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Yucca Mountain Site Characterization Project

Estimation of the Impact of Water Movement from Sewage and Settling Ponds Near a Potential High Level Radioactive Waste Repository in Yucca Mountain, Nevada

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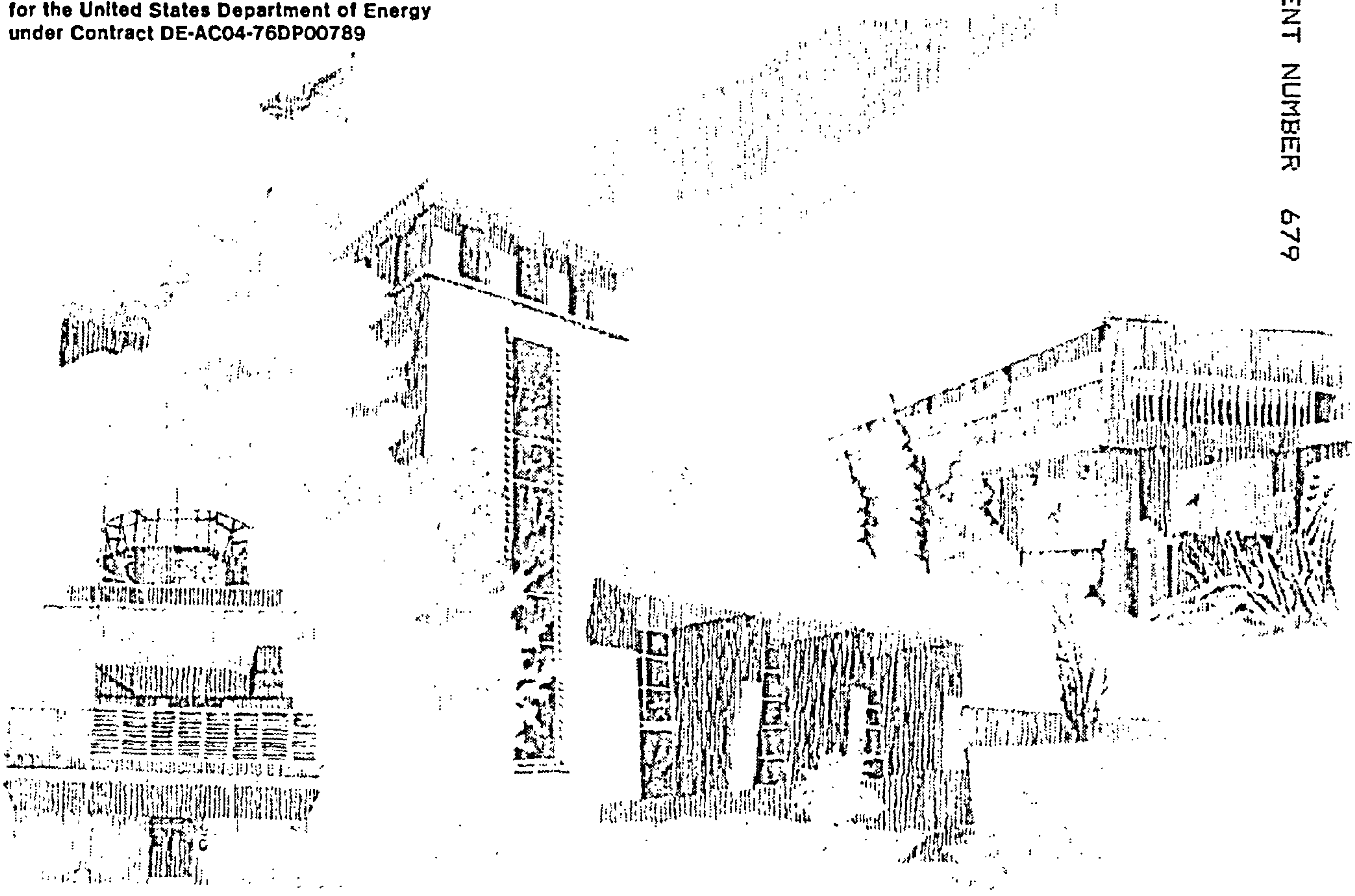

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Estimation of the Impact of Water Movement from Sewage and Settling Ponds Near a Potential High Level Radioactive Waste Repository in Yucca Mountain, Nevada

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Abstract

The Yucca Mountain Site Characterization Project is studying Yucca Mountain in southwestern Nevada as a potential site for a high-level nuclear waste repository. Site characterization includes surface-based and underground testing. Analyses have been performed to design site characterization activities with minimal impact on the ability of the site to isolate waste, and on tests performed as part of the characterization process. One activity of site characterization is the construction of an Exploratory Studies Facility, which may include underground shafts, drifts, and ramps, and the accompanying ponds used for the storage of sewage water and muck water removed from construction operations. The information in this report pertains to the two-dimensional numerical calculations modelling the movement of sewage and settling pond water, and the potential effects of that water on repository performance and underground experiments. This document contains information that has been used in preparing Appendix I of the Exploratory Studies Facility Design Requirements document (ESF DR) for the Yucca Mountain Site Characterization Project.

The work described in this report was conducted under Work Breakdown Structure (WBS) 1.2.1.4.7.

Acknowledgements

The authors would like to acknowledge the work of the following people who assisted in creating this document:

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1. INTRODUCTION

The Yucca Mountain Site Characterization Project (YMP) is studying Yucca Mountain in southwestern Nevada as a potential site for a high-level nuclear waste repository. Site characterization includes surface-based and underground testing. Underground testing is to be facilitated by the construction of an Exploratory Studies Facility (ESF).[1] Water will be used during the construction of the exploratory facility, and for daily operations such as dust control and sewage disposal. Waste water from drilling operations will be contained in settling ponds in a muck storage area, and sewage water will be discharged from the sanitary waste disposal system into sewage ponds. The settling ponds will be lined to prevent water from leaking into the rock mass beneath. Because flow of groundwater has the potential for reducing the ability of the site to safely isolate waste, there is concern that water infiltration from the surface ponds can degrade repository performance or impact experiments conducted in the ESF. This report describes calculations that were performed to estimate the extent of water movement from unlined sewage and settling ponds, and from potential leaks in settling pond liners, and to estimate the resulting changes in saturation. Calculations were also performed to investigate the impact of different sewage pond locations on the ability of the site to safely store radioactive waste, and on experiments to be performed in the ESF. The results of the calculations will be used to support ESF design, will be incorporated into the Exploratory Studies Facility Design Requirements document (ESF DR), and will be available for guidance in locating the muck storage and sewage ponds for minimal effects on the potential repository.

These calculations constituted one of eleven ESF analyses being performed in support of the ESF DR. The particular analysis described in this report is ESF Analysis 3, and it is intended to provide a basis for the evaluation of the movement of water from muck storage and sewage ponds, and the potential effects of that water on experiments and repository performance. The calculations and analyses performed for ESF Analysis 3 were conducted as a Quality-Related activity in accordance with Sandia National Laboratories' implementation of the Yucca Mountain Project Quality Assurance plan and were controlled by Problem Definition Memo (PDM) 72-31. This work was performed under the Sandia National Laboratories Nuclear Waste Repository Technology Department Quality Assurance Plan under WBS 1.2.1.4.7.

These calculations are based on available data and on the present conceptual understanding of the processes and mechanisms perceived to be active at Yucca Mountain. Due to our limited knowledge of Yucca Mountain prior to site characterization, the hydrogeological conceptual model, other existing conceptual models of the physical processes, and the mathematical models used in these analyses are not validated. Therefore, considerable uncertainty exists in these results. Recommendations based on the results of these analyses are intended to provide guidance for applying engineering judgment during the design, construction, and operation of the ESF, and therefore must provide relevant results to the architects and engineers who design the ESF. Refinement of the results is an ongoing and iterative process, which must

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[1] The Exploratory Shaft Facility was renamed the Exploratory Studies Facility in February 1991.

complement site characterization. These calculations may be refined as better understanding evolves through site characterization and through additional analyses, which will address uncertainties and the sensitivity of the results to alternate conceptual models.

2. APPROACH

Calculations of water movement in layered, fractured, unsaturated porous media using the currently accepted mathematical models are complex and require sophisticated computer codes. The computer program NORIA-SP [Hopkins, et al., 1991] was used to perform the two-dimensional calculations presented in this report. NORIA [Bixler, 1985], a finite element code, numerically solves the two-dimensional Richards' equation for the transient flow of water in layered, fractured, unsaturated porous media. NORIA has been used extensively in such analyses in the Yucca Mountain Project. NORIA does not simulate radionuclide transport and does not perform groundwater travel time (GWTT) calculations. NORIA-SP is a single phase (liquid water) version of NORIA. Because the mathematical model for single phase flow in NORIA-SP is much simpler than the two-phase model implemented in NORIA, single phase calculations are more economical. In these calculations, the fractures and matrix were treated as an equivalent porous media via the composite porosity model [Peters and Klavetter, 1988], and the van Genuchten model [van Genuchten, 1980] was used to describe the characteristic curves for the matrix and fractures. Multiphase affects were assumed to be negligible. NORIA-SP has met the requirements of SNL's implementation of the YMP's criteria for software quality assurance. For these reasons, NORIA-SP was chosen to perform the two-dimensional calculations.

Because only the water that enters the mountain can effect repository performance and underground tests, these calculations were posed in terms of the amount of water held in an above-surface pond maintained at a specified depth. The effects of evapotranspiration were disregarded. The physics associated with water transport at the surface is complicated and includes unpredictable variables such as the weather and surface topography. For these calculations, the rate of water infiltration into the surface beneath the above-ground pond is a function only of the depth of the pond and the in-situ saturation and material properties of the surface rock layer, and it is assumed that water entering the surface cannot leave the mountain.

3. CALCULATIONS

The problem is conceptualized as follows. The mountain as represented in Figure 1 is at the steady-state saturation conditions that correspond to a uniform infiltration of 0.01 mm/yr through the surface of the mountain.[2] At

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[2] Montazer and Wilson (1984) estimate the percolation rate through the tuff matrix in the Topopah Spring unit to be between 10^{-4} and 10^{-7} mm/yr. Weeks and Wilson (1984) estimate the rate to be between 0.003 and 0.2 mm/yr. Based on these estimates, 0.01 mm/yr was chosen as a representative value for the steady-state surface infiltration. Also, saturation values obtained by the one- and two-dimensional steady-state calculations at 0.01 mm/yr are within the range of saturation values that presently reside in the Reference Information Base (RIB), with the exception of those reported for the vitric Paintbrush Tuff layer PTn (see the explanation in Section 4.1.1).

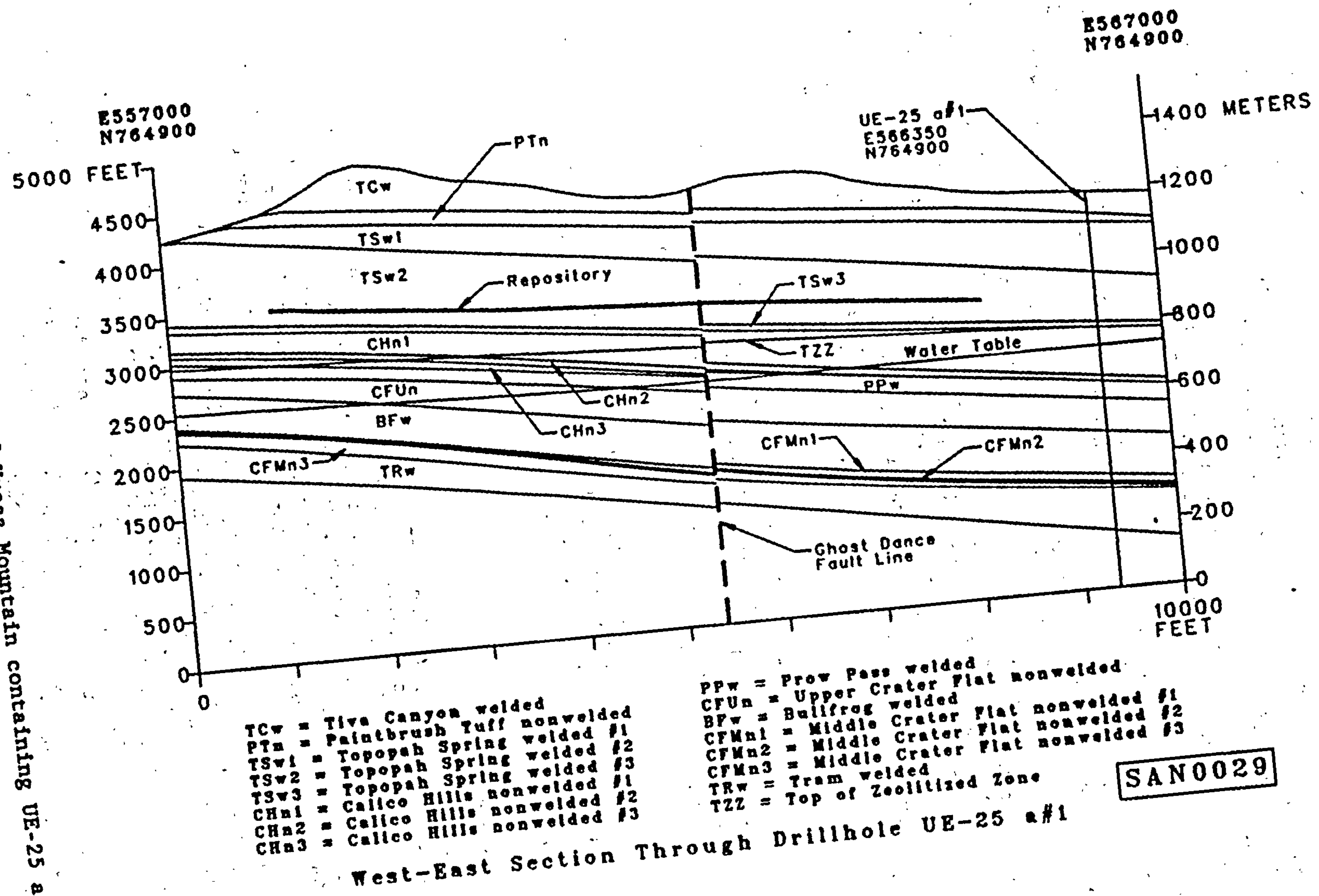

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Figure 1: West-East section of Yucca Mountain containing UE-25 a#1

"time zero," a pond of waste water is maintained at a constant depth at a location outside the boundary of the repository block. This pond water begins to infiltrate the top of the mountain at a rate determined by the pressure head of the pond, while water continues to infiltrate the mountain through the remaining surface at 0.01 mm/yr. The pond is removed after five years, after which the infiltration into the entire surface returns to a uniform 0.01 mm/yr. The movement of this pond water is followed over 10,000 years in the two-dimensional calculations described below.

The sewage pond and the muck storage pond are each designed to hold waste water maintained at a constant depth during the expected five year ESF construction and operation period. For the purposes of these calculations, it was assumed that the water infiltrates the surface uniformly through the design area of the pond. Calculations were performed for pond locations both near and two miles from the potential repository boundary. Values for the ponds' depths, areas, and locations were obtained from Configuration B3 (Options 13 and 30) of the ESF Alternative Study [Stevens and Costin, 1991] and the Yucca Mountain Site Characterization Plan [SNL, 1987]. The calculations are simplified to two dimensions by assuming radial symmetry for the infiltration process, and that the stratigraphic layers are horizontal and parallel. The goals of the sewage and settling pond analyses were the following:

- Using boundary conditions that represent the Title I design depths of the sewage and settling ponds, determine the potential effects of the location and leakage rates of the ponds on saturation at the repository horizon during the 10,000 years following emplacement of water in the ponds; and

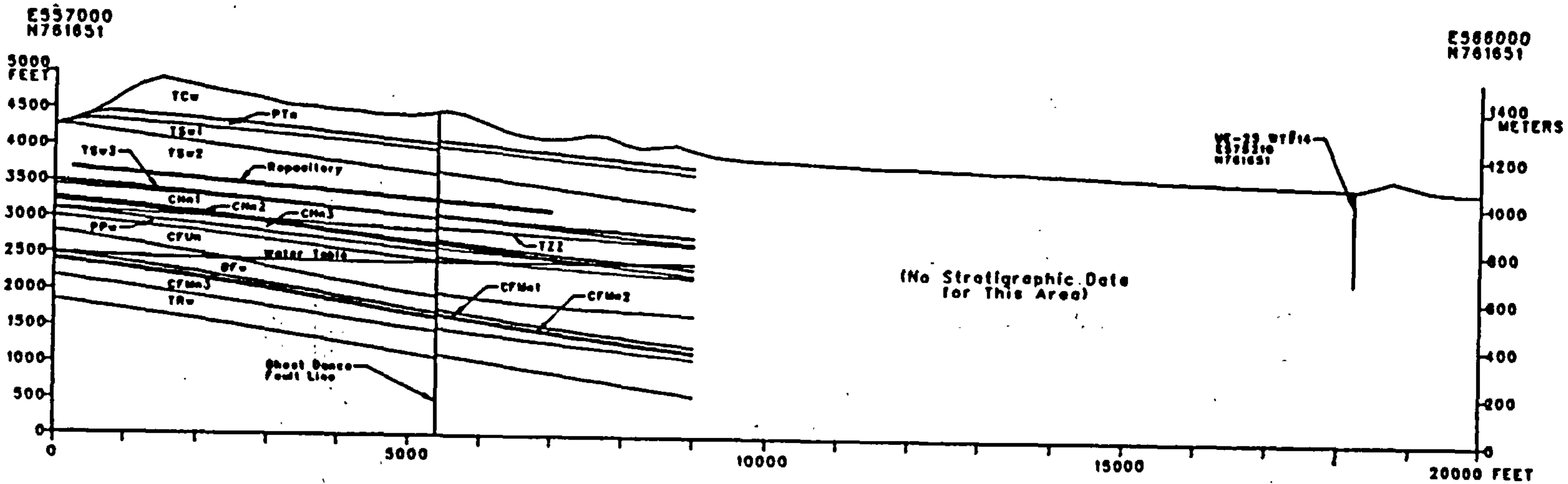
- Using the same calculations, determine the potential effect on experiments to be conducted in the ESF, and set guidelines for locations of experiments.

3.1 <u>Sewage Ponds</u>

3.1.1 <u>Discussion</u>

The effects of sewage pond location were investigated by performing calculations at two locations--one near the edge of the repository block (Sewage Case #1) and the other approximately two miles east of the repository boundary (Sewage Case #2). These locations were selected to correspond to the Title I design for the locations for muck settling ponds and the sewage ponds [YMP, 1989]. The following assumptions were made for the analysis.

- Data for Well UE-25 a#1, which is in Version 2.002 of the Reference Information Base (RIB), but not in current RIB, were used for the stratigraphy at the Title I settling pond location near the potential repository boundary (Sewage Case #1). Data for USGS Well UE-25 WT#14 [Muller and Kibler, 1985] were used for the stratigraphy at the Title I sewage ponds location (Sewage Case #2). These data were chosen because these boreholes are the closest to the proposed pond locations. Figures 1 and 2 show vertical sections through Yucca Mountain that include either UE-25 a#1 or UE-25 WT#14, respectively, and the nearby repository. The hydrological layers shown in these figures are those defined by Ortiz et



TCw = Tiva Canyon welded
PTn = Paintbrush Tuff nonwelded
TSw1 = Topopah Spring welded #1
TSw2 = Topopah Spring welded #2
TSw3 = Topopah Spring welded #3
CHn1 = Calico Hills nonwelded #1
CHn2 = Calico Hills nonwelded #2
CHn3 = Calico Hills nonwelded #3

PPw = Prow Pass welded
CFUn = Upper Crater Flat nonwelded
BFw = Bullfrog welded
CFMn1 = Middle Crater Flat nonwelded #1
CFMn2 = Middle Crater Flat nonwelded #2
CFMn3 = Middle Crater Flat nonwelded #3
TRw = Tram welded
TZZ = Top of Zeolitized Zone

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West-East Section Through Drillhole UE-25 WT#14

Figure 2: West-East section of Yucca Mountain containing UE-25 WT#14

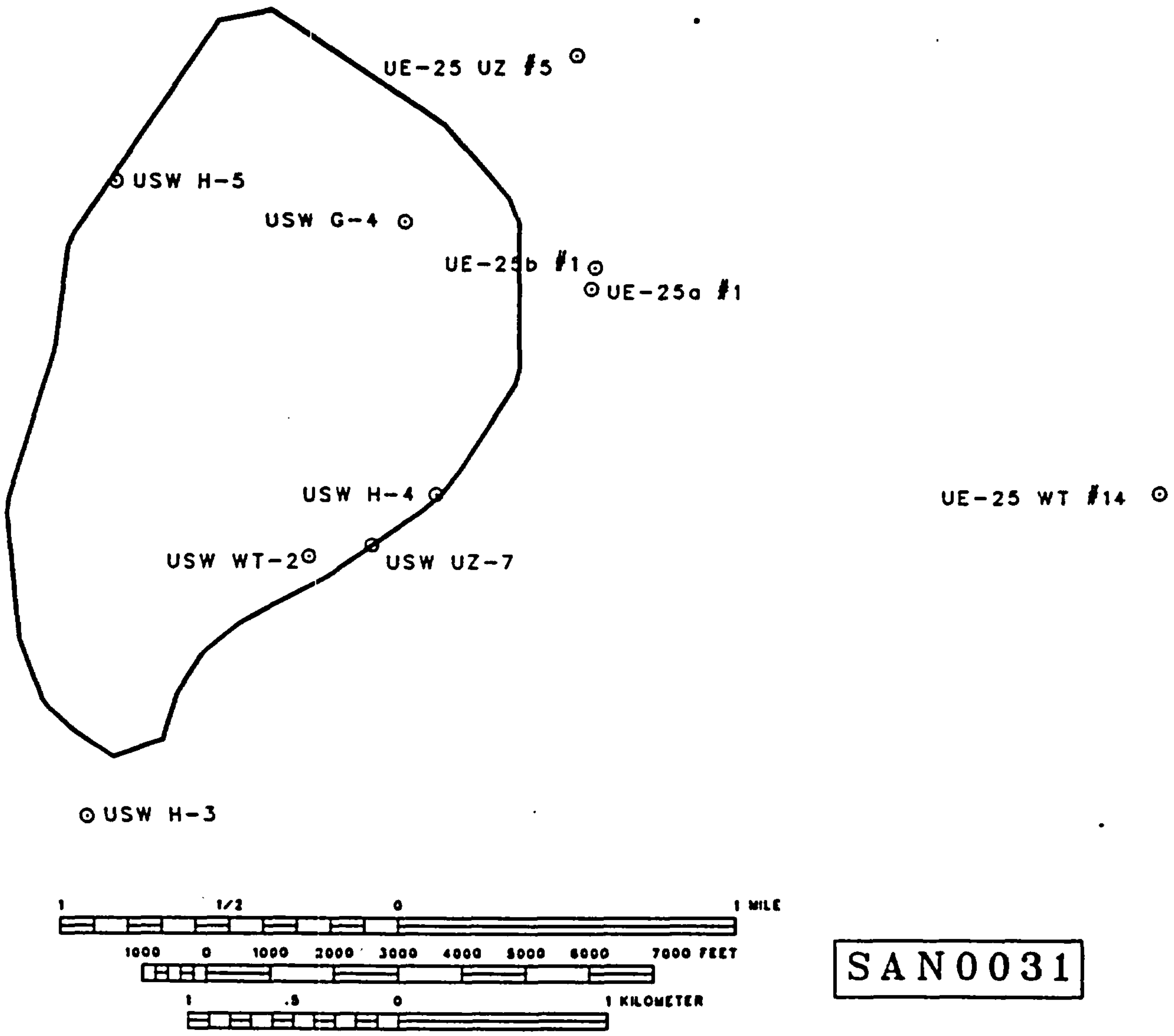

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Figure 3: Locations of boreholes UE-25a#1 and UE-25WT#14 near potential Yucca Mountain repository

al. (1985). Figure 3 shows the locations of these two boreholes with respect to the potential repository block.

- The hydrologic properties of USW G-4 [Peters et al., 1984] were used for these calculations to maintain consistency with the calculations performed for other ESF Analyses (see Appendix A for a listing of the hydrologic properties). The material properties for the alluvium layer at the surface at the muck storage location were those values estimated by Alan Flint of the U.S. Geological Survey (personal communication, July 19, 1989). The thermomechanical properties in each layer were assumed to be homogeneous and isotropic throughout the layer.

- The problem domain was defined as two-dimensional and axisymmetric. The surface and the hydrogeologic layers were modelled as horizontal and parallel. The two pond locations selected for this analysis are downgrade from the ESF surface facility. Results of two-dimensional cartesian calculations COVE2A [Hopkins, 1990] and HYDROCOIN [Prindle and Hopkins, 1990] show that the dip of the TSw1 unit acts to divert water from the repository block. Thus, the no dip assumption is conservative if the mountain is indeed homogeneous and isotropic, as assumed in the hydrogeological models used in COVE2A and HYDROCOIN, and in these calculations. Also, the effects of evapotranspiration were not included in the analysis. NORIA-SP was used to model the problem as a single phase flow problem.

- A steady-state infiltration of 0.01 mm/year was specified as the initial condition, from which NORIA-SP determined the steady-state saturation levels throughout the stratigraphy. These steady-state conditions served as the initial state (time zero) for the perturbed flow calculation.

- The ground surface was the upper boundary, and the water table was the lower boundary for the computational domain at each pond location. The surface area of the pond was equivalent to the surface area of the Title I design for sewage ponds (9,351 m^2), and the depth of water in the pond was kept at a constant 1.83 m for the five-year ESF construction and operation period. The sewage pond was assumed to be unlined; therefore, the upper boundary condition was a total pressure equal to a constant head of 1.83 m at the base of the pond for five years, and a constant 0.01 mm/year flux on the remaining surface. After five years, a constant 0.01 mm/year flux was imposed on the entire surface. One vertical boundary was the axis of symmetry. The other vertical boundary was located at a radius of 600 m from the axis of symmetry. No flux boundary conditions were imposed on both vertical boundaries, and the lower boundary was set to a total pressure which corresponded to saturated conditions.

- The computational domain used in NORIA-SP was two-dimensional and axisymmetric, with a 600 m radius centered about the axis of the pond. The height of the grid was dependent on the stratigraphy at each of the locations. The sewage water was uniformly distributed over an area of radius 54.6 m (equivalent to 9,351 m^2 sewage pond area).

There were numerical stability problems in the calculation of Case #1. The instability problems occurred in the alluvium layer. Originally, the computational grid was designed so that there was only one layer of elements in the alluvium layer. It was initially decided to restructure the grid without alluvium, then proceed with the problem. Leaving out the alluvium would add a factor of conservatism to the determination of the effect on saturation at the repository horizon. Thus, the pressure head boundary condition of 1.83 m was applied to the Tiva Canyon welded tuff layer for Case #1, and all calculations were made accordingly. The calculations proceeded easily. Figure 4 displays the computational grid used for the calculations for Case #1. It was learned during the work for the ESF Analysis for surficial water application [Fewell et al., 1991] that calculations in the alluvium layer will have instability problems when a high pressure gradient is imposed there. Later calculations were performed for Sewage Case #1 with two, then three, finite element layers in the alluvium. The calculation with two finite element layers was still unstable, but the calculation with three layers proceeded smoothly. The results of the latter were analyzed to assess the conservatism of the original results.

The calculation of Case #2 proceeded easily. The stratigraphy for Well UE-25WT#14 was used for Case #2, for which the entire stratigraphy from surface to water table is in the Topopah Spring TSw2 layer. Figure 5 displays the computational grid used for the calculations for Case #2.

3.1.2 Results

The results of the original calculations for Case #1, with Tiva Canyon (TCw) as the top layer, indicate that there will be no effect on experiments in the ESF or on potential repository performance because water movement and changes in saturation do not penetrate to repository depth. Figure 6 presents saturation profiles along the vertical axis of the pond, at various times up to 10,000 years. Through 10,000 years, the sewage water will not alter saturation values below an elevation of 1000 meters above sea level, nearly 100 meters above the repository at the nearest edge. Figures 7, 8, and 9 present contour plots showing the change in saturation from in situ conditions at 5, 100, and 10,000 years after the start of ESF construction, respectively.[3] During the active life of the potential repository (the first 100 years), the infiltrated water affects saturation levels in TCw only, and in an area four times larger than the original pond area. Because of the Title I location chosen for this case, sewage water will not enter any region directly above the repository.

The follow-up calculations, for which the top hydrological layer was the alluvium layer, supported the conclusion that a sewage pond located off the repository block will have no effects on ESF experiments and repository performance. However, there were some significant differences in the results from the original calculations. The volume of water that infiltrated the mountain through the alluvium surface was an order of magnitude greater than the amount that entered through the TCw surface. The saturation profiles along the axis of the pond, which are shown in Figure 10, illustrate the additional infiltration of water through the alluvium. The reason for this increase in infiltrated water is that the conductivity and porosity of the alluvium are much higher than those for TCw. The water also dispersed to a

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[3] The vertical dashed line in the contour plots indicates the outer edge of the sewage pond.

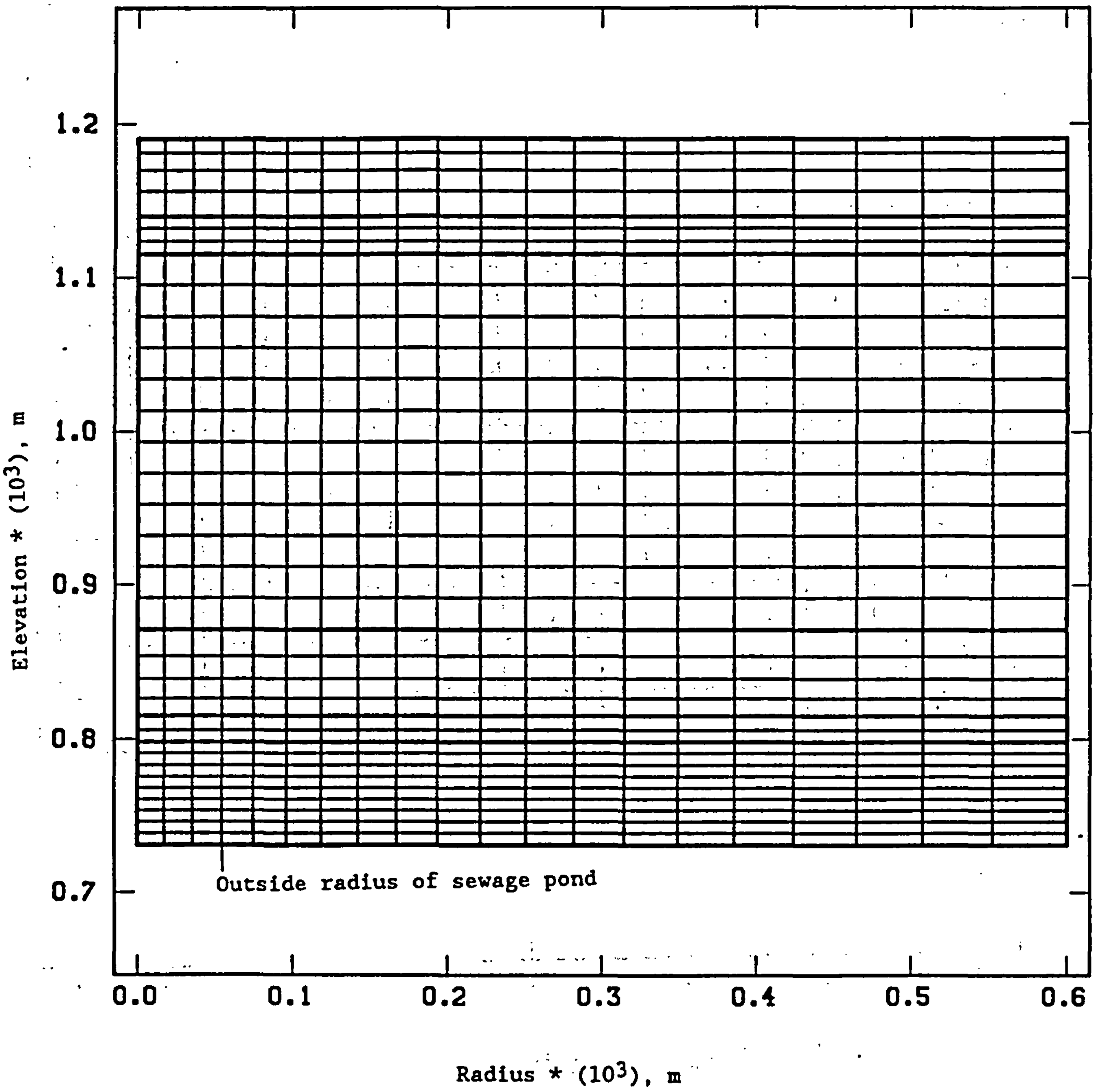

Figure 4: Two dimensional computational grid for Sewage Case #1

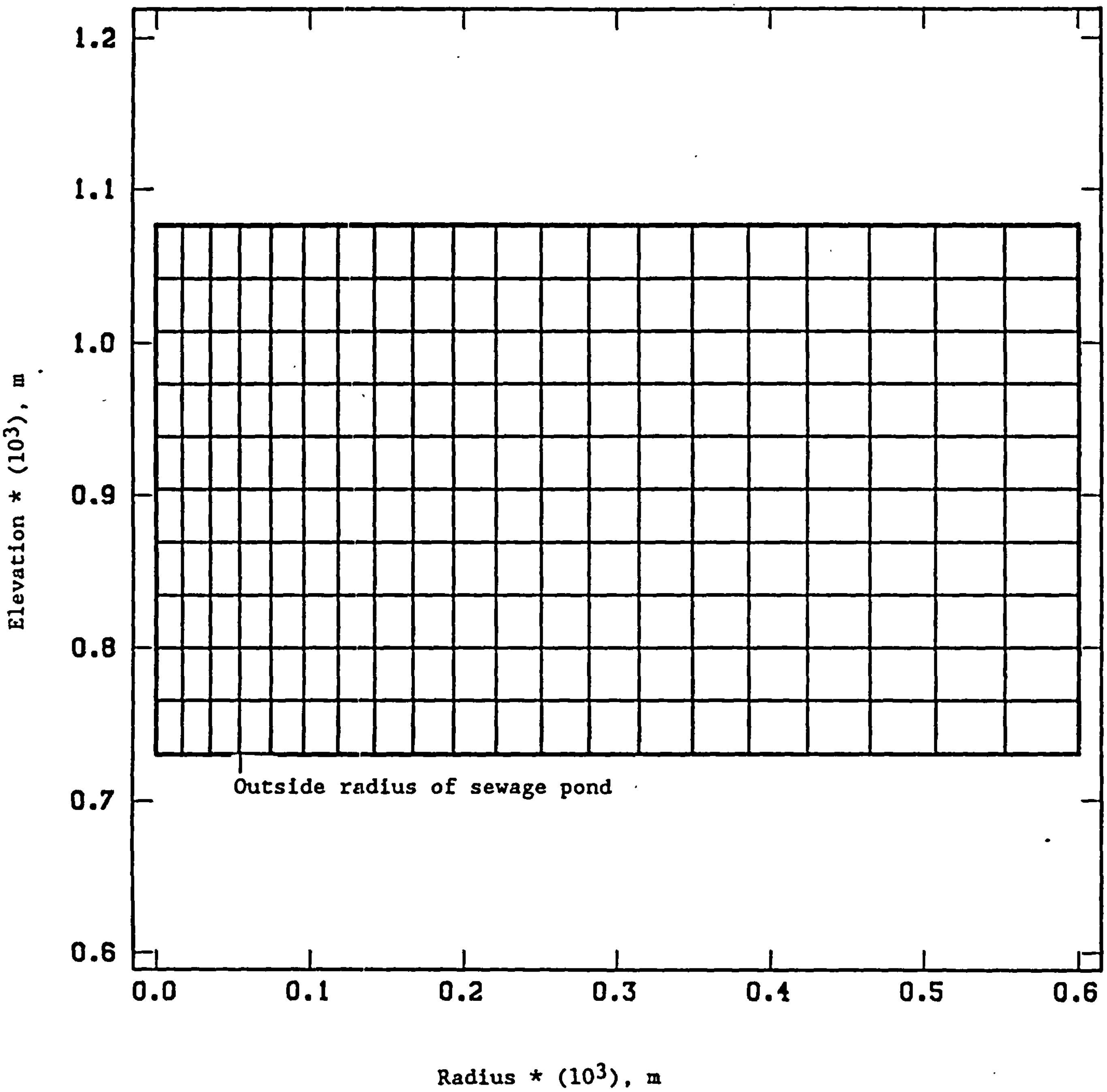

Figure 5: Two dimensional computational grid for Sewage Case #2

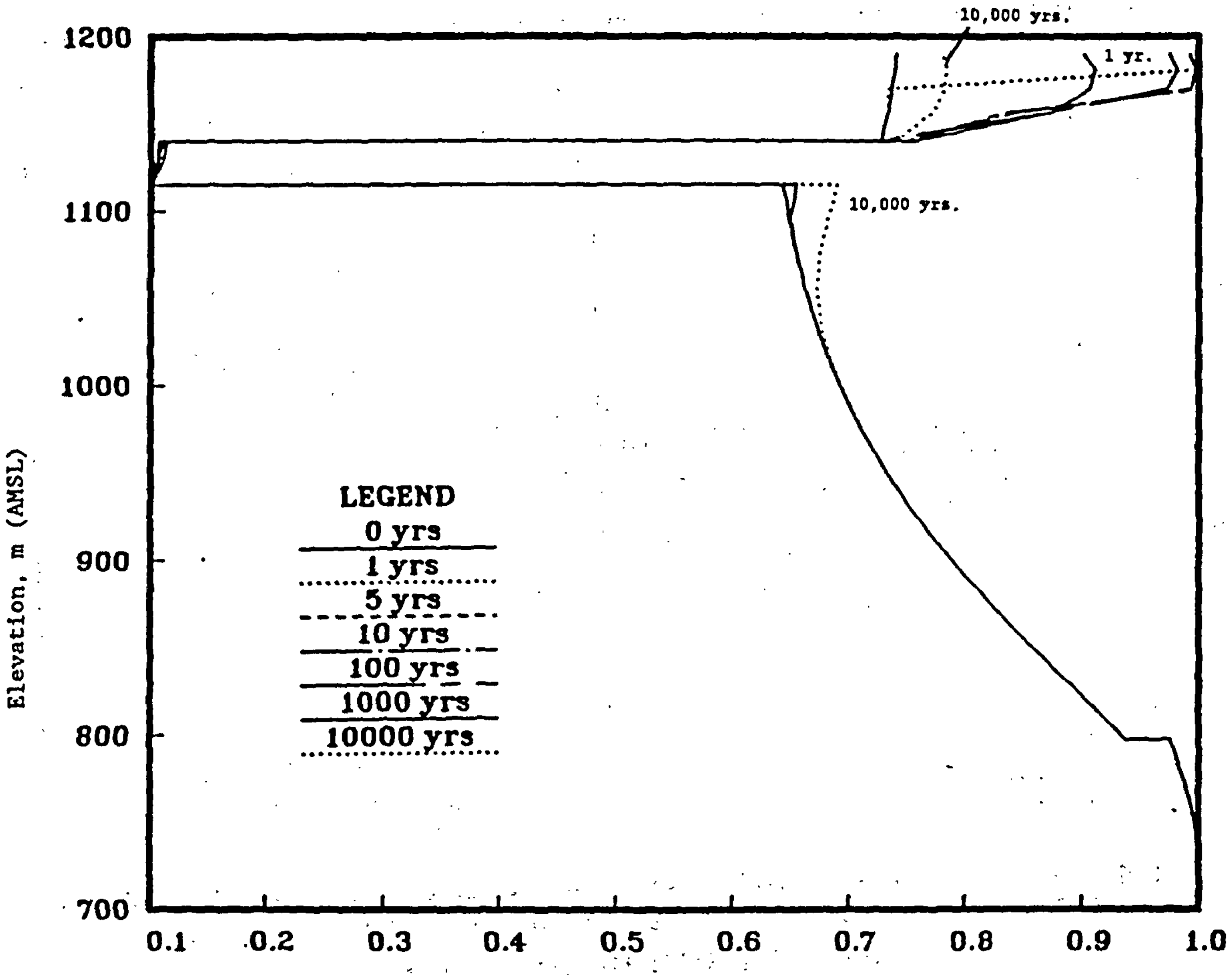

Figure 6: Saturation profiles for Sewage Case #1, no alluvium

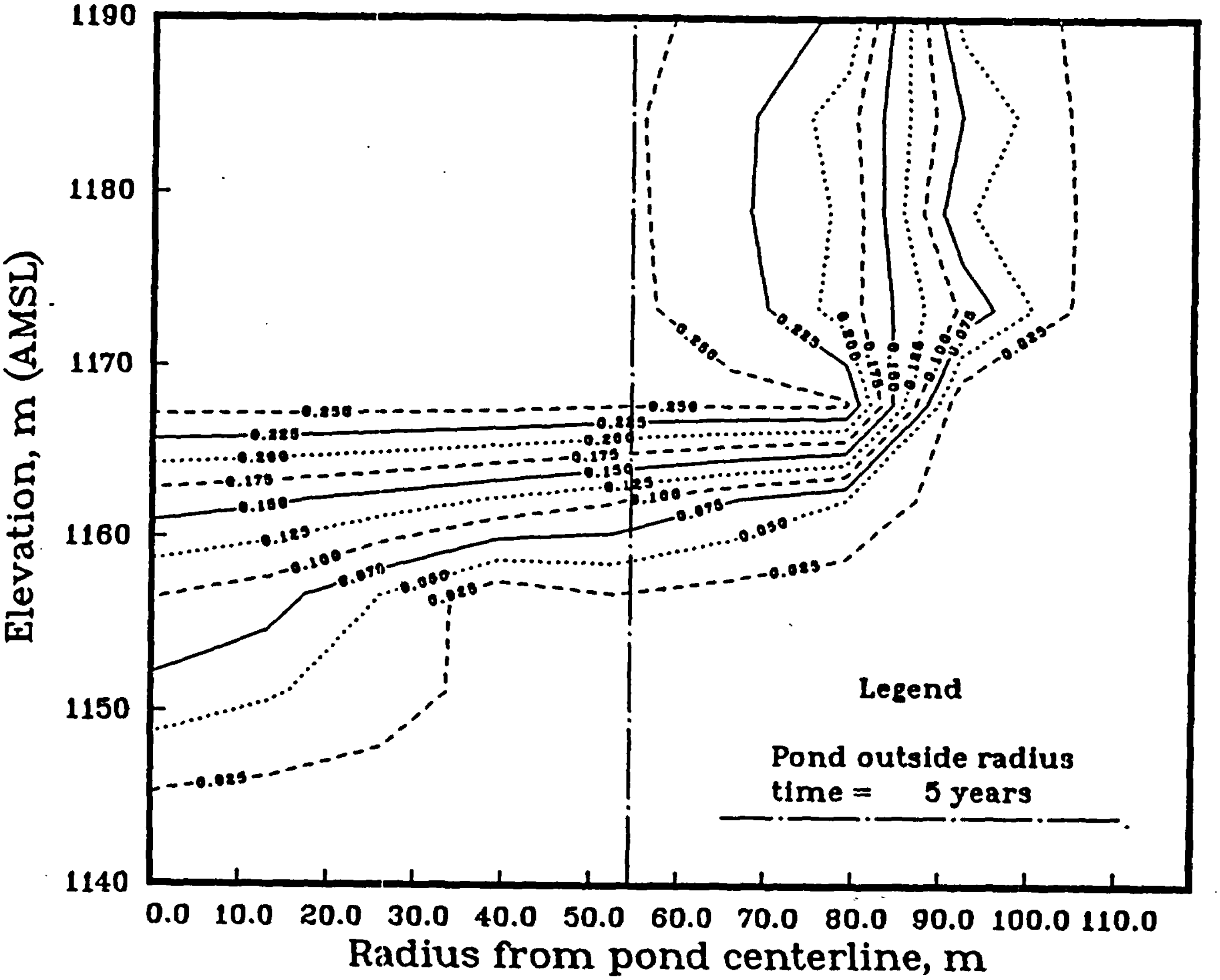

Figure 7: Contour plot for Sewage Case #1, no alluvium:
Change from in-situ saturation after 5 years

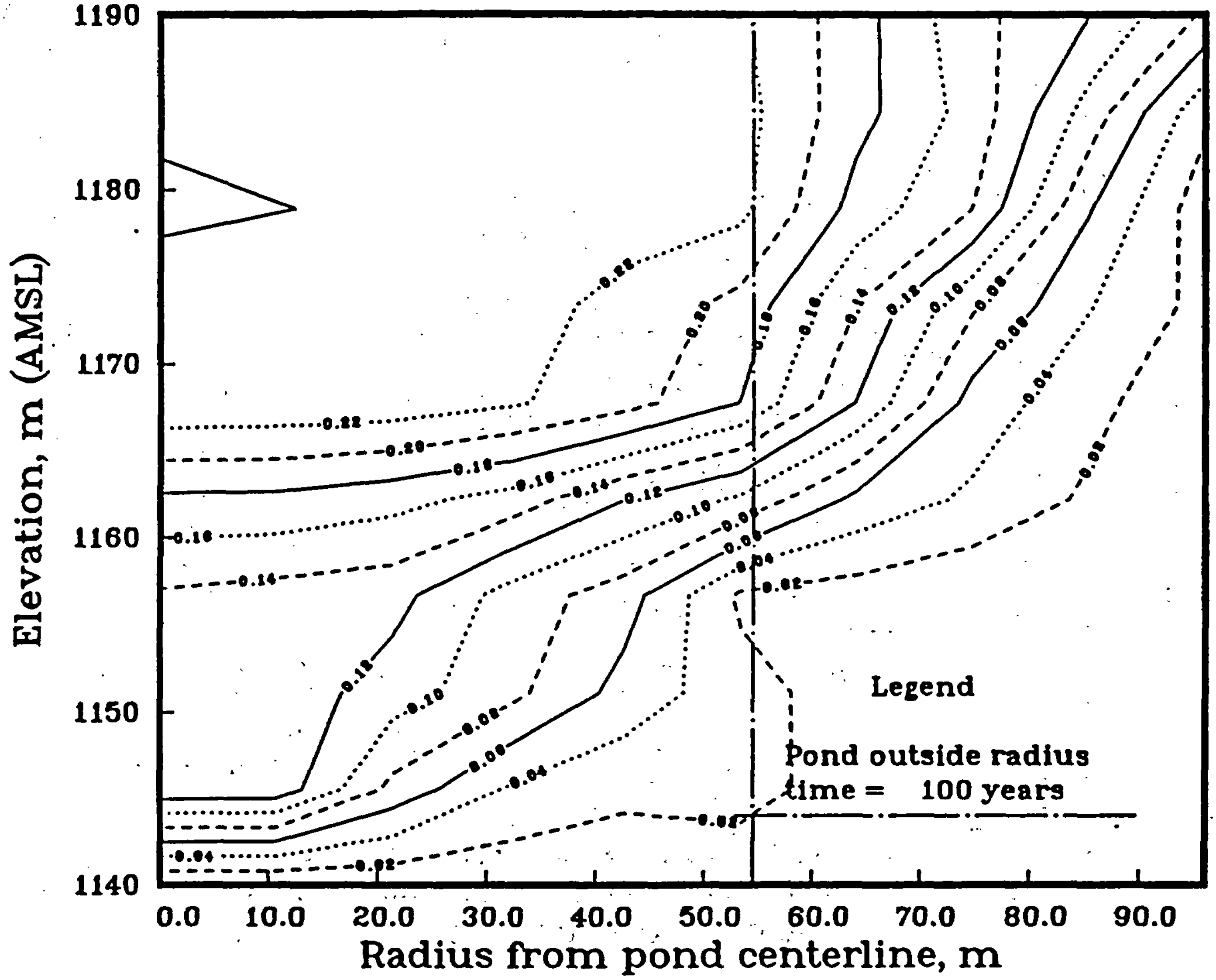

Figure 8: Contour plot for Sewage Case #1, no alluvium:
Change from in-situ saturation after 100 years

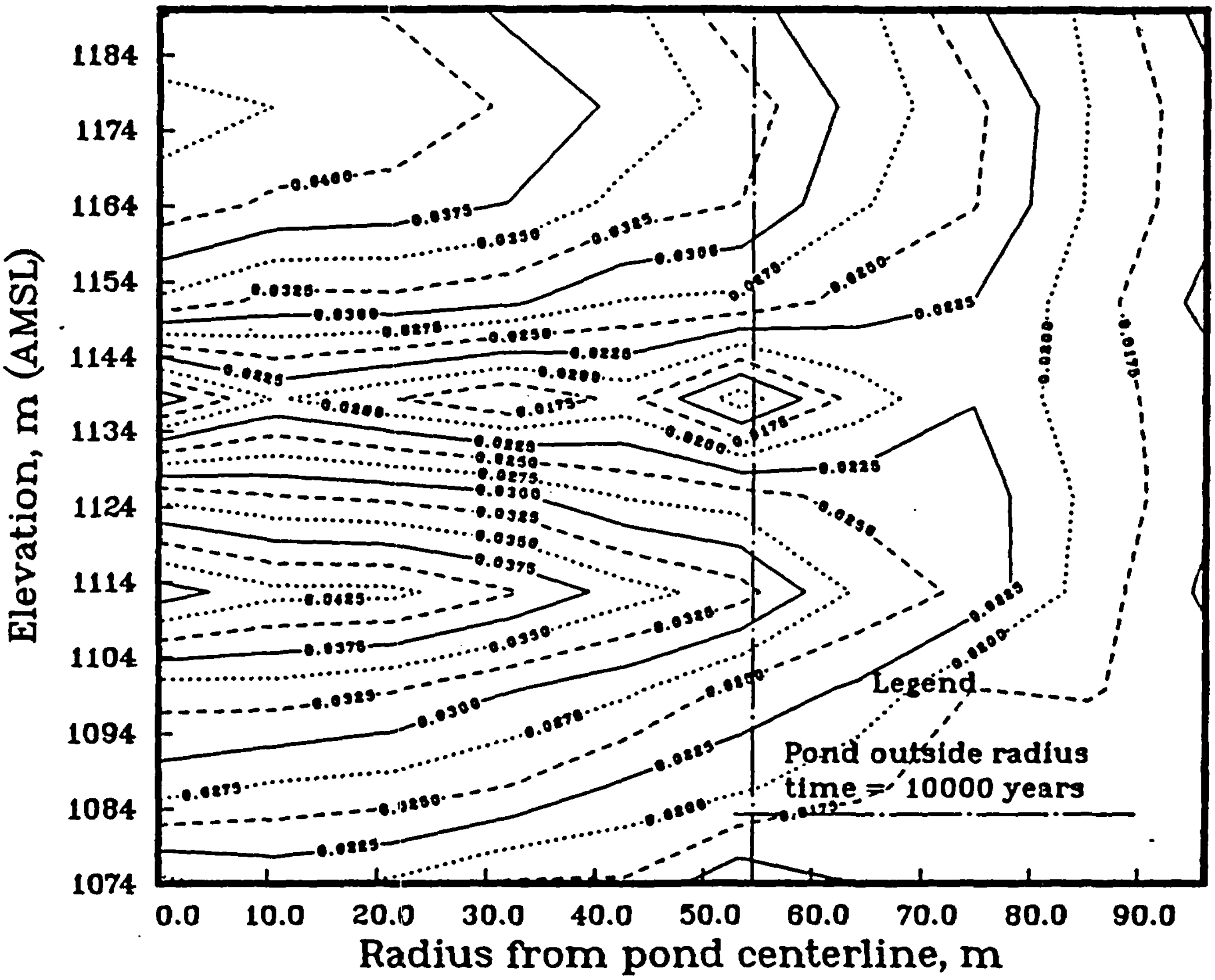

Figure 9: Contour plot for Sewage Case #1, no alluvium:
Change from in-situ saturation after 10,000 years

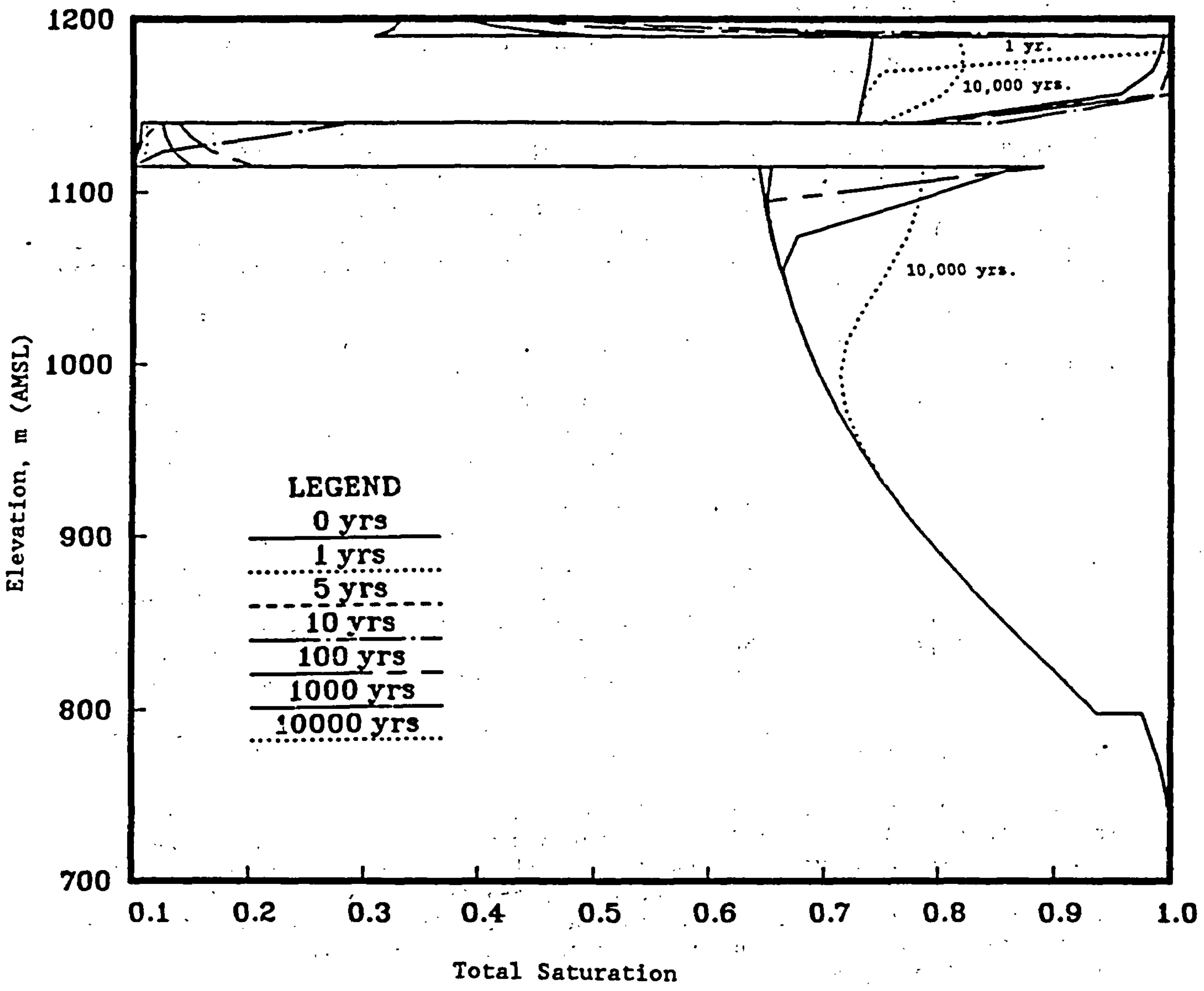

Figure 10: Saturation profiles for Sewage Case #1, with alluvium

larger area in the alluvium than in TCw, to an area roughly ten times the original pond area. This dispersion is demonstrated in Figures 11, 12, and 13, which show contour plots for the change in saturation from in situ conditions at 5, 100, and 10,000 years after the beginning of ESF construction, respectively. Figure 14 illustrates the dispersion of the pond water relative to the location of the repository. The boundary of the drainage plume shown in Figure 14 is defined by that area where the saturation level is increased by at least 0.1%, or 0.001. It is evident from Figure 14 that any sewage pond with the Title I design attributes located outside the repository boundary, and at or below the surface elevation above the repository, will have no effect on potential repository performance or on experiments conducted in the ESF.

Further examination of the two sets of calculations described above illustrate the impact of fracture flow through the Tiva Canyon welded tuff. The saturation profiles in TCw (elevation 1140-1190 m) at 1 and 5 years are approximately the same with and without the alluvium (Figures 6 and 10, respectively), with the profiles for the case with alluvium showing slightly higher saturation levels. Both cases show that TCw becomes nearly saturated with pond water, and therefore fracture flow is expected to dominate the infiltration process into the underlying non-welded Paintbrush Tuff (PTn). Furthermore, because of the high capacity and conductivity of the overlying alluvium layer, TCw remains nearly saturated for a much longer period of time than with no alluvium. This results in more water infiltrating PTn, which is highly porous and has a low conductivity. Because of its high porosity, PTn acts like a sponge to retard the downward movement of the water. Therefore, fracture flow in TCw will be abated by PTn, and the Topopah Spring units will be protected from large inflows of water.

The results of Case #2, which is two miles away from the proposed repository horizon and in entirely in the Topopah Spring member, indicate that sewage water stored at that location will disperse throughout an area four times as large as the pond during the active life of the repository, and throughout an area approximately ten times as large as the pond at 10,000 years. Figures 15 and 16 show contour plots for the change in saturation from in situ conditions at 5 and 10,000 years, respectively. A pond at this location will have no impact on activities at the repository.

It can be concluded from these analyses that sewage ponds with depths no greater than 1.83 m, located off the repository boundary, and at or below the surface elevation above the repository, will have no effect on the repository performance or on experiments conducted in the ESF. The one possible exception to this, not covered in this analysis, is the potential effect of surface sewage water on an underground ramp running from an off-repository location to the repository horizon. These conclusions are contingent on the current knowledge of hydrological conditions at Yucca Mountain, including water flow parameters such as surface and underground fracture flow.

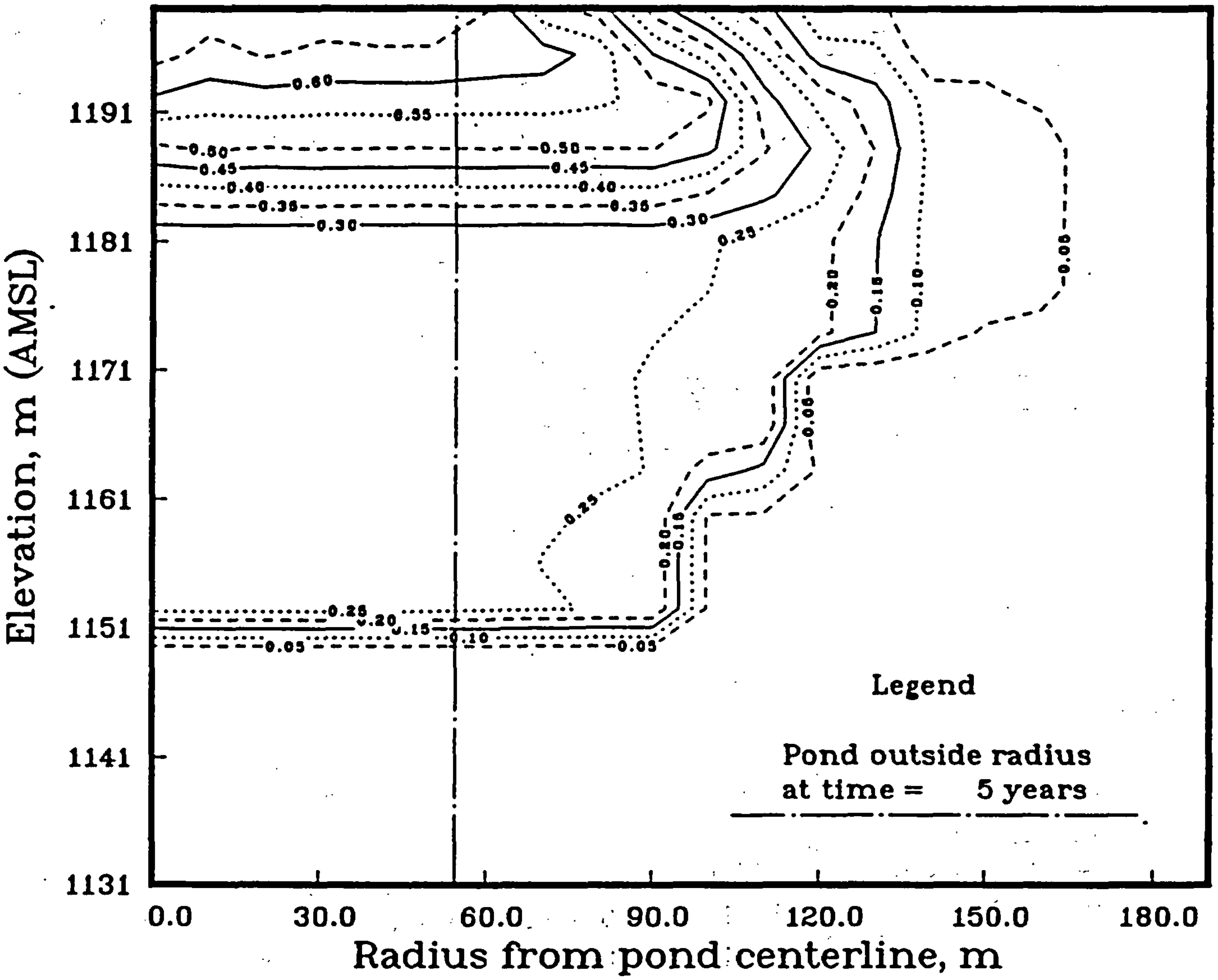

Figure 11: Contour plot for Sewage Case #1, with alluvium:
Change from in-situ saturation after 5 years

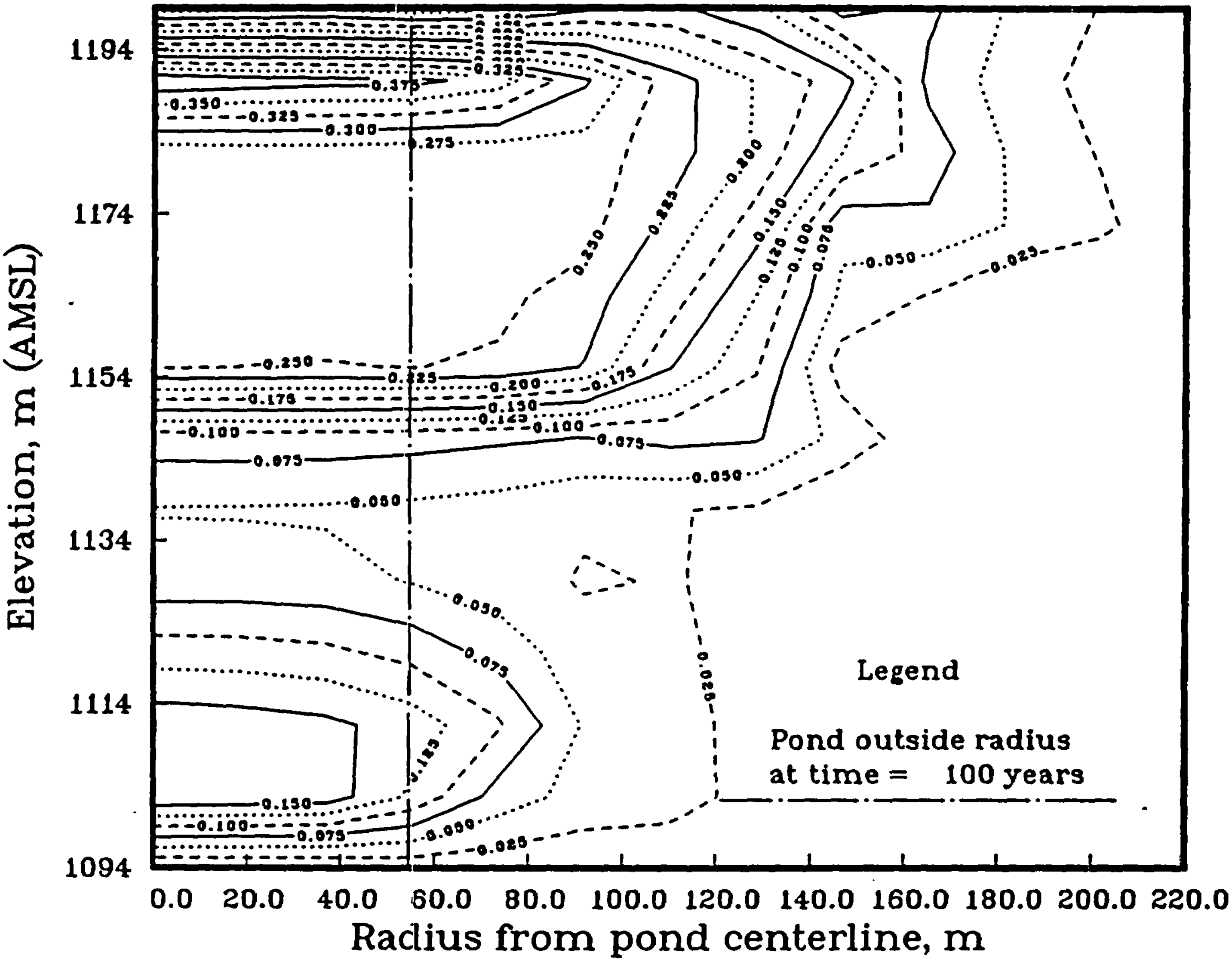

Figure 12: Contour plot for Sewage Case #1, with alluvium:
Change from in-situ saturation after 100 years

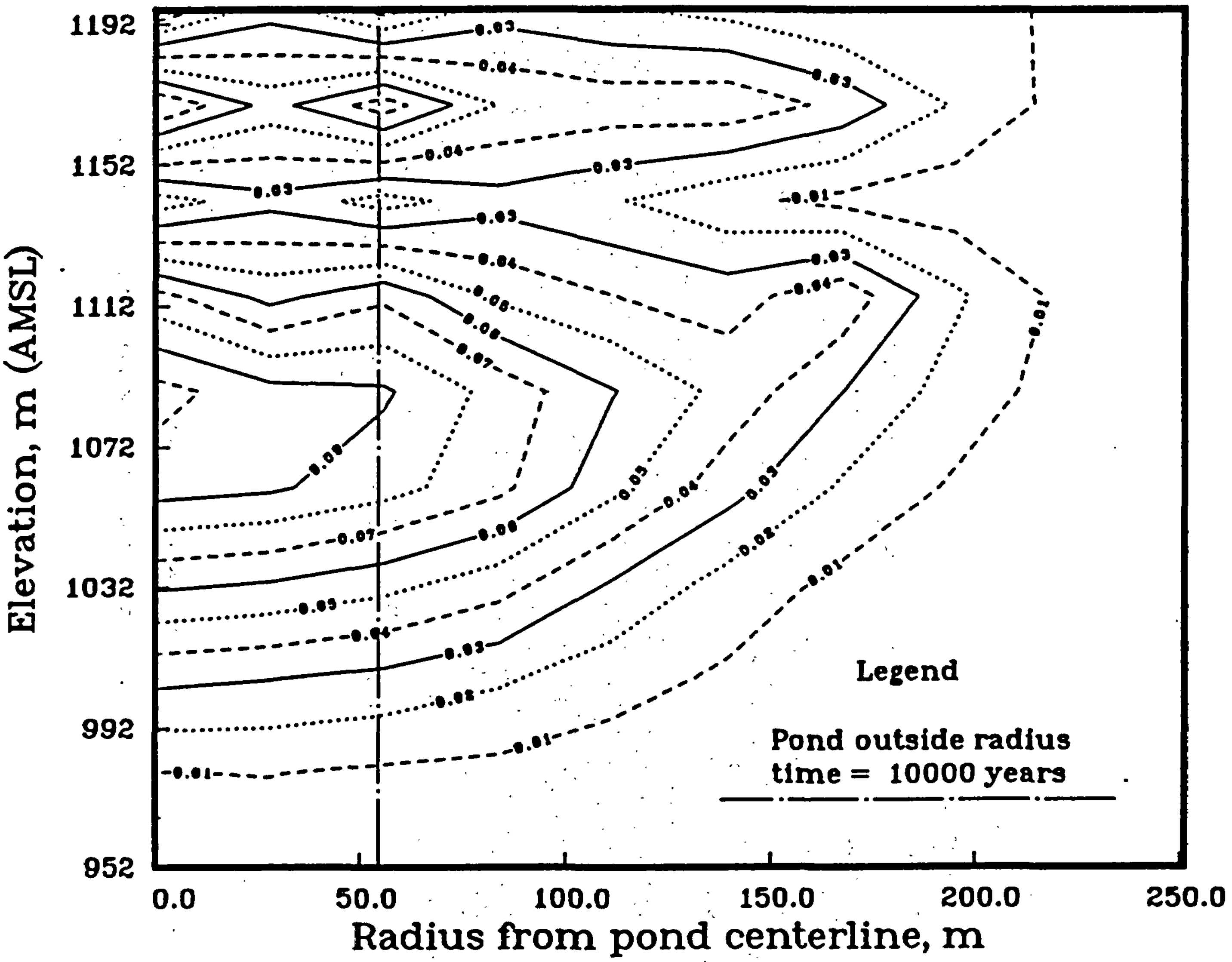

Figure 13: Contour plot for Sewage Case #1, with alluvium: Change from in-situ saturation after 10,000 years

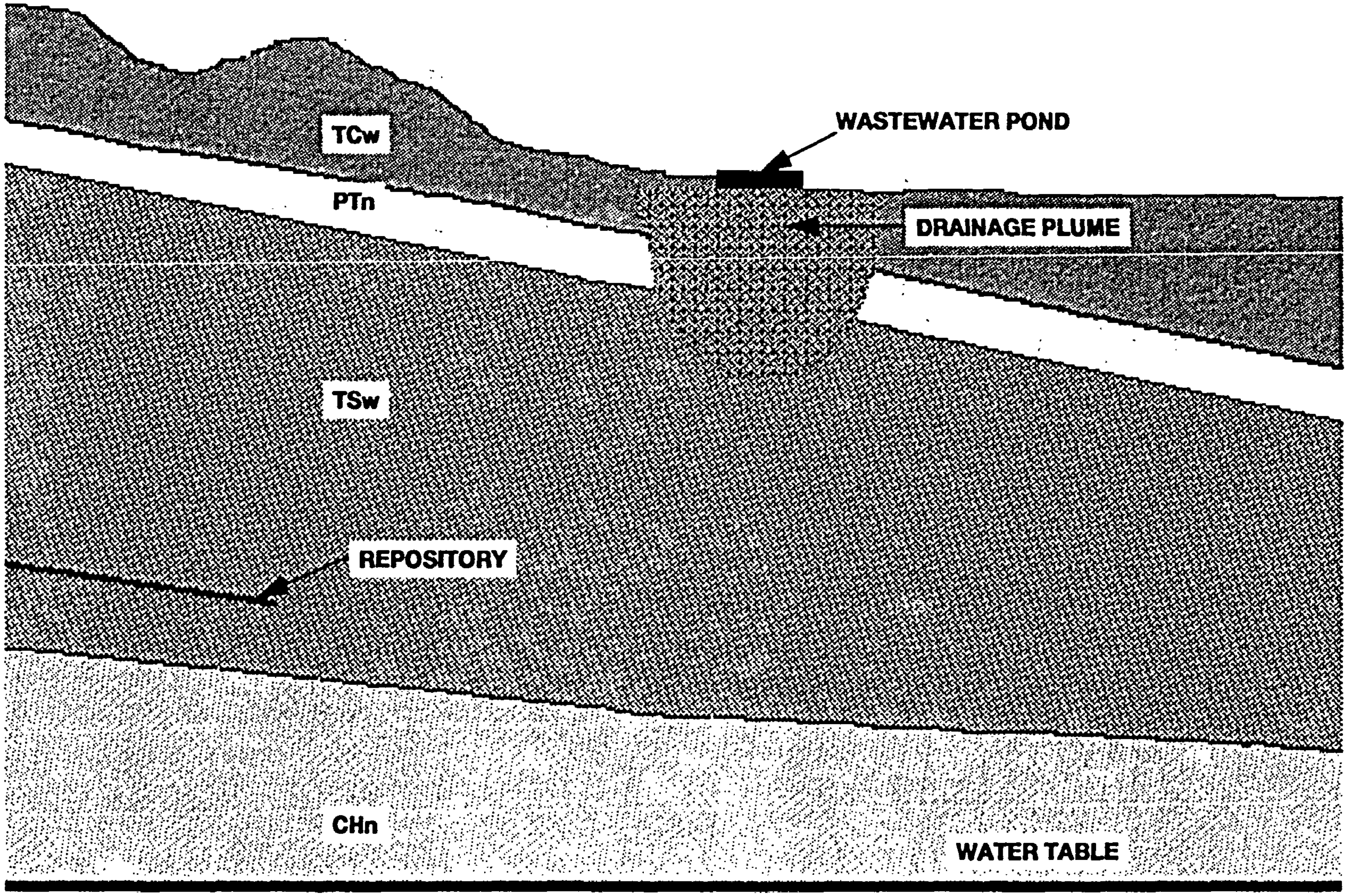

Figure 14: Maximum dispersion of sewage pond water in 10,000 years

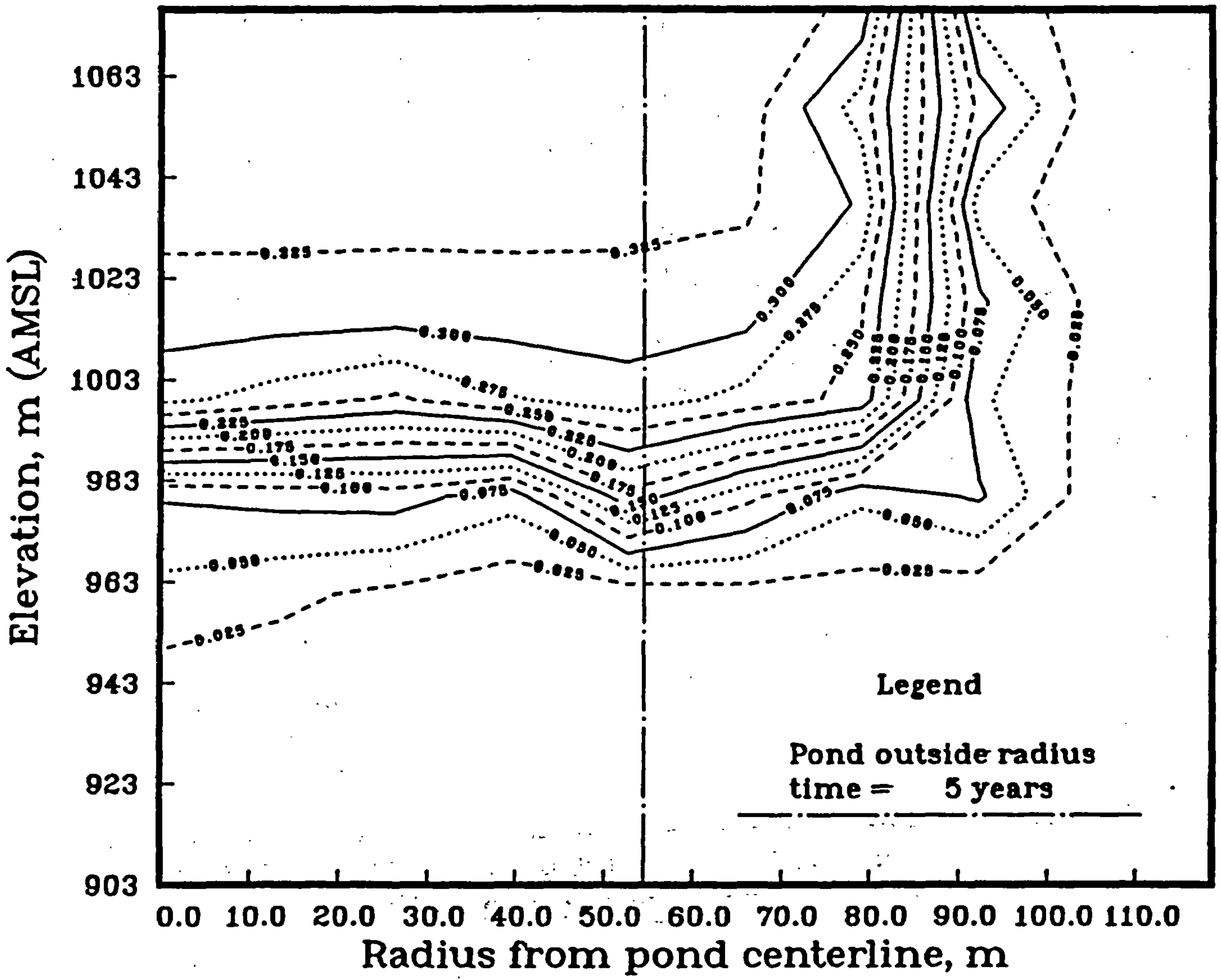

Figure 15: Contour plot for Sewage Case #2:
Change from in-situ saturation after 5 years

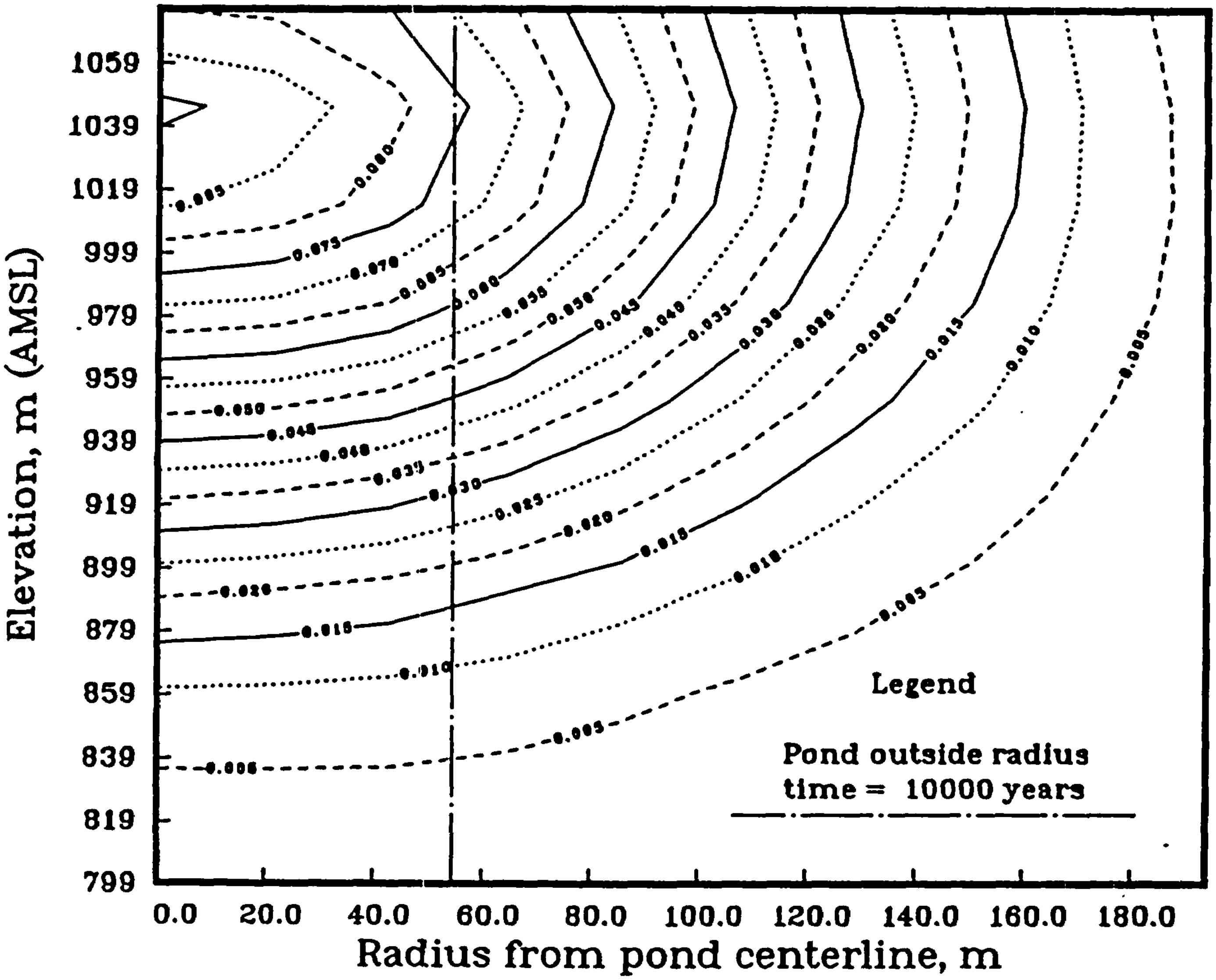

Figure 16: Contour plot for Sewage Case #2:
Change from in-situ saturation after 100 years

3.2 Settling Ponds

3.2.1 Discussion

The movement of water from settling ponds and the effects of leaks in pond liners were analyzed using NORIA-SP calculations for a pond at a location near the edge of the repository block. Calculations were performed for leakages which correspond to 100, 10, and 1 % (Settling Pond Cases 1, 2, and 3, respectively) of the Title I design settling pond surface area (1810 m^2). The following assumptions were made for the analysis (each is the same or analogous to the assumptions for the sewage pond cases):

- Data for Well UE-25 a#1, which is in Version 2.002 of the RIB but not in current RIB, were used for the stratigraphy at the muck storage location. These data were chosen because this bore hole is the closest to the proposed settling pond location.
- The hydrologic properties of USW G-4 [Peters et al., 1984] were used for these calculations (see Appendix A). The material properties for the alluvium layer at the surface at the muck storage location were those values recently estimated by Alan Flint of the U.S. Geological Survey (personal communication, July 19, 1989). The thermomechanical properties in each layer were assumed to be homogeneous and isotropic throughout the layer.
- The problem domain was defined as two-dimensional and axisymmetric. The surface and the hydrogeologic layers were modelled as horizontal and parallel. The settling pond location selected for this analysis is downgrade from the ESF surface facility. Also, the effects of evapotranspiration were not included in the analysis. NORIA-SP was used to model the problem as a single phase flow problem.
- A steady-state infiltration of 0.01 mm/year was specified as the initial condition, from which NORIA-SP determined the steady-state saturation levels throughout the stratigraphy. These steady-state conditions served as the initial state (time zero) for the perturbed flow calculation.
- The computational domain used in NORIA-SP was two-dimensional and axisymmetric, with a height of 468.4 m, and centered about the pond. For unlined ponds, i.e., leaks corresponding to 100% of the pond surface, the radius of the computational grid was 600 m, whereas for leakages of 10 and 1 percent, the radius of the grid was 200 m. The water from the settling pond was uniformly distributed over the leakage surface area. The computational grids used for the 100%, 10%, and 1% leakage cases are shown in Figures 17, 18, and 19, respectively.
- Leaks were assumed to be discrete with negligible impedance to flow. As a result, it was decided to lump together all of the "cracks" into an aggregate leakage surface area, with the water pressure at the leaks equal to a pressure head of 3.05 m, the depth of the settling pond.
- The ground surface was the upper boundary, and the water table was the lower boundary for the computational domain. The surface area of the pond was equivalent to the surface area of the Title I design for settling

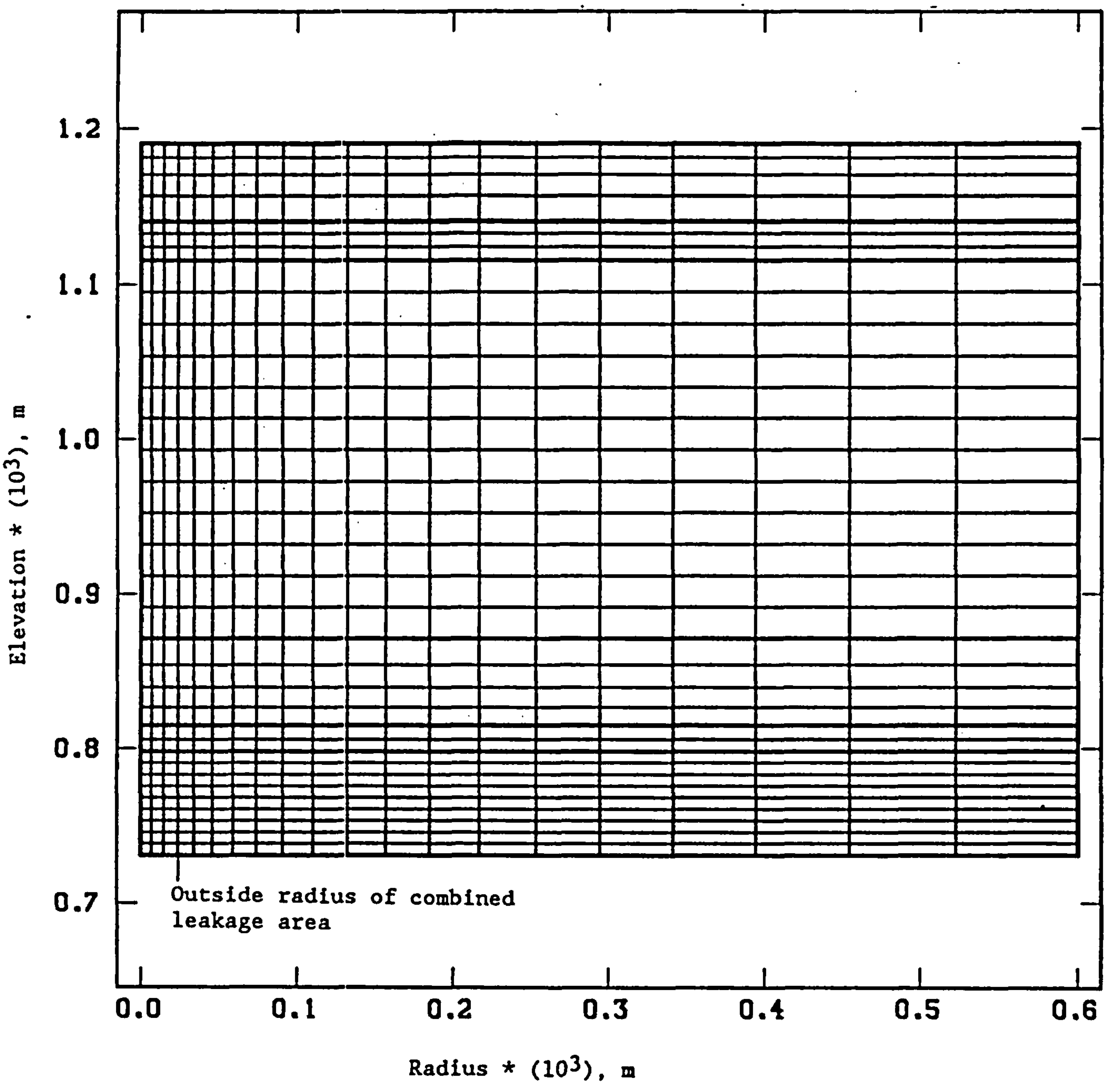

Figure 17: Two dimensional computational grid for Settling Pond Case #1, 100% leakage (no liner)

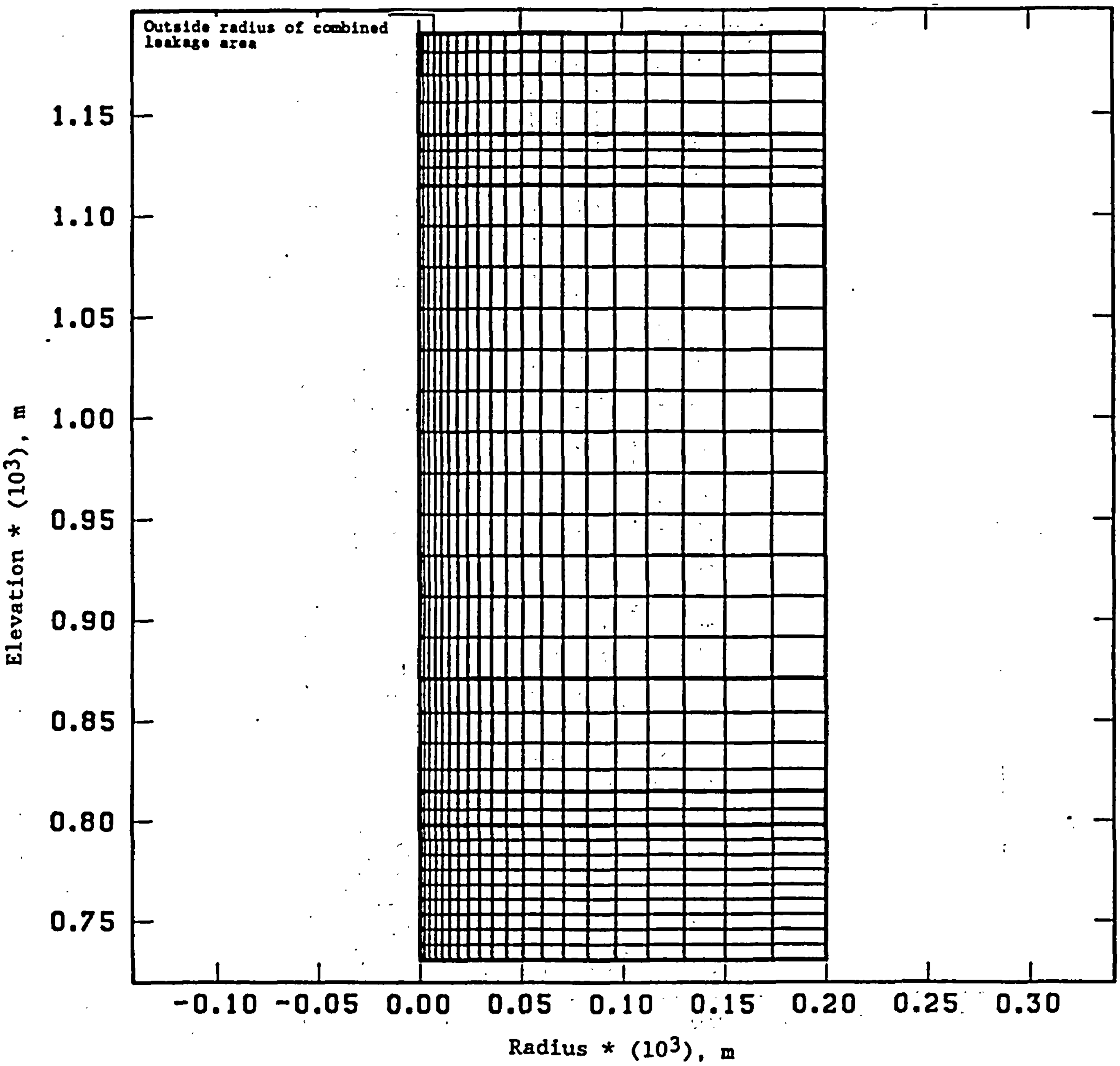

Figure 18: Two dimensional computational grid for Settling Pond Case #2, 10% leakage

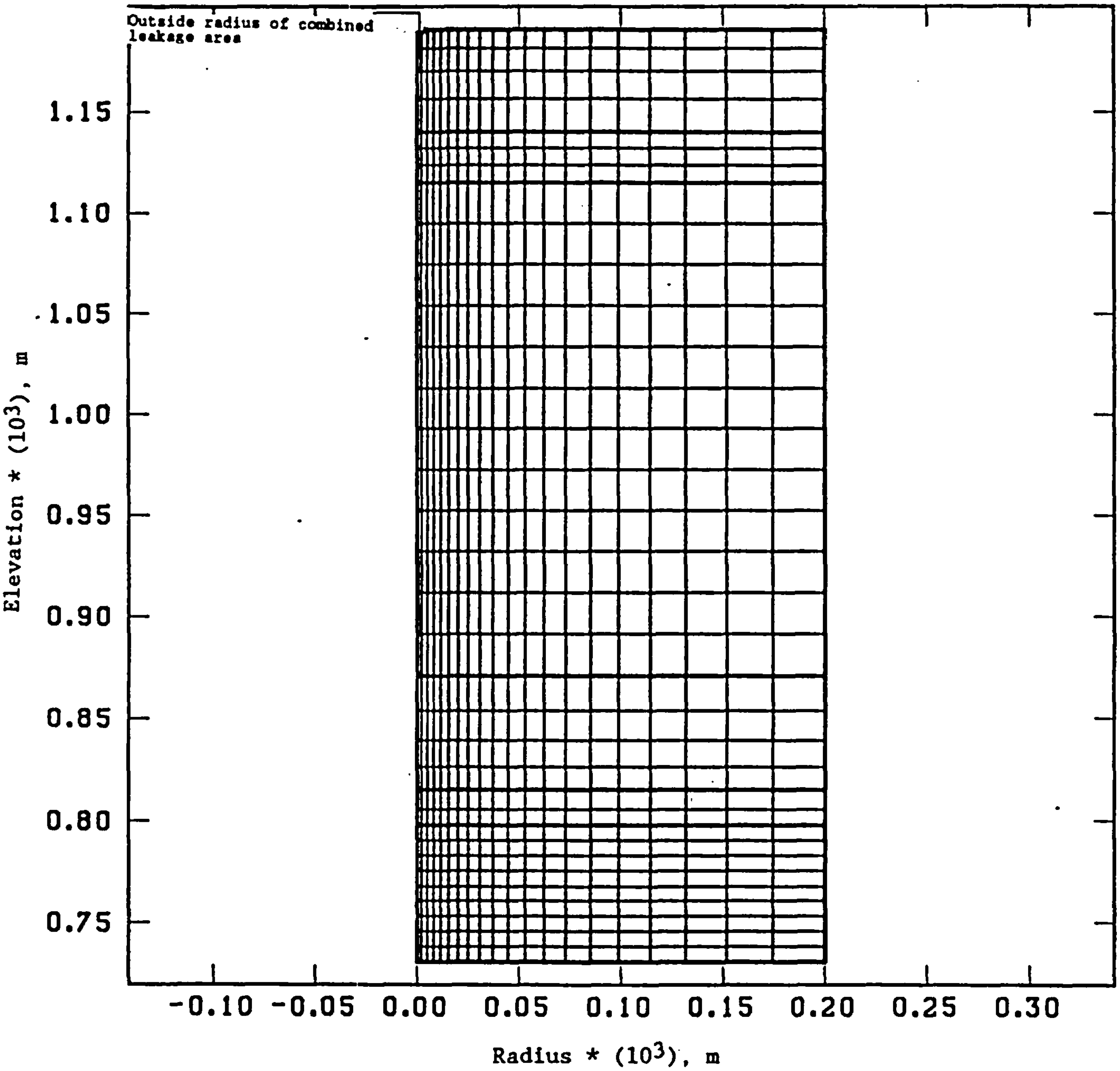

Figure 19: Two dimensional computational grid for Settling Pond Case #3, 1% leakage

ponds (1,810 m^2), and the depth of water in the pond was kept at a constant 3.05 m for five years. For the three cases of leakage rates, 100% (unlined), 10%, and 1%, the leakage surface area was 1810, 181, and 1.81 m^2, respectively. The upper boundary condition was a constant head of 3.05 m along the leakage surface area for five years and a constant 0.01 mm/year flux on the remaining surface. After five years, a constant 0.01 mm/year flux was imposed on the leakage surface area. One vertical boundary was the axis of symmetry. The other vertical boundary was located at 600 m radius from the axis of symmetry for the 100% leakage case, and at 200 m radius for the 10% and 1% cases. No flux boundary conditions were imposed on both vertical boundaries, and the lower boundary was set to a total pressure which corresponded to saturated conditions.

The instability problems encountered in the sewage pond calculations were also encountered in the settling pond calculations. The action taken was the same as for the sewage pond case: that is, to eliminate the alluvium layer from the calculational grid. No additional calculations were run for the settling pond problem with an alluvium layer; the results of the sewage pond calculations indicate that such additional calculations are unnecessary.

3.2.2 Results

The results of the settling pond analysis are presented in Figures 20-27, and they indicate that the water contained in the muck storage ponds does not affect experiments in the ESF or repository performance. Figure 20 shows the saturation profiles at various times along the pond axis for the unlined settling pond. Figures 21, 22, and 23 show contour plots of the change in saturation from in situ conditions at 5, 10, and 100 years after the beginning of ESF construction, respectively.[4] During the active life of the repository, muck storage water will disperse to an area four times the original pond area. The long term effects of the unlined settling pond were approximately the same as those for the sewage pond at the same location.

Some interesting results can be seen from the calculations used to study the effects of leakage. The disturbance zones for the 10% leakage case are reflected in Figures 24 and 25, by the magnitude and locus of changes in saturation at 5 and 10 years, respectively. It is observed that the disturbance zone for the 10% leakage case extends out to a larger area respective to the lumped leakage surface area, but also extends to a shallower depth, than for 100% leakage. The behavior is consistent with the 1% leakage case, as shown in Figures 26 and 27.

It can be concluded from these analyses that settling ponds with depths no greater than 3.05 m, located outside the repository boundary, and at or below the surface elevation above the repository, will have no effect on potential repository performance or on experiments conducted in the ESF. The one possible exception to this, not covered in this analysis, is the potential effect of muck storage water on an underground ramp running from an off-repository location to the repository horizon. These conclusions are

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[4] The vertical dashed line on the contour plots refers to the outer radius of the combined leakage area.

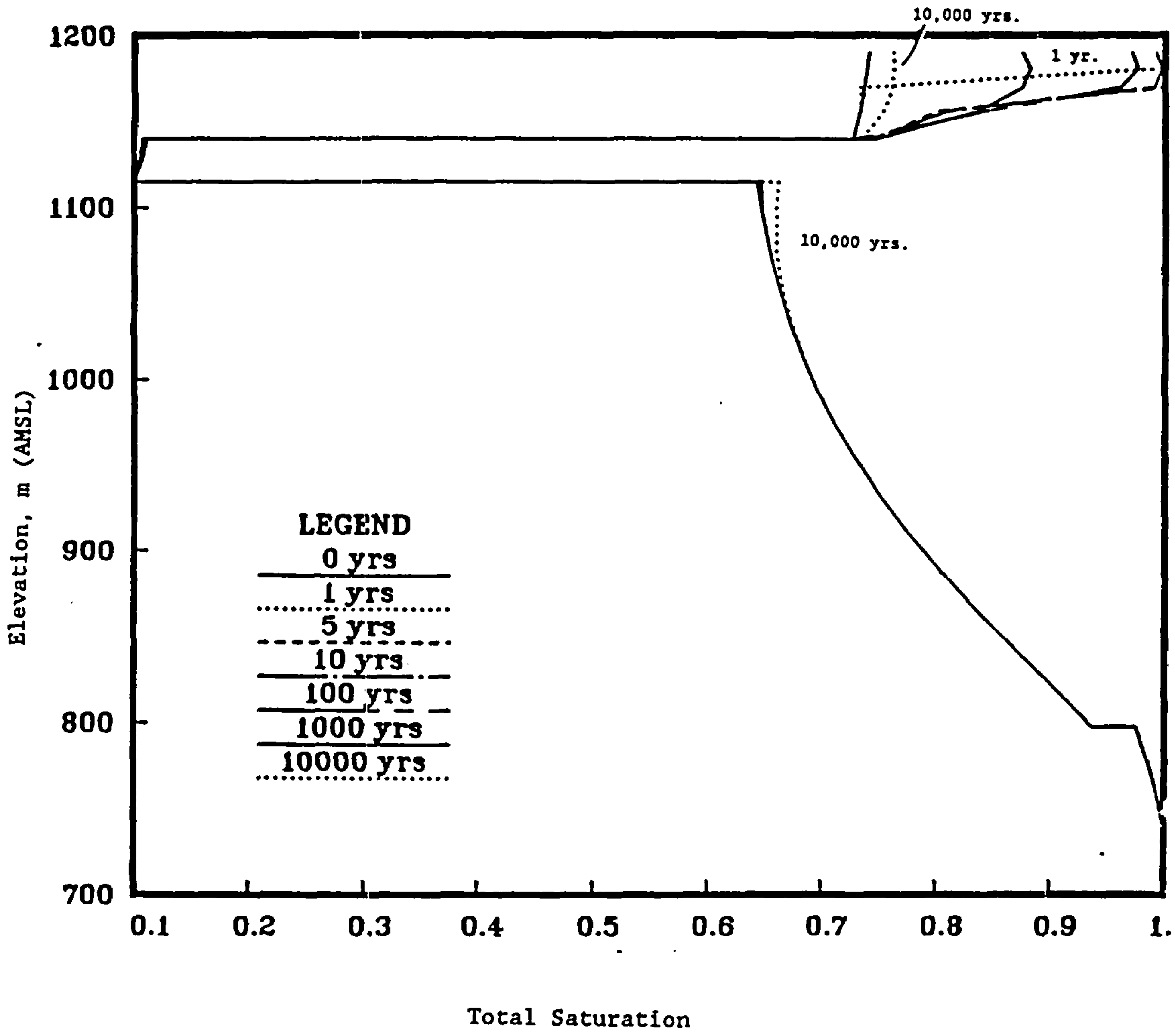

Figure 20: Saturation profiles for Settling Pond Case #1, 100% leakage

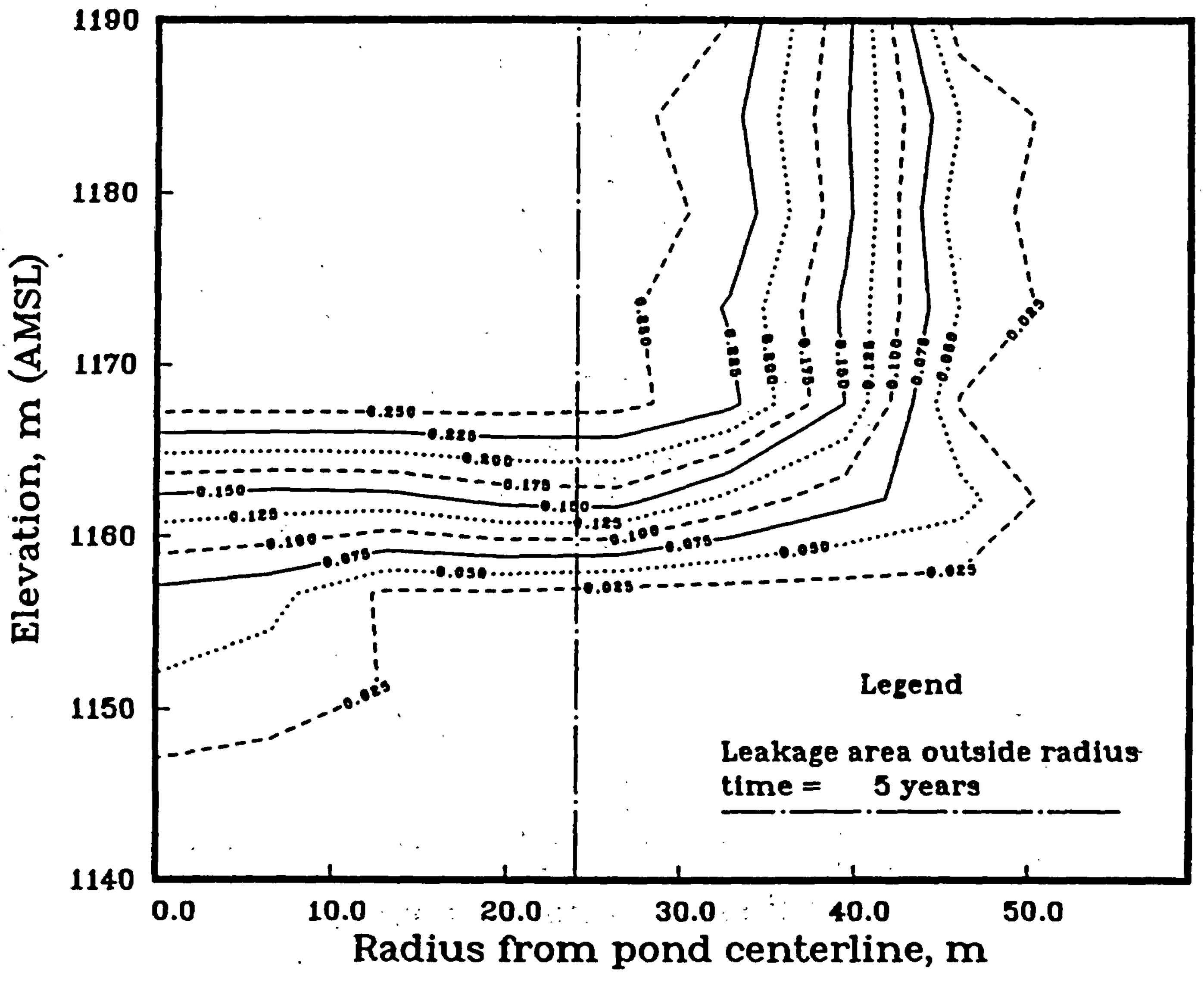

Figure 21: Contour plot for Settling Pond Case #1, 100% leakage: Change from in-situ saturation after 5 years

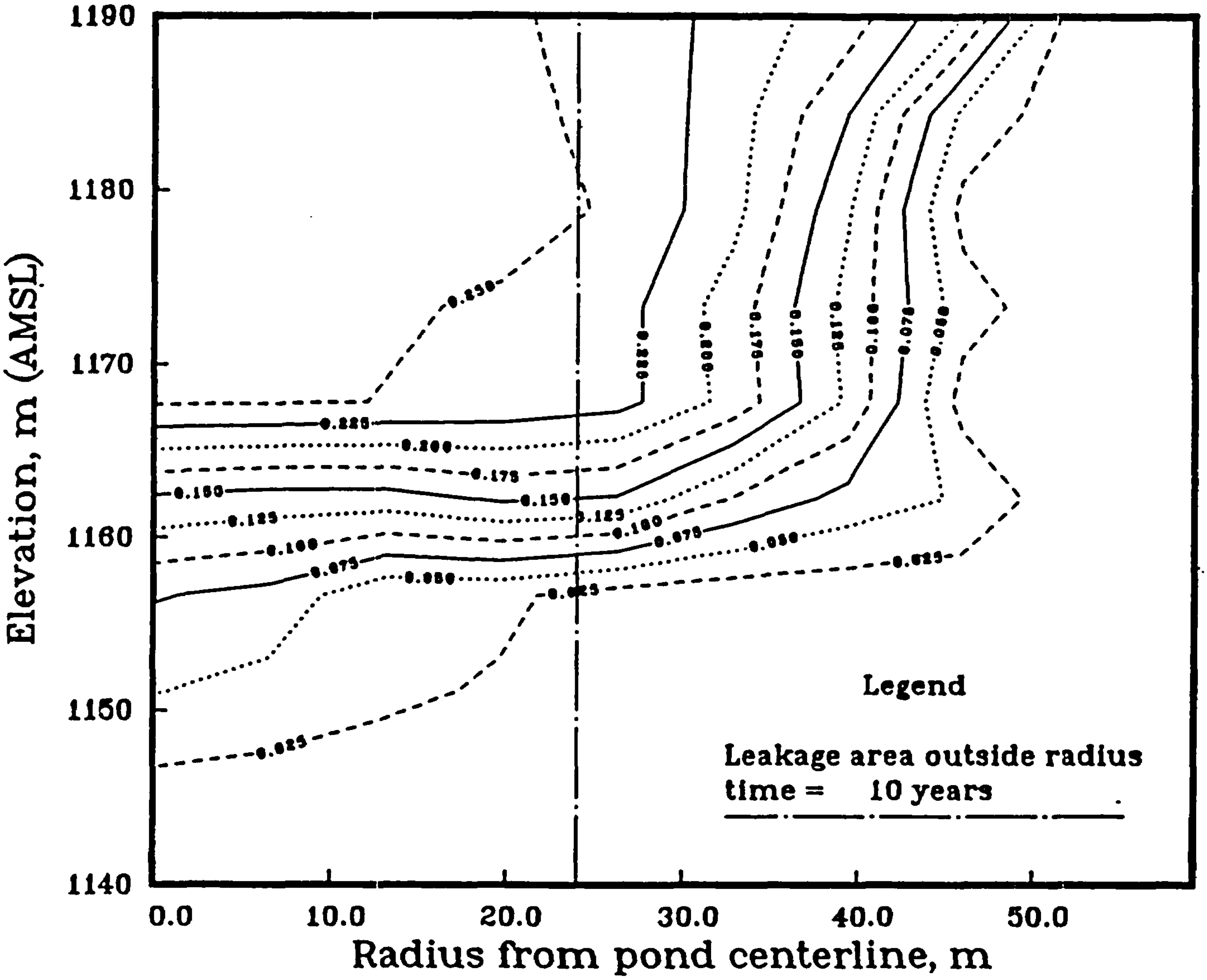

Figure 22: Contour plot for Settling Pond Case #1, 100% leakage:
Change from in-situ saturation after 10 years

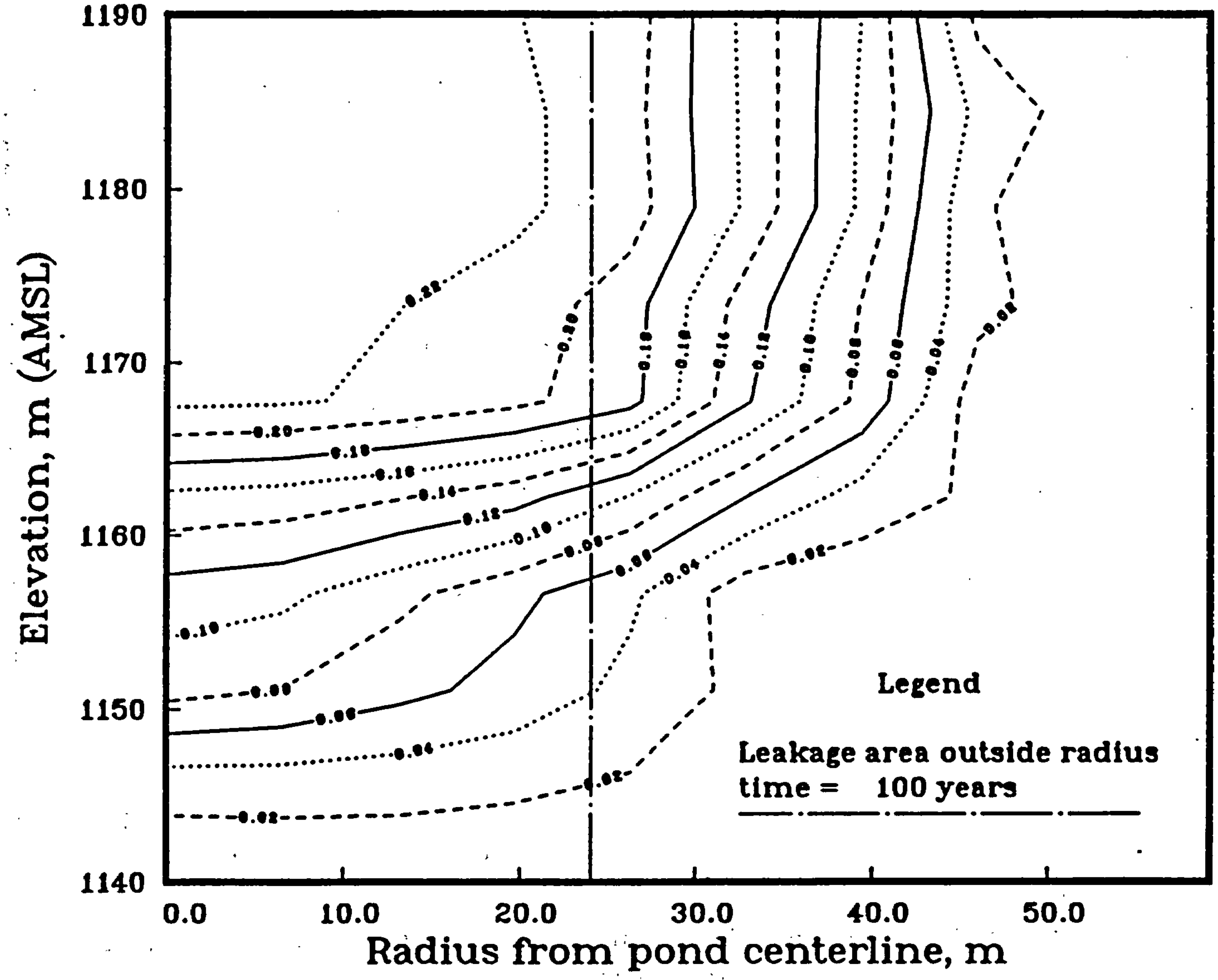

Figure 23: Contour plot for Settling Pond Case #1, 100% leakage: Change from in-situ saturation after 100 years

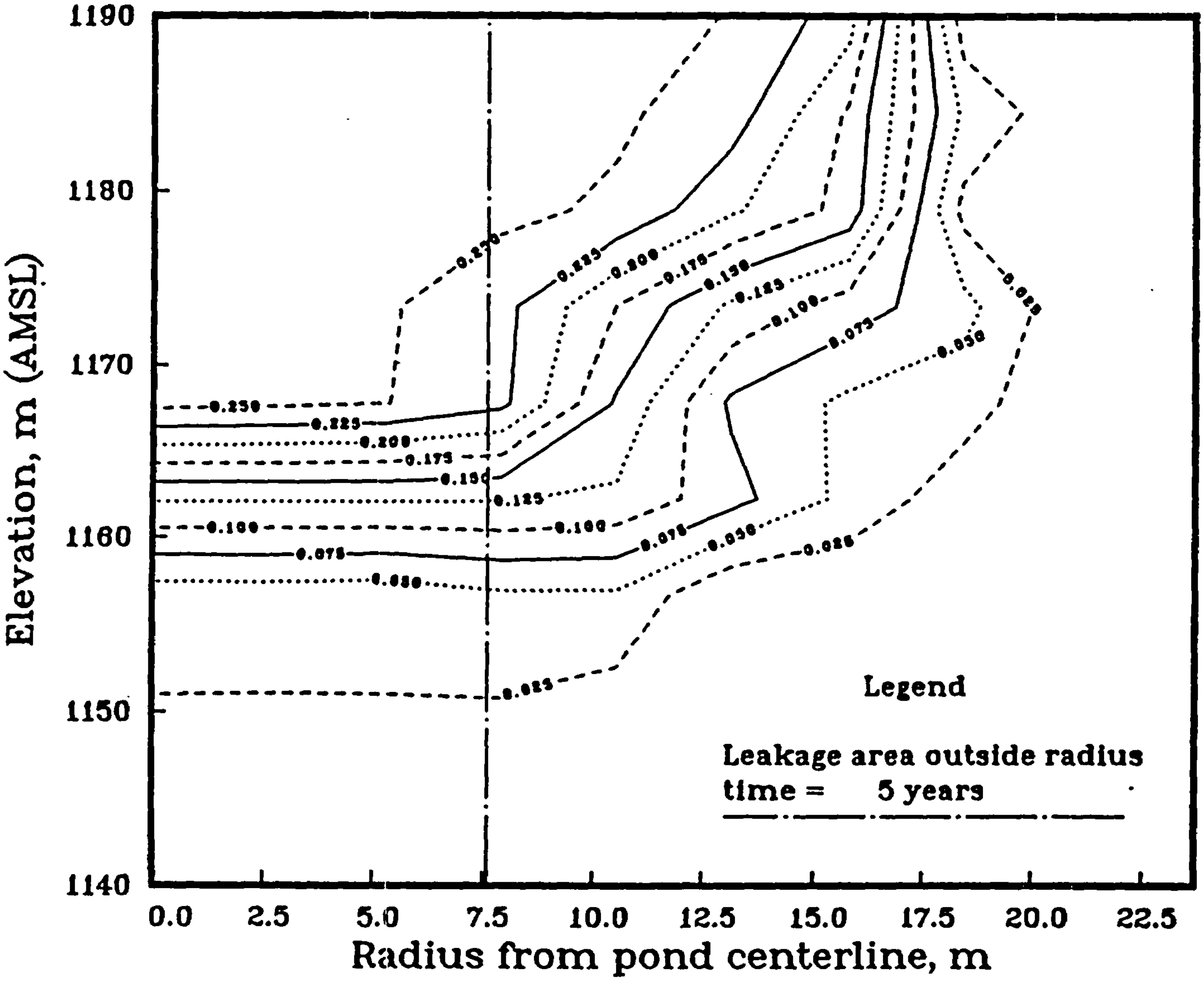

Figure 24: Contour plot for Settling Pond Case #2, 10% leakage:
Change from in-situ saturation after 5 years

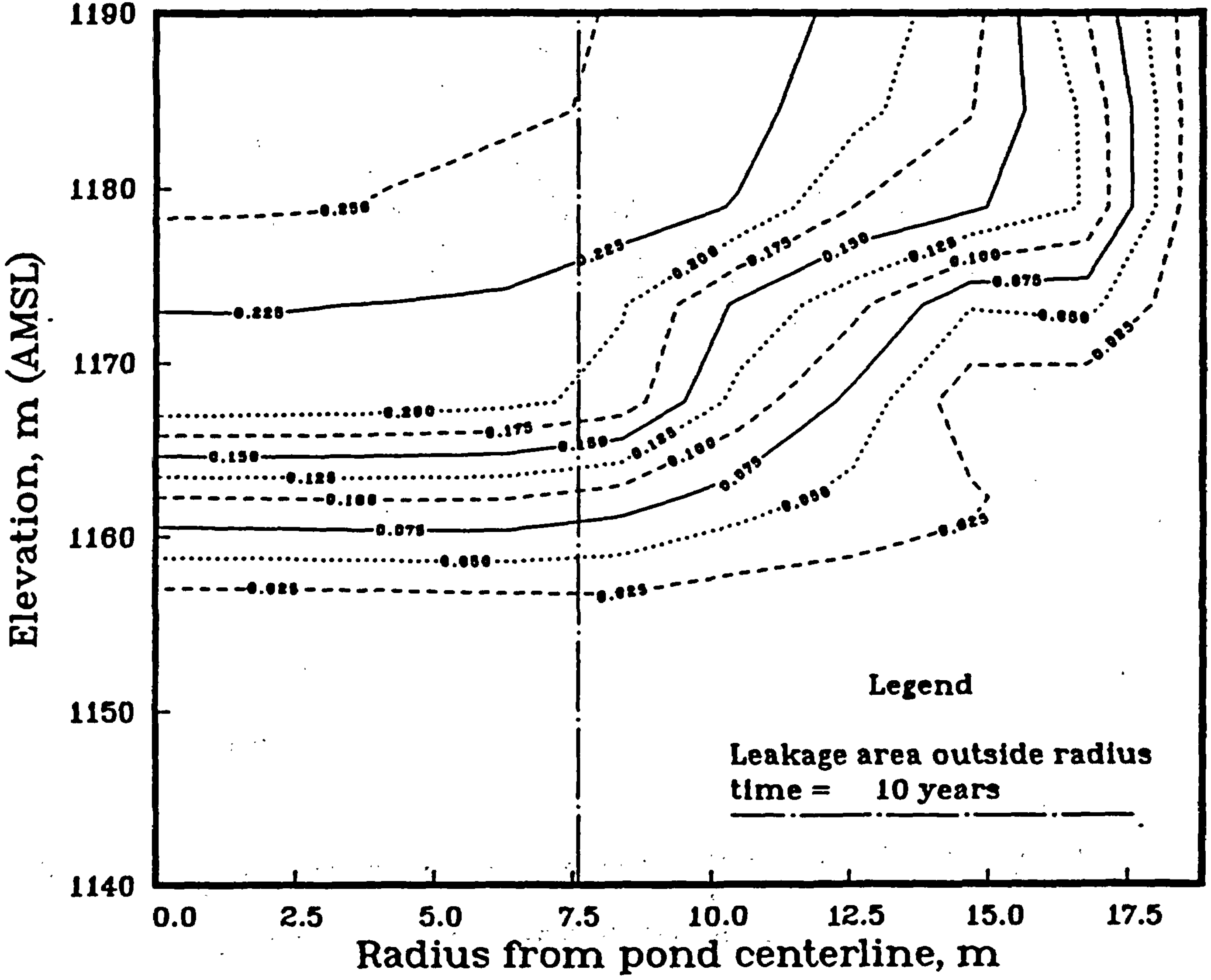

Figure 25: Contour plot for Settling Pond Case #2, 10% leakage: Change from in-situ saturation after 10 years

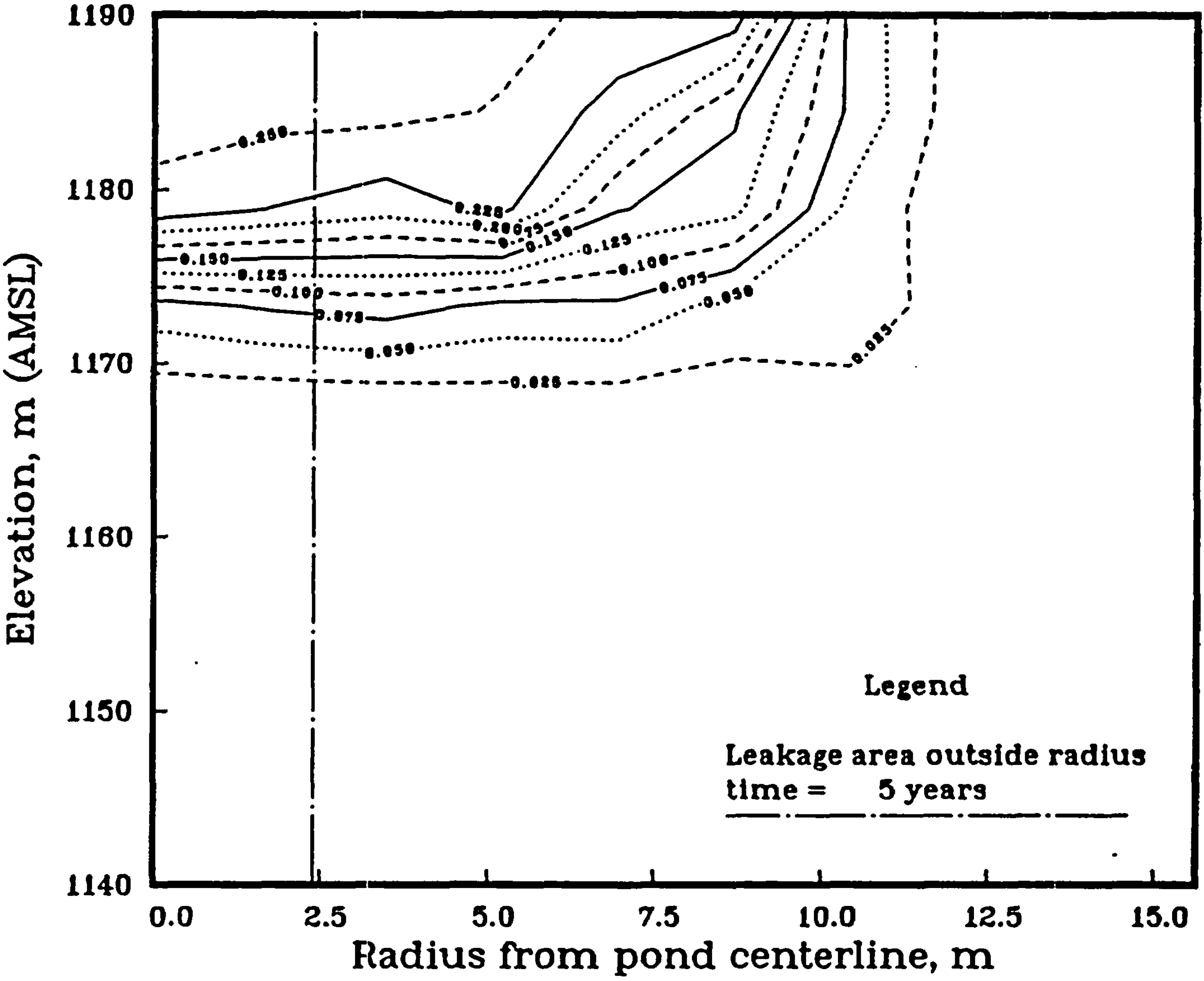

Figure 26: Contour plot for Settling Pond Case #3, 1% leakage: Change from in-situ saturation after 5 years

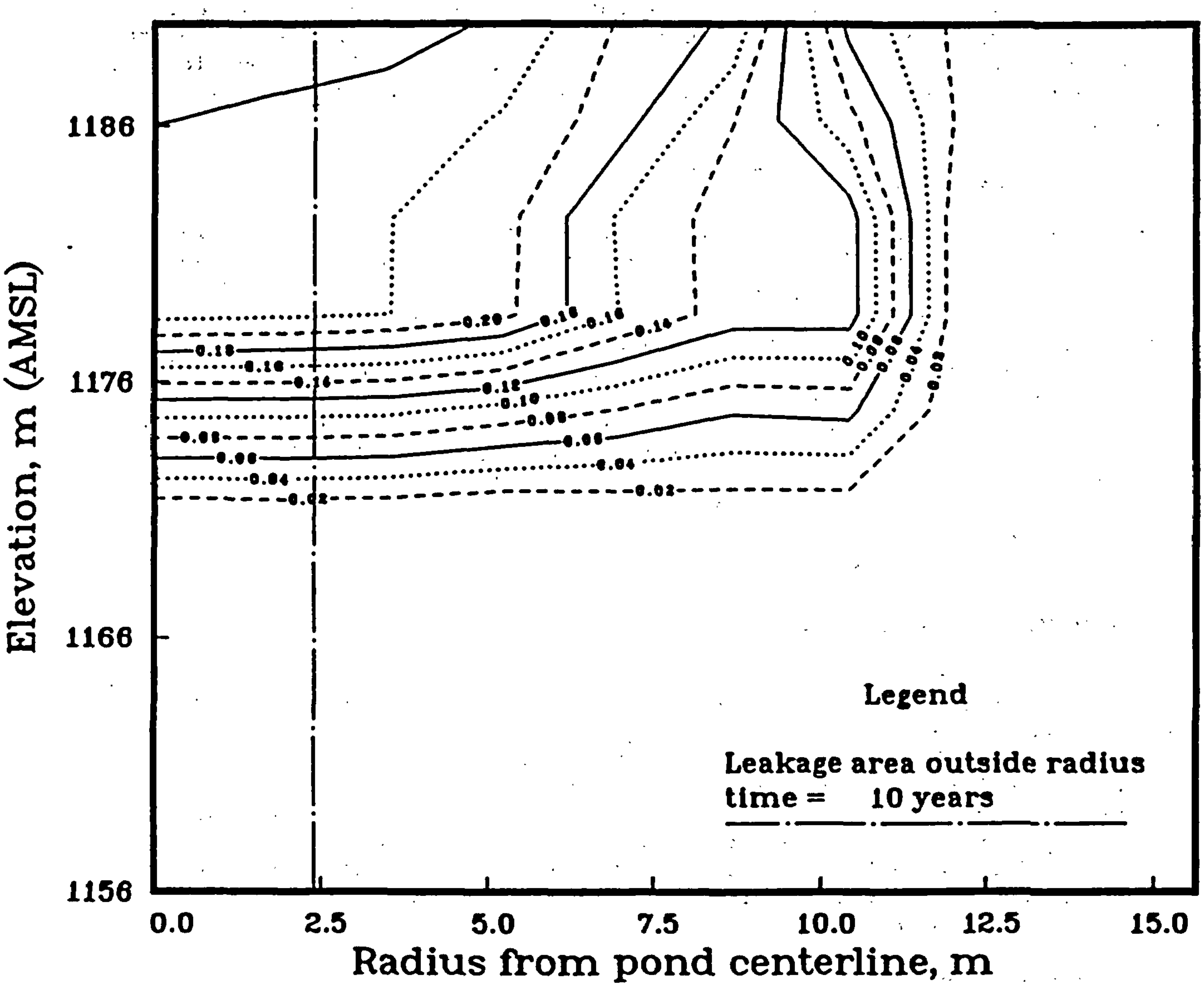

Figure 27: Contour plot for Settling Pond Case #3, 1% leakage: Change from in-situ saturation after 10 years

contingent on the current knowledge of hydrological conditions at Yucca Mountain, including water flow parameters such as surface and underground fracture flow.

4. LIMITATIONS AND ASSUMPTIONS

The validity of the results of this analysis depend on the assumptions underlying the conceptual model of flow. This section contains a list of the assumptions and a discussion of the potential errors in the calculations if these assumptions are incorrect. Omitted is the fundamental question of the applicability of Darcy's law and Richards' equation -- capillary-bundle theory in general -- to the modelling of unsaturated flow through relatively impermeable rock.

4.1 Material Properties Used for PTn

The results of the calculations are sensitive to the material properties used. Data reported from the RIB and data given by Weeks and Wilson (1984) suggest that the highly porous, highly conductive Paintbrush Tuff non-welded unit (PTn) is more saturated than the initial condition given for these calculations. (Greater initial saturation reduces the amount of space available to store the incoming surface water. Greater initial saturation also calls into question the choice of parameter values for the characteristic curve.) The material hydrologic properties used in the calculations for PTn come from a core sample taken at drill hole USW GU-3, not USW G-4. However, the properties for the USW GU-3 sample are near the average of values reported for USW G-4 samples [Peters et al., 1984]. A different porosity value or a different characteristic curve for PTn could significantly change the amount of water which perturbs the saturation at the repository horizon and the GWTT.

4.2 Homogeneity of Geologic Units

Geologic units, e.g., the Tiva Canyon welded tuffs, are modelled with a single matrix material and a single fracture material. It is known that hydrologic properties from samples within a geologic unit can vary greatly [Peters et al., 1984]. It is unknown what effect this variation would have on flow. For these particular analyses, variations in hydrologic properties in highly conductive and porous regions, such as the surficial alluvium and PTn, may have large effects on the vertical and horizontal dispersion of water. If highly conductive regions are vertically connected, GWTT could be shortened. If highly conductive regions are horizontally connected, lateral dispersion of flow could be enhanced.

4.3 Composite-porosity Model

The composite-porosity model treats the matrix and the fractures as an equivalent porous medium. The pressure head in the matrix and the fractures at any given location are assumed equal.

Different flow models have been proposed for Yucca Mountain. For example, the weeps-and-seeps model holds that flow is primarily in limited regions down connected fracture networks. Water to sustain these weeps and seeps comes from diversion of large areas of surface water into these limited regions. Water in a weep travels at much higher velocity than water in an equivalent porous medium. If the weeps-and-seeps model is applicable to flow at Yucca Mountain, the result would be that a great deal of the surface water could flow directly to the water table within a few years. Such short travel times imply that surface water associated with muck storage ponds and sewage ponds would not affect the repository: first, the matrix would have little time to saturate, and second, the water would be gone before the repository would be sealed. As these weeps may be visible within the ESF, it could be of benefit to add a tracer to the waste waters to identify the source of weep flow.

4.4 Fracture Apertures

Fracture apertures used in these calculations were taken from laboratory measurements on core samples [Peters et al., 1984]. Actual fractures within Yucca Mountain could have much different apertures. Smaller apertures would tend to favor more flow through the matrix, decreasing GWTT, but increasing saturations. Larger apertures may have the opposite effect. Larger apertures could also favor a mechanism of flow different from that modelled by the composite-porosity model. Presence of extremely large apertures (fault zones) could increase the chance of a weeps-and-seeps mechanism that would short-circuit flow directly to the water table.

5. CONCLUSIONS

The results of these analyses indicate that neither a sewage pond with a volume of 17,100 m3 and a depth of 1.83 m, nor a settling pond with a volume of 5520 m3 and a depth of 3.05 m, located outside the repository boundary, and at or below the surface elevation above the repository, will have any effect on the potential repository performance or on experiments conducted in the ESF. These results are based on the Title I design specifications for the ESF and the underlying assumptions of this analysis. The dispersion of the pond water will be limited to the alluvium and Tiva Canyon layers during the active life of the potential repository (the first 100 years).

Additional analyses may be required to answer questions concerning specific aspects of the ESF Title II Design to ensure compliance of the design with the federal regulations listed in 10 CFR 60. The following are suggested additional analyses for determining sewage and settling pond locations.

- Use the results from these calculations to determine the possible effects on an underground ramp located near or below a waste water pond. The effects on experiments in the ramp should be considered, as well as the possibility of the ramp acting as a preferential pathway for fluid flow that could affect potential repository performance.

- Investigate the sensitivity of the analysis to variations in fracture characteristics in TCw, and to variations in porosity in PTn.

- Perform the previous calculations with non-homogeneous, non-isotropic hydrological parameters.

- Perform a new calculation that includes the effects of downdip (this would require a three-dimensional analysis). This can be used to determine the effects of locating a sewage or settling pond above the repository.

- Perform additional analyses to consider the effects of evapotranspiration from the area surrounding the ponds.

6. REFERENCES

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Appendix A

Parameters Used for the Analyses

Water Properties

Description of variable, units	Value	Reference
Density of water, kg/m^3	1000	Standard
Compressibility of water, 1/m	4.30E-06	Standard
Dyn. Viscosity of water, kg/(m*sec)	0.001	Standard @ 68°F
Acceleration of gravity, m/sec^2	9.8	Standard
Steady-st. infil. rate (q), mm/yr	0.01	Given: Boundary condition
m/sec	3.17E-13	on surface

UE-25 a#1 Stratigraphy and Rock Characteristics

Description of variable, units	Value	Reference
Material # 1 - CHnz, Calico Hills (water table is bottom boundary)		
Min. elevation, m	730.6	RIB, Version 2.002 (water table)
Max. elevation, m	798	RIB, Version 2.002
Matrix effective porosity, none	0.28	CHnz/G4-11 SAND84-1471[a]
Matrix sat. hyd. conductivity, m/s	2.00E-11	CHnz/G4-11 SAND84-1471
Matrix van Genuchten parameters		
Saturation value, none	1	CHnz/G4-11 SAND84-1471
Residual saturation, none	0.11	CHnz/G4-11 SAND84-1471
ALPHA coefficient, 1/m	0.00308	CHnz/G4-11 SAND84-1471
BETA coefficient, none	1.602	CHnz/G4-11 SAND84-1471
Fracture effective porosity, none	1	CHnz/G4-4F SAND84-1471
Fract. sat. hyd. conductivity, m/s	2.00E-04	CHnz/G4-4F SAND84-1471
Fracture van Genuchten parameters		
Saturation value, none	1	CHnz/G4-4F SAND84-1471
Residual saturation, none	0.0395	CHnz/G4-4F SAND84-1471
ALPHA coefficient, 1/m	1.2851	CHnz/G4-4F SAND84-1471
BETA coefficient, none	4.23	CHnz/G4-4F SAND84-1471
Fracture porosity, none	4.60E-05	SAND84-1471
Bulk-rock compressibility, 1/m	2.60E-06	SAND84-1471
Fracture compressibility, 1/m	2.80E-08	SAND84-1471
Material # 2 - TSw3, Topopah Springs		
Min. elevation, m	798	RIB, Version 2.002
Max. elevation, m	815	RIB, Version 2.002
Matrix effective porosity, none	0.11	TSw2/G4-6 SAND84-1471
Matrix sat. hyd. conductivity, m/s	1.90E-11	TSw2/G4-6 SAND84-1471
Matrix van Genuchten parameters		
Saturation value, none	1	TSw2/G4-6 SAND84-1471
Residual saturation, none	0.08	TSw2/G4-6 SAND84-1471
ALPHA coefficient, 1/m	0.00567	TSw2/G4-6 SAND84-1471
BETA coefficient, none	1.798	TSw2/G4-6 SAND84-1471
Fracture effective porosity, none	1	TSw2/G4-2F SAND84-1471
Fract. sat. hyd. conductivity, m/s	1.75E-05	TSw2/G4-2F SAND84-1471
Fracture van Genuchten parameters		
Saturation value, none	1	TSw2/G4-2F SAND84-1471
Residual saturation, none	0.0395	TSw2/G4-2F SAND84-1471
ALPHA coefficient, 1/m	1.2851	TSw2/G4-2F SAND84-1471
BETA coefficient, none	4.23	TSw2/G4-2F SAND84-1471
Fracture porosity, none	1.80E-04	TSw2/G4-2F SAND84-1471
Bulk-rock compressibility, 1/m	5.80E-07	TSw2/G4-2F SAND84-1471
Fracture compressibility, 1/m	1.20E-07	TSw2/G4-2F SAND84-1471

UE-25 a#1 Stratigraphy and Rock Characteristics

Description of variable, units	Value	Reference
Material # 3 - TSw2, Topopah Springs (repository horizon)		
Min. elevation, m	815	RIB, Version 2.002
Max. elevation, m	871	RIB, Version 2.002
Matrix effective porosity, none	0.11	TSw2/G4-6 SAND84-1471
Matrix sat. hyd. conductivity, m/s	1.90E-11	TSw2/G4-6 SAND84-1471
Matrix van Genuchten parameters		
Saturation value, none	1	TSw2/G4-6 SAND84-1471
Residual saturation, none	0.08	TSw2/G4-6 SAND84-1471
ALPHA coefficient, 1/m	0.00567	TSw2/G4-6 SAND84-1471
BETA coefficient, none	1.798	TSw2/G4-6 SAND84-1471
Fracture effective porosity, none	1	TSw2/G4-2F SAND84-1471
Fract. sat. hyd. conductivity, m/s	1.75E-05	TSw2/G4-2F SAND84-1471
Fracture van Genuchten parameters		
Saturation value, none	1	TSw2/G4-2F SAND84-1471
Residual saturation, none	0.0395	TSw2/G4-2F SAND84-1471
ALPHA coefficient, 1/m	1.2851	TSw2/G4-2F SAND84-1471
BETA coefficient, none	4.23	TSw2/G4-2F SAND84-1471
Fracture porosity, none	1.80E-04	SAND84-1471
Bulk-rock compressibility, 1/m	5.80E-07	SAND84-1471
Fracture compressibility, 1/m	1.20E-07	SAND84-1471
Material # 4 - TSw1, Topopah Springs		
Min. elevation, m	871	RIB, Version 2.002
Max. elevation, m	1115	RIB, Version 2.002
Matrix effective porosity, none	0.11	TSw1/G4-6 SAND84-1471
Matrix sat. hyd. conductivity, m/s	1.90E-11	TSw1/G4-6 SAND84-1471
Matrix van Genuchten parameters		
Saturation value, none	1	TSw1/G4-6 SAND84-1471
Residual saturation, none	0.08	TSw1/G4-6 SAND84-1471
ALPHA coefficient, 1/m	0.00567	TSw1/G4-6 SAND84-1471
BETA coefficient, none	1.798	TSw1/G4-6 SAND84-1471
Fracture effective porosity, none	1	TSw1/G4-2F SAND84-1471
Fract. sat. hyd. conductivity, m/s	2.20E-05	TSw1/G4-2F SAND84-1471
Fracture van Genuchten parameters		
Saturation value, none	1	TSw1/G4-2F SAND84-1471
Residual saturation, none	0.0395	TSw1/G4-2F SAND84-1471
ALPHA coefficient, 1/m	1.2851	TSw1/G4-2F SAND84-1471
BETA coefficient, none	4.23	TSw1/G4-2F SAND84-1471
Fracture porosity, none	4.10E-05	SAND84-1471
Bulk-rock compressibility, 1/m	1.20E-06	SAND84-1471
Fracture compressibility, 1/m	5.60E-08	SAND84-1471

UE-25 a#1 Stratigraphy and Rock Characteristics

Description of variable, units	Value	Reference
Material # 5 - PTn, Paintbrush Tuff		
Min. elevation, m	1115	RIB, Version 2.002
Max. elevation, m	1140	RIB, Version 2.002
Matrix effective porosity, none	0.4	PTn/GU3-7 SAND84-1471
Matrix sat. hyd. conductivity, m/s	3.90E-07	PTn/GU3-7 SAND84-1471
Matrix van Genuchten parameters		
Saturation value, none	1	PTn/GU3-7 SAND84-1471
Residual saturation, none	0.1	PTn/GU3-7 SAND84-1471
ALPHA coefficient, 1/m	0.015	PTn/GU3-7 SAND84-1471
BETA coefficient, none	6.872	PTn/GU3-7 SAND84-1471
Fracture effective porosity, none	1	PTn/G4-3F SAND84-1471
Fract. sat. hyd. conductivity, m/s	6.10E-04	PTn/G4-3F SAND84-1471
Fracture van Genuchten parameters		
Saturation value, none	1	PTn/G4-3F SAND84-1471
Residual saturation, none	0.0395	PTn/G4-3F SAND84-1471
ALPHA coefficient, 1/m	1.2851	PTn/G4-3F SAND84-1471
BETA coefficient, none	4.23	PTn/G4-3F SAND84-1471
Fracture porosity, none	2.70E-05	SAND84-1471
Bulk-rock compressibility, 1/m	8.20E-06	SAND84-1471
Fracture compressibility, 1/m	1.90E-07	SAND84-1471
Material # 6 - TCw, Tiva Canyon		
Min. elevation, m	1140	RIB, Version 2.002
Max. elevation, m	1190	RIB, Version 2.002
Matrix effective porosity, none	0.08	TCw/G4-1 SAND84-1471
Matrix sat. hyd. conductivity, m/s	9.70E-12	TCw/G4-1 SAND84-1471
Matrix van Genuchten parameters		
Saturation value, none	1	TCw/G4-1 SAND84-1471
Residual saturation, none	0.002	TCw/G4-1 SAND84-1471
ALPHA coefficient, 1/m	0.00821	TCw/G4-1 SAND84-1471
BETA coefficient, none	1.558	TCw/G4-1 SAND84-1471
Fracture effective porosity, none	1	TCw/G4-2F SAND84-1471
Fract. sat. hyd. conductivity, m/s	3.80E-05	TCw/G4-2F SAND84-1471
Fracture van Genuchten parameters		
Saturation value, none	1	TCw/G4-2F SAND84-1471
Residual saturation, none	0.0395	TCw/G4-2F SAND84-1471
ALPHA coefficient, 1/m	1.2851	TCw/G4-2F SAND84-1471
BETA coefficient, none	4.23	TCw/G4-2F SAND84-1471
Fracture porosity, none	1.40E-04	SAND84-1471
Bulk-rock compressibility, 1/m	6.20E-07	SAND84-1471
Fracture compressibility, 1/m	1.32E-06	SAND84-1471

UE-25 a#1 Stratigraphy and Rock Characteristics

Description of variable, units	Value	Reference
Material # 7 - UO (Alluvium) (Top elevation is ground surface)		
Min. elevation, m	1190	RIB, Version 2.002
Max. elevation, m	1199	RIB, Version 2.002
Matrix effective porosity, none	0.32	Alluvium[b]
Matrix sat. hyd. conductivity, m/s	5.00E-07	Alluvium[b]
Matrix van Genuchten parameters		
Saturation value, none	1	Alluvium[c]
Residual saturation, none	0.3	Alluvium[c]
ALPHA coefficient, 1/m	0.423	Alluvium[c]
BETA coefficient, none	2.06	Alluvium[c]
Fracture porosity, none	0	
Bulk-rock compressibility, 1/m	0	
Fracture compressibility, 1/m	0	

a - Hydrogeologic parameters are selected from SAND84-1471 because values currently in the RIB are incomplete, and to maintain consistency with other analyses -- see Section 3.1.1 for further discussion.

b - Communication from Alan Flint, U. S. Geological Survey

c - van Genuchten, M., "A Closed-Form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils," Soil Sci. Soc. Am. J., Vol. 44, pp. 892-898, 1980.

UE-25 WT#14 Stratigraphy and Rock Characteristics

Description of variable, units	Value	Reference
Material # 1 - TSw2, Topopah Springs		
Min. elevation, m	730.6	USGS-OFR-86-46[d] (water table)
Max. elevation, m	1076.5	USGS-OFR-86-46 (surface)
Matrix effective porosity, none	0.11	TSw2/G4-6 SAND84-1471
Matrix sat. hyd. conductivity, m/s	1.90E-11	TSw2/G4-6 SAND84-1471
Matrix van Genuchten parameters		
Saturation value, none	1	TSw2/G4-6 SAND84-1471
Residual saturation, none	0.08	TSw2/G4-6 SAND84-1471
ALPHA coefficient, 1/m	0.00567	TSw2/G4-6 SAND84-1471
BETA coefficient, none	1.798	TSw2/G4-6 SAND84-1471
Fracture effective porosity, none	1	TSw2/G4-2F SAND84-1471
Fract. sat. hyd. conductivity, m/s	1.75E-05	TSw2/G4-2F SAND84-1471
Fracture van Genuchten parameters		
Saturation value, none	1	TSw2/G4-2F SAND84-1471
Residual saturation, none	0.0395	TSw2/G4-2F SAND84-1471
ALPHA coefficient, 1/m	1.2851	TSw2/G4-2F SAND84-1471
BETA coefficient, none	4.23	TSw2/G4-2F SAND84-1471
Fracture porosity, none	1.80E-04	SAND84-1471
Bulk-rock compressibility, 1/m	5.80E-07	SAND84-1471
Fracture compressibility, 1/m	1.20E-07	SAND84-1471

d - RIB does not contain this stratigraphy, and no other stratigraphies near this potential waste water pond location.

APPENDIX B

Reference Information Base and Site Engineering Properties Data Base

This report uses information from the Reference Information Base; see Appendix A for a listing of the values used.

This report contains no candidate information for inclusion in the Reference Information Base.

This report contains no candidate information for inclusion in the Site and Engineering Properties Data Base.

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