the Compton scatter produced within the NaI crystal by ^{214}Bi and low-energy scattered environmental radiation. This was significant because a NaI(Tl) detector's response to gamma photons is energy dependent; that is, low energy photons are more likely to be counted than high energy photons. Therefore, by setting a threshold to exclude low energy photons from being counted, the number of counts observed was influenced more by the energies of interest (i.e., the ^{214}Bi photons). Without this threshold, a small increase in the number of counts resulting from residual ^{226}Ra activity in Sherwood Site soils would be masked by the high number of counts produced by low-energy scattered photons.

3.3 Calibration

Calibration was performed in a reproducible constant geometry relative to the detector, in an effort to eliminate unnecessary variability with respect to the instrument.

In addition to calibration, performance checks were conducted three times throughout each field-surveying day, using a small pitchblende sample. Pitchblende, a uranium ore, was selected as the check source material to ensure that the performance checks were made with the same gamma-emitting nuclides as those being measured in the field (primarily the ^{214}Bi daughter product of ^{226}Ra).

The details of calibration and the associated documentation are discussed in Appendix A.

3.4 Shielding

It was recognized that the effects of extraneous gamma radiation could produce gamma flux measurements that would not necessarily be representative of the soil within a given regulatory compliance grid. Sources of extraneous gamma radiation, commonly referred to as shine, include the following: elevated gamma radiation resulting from elevated ^{226}Ra, ^{40}K, or Th_{nat} in areas adjacent to, but not part of, the grid of interest; and low energy gamma radiation contributed by scattered environmental radiation.

A series of field studies were conducted in May 1993, since little information was available pertaining to effective shielding of environmental radiation. A detailed description of the shielding studies is presented in Appendix D to the *Sherwood Project Radiological Verification Report*, (WNI, 1994 et seq.).

Based on the shielding studies, a 3-inch-high, 1.75-inch-thick lead shield was selected for gamma readings taken by the integrated counting method. This size was chosen for two reasons: (1) additional shield height or thickness was shown to not reduce the shine significantly, and (2) additional size would increase the weight of the shield significantly. Therefore, the marginal benefit of using a larger shield was weighted against the increased difficulty and risk of physical injury in performing the survey.

The same shield configuration was utilized for the composite soil sample counting method, whereby the shield was placed in a standard geometry bucket, allowing the detector to rest directly on top of the soil to be measured.

3.5 Control Charts

As discussed in Section 3.2, performance checks were conducted and recorded throughout each service day for the purpose of generating control charts. A control chart is a tool used to determine if an instrument is drifting outside of acceptable control limits over time. These limits were established as the upper and lower 95% confidence limits, but not to exceed $\pm$ 20% of the mean in accordance with ANSI N323.

Each control chart was based on approximately 30 performance checks (an instrument-month). The mean and control limits of a control chart can vary significantly with the addition of each new data point when the chart is based on only a limited number of data points. Therefore, the fact that a single reading or a few consecutive readings do not fall within the control limits at a given time does not indicate that these same values will not fall within the control limits after sufficient data have been collected to characterize the population. Conversely, readings which are within the control limits at a given time can fall out of the control limits with the addition of data.

During verification more attention was given to performance checks which were low than to those which were high. When an instrument is reading high, the implication is that false positives would result which, from a compliance standpoint, is not of concern as this would only lead to the cleanup of soils which are already clean. In general, the following protocol was observed:

- If a reading fell outside the acceptable control limits, a new reading was taken.
- If the second reading fell within acceptable limits, it was assumed that the instrument was performing within acceptable limits.
- If the second reading also fell outside the acceptable range, the instrument in question was closely observed over the course of the next several control checks to determine if a systematic drift was apparent.

- Additionally, in accordance with ANSI N323, if a performance check was observed to deviate from the mean by more than 20%, the instrument was removed from service and sent to the manufacturer for repair and/or recalibration.

The control charts for the 1995 field work are provided in Appendix A.

3.6 Correction Factors

Gamma survey instruments do not give identical readings in identical gamma flux fields due to slight variations associated with the specific detector and electronics of the instruments. As such, measures were taken to ensure that the instruments used in the field verification program were consistent with the two instruments that were used in the correlation study. The purpose of these measurements was to account for the instrument-specific variations and to normalize the verification measurements to the measurements taken during the 1993 correlation study (WNI, 1994 et seq.).

The 1995 radiological field verification program utilized six gamma survey instruments to determine when residual radionuclide concentrations in soils had been cleaned up to acceptable regulatory limits. Two of these instruments were used to establish the gamma-radium correlation described in the Sherwood Radiological Verification Program Report (WNI, 1994 et seq.).

An instrument-specific correction factor was applied to the raw gamma readings obtained by each instrument in order to normalize the readings of that instrument to the mean readings of the instruments used in developing the 1993 correlation. Using this approach, it was possible to determine if the ^{226}Ra concentrations of soils within a given grid met the regulatory standard by comparing the corrected external gamma radiation measurements directly to the action levels established by the gamma-radium correlation (WNI, 1994 et seq.).

Appendix A provides a discussion that establishes the basis for determining the instrument-specific correction factors, describes the calculations used to obtain these correction factors, reviews studies designed to verify the appropriateness of the correction factors, as well as studies designed to investigate the variability of the instruments.

4.0 DATA MANAGEMENT AND RESULTS

A common problem encountered in the decontamination and decommissioning process is the management of the large amount of data that are collected to demonstrate compliance with applicable standards. This section describes the types of data generated and how the data were reduced. All original laboratory results on verification soil samples are provided in Appendix B and the database used to maintain documentation is provided in Appendix C.

4.1 Data Generation

Three types of data were generated and collected during the cleanup and verification of the Sherwood Site: (1) gamma measurement data; (2) soil sample data; and (3) supplementary data.

4.1.1 Gamma Measurement Data

Gamma measurement data were generated using two types of gamma measurements, as discussed in Section 2.3. When a grid was gamma surveyed, the grid identification was manually entered and the gamma reading was automatically logged into the instrument. The readings were periodically down loaded to data files throughout the day. These data files were imported into a spreadsheet that was used to determine the status of each grid (i.e., verified or failed). After the status was determined, grid identification numbers were checked against a master database to ensure the identification numbers in the data file corresponded to actual grids. After the data file was checked, the gamma readings, grid identification, survey date, and grid status were imported into the verification database. No physical documentation was necessary since all gamma survey data were handled electronically.

4.1.2 Soil Sample Data

Two types of soil samples were collected to determine grid compliance: composite gamma survey and verification/confirmation.

Composite soil samples for gamma measurement were collected in areas of steep terrain where an integrated, walkaround gamma survey method was not feasible. Composite samples were collected; homogenized; split, if necessary; and measured in a laboratory using gamma instrumentation.

Verification/confirmation soil samples were collected, homogenized, split, and shipped to the laboratory for radionuclide analyses. The data for both types of samples were collected and tracked electronically using a lot numbering system. The details of this system are contained in Appendix B.

4.1.3 Supplementary Data

In addition to the soil sample and gamma survey data, supplementary data were generated. The supplementary data were generated for three purposes:

- To document changes to the Verification Program (i.e., grid modifications);
- To document compliance based on performance criteria; and
- To simplify data tracking during cleanup.

Each of these types of supplementary data are discussed in the following sections.

4.1.3.1 Grid Modifications

As the final radiological verification project evolved, it was recognized that modifications to the Verification Program would be required. Therefore, a change log, provided in Appendix D, was developed to catalogue the modifications. The supplementary data from the change log was incorporated into the database in the form of records. These records, provided in Appendix C, documented the grid modifications, which included:

1. **Excluded Grids** - Grids that were inadvertently placed on mine overburden or the tailing impoundment surface were excluded from the Verification Program. These grids are shown in Drawing 3. Correspondence between WDOH and WNI documenting the exclusion of the grids is included in Appendix I.

2. **Soil Reclassifications** - Soil reclassification was conducted for one of the following reasons: (1) Initially, areas of weathered quartz monzonite were mapped on a gross scale based on competent bedrock and structure. It was later determined that weathered quartz monzonite encompassed a much larger portion of the site in the form of coarse to medium-fragmented material. (2) In some cases, excavation during cleanup resulted in a change of material type (i.e., the upper soil was removed, which revealed a new soil type). The reclassified grids are shown in Drawing 4.

3. **Area Reclassifications** - As a result of gamma surveys or soil sample analyses, some secondary grids were identified as contaminated. The secondary grids were reclassified as Primary grids in accordance with Appendix H of the *Sherwood Project Verification Program Report* (WNI, 1994 et seq.).

   In addition to reclassification of grids due to identification of contamination, several periodically spaced grids on the haul road running from the mill process area and claricone spill area to the tailing impoundment were reclassified as P2 grids. Since the mill process area and claricone areas were classified as P2 areas (i.e., 100% soil sampling) it was determined that the haul road out of these areas should be spot checked to demonstrate that significant spillage of P2 material had not occurred during removal of material from these areas.

   All reclassified grids are shown on Drawing 4.

4. **Additional Grids** - When a secondary grid constituting a "buffer zone" grid (WNI, 1994, Appendix H, page H.8) around a Primary area was reclassified, the addition of a new buffer zone of secondary grids was necessary. Also, new grids

were added in the solution holding pond and on the solution holding pond embankment. These grids were used to demonstrate that the material under the liner was in compliance and that material could be excavated from the embankment. Additionally, grids were added to the haul road out of the evaporation pond to demonstrate that no significant spillage had occurred during removal of material from the pond. All additional grids are shown in Drawing 3.

4.1.3.2 Compliance By Demonstrated Performance

Supplementary data were generated to demonstrate compliance based on the performance criteria discussed in Section 2.5. For site-specific conditions, performance criteria were developed as an alternative to gamma measurements or soil sampling. These criteria addressed: (1) grids below the ground water table; (2) grids with naturally elevated radionuclide concentrations; and (3) grids which were in bedrock. Performance Criterion 2 was not applied; however, Criteria 1 and 3 were used. Documentation of such grids is recorded in the database as verified "ground water" or verified "bedrock." The location of these grids is shown in Drawing 5.

4.1.3.3 Cleanup Monitoring

Procedures for generating supplementary data to simplify data tracking were adopted in April 1995, approximately one month into the project. The need for such procedures became evident when the data set grew to a size that made it difficult to determine where, and when, areas had been cleaned.

To distinguish grids that had been excavated following the last gamma survey or soil sample, a record was developed to document the date of the excavation and to indicate that the grid status was cleaned and ready to be resurveyed or resampled.

4.2 Compliance Status and Data Reduction

Data reduction was necessary to consolidate all available information into a concise format which could be used as a basis for making decisions regarding day-to-day cleanup and verification activities and to document that areas were verified as being releasable for unrestricted use. However, due to the scope of this project and the complexity of the data set, the amount of data generated made conventional data reduction techniques ineffective and cumbersome. The following sections detail the data reduction system, which ultimately utilized the last set of data collected for any compliance grid to demonstrate that residual radionuclide concentrations were below applicable regulatory limits.

4.2.1 Project Scope and Complexity

Several issues were identified during the preliminary investigation of the Sherwood Site. These issues complicated data reduction by increasing the possible data combinations used to demonstrate regulatory compliance. The complicating issues were as follows:

1. **Soil Type** - Using the background sample results, two background concentrations of natural ^{226}Ra content in soil were identified (one for weathered quartz monzonite and one for sand/float). The cleanup requirements, which are given in terms of acceptable ^{226}Ra concentrations above background levels, became soil specific, meaning the cleanup levels for both the gamma surveys and laboratory results became soil specific.

2. **Gamma Measurement Methods** - Two types of gamma measurements, each with a specific gamma action level, would be used. This factor, coupled with the soil types, made the cleanup levels dependent on both the soil type and the gamma measurement method, thereby ultimately resulting in six different cleanup and verification action levels.

3. **Area Designation** - Special areas were identified where there was not necessarily secular equilibrium within the ^{238}U decay series, which meant that detection of elevated ^{226}Ra levels would not guarantee detection of elevated ^{230}Th levels. Therefore, gamma measurements were not used for detection of contamination. These areas were designated as 100% soil sampling areas.

4. **Confirmation Sampling - Confirmation samples were taken in a certain percentage of all** gamma measurement grids to demonstrate the continued reliability of the gamma measurement techniques. Sampling frequencies were designed to be consistent with the overall program philosophy, which was to concentrate sampling efforts in areas where the greatest potential for contamination existed. Since the contamination potential differed to a great degree, two sampling frequencies were used. In areas where contamination was more likely to exist (i.e., P1 and P2 grids in the mill area), the confirmation sampling frequency was designated as 10%. In all other areas where contamination could exist but was not likely to exist (i.e., S, and T grids), 5% of the grids were sampled.

5. **Cleanup -** During the course of the project, many grids were identified to be above the action limits and, therefore, they required cleanup and resampling. It was necessary to be able to identify these areas on a real-time basis to avoid undue delays in performing additional excavation and to schedule resurveying and resampling after excavation was complete.

6. **Project Extent and Timeline -** A grid system consisting of approximately 4,420 contiguous 10m x 10m grids were placed over an area of approximately 110 acres, and approximately 170 acres were gridded with 330 10m x 10m grids which were placed on 50m centers. The survey coordinates and elevation of each grid are shown in Appendix H. By the conclusion of this project, nearly 10,000 grid records had been generated and tracked for more than a year (1995-1996). During the peak of verification operations, several hundred pieces of data were generated daily.

As a result of the complicating issues described above, demonstration of compliance became a function of gamma measurement methods, soil type, nature of contamination, and cleanup activities. This resulted in a complex data set which could have proven difficult to keep accurate and sufficiently detailed to demonstrate compliance while being sufficiently current to direct project activities. Therefore, a geographic information system (GIS) was developed to handle and reduce the data.

4.2.2 Geographic Information System

A GIS is any system that links geography and data. The most common method for doing this is to link a map to a database. The system developed for this project was composed of four elements: (1) a relational database, (2) an AutoCAD base drawing, (3) the AutoCAD Data Extension (ADE) program, and (4) queries (*custom programs*).

The relational database was used to store information such as gamma survey results, laboratory results, and dates, on a grid-specific basis. An AutoCAD base drawing was produced, which consisted of the grid entities with attributes that contained the information necessary to uniquely identify an individual grid. The purpose of the ADE program was to generate color-coded maps by executing queries which identified the current status of the grid as recorded in the database and assigned a corresponding color code to the grid. Examples of such progress maps are provided in Drawing 6.

4.2.2.1 Relational Database and Base Drawing Construction

Database and base map construction require that a unique identifier (grid identification) common to both the data records and the AutoCAD entities be assigned to each grid. The database was designed to associate information such as gamma readings, lot number, laboratory results, testing procedure, date, and grid status to the unique identifier. The AutoCAD base map attaches information such as color, thickness, text value, and entity type to this unique identifier. Once the information has been associated to the unique identifier, ADE provides the link that allows the information to flow from AutoCAD to the database and vice versa.

4.2.2.2 Map Generation using ADE and Queries

Since project progress depended on the ability to distinguish between verified and unverified areas, ADE was used to execute queries which selected the current status of the grid in the database and assigned representative colors in AutoCAD. Progress maps were generated to reflect the status of each grid using the following colors:

Green =	VERIFIED	- gamma measurement or verification soil sample grids in compliance.
	VALIDATED	- confirmation grids in compliance.
Red =	FAILED	- gamma survey or verification soil sample grids out of compliance.
	UNVALIDATED	- confirmation grids out of compliance.
Yellow =	PENDING	- verification grids awaiting laboratory results.
White =	CONFIRMATION	- confirmation grids awaiting laboratory results.
Gray =	INCOMPLETE	- grids awaiting gamma surveys or soil sampling.
Purple =	EXCLUDED	- grids that were excluded from the original plan.

For further definition of status, see Appendix C.

4.3 Results

The final verification results along with the history of each grid is presented in Appendix C, wherein the final gamma readings and laboratory results are shown shaded. Upon review of Appendix C, the following may be noted:

- Initial measurements revealed that 95% of all gamma and soil sample grids were below the applicable regulatory standards for ^{226}Ra.
- 85% of all gamma grids and 60% of all soil sample grids are currently at essentially background levels (less than 2 pCi ^{226}Ra/g).
- All gamma and soil sample grids that were in excess of the limits for ^{226}Ra of ^{230}Th, were excavated until results indicated radionuclide concentrations were below the applicable limits.

- In an effort to implement ALARA, 10% of all passing gamma grids, and 35% of all passing soil sample grids were excavated to further reduce residual radionuclide concentrations in soils.

- After acceptable soil concentrations were achieved, approximately 200 grids were sampled for uranium ($^{238}U+^{234}U$), 95% of which were below the WDOH guideline.

5.0 QUALITY ASSURANCE/QUALITY CONTROL OF SOIL SAMPLE ANALYSES

Extensive QA/QC of laboratory results was performed throughout the course of verification sample analyses. The three separate programs described below contributed to the overall QA/QC of the laboratory results.

The primary QC, conducted by Yankee Atomic Environmental Laboratory, consisted of internal laboratory QA/QC of analytic results. This program consisted of internal laboratory controls such as analytical blanks, matrix spikes, and duplicates that were prepared with each sample batch. The results of these controls were required to be within specific acceptability criteria. The details of the internal QC program, as well as the acceptability criteria, are discussed in Section 5.1.

For secondary QC of analyses, WNI administered a performance-based quality program by submitting a blind performance evaluation sample (PES) with approximately every 20 samples. If the results on the blind sample were reported to be within the established criterion, the accompanying sample analyses were accepted. A summary of the PES program is provided in Sections 5.2 and 5.3, while the details are described in Appendix E.

Finally, independent QA/QC of analytic results and confirmation of regulatory compliance was provided by the WDOH. Approximately 100 samples were split between WNI's laboratory and WDOH's laboratory for the purpose of comparison and regulatory confirmation. A discussion of these split samples is presented in Section 5.4.

5.1 Internal Laboratory Quality Assurance Quality Control

The internal laboratory QA/QC was designed to assess the laboratory's precision, accuracy, and overall capabilities at adequately conducting the requested analytical methods. Three analytic QC indicators were used for every sample set of 20 or fewer samples to assess the laboratory's performance. The three indicators used are detailed below.

1. Analytical Blank

   An analytical blank is a water sample that is prepared and analyzed with the sample batch as an indicator of any potential contamination that could have been introduced at the laboratory. It is not feasible to use a soil matrix for the blank, since any soil will naturally contain some level of the analytes of interest, such as uranium or thorium. An acceptable laboratory blank is defined as having an activity which is less than three times its corresponding one standard deviation. If the activity of a blank exceeds these limits, the entire sample set is prepared and analyzed a second time. The results of all laboratory blank analyses are provided in Tables 1, 2, and 3 for ^{226}Ra, ^{230}Th, and isotopic uranium, respectively.

2. Matrix Spike

   The matrix spike is an indicator of accuracy, that is, how close the laboratory can come to a known value. Due to the inherent problems associated with spiking a soil matrix, the matrix spike used was a National Institute of Standards and Technology (NIST) standard reference material having known constituent concentrations. The NIST standard used was prepared and analyzed in the same way as the verification samples in each sample set. Agreement for spike results was accepted if the individual value was within 15 percent or two standard deviations of the known value. The results of all laboratory QC spike analyses are provided in Tables 4, 5, and 6 for ^{226}Ra, ^{230}Th, and isotopic uranium, respectively.

3. Duplicate Results

   Duplicates are an indicator of precision, that is, reproducibility of analytic results. Duplicates are an integral part of laboratory QA/QC since it is important that the data are reproducible as well as correct. Duplicates were obtained by taking two aliquots from one sample of NIST standard reference material. This method was chosen over duplicate analysis of verification samples since it allowed for tighter control limits on reproducibility than would have been possible using verification samples due to the inherent variability of field samples. The aliquots of the NIST standard reference materials were prepared and analyzed as separate samples with the rest of the verification sample set.

Duplicate results were accepted if the paired measurements were within 15% of their average value or if the two standard deviation range established for each of the analysis results overlapped. The results for all laboratory QC duplicate analyses are provided in Tables 7, 8, and 9 for ^{226}Ra, ^{230}Th, and isotopic uranium, respectively.

As can be seen from Tables 1-9, all internal laboratory QA/QC results fell within the specific criteria, and all associated data was accepted.

5.2 Performance-Based Quality/Assurance Quality Control of Laboratory Analyses

Historically, many QA/QC programs for radiochemical analyses of soil samples, as well as other matrices, have used replicate analyses of samples. There are essentially two methods for performing replicate sample analyses. The first method is inter-laboratory comparison, which involves the analysis of split samples among two or more laboratories. The second method is intra-laboratory comparison, which involves the multiple analyses of samples within a single laboratory.

In cases where an inter-laboratory comparison is used, if the results from two or more laboratories using the same analytical method compare favorably, there is some assurance that the reported results are both precise and accurate. However, if two laboratories report significantly different results on any given sample, it is difficult to determine which, if any, laboratory has reported correctly, and a costly search for both precision and accuracy typically results.

In cases where intra-laboratory comparison is used, if the results on a single sample compare favorably, the only assurance is of precision (i.e., reproducibility) with no assurance of accuracy.

Therefore, the use of inter-laboratory or intra-laboratory comparisons are, by themselves, inadequate to effectively evaluate the quality of laboratory results. However, by combining aspects of both methods, a hybrid QA/QC procedure for assessing laboratory results was developed around the concepts of the Standard Reference Sample (SRS) and the Performance Evaluation Sample (PES).

The principal strategy of this QA/QC plan can be stated as follows: if a laboratory can initially demonstrate acceptable analytic precision and accuracy for preset data quality objectives on the SRS, an acceptance criterion based on analytic precision alone can be established for analytical results on subsequent PESs. This strategy assumes that ongoing intra-laboratory QC is also acceptable. Section 5.3 describes the criteria used to determined if PES results are acceptable, as well as the procedure to be used if PES results are not acceptable. A complete discussion of the PES program is contained in Appendix E.

5.3 Assessment of Performance Evaluation Sample Results

PESs were used on a continuing basis during verification. For each soil sample set of 20 or fewer samples, one PES aliquot was submitted blindly to the laboratory for analysis. Upon receipt of analytic results for a sample set, the corresponding PES results were reviewed to determine if they were within the established acceptable limits. Table 10 summarizes the laboratory data used to establish the PES control limits, and Table 11 provides those control limits. If the results were found to be within the established range, the results were accepted. If the results were not within the established range, additional procedures were followed to determine if the failure was due to laboratory error or to variability within the PES, as discussed above. The results of all PES analyses for QA/QC of verification samples are provided in Table 12 and can be cross-referenced to the sample lot using their sample set lot number.

If the results of the PES analysis were not acceptable, four samples from the corresponding sample set were retested. One of the samples retested was the PES associated with the sample set. A review of the retest results and all internal laboratory QA/QC for both the original and retest results was conducted. If the retested sample results were similar to the original results, and all internal laboratory QA/QC data were within acceptable limits, the results on the original sample set were accepted and the original failed PES results were attributed to variability. Table 13 summarizes the results for all retested sample sets. As can be seen on Tables 12 and 13, all PES results were acceptable, either initially or upon reanalysis.

5.4 WDOH/WNI Split Samples

As discussed in Section 5.0, an independent component of QA/QC of analytic results was provided by the WDOH. As discussed in the WNI correspondence to WDOH on July 19, 1996 (correspondence reproduced in Appendix I) approximately 100 split samples were analyzed by the WDOH, 70 of which represent the existing surface soils and therefore constitute regulatory confirmation samples. The locations of the grids sampled are shown on Drawing 7. The soil analysis results were evaluated by comparing the WDOH results to the primary laboratory results on a population basis. Tables 14, 15, and 16 present the results from both laboratories for ^{226}Ra, ^{230}Th, and ^{238}U, respectively.

The evaluation was conducted using a matched paired t-test. The data were considered acceptable if there was no apparent difference in the means of the two populations sampled. A significant difference between the two sample population means would imply a difference in laboratory results. If a significant difference in means occurred, the only assumptions were that: (1) the relative frequency distribution of the population of differences was approximately normal and (2) the paired differences were randomly selected from the population of differences.

The following procedure was used to determine if the means were the same:

1. Determine the t-distribution test statistic.

   The test statistic was determined by the following expression:

$$t = \frac{\bar{x}_d}{\left(\frac{S_d}{\sqrt{n_d}}\right)}$$

Where:

$t=$ t-distribution test statistic;

$x_d =$ the mean of the sample population composed of the difference in values between WNI and WDOH analytic results on individual split samples;

$S_d =$ the standard deviation of the sample population composed of the difference in values between WNI and WDOH analytic results on individual split samples; and

$n_d =$ the number of difference values in the sample population.

2. Determine the $t_{critical}$ value.
   The $t_{critical}$ value was determined from a standard t table using a two-tailed level of significance (the *a* risk for when the means are equal) of 0.05 at n_d -1 degrees of freedom.

3. Determine if the population of primary laboratory split samples is the same as the population of WDOH split samples.

   This determination was made by considering the following two hypotheses:

Null Hypothesis:	H_0: $\mu_1 = \mu_2$
Alternative Hypothesis:	H_a: $\mu_1 \neq \mu_2$

   If $-t_{critical} \leq t \leq +t_{critical}$, the null hypothesis, was accepted, meaning that the primary split laboratory sample population were not statistically different from the WDOH split sample population.

However, if $t < -t_{critical}$ or $t > +t_{critical}$, the null hypothesis was rejected in favor of the alternative hypothesis, meaning that the primary laboratory split sample population was statistically different from the WDOH split sample population.

After a comparison was made using a paired t-test, a linear regression was performed to determine the difference between the populations. A discussion of the linear regression is found in Section 5.4.3. The results of the statistical analyses comparing the WDOH sample set to the WNI sample set are presented below.

5.4.1 Comparison Results

As discussed above, the WDOH/WNI split samples were compared using a paired t-test to determine if the means of the two populations (i.e., the WNI and the WDOH split samples) were significantly different. The results are summarized below, the split sample data that were compared are provided in Tables 14 through 16, and Appendix F contains the output of the analyses, including linear regression plots of the paired data.

Radium-226

The results of the paired t-test on ^{226}Ra analyses indicate that the two population means were not significantly different. The population means differed by 2.1%, with WDOH on the low side.

Thorium-230

The results of the paired t-test on ^{230}Th analyses indicate that the two population means were significantly different. The population means differed by 9.7%, with WDOH on the high side.

Based on the analysis results, two outlying observations were identified where WDOH reported significantly higher ^{230}Th results than did WNI. The outlying observations compare as follows:

Grid ID	WNI Th-230 (pCi/g)	WDOH Th-230 (pCi/g)
C3-479495F	4.54 ± 0.32	12.4 ± 0.3
C3-582599F	2.26 ± 0.20	15.7 ± 0.3

Both of the grids from which the discrepant samples were taken are located in the evaporation pond, which is shown on Figure 3.

Both of these discrepant samples were taken from grids which had previously been excavated and resampled. That is, when initial WNI analyses indicated that grids should be cleaned further, the grid was excavated and resampled. In some cases, WDOH was on site at a time that was convenient to allow WDOH to receive a split of the subsequent sample. Therefore, WDOH received two samples from some grids-one sample from before excavation and one from after excavation.

Grid ID	Date	WNI Th-230 (pCi/g)	WDOH Th-230 (pCi/g)
C3-479495F	April '95	5.65 ± 0.32	5.76 ± 0.21
C3-479495F	July '95	4.54 ± 0.32	12.4 ± 0.3
C3-582599F	April '95	5.35 ± 0.40	7.11 ± 0.25
C3-582599F	July '95	2.26 ± 0.20	15.7 ± 0.3

Without these two discrepant samples, the two populations pass the t-test; that is, the means of the populations are no longer significantly different and the bias in the mean is reduced to less than 4.5%, with WDOH on the high side.

Uranium-238

The results of the paired t-test on ^{238}U analyses indicate that the two population means were significantly different. The population means differed by 13.3%, with WDOH on the low side. Because WDOH is biased to the low side, the population difference is of no consequence from a compliance standpoint.

5.4.2 Situation Analysis

From a compliance standpoint, only the split sample analyses on ^{230}Th are of consequence. Based on correspondence dated June 10, 1996 this issue was resolved by WNI adjusting its ^{230}Th values to be consistent with the WDOH data population, and taking appropriate actions to assure compliance with applicable requirements. The method of adjustment, and the compliance actions taken are discussed in Section 5.4.3.

5.4.2.1 WNI Analytical Results

Laboratory Selection

All soil samples analyzed for radionuclide concentrations were analyzed by Yankee Atomic Electric Laboratory (YAEL). This laboratory was initially selected based on their well-known reputation for performing excellent radiochemical analyses. YAEL is one of the few private laboratories used by the NIST for characterization and standardization of NIST-certified primary reference material samples. Additionally, the laboratory manager, Dr. David E. McCurdy, is a recognized industry expert and chairs the ANSI N42.2 subcommittee on measurement and associated instrumentation quality assurance for radioassay laboratories. Furthermore, Dr. McCurdy and YAEL have directed, produced and distributed quality control samples since 1987 for some of the most extensive third-party measurement assurance programs in the United States. Participants in these programs include six national utilities and three federal government agencies.

Following initial selection of the laboratory and prior to characterization of the WNI PES, YAEL was subjected to a blind QC check of their analytical results by submission of a standard reference soil sample (NIST SRM#4353). It should be noted that YAEL did not participate in certification of this particular sample and, therefore, no propagated bias can be inferred. As discussed in Appendix E, YAEL's reported results were correct; that is, the two sigma uncertainty associated with YAEL analyses were within the two sigma uncertainty of the certified value. It must be noted that YAEL uncertainties were *counting error only*, which is a more restrictive comparison than if total propagated error had been considered. Therefore, it was determined that YAEL was readily capable of producing accurate results.

<u>QA/QC of Verification Sample Analyses</u>

As discussed in Section 5.2 and Appendix E, the PES was characterized for the purpose of providing continuous QC of analytic results throughout the duration of the verification program. The principal philosophy of the QA/QC program was as follows: if the laboratory could initially demonstrate acceptable analytic accuracy for preset data quality objectives, then, an acceptance criterion based on analytic precision alone could be established for analytic results on subsequent samples. That is, if the laboratory could initially produce correct results on the SRS, then

QA/QC of subsequent samples could be accomplished by continuously producing the same results on the same sample (i.e., precision on the PES).

Based on the characterization, control limits were established using 5 and 95 percentile parameters. The control limits were used for QC of laboratory results throughout the verification program. As discussed in Section 5.0 and 5.2, a PES aliquot was submitted blindly to the laboratory with every 20 or fewer samples. Aliquots found to be outside of the control limits were investigated to determine if the aliquot had failed due to variability in the PES or due to laboratory error. This investigation was conducted by reanalysis of the PES in question and 3 other samples from the sample set represented by the PES. If the results of the reanalysis were similar to the initial analyses, and all internal laboratory QC (i.e., splits, blanks, and duplicates as discussed in Section 5.1) were within control for both the original sample set and the retested sample set, the results were accepted. Table 12 provides a listing of all PES analyses performed during verification, and Table 13 presents the original and retest results on PES samples found to be out of control.

It can be seen from Tables 12 and 13 that out of 102 analyses, one PES analysis was out of control for ^{226}Ra and seven PES analysis were out of control for ^{230}Th. It should be noted that, if the population of PES aliquots were normally distributed, as many as approximately 10 out of 100 samples could be expected to fail for both constituents due to variability alone, based on the 5 and 95 percentile parameters used to establish the control limits.

Post-Analytical Review of YAEL Results and Traceability

When it was determined that a statistical difference existed between WNI and WDOH analytical results, WNI requested that YAEL review all analyses conducted on NIST-traceable materials (see Section 5.1 regarding matrix spikes and duplicates), compare YAEL analytical results on NIST-traceable materials to acceptability criteria used by national measurement assurance programs (MAPs), and to discuss YAEL performance in national quality assurance programs (QAPs).

The results of this review, provided in Appendix G, indicated that while there is a consistent bias in the analyses performed on certified NIST-traceable materials, this bias is within the acceptance range for all major national MAPs and that YAEL's performance in national QAPs has historically been very good.

5.4.2.2 WDOH Analytical Results

The WDOH provided analytical analyses on the PES aliquots. Table 17 presents the analyses results on the PESs as reported by WDOH, and Table 18 presents a reproduction of the WDOH data as received.

5.4.2.3 Comparison of YAEL to NIST Reference Material

By contract, YAEL analyzed batch QC samples of known radionuclide concentrations with every set of Sherwood Site soil samples analyzed. The QC material assayed included: 230Th - NIST SRM Rocky Flats (#4353) or Peruvian (#4355) soils; 238U - Rocky Flats (#4353) soil; and 226Ra - YAEL Standardized/Certified UMTRA soils (MK GUNA16-B and MK GUNB32-A). A statistical evaluation of the results for the 230Th batch QC samples indicates the existence of a general negative bias with respect to the quoted values: the mean of 76 assays had a -3.99% bias (1.15 ± 0.09 pCi/g) compared to the Rocky Flats soil content of 1.197 ± 0.020 pCi/g, and the mean of 80 assays had a -7.05% bias (1.00 ± 0.09 pCi/g) compared to the Peruvian soil content of 1.073 ± 0.018 pCi/g. A negative bias was also found for the uranium batch QC samples of Rocky

Flats soil: the mean of 23 assays for 234U had a -4.52% bias (1.009 ± 0.065 pCi/g) compared to the Rocky Flats soil content of 1.057 ± 0.013 pCi/g, and the mean of 23 assays for 238U had a -8.36% bias (0.963 ± 0.071 pCi/g) compared to the Rocky Flats soil content of 1.051 ± 0.018 pCi/g. No significant bias was found for the ^{226}Ra batch QC samples of YAEL-certified soil materials: the mean of 38 assays for ^{226}Ra had a -2.22% bias (65.9 ± 1.9 pCi/g) compared to the MK GUNA16-B soil content of 67.4 ± 1.1 pCi/g, and the mean of 38 assays for ^{226}Ra had a +1.11% bias (51.1 ± 5.1 pCi/g) compared to the MK GUNB32-A soil content of 50.5 ± 0.8 pCi/g. A copy of the tabulated results is included in Appendix G.

Based on the batch QC samples, it appears that YAEL may have a slight negative bias for ^{230}Th and the isotopes of uranium in soils. These observed biases, however, are well within the range of acceptable performance criteria used by national assurance programs, as discussed in Appendix G.

5.4.3 Resolution of Split Sample Population Discrepancies

To summarize, the WNI/WDOH split sample results indicate no significant difference between the two laboratories for ^{226}Ra, and the results for ^{238}U indicate that the population means differ by 13.3%, with WDOH on the low side. Given that the ^{226}Ra split samples compared favorably and WNI is comparatively conservative for ^{238}U, no compliance issues exist regarding verification soil samples relative to these radio nuclides.

From a compliance standpoint, only the split analyses on ^{230}Th are of consequence. The population means statistically differed, with the WDOH sample population mean exceeding the WNI mean by 9.7%. As demonstrated in Appendix F, the best fit linear regression line of the paired data is expressed by the equation:

$$WDOH = 1.04WNI + 0.3$$

Where *WDOH* is the analytic result obtained by WDOH in pCi/g, and *WNI* is the analytic result obtained by WNI in pCi/g.

In an effort to bring final radiological closure to the Sherwood Site, WNI agreed, under protest, to adjust all ^{230}Th analyses in accordance with the above equation and to accept the WDOH analytical results on the grossly discrepant analyses discussed in Section 5.4.1. It must be emphasized however, that based on Yankee Atomic Environmental Laboratory's consistent and continuous excellent performance in national QA/QC programs, the internal laboratory QA/QC program discussed in Section 5.1, and the WNI administered performance-based QA/QC program discussed in Section 5.2, the analytic results for all verification data produced by YAEL should be considered accurate and precise within an acceptable level of uncertainty.

The impacts relative to the Sherwood Radiological Verification Program are listed below:

1. If all soil sample analyses for 230Th are adjusted in accordance with the above equation, three grids would exceed the release criterion for surface soils. These grids are:

   C1-396419F - This grid is situated in the truck shop roadway. This grid was not previously included in the truck shop road exclusionary area (see April 3, 1996 WNI Revision #14 to the April 1992 Sherwood Mill Decommissioning Plan as approved by WDOH on May 6, 1996 via Amendment No. 27 to WN-I0133-1), since the grid previously passed based on no adjustment.

Following WDOH inspection of the grid and confirmation that the grid was backfilled with mine overburden, WNI submitted the June 19, 1996 Revision #15 to the April 1992 Sherwood Mill Decommissioning Plan, and WDOH approval remained pending at the time of submittal of this Radiological Verification Completion Report.

C3-478454F and M1-296333F - The C3 grid is situated in the (barium chloride) evaporation pond drainage, and the M1 grid is situated in the western part of the mill site. These grids are both in areas that will be backfilled as part of the final regrading. As a result, both these grids will be backfilled and verified using the subsurface radiological standards, as approved via the WDOH letter dated April 4, 1996.

2. Two grids (C3-479495F and C3-582599F) in the bottom of the (barium chloride) evaporation pond would pass if WNI data are adjusted, but would fail if WDOH data are used. Because the July 1995 WNI/WDOH split sample data differ significantly, the Sherwood Radiological Verification Protocol approved by WDOH specifies that the grids be treated on an individual basis.

   Since both grids will pass the subsurface radiological standards using either WNI or WDOH data, these grids will be backfilled and verified using the subsurface standards, as approved via the WDOH letter dated April 4, 1996. For purposes of confirming that these grids have been backfilled with a minimum of six inches of soil, the elevations of the center point of each grid that will be verified using the subsurface standards are given on Drawing 14. Following backfilling of these grids, an addendum to this report will be filed providing the final backfilled elevation of these grids.

6.0 QUALITY ASSURANCE/QUALITY CONTROL OF GAMMA MEASUREMENTS

In addition to the three types of QA/QC of laboratory results performed throughout the course of the verification program, QA/QC of gamma measurements was also conducted. The WDOH performed gamma surveys in a total of 129 randomly selected gamma survey grids; 90 in July 1995 and 39 in July 1996, the locations of which are shown on Drawing 8. The results of the WDOH gamma surveys were compared to the original results, and are contained in Tables 19 and 20. In 1995, the mean of the WDOH results was 1596 total counts, while the mean of the original results was 1565 total counts. In 1996, the mean of the WDOH results was 1521 total counts, while the mean of the original results was 1474 total counts.

The WDOH result was subtracted from the original result to quantify the difference between the two readings. These differences were then plotted according to frequency distributions as shown on Figures 4 and 5. The sample populations show a normal distribution, which is centered near zero, demonstrating that the results compare favorably.

Further, the primary purpose of the grids selected in 1996 was to demonstrate that, on a random basis, no area was identified to exhibit gamma readings above the action level. As can be seen in Table 20, no grid was identified to exhibit a gamma reading above the action level of 2110 counts per 150 seconds in sand/float grids, or 2680 counts per 150 seconds in weathered quartz monzonite grids.

7.0 VERIFICATION PLAN MODIFICATIONS

This section addresses special situations and conditions encountered during final verification and presents the methods that were used to resolve these situations.

7.1 Anomalies

As discussed in Section 2.4, the Sherwood Site was divided into several areas which were defined by the nature and extent of contamination. These area types and the methods of verification are summarized below:

Area	Description	% Soil Samples	% Gamma
P1	Affected areas in association	10	100
P2	Affected areas not in association	100	N/A
S	Unaffected areas near affected areas	5	100
T	Remote unaffected areas	5	100
A	Remote areas along access roads	100	N/A

As summarized above, confirmation soil samples were periodically collected in all areas that were verified by 100% gamma measurements. The intent of these confirmation soil samples was: (1) to demonstrate the effectiveness of the gamma-radium correlation in identifying areas of contamination; and (2) to demonstrate that areas defined as "in association" did not exhibit elevated levels of ^{230}Th or U without elevated levels of ^{226}Ra.

Confirmation sample grids were selected using two criteria: (1) sufficient spatial distribution across the areas that were gamma measured; and (2) high gamma results. In P1 areas (areas of 10% confirmation sampling), the criteria were satisfied by selecting the grid with the highest gamma reading within contiguous groups of 10 grids. Similarly, for S and T areas, the grid with the highest gamma reading for every 20 grids was selected. As a result, the likelihood of identifying false negatives (i.e., grids which pass the gamma survey but have radionuclide concentrations above the limit) was maximized.

As a result of the confirmation sampling program, four grids out of approximately 320 confirmation grids were identified to be of consequence. These grids are discussed below and are shown on Drawings 8 and 9.

7.1.1 False Negative

One grid (C1-418440F, shown on Drawing 9) was identified as a false negative. The integrated gamma survey result of 2003 counts per 150 seconds was below the action level of 2110; however, the laboratory results indicated a ^{226}Ra concentration of 9.21 pCi/g, which exceeds the 5 pCi/g above background limit. The grid in question was subsequently cleaned and resampled. The analytical results on the soil sample taken after the grid had been cleaned indicated a ^{226}Ra concentration of 6.41 pCi/g, which also exceeded the 5 pCi/g above background limit. Upon further investigation, it was determined that this grid, as well as four other adjacent grids that exhibited elevated gamma readings, were located on the truck shop road. It was known that the fill material used to construct the road was composed of mine overburden and was placed prior to construction of the Sherwood Mill. Therefore, any elevated radionuclide concentrations were not reflective of byproduct material. As a result, WNI requested, via a letter dated April 3, 1996, permission to exclude these grids from the plan and exempt them from verification. Via License Amendment 27 WDOH approved the grid amendments and the issue was closed.

7.1.2 Association Issues

Three grids were identified by confirmation sampling to contain elevated concentrations of ^{230}Th and/or U_{nat} without elevated concentrations of ^{226}Ra. As such, these grids were out of association. Resolution of these anomalies was achieved by reclassifying the areas as P2 (no association), determining via soil sampling the extent of the area around the initial anomalous grid that was out of association via soil sampling, and cleaning the identified areas until compliance was achieved. The locations of these three grids are shown on Drawing 10, and details regarding the subsequent cleanup and excavation are shown on Drawings 11, 12, and 13. As shown on these drawings, one boundary row of unexcavated grids was used to demonstrate that containment of the anomalous non-association areas was achieved.

7.2 Plan Modifications

As discussed in Section 4.1.3, several minor modifications to the 12/94 Radiological Verification Plan were made during the course of verification. These modifications included changes in soil type, grid exclusions, and changes in area type. A log of all field modifications is presented in Appendix D.

In addition to these minor modifications, two policy modifications were made:

1. Due to WNI's diligent effort in pursuit of the ALARA philosophy throughout cleanup and verification, WDOH granted approval via letter dated April 4, 1996, for WNI to use the subsurface release standards of 15 pCi/g above background levels in areas that would receive 6 or more inches of clean backfill as part of the final site regrading plan. The location of the 12 grids that meet this standard, and that will be backfilled, are shown on Drawing 14, while a listing of the grid identification numbers is provided in Table 21. For purposes of confirming that these grids have been backfilled with a minimum of six inches of soil, the elevations of the center point of each grid that will be verified using the subsurface standards are given on Drawing

14. Following backfilling of these grids, an addendum to this report will be filed providing the final backfilled elevation of these grids.

2. During the initial stages of the verification program in 1995, WNI determined that the previously approved "quick count" method of laboratory analysis for ^{226}Ra, whereby gamma spectroscopy could be performed by the laboratory immediately upon sample receipt, was abandoned in favor of traditional methods of ^{226}Ra analyses which allow for complete ^{222}Rn and daughter ingrowth.

8.0 CONCLUSIONS

Based on the gamma survey and soil sample data presented in this report, all areas of the Sherwood Site, with the exception of the tailing impoundment, contain residual radionuclide concentrations below the applicable radiological standards. These areas are suitable for release for unrestricted use. In addition, as discussed in the WDOH letter dated June 21, 1996, the barium chloride drainage and evaporation ponds are suitable for release for unrestricted use after grids to be verified using the subsurface standard discussed in Section 7.2 have been backfilled.

9.0 REFERENCES

Western Nuclear, Inc. (WNI), 1994. "Radiological Verification Program", Addendum, Revision #6 to the Sherwood Project Mill Decommissioning Plan

TABLE 1. LABORATORY QC BLANK RESULTS FOR ^{226}Ra

^{226}Ra via Gamma Spectrometry

Lot Number	LSN	Activity (pCi/g)	QA * Acceptance
95-10,14	R54127	(-9.5 ± 11) E-02	Acceptable
95-12	R53617	(0 ± 0.12) E-00	Acceptable
95-13	R53489	(-5 ± 153) E-03	Acceptable
95-22	R53347	(0 ± 1.4) E-01	Acceptable
95-25 (R)	R56714	(1.5 ± 2.4) E-01	Acceptable
95-44	R52831	(2.2 ± 5.3) E-02	Acceptable
95-51	R54840	(5.0 ± 11) E-02	Acceptable
95-59,78	R54450	(3.0 ± 7.3) E-02	Acceptable
95-61	R54546	(1.2 ± 1.2) E-01	Acceptable
95-84	R54971	(1.2 ± 1.0) E-01	Acceptable
95-92,93,106	R55288	(1.2 ± 2.3) E-01	Acceptable
95-114	R55592	(-1 ± 31) E-02	Acceptable
95-115,128	R54733	(5 ± 12) E-02	Acceptable
95-116	R55125	(1.6 ± 2.4) E-01	Acceptable
95-122	R55436	(4.6 ± 4.5) E-01	Acceptable
95-131	R55678	(2.3 ± 2.5) E-01	Acceptable
95-139	R55879	(2.0 ± 2.3) E-01	Acceptable
95-147,149	R56687	(2.3 ± 3.4) E-01	Acceptable
95-155,156,157,163,164 (O)	R57867	(4.5 ± 4.0) E-01	Acceptable
95-160	R57614	(4.0 ± 3.7) E-01	Acceptable
95-17	R53834	(1.1 ± 2.0) E-01	Acceptable
95-18,27	R54323	(3 ± 12) E-02	Acceptable
95-23	R53073	(7 ± 15) E-02	Acceptable
95-24	R54014	(5.5 ± 8.5) E-02	Acceptable
95-60	R54401	(1 ± 11) E-02	Acceptable
95-66	R54621	(1.0 ± 1.4) E-01	Acceptable
95-77,117	R54920	(5.5 ± 3.8) E-01	Acceptable
95-82	R54785	(1.3 ± 1.8) E-01	Acceptable
95-99,123	R55074	(1.1 ± 1.5) E-01	Acceptable
95-108,110	R55236	(-2 ± 14) E-02	Acceptable
95-121	R55480	(-6 ± 12) E-02	Acceptable
95-133	R55630	(2.4 ± 2.7) E-01	Acceptable
95-137	R55796	(-1 ± 12) E-02	Acceptable
95-150	R56634	(6.6 ± 9.4) E-02	Acceptable
95-155,156,157 (Splits)	R57356	(6 ± 20) E-02	Acceptable
95-162	R57722	(6.8 ± 5.1) E-01	Acceptable
95-163,164	R57867	(4.5 ± 4.0) E-01	Acceptable
96-8	R58779	(2 ± 12) E-02	Acceptable
96-9	R58802	(4.7 ± 4.5) E-01	Acceptable
96-10	R58819	(5 ± 12) E-02	Acceptable
96-11	R58846	(9 ± 26) E-02	Acceptable
96-12,14	R58870	(1.7 ± 1.7) E-01	Acceptable
96-13	R58894	(2.0 ± 1.7) E-01	Acceptable
96-18,19	R59609	(8 ± 22) E-02	Acceptable

* As required by the YAEL QA Program, statistically zero activity is required for analytical blanks (e.g. activity less than three times its corresponding one standard deviation).

TABLE 1. (continued) LABORATORY QC BLANK RESULTS FOR ^{226}Ra

^{226}Ra via Gamma Spectrometry

Lot Number	LSN	Activity (pCi/g)	QA * Acceptance
95-11	R53570	(0.00 ± 0.19) E-00	Acceptable
95-15	R53718	(1.2 ± 1.2) E-01	Acceptable
95-16	R54103	(-4.7 ± 9.8) E-02	Acceptable
95-21	R53988	(5.2 ± 9.1) E-02	Acceptable
95-25	R53027	(2.9 ± 5.5) E-02	Acceptable
95-26	R54076	(-2.6 ± 17) E-02	Acceptable
95-31	R53264	(6.6 ± 9.7) E-02	Acceptable
95-35,34,32	R54036	(0.0 ± 1.0) E-01	Acceptable
95-36B	R53363	(1.2 ± 1.2) E-01	Acceptable
95-43	R54299	(7.0 ± 9.9) E-02	Acceptable
95-58	R54425	(0 ± 13) E-02	Acceptable
95-62	R54571	(1.3 ± 1.7) E-01	Acceptable
95-64	R54596	(4 ± 14) E-02	Acceptable
95-68	R54646	(3 ± 11) E-02	Acceptable
95-79,69	R54760	(1.0 ± 1.5) E-01	Acceptable
95-74,134	R54946	(1.3 ± 1.2) E-01	Acceptable
95-85	R54808	(7 ± 12) E-02	Acceptable
95-96,97	R55152	(-4 ± 11) E-02	Acceptable
95-102,105	R55100	(5 ± 16) E-02	Acceptable
95-109,111	R55262	(-6 ± 23) E-02	Acceptable
95-118,120	R55316	(7 ± 13) E-02	Acceptable
95-119	R55611	(1.0 ± 3.7) E-01	Acceptable
95-124	R55655	(-9 ± 19) E-02	Acceptable
95-126	R55459	(-4 ± 19) E-02	Acceptable
95-127,130	R55413	(1.5 ± 2.1) E-01	Acceptable
95-83,129	R54996	(2.1 ± 2.3) E-01	Acceptable
95-136	R55821	(8 ± 14) E-02	Acceptable
95-138,144	R55854	(4.8 ± 4.2) E-01	Acceptable
95-140	R55901	(4 ± 15) E-02	Acceptable
95-141,143	R55708	(9 ± 15) E-02	Acceptable
95-148,151	R56660	(7 ± 11) E-02	Acceptable
95-152	R56706	(1.2 ± 1.3) E-01	Acceptable
95-159	R57592	(2.7 ± 2.7) E-01	Acceptable
95-161	R57700	(5.3 ± 4.0) E-01	Acceptable

* As required by the YAEL QA Program, statistically zero activity is required for analytical blanks (e.g. activity less than three times its corresponding one standard deviation).

TABLE 2. LABORATORY QC BLANK RESULTS FOR ^{230}Th

^{230}Th via Alpha Spectrometry

Lot Number	LSN	Activity (pCi/g)	QA * Acceptance
95-7	W52646	(1.7 ± 2.1) E-02	Acceptable
95-7	W52647	(2.3 ± 2.8) E-02	Acceptable
95-11	W53571	(3.4 ± 2.8) E-02	Acceptable
95-15	W53719	(2.7 ± 3.2) E-02	Acceptable
95-16	W54104	(-8 ± 28) E-03	Acceptable
95-21	W53989	(4.4 ± 3.1) E-02	Acceptable
95-23	W53074	(1.0 ± 3.5) E-02	Acceptable
95-25	W53028	(-1 ± 32) E-03	Acceptable
95-26	W54077	(-7 ± 22) E-03	Acceptable
95-31	W53265	(5 ± 40) E-03	Acceptable
95-35,34,32	W54037	(1.2 ± 3.2) E-02	Acceptable
95-36B	W53364	(2.7 ± 2.5) E-02	Acceptable
95-43	W54300	(1.7 ± 2.8) E-02	Acceptable
95-58	W54426	(1.4 ± 2.0) E-02	Acceptable
95-62	W54572	(-1 ± 24) E-03	Acceptable
95-64	W54597	(-6 ± 23) E-03	Acceptable
95-68	W54647	(-2.3 ± 1.9) E-02	Acceptable
95-74,134	W54947	(2.6 ± 2.6) E-02	Acceptable
95-79,69	W54761	(-8 ± 26) E-03	Acceptable
95-83,129	W54997	(-5 ± 28) E-03	Acceptable
95-85	W54809	(1.5 ± 2.9) E-02	Acceptable
95-92,93,106	W55289	(8 ± 30) E-03	Acceptable
95-96,97	W55153	(-2 ± 29) E-03	Acceptable
95-99,123	W55075	(3.1 ± 6.8) E-02	Acceptable
95-108,110	W55237	(-1.7 ± 2.0) E-02	Acceptable
95-114	W55593	(-1.9 ± 2.3) E-02	Acceptable
95-121	W55481	(-2.3 ± 2.4) E-02	Acceptable
95-122	W55437	(3.4 ± 3.7) E-02	Acceptable
95-99,123	W55075	(3.1 ± 6.8) E-02	Acceptable
95-83,129	W54997	(-5 ± 28) E-03	Acceptable
95-131	W55679	(3.8 ± 3.3) E-02	Acceptable
95-133	W55631	(-1.5 ± 2.0) E-02	Acceptable
95-74,134	W54947	(2.6 ± 2.6) E-02	Acceptable
95-137	W55797	(3 ± 28) E-03	Acceptable
95-139	W55880	(-1.2 ± 2.1) E-02	Acceptable
95-147,149	W56688	(-1.3 ± 2.3) E-02	Acceptable
95-150	W56635	(-1.3 ± 2.1) E-02	Acceptable
95-155,156,157,163,164 (R)	W57357	(7 ± 33) E-03	Acceptable
95-155,156,157,163,164 (O)	W57868	(4 ± 30) E-03	Acceptable
95-160	W57615	(-1.0 ± 2.1) E-02	Acceptable
95-162	W57723	(4 ± 29) E-03	Acceptable
95-140	W55902	(-1 ± 28) E-03	Acceptable

* As required by the YAEL QA Program, statistically zero activity is required for analytical blanks (e.g. activity less than three times its corresponding one standard deviation).

TABLE 2. (continued) LABORATORY QC BLANK RESULTS FOR ^{230}Th

^{230}Th via Alpha Spectrometry

Lot Number	LSN	Activity (pCi/g)	QA * Acceptance
95-10,14	W54128	(3.8 ± 3.0) E-03	Acceptable
95-12	W53618	(2.2 ± 2.9) E-02	Acceptable
95-13	W53490	(1.5 ± 2.8) E-02	Acceptable
95-17	W53835	(-6 ± 29) E-03	Acceptable
95-18,27	W54324	(-7 ± 25) E-03	Acceptable
95-22	W53348	(7 ± 35) E-03	Acceptable
95-23,34	W56789	(3.0 ± 3.5) E-02	Acceptable
95-24	W54015	(-4 ± 32) E-03	Acceptable
95-23,34 (R)	W56789	(3.0 ± 3.5) E-02	Acceptable
95-44	W52832	(-2.3 ± 5.7) E-03	Acceptable
95-51	W53108	(-1.4 ± 2.8) E-02	Acceptable
95-59,78	W54451	(2 ± 41) E-03	Acceptable
95-60	W54402	(-8 ± 25) E-03	Acceptable
95-61	W54547	(1.4 ± 2.6) E-02	Acceptable
95-66	W54622	(8 ± 30) E-03	Acceptable
95-68 (R)	W58095	(1.5 ± 1.1) E-01	Acceptable
95-77,117	W54921	(6 ± 30) E-03	Acceptable
95-82	W54786	(1.5 ± 3.0) E-02	Acceptable
95-84	W54972	(-5 ± 24) E-03	Acceptable
95-102,105	W55101	(2.7 ± 4.0) E-02	Acceptable
95-109,111	W55263	(1.8 ± 3.4) E-02	Acceptable
95-115,128	W54734	(2.2 ± 2.8) E-02	Acceptable
95-116	W55126	(2.5 ± 3.6) E-02	Acceptable
95-116,124,131 (R)	W56987	(2 ± 30) E-03	Acceptable
95-118,120	W55317	(-4 ± 27) E-03	Acceptable
95-119	W55612	(2.6 ± 7.8) E-02	Acceptable
95-124	W55656	(3.1 ± 3.2) E-02	Acceptable
95-126	W55460	(2 ± 29) E-03	Acceptable
95-127,130	W55414	(5 ± 27) E-03	Acceptable
95-136	W55822	(1 ± 27) E-03	Acceptable
95-138,144	W55855	(-6 ± 23) E-03	Acceptable
95-141,143	W55709	(-1.3 ± 2.3) E-02	Acceptable
95-148,151	W56661	(8 ± 22) E-03	Acceptable
95-152,153	W56707	(1.8 ± 2.9) E-02	Acceptable
95-158	W57118	(1.4 ± 2.7) E-02	Acceptable
95-159	W57593	(-5 ± 25) E-03	Acceptable
95-161	W57701	(-1 ± 27) E-03	Acceptable
95-163,164	W57868	(4 ± 30) E-03	Acceptable
96-8	W58780	(4.2 ± 3.6) E-02	Acceptable
96-9	W58803	(4.9 ± 4.3) E-02	Acceptable
96-10	W58820	(3.2 ± 2.8) E-02	Acceptable
96-11	W58847	(5.3 ± 3.9) E-02	Acceptable
96-12,14	W58871	(3.7 ± 3.0) E-02	Acceptable
96-13	W58895	(4 ± 29) E-03	Acceptable
96-18,19	W59610	(2.7 ± 3.5) E-02	Acceptable

* As required by the YAEL QA Program, statistically zero activity is required for analytical blanks (e.g. activity less than three times its corresponding one standard deviation).

TABLE 3. LABORATORY QC BLANK RESULTS FOR ISOTOPIC URANIUM

^{234}U, ^{235}U, and ^{238}U via Alpha Spectrometry

Lot Number	Nuclide	LSN	Activity (pCi/g)	QA * Acceptance
Note 1	^{234}U	U55973	(7 ± 10) E-03	Acceptable
	^{235}U		(4.7 ± 8.8) E-03	Acceptable
	^{238}U		(5 ± 53) E-04	Acceptable
Note 1	^{234}U	U55974	(3.8 ± 7.3) E-03	Acceptable
	^{235}U		(-1.0 ± 1.4) E-03	Acceptable
	^{238}U		(5 ± 54) E-04	Acceptable
95-159,160	^{234}U	U57619	(1.6 ± 1.1) E-02	Acceptable
	^{235}U		(2.5 ± 5.0) E-03	Acceptable
	^{238}U		(9.6 ± 9.1) E-03	Acceptable
95-164	^{234}U	U57869	(1.2 ± 1.2) E-02	Acceptable
	^{235}U		(5.3 ± 9.2) E-03	Acceptable
	^{238}U		(4.6 ± 7.4) E-03	Acceptable
Note 2	^{234}U	U56711	(4.8 ± 6.1) E-03	Acceptable
	^{235}U		(5.6 ± 6.3) E-03	Acceptable
	^{238}U		(5.6 ± 5.5) E-03	Acceptable
95-43,84,85,96	^{234}U	U58292	(1.9 ± 7.5) E-03	Acceptable
	^{235}U		(8 ± 13) E-03	Acceptable
	^{238}U		(3.2 ± 7.3) E-03	Acceptable
95-43,105,122	^{234}U	U58221	(3.1 ± 2.6) E-02	Acceptable
	^{235}U		(6 ± 13) E-03	Acceptable
	^{238}U		(-9 ± 12) E-04	Acceptable
Note 3	^{234}U	U56639	(9 ± 58) E-04	Acceptable
	^{235}U		(-2.9 ± 2.9) E-03	Acceptable
	^{238}U		(4.8 ± 7.7) E-03	Acceptable
Note 4	^{234}U	U57189	(2 ± 11) E-03	Acceptable
	^{235}U		(-1.8 ± 1.8) E-03	Acceptable
	^{238}U		(-7 ± 11) E-04	Acceptable
95-137,138,150	^{234}U	U56844	(6 ± 10) E-03	Acceptable
	^{235}U		(-1.6 ± 2.2) E-03	Acceptable
	^{238}U		(1.5 ± 5.9) E-03	Acceptable
95-156,157	^{234}U	U57357	(1.5 ± 7.5) E-03	Acceptable
	^{235}U		(4.0 ± 9.0) E-03	Acceptable
	^{238}U		(1.3 ± 0.5) E-02	Acceptable
95-7	^{234}U	U54813	(3.4 ± 4.1) E-02	Acceptable
	^{235}U		(-3.5 ± 2.9) E-03	Acceptable
	^{238}U		(-1.4 ± 1.7) E-03	Acceptable

* As required by the YAEL QA Program, statistically zero activity is required for analytical blanks (e.g. activity less than three times its corresponding one standard deviation).

Notes:

1 Sample corresponds to Lot Numbers: 95-11,12,13,15,17,18,21,22,23,24,25,26,27,58,59

2 Sample corresponds to Lot Numbers: 95-12,13,21,26,36B,43,74,85,93,102,105, 106,123,126,131,133,140,148,149,152

3 Sample corresponds to Lot Numbers: 95-58,82,83,96,105,106,120,141

4 Sample corresponds to Lot Numbers: 95-60,68,69,99,114,115,116,117

TABLE 3. (continued) LABORATORY QC BLANK RESULTS FOR ISOTOPIC URANIUM

^{234}U, ^{235}U, and ^{238}U via Alpha Spectrometry

Lot Number	Nuclide	LSN	Activity (pCi/g)	QA * Acceptance
95-164	^{234}U	U58275	(4.5 ± 5.2) E-03	Acceptable
	^{235}U		(4 ± 47) E-03	Acceptable
	^{238}U		(4.5 ± 5.2) E-03	Acceptable
96-8	^{234}U	U58780	(3 ± 11) E-03	Acceptable
	^{235}U		(5 ± 13) E-03	Acceptable
	^{238}U		(9 ± 13) E-03	Acceptable
96-9	^{234}U	U58803	(5.5 ± 6.9) E-03	Acceptable
	^{235}U		(6.2 ± 8.5) E-03	Acceptable
	^{238}U		(5.9 ± 6.8) E-03	Acceptable
96-10	^{234}U	U58820	(5.1 ± 7.8) E-03	Acceptable
	^{235}U		(5.7 ± 9.6) E-03	Acceptable
	^{238}U		(1.9 ± 5.6) E-03	Acceptable
96-11	^{234}U	U58847	(9.8 ± 8.8) E-03	Acceptable
	^{235}U		(2.4 ± 4.8) E-03	Acceptable
	^{238}U		(3.5 ± 5.6) E-03	Acceptable
96-12,14	^{234}U	U58871	(5.5 ± 5.5) E-03	Acceptable
	^{235}U		(3.4 ± 4.8) E-03	Acceptable
	^{238}U		(3.7 ± 4.9) E-03	Acceptable
96-13	^{234}U	U58895	(7.2 ± 7.7) E-03	Acceptable
	^{235}U		(9 ± 50) E-04	Acceptable
	^{238}U		(1 ± 4.0) E-03	Acceptable
96-18,19	^{234}U	U59610	(1.13 ± 0.97) E-02	Acceptable
	^{235}U		(1.2 ± 4.7) E-02	Acceptable
	^{238}U		(2.3 ± 5.3) E-03	Acceptable

* As required by the YAEL QA Program, statistically zero activity is required for analytical blanks (e.g. activity less than three times its corresponding one standard deviation).

TABLE 4. LABORATORY QC SPIKE RESULTS FOR ^{226}Ra

^{226}Ra via Gamma Spectrometry - MK GUNA16-B (Known value = 67.4 pCi/g)

Lot Number	LSN	Activity (pCi/g)	QA * Comparison
95-7	R52806	66.3 ± 1.2	Acceptable
95-7	R52690	68.3 ± 1.1	Acceptable
95-10,14	R54131	66.0 ± 1.3	Acceptable
95-13	R53491	66.1 ± 1.2	Acceptable
95-12	R53621	67.0 ± 1.1	Acceptable
95-17	R53838	65.9 ± 1.3	Acceptable
95-18,27	R54327	66.4 ± 1.1	Acceptable
95-22	R53349	66.6 ± 1.1	Acceptable
95-23	R53077	66.2 ± 1.2	Acceptable
95-24	R54018	67.9 ± 1.7	Acceptable
95-25 (R)	R56715	64.2 ± 3.5	Acceptable
95-44	R53075	67.3 ± 1.1	Acceptable
95-51	R54841	65.9 ± 2.2	Acceptable
95-59,78	R54454	65.4 ± 1.6	Acceptable
95-60	R54405	65.5 ± 1.1	Acceptable
95-61	R54550	66.9 ± 1.6	Acceptable
95-66	R54625	66.7 ± 1.6	Acceptable
95-82	R54789	67.1 ± 2.2	Acceptable
95-84	R54975	65.5 ± 2.2	Acceptable
95-92,93,106	R55292	69.7 ± 3.5	Acceptable
95-99,123	R55078	64.9 ± 2.7	Acceptable
95-108,110	R55240	64.1 ± 2.8	Acceptable
95-114	R55596	63.1 ± 3.5	Acceptable
95-115,128	R54737	65.1 ± 2.2	Acceptable
95-116	R55129	65.8 ± 2.8	Acceptable
95-77,117	R54924	65.6 ± 2.2	Acceptable
95-121	R55484	65.0 ± 3.5	Acceptable
95-122	R55440	66.4 ± 3.4	Acceptable
95-131	R55682	67.3 ± 3.5	Acceptable
95-133	R55634	63.5 ± 3.5	Acceptable
95-137	R55800	69.6 ± 3.6	Acceptable
95-139	R55883	61.8 ± 3.4	Acceptable
95-147,149	R56691	61.9 ± 3.4	Acceptable
95-150	R56638	61.7 ± 3.3	Acceptable
95-155,156,157 (Splits)	R57360	65.2 ± 3.5	Acceptable
95-155,156,157,163,164	R57874	65.4 ± 3.4	Acceptable
95-160	R57618	67.8 ± 3.4	Acceptable
95-162	R57726	69.8 ± 3.5	Acceptable
95-163,164	R57874	65.4 ± 3.4	Acceptable
96-9	R58806	65.0 ± 3.4	Acceptable
96-11	R58850	66.6 ± 3.5	Acceptable
96-13	R58898	63.8 ± 3.5	Acceptable
96-18,19	R59613	60.0 ± 3.4	Acceptable

* As required by the YAEL QA Program, agreement for spike results is achieved when the individual value is within 20% OR 2-Sigma of the "known" value.

TABLE 4. (continued) LABORATORY QC SPIKE RESULTS FOR ^{226}Ra

^{226}Ra via Gamma Spectrometry - MK GUNB32-A (Known value = 50.5 pCi/g)

Lot Number	LSN	Activity (pCi/g)	QA * Comparison
95-7	R52807	54.9 ± 1.1	Acceptable
95-7	R52691	53.4 ± 1.0	Acceptable
95-11	R53569	50.5 ± 1.1	Acceptable
95-15	R53722	50.8 ± 1.1	Acceptable
95-16	R54107	49.6 ± 1.5	Acceptable
95-21	R53992	55.3 ± 1.5	Acceptable
95-25	R53076	50.7 ± 1.1	Acceptable
95-26	R54080	54.2 ± 1.2	Acceptable
95-31	R53266	49.7 ± 1.0	Acceptable
95-35,34,32	R54040	52.1 ± 1.5	Acceptable
95-36B	R53365	53.1 ± 1.0	Acceptable
95-43	R54303	53.5 ± 1.0	Acceptable
95-58	R54429	52.3 ± 1.0	Acceptable
95-62	R54575	49.9 ± 1.4	Acceptable
95-64	R54600	49.4 ± 1.4	Acceptable
95-68	R54650	51.4 ± 1.4	Acceptable
95-74,134	R54950	50.0 ± 1.9	Acceptable
95-79,69	R54764	48.7 ± 1.9	Acceptable
95-83,129	R55000	49.4 ± 1.9	Acceptable
95-85	R54812	49.4 ± 1.9	Acceptable
95-96,97	R55156	51.1 ± 2.4	Acceptable
95-102,105	R55104	48.8 ± 2.4	Acceptable
95-109,111	R55266	48.7 ± 3.0	Acceptable
95-118,120	R55320	50.4 ± 3.0	Acceptable
95-119	R55615	49.8 ± 3.0	Acceptable
95-124	R55659	49.8 ± 3.0	Acceptable
95-126	R55463	53.9 ± 3.2	Acceptable
95-127,130	R55417	51.7 ± 3.1	Acceptable
95-136	R55825	48.7 ± 3.0	Acceptable
95-138,144	R55858	47.8 ± 3.0	Acceptable
95-140	R55905	50.9 ± 3.0	Acceptable
95-141,143	R55712	49.1 ± 2.9	Acceptable
95-148,151	R56664	50.5 ± 3.1	Acceptable
95-152	R56710	47.1 ± 3.0	Acceptable
95-159	R57596	50.3 ± 3.1	Acceptable
95-161	R57704	48.6 ± 3.0	Acceptable
96-8	R58783	49.1 ± 3.0	Acceptable
96-10	R58823	49.0 ± 3.0	Acceptable
96-12,14	R58874	46.5 ± 3.0	Acceptable

* As required by the YAEL QA Program, agreement for spike results is achieved when the individual value is within 20% OR 2-Sigma of the "known value".

TABLE 5. LABORATORY QC SPIKE RESULTS FOR ^{230}Th

^{230}Th via Alpha Spectrometry - NIST Rocky Flats (Known value = 1.197 pCi/g)

Lot Number	LSN	Activity (pCi/g)	QA * Comparison
95-7	W52648	1.16 ± 0.15	Acceptable
	W52649	1.25 ± 0.13	Acceptable
95-11	W53572	1.26 ± 0.13	Acceptable
	W53573	1.12 ± 0.13	Acceptable
95-15	W53720	1.08 ± 0.13	Acceptable
	W53721	1.16 ± 0.14	Acceptable
95-16	W54105	0.99 ± 0.13	Acceptable
	W54106	1.08 ± 0.14	Acceptable
95-21	W53990	0.994 ± 0.094	Acceptable
	W53991	1.058 ± 0.097	Acceptable
95-23	W53105	1.01 ± 0.13	Acceptable
	W53106	1.09 ± 0.14	Acceptable
95-25	W53051	1.09 ± 0.14	Acceptable
	W53052	1.19 ± 0.15	Acceptable
95-26	W54078	1.12 ± 0.15	Acceptable
	W54079	1.16 ± 0.15	Acceptable
95-31	W53267	1.03 ± 0.12	Acceptable
	W53268	1.09 ± 0.15	Acceptable
95-35,34,32	W54038	1.00 ± 0.12	Acceptable
	W54039	1.05 ± 0.12	Acceptable
95-36B	W53366	1.33 ± 0.14	Acceptable
	W53367	1.31 ± 0.13	Acceptable
95-43	W54301	1.11 ± 0.13	Acceptable
	W54302	1.24 ± 0.14	Acceptable
95-58	W54427	1.23 ± 0.15	Acceptable
	W54428	1.16 ± 0.12	Acceptable
95-62	W54573	1.02 ± 0.11	Acceptable
	W54574	1.03 ± 0.11	Acceptable
95-64	W54598	1.23 ± 0.12	Acceptable
	W54599	1.41 ± 0.13	Acceptable
95-68	W54648	1.16 ± 0.10	Acceptable
	W54649	1.16 ± 0.10	Acceptable
95-74,134	W54948	1.05 ± 0.10	Acceptable
	W54949	1.15 ± 0.11	Acceptable
95-79,69	W54762	1.15 ± 0.12	Acceptable
	W54763	1.09 ± 0.12	Acceptable
95-83,129	W54988	1.25 ± 0.14	Acceptable
	W54999	1.15 ± 0.13	Acceptable
95-85	W54810	1.10 ± 0.13	Acceptable
	W54811	1.21 ± 0.14	Acceptable

* As required by the YAEL QA Program, agreement for spike results is achieved when the individual value is within 20% OR 2-Sigma of the "known" value.

TABLE 5. (continued) LABORATORY QC SPIKE RESULTS FOR ^{230}Th

^{230}Th via Alpha Spectrometry - NIST Rocky Flats (Known value = 1.197 pCi/g)

Lot Number	LSN	Activity (pCi/g)	QA * Comparison
95-92,93,106	W55290	1.33 ± 0.15	Acceptable
	W55291	1.17 ± 0.12	Acceptable
95-96,97	W55154	1.048 ± 0.081	Acceptable
	W55155	1.266 ± 0.091	Acceptable
95-99,123	W55076	1.14 ± 0.14	Acceptable
	W55077	1.13 ± 0.15	Acceptable
95-108,110	W55238	1.01 ± 0.13	Acceptable
	W55239	1.28 ± 0.16	Acceptable
95-114	W55594	1.16 ± 0.12	Acceptable
	W55595	1.19 ± 0.11	Acceptable
95-122	W55438	1.12 ± 0.12	Acceptable
	W55439	1.10 ± 0.12	Acceptable
95-131	W55680	1.09 ± 0.13	Acceptable
	W55681	1.29 ± 0.14	Acceptable
95-133	W55632	1.14 ± 0.10	Acceptable
	W55633	1.060 ± 0.097	Acceptable
95-137	W55798	1.17 ± 0.13	Acceptable
	W55799	1.30 ± 0.13	Acceptable
95-139	W55881	1.06 ± 0.11	Acceptable
	W55882	1.13 ± 0.13	Acceptable
95-147,149	W56689	1.23 ± 0.12	Acceptable
	W56690	1.05 ± 0.11	Acceptable
95-150	W56636	1.06 ± 0.11	Acceptable
	W56637	1.14 ± 0.12	Acceptable
95-155,156,157,153 (R)	W57358	1.11 ± 0.12	Acceptable
	W57359	1.36 ± 0.14	Acceptable
95-155,156,157,153 (O)	W57872	1.20 ± 0.12	Acceptable
	W57873	1.20 ± 0.13	Acceptable
95-160	W57616	1.14 ± 0.10	Acceptable
	W57617	1.073 ± 0.099	Acceptable
95-162	W57724	1.15 ± 0.11	Acceptable
	W57725	1.31 ± 0.12	Acceptable
95-121	W55482	1.21 ± 0.13	Acceptable
	W55483	1.13 ± 0.12	Acceptable

* As required by the YAEL QA Program, agreement for spike results is achieved when the individual value is within 20% OR 2-Sigma of the "known" value.

TABLE 5. (continued) LABORATORY QC SPIKE RESULTS FOR ^{230}Th

^{230}Th via Alpha Spectrometry - NIST Peruvian (Known value = 1.073 pCi/g)

Lot Number	LSN	Activity (pCi/g)	QA * Comparison
95-140	W55903	1.05 ± 0.12	Acceptable
	W55904	0.93 ± 0.12	Acceptable
95-10,14	W54129	0.98 ± 0.12	Acceptable
	W54130	1.01 ± 0.12	Acceptable
95-12	W53619	0.904 ± 0.097	Acceptable
	W53620	0.91 ± 0.11	Acceptable
95-13	W53492	1.01 ± 0.14	Acceptable
	W53493	0.96 ± 0.13	Acceptable
95-17	W53836	0.933 ± 0.090	Acceptable
	W53837	0.95 ± 0.13	Acceptable
95-18,27	W54325	0.91 ± 0.11	Acceptable
	W54326	0.93 ± 0.11	Acceptable
95-22	W53350	0.90 ± 0.13	Acceptable
	W53351	1.01 ± 0.14	Acceptable
95-23,34 (R)	W56790	0.95 ± 0.12	Acceptable
	W56791	0.97 ± 0.12	Acceptable
95-24	W54016	0.88 ± 0.11	Acceptable
	W54017	0.89 ± 0.11	Acceptable
95-44	W52829	0.881 ± 0.880	Acceptable
	W53030	0.92 ± 0.12	Acceptable
95-51	W53181	1.02 ± 0.13	Acceptable
	W53182	0.92 ± 0.16	Acceptable
95-59,78	W54452	0.95 ± 0.13	Acceptable
	W54453	0.94 ± 0.11	Acceptable
95-60	W54403	1.06 ± 0.12	Acceptable
	W54404	0.97 ± 0.12	Acceptable
95-61	W54548	0.89 ± 0.11	Acceptable
	W54549	0.95 ± 0.12	Acceptable
95-66	W54623	1.01 ± 0.14	Acceptable
	W54624	0.93 ± 0.12	Acceptable
95-68 (R)	W58096	1.21 ± 0.16	Acceptable
	W58097	1.23 ± 0.17	Acceptable
95-77,117	W54922	0.98 ± 0.12	Acceptable
	W54923	0.92 ± 0.12	Acceptable
95-82	W54787	0.91 ± 0.12	Acceptable
	W54788	1.15 ± 0.14	Acceptable
95-84	W54973	0.933 ± 0.090	Acceptable
	W54974	0.91 ± 0.10	Acceptable

* As required by the YAEL QA Program, agreement for spike results is achieved

TABLE 5. (continued) LABORATORY QC SPIKE RESULTS FOR ^{230}Th

^{230}Th via Alpha Spectrometry - NIST Peruvian (Known value = 1.073 pCi/g)

Lot Number	LSN	Activity (pCi/g)	QA * Comparison
95-102,105	W55102	1.14 ± 0.14	Acceptable
	W55103	0.95 ± 0.13	Acceptable
95-109,111	W55264	1.15 ± 0.15	Acceptable
	W55265	0.939 ± 0.098	Acceptable
95-115,128	W54735	1.13 ± 0.12	Acceptable
	W54736	1.26 ± 0.14	Acceptable
95-116	W55127	0.98 ± 0.13	Acceptable
	W55128	1.03 ± 0.13	Acceptable
95-116,124,131 (R)	W56988	0.95 ± 0.12	Acceptable
	W56989	1.16 ± 0.12	Acceptable
95-118,120	W55318	1.02 ± 0.12	Acceptable
	W55319	0.95 ± 0.12	Acceptable
95-119	W55613	1.18 ± 0.15	Acceptable
	W55614	1.05 ± 0.12	Acceptable
95-118,120	W55318	1.02 ± 0.12	Acceptable
	W55319	0.95 ± 0.12	Acceptable
95-124	W55657	0.92 ± 0.12	Acceptable
	W55658	1.07 ± 0.13	Acceptable
95-126	W55461	1.01 ± 0.11	Acceptable
	W55462	0.96 ± 0.10	Acceptable
95-127,130	W55415	1.018 ± 0.094	Acceptable
	W55416	1.053 ± 0.099	Acceptable
95-115,128	W54735	1.13 ± 0.12	Acceptable
	W54736	1.26 ± 0.14	Acceptable
95-136	W55823	1.10 ± 0.11	Acceptable
	W55824	1.06 ± 0.11	Acceptable
95-138,144	W55856	1.06 ± 0.10	Acceptable
	W55857	1.006 ± 0.094	Acceptable
95-141,143	W55710	0.884 ± 0.099	Acceptable
	W55711	0.901 ± 0.096	Acceptable
95-148,151	W56662	1.03 ± 0.11	Acceptable
	W56663	0.939 ± 0.096	Acceptable
95-152,153	W56708	0.96 ± 0.10	Acceptable
	W56709	0.99 ± 0.11	Acceptable
95-158	W57119	0.91 ± 0.10	Acceptable
	W57120	0.97 ± 0.10	Acceptable
95-159	W57594	0.97 ± 0.12	Acceptable
	W57595	1.01 ± 0.11	Acceptable
95-161	W57702	1.01 ± 0.11	Acceptable
	W57703	1.06 ± 0.12	Acceptable

* As required by the YAEL QA Program, agreement for spike results is achieved when the individual value is within 20% OR 2-Sigma of the "known" value.

TABLE 5. (continued) LABORATORY QC SPIKE RESULTS FOR ^{230}Th

^{230}Th via Alpha Spectrometry - NIST Peruvian (Known value = 1.197 pCi/g)

Lot Number	LSN	Activity (pCi/g)	QA * Comparison
95-163,164	W57872	1.20 ± 0.12	Acceptable
	W57873	1.20 ± 0.13	Acceptable
96-8	W58781	1.25 ± 0.13	Acceptable
	W58782	1.21 ± 0.13	Acceptable
96-9	W58804	1.12 ± 0.11	Acceptable
	W58805	1.10 ± 0.11	Acceptable
96-10	W58821	1.17 ± 0.11	Acceptable
	W58822	1.22 ± 0.12	Acceptable
96-11	W58848	1.07 ± 0.11	Acceptable
	W58849	1.19 ± 0.11	Acceptable
96-12,14	W58872	1.16 ± 0.12	Acceptable
	W58873	1.14 ± 0.12	Acceptable
96-13	W58896	1.20 ± 0.13	Acceptable
	W58897	1.20 ± 0.13	Acceptable
96-18,19	W59611	1.08 ± 0.12	Acceptable
	W59612	1.15 ± 0.13	Acceptable

* As required by the YAEL QA Program, agreement for spike results is achieved when the individual value is within 20% OR 2-Sigma of the "known" value.

TABLE 6. LABORATORY QC SPIKE RESULTS FOR ISOTOPIC URANIUM

^{234}U and ^{238}U via Alpha Spectrometry - NIST Rocky Flats (^{234}U Known value = 1.057 pCi/g)
(^{238}U Known value = 1.051 pCi/g)

Lot Number	LSN	^{234}U Activity (pCi/g)	^{238}U Activity (pCi/g)	QA * Comparison
95-7	U22371	0.92 ± 0.17	0.87 ± 0.16	Acceptable
95-7	U54838	0.966 ± 0.094	0.925 ± 0.091	Acceptable
	U54839	0.994 ± 0.094	0.920 ± 0.091	Acceptable
Note 1	U55949	1.01 ± 0.11	1.01 ± 0.11	Acceptable
	U55950	0.92 ± 0.10	0.88 ± 0.10	Acceptable
95-159,160	U57620	0.96 ± 0.11	0.95 ± 0.11	Acceptable
	U57621	1.04 ± 0.12	1.03 ± 0.11	Acceptable
95-164	U57870	1.034 ± 0.099	0.979 ± 0.096	Acceptable
	U57871	0.975 ± 0.096	0.969 ± 0.095	Acceptable
Note 2	U56712	0.966 ± 0.090	0.891 ± 0.086	Acceptable
	U56713	1.007 ± 0.093	0.938 ± 0.090	Acceptable
95-43,84,85,96	U58293	0.903 ± 0.095	0.914 ± 0.096	Acceptable
	U58294	1.03 ± 0.10	10.2 ± 0.10	Acceptable
95-43,105,122	U58222	1.04 ± 0.11	1.08 ± 0.11	Acceptable
	U85223	1.02 ± 0.10	0.94 ± 0.10	Acceptable
Note 3	U56640	1.20 ± 0.10	1.16 ± 0.10	Acceptable
	U56641	1.07 ± 0.10	0.930 ± 0.093	Acceptable
Note 4	U57190	0.926 ± 0.099	0.859 ± 0.095	Acceptable
	U57191	1.05 ± 0.11	0.97 ± 0.11	Acceptable
95-137,138,150	U56845	1.058 ± 0.074	1.023 ± 0.073	Acceptable
	U56846	1.042 ± 0.073	0.993 ± 0.071	Acceptable
95-156,157	U57358	0.99 ± 0.11	0.882 ± 0.099	Acceptable
	U57359	1.09 ± 0.11	1.02 ± 0.11	Acceptable
95-164	U58276	0.97 ± 0.10	1.02 ± 0.10	Acceptable
	U58277	0.99 ± 0.10	0.885 ± 0.094	Acceptable
96-8	U58781	0.984 ± 0.09	0.964 ± 0.08	Acceptable
	U58782	0.996 ± 0.09	0.991 ± 0.09	Acceptable
96-9	U58804	0.98 ± 0.10	0.934 ± 0.1	Acceptable
	U58805	0.96 ± 0.10	1.01 ± 0.10	Acceptable
96-10	U58821	0.918 ± 0.095	0.858 ± 0.09	Acceptable
	U58822	0.99 ± 0.10	0.96 ± 0.10	Acceptable
96-11	U58848	1.026 ± 0.095	0.962 ± 0.092	Acceptable
	U58849	0.946 ± 0.090	0.895 ± 0.087	Acceptable
96-12,14	U58872	1.009 ± 0.092	0.885 ± 0.09	Acceptable
	U58873	0.975 ± 0.093	1.019 ± 0.095	Acceptable
96-13	U58896	0.96 ± 0.10	1.00 ± 0.11	Acceptable
	U58897	1.00 ± 0.10	0.96 ± 0.10	Acceptable
96-18,19	U59611	0.91 ± 0.11	0.97 ± 0.11	Acceptable
	U59612	1.03 ± 0.11	0.97 ± 0.11	Acceptable

* As required by the YAEL QA Program, agreement for spike results is achieved when the individual value is within 20% OR 2-Sigma of the "known" value.

Notes:

1 Sample corresponds to the following Lot Numbers: 95-11,12,13,15,17,18,21,22,23,24,25,26, 27,58,59

2 Sample corresponds to the following Lot Numbers: 95-12,13,21,26,36B,43,74,85,93,102,105, 106,123,126,131,133,140,148,149,152

3 Sample corresponds to the following Lot Numbers: 95-58,82,83,96,105,106,120,141

4 Sample corresponds to the following Lot Numbers: 95-60,68,69,99,114,115,116,117

TABLE 7. LABORATORY QC DUPLICATE RESULTS FOR ^{226}Ra

^{226}Ra via Gamma Spectrometry - MK GUN16A-B

Lot Number	Original LSN	Activity (pCi/g)	Duplicate LSN	Activity (pCi/g)	QA * Comparison
95-10,14	R54018	67.9 ± 1.7	R54131	66.0 ± 1.3	Acceptable
95-12	R53491	66.1 ± 1.2	R53621	67.0 ± 1.1	Acceptable
95-13	R53489	66.6 ± 1.1	R53491	66.1 ± 1.2	Acceptable
95-22	R53077	66.2 ± 1.2	R53349	66.6 ± 1.1	Acceptable
95-25 (R)	R55484	65.0 ± 3.5	R56715	64.2 ± 3.5	Acceptable
95-44	R52806	66.3 ± 1.2	R53075	67.3 ± 1.1	Acceptable
95-51	R54789	67.1 ± 2.2	R54841	65.9 ± 2.2	Acceptable
95-59,78	R54405	65.5 ± 1.1	R54454	65.4 ± 1.6	Acceptable
95-61	R54454	65.4 ± 1.6	R54550	66.9 ± 1.6	Acceptable
95-84	R54924	65.6 ± 2.2	R54975	65.5 ± 2.2	Acceptable
95-92,93,106	R55240	64.1 ± 2.8	R55292	69.7 ± 3.5	Acceptable
95-114	R56715	64.2 ± 3.5	R55596	63.1 ± 3.5	Acceptable
95-115,128	R54625	66.7 ± 1.6	R54737	65.1 ± 2.2	Acceptable
95-116	R55078	64.9 ± 2.7	R55129	65.8 ± 2.8	Acceptable
95-122	R55292	69.7 ± 3.5	R55440	66.4 ± 3.4	Acceptable
95-131	R55634	63.5 ± 3.5	R55682	67.3 ± 3.5	Acceptable
95-139	R56541	65.6 ± 3.5	R55883	61.8 ± 3.4	Acceptable
95-147,149	R56638	61.7 ± 3.3	R56691	61.9 ± 3.4	Acceptable
95-155,156,157 (O)	R57726	69.8 ± 3.5	R57874	65.4 ± 3.4	Acceptable
95-160	R57360	65.2 ± 3.5	R57618	67.8 ± 3.4	Acceptable
95-17	R53621	67.0 ± 1.1	R53838	65.9 ± 1.3	Acceptable
95-18,27	R54131	66.0 ± 1.3	R54327	66.4 ± 1.1	Acceptable
95-23	R53075	67.3 ± 1.1	R53077	66.2 ± 1.2	Acceptable
95-24	R53838	65.9 ± 1.3	R54018	67.9 ± 1.7	Acceptable
95-60	R54327	66.4 ± 1.1	R54405	65.5 ± 1.1	Acceptable
95-66	R54550	66.9 ± 1.6	R54625	66.7 ± 1.6	Acceptable
95-77,117	R54841	65.9 ± 2.2	R54924	65.6 ± 2.2	Acceptable
95-82	R54737	65.1 ± 2.2	R54789	67.1 ± 2.2	Acceptable
95-99,123	R54975	65.5 ± 2.2	R55078	64.9 ± 2.7	Acceptable
95-108,110	R55129	65.8 ± 2.8	R55240	64.1 ± 2.8	Acceptable
95-121	R55440	66.4 ± 3.4	R55484	65.0 ± 3.5	Acceptable
95-133	R55596	63.1 ± 3.5	R55634	63.5 ± 3.5	Acceptable
95-137	R55682	67.3 ± 3.5	R55800	69.6 ± 3.6	Acceptable
95-150	R55883	61.8 ± 3.4	R56638	61.7 ± 3.3	Acceptable
95-155,156,157 (Splits)	R56691	61.9 ± 3.4	R57360	65.2 ± 3.5	Acceptable
95-162	R57618	67.8 ± 3.4	R57726	69.8 ± 3.5	Acceptable
95-163,164	R57726	69.8 ± 3.5	R57874	65.4 ± 3.4	Acceptable
96-8	R57704	48.6 ± 3.0	R58783	49.1 ± 3.0	Acceptable
96-9	R57874	65.4 ± 3.4	R58806	65.0 ± 3.4	Acceptable
96-10	R58783	49.1 ± 3.0	R58823	49.0 ± 3.0	Acceptable
96-11	R58806	65.0 ± 3.4	R58850	66.6 ± 3.5	Acceptable
96-12,14	R58823	49.0 ± 3.0	R58874	46.5 ± 3.0	Acceptable
96-13	R58850	66.6 ± 3.5	R58898	63.8 ± 3.5	Acceptable
96-18,19	R58898	63.8 ± 3.5	R59613	60.0 ± 3.4	Acceptable

* As required by the YAEL QA Program, agreement for duplicate results is achieved when the paired measurements are within 15% of their average value OR if the two standard deviation range established for each of the analysis results overlap.

TABLE 7. (continued) LABORATORY QC DUPLICATE RESULTS FOR ^{226}Ra

^{226}Ra via Gamma Spectrometry - MK GUN32B-A

Lot Number	Original LSN	Activity (pCi/g)	Duplicate LSN	Activity (pCi/g)	QA * Comparison
95-11	R53365	53.1 ± 1.0	R53569	50.5 ± 1.1	Acceptable
95-15	R53569	50.5 ± 1.1	R53722	50.8 ± 1.1	Acceptable
95-16	R54040	52.1 ± 1.5	R54107	49.6 ± 1.5	Acceptable
95-21	R53722	50.8 ± 1.1	R53992	55.3 ± 1.5	Acceptable
95-25	R52807	54.9 ± 1.1	R53076	50.7 ± 1.1	Acceptable
95-26	R54107	49.6 ± 1.5	R54080	54.2 ± 1.2	Acceptable
95-31	R53076	50.7 ± 1.1	R53266	49.7 ± 1.0	Acceptable
95-35,34,32	R53992	55.3 ± 1.5	R54040	52.1 ± 1.5	Acceptable
95-36B	R53266	49.7 ± 1.0	R53365	53.1 ± 1.0	Acceptable
95-43	R54080	54.2 ± 1.2	R54303	53.5 ± 1.0	Acceptable
95-58	R54303	53.5 ± 1.0	R54429	52.3 ± 1.0	Acceptable
95-62	R54429	52.3 ± 1.0	R54575	49.9 ± 1.4	Acceptable
95-64	R54575	49.9 ± 1.4	R54600	49.4 ± 1.4	Acceptable
95-68	R54600	49.4 ± 1.4	R54650	51.4 ± 1.4	Acceptable
95-79,69	R54650	51.4 ± 1.4	R54764	48.7 ± 1.9	Acceptable
95-74,134	R54812	49.4 ± 1.9	R54950	50.0 ± 1.9	Acceptable
95-85	R54764	48.7 ± 1.9	R54812	49.4 ± 1.9	Acceptable
95-96,97	R55104	48.8 ± 2.4	R55156	51.1 ± 2.4	Acceptable
95-102,105	R55000	49.4 ± 1.9	R55104	48.8 ± 2.4	Acceptable
95-109,111	R55156	51.1 ± 2.4	R55266	48.7 ± 3.0	Acceptable
95-118,120	R55266	48.7 ± 3.0	R55320	50.4 ± 3.0	Acceptable
95-119	R55659	49.8 ± 3.0	R55615	49.8 ± 3.0	Acceptable
95-124	R55463	53.9 ± 3.2	R55659	49.8 ± 3.0	Acceptable
95-126	R55417	51.7 ± 3.1	R55463	53.9 ± 3.2	Acceptable
95-127,130	R55320	50.4 ± 3.0	R55417	51.7 ± 3.1	Acceptable
95-83,129	R54950	50.0 ± 1.9	R55000	49.4 ± 1.9	Acceptable
95-136	R55712	49.1 ± 2.9	R55825	48.7 ± 3.0	Acceptable
95-138,144	R56514	52.3 ± 3.1	R55858	47.8 ± 3.0	Acceptable
95-140	R55858	47.8 ± 3.0	R55905	50.9 ± 3.0	Acceptable
95-141,143	R55615	49.8 ± 3.0	R55712	49.1 ± 2.9	Acceptable
95-148,151	R55905	50.9 ± 3.0	R56664	50.5 ± 3.1	Acceptable
95-152	R56664	50.5 ± 3.10	R56710	47.1 ± 3.0	Acceptable
95-159	R57247	52.4 ± 3.1	R57596	50.3 ± 3.1	Acceptable
95-161	R57596	50.3 ± 3.1	R57704	48.6 ± 3.0	Acceptable

* As required by the YAEL QA Program, agreement for duplicate results is achieved when the paired measurements are within 15% of their average value OR if the two standard deviation range established for each of the analysis results overlap.

TABLE 8. LABORATORY QC DUPLICATE RESULTS FOR ^{230}Th

^{230}Th via Alpha Spectrometry - NIST Rocky Flats

Lot Number	Original LSN	Activity (pCi/g)	Duplicate LSN	Activity (pCi/g)	QA * Comparison
95-7	W52648	1.16 ± 0.15	W52649	1.25 ± 0.13	Acceptable
95-11	W53572	1.26 ± 0.13	W53573	1.12 ± 0.13	Acceptable
95-15	W53720	1.08 ± 0.13	W53721	1.16 ± 0.14	Acceptable
95-16	W54104	0.99 ± 0.13	W54106	1.08 ± 0.14	Acceptable
95-21	W53990	0.994 ± 0.094	W53991	1.058 ± 0.097	Acceptable
95-23	W53105	1.01 ± 0.13	W53106	1.09 ± 0.14	Acceptable
95-25	W53051	1.09 ± 0.14	W53052	1.19 ± 0.15	Acceptable
95-26	W54078	1.12 ± 0.15	W54079	1.16 ± 0.15	Acceptable
95-31	W53267	1.03 ± 0.12	W53268	1.09 ± 0.15	Acceptable
95-35,34,32	W54038	1.00 ± 0.12	W54039	1.05 ± 0.12	Acceptable
95-36B	W53366	1.33 ± 0.14	W53367	1.31 ± 0.13	Acceptable
95-43	W54301	1.11 ± 0.13	W54302	1.24 ± 0.14	Acceptable
95-58	W54427	1.23 ± 0.15	W54428	1.16 ± 0.12	Acceptable
95-62	W54573	1.02 ± 0.11	W54574	1.03 ± 0.11	Acceptable
95-64	W54598	1.23 ± 0.12	W54599	1.41 ± 0.13	Acceptable
95-68	W54648	1.16 ± 0.10	W54649	1.16 ± 0.10	Acceptable
95-74,134	W54948	1.05 ± 0.10	W54949	1.15 ± 0.11	Acceptable
95-79,69	W54762	1.15 ± 0.12	W54763	1.09 ± 0.12	Acceptable
95-83,129	W54998	1.25 ± 0.14	W54999	1.15 ± 0.13	Acceptable
95-85	W54810	1.10 ± 0.13	W54811	1.21 ± 0.14	Acceptable
95-92,93,106	W55290	1.33 ± 0.15	W55291	1.17 ± 0.12	Acceptable
95-96,97	W55154	1.048 ± 0.081	W55155	1.266 ± 0.091	Acceptable
95-99,123	W55076	1.14 ± 0.14	W55077	1.13 ± 0.15	Acceptable
95-108,110	W55238	1.01 ± 0.13	W55239	1.28 ± 0.16	Acceptable
95-114	W55594	1.16 ± 0.12	W55595	1.19 ± 0.11	Acceptable
95-121	W55482	1.21 ± 0.13	W55483	1.13 ± 0.12	Acceptable
95-122	W55438	1.12 ± 0.12	W55439	1.10 ± 0.12	Acceptable
95-99,123	W55076	1.14 ± 0.14	W55077	1.13 ± 0.15	Acceptable
95-83,129	W54998	1.25 ± 0.14	W54999	1.15 ± 0.13	Acceptable
95-131	W55680	1.09 ± 0.13	W55681	1.29 ± 0.14	Acceptable
95-133	W55632	1.14 ± 0.10	W55633	1.060 ± 0.097	Acceptable
95-74,134	W54948	1.05 ± 0.10	W54949	1.15 ± 0.11	Acceptable
95-137	W55798	1.17 ± 0.13	W55799	1.3 ± 0.13	Acceptable
95-139	W55881	1.06 ± 0.11	W55882	1.13 ± 0.13	Acceptable
95-147,149	W56689	1.23 ± 0.12	W56690	1.05 ± 0.11	Acceptable
95-150	W56636	1.06 ± 0.11	W56637	1.14 ± 0.12	Acceptable
95-147,149	W56689	1.23 ± 0.12	W56690	1.05 ± 0.11	Acceptable
95-155,156,157,153(R)	W57358	1.11 ± 0.12	W57359	1.36 ± 0.14	Acceptable
95-155,156,157,153(O)	W57872	1.20 ± 0.12	W57873	1.2 ± 0.13	Acceptable
95-160	W57616	1.14 ± 0.10	W57617	1.073 ± 0.099	Acceptable
95-162	W57724	1.15 ± 0.11	W57725	1.31 ± 0.12	Acceptable

* As required by the YAEL QA Program, agreement for duplicate results is achieved when the paired measurements are within 15% of their average value OR if the two standard deviation range established for each of the analysis results overlap.

TABLE 8. (continued) LABORATORY QC DUPLICATE RESULTS FOR ^{230}Th

^{230}Th via Alpha Spectrometry - NIST Peruvian

Lot Number	Original LSN	Activity (pCi/g)	Duplicate LSN	Activity (pCi/g)	QA * Comparison
95-140	W55903	1.05 ± 0.12	W55904	0.93 ± 0.12	Acceptable
95-10,14	W54129	0.98 ± 0.12	W54130	1.01 ± 0.12	Acceptable
95-12	W53619	0.904 ± 0.097	W53620	0.91 ± 0.11	Acceptable
95-13	W53492	1.01 ± 0.14	W53493	0.96 ± 0.13	Acceptable
95-17	W53836	0.933 ± 0.090	W53837	0.95 ± 0.13	Acceptable
95-18,27	W54325	0.91 ± 0.11	W54326	0.93 ± 0.11	Acceptable
95-22	W53350	0.90 ± 0.13	W53351	1.01 ± 0.14	Acceptable
95-23,34	W56790	0.95 ± 0.12	W56791	0.97 ± 0.12	Acceptable
95-24	W54016	0.88 ± 0.11	W54017	0.89 ± 0.11	Acceptable
95-23,34 (R)	W56790	0.95 ± 0.12	W56791	0.97 ± 0.12	Acceptable
95-44	W52829	0.881 ± 0.088	W53030	0.92 ± 0.12	Acceptable
95-51	W53181	1.02 ± 0.13	W53182	0.92 ± 0.16	Acceptable
95-59,78	W54452	0.95 ± 0.13	W54453	0.94 ± 0.11	Acceptable
95-60	W54403	1.06 ± 0.12	W54404	0.97 ± 0.12	Acceptable
95-61	W54548	0.89 ± 0.11	W54549	0.95 ± 0.12	Acceptable
95-66	W54623	1.01 ± 0.14	W54624	0.93 ± 0.12	Acceptable
95-68 (R)	W58096	1.21 ± 0.16	W58097	1.23 ± 0.17	Acceptable
95-77,117	W54922	0.98 ± 0.12	W54923	0.92 ± 0.12	Acceptable
95-59,78	W54452	0.95 ± 0.13	W54453	0.94 ± 0.11	Acceptable
95-82	W54787	0.91 ± 0.12	W54788	1.15 ± 0.14	Acceptable
95-84	W54973	0.933 ± 0.090	W54974	0.91 ± 0.10	Acceptable
95-102,105	W55102	1.14 ± 0.14	W55103	0.95 ± 0.13	Acceptable
95-109,111	W55264	1.15 ± 0.15	W55265	0.939 ± 0.098	Acceptable
95-115,128	W54735	1.13 ± 0.12	W54736	1.26 ± 0.14	Acceptable
95-116	W55127	0.98 ± 0.13	W55128	1.03 ± 0.13	Acceptable
95-116,124,131 (R)	W56988	0.95 ± 0.12	W56989	1.16 ± 0.12	Acceptable
95-118,120	W55318	1.02 ± 0.12	W55319	0.95 ± 0.12	Acceptable
95-119	W55613	1.18 ± 0.15	W55614	1.05 ± 0.12	Acceptable
95-124	W55657	0.92 ± 0.12	W55658	1.07 ± 0.13	Acceptable
95-126	W55461	1.01 ± 0.11	W55462	0.96 ± 0.10	Acceptable
95-127,130	W55415	1.018 ± 0.094	W55416	1.053 ± 0.099	Acceptable
95-136	W55823	1.10 ± 0.11	W55824	1.06 ± 0.11	Acceptable
95-138,144	W55856	1.06 ± 0.10	W55857	1.006 ± 0.094	Acceptable
95-141,143	W55710	0.884 ± 0.099	W55711	0.901 ± 0.096	Acceptable
95-148,151	W56662	1.03 ± 0.11	W56663	0.939 ± 0.096	Acceptable
95-152,153	W56708	0.96 ± 0.10	W56709	0.99 ± 0.11	Acceptable
95-158	W57119	0.91 ± 0.10	W57120	0.97 ± 0.10	Acceptable
95-159	W57594	0.97 ± 0.12	W57595	1.01 ± 0.11	Acceptable
95-161	W57702	1.01 ± 0.11	W57703	1.06 ± 0.12	Acceptable
95-163,164	W57872	1.20 ± 0.12	W57873	1.20 ± 0.13	Acceptable
96-8	W58781	1.25 ± 0.13	W58782	1.21 ± 0.13	Acceptable
96-9	W58804	1.12 ± 0.11	W58805	1.10 ± 0.11	Acceptable
96-10	W58821	1.17 ± 0.11	W58822	1.22 ± 0.12	Acceptable
96-11	W58848	1.07 ± 0.11	W58849	1.19 ± 0.11	Acceptable
96-12,14	W58872	1.16 ± 0.12	W58873	1.14 ± 0.12	Acceptable
96-13	W58896	1.20 ± 0.13	W58897	1.20 ± 0.13	Acceptable
96-18,19	W59611	1.08 ± 0.12	W59612	1.15 ± 0.13	Acceptable

* As required by the YAEL QA Program, agreement for duplicate results is achieved when the paired measurements are within 15% of their average value OR if the two standard deviation range established for each of the analysis results overlap.

TABLE 9. LABORATORY QC DUPLICATE RESULTS FOR ISOTOPIC URANUIM
^{234}U, ^{235}U, and ^{238}U via Alpha Spectrometry - NIST Rocky Flats

Lot Number	Nuclide	Original LSN	Activity (pCi/g)	Duplicate LSN	Activity (pCi/g)	QA * Comparison
95-7	^{234}U	U54838	0.966 ± 0.094	U54839	0.994 ± 0.094	Acceptable
	^{235}U		0.049 ± 0.021		0.036 ± 0.019	Acceptable
	^{238}U		0.925 ± 0.091		0.92 ± 0.091	Acceptable
Note 1	^{234}U	U55949	1.01 ± 0.11	U55950	0.92 ± 0.10	Acceptable
	^{235}U		0.053 ± 0.026		0.037 ± 0.021	Acceptable
	^{238}U		1.01 ± 0.11		0.88 ± 0.10	Acceptable
95-159,160	^{234}U	U57620	0.96 ± 0.11	U57621	1.04 ± 0.12	Acceptable
	^{235}U		0.051 ± 0.026		0.037 ± 0.024	Acceptable
	^{238}U		0.95 ± 0.11		1.03 ± 0.11	Acceptable
95-164	^{234}U	U57870	1.034 ± 0.099	U57871	0.975 ± 0.096	Acceptable
	^{235}U		0.053 ± 0.022		0.040 ± 0.020	Acceptable
	^{238}U		0.979 ± 0.096		0.969 ± 0.095	Acceptable
Note 2	^{234}U	U56712	0.966 ± 0.090	U56713	1.007 ± 0.093	Acceptable
	^{235}U		0.033 ± 0.018		0.046 ± 0.020	Acceptable
	^{238}U		0.891 ± 0.086		0.938 ± 0.090	Acceptable
95-43,84,85,96	^{234}U	U58923	0.903 ± 0.095	U58924	1.03 ± 0.10	Acceptable
	^{235}U		0.041 ± 0.020		0.049 ± 0.022	Acceptable
	^{238}U		0.914 ± 0.096		1.02 ± 0.10	Acceptable
95-43,105,122	^{234}U	U58222	1.04 ± 0.11	U58223	1.02 ± 0.10	Acceptable
	^{235}U		0.040 ± 0.021		0.049 ± 0.022	Acceptable
	^{238}U		1.08 ± 0.11		0.94 ± 0.10	Acceptable
Note 3	^{234}U	U56640	1.20 ± 0.10	U56441	1.07 ± 0.10	Acceptable
	^{235}U		0.044 ± 0.019		0.050 ± 0.022	Acceptable
	^{238}U		1.16 ± 0.10		0.930 ± 0.093	Acceptable
Note 4	^{234}U	U57190	0.926 ± 0.099	U57191	1.05 ± 0.11	Acceptable
	^{235}U		0.057 ± 0.025		0.054 ± 0.026	Acceptable
	^{238}U		0.859 ± 0.095		0.97 ± 0.11	Acceptable
95-43,84,96	^{234}U	U58293	0.903 ± 0.095	U58294	1.03 ± 0.10	Acceptable
	^{235}U		0.041 ± 0.020		0.049 ± 0.022	Acceptable
	^{238}U		0.914 ± 0.096		1.02 ± 0.10	Acceptable
95-137,138,150	^{234}U	U56845	1.058 ± 0.074	U56846	1.042 ± 0.073	Acceptable
	^{235}U		0.064 ± 0.019		0.052 ± 0.016	Acceptable
	^{238}U		1.023 ± 0.073		0.993 ± 0.071	Acceptable
95-156,157	^{234}U	U57358	0.99 ± 0.11	U57359	1.09 ± 0.11	Acceptable
	^{235}U		0.045 ± 0.022		0.040 ± 0.023	Acceptable
	^{238}U		0.882 ± 0.099		1.02 ± 0.11	Acceptable
95-43,105,122	^{234}U	U58222	1.04 ± 0.11	U58223	1.02 ± 0.10	Acceptable
	^{235}U		0.040 ± 0.021		0.049 ± 0.022	Acceptable
	^{238}U		1.08 ± 0.11		0.94 ± 0.10	Acceptable

* As required by the YAEL QA Program, agreement for duplicate results is achieved when the paired measurements are within 15% of their average value OR if the two standard deviation range established for each of the analysis results overlap.

Notes:
1 Sample corresponds to the following Lot Numbers: 95-11,12,13,15,17,18,21,22,23,24,25,26,27,58,59
2 Sample corresponds to the following Lot Numbers: 95-12,13,21,26,36B,43,74,85,93,102,105,106,123, 126,131,133,140,148,149,152
3 Sample corresponds to the following Lot Numbers: 95-58,82,83,96,105,106,120,141
4 Sample corresponds to the following Lot Numbers: 95-60,68,69,99,114,115,116,117

TABLE 9. (continued) LABORATORY QC DUPLICATE RESULTS FOR ISOTOPIC URANUIM
^{234}U, ^{235}U, and ^{238}U via Alpha Spectrometry - NIST Rocky Flats

Lot Number	Nuclide	Original LSN	Activity (pCi/g)	Duplicate LSN	Activity (pCi/g)	QA * Comparison
95-164	^{234}U	U58276	0.97 ± 0.10	U58277	0.99 ± 0.10	Acceptable
	^{235}U		0.51 ± 0.023		0.037 ± 0.023	Acceptable
	^{238}U		1.02 ± 0.10		0.885 ± 0.094	Acceptable
96-8	^{234}U	U58781	0.984 ± 0.085	U58782	0.996 ± 0.088	Acceptable
	^{235}U		0.048 ± 0.019		0.045 ± 0.019	Acceptable
	^{238}U		0.964 ± 0.084		0.991 ± 0.088	Acceptable
96-9	^{234}U	U58804	0.98 ± 0.10	U58805	0.96 ± 0.10	Acceptable
	^{235}U		0.043 ± 0.021		0.036 ± 0.021	Acceptable
	^{238}U		0.934 ± 0.097		1.01 ± 0.10	Acceptable
96-10	^{234}U	U58821	0.918 ± 0.095	U58822	0.99 ± 0.10	Acceptable
	^{235}U		0.034 ± 0.018		0.047 ± 0.022	Acceptable
	^{238}U		0.858 ± 0.091		0.96 ± 0.10	Acceptable
96-11	^{234}U	U58848	1.026 ± 0.095	U58849	0.946 ± 0.090	Acceptable
	^{235}U		0.050 ± 0.021		0.046 ± 0.020	Acceptable
	^{238}U		0.962 ± 0.092		0.895 ± 0.087	Acceptable
96-12,14	^{234}U	U58872	1.009 ± 0.092	U58873	0.975 ± 0.093	Acceptable
	^{235}U		0.040 ± 0.018		0.039 ± 0.019	Acceptable
	^{238}U		0.885 ± 0.085		1.019 ± 0.095	Acceptable
96-13	^{234}U	U58896	0.96 ± 0.10	U58897	1.00 ± 0.10	Acceptable
	^{235}U		0.058 ± 0.027		0.050 ± 0.023	Acceptable
	^{238}U		1.00 ± 0.11		0.96 ± 0.10	Acceptable
96-18,19	^{234}U	U59611	0.91 ± 0.11	U59612	1.03 ± 0.11	Acceptable
	^{235}U		0.046 ± 0.024		0.046 ± 0.024	Acceptable
	^{238}U		0.97 ± 0.11		0.97 ± 0.11	Acceptable

* As required by the YAEL QA Program, agreement for duplicate results is achieved when the paired measurements are within 15% of their average value OR if the two standard deviation range established for each of the analysis results overlap.

TABLE 10. PES CHARACTERIZATION

Sample ID	^{234}U			^{235}U			^{238}U			^{230}Th			^{226}Ra		
1037	2.96	±	0.18	0.130	±	0.035	2.94	±	0.18	3.92	±	0.31	5.12	±	0.14
1066	2.93	±	0.18	0.142	±	0.036	2.91	±	0.18	5.22	±	0.38	4.76	±	0.14
2036	2.76	±	0.17	0.097	±	0.029	2.89	±	0.17	3.83	±	0.32	6.30	±	0.23
2090	2.67	±	0.17	0.135	±	0.035	2.56	±	0.17	4.26	±	0.27	5.66	±	0.22
2125	2.63	±	0.16	0.090	±	0.029	2.71	±	0.17	5.42	±	0.42	7.64	±	0.24
3001	2.59	±	0.17	0.110	±	0.032	2.65	±	0.17	3.64	±	0.33	4.75	±	0.19
3064	2.74	±	0.18	0.113	±	0.032	2.67	±	0.17	4.11	±	0.35	5.63	±	0.21
3105	3.54	±	0.21	0.157	±	0.038	3.37	±	0.20	5.98	±	0.42	6.24	±	0.16
4025	3.06	±	0.18	0.128	±	0.034	3.16	±	0.19	5.83	±	0.41	6.59	±	0.24
4077	2.66	±	0.17	0.114	±	0.032	2.76	±	0.17	4.08	±	0.32	5.89	±	0.21
4091	2.76	±	0.19	0.133	±	0.037	2.83	±	0.19	3.82	±	0.23	6.03	±	0.22
4099	2.73	±	0.10	0.126	±	0.020	2.72	±	0.10	4.04	±	0.18	4.85	±	0.12
4113	3.06	±	0.18	0.169	±	0.038	3.12	±	0.18	5.12	±	0.36	5.77	±	0.21
5007	2.93	±	0.11	0.124	±	0.021	2.87	±	0.10	4.02	±	0.19	10.25	±	0.15
5112	2.92	±	0.18	0.104	±	0.032	3.07	±	0.19	5.96	±	0.39	7.46	±	0.24
6030	2.54	±	0.16	0.113	±	0.032	2.66	±	0.17	6.13	±	0.43	6.63	±	0.22
7013	3.75	±	0.22	0.172	±	0.040	3.61	±	0.21	5.17	±	0.36	5.99	±	0.21
7024	2.89	±	0.10	0.123	±	0.019	2.83	±	0.10	4.98	±	0.21	5.38	±	0.13
7029	2.70	±	0.18	0.135	±	0.036	2.69	±	0.18	4.57	±	0.37	7.25	±	0.23
7037	2.58	±	0.17	0.097	±	0.030	2.60	±	0.17	5.18	±	0.42	6.60	±	0.23
7063	2.86	±	0.17	0.142	±	0.035	2.83	±	0.17	5.89	±	0.42	5.78	±	0.21
7071	2.96	±	0.19	0.139	±	0.037	2.71	±	0.18	4.54	±	0.32	7.87	±	0.25
7079	2.50	±	0.17	0.106	±	0.032	2.35	±	0.16	3.88	±	0.30	6.95	±	0.22
7094	3.05	±	0.19	0.124	±	0.035	2.77	±	0.18	4.98	±	0.33	6.26	±	0.22
7119	3.89	±	0.22	0.179	±	0.041	3.82	±	0.22	4.81	±	0.30	6.37	±	0.22
8056	3.08	±	0.19	0.167	±	0.039	3.18	±	0.19	5.05	±	0.34	6.83	±	0.23
8099	2.95	±	0.18	0.133	±	0.035	2.93	±	0.18	4.64	±	0.34	6.74	±	0.23
8117	2.69	±	0.18	0.137	±	0.036	2.63	±	0.17	5.11	±	0.36	6.47	±	0.22

Uncertainty reported at 2σ.

TABLE 11. PES CONTROL LIMITS

Radionuclide	PES Acceptance Range (pCi/g)
^{234}U	2.52 < Result < 3.83
^{235}U	0.093 < Result < 0.176
^{238}U	2.44 < Result < 3.73
^{230}Th	3.5 < Result < 6.1
^{226}Ra	4.75 < Result < 9.3

TABLE 12. PES QA/QC RESULTS

LOT#	Ra-226			Th-230			Ra-date	Th-date
95-10	5.590	±	0.160	4.345	±	0.346	9/14	8/21
95-11	8.670	±	0.390	3.905	±	0.256	8/2	6/28
95-12	6.89	±	0.30	4.365	±	0.264	8/16	8/9
95-13	5.230	±	0.170	4.475	±	0.331	7/26	6/26
95-14	6.410	±	0.170	4.583	±	0.320	9/14	8/21
95-15	5.950	±	0.230	4.180	±	0.327	8/21	7/17
95-16	5.62	±	0.18	4.623	±	0.368	9/11	8/7
95-17	5.400	±	0.150	4.260	±	0.280	8/30	7/24
95-18	8.440	±	0.280	5.90	±	0.41	9/18	8/24
95-21	5.130	±	0.150	5.130	±	0.290	9/5	7/25
95-22	5.870	±	0.159	4.450	±	0.270	7/17	6/14
95-23*	5.090	±	0.109	3.330	±	0.220	6/21	5/25
95-24	6.560	±	0.180	3.91	±	0.29	9/5	8/28
95-25*	4.590	±	0.110	4.870	±	0.280	6/14	5/17
95-26	5.840	±	0.160	4.129	±	0.353	9/12	8/11
95-27	5.210	±	0.150	4.080	±	0.310	9/20	8/17
95-31	6.350	±	0.260	4.260	±	0.270	7/10	6/5
95-32	6.730	±	0.170	5.713	±	0.401	9/7	8/7
95-34*	5.890	±	0.170	10.404	±	0.695	9/5	8/11
95-35	6.570	±	0.180	3.639	±	0.300	9/7	8/7
95-36B	5.060	±	0.510	5.110	±	0.370	7/19	6/19
95-43	5.050	±	0.150	4.212	±	0.353	9/19	8/21
95-51	4.910	±	0.38	3.640	±	0.220	7/12	5/26
95-58	5.340	±	0.160	5.580	±	0.310	9/25	8/28
95-59	6.15	±	0.16	4.450	±	0.350	9/27	8/28
95-60	6.100	±	0.160	3.895	±	0.283	9/25	8/21
95-61	5.04	±	0.15	3.830	±	0.270	9/28	9/5
95-62	4.87	±	0.15	3.970	±	0.270	10/3	9/13
95-64	6.13	±	0.16	4.840	±	0.290	10/3	9/18
95-66	5.590	±	0.16	5.040	±	0.340	10/5	9/19
95-68*	4.880	±	0.15	6.25	±	0.32	10/5	9/25
95-69	4.950	±	0.28	4.54	±	0.33	10/11	9/27
95-74	5.520	±	0.16	3.92	±	0.31	10/17	10/11
95-77	5.380	±	0.15	5.13	±	0.33	10/18	10/11
95-78	5.98	±	0.16	4.790	±	0.360	9/27	8/28
95-79	5.020	±	0.16	3.51	±	0.24	10/11	9/27
95-82	4.75	±	0.41	3.61	±	0.26	10/16	9/27
95-83	5.450	±	0.16	4.60	±	0.31	10/23	10/11
95-84	4.760	±	0.40	3.58	±	0.35	10/23	10/17
95-85	4.90	±	0.15	4.93	±	0.37	10/16	9/28
95-92	5.960	±	0.16	5.01	±	0.33	10/31	10/31
95-93	6.250	±	0.17	5.91	±	0.45	10/31	10/31

*Shading indicates result outside control limits
Th-230: 3.5 < Result < 6.1
Ra-226: 4.75 < Result < 9.3

TABLE 12 (continued) PES QA/QC RESULTS

LOT#	Ra-226			Th-230			Ra-date	Th-date
95-96	6.460	±	0.170	4.61	±	0.30	10/30	10/31
95-97	4.850	±	0.160	5.64	±	0.28	10/20	10/30
95-99	4.800	±	0.150	4.59	±	0.32	10/17	10/26
95-102	8.010	±	0.190	5.27	±	0.35	10/26	10/26
95-105	6.680	±	0.170	6.06	±	0.49	10/26	10/26
95-106	8.320	±	0.190	4.01	±	0.28	11/2	10/31
95-108	5.560	±	0.16	4.620	±	0.31	10/20	10/30
95-109	4.930	±	0.15	5.85	±	0.36	10/31	10/31
95-110	6.520	±	0.22	4.890	±	0.35	10/20	10/30
95-111	8.76	±	0.16	4.29	±	0.28	10/31	10/31
95-114	6.520	±	0.17	4.97	±	0.30	11/20	10/31
95-115	6.650	±	0.17	4.50	±	0.29	10/11	9/11
95-116*	6.910	±	0.18	3.450	±	0.230	10/30	11/15
95-117	5.160	±	0.15	5.93	±	0.38	10/20	10/23
95-118	6.480	±	0.16	4.53	±	0.31	11/6	10/31
95-119	6.950	±	0.45	5.58	±	0.39	11/20	11/15
95-120	5.430	±	0.16	4.06	±	0.28	11/6	10/31
95-121	8.820	±	0.59	3.57	±	0.26	11/13	10/31
95-122	7.900	±	0.20	5.35	±	0.32	11/13	10/31
95-123	6.010	±	0.30	6.05	±	0.41	10/17	10/26
95-124*	4.800	±	0.11	3.440	±	0.26	11/15	11/22
95-126	6.900	±	0.18	4.59	±	0.33	11/13	10/31
95-127	7.470	±	0.30	5.280	±	0.240	10/31	11/7
95-128	5.610	±	0.16	3.74	±	0.24	10/11	9/11
95-129	5.450	±	0.13	4.89	±	0.34	10/23	10/11
95-130	6.120	±	0.16	4.49	±	0.23	10/31	11/7
95-131*	7.330	±	0.15	3.47	±	0.25	11/15	11/7
95-133	5.170	±	0.23	5.00	±	0.28	11/20	10/31
95-134	6.54	±	0.17	4.62	±	0.31	10/20	10/17
95-136	4.980	±	0.150	3.99	±	0.24	11/27	11/15
95-137	4.810	±	0.39	4.28	±	0.25	11/27	12/5
95-138	5.99	±	0.16	5.46	±	0.28	12/28	12/5
95-139	6.370	±	0.17	4.89	±	0.31	12/28	11/16
95-140	7.690	±	0.180	4.27	±	0.30	12/28	12/5
95-141	6.890	±	0.170	4.32	±	0.29	11/16	12/21
95-143	6.640	±	0.170	3.73	±	0.25	11/17	1/10
95-147	6.700	±	0.17	4.42	±	0.32	1/2	1/12
95-148	5.170	±	0.14	5.56	±	0.33	12/29	12/13
95-149	5.420	±	0.38	3.73	±	0.26	1/4	1/10
95-150	7.1	±	0.18	5.23	±	0.31	12/29	12/5
95-151	6.210	±	0.14	5.99	±	0.37	12/29	12/21
95-152	8.13	±	0.19	5.23	±	0.30	1/2	1/4
95-155	8.960	±	0.190	5.140	±	0.320	4/1	3/8

*Shading indicates result outside control limits
Th-230: 3.5 < Result < 6.1
Ra-226: 4.75 < Result < 9.3

TABLE 12 (continued) PES QA/QC RESULTS

LOT#	Ra-226			Th-230			Ra-date	Th-date
95-156	6.970	±	0.170	3.710	±	0.270	2/26	3/1
95-157	6.950	±	0.170	4.100	±	0.270	2/26	3/1
95-159	5.980	±	0.150	4.35	±	0.26	3/20	2/23
95-160	7.210	±	0.160	3.71	±	0.21	3/21	2/23
95-161	8.070	±	0.180	4.200	±	0.270	3/28	3/8
95-162	7.910	±	0.190	4.18	±	0.26	4/1	3/4
95-163	7.450	±	0.180	6.03	±	0.36	4/1	3/4
95-164*	7.160	±	0.180	2.830	±	0.190	4/1	3/1
96-8	5.750	±	0.150	5.60	±	0.35	6/17	5/20
96-9	5.350	±	0.150	6.01	±	0.40	6/17	5/23
96-10	5.280	±	0.150	4.72	±	0.28	6/21	5/22
96-11	6.260	±	0.160	4.58	±	0.27	6/21	5/29
96-12	6.400	±	0.170	4.33	±	0.27	6/24	5/28
96-13	7.280	±	0.170	5.70	±	0.32	6/27	6/3
96-14	5.480	±	0.150	5.63	±	0.33	7/1	5/28
96-18	6.930	±	0.220	5.29	±	0.34	7/23	7/1
96-19	7.260	±	0.220	5.03	±	0.34	7/23	7/1

*Shading indicates result outside control limits
Th-230: 3.5 < Result < 6.1
Ra-226: 4.75 < Result < 9.3

TABLE 13. RETESTED PES RESULTS

		ORIGINAL			RETEST		
		Th-230			Th-230		
ORIGINAL LOT 95-23	M1-975998S	0.94	±	0.11	1.12	±	0.13
	M2-021043S	2.18	±	0.19	1.94	±	0.17
	M1-723758S	0.803	±	0.084	0.91	±	0.11
PES /RETEST PES	M1-757043S	3.33	±	0.22	3.33	±	0.25
ORIGINAL LOT 95-34	C3-582599F	5.35	±	0.40	6.00	±	0.37
	C3-619636F	14.59	±	0.99	13.17	±	0.72
	C3-647661F	19.6	±	1.3	20.1	±	1.1
PES /RETEST PES	C3-627098F	10.4	±	0.70	9.20	±	0.53
ORIGINAL LOT 95-68	C3-142186S	3.87	±	0.22	4.09	±	0.36
	C3-104150S	6.77	±	0.36	6.07	±	0.38
	C3-105151S	1.28	±	0.12	1.12	±	0.12
PES /RETEST PES	C3-107010S	6.25	±	0.32	5.73	±	0.45
ORIGINAL LOT 95-116	C3-541556F	16.94	±	0.91	17.23	±	0.93
	C3-572589F	30.6	±	1.6	27.8	±	1.4
	C3-525540F	1.46	±	0.14	1.65	±	0.15
PES /RETEST PES	C3-545084F	3.45	±	0.23	3.75	±	0.25
ORIGINAL LOT 95-124	M1-568606F	3.34	±	0.26	3.29	±	0.25
	M1-365405F	1.05	±	0.14	1.13	±	0.12
	M1-335373Q	5.68	±	0.39	5.65	±	0.35
PES /RETEST PES	M1-415017Q	3.44	±	0.26	3.27	±	0.24
ORIGINAL LOT 95-131	TE-577595F	0.99	±	0.13	1.16	±	0.13
	TE-544562Q	1.54	±	0.17	1.47	±	0.14
	TE-497512Q	2.3	±	0.22	2.15	±	0.19
PES /RETEST PES	TE-535001F	3.47	±	0.25	3.30	±	0.23
ORIGINAL LOT 95-164	C1-418440F	5.63	±	0.33	4.52	±	0.34
	M1-448489Q	4.47	±	0.27	4.61	±	0.28
PER/RETEST PES	M1-495033F	2.83	±	0.19	2.82	±	0.22
		ORIGINAL			RETEST		
		Ra-226			Ra-226		
ORIGINAL LOT 95-25	M1-957981S	1.278	±	0.072	1.263	±	0.075
	M1-886912F	1.457	±	0.098	1.417	±	0.098
	M1-860887F	1.301	±	0.089	1.213	±	0.087
PES /RETEST PES	M1-847042F	4.59	±	0.11	4.61	±	0.12

TABLE 14. COMPARISON OF SPLIT SAMPLE ANALYSES: ^{226}Ra

				WNI RESULTS			WDOH RESULTS		
Grid ID		LOT#	State Sample Date	Ra-226 pCi/g			Ra-226 pCi/g		
C1-019028F	f	95-58	4/25/95	1.360	±	0.090	1.24	±	0.06
C1-041050F	f	95-58	4/25/95	1.390	±	0.090	1.41	±	0.05
C1-210235F	f	95-59	4/24/95	0.940	±	0.080	1.13	±	0.04
C1-218241F	f	95-121	7/24/95	1.510	±	0.110	1.23	±	0.04
C1-401424F	f	95-121	7/24/95	0.990	±	0.080	1.15	±	0.04
C1-418440F	f	95-121	7/24/95	9.210	±	0.200	7.34	±	0.16
C1-418440F		95-164		6.410	±	0.170			
C1-481502F	f	95-128	7/25/95	9.210	±	0.200	1.1	±	0.04
C1-525544F	f	95-106	6/22/95	2.160	±	0.110	2.38	±	0.07
C1-556943F	f	95-121	7/24/95	1.210	±	0.080	1.09	±	0.05
C1-609624F	f	95-128	7/25/95	3.410	±	0.140	1	±	0.05
C1-702716F	f	95-121	7/24/95	1.070	±	0.090	1	±	0.04
C1-709723S	f	95-59	4/24/95	1.230	±	0.080	1.14	±	0.04
C1-750581S	f	95-59	4/24/95	1.200	±	0.070	1.63	±	0.17
C2-614637F	a	95-105	6/22/95	1.690	±	0.100	1.4	±	0.1
C2-614637F		95-140		1.580	±	0.090			
C2-625648S	f	95-59	4/24/95	1.000	±	0.080	1.03	±	0.06
C2-667692S	f	95-59	4/24/95	1.030	±	0.090	1.12	±	0.04
C2-676702F	a	95-105	6/22/95	1.170	±	0.080	1.52	±	0.05
C2-725752F	f	95-121	7/24/95	1.250	±	0.090	1.12	±	0.04
C2-745772S	f	95-59	4/24/95	0.910	±	0.080	1.12	±	0.04
C2-757784F	f	95-58	4/25/95	1.040	±	0.080	1.08	±	0.05
C2-794827F	f	95-59	4/24/95	1.270	±	0.090	1.38	±	0.06
C2-806840F	f	95-106	6/22/95	1.100	±	0.090	1.07	±	0.04
C2-878917F	f	95-106	6/22/95	1.490	±	0.100	1.22	±	0.04
C2-895932F	f	95-59	4/24/95	1.500	±	0.100	1.4	±	0.05
C2-997037F	f	95-106	6/22/95	2.540	±	0.120	1.85	±	0.06
C2-997037F		95-164							
C3-044092S	f	95-59	4/24/95	2.100	±	0.110	1.7	±	0.1
C3-094140S	f	95-59	4/24/95	2.760	±	0.120	2.5	±	0.07
C3-186228S	f	95-58	4/25/95	0.900	±	0.080	1.02	±	0.06
C3-316345F	f	95-106	6/22/95	1.950	±	0.100	1.68	±	0.07
C3-316345F		95-106		3.130	±	0.130			
C3-364386F	f	95-58	4/25/95	1.570	±	0.100	1.62	±	0.08
C3-398421F	a	95-120	7/18/95	1.270	±	0.090	1.08	±	0.04
C3-479495F	a	95-35	4/11/95	1.260	±	0.090	1.51	±	0.05
C3-479495F	a	95-117	7/18/95	1.420	±	0.096	1.48	±	0.04
C3-537552F	a	95-31	4/11/95	1.010	±	0.090	1.1	±	0.05
C3-537552F	a	95-116	7/18/95	1.130	±	0.090	1.36	±	0.05
C3-537552F		95-155	.	1.110	±	0.090			

TABLE 14. (continued) COMPARISON OF SPLIT SAMPLE ANALYSES: ^{226}Ra

				WNI RESULTS			WDOH RESULTS		
Grid ID		LOT#	State Sample Date	Ra-226 pCi/g			Ra-226 pCi/g		
C3-540555F	a	95-32	4/11/95	1.020	±	0.090	1.18	±	0.04
C3-540555F	a	95-116	7/17/95	1.160	±	0.090	1.06	±	0.05
C3-582599F	a	95-34	4/11/95	1.000	±	0.080	0.99	±	0.05
C3-582599F	a	95-114	7/13/95	1.150	±	0.090	1.16	±	0.04
C3-584601F	f	95-121	7/24/95	1.250	±	0.090	1.17	±	0.04
C3-586603F	a	95-118	7/18/95	1.210	±	0.090	1.07	±	0.05
C3-619636F	a	95-34	4/11/95	0.900		0.060	1.13		0.05
C3-619636F	a	95-115	7/12/95	1.250	±	0.090	1.18	±	0.04
C3-619636F		95-155		1.220	±	0.090			
C3-647661F	a	95-34	4/11/95	1.010	±	0.090	1.27	±	0.04
C3-647661F	a	95-115	7/18/95	1.340	±	0.090	1.34	±	0.06
C3-647661F		95-157		1.150	±	0.090			
M1-115125S	f	95-59	4/24/95	2.070	±	0.110	1.68	±	0.07
M1-123136S	f	95-59	4/24/95	1.250	±	0.090	1.21	±	0.04
M1-183204S	f	95-121	7/24/95	2.220	±	0.110	1.9	±	0.1
M1-211232S	f	95-121	7/24/95	1.530	±	0.100	1.45	±	0.05
M1-223246S	a	95-120	7/18/95	3.660	±	0.130	3.94	±	0.13
M1-223246S		95-164							
M1-226249S	a	95-105	6/22/95	1.910	±	0.110	1.9	±	0.1
M1-268302Q	f	95-58	4/25/95	3.370	±	0.130	2.53	±	0.08
M1-268302Q		95-164							
M1-271305Q	f	95-106	6/22/95	1.470	±	0.100	1.27	±	0.06
M1-283317S	f	95-106	6/22/95	1.810	±	0.100	1.44	±	0.06
M1-296333F	f	95-121	7/24/95	4.910	±	0.140	4.6	±	0.1
M1-310347S	a	95-16	4/11/95	2.070	±	0.100	4.46	±	0.13
M1-310347S		95-138		1.730	±	0.100			
M1-337375Q	f	95-58	4/25/95	2.880	±	0.120	2.73	±	0.09
M1-337375Q		95-164							
M1-342380S	a	95-14	4/11/95	1.750	±	0.100	1.55	±	0.05
M1-342380S		95-150		1.250	±	0.090			
M1-348386S	a	95-16	4/11/95	1.660	±	0.100	1.77	±	0.06
M1-348386S		95-137		1.150	±	0.090			
M1-382422S	a	95-34	4/11/95	1.490	±	0.100	1.36	±	0.03
M1-382422S		95-150		1.120	±	0.090			
M1-388428S	a	95-17	4/11/95	1.260	±	0.070	1.12	±	0.04
M1-416457S	f	95-106	6/22/95	1.240	±	0.100	1.19	±	0.04
M1-459500S	a	95-21	4/11/95	1.260	±	0.090	1.26	±	0.05
M1-459500S		95-137		1.120	±	0.090			

TABLE 14. (continued) COMPARISON OF SPLIT SAMPLE ANALYSES: ^{226}Ra

				WNI RESULTS			WDOH RESULTS		
Grid ID		LOT#	State Sample Date	Ra-226 pCi/g			Ra-226 pCi/g		
M1-501543S	a	95-10	4/11/95	1.340	±	0.090	1.22	±	0.04
M1-501543S		95-150		1.110	±	0.090			
M1-504546S	a	95-12	4/11/95	0.950	±	0.070	1.08	±	0.06
M1-549590S	a	95-11	4/11/95	1.330	±	0.090	1.25	±	0.06
M1-549590S		95-139		1.070	±	0.080			
M1-552593S	a	95-13	4/11/95	1.010	±	0.090	1.1	±	0.03
M1-576614S	f	95-58	4/25/95	1.430	±	0.090	1.52	±	0.06
M1-618655S	f	95-106	6/22/95	1.330	±	0.080	1.12	±	0.05
M1-623660S	a	95-11	4/11/95	0.970	±	0.080	1.08	±	0.05
M1-642678F	a	95-105	6/22/95	1.010	±	0.080	1.1	±	0.1
M1-669705S	f	95-58	4/25/95	1.070	±	0.090	1.09	±	0.04
M1-690725S	a	95-23	4/11/95	0.920	±	0.060	1.11	±	0.05
M1-697732F	a	95-13	4/11/95	1.220	±	0.090	1.09	±	0.06
M1-717752S	f	95-58	4/25/95	3.410	±	0.130	3.3	±	0.1
M1-717752S		96-10		2.580	±	0.110			
M1-759793S	a	95-22	4/11/95	0.920	±	0.080	0.99	±	0.06
M1-780813F	a	95-105	6/22/95	1.690	±	0.100	1.6	±	0.1
M1-780813F		95-156		1.31	±	0.09			
M1-780813F		96-14		0.959	±	0.086			
M1-785818S	f	95-58	4/25/95	1.090	±	0.080	1.09	±	0.06
M1-785818S		96-8		1.02	±	0.08			
M1-787820S	f	95-58	4/25/95	1.040	±	0.080	1.08	±	0.06
M1-794827S	a	95-12	4/11/95	1.020	±	0.090	1.07	±	0.04
M1-797830F	a	95-26	4/11/95	1.010	±	0.080	1.11	±	0.05
M1-809841Q	a	95-105	6/22/95	1.570	±	0.100	1.5	±	0.1
M1-850877S	f	95-58	4/25/95	0.970	±	0.080	1.01	±	0.06
M1-853880S	f	95-58	4/25/95	1.000	±	0.080	1.11	±	0.04
M1-858885F	a	95-25	4/11/95	1.000	±	0.090	1.06	±	0.05
M1-880906S	f	95-58	4/25/95	0.980	±	0.080	1.03	±	0.05
M1-894920F	a	95-105	6/22/95	1.220	±	0.090	1.25	±	0.05
M1-894920F		96-9		1.07	±	0.08			
M1-949973F	a	95-105	6/22/95	1.090	±	0.090	1.17	±	0.04
M1-954978S	f	95-58	4/25/95	1.340	±	0.090	1.46	±	0.06
M1-963986F	f	95-128	7/25/95	1.390	±	0.090	1.39	±	0.05
M2-002024S	f	95-58	4/25/95	0.970	±	0.080	1.1	±	0.05
M2-015037F	a	95-105	6/22/95	1.060	±	0.080	1.27	±	0.04
M2-024748S	f	95-106	CANCELED ANALYSES				1.27	±	0.06
TE-383388F	f	95-121	7/24/95	0.90	±	0.08	1.07	±	0.04
TE-864878F	f	95-121	7/24/95	1.22	±	0.08	1.13	±	0.05
TW-299312F	f	95-121	7/24/95	0.96	±	0.08	1.09	±	0.39

TABLE 14. (continued) COMPARISON OF SPLIT SAMPLE ANALYSES: ^{226}Ra

				WNI RESULTS			WDOH RESULTS		
Grid ID		LOT#	State Sample Date	Ra-226 pCi/g			Ra-226 pCi/g		
TW-823835F	f	95-59	4/25/95	1.036	±	0.08	1.11	±	0.04
TW-823835F	f	95-121	7/24/95	1.02	±	0.08	1.12	±	0.04
TW-947954F	f	95-121	7/24/95	1.42	±	0.09	1.17	±	0.04

Note: Shading indicates grids that have been resampled after the State Split sample was taken.

TABLE 15. COMPARISON OF SPLIT SAMPLE ANALYSES: ^{230}Th

Grid ID		LOT#	State Sample Date	WNI RESULTS Th-230 pCi/g			WDOH RESULTS Th-230 pCi/g		
C1-019028F	f	95-58	4/25/95	1.34	±	0.14	1.47	±	0.11
C1-041050F	f	95-58	4/25/95	1.58	±	0.15	1.68	±	0.13
C1-210235F	f	95-59	4/24/95	0.91	±	0.12	1.46	±	0.11
C1-218241F	f	95-121	7/24/95	1.44	±	0.15	1.9	±	0.1
C1-401424F	f	95-121	7/24/95	1.32	±	0.14	1.8	±	0.2
C1-418440F	f	95-121	7/24/95	9.44	±	0.53	8.59	±	0.26
C1-418440F		95-164		5.63	±	0.33			
C1-481502F	f	95-128	7/25/95	9.44	±	0.53	7.1	±	0.28
C1-525544F	f	95-106	6/22/95	3.21	±	0.23	3.6	±	0.1
C1-556943F	f	95-121	7/24/95	1.26	±	0.14	0.97	±	0.09
C1-609624F	f	95-128	7/25/95	3.41	±	0.23	1.29	±	0.11
C1-702716F	f	95-121	7/24/95	1.07	±	0.12	1.4	±	0.1
C1-709723S	f	95-59	4/24/95	0.93	±	0.12	1.33	±	0.1
C1-750581S	f	95-59	4/24/95	3.47	±	0.29	4.93	±	0.19
C2-614637F	a	95-105	6/22/95	4.18	±	0.30	4.67	±	0.23
C2-614637F		95-140		5.06	±	0.34			
C2-625648S	f	95-59	4/24/95	0.89	±	0.12	1.13	±	0.08
C2-667692S	f	95-59	4/24/95	1.26	±	0.15	1.58	±	0.11
C2-676702F	a	95-105	6/22/95	2.58	±	0.23	2.58	±	0.35
C2-725752F	f	95-121	7/24/95	1.62	±	0.15	1.7	±	0.1
C2-745772S	f	95-59	4/24/95	1.08	±	0.13	1.16	±	0.09
C2-757784F	f	95-58	4/25/95	1.18	±	0.11	1.2	±	0.11
C2-794827F	f	95-59	4/24/95	2.37	±	0.23	1.77	±	0.1
C2-806840F	f	95-106	6/22/95	1.74	±	0.18	1.2	±	0.1
C2-878917F	f	95-106	6/22/95	1.43	±	0.13	0.72	±	0.09
C2-895932F	f	95-59	4/24/95	1.56	±	0.18	3.31	±	0.16
C2-997037F	f	95-106	6/22/95	2.76	±	0.20	5.4	±	0.3
C2-997037F		95-164							
C3-044092S	f	95-59	4/24/95	3.63	±	0.30	4.5	±	0.18
C3-094140S	f	95-59	4/24/95	4.17	±	0.35	2.97	±	0.13
C3-186228S	f	95-58	4/25/95	0.86	±	0.11	1.19	±	0.11
C3-316345F	f	95-106	6/22/95	3.55	±	0.24	1.12	±	0.12
C3-316345F		95-106		5.75	±	0.32			
C3-364386F	f	95-58	4/25/95	3.84	±	0.31	3.46	±	0.18
C3-398421F	a	95-120	7/18/95	3.05	±	0.23	3.8	±	0.2
C3-479495F	a	95-35	4/11/95	5.64	±	0.32	5.76	±	0.21
C3-479495F	a	95-117	7/18/95	4.54	±	0.32	12.4	±	0.3
C3-537552F	a	95-31	4/11/95	11.98	±	0.64	11.5	±	0.3
C3-537552F	a	95-116	7/18/95	18.78	±	1.00	12.5	±	0.3
C3-537552F		95-155		9.17	±	0.55			

TABLE 15. (continued) COMPARISON OF SPLIT SAMPLE ANALYSES: ^{230}Th

				WNI RESULTS			WDOH RESULTS		
Grid ID		LOT#	State Sample Date	Th-230 pCi/g			Th-230 pCi/g		
C3-540555F	a	95-32	4/11/95	6.30	±	0.46	6.03	±	0.25
C3-540555F	a	95-116	7/17/95	7.42	±	0.48	6.7	±	0.2
C3-582599F	a	95-34	4/11/95	5.35	±	0.40	7.11	±	0.25
C3-582599F	a	95-114	7/13/95	2.26	±	0.20	15.7	±	0.3
C3-584601F	f	95-121	7/24/95	1.06	±	0.12	1.7	±	0.1
C3-586603F	a	95-118	7/18/95	1.14	±	0.13	1.3	±	0.1
C3-619636F	a	95-34	4/11/95	14.59	±	0.99	17.2	±	0.4
C3-619636F	a	95-115	7/12/95	14.62	±	1.02	16.9		0.3
C3-619636F		95-155		14.15	±	0.75			
C3-647661F	a	95-34	4/11/95	19.60	±	1.30	21.4	±	0.5
C3-647661F	a	95-115	7/18/95	19.07	±	1.22	23.9	±	0.4
C3-647661F		95-157		12.27	±	0.61			
M1-115125S	f	95-59	4/24/95	1.80	±	0.18	1.65	±	0.11
M1-123136S	f	95-59	4/24/95	1.61	±	0.17	1.69	±	0.12
M1-183204S	f	95-121	7/24/95	2.44	±	0.19	2.6	±	0.2
M1-211232S	f	95-121	7/24/95	1.95	±	0.17	2.2	±	0.2
M1-223246S	a	95-120	7/18/95	5.01	±	0.35	5.1	±	0.2
M1-223246S		95-164							
M1-226249S	a	95-105	6/22/95	3.73	±	0.28	4	±	0.21
M1-268302Q	f	95-58	4/25/95	2.92	±	0.25	4.56	±	0.23
M1-268302Q		95-164							
M1-271305Q	f	95-106	6/22/95	1.55	±	0.14	1.8	±	0.1
M1-283317S	f	95-106	6/22/95	1.76	±	0.16	1.7	±	0.1
M1-296333F	f	95-121	7/24/95	6.73	±	0.42	5.7	±	0.2
M1-310347S	a	95-16	4/11/95	4.31	±	0.34	4.96	±	0.2
M1-310347S		95-138		4.12	±	0.18			
M1-337375Q	f	95-58	4/25/95	3.17	±	0.21	3.7	±	0.2
M1-337375Q		95-164							
M1-342380S	a	95-14	4/11/95	3.45	±	0.29	4.71	±	0.2
M1-342380S		95-150		2.99	±	0.18			
M1-348386S	a	95-16	4/11/95	1.86	±	0.20	2.63	±	0.15
M1-348386S		95-137		1.91	±	0.18			
M1-382422S	a	95-34	4/11/95	1.99	±	0.21	3.51	±	0.17
M1-382422S		95-150		2.12	±	0.12			
M1-388428S	a	95-17	4/11/95	1.22	±	0.11	1.28	±	0.11
M1-416457S	f	95-106	6/22/95	2.08	±	0.16	1.8	±	0.1
M1-459500S	a	95-21	4/11/95	22.14	±	0.96	26	±	0.4
M1-459500S		95-137		2.88	±	0.25			

TABLE 15. (continued) COMPARISON OF SPLIT SAMPLE ANALYSES: ^{230}Th

				WNI RESULTS			WDOH RESULTS		
Grid ID		LOT#	State Sample Date	Th-230 pCi/g			Th-230 pCi/g		
M1-501543S	a	95-10	4/11/95	3.93	±	0.38	3.93	±	0.17
M1-501543S		95-150		2.04	±	0.11			
M1-504546S	a	95-12	4/11/95	0.93	±	0.12	1.26	±	0.11
M1-549590S	a	95-11	4/11/95	3.81	±	0.30	2.68	±	0.16
M1-549590S		95-139		1.24	±	0.11			
M1-552593S	a	95-13	4/11/95	0.99	±	0.13	1.52	±	0.11
M1-576614S	f	95-58	4/25/95	2.24	±	0.16	2.32	±	0.16
M1-618655S	f	95-106	6/22/95	6.07	±	0.38	5.9	±	0.2
M1-623660S	a	95-11	4/11/95	1.02	±	0.13	1.23	±	0.12
M1-642678F	a	95-105	6/22/95	1.16	±	0.13	0.766	±	0.09
M1-669705S	f	95-58	4/25/95	1.18	±	0.12	1.51	±	0.11
M1-690725S	a	95-23	4/11/95	0.73	±	0.10	0.92	±	0.09
M1-697732F	a	95-13	4/11/95	1.40	±	0.18	1.76	±	0.1
M1-717752S	f	95-58	4/25/95	4.77	±	0.26	4.32	±	0.18
M1-717752S		96-10		2.83	±	0.21			
M1-759793S	a	95-22	4/11/95	1.07	±	0.14	1.1	±	0.11
M1-780813F	a	95-105	6/22/95	21.84	±	1.18	22	±	0.5
M1-780813F		95-156		7.01	±	0.44			
M1-780813F		96-14		1.07	±	0.11			
M1-785818S	f	95-58	4/25/95	1.33	±	0.12	1.16	±	0.12
M1-785818S		96-8		1.04	±	0.11			
M1-787820S	f	95-58	4/25/95	0.96	±	0.10	1.76	±	0.14
M1-794827S	a	95-12	4/11/95	0.89	±	0.11	1.15	±	0.11
M1-797830F	a	95-26	4/11/95	1.11	±	0.15	1.54	±	0.12
M1-809841Q	a	95-105	6/22/95	2.18	±	0.19	0.358	±	0.07
M1-850877S	f	95-58	4/25/95	1.57	±	0.14	1.14	±	0.1
M1-853880S	f	95-58	4/25/95	1.11	±	0.11	1.22	±	0.11
M1-858885F	a	95-25	4/11/95	1.05	±	0.12	0.759	±	0.067
M1-880906S	f	95-58	4/25/95	1.13	±	0.13	1.37	±	0.11
M1-894920F	a	95-105	6/22/95	1.68	±	0.21	1.6	±	0.1
M1-894920F		96-9		1.41	±	0.12			
M1-949973F	a	95-105	6/22/95	1.53	±	0.17	1.39	±	0.17
M1-954978S	f	95-58	4/25/95	1.62	±	0.14	1.59	±	0.12
M1-963986F	f	95-128	7/25/95	2.50	±	0.19	1.42	±	0.11
M2-002024S	f	95-58	4/25/95	0.90	±	0.11	0.562	±	0.068
M2-015037F	a	95-105	6/22/95	1.62	±	0.16	1.58	±	0.13
M2-024748S	f	95-106	CANCELED ANALYSES				1.97	±	0.11
TE-383388F	f	95-121	7/24/95	1.20	±	0.13	1.22	±	0.11
TE-864878F	f	95-121	7/24/95	1.61	±	0.16	1.36	±	0.1
TW-299312F	f	95-121	7/24/95	1.06	±	0.12	1.11	±	0.1

TABLE 15. (continued) COMPARISON OF SPLIT SAMPLE ANALYSES: ^{230}Th

				WNI RESULTS			WDOH RESULTS		
Grid ID		LOT#	State Sample Date	Th-230 pCi/g			Th-230 pCi/g		
TW-823835F	f	95-59	4/25/95	1.75	±	0.18	1.46	±	0.11
TW-823835F	f	95-121	7/24/95	0.99	±	0.12	0.98	±	0.1
TW-947954F	f	95-121	7/24/95	2.01	±	0.17	2.3	±	0.2

Note: Shading indicates grids that have been resampled after the State Split sample was taken.

TABLE 16. COMPARISON OF WNI/WDOH SPLIT SAMPLE RESULTS: ^{238}U

				WNI RESULTS			WDOH RESULTS		
Grid ID		LOT#	State Sample Date	U-238 pCi/g			U-238 pCi/g		
C1-709723S	f	95-59	4/24/95	1.174	±	0.1185	1.21	±	0.26
C1-750581S	f	95-59	4/24/95	1.088	±	0.1155	1.25	±	0.17
C2-625648S	f	95-59	4/24/95	0.9456	±	0.1053	0.87	±	0.39
C2-667692S	f	95-59	4/24/95	1.115	±	0.1148	1	±	0.25
C2-745772S	f	95-59	4/24/95	1.026	±	0.1106	1.19	±	0.28
C2-794827F	f	95-59	4/24/95	1.52	±	0.1344	1.59	±	0.38
C2-806840F	f	95-106	6/22/95	1.033	±	0.09876	1.32	±	0.26
C2-878917F	f	95-106	6/22/95	1.331	±	0.1099	1.77	±	0.31
C2-895932F	f	95-59	4/24/95	1.696	±	0.1471	1.77	±	0.31
C2-997037F	f	95-106	6/22/95	7.06	±	0.3331	4.81	±	0.38
C2-997037F		95-164		3.11	±	0.19			
M1-223246S	a	95-120	7/18/95	5.129	±	0.2623	3.71	±	0.53
M1-223246S		95-164		0.885	±	0.089			
M1-226249S	a	95-105	6/22/95	2.349	±	0.1531	2	±	0.3
M1-268302Q	f	95-58	4/25/95	6.603	±	0.3828	6.24	±	0.56
M1-268302Q		95-164		2.42	±	0.16			
M1-271305Q	f	95-106	6/22/95	1.388	±	0.1147	1.43	±	0.39
M1-283317S	f	95-106	6/22/95	1.67	±	0.1263	1.87	±	0.34
M1-337375Q	f	95-58	4/25/95	6.326	±	0.3464	4.48	±	0.57
M1-337375Q		95-164		2.32	±	0.16			
M1-388428S	a	95-17	4/11/95	1.099	±	0.1119	1.43	±	0.28
M1-494536F	f	95-58	4/25/95	3.951	±	0.2197	3.04	±	0.37
M1-504546S	a	95-12	4/11/95	0.8657	±	0.1041	1.31	±	0.24
M1-552593S	a	95-13	4/11/95	1.061	±	0.1169	1.46	±	0.19
M1-576614S	f	95-58	4/25/95	3.213	±	0.2159	2.1	±	0.42
M1-618655S	f	95-106	6/22/95	2.51	±	0.16	2.2	±	0.33
M1-623660S	a	95-11	4/11/95	1.12	±	0.1298	1.34	±	0.37
M1-690725S	a	95-23	4/11/95	1.421	±	0.135	1.4	±	0.19
M1-697732F	a	95-13	4/11/95	1.549	±	0.1416	1.8	±	0.5
M1-717752S	f	95-58	4/25/95	4.383	±	0.2752	2.4	±	0.5
M1-717752S		96-10		2.65	±	0.18			
M1-759793S	a	95-22	4/11/95	1.856	±	0.159	1.87	±	0.48
M1-780813F	a	95-105	6/22/95	7.76	±	0.35	5.9	±	0.4
M1-780813F		96-14		1.652	±	0.1287			
M1-780813F		95-156		4.289	±	0.2552			
M1-785818S	f	95-58	4/25/95	1.733	±	0.1496	1.1	±	0.3
M1-785818S		96-8		1.324	±	0.1001			
M1-787820S	f	95-58	4/25/95	1.886	±	0.1579	1.25	±	0.45
M1-794827S	a	95-12	4/11/95	1.055	±	0.1151	1.23	±	0.28
M1-797830F	a	95-26	4/11/95	1.408	±	0.134	1.9	±	0.4

TABLE 16. (Continued) COMPARISON OF SPLIT SAMPLE RESULTS: ^{238}U

				WNI RESULTS			WDOH RESULTS		
Grid ID		LOT#	State Sample Date	U-238 pCi/g			U-238 pCi/g		
M1-850877S	f	95-58	4/25/95	1.252	±	0.1253	1.04	±	0.41
M1-853880S	f	95-58	4/25/95	2.557	±	0.1898	1.87	±	0.33
M1-858885F	a	95-25	4/11/95	3.041	±	0.2216	2.4	±	0.4
M1-880906S	f	95-58	4/25/95	1.527	±	0.1337	1.51	±	0.35
M1-894920F	a	95-105	6/22/95	2.21	±	0.17	2.12	±	0.28
M1-894920F		96-9		1.838	±	0.1442			
M1-954978S	f	95-58	4/25/95	2.546	±	0.1834	1.8	±	0.5
M2-002024S	f	95-58	4/25/95	1.791	±	0.1519	1.9	±	0.5
M2-024748S	f	95-106	CANCELED ANALYSES				1.79	±	0.34

Note: Shading indicates grids that have been resampled after the State Split sample was taken.

TABLE 17. WDOH ANALYTICAL RESULTS ON THE PES

				WET CHEMISTRY		
DATE	^{226}Ra	^{230}Th	^{238}U	^{226}Ra	^{238}U	^{234}U
4/24/96	4.63 ± 0.18	6.57 ± 0.24	2.2 ± 0.6	5.7 ± 0.5	3.18 ± 0.17	3.27 ± 0.17
6/22/96	5.26 ± 0.12	3.35 ± 0.18	2.59 ± 0.34	4.6 ± 0.3	2.34 ± 0.15	2.44 ± 0.16
6/22/96	5.12 ± 0.12	4.71 ± 0.17	2.73 ± 0.36	4.9 ± 0.3	2.76 ± 0.15	2.54 ± 0.15
6/22/96	6.37 ± 0.18	5.2 ± 0.3	2.48 ± 0.46	5.2 ± 0.4	2.84 ± 0.16	2.89 ± 0.16
4/11/96	5.81 ± 0.16	4.24 ± 0.23	2.54 ± 0.56	4.2 ± 0.3	2.87 ± 0.16	2.51 ± 0.15
6/22/96	5.84 ± 0.14	4.7 ± 0.2	2.95 ± 0.36	5.2 ± 0.3	2.47 ± 0.14	2.33 ± 0.14

Note: Shaded values indicate analytical results outside of PES acceptance range as given below.

PES ACCEPTANCE RANGES

^{234}U: 2.52 < RESULT < 3.83

^{235}U: 0.093 < RESULT < 0.176

^{238}U: 2.44 < RESULT < 3.73

^{230}Th: 3.5 < RESULT < 6.1

^{226}Ra: 4.74 < RESULT < 9.3

TABLE 18 -WDOH Analytical Results as Received

site location	Date	Lab id	Ra-226 (da)*		Th-228		Th-230		Th-232		U-238 (da)*		Ra-226		U-238		U-234		Total U	
			activity	error	activity	error	activity	error	activity	error	activity	error	activitiy	error	activity	error	activity	error	activity	error
C1-019-128F	4/24/95	16596	1.24	0.06	1.93	0.13	1.47	0.11	1.97	0.12	1.77	0.43								
C1-041-050F	4/24/95	16591	1.41	0.05	1.41	0.12	1.68	0.13	1.24	0.11	3.35	0.39								
C1-210-235F	4/24/95	16607	1.13	0.04	1.71	0.12	1.46	0.11	1.57	0.11	1.14	0.27								
C1-218-241F	7/24/95	16992	1.23	0.04	1.3	0.1	1.9	0.1	1.3	0.1	1.8	0.3								
C1-481-502F	7/25/95	16978	1.1	0.04	1.26	0.12	7.1	0.28	1.12	0.11	1.58	0.24								
C1-525-544	6/22/95	16832	2.38	0.07	1.4	0.1	3.6	0.1	1.3	0.1	1.65	0.3								
C1-609-624F	7/25/95	16979	1	0.05	1.33	0.11	1.29	0.11	1.15	0.1	1.01	0.26								
C1-709-723S	4/24/95	16600	1.14	0.04	1.28	0.11	1.33	0.1	1.11	0.09	1.21	0.26	1.1	0.2	0.99	0.1	1.14	0.11	2.19	0.15
C1-750-581S	4/24/95	16601	1.63	0.17	1.32	0.11	4.93	0.19	1.17	0.09	1.25	0.17								
C2-614-637	6/22/95	16824	1.4	0.1	1.78	0.14	4.67	0.23	1.51	0.13	2	0.3								
C2-625-648S	4/24/95	16608	1.03	0.06	1.31	0.09	1.13	0.08	1.22	0.08	0.87	0.39								
C2-667-692S	4/24/95	16598	1.12	0.04	1.17	0.1	1.58	0.11	1.12	0.09	1	0.25								
C2-676-702	6/22/95	16822	1.52	0.05	1.28	0.25	2.58	0.35	1.11	0.22	1.9	0.3								
C2-725-752F	7/24/95	16989	1.12	0.04	1.5	0.1	1.7	0.1	1.3	0.1	1.3	0.2								
C2-745-772S	4/24/95	16609	1.12	0.04	1.17	0.08	1.16	0.09	1.12	0.08	1.19	0.28								
C2-757-784F	4/24/95	16586	1.08	0.05	1.55	0.12	1.2	0.11	1.46	0.12	1.46	0.4								
C2-794-827F	4/24/95	16606	1.38	0.06	1.28	0.09	1.77	0.1	1.12	0.08	1.59	0.38								
C2-806-840	6/22/95	16831	1.07	0.04	1.6	0.1	1.2	0.1	1.5	0.1	1.32	0.26								
C2-878-917	6/22/95	16838	1.22	0.04	1.04	0.1	0.72	0.09	1.02	0.1	1.77	0.31								
C2-895-932F	4/24/95	16605	1.4	0.05	3.74	0.17	3.31	0.16	3.98	0.17	1.77	0.31								
C2-997-037	6/22/95	16837	1.85	0.06	1.7	0.2	5.4	0.3	1.6	0.2	4.81	0.38								
C3-044-092S	4/24/95	16602	1.7	0.1	1.37	0.11	4.5	0.18	1.17	0.09	2.2	0.3								
C3-094-140S	4/24/95	16610	2.5	0.07	0.801	0.068	2.97	0.13	0.859	0.069	3.03	0.37	2.2	0.2	2.83	0.15	2.84	0.15	5.82	0.22
C3-186-228S	4/24/95	16588	1.02	0.06	1.34	0.11	1.19	0.11	1.28	0.11	0.72	0.44								
C3-316-345	6/22/95	16839	1.68	0.07	0.92	0.11	1.12	0.12	0.73	0.1	1.77	0.32								
C3-364-386F	4/24/95	16587	1.62	0.08	1.31	0.11	3.46	0.18	1.25	0.11	1.64	0.46								
C3-398-421F	7/18/95	16997	1.08	0.04	1.3	0.1	3.8	0.2	1.1	0.1	3.78	0.32								
C3-479-495F	4/11/95	16517	1.48	0.04	1.39	0.12	5.76	0.21	1.42	0.11	0.629	0.23								
C3-479-495F	7/18/95	16998	1.51	0.05	1.3	0.1	12.4	0.3	1.3	0.1	1.71	0.29								
C3-537-552F	4/11/95	16518	1.36	0.05	5.34	0.23	11.5	0.3	6.45	0.24	1.58	0.3								
C3-537-552F	7/18/95	16999	1.1	0.05	1.3	0.1	12.5	0.3	1.2	0.1	2	0.34								
C3-540-555F	4/11/95	16519	1.06	0.05	1.3	0.13	6.03	0.25	1.58	0.13	3.53	0.43								
C3-540-555F	7/17/95	17001	1.18	0.04	1.3	0.1	6.7	0.2	1.5	0.1	3.6	0.3								
C3-582-599F	4/11/95	16520	1.16	0.04	1.23	0.12	7.11	0.25	1.31	0.11	1.48	0.3								

TABLE 18 -WDOH Analytical Results as Received

site location	Date	Lab id	Ra-226 (da)*		Th-228		Th-230		Th-232		U-238 (da)*		Ra-226		U-238		U-234		Total U	
			activity	error	activity	error	activity	error	activity	error	activity	error	activitiy	error	activity	error	activity	error	activity	error
C3-582-599F	7/13/95	17003	0.99	0.05	1.3	0.1	15.7	0.3	1.5	0.1	1.7	0.3								
C3-584-601F	7/24/95	16993	1.17	0.04	2.1	0.1	1.7	0.1	2.1	0.1	1.3	0.3								
C3-586-603F	7/18/95	16996	1.07	0.05	1.1	0.1	1.3	0.1	1.1	0.1	1.51	0.3								
C3-619-636F	4/11/95	16521	1.18	0.04	1.73	0.15	17.2	0.4	1.55	0.13	1.28	0.29								
C3-619-636F	7/12/95	17002	1.13	0.05	1.4	0.1	16.9	0.3	1.6	0.1	1.66	0.26								
C3-647-661F	4/11/95	16522	1.34	0.06	1.61	0.15	21.4	0.5	1.57	0.13	1.02	0.42								
C3-647-661F	7/18/95	17000	1.27	0.04	1.5	0.1	23.9	0.4	1.6	0.1	1.2	0.3								
CI-401-424F	7/24/95	16986	1.15	0.04	1.4	0.1	1.8	0.2	1.3	0.1	1.5	0.3								
CI-418-440F	7/24/95	16985	7.34	0.16	1.53	0.11	8.59	0.26	1.69	0.12	7.22	0.52								
CI-556-943F	7/24/95	16984	1.09	0.05	1.2	0.1	0.97	0.09	1	0.1	1.14	0.29								
CI-702-716F	7/24/95	16987	1	0.04	1.7	0.1	1.4	0.1	1.5	0.1	0.9	0.2								
M1-115-125S	4/24/95	16603	1.68	0.07	1.19	0.1	1.65	0.11	1.01	0.09	2	0.44								
M1-123-136S	4/24/95	16604	1.21	0.04	1.24	0.1	1.69	0.12	1.21	0.1	1.5	0.3								
M1-183-204S	7/24/95	16988	1.9	0.1	1.6	0.1	2.6	0.2	1.4	0.1	1.6	0.3								
M1-211-232S	7/24/95	16990	1.45	0.05	1.5	0.1	2.2	0.2	1.2	0.1	1.5	0.3								
M1-223-246S	7/18/95	16995	3.94	0.13	2.5	0.1	5.1	0.2	2.3	0.1	3.71	0.53								
M1-226-249	6/22/95	16826	1.9	0.1	1.59	0.14	4	0.21	1.2	0.12	2	0.3	2.6	0.3	2.35	0.14	2.38	0.14	4.88	0.2
M1-268-302S	4/24/95	16585	2.53	0.08	5.05	0.24	4.56	0.23	4.86	0.24	6.24	0.56								
M1-271-305	6/22/95	16834	1.27	0.06	2.9	0.1	1.8	0.1	2.8	0.1	1.43	0.39								
M1-283-317	6/22/95	16830	1.44	0.06	1.3	0.1	1.7	0.1	1.1	0.1	1.87	0.34								
M1-296-333F	7/24/95	16991	4.6	0.1	2	0.2	5.7	0.2	1.8	0.1	6.2	0.5	4.5	0.3	6.7	0.2	7.1	0.2	14.2	0.3
M1-310-347S	4/11/95	16512	4.46	0.13	1.48	0.12	4.96	0.2	1.54	0.11	5.58	0.7								
M1-337-375Q	4/24/95	16594	2.73	0.09	2.13	0.15	3.7	0.2	2.15	0.15	4.48	0.57								
M1-342-380S	4/11/95	16508	1.55	0.05	1.55	0.13	4.71	0.2	1.41	0.11	2.33	0.22								
M1-348-386S	4/11/95	16514	1.77	0.06	1.3	0.11	2.63	0.15	1.25	0.1	2.05	0.32								
M1-382-422S	4/11/95	16511	1.36	0.03	1.49	0.12	3.51	0.17	1.44	0.11	1.5	0.12								
M1-388-428S	4/11/95	16515	1.12	0.04	1.47	0.12	1.28	0.11	1.38	0.11	1.43	0.28								
M1-416-457	6/22/95	16835	1.19	0.04	2.7	0.2	1.8	0.1	2.9	0.2	2.1	0.35								
M1-459-500S	4/11/95	16509	1.26	0.05	1.41	0.12	26	0.4	1.65	0.11	3.88	0.33								
M1-494-536F	4/24/95	16589	1.97	0.06	1.72	0.13	11.5	0.3	1.54	0.12	3.04	0.37	1.7	0.2	2.83	0.16	3.27	0.17	6.22	0.23
M1-501-543S	4/11/95	16510	1.22	0.04	1.42	0.11	3.93	0.17	1.7	0.11	2.52	0.23								
M1-504-546S	4/11/95	16513	1.08	0.06	1.75	0.13	1.26	0.11	1.6	0.12	1.31	0.24								
M1-549-590S	4/11/95	16531	1.25	0.06	0.92	0.093	2.68	0.16	0.867	0.09	1.9	0.5	1.24	0.27	1.81	0.12	1.89	0.13	3.84	0.18
M1-552-593S	4/11/95	16516	1.1	0.03	1.37	0.12	1.52	0.11	1.27	0.1	1.46	0.19								

TABLE 18 -WDOH Analytical Results as Received

site location	Date	Lab id	Ra-226 (da)*		Th-228		Th-230		Th-232		U-238 (da)*		Ra-226		U-238		U-234		Total U	
			activity	error	activity	error	activity	error	activity	error	activity	error	activitiy	error	activity	error	activity	error	activity	error
M1-576-614S	4/24/95	16592	1.52	0.06	1.82	0.14	2.32	0.16	2.36	0.16	2.1	0.42								
M1-618-655	6/22/95	16833	1.12	0.05	1.5	0.1	5.9	0.2	1.5	0.1	2.2	0.33								
M1-623-660S	4/11/95	16527	1.08	0.05	1.47	0.14	1.23	0.12	1.44	0.12	1.34	0.37								
M1-642-678	6/22/95	16821	1.1	0.1	1.07	0.1	0.766	0.09	0.945	0.096	1.5	0.3								
M1-669-705S	4/24/95	16595	1.09	0.04	1.48	0.11	1.51	0.11	1.29	0.1	1.38	0.32								
M1-690-725S	4/11/95	16524	1.11	0.05	1.16	0.12	0.92	0.09	1.09	0.1	1.4	0.19								
M1-697-732F	4/11/95	16530	1.09	0.06	1.74	0.1	1.76	0.1	1.76	0.11	1.8	0.5								
M1-717-752S	4/24/95	16581	3.3	0.1	1.28	0.1	4.32	0.18	1.09	0.09	2.4	0.5	3.6	0.4	2.94	0.15	2.89	0.15	6	0.22
M1-759-793S	4/11/95	16525	0.99	0.06	1.43	0.13	1.1	0.11	1.23	0.11	1.87	0.48	0.94	0.24	1.34	0.11	1.51	0.11	2.93	0.16
M1-780-813	6/22/95	16825	1.6	0.1	1.73	0.13	22	0.5	1.77	0.13	5.9	0.4								
M1-785-818S	4/24/95	16583	1.09	0.06	1.1	0.11	1.16	0.12	0.878	0.099	1.1	0.3								
M1-787-820S	4/24/95	16593	1.08	0.06	1.51	0.13	1.76	0.14	1.5	0.13	1.25	0.45								
M1-794-827S	4/11/95	16526	1.07	0.04	1.21	0.12	1.15	0.11	1.18	0.1	1.23	0.28								
M1-797-830F	4/11/95	16529	1.11	0.05	1.43	0.11	1.54	0.12	1.39	0.11	1.9	0.4								
M1-809-849	6/22/95	16827	1.5	0.1	0.183	0.052	0.358	0.07	0.251	0.055	1.5	0.3								
M1-850-877S	4/24/95	16597	1.01	0.06	1.11	0.1	1.14	0.1	1.1	0.09	1.04	0.41								
M1-853-880S	4/24/95	16584	1.11	0.04	1.5	0.12	1.22	0.11	1.5	0.12	1.87	0.33								
M1-858-885F	4/11/95	16528	1.06	0.05	1.07	0.08	0.759	0.067	1.08	0.07	2.4	0.4								
M1-880-906S	4/24/95	16590	1.03	0.05	1.5	0.12	1.37	0.11	1.45	0.11	1.51	0.35								
M1-894-920	6/22/95	16828	1.25	0.05	1.3	0.1	1.6	0.1	1.3	0.1	2.12	0.28								
M1-949-973	6/22/95	16823	1.17	0.04	1.24	0.11	1.39	0.17	1.19	0.11	2.1	0.3								
M1-954-978S	4/24/95	16582	1.46	0.06	1.32	0.11	1.59	0.12	1.18	0.1	1.8	0.5								
M1-963-986F	7/25/95	16977	1.39	0.05	1.27	0.11	1.42	0.11	1.41	0.11	1.61	0.32								
M2-002-024S	4/24/95	16580	1.1	0.05	0.615	0.069	0.562	0.068	0.615	0.064	1.9	0.5								
M2-015-037	6/22/95	16820	1.27	0.04	1.15	0.11	1.58	0.13	1.16	0.11	2	0.3	1.4	0.2	1.84	0.13	1.82	0.13	3.79	0.18
M2-024-748	6/22/95	16836	1.27	0.06	1.32	0.09	1.97	0.11	1.32	0.09	1.79	0.34								
PES	4/24/95	16579	4.63	0.18	1.38	0.11	6.57	0.24	1.33	0.11	2.2	0.6	5.7	0.5	3.18	0.17	3.27	0.17	6.62	0.24
PES	6/22/95	16841	5.12	0.12	1.23	0.09	4.71	0.17	1.18	0.08	2.73	0.36	4.9	0.3	2.76	0.15	2.54	0.15	5.42	0.21
PES	6/22/95	16840	5.26	0.12	0.94	0.1	3.35	0.18	1.05	0.1	2.59	0.34	4.6	0.3	2.34	0.15	2.44	0.16	4.9	0.22
PES	6/22/95	16842	6.37	0.18	1.5	0.2	5.2	0.3	1.5	0.1	2.48	0.46	5.2	0.4	2.84	0.16	2.89	0.16	5.89	0.23
PES 8113	4/11/95	16523	5.81	0.16	1.31	0.14	4.24	0.23	1.22	0.12	2.54	0.56	4.2	0.3	2.87	0.16	2.51	0.15	5.52	0.23
PES, M1-055-061	6/22/95	16829	5.84	0.14	1.2	0.1	4.7	0.2	1.2	0.1	2.95	0.36	5.2	0.3	2.47	0.14	2.33	0.14	4.95	0.21
TE-383-388F	7/24/95	16981	1.07	0.04	1.72	0.13	1.22	0.11	1.43	0.11	1.09	0.26								
TE-864-878F	7/24/95	16982	1.13	0.05	1.35	0.1	1.36	0.1	1.13	0.09	1.01	0.27								

TABLE 18 -WDOH Analytical Results as Received

site location	Date	Lab id	Ra-226 (da)*		Th-228		Th-230		Th-232		U-238 (da)*		Ra-226		U-238		U-234		Total U	
			activity	error	activity	error	activity	error	activity	error	activity	error	activitiy	error	activity	error	activity	error	activity	error
TW-299-312F	7/24/95	16983	1.09	0.39	1.65	0.12	1.11	0.1	1.14	0.1	1.01	0.25								
TW-823-835F	4/24/95	16599	1.11	0.04	1.61	0.12	1.46	0.11	1.42	0.11	1.15	0.29	1.1	0.2	0.79	0.08	0.79	0.08	1.63	0.11
TW-823-835F	7/24/95	16980	1.12	0.04	1.32	0.11	0.98	0.1	1.08	0.1	1.03	0.26								
TW-947-954F	7/24/95	16994	1.17	0.04	1.5	0.1	2.3	0.2	1.6	0.1	1.2	0.3								

TABLE 19. 1995 COMPARISON OF GAMMA SURVEYS

Grid ID	Original Result	State 07/24/95 Result	Difference
	Total Counts	Total Counts	
C1-019028F	1466	1451	15
C1-041050F	1434	1485	-51
C1-210235F	1457	1447	10
C1-260283F	1587	1694	-107
C1-275298F	1432	1356	76
C1-302325F	1252	1355	-103
C1-401424F	1336	1477	-141
C1-418440F	2003	2232	-229
C1-481502F	1642	1407	235
C1-525544F	1729	1804	-75
C1-549567F	1798	1419	379
C1-563580F	1469	1327	142
C1-702716F	1320	1337	-17
C2-656681F	1211	1188	23
C2-725752F	1560	1495	65
C2-736763S	1222	1418	-196
C2-746772AS	1438	1613	-175
C2-755782F	1273	1161	112
C2-893930F	1569	1782	-213
C3-053101S	1387	1498	-111
C3-176222F	1351	1386	-35
C3-182224S	1267	1366	-99
C3-364386F	1644	1659	-15
C3-395418F	1334	1395	-61
C3-499514F	1422	1473	-51
M1-115125S	1582	1536	46
M1-123136S	1714	1472	242
M1-159180F	2046	1982	64
M1-183204S	1725	1617	108
M1-192478F	1361	1344	17
M1-296333F	1944	2006	-62
M1-327365F	1468	1496	-28
M1-441482F	1492	1618	-126
M1-448489Q	2996	3360	-364
M1-532573Q	1684	1619	65
M1-642678F	1620	1545	75
M1-669705S	1326	1452	-126
M1-780813F	1461	1480	-19
M1-806743F	1448	1554	-106
M1-809841Q	1698	1738	-40
M1-894920F	1537	1485	52
M1-949973F	1458	1559	-101
M1-963986F	1620	1594	26
M2-015037F	1338	1229	109
M2-033052F	1115	1178	-63

TABLE 19. (continued) 1995 COMPARISON OF GAMMA SURVEYS

Grid ID	Original Result	State 07/24/95 Result	Difference
	Total Counts	Total Counts	
M2-055068F	1409	1399	10
M2-065076F	1272	1293	-21
M2-067078F	1342	1330	12
M2-086912F	1364	1509	-145
TE-038044F	1537	1533	4
TE-110117F	1384	1466	-82
TE-196203F	1407	1540	-133
TE-247254Q	1924	1917	7
TE-283290F	1408	1429	-21
TE-315323F	1292	1427	-135
TE-365371AF	1407	1480	-73
TE-383388F	1464	1472	-8
TE-416423F	2199	1818	381
TE-446455Q	2357	2288	69
TE-586605F	1378	1417	-39
TE-730739F	1304	1377	-73
TE-797808F	1501	1576	-75
TE-864878F	1608	1623	-15
TE-943956AQ	1937	1573	364
TE-974985Q	1869	1882	-13
TS-027033S	1722	1820	-98
TS-049055S	1807	1779	28
TS-073079S	1651	1854	-203
TS-116122S	1572	1693	-121
TS-139146S	1716	1677	39
TS-156B158CF	1587	1620	-33
TW-002008F	1539	1458	81
TW-039049F	1674	1643	31
TW-109131F	1461	1520	-59
TW-145168F	1587	1512	75
TW-228245F	1332	1554	-222
TW-299312F	1331	1432	-101
TW-361372F	1423	1602	-179
TW-391401F	1366	1564	-198
TW-407416F	1456	1636	-180
TW-438447Q	2157	2358	-201
TW-508519Q	2352	2555	-203
TW-534557F	1398	1613	-215
TW-574599F	1498	1582	-84
TW-614639F	1518	1596	-78
TW-701717F	1544	1624	-80
TW-765777F	1537	1580	-43
TW-817829F	1472	1482	-10
TW-849860F	1423	1474	-51
TW-982004S	2093	1962	131
Mean	795	817	-22

TABLE 20. 1996 COMPARISON OF GAMMA SURVEYS

Grid ID	Original Result	State 07/10/96 Result	Difference
	Total Counts	Total Counts	
C1-026035F	1682	1719	-37
C1-235258F	1468	1377	91
C1-508528F	1686	1387	299
C2-619642S	1360	1337	23
C2-649673S	1316	1316	0
C2-679705F	1065	1402	-337
C2-920960F	1659	1691	-32
C2-993033F	1738	1690	48
C2-999039F	1455	1459	-4
C3-138182S	1552	1753	-201
C3-190232S	1322	1286	36
C3-220262F	1397	1365	32
C3-257288F	1765	1628	137
C3-268297F	1256	1435	-179
C3-417435F	1395	1536	-141
C3-542557F	1360	1552	-192
C3-549566F	1325	1429	-104
C3-573590F	1378	1473	-95
M1-200221Q	2041	2086	-45
M1-205226S	1526	1623	-97
M1-389429S	1427	1615	-188
M1-453494F	1712	1944	-232
M1-593631F	1424	1483	-59
M1-611648F	1541	1547	-6
M1-776809Q	1692	1720	-28
M1-894920F	1537	1464	73
M1-898924F	1622	1482	140
M1-913630F	1571	1608	-37
M1-982699F	1598	1531	67
M1-997020F	1272	1367	-95
M2-056069F	1595	1235	360
T1-007022F	1661	1842	-181
T1-193216F	1409	1449	-40
T1-361380F	1179	1364	-185
T1-403426F	1073	1268	-195
T1-583602F	961	1409	-448
T2-003024F	1311	1445	-134
TS-066072S	1698	1573	125
TW-547571F	1439	1420	19
Mean	1474	1521	-47

TABLE 21. ELEVATION OF GRID CENTERS PRIOR TO BACKFILLING

Grid ID	Northing	Easting	Grid Center Elevation
M1-296333F	331017.68	2666738.33	2057.91'
C3-420438F	329639.73	2668673.39	1957.59'
C3-619636F	329213.18	2668772.62	1964.59'
C3-633649F	329180.48	2668706.64	1961.01'
C3-588605F	329277.85	2668805.74	1957.42'
C3-555572F	329344.60	2668772.39	1955.63'
C3-582599F	329278.97	2668608.28	1949.67'
C3-613630F	329213.99	2668575.63	1959.64'
C3-509524F	329475.85	2668608.61	1957.59'
C3-508523F	329475.68	2668575.47	1964.23'
C3-479495F	329508.50	2668608.50	1964.30'
C3-478494F	329508.50	2668575.50	1968.90'

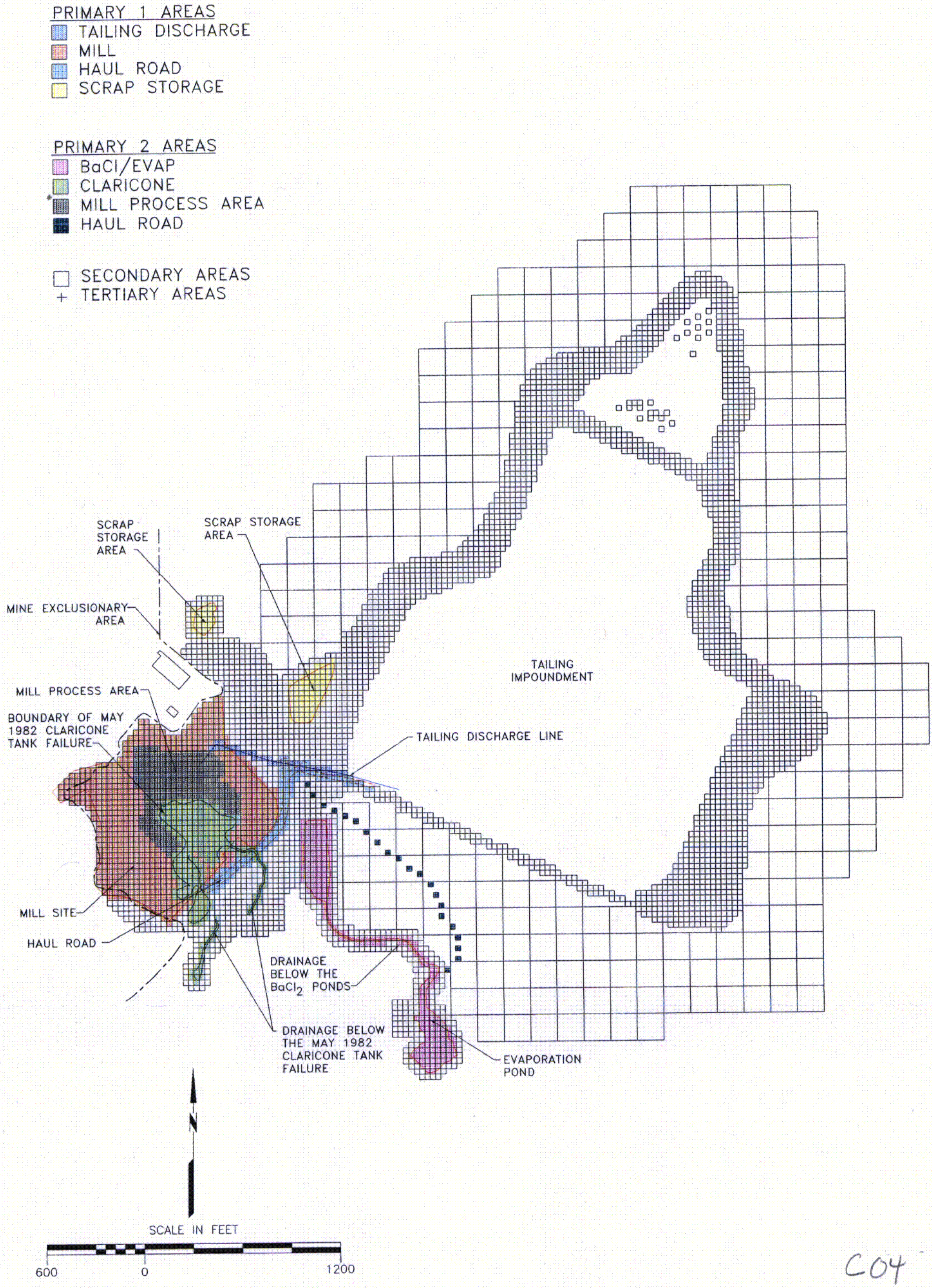

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FIGURE 1
RADIOLOGICAL VERIFICATION AREAS AND GRID SYSTEMS

Date: JULY 1996
Project: 09-353/FINAL
File: RAD-GRID

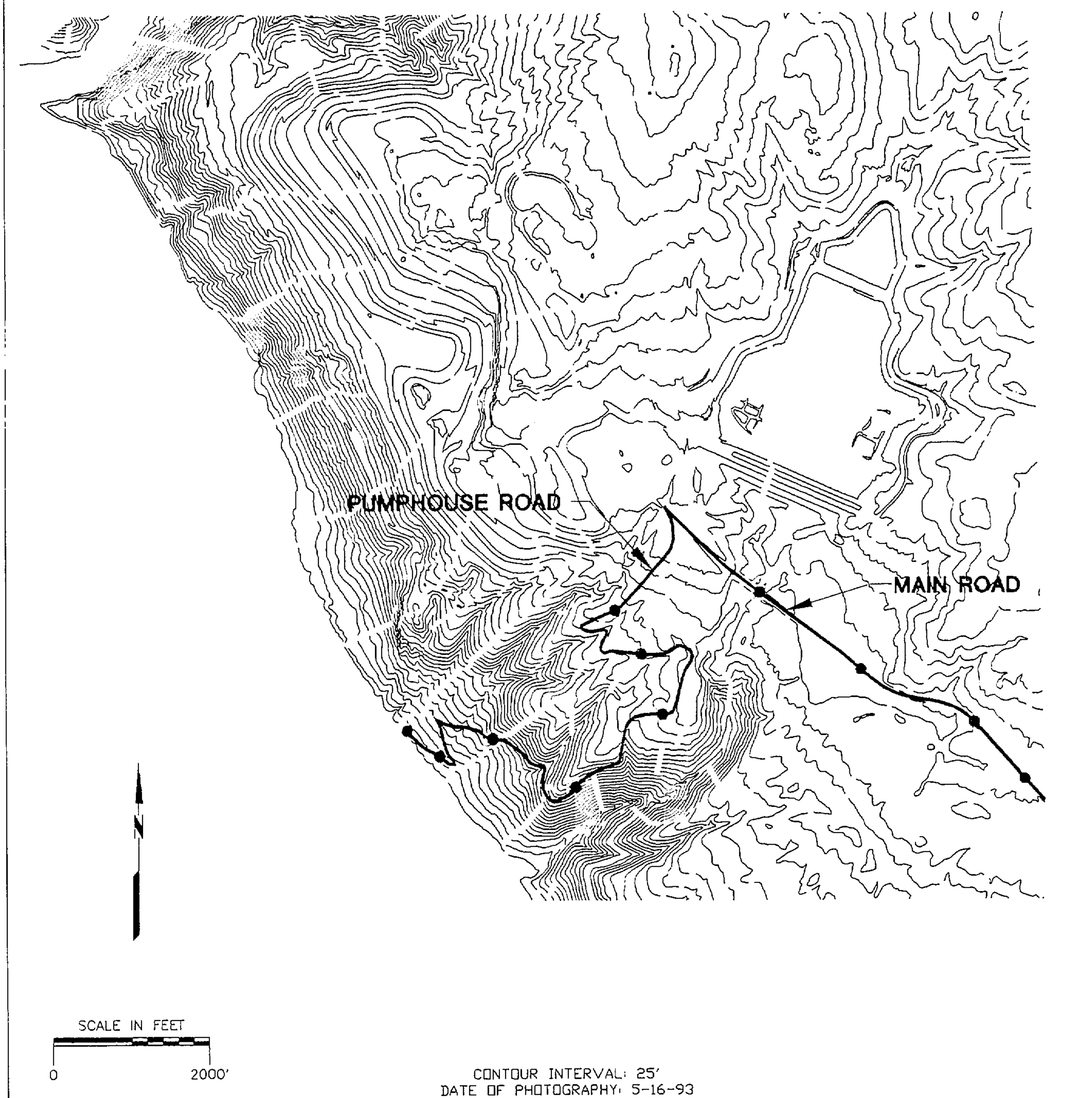

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FIGURE 2
ANCILLARY AREAS

Date:	JUNE 1996
Project:	09-353/FINAL
File:	FIGH-2

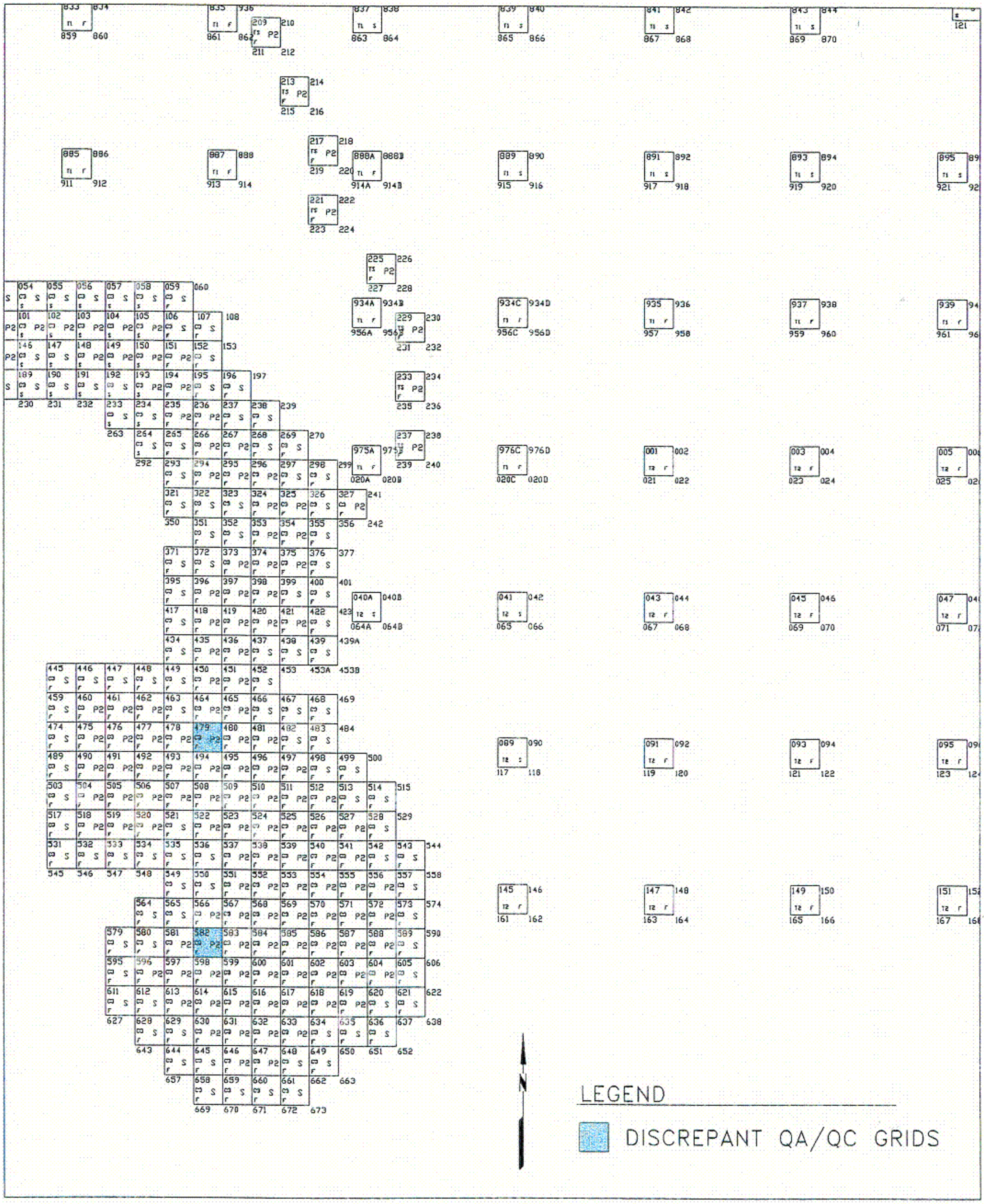

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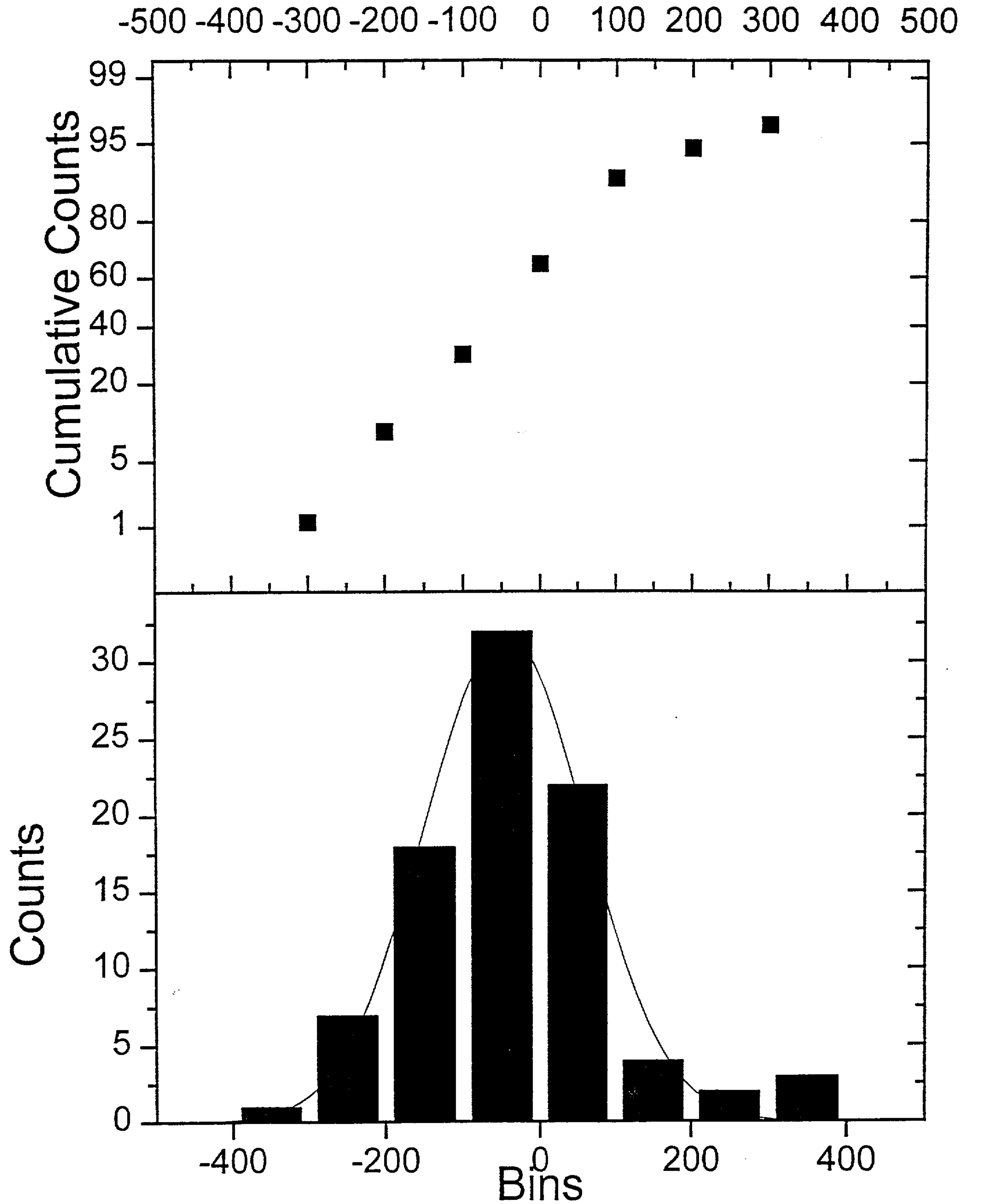
FIGURE 3
DISCREPANT QA/QC GRIDS

Date:	JULY 1996
Project:	09-353
File:	FINAL\DISCREP

C05



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INCORPORATED

FIGURE 4
1995 COMPARISON
OF GAMMA SURVEYS

Date:	JULY 1996
Project:	09-353
File:	SURVEYS

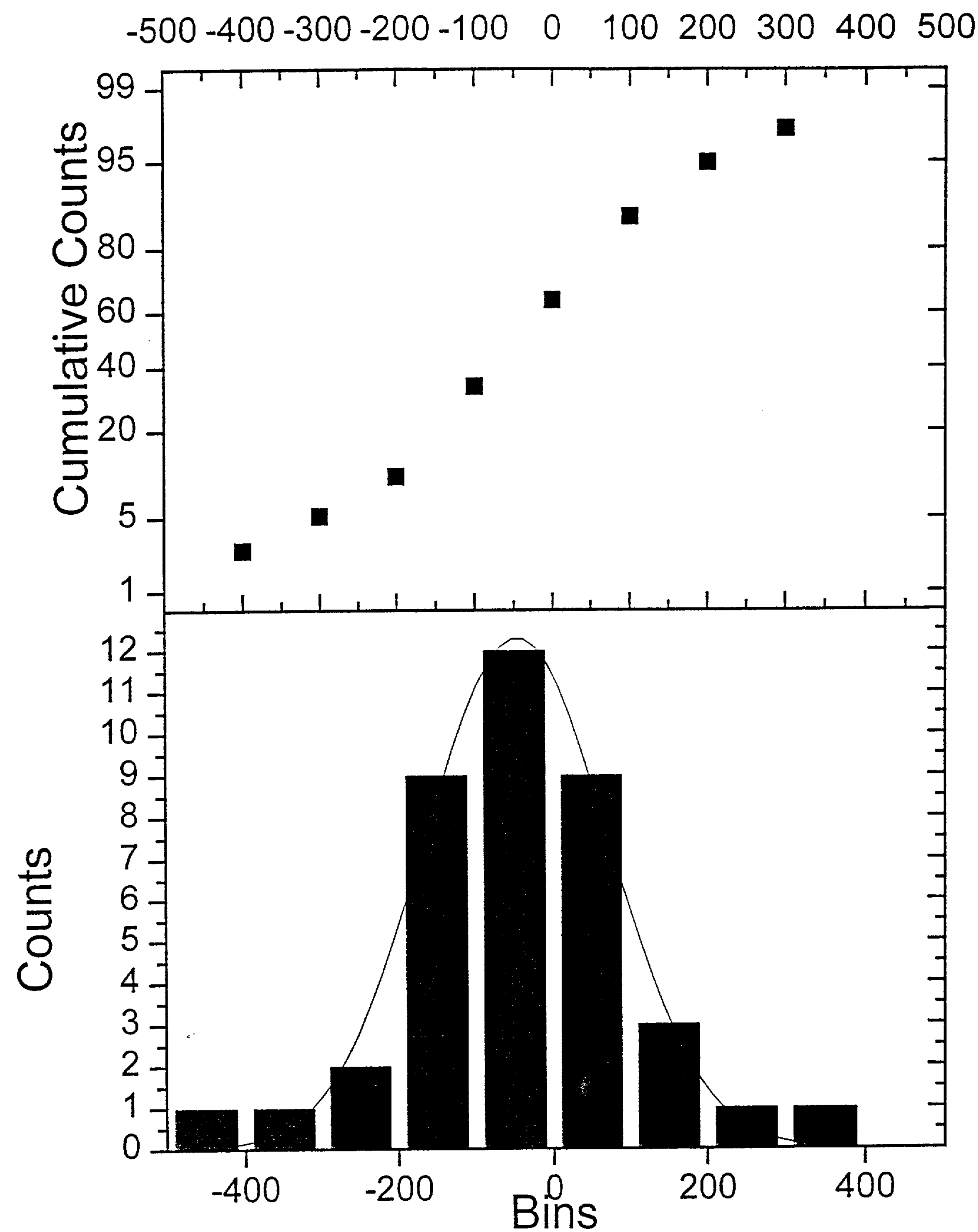

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FIGURE 5
1996 COMPARISON
OF GAMMA SURVEYS

Date:	JULY 1996
Project:	09–353
File:	SURVEYS