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JUL 11 1984

MEMORANDUM FOR: Robert E. Browning, Director
Division of Waste Management

FROM: Malcolm R. Knapp, Chief
Geotechnical Branch
Division of Waste Management

SUBJECT: APPENDIX B TO RATIONALE FOR 10 CFR 60 IN TERMS OF EPA STANDARD 40 CFR 191

Richard Codell, with the assistance of Dan Fehringer and M.J. Wise, has prepared an appendix to "Rationale for the Performance Objectives in 10 CFR 60." The original document (Rationale) was an exposition on the reasons why the performance criteria for HLW repositories in 10 CFR 60 were meaningful in the context of the standards set forth in EPA's 40 CFR 191. The staff concluded on the basis of numerous computer studies, that the NRC performance criteria were in fact meaningful and would add materially to the safety of HLW repositories.

The original study, however, was based upon Draft 19 of the EPA standards. On December 29, 1982, shortly after the publication of the Rationale, the EPA published a revision of Draft 19 as a proposed rule. Differences between the Proposed Rule and Draft 19 were considered great enough that some of the computations used in the Rationale had to be repeated. Appendix A to the Rationale, dated 2/1/83, was prepared, detailing the results of the computations and comparing them to the original computations. It was concluded in Appendix A that the changes in the EPA standard did not invalidate the original conclusions drawn in the Rationale.

On February 2, 1984, EPA distributed Working Draft 3 of the Final 40 CFR 191 rule. The changes in this draft necessitated another round of calculations on which to base the Rationale. The results of these calculations are presented in Appendix B which is attached to this memo.

Our analyses for the undisturbed site cases indicate that reliance on the NRC 1000-year travel time criterion may not be as important as demonstrated for previous drafts of the EPA proposed rule; that is, groundwater travel times shorter than 1000 years do not necessarily cause a large increase in the release rate of critical radionuclides from the repository. This difference is primarily caused by the increase in permitted levels of several radionuclides, notably U-234, whose rates of release from the underground repository are highly sensitive to travel time for the range of conditions considered in this analysis.

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The 1000-year groundwater travel time did, however, have an impact on the frequency of non-compliance of the repositories with the EPA rule. In performing this study, a large number of possible cases were evaluated with our performance models. It was found that the frequency of non-compliance with the EPA rule was substantially reduced if those cases failing to meet the 1000-year groundwater travel time criterion were eliminated. Furthermore, as noted in the Supplementary Information to 10 CFR Part 60, the 1000-year criterion is intended to be an independent, quantitative measurement of merit for the geologic setting, and to serve as a redundant barrier to provide increased confidence in over-all repository performance. Those considerations were outside the scope of this analysis.

This submittal satisfies OPS Plan Commitment Item 531114. We will be happy to brief you on the contents of Appendix B if you so desire.

/S/

Malcolm R. Knapp, Chief
Geotechnical Branch Division of Waste Management

Enclosure: As stated

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RATIONALE FOR THE PERFORMANCE OBJECTIVES IN 10 CFR PART 60

APPENDIX B - IMPACT OF WORKING DRAFT 3 OF EPA STANDARD (40 CFR PART 191)

Introduction

Since the completion of the main report, "Rationale for the Performance Objectives in 10 CFR 60 (Rationale)" there have been several revisions to the proposed EPA standard 40 CFR 191. Appendix A to the Rationale, dated 2/1/83, addresses changes to the EPA standard dated December 29, 1982. That appendix stated that the conclusions drawn from the original Rationale would not be affected materially by the then proposed revision to 40 CFR 191.

On February 2, 1984, the Environmental Protection Agency distributed Working Draft 3 of its final 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (Ref. B-1), to other Federal agencies for review.

The definitions (§191.12) in Working Draft 3 differ from the earlier Draft No. 19 of the proposed Standard used in the Rationale. Changes with the potential for impact to the performance objectives of 10 CFR 60 are discussed below.

1) The term "underground resources of drinking water" used in Draft No. 19 has been deleted. A new term, "major source of groundwater" is now defined as follows:

> "Major source of groundwater" means an aquifer that: (1) is saturated with water having less then 10,000 milligrams per liter of total dissolved solids, (2) is within 2,500 feet of the land surface, and (3) has a transmissivity greater than 200 gallons per day per foot (or 30×10^{-6} meters squared per second) as averaged or integrated for at least a period of a year over the controlled area of a disposal systems site provided that each formation included within a major source of groundwater has a horizontal hydraulic conductivity greater than 2 gallons/day/square foot (or 10^{-6} meter per second).

The term "transmissivity", used in the definition above, is also defined as follows:

> "Transmissivity" means the product of horizontal hydraulic conductivity and saturated thickness of an underground formation. Transmissivity of a series of formations is the sum of the individual transmissivities of each formation comprising the series. The product of transmissivity and

hydraulic gradient is horizontal discharge per unit width of the formation.

The term "sole source aquifer" is defined as:

"Sole source aquifer" means an aquifer that has been designated by the Administrator pursuant to sections 124 (a) or (e) of the Safe Drinking Water Act (Public Law 95-523), as amended by Public Law 95-190, 42 U.S.C. 300 (f) et seq.)

2) A new term, "controlled area" is defined as:

"Controlled area" means a surface location, to be identified by permanent markers and other passive institutional controls, extending no more than ten kilometers in a horizontal direction from the original location of any of the radioactive wastes in a disposal system, and the underlying subsurface, which area has been committed to use as a disposal systems and from which incompatible activities would be restricted after disposal.

3) Another new term, "undisturbed performance" is defined as follows:

"Undisturbed performance" means the predicted behavior of a disposal system if it is not disrupted by human intrusion or the occurrence of unlikely natural events (such as seismic or volcanic activity), including consideration of the uncertainties in predicted behavior.

4) The definition of accessible environment has been changed so that the distance from the original location of the radioactive wastes to the accessible environment, which was 1 mile in Draft No. 19, is the extent of the controlled area or, if a major source of groundwater is present, the extent of the controlled area but not to exceed 2 kilometers.

5) The release limits of the radionuclides which appear in Table A of Draft 19 and Table 2 of the Rationale, have been changed. The original and revised limits appear in Table B-2.

6) Working Draft 3 also includes new "groundwater protection requirements" as follows:

Disposal systems for spent nuclear fuel or high-level or transuranic radioactive waste shall be designed to provide a reasonable expectation that for 1,000 years after disposal, undisturbed performance of the disposal system shall not increase the radionuclide concentrations in any major source of groundwater or any sole source aquifer by more than:

a) 15 picocuries per liter of alpha-emitting radionuclides, or

b) the combined concentrations of radionuclides that emit either beta or gamma radiation that would produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem per year if an individual continuously consumed 2 liters per day of drinking water from such a source of groundwater.

It is assumed that the groundwater protection requirements listed above in Item 6 will be achieved through repository site selection, either by locating a repository where there are no major sources of groundwater or by demonstrating that the groundwater flow conditions at the site will prevent any released radionuclides from reaching major sources of groundwater. With this assumption in effect, only two of the above changes, Items 4 and 5, could have any effect upon the calculations and, hence, the conclusions of the analysis upon which the Rationale document is based. In particular, potentially affected calculations (and conclusions) involve Figures 15-21, 23, and 25 and Table 5 in Chapters VII and VIII. Therefore, these calculations were redone, reflecting these two differences, and results compared with the earlier calculations, ad discussed below. For ease in comparison, Figures 15B to 21B, 23B, and 25B, based on Working Draft 3 are presented side-by-side with the corresponding figures based on Draft No. 19.

The differences between the Draft No. 19 and Working Draft 3 cases are for the most part minor. Working Draft 3 is less stringent than Draft 19. Larger release rates would therefore be permitted under the new standard. For example, in the bedded salt case shown in Figures 16 and 16B, the release rate necessary to satisfy a 10 percent failure for the Working Draft 3 standard is about double the Draft 19 standard for a 2,000 year travel time. Virtually the same conclusion can be drawn for the zeolitized tuff case shown in Figures 18 and 18B. Given the two to four order of magnitude range of the variable and results, the factor of two increase in the permissable release rates would not affect the Staff's conclusions in the Rationale document.

An important difference between the Draft 19 and Working Draft 3 versions of the standard is evident in the travel time - release rate trade-off plots for basalt, bedded salt and zeolitized tuff, Figures 15, 16, and 18 respectively.

Figures 15, 16, and 18 were prepared using the Draft 19 standard, and demonstrate the rationale for the 1,000 year groundwater travel time required by 10 CFR 60. The probability of failing the EPA standard markedly increases for travel times less than about 200-300 years for these cases.

Most of the basis for the 1,000 year travel time requirement disappears when the Working Draft 3 standard is substituted for the Draft 19 standard, as demonstrated in figures 15B, 16B, and 18B. Except for a relatively small effect in the basalt case, Figure 15B, there is no marked increase in the failure rate of the EPA standard for travel times of less than 1000 years.

The apparent reason that the trade-off curves no longer demonstrate the rationale for the 1,000 year travel time is primarily due to the increased release limits permitted by Working Draft 3. The primary contributors to failure of the Draft 19 EPA standard for short travel times appear to have been the radionuclides C14, Tc99, Np237 and U234. Using the zeolitized tuff case as an example, for groundwater travel times less than 300 years, and release rates less than 10^{-5} per year, the radionuclides C14, Tc99, Np237 and U234 contributed about 7.1, 18.8, 6.5 and 67.5 percent respectively to the failure of the standard.

The release limit under Working Draft 3 for C14 has been halved, but the release limits for Tc99, Np 237 and U234 have been increased by a factor of 5, 5 and 10 respectively. The contributions of Tc99, Np237 and U234 to the failure of the EPA standard therefore has been diminished. The relatively large influence of the change in the U234 standard is demonstrated for the zeolitized tuff case by repeating the run for Figure 18 employing the Draft 19 standard except for U234, where the Working Draft 3 standard was specified. The results are shown in Figure 18C. Similar results are demonstrated for the basalt and bedded salt cases in Fig. 15C and 17C respectively.

The overall benefit of the 10 CFR 60 rule is still demonstrated by showing the probability of failure of the EPA standard with and without the NRC rule. Figures 19 and 19B contrast the results, assuming anticipated processes and events, of the relationship between releases (in terms of fractions of the standard) and the probability of those releases for a geologic repository in basalt, using Draft No. 19 and Working Draft 3 assumptions, respectively. Comparison of the two figures shows that there is a small decline in release probability for Working Draft 3, for the range of conditions considered in this case. The results do not change the validity of the conclusion based on the Draft No. 19 calculations. Similar results and conclusions were obtained for a geologic repository in bedded salt, as illustrated in Figures 20 and 20B. The probability for a 10^{-5} fraction of the EPA Working Draft 3 release limit is reduced by a factor of no less than 0.85 of the probability calculated for the Draft 19 standard.

Comparison of the respective figures for non-zeolitized tuff, Figures 21 and 21B shows a small difference in performance with respect to the two standards being considered. Working Draft 3 causes a lower probability of release; e.g., the probability of exceeding 10^{-3} fraction of the EPA Working Draft 3 release limits is about a factor of 0.7 and 0.85 of the probabilities calculated for the Draft 19 standard, for the unrestricted and 10 CFR 60-compliance cases respectively.

Figures 23 and 23B contrast the results for the fault scenario in basalt for the Draft 19 version and Working Draft 3 of the standard. Working Draft 3 causes a decreased probability of exceeding the release standard. For a release equal to the EPA Working Draft 3 release standard, the probability is not less than a factor of about 0.8 of that calculated with Draft 19. The relative impact of 10 CFR Part 60 on limiting the consequences of this scenario is not significantly affected.

Figures 25 and 25B display the consequences of the borehole scenario. Comparison of the two figures again leads to the conclusion that the differences in performance, based on the ranges of parameters considered by the staff, between Draft No. 19 and Working Draft 3 calculations are negligible and do not change the validity of the conclusion based on the Draft No. 19 calculations.

Table 5 of the Rationale has been revised and is presented in Table B5. Working Draft 3 would allow significantly higher releases of some radionuclides, but the calculations presented in this table demonstrate that the release rates could still be either above or below the proposed standard. Therefore, the conclusions drawn from Table 5 in the Rationale are still valid. Note also that in all cases, the probability of exceeding the EPA standard, or fraction of that standard, would be decreased where the 10 CFR 60 criteria were stipulated.

Conclusion

The computations of repository performance made in establishing the rationale for 10 CFR 60 in terms of the EPA standard in Draft 19 of 40 CFR 191 were repeated in light of new criteria set forth in Working Draft 3 of the EPA Standard. The results of these computations demonstrate that the probability of exceeding the EPA standard, or fraction of that standard, would still be decreased where the 10 CFR 60 criteria were stipulated. The 1,000 year groundwater travel time criterion however did not appear to be supported by the results of the computations using Working Draft 3. Computations using Draft 19 of the EPA standard showed a marked drop in the probability of violation of the standard for travel times of several hundred years or greater, but no such behavior could be demonstrated for Working Draft 3.

The results of this exercise, therefore, may lead to the conclusion that the 1,000 year groundwater travel time criterion is not necessary for 10 CFR 60.

REFERENCES

B-1 U.S. Environmental Protection Agency, "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Working Draft 3, 40 CFR 191, 2/1/84.

Table B2* - RELEASE LIMITS FOR CONTAINMENT REQUIREMENTS

(Cumulative Releases to the Accessible Environment

for 10;000 Years After Disposal)

Radionuclide	Draft 19 Release Limits (curies/per 1000 MTHM)	Present Draft Release Limit (curies/per 1000 MTHM)
Americium-241	10	100
Americium-243	4	100
Carbon-14	200	100
Cesium-135	2000	1000
Cesium-137	500	1000
Neptunium-237	20	100
Plutonium-238	400	100
Plutonium-239	100	100
utonium-240	100	100
Plutonium-242	100	100
Radium-226	3	100
Strontium-90	80	1000
Technetium-99	2000	10000
Tin-126	80	1000
Any other alpha-emitting radionuclide	10	100
Any other radionuclide that does not emit alpha particles	500	1000

* Taken from Ref B1

Table B5. Effect of 10^{-5} per year release rate in complying with the EPA standard.

NUCLIDE	REPOSITORY INVENTORY @ 1000 yr (Ci/100,000 MTHM)	RELEASE RATE IF EQUAL TO INVENTORY TIMES 10^{-5}* (Ci/yr)	TOTAL RELEASE (YEARS 1000 to 10,000) (Ci)	EPA LIMIT (Ci/100,000 MTHM) Draft 19	EPA LIMIT (Ci/100,000 MTHM) Working Draft 3	RATIO OF TOTAL RELEASE TO EPA LIMIT Draft 19	RATIO OF TOTAL RELEASE TO EPA LIMIT Working Draft 3
Am-241	9.24E7	9.2E2	3.0E6	1,000	10,000	3,000	300
Am-243	1.57E6	1.6E1	1.4E5	400	10,000	350	14.5
C-14	1.35E3	1.4E-2	1.2E2	20,000	10,000	0.006	0.012
Cs-135	2.23E4	2.2E-1	2.0E3	200,000	100,000	0.01	0.02
Cs-137	1.00	1.0E-5	3.4E-3	50,000	100,000	0	0
Np-237	1.0E5	1.0E0	9.0E3	2,000	10,000	4.5	0.9
Pu-238	9.8E4	9.8E-1	8.2E2	40,000	10,000	0.02	.082

Table B5 (Continued)

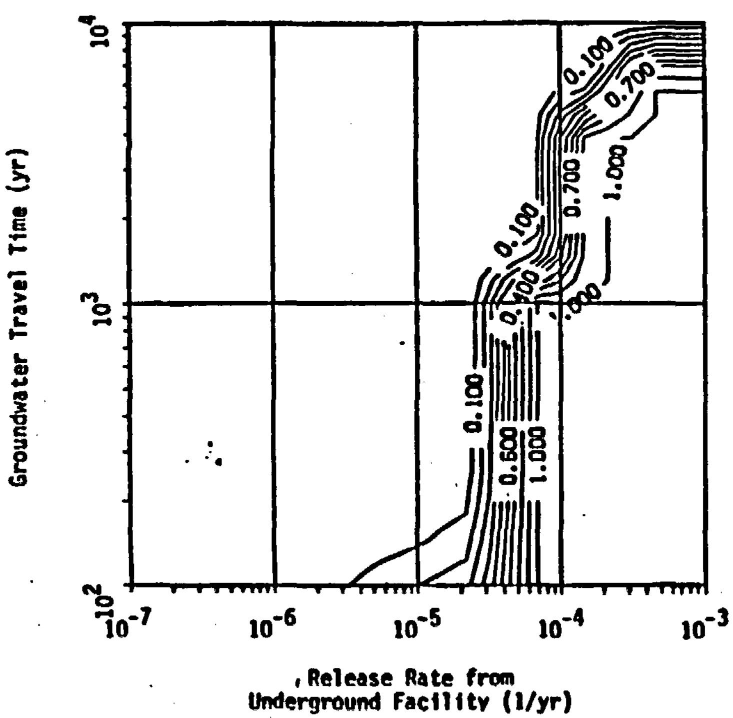
NUCLIDE	REPOSITORY INVENTORY @ 1000 yr (Ci/100,000 MTHM)	RELEASE RATE IF EQUAL TO INVENTORY TIMES 10^{-5}* (Ci/yr)	TOTAL RELEASE (YEARS 1000 to 10,000) (Ci)	EPA LIMIT (Ci/100,000 MTHM)		RATIO OF TOTAL RELEASE TO EPA LIMIT	
				Draft 19	Working Draft 3	Draft 19	Working Draft 3
Pu-239	3.2E7	3.2E2	2.9E6	10,000	10,000	290	290
Pu-240	4.4E7	4.4E2	4.0E6	10,000	10,000	400	400
Pu-242	1.7E5	1.7E0	1.5E4	10,000	10,000	1.5	1.5
Ra-226	2.84E2**	2.84E-3	2.6E1	300	10,000	0.09	0.0026
Sr-90	1.5E-1	1.5E-6	4.8E-4	8,000	100,000	0	0
Tc-99	1.4E6	1.4E1	1.3E5	200,000	1.0E6	0.65	0.13
Sn-126	5.6E4	5.6E-1	5.0E3	8,000	10,000	0.62	0.5
Total	1.7×10^8	1.7E3					

* Equal to 10^{-5} x values in column 1. Note that release rates at or below 1.7 Ci/yr (0.1% of total rate) meet the rule.

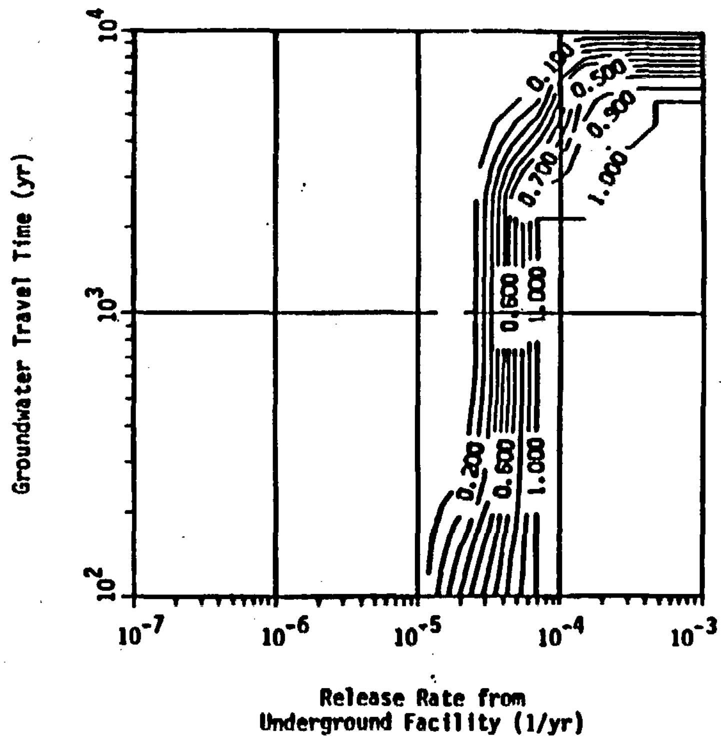
** Release calculations based on inventory at 1000 years. In the absence of leaching, the quantity of Ra-226 would increase to 1.22E4 Ci per 100,000 MTHM at 10,000 years.

ROUTINE RELEASE

BASALT



15. Draft 19 Assumed



15B. Proposed Version Assumed

Figures 15 and 15B Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is basalt. Figure 15 assumes Draft 19 of the EPA standard; Figure 15B assumes the proposed version.

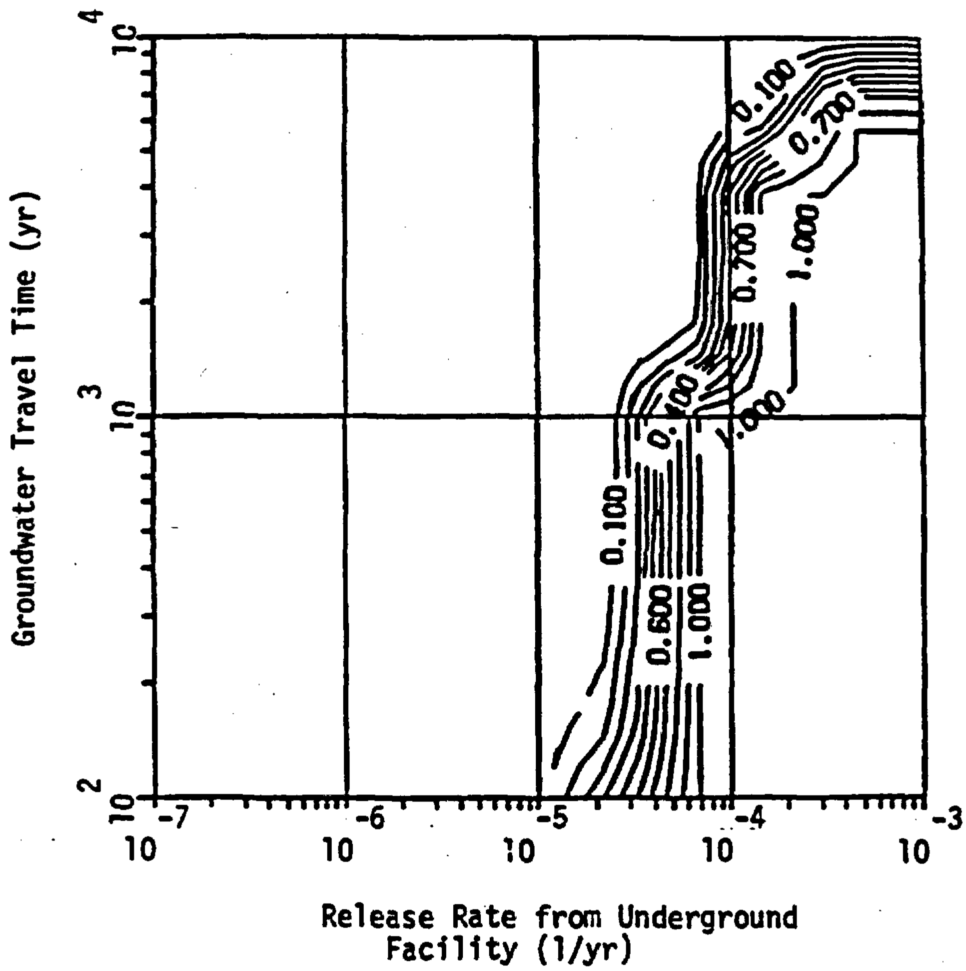
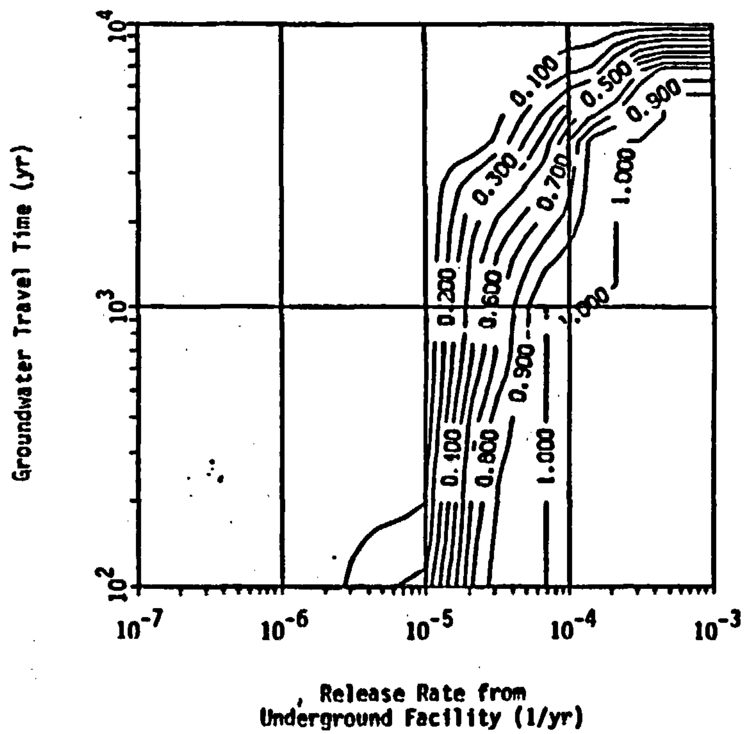
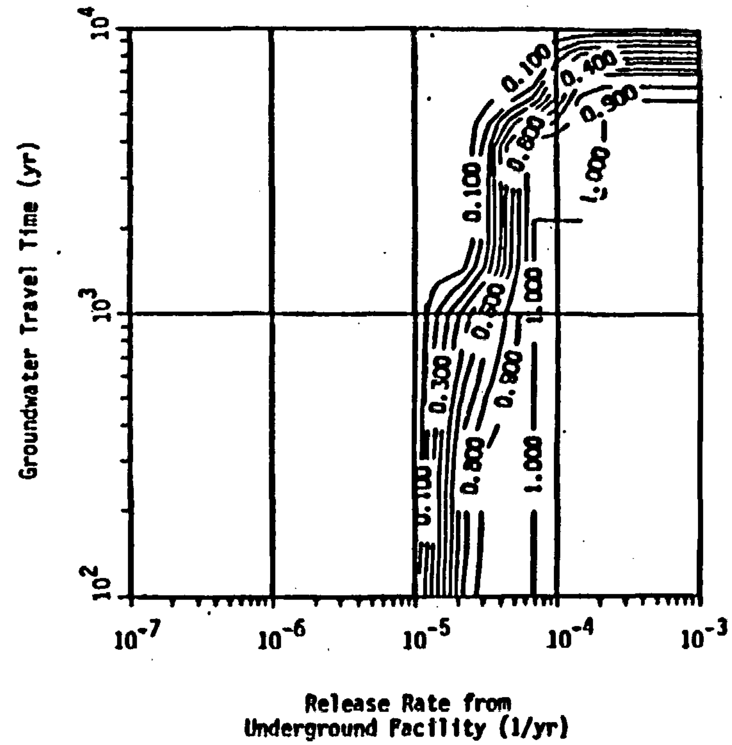


Figure 15C - Contours of constant fraction of cases failing to comply with the Draft 19 Standard, except Working Draft 3 Standard for U234. Medium is Basalt.

ROUTINE RELEASE
BEDDED SALT



16. Draft 19 Assumed



16B. Proposed Version Assumed

Figures 16 and 16B. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is bedded salt. Figure 16 assumes Draft 19 of the EPA standard; Figure 16B assumes the proposed version.

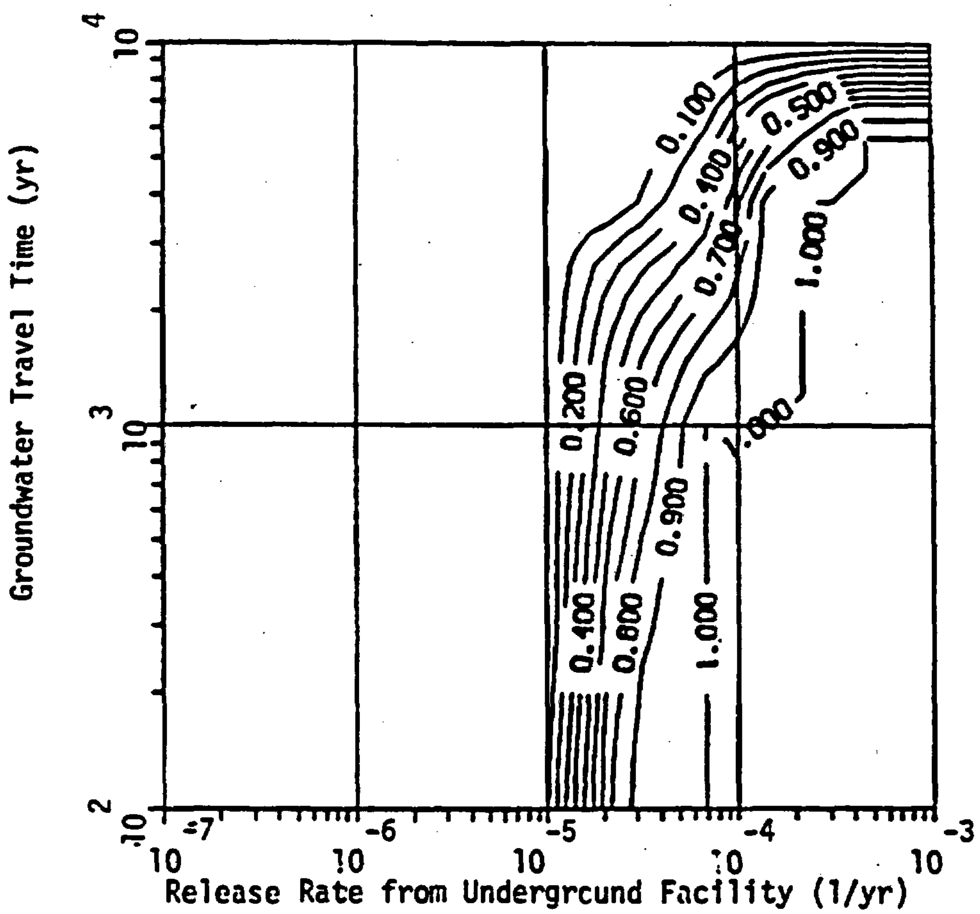
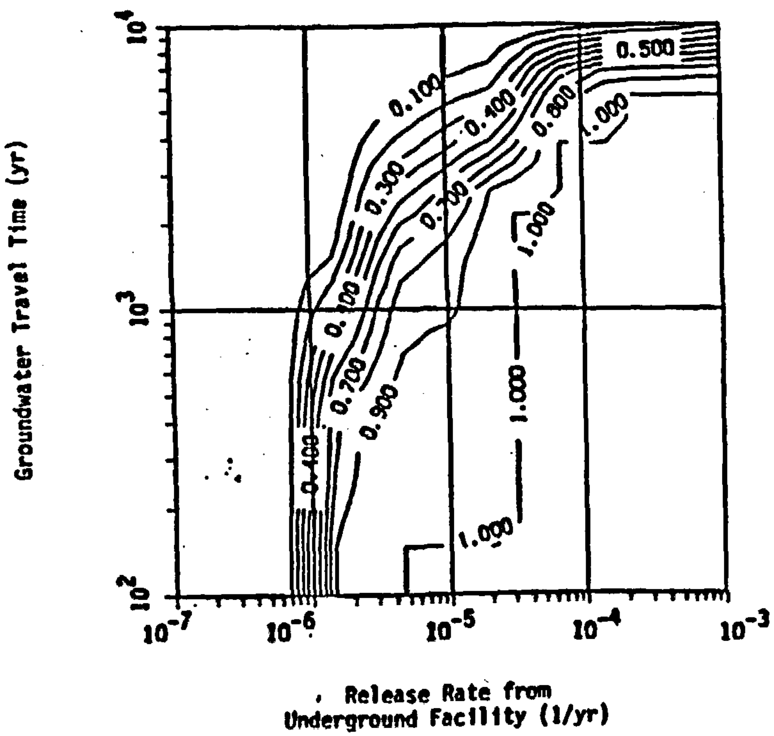
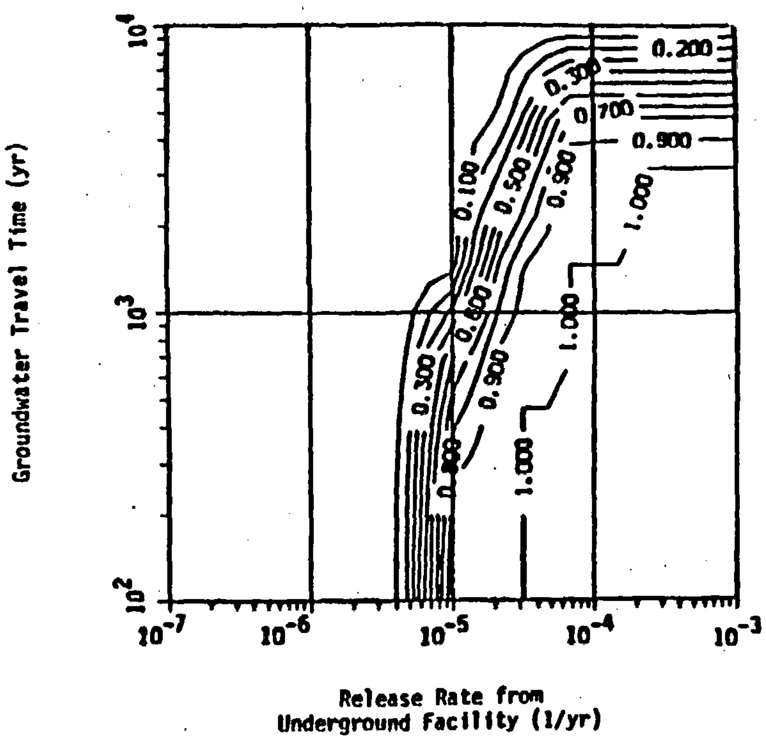


Figure 16C - Contours of constant fraction of cases failing to comply with the Draft 19 Standard, except Working Draft 3 Standard for U234. Medium is Bedded Salt.

ROUTINE RELEASE
NON-ZEOLITIZED TUFF



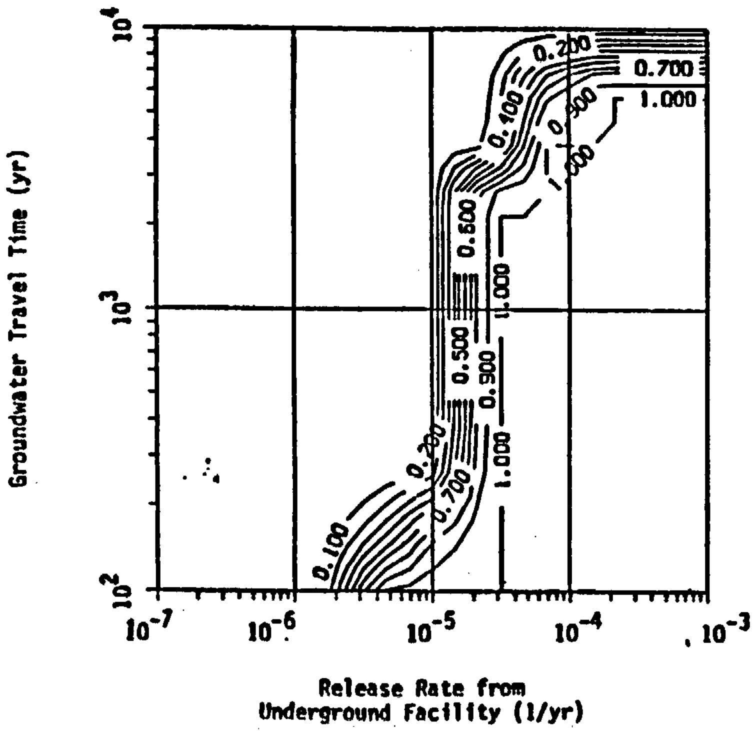
17. Draft 19 Assumed



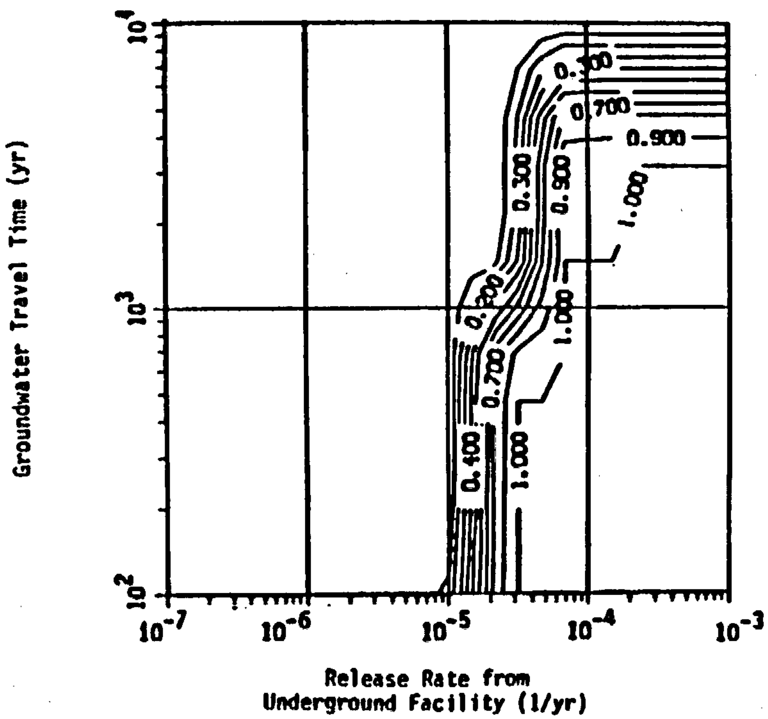
17B. Proposed Version Assumed

Figures 17 and 17B. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is non-zeolitized tuff. Figure 17 assumes Draft 19 of the EPA standard; Figure 17B assumes the proposed version.

ROUTINE RELEASE
ZEOLITIZED TUFF



18. Draft 19 Assumed



18B. Proposed Version Assumed

Figures 18 and 18B. Contours of constant fraction of cases failing to comply with the assumed standard, as a function of limiting release rate and travel time. Medium is zeolitized tuff. Figure 18 assumes Draft 19 of the EPA standard; Figure 18B assumes the proposed version.

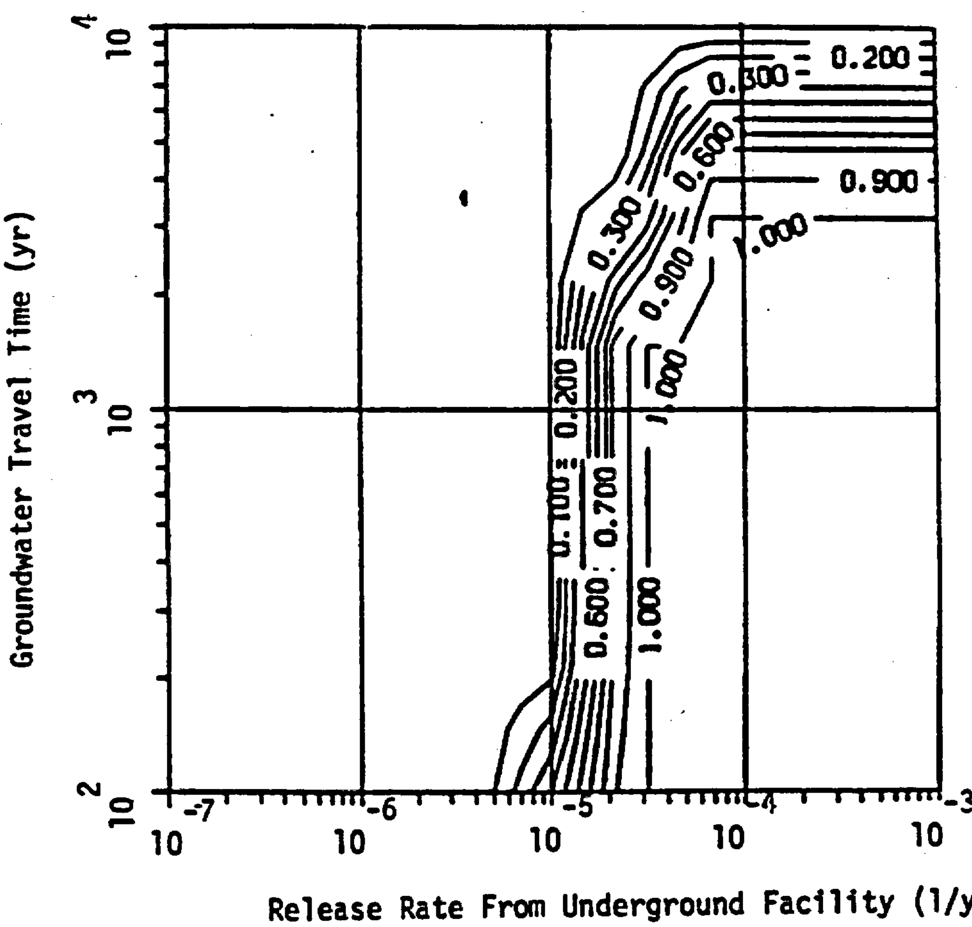
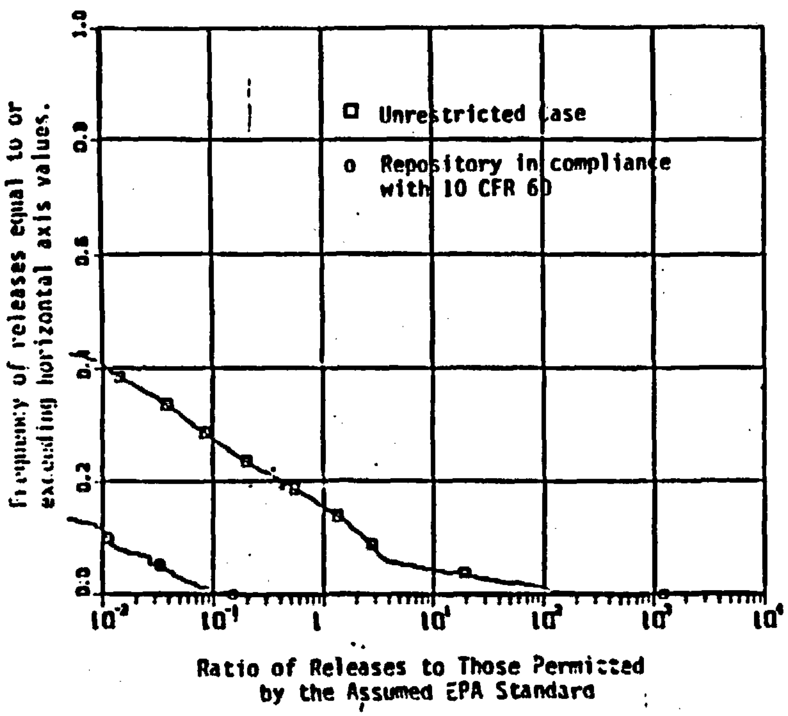
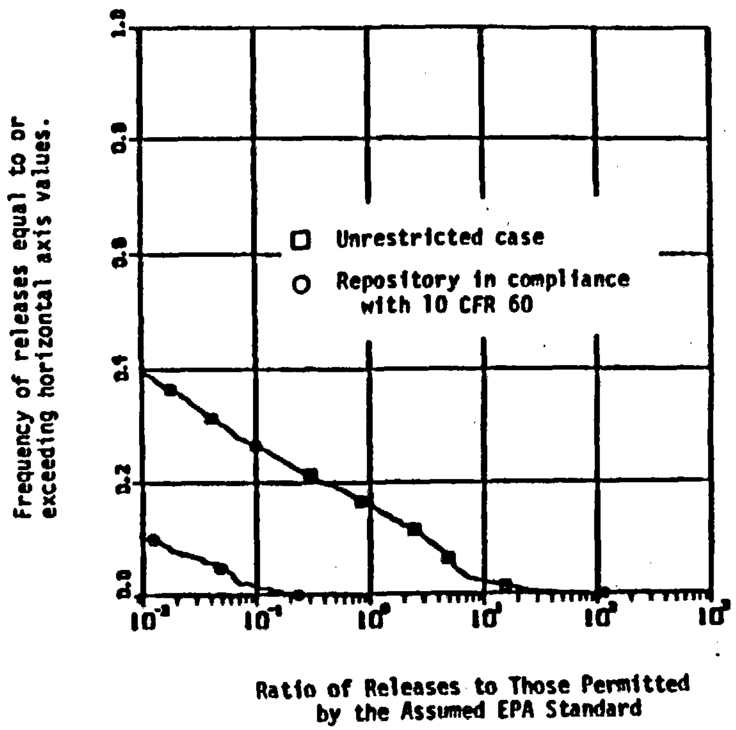


Figure 18C - Contours of constant fraction of cases failing to comply with Draft 19 Standard, except Working Draft 3 Standard for U234. Medium is Zeolitized Tuff.

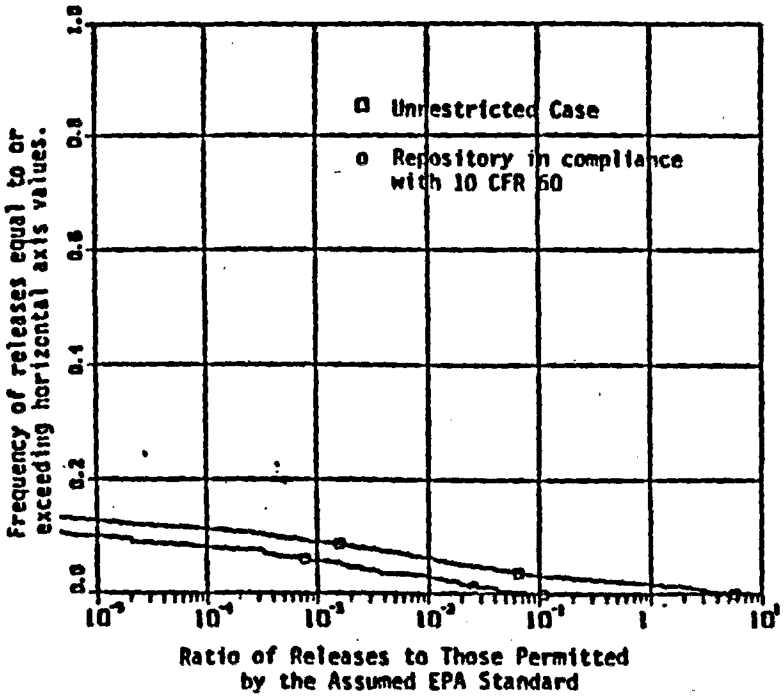


19. Draft 19 Assumed

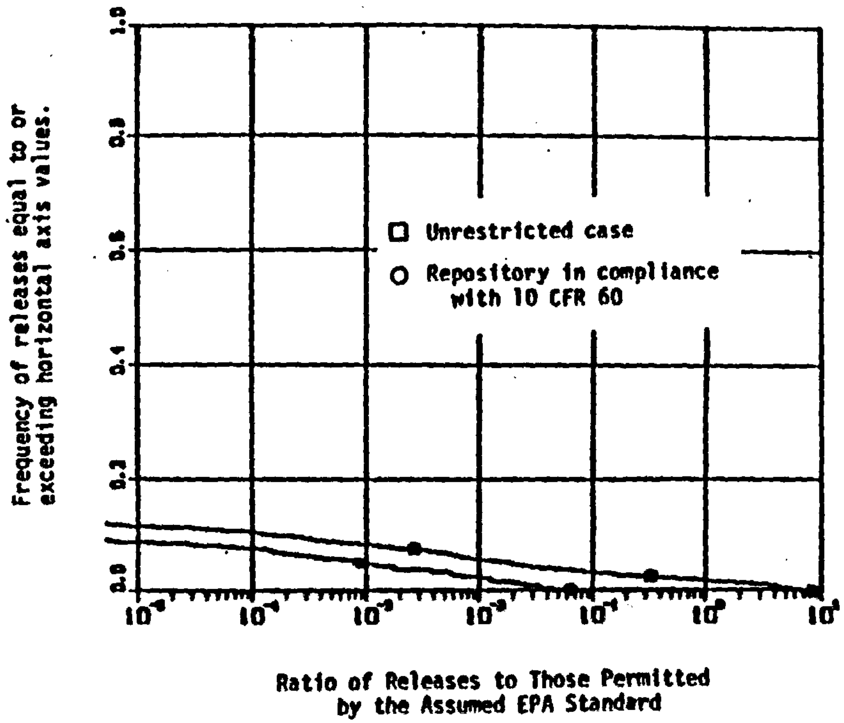


19B. Proposed Version Assumed

Figures 19 and 19B. Relationship between releases from a geologic repository and the probability of those releases for the routine scenario for basalt. Figure 19 assumes Draft 19 of the EPA standard; Figure 19B assumes the proposed version.

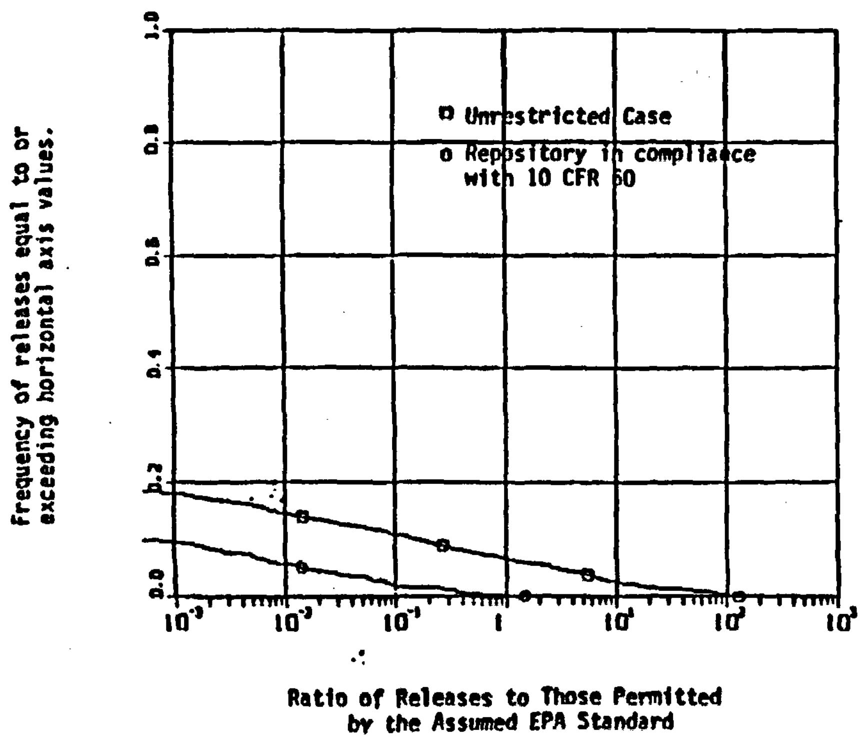


20. Draft 19 Assumed

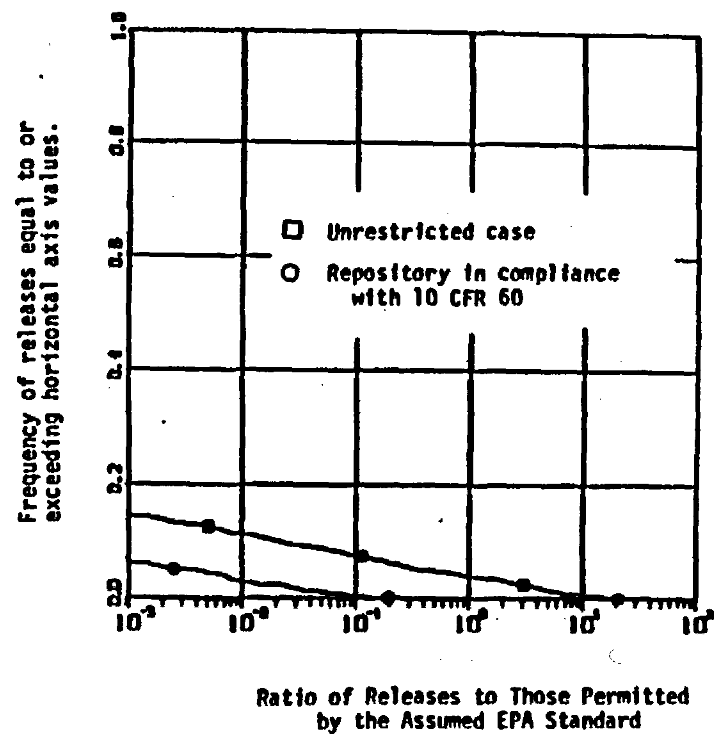


20B. Proposed Version Assumed

Figures 20 and 20B. Relationship between releases from a geologic repository and the probability of those releases for the routine release scenario for bedded salt. Figure 20 assumes Draft 19 of the EPA standard; Figure 20B assumes the proposed version.

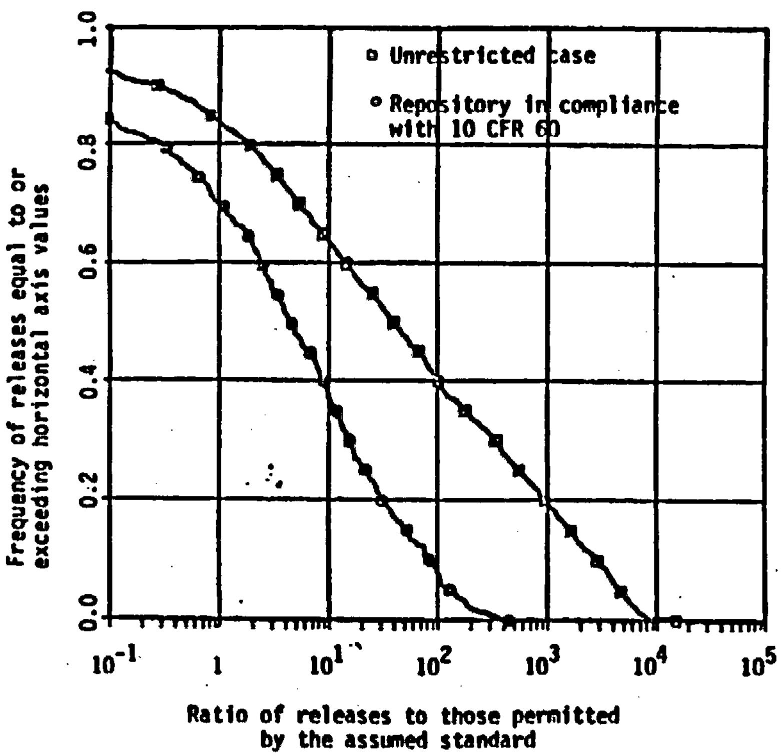


21. Draft 19 Assumed

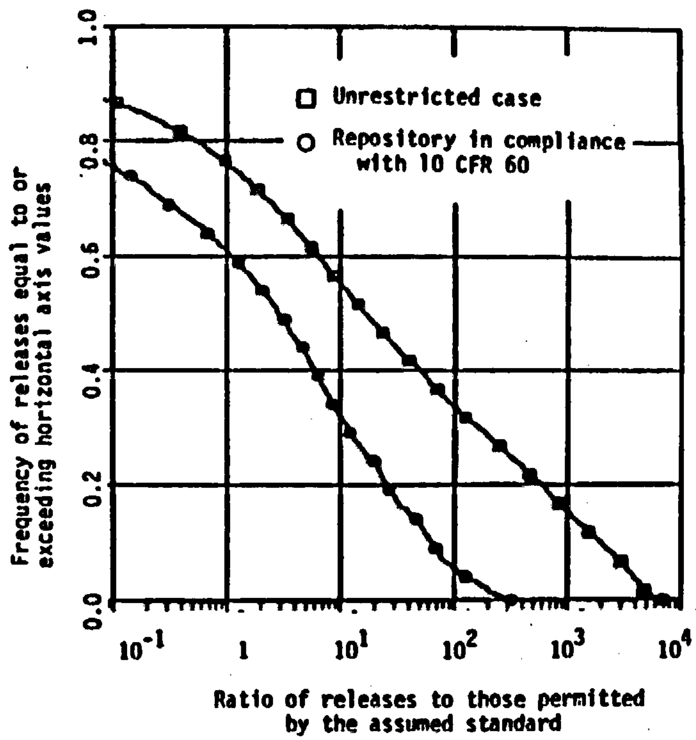


21B. Proposed Version Assumed

Figures 21 and 21B. Relationship between releases from a geologic repository and the probability of those releases for the routine release scenario for non-zeolitized tuff. Figure 21 assumes Draft 19 of the EPA standard; Figure 21B assumes the proposed version.

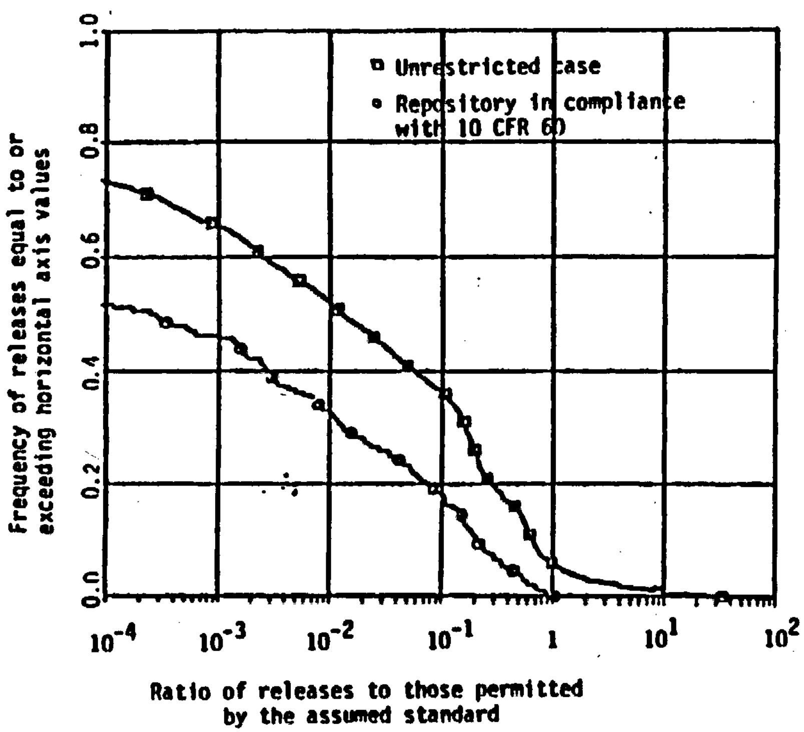


23. Draft 19 Assumed

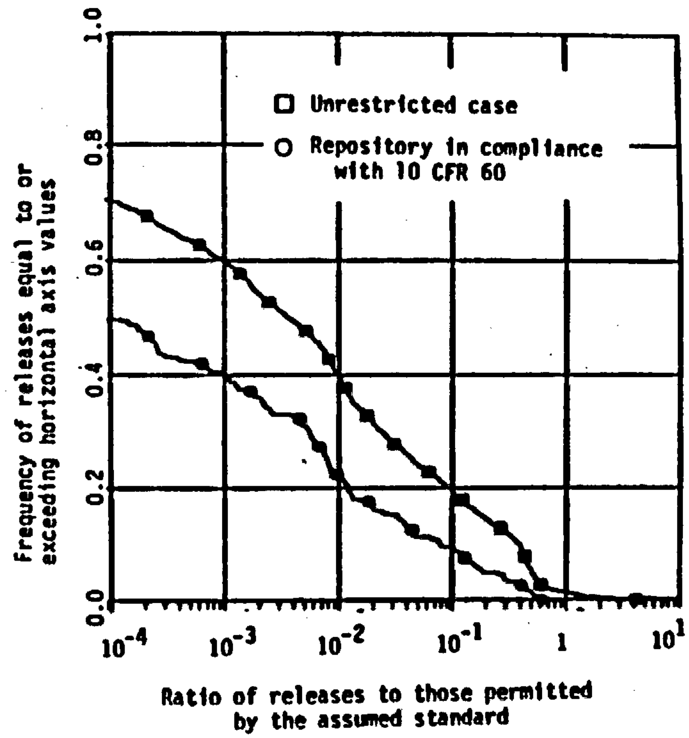


23B. Proposed Version Assumed

Figures 23 and 23B. Relationship between releases in the fault scenario and probability of those releases. Figure 23 assumes Draft 19 of the EPA standard; Figure 23B assumes the proposed version.



25. Draft 19 Assumed



25B. Proposed Version Assumed

Figures 25 and 25B. Relationship between releases in the borehole scenario and probability of those releases. Figure 25 assumes Draft 19 of the EPA standard; Figure 25B assumes the proposed version.