



U.S. NUCLEAR REGULATORY COMMISSION
STANDARD REVIEW PLAN
OFFICE OF NUCLEAR REACTOR REGULATION

2.4.13 ACCIDENTAL RELEASES OF LIQUID EFFLUENTS IN GROUND AND SURFACE WATERS

REVIEW RESPONSIBILITIES

Primary - Hydrologic and Geotechnical Engineering Branch (HGEB) Civil Engineering and Geosciences Branch (ECGB)¹

Secondary - None Plant Systems Branch (SPLB)
Emergency Preparedness and Radiation Protection Branch (PERB)²

I. AREAS OF REVIEW

The ability of the ground and surface water environment to delay, disperse, dilute, or concentrate accidental radioactive liquid effluent releases is reviewed with emphasis on relating the effects of such releases to existing and known future uses of ground and surface water resources. (Note that effects of normal releases and of the more likely accidents are discussed in the applicant's environmental report.)

Review Interfaces

The ECGB coordinates SPLB and PERB evaluations that interface with the overall evaluation of accidental releases of liquid effluents in ground and surface waters, as follows:³

- a. The ECGB consults SPLB and PERB when choosing accident scenarios leading to the most adverse contamination of ground or surface water via groundwater pathways.
- b. Dilutions and travel times resulting from the analysis of contamination are checked by PERB to determine acceptability.

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USNRC STANDARD REVIEW PLAN

Standard review plans are prepared for the guidance of the Office of Nuclear Reactor Regulation staff responsible for the review of applications to construct and operate nuclear power plants. These documents are made available to the public as part of the Commission's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Standard review plans are not substitutes for regulatory guides or the Commission's regulations and compliance with them is not required. The standard review plan sections are keyed to the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. Not all sections of the Standard Format have a corresponding review plan.

Published standard review plans will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C. 20555.

- c. Initial concentrations of radionuclides in the body of water under consideration are provided by PERB for the most critical event, and the acceptability of resulting concentrations of radioactive effluent at specified points of interest are determined by ECGB in consultation with PERB.⁴

II. ACCEPTANCE CRITERIA

Acceptance criteria for this Standard Review Plan (SRP)⁵ section relate to 10 CFR Part 100 as it requires that hydrologic characteristics of the site be evaluated with respect to the consequences of the escape of radioactive material from the facility.

To meet the requirements of 10 CFR Part 100 with respect to accidental releases of liquid effluents, the following specific criteria are used:

1. Radionuclide transport characteristics of the groundwater environment with respect to existing and future users must be described. Estimates and bases for coefficients of dispersion, adsorption, groundwater velocities, travel times, gradients, permeabilities, porosities, and groundwater or piezometric levels between the site and existing or known future surface and groundwater users must be described and be consistent with site characteristics. Potential pathways of contamination to groundwater users must also be identified. Sources of data must be described and referenced.
2. Transport characteristics of the surface water environment with respect to existing and known future users must be described for conditions which reflect worst-case release mechanisms and source terms so as to postulate the most pessimistic contamination from accidentally released liquid effluents. Estimates of physical parameters necessary to calculate the transport of liquid effluent from the points of release to the site of existing or known future users must be described. Potential pathways of contamination to surface water users must be identified. Sources of information and data must be described and referenced. Acceptance is based on the staff's evaluation of the applicant's computational methods and the apparent completeness of the set of parameters necessary to perform the analysis.
3. Mathematical models are acceptable to analyze the flow field and dispersion of contaminants in ground and surface waters, providing that the models have been verified by field data and that conservative site-specific hydrologic parameters are used. Furthermore, conservatism must be the guide in selecting the proper model to represent a specific physical situation. Radioactive decay and sediment adsorption may be considered, if applicable, providing that the adsorption factors are conservative and site specific. Regulatory Guide 1.113 provides guidance in selecting and using surface water models.

Technical Rationale

The technical rationale for application of these acceptance criteria to reviewing accidental releases of liquid effluents in ground and surface waters is discussed in the following paragraphs:⁶

Compliance with 10 CFR Part 100 requires that local geological and hydrological characteristics be considered when determining the acceptability of a nuclear power plant site. The geological and hydrological characteristics of the site may have a bearing on the potential consequences of radioactive materials escaping from the facility. Special precautions should be planned if a reactor will be located at a site where a significant quantity of radioactive effluent could accidentally flow into nearby streams or rivers or find ready access to underground water tables.

These criteria apply to SRP Section 2.4.13 because the reviewer evaluates site hydrologic characteristics with respect to the potential consequences of radioactive materials escaping from the facility. Radionuclide transport characteristics of ground and surface water environments are reviewed with respect to accidental releases in order to ensure that current and future users of ground and surface water are not adversely affected by an accidental release from the facility. Regulatory Guide 1.113 provides guidance in selecting and using surface water models for analyzing the flow field and dispersion of contaminants in surface waters.

Meeting the requirements of 10 CFR Part 100 provides assurance that accidental releases of liquid effluents to ground and surface waters, and their adverse impact on public health and safety, will be minimized.⁷

III. REVIEW PROCEDURES

Section 2.4.13 of the applicant's safety analysis report (SAR)⁸ is reviewed to identify any missing data, information, or analysis necessary for the staff's evaluation. Applicant responses to the requested information will be evaluated using the methods outlined below, and staff positions will be developed. Resolution, if possible, of differences between the staff's and the applicant's estimation of liquid effluent dispersion will be coordinated through the LPMNRR Project Manager;⁹ and the safety evaluation report (SER)¹⁰ will be written accordingly.

The staff will make independent calculations of the transport capabilities and potential contamination pathways of the groundwater environment under accidental conditions with respect to existing and future users. Special attention should be directed to proposed facilities with permanent dewatering systems to assure¹¹ that pathways created by those systems have been identified. The staff will, in consultation with the Effluent Treatment Systems Branch (ETSB)PERB and SPLB,¹² choose the accident scenarios leading to the most adverse contamination of the groundwater or the surface water via the groundwater pathways. Analysis of the contamination will commence with the simplest models, such as those presented in References 8 and 21 and 22,¹³ using demonstrably conservative assumptions and coefficients. Dilutions and travel times (or alternatively, concentrations directly) resulting from the preliminary analyses will then be checked by ETSBPERB¹⁴ to determine acceptability. If the indicated concentrations of radionuclides, identified by ETSBPERB,¹⁵ are less than the values identified in 10 CFR Part 20, Appendix B, Table H2,¹⁶ Column 2, no further computational

efforts will be warranted. Further analyses using progressively more realistic and less conservative modeling techniques, such as those of References 13 and 2524,¹⁷ will be undertaken if the preliminary results are not acceptable.

Independent calculations will be made of liquid effluent transport for the surface pathways identified. For preliminary analysis, the staff will employ simplified calculational procedures or models, such as those contained in References 3 and 9. The analysis will be performed using demonstrably conservative coefficients and assumptions, and the physical conditions (such as lowest recorded river flow) likely to give the most adverse dispersion of the liquid effluent. The applicant's model assumption and results will be compared with the staff's results to ~~assure~~ ensure that the results are comparably conservative. The estimation of liquid effluent dispersion will reflect potential future changes that might result from variations in use by known future surface and groundwater users.

Concentrations of radionuclides in the body of water under consideration will be calculated based on the staff's dispersion computations and with initial concentrations provided by the ~~Effluent Treatment Systems Branch (ETSB)PERB~~¹⁸ for the most critical event. Acceptability of the resultant concentrations of radioactive effluent at the points of interest will be determined by consultation with ~~ETSB~~PERB.¹⁹ If the concentrations of the diluted liquid effluents computed by the staff are within acceptable limits of Appendix B, Table H2,²⁰ Column 2, of 10 CFR Part 20, no further computation effort is indicated. If the concentrations computed by conservative simplified methods exceed the limits of 10 CFR Part 20, more precise and less conservative models, such as those used for hydrothermal prediction (Ref. 10), and coefficients will be employed by the staff.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.²¹

IV. EVALUATION FINDINGS

For construction permit (CP) reviews, the findings will summarize the applicant's and the staff's estimates of dilution factors, dispersion coefficients, flow velocities, travel times, and potential contamination pathways between the site and the nearest water user in conformance with 10 CFR Part 100. If the estimates are comparable, or if no potential problem exists, staff concurrence with the applicant's estimates will be stated. If the staff predicts substantially more conservative conditions, a statement of the staff basis will be made.

For operating license (OL) reviews of plant designs that have had detailed reviews of severe accidental effluent releases at the CP stage, the CP conclusions will be referenced. If no CP review of effluent releases was undertaken of the scope indicated herein, this will be indicated. Any new potential pathways or changes in water usage that can be identified in the OL review will also be analyzed and reported.

Sample statements for CP reviews follow:

The staff concludes that the plant meets the requirements of 10 CFR Part 100 with respect to potential accidental releases of radioactive liquid effluents. This conclusion is based on the following analysis:

A postulated failure of the miscellaneous waste collection tank (the tank outside of containment with the highest radioactive inventory) was analyzed to estimate the concentration of radioactive contaminants in nearby wells. The contents of the tank were conservatively assumed to enter the groundwater instantaneously, and the nuclides were assumed to travel with the water with no credit taken for ion exchange processes. The nearest downgradient potable water well is located 880 meters (2900 feet)²² northeast of the plant. Assuming a very high permeability of ~~1500 x 10⁻⁶ centimeters~~ 15 micrometers (590 microinches)²³ per second, the travel time to the nearest down gradient potable well was 9.5 years. The calculated concentrations of all nuclides were well below the maximum permissible concentrations listed in 10 CFR Part 20, Appendix B, Table H2.²⁴ In this analysis, it was also assumed that the contents of the tank traveled with the groundwater to A Creek. It was then assumed to mix with creek water, flow into Lake B, and then to the water supply intake for the city of C. Concentrations at the water supply intake for the city of C were also small fractions of 10 CFR Part 20 limits for all nuclides.

A postulated failure of the distillate storage tank, which will be located in the plant yard, was also analyzed. It was conservatively assumed that the entire contents of the tank are introduced, as a slug release, into Lake B at the mouth of A Creek. (In reality, a failure of this tank would result in effluent flowing through the site drainage to A Creek, where it would be diluted before entering the lake.) Our analysis showed that the concentration of all nuclides would be small fractions of the 10 CFR Part 20 limits at the water supply intake for the city of C.

Additional discussion of the radiological consequences of the postulated tank failures described above is provided in Section ~~15.315.7.3~~²⁵ of this report.

For design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.²⁶

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.²⁷ Except in those cases in which the applicant proposes an acceptable alternative method for complying with

specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.²⁸

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

In addition to the following references describing methods and techniques of evaluation, published data published²⁹ by Federal, State, and other agencies and organizations will be used as available.

1. 10 CFR Part 100, "Reactor Site Criteria."
2. N. H. Brooks, "Diffusion of Sewage Effluent in an Ocean Current," in "Waste Disposal in the Marine Environment," Pergamon Press, New York (1960).
3. H. B. Fisher, "The Mechanics of Dispersion in Natural Streams," Jour. Sanitary Engineering Division, Proc. Am. Soc. Civil Engineers, Vol. 93, No. HY6, pp. 187-216 (1968).
4. H. B. Fischer, "Dispersion Predictions in Natural Streams," Jour. Sanitary Engineering Division, Proc. Am. Soc. Civil Engineers, Vol. 94, No. SA5, pp. 927-943 (1968).
5. E. Gasper and M. Oncescu, "Radioactive Tracers in Hydrology," Elsevier Publishing Co., New York (1972).
6. S. N. Davis and R. J. M. DeWiest, "Hydrogeology," John Wiley & Sons, Inc., New York (1966).
7. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."
8. "~~NRC Dispersion Workbook~~" (in preparation): NUREG-0868, "A Collection of Mathematical Models for Dispersion in Surface Water and Groundwater" (June 1982).³⁰
9. Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I."
10. G. H. Jirka, G. Abraham, D. R. F. Harleman, "An Assessment of Techniques for Hydrothermal Prediction," USNRC, NUREG-0044, 1976.
11. Regulatory Guide 4.4, "Reporting Procedure for Mathematical Models Selected to Predict Heated Effluent Dispersion in Natural Bodies of Water."

12. S. W. Ahlstrom, R. J. Serne, R. C. Routson, and O. B. Cearlock, "Methods for Estimating Transport Model Parameters for Regional Groundwater Systems," BNWL-1717, Battelle Pacific Northwest Laboratories, Richland, Washington (1972).
13. R. C. Routson and R. J. Serne, "One-Dimensional Model of the Movement of Trace Radioactive Solutes Through Soil Columns: The PERCOL Model," BNWL-1718, Battelle Pacific Northwest Laboratories, Richland, Washington (1972).
14. R. C. Routson and R. J. Serne, "Experimental Support Studies for the PERCOL and Transport Models," BNWL-1719, Battelle Pacific Northwest Laboratories, Richland, Washington (1972).
15. K. L. Kipp, D. B. Cearlock, and A. E. Reisenauer, "Mathematical Modeling of a Large, Transient, Unconfined Aquifer with a Heterogeneous Permeability Distribution," paper presented at the 54th Annual Meeting of the American Geophysical Union, Washington, DC, April 1973.
16. W. H. Li and F. H. Lai, "Experiments on Lateral Dispersion in Porous Media," Jour. Hydraulics Division, Proc. Am. Soc. Civil Engineers, Vol. 92, No. HY6 (1966).
17. W. H. Li and G. T. Yeh, "Dispersion of Miscible Liquids in a Soil," Water Resources Research, Vol. 4, pp. 369-377 (1968).
18. D. R. F. Harleman, P. F. Mehlhorn, and R. R. Rumer, "Dispersion Permeability Correlation in Porous Media," Jour. Hydraulics Division, Proc. Am. Soc. Civil Engineers, Vol. 89, No. HY2, pp. 67-85 (1963).
19. L. E. Addison, D. R. Freidrichs, and K. L. Kipp, "The Transmissivity Iterative Programs on the PDP-9 Computer--A Man-Machine Interactive System," BNWL-1707, Battelle Pacific Northwest Laboratories, Richland, Washington (1972).
20. "Fundamentals of Transport Phenomena in Porous Media," International Association for Hydraulic Research, Elsevier Publishing Company, New York (1972).
- ~~21. R. Codell and D. Schreiber, "NRC Models for Evaluating the Transport of Radionuclides in Groundwater," Proceedings of Symposium on Management of Data Base Low-Level Radioactive Wastes, May 1977, Georgia Institute of Technology, Atlanta, Georgia (in preparation).³¹~~
2221. F. A. Appel and J. D. Bredehoeft, "Status of Groundwater Modeling in the U.S. Geological Survey," USGS Circular 737 (1976).
2322. American Nuclear Society, "Standards for Evaluating Radionuclide Transport in Groundwater, Draft 2."³²

2423. J. O. Duguid and M. Reeves, "Material Transport Through Porous Media: A Finite Element Galerkin Model," ORNL-4928, Oak Ridge National Laboratory, Environmental Science Division, Publication 733, March 1976.
2524. R. L. Taylor and C. B. Brown, "Darcy's Flow Solutions with a Free Surface," Journal of the Hydraulics Division, ASCE, Vol. 93, No. HY2, pp. 25-33, March 1967.
2625. S. P. Neuman and P. A. Witherspoon, "Finite Element Method of Analyzing Steady Seepage with a Free Surface," Water Resources Research, Vol. 6, No. 3, pp. 889-897, June 1970.
2726. S. P. Neuman and P. A. Witherspoon, "Analysis of Nonsteady Flow with a Free Surface Using the Finite Element Method," Water Resources Research, Vol. 7, No. 3, pp. 661-663, June 1971.
2827. G. F. Pinder and E. O. Frind, "Application of Galerkin's Procedure to Aquifer Analysis," Water Resources Research, Vol. 8, No. 1, pp. 108-120, February 1972.
2928. J. Rubin and R. V. James, "Dispersion-Affected Transport of Reacting Solutes in Saturated Porous Media: Galerkin Method Applied to Equilibrium Controlled Exchange in Unidirectional Steady Water Flow," Water Resources Research, Vol. 9, No. 5, pp. 1332-1356, October 1973.
3029. E. O. Frind and G. F. Pinder, "Galerkin Solution of the Inverse Problem for Aquifer Transmissivity," Water Resource Research, Vol. 9, No. 5, pp. 1397-1410, October 1973.
3130. G. F. Pinder, "A Galerkin-Finite Element Simulation of Groundwater Contamination on Long Island, New York," Water Resources Research, Vol. 9, No. 6, pp. 1657-1669, December 1973.
3231. M. Reeves and J. O. Duguid, "Water Movement Through Saturated-Unsaturated Porous Media: A Finite Element-Galerkin Model," ORNL-4927, Oak Ridge National Laboratory, Oak Ridge, Tennessee, February 1975.
32. 10 CFR Part 20, "Standards for Protection Against Radiation."³³

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Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current primary review branch name and designation	Changed PRB to Civil Engineering and Geosciences Branch (ECGB).
2.	Current secondary review branch names and designations	Added two secondary review branches and their designations: Plant Systems Branch (SPLB) and Emergency Preparedness and Radiation Protection Branch (PERB).
3.	SRP-UDP format item	Added "Review Interfaces" and lead-in sentence to AREAS OF REVIEW.
4.	SRP-UDP format item	Added review interfaces for PERB and SPLB. These are derived from subsection III, REVIEW PROCEDURES.
5.	Editorial	Defined "SRP" as "Standard Review Plan."
6.	SRP-UDP format item	Added "Technical Rationale" and lead-in paragraph to ACCEPTANCE CRITERIA.
7.	SRP-UDP format item	Added technical rationale for 10 CFR Part 100.
8.	Editorial	Defined "SAR" as "safety analysis report."
9.	Current title for project manager	Deleted "LPM" and added "NRR Project Manager" in its place.
10.	Editorial	Defined "SER" as "safety evaluation report."
11.	Editorial	Changed "assure" to "ensure" (global change for this section).
12.	Current secondary review branches	Changed SRB to PERB and SPLB.
13.	Editorial	Updated reference citations from "References 21 and 22" to "References 8 and 21."
14.	Current secondary review branch	Changed SRB to PERB.
15.	Current secondary review branch	Changed SRB to PERB.
16.	Integrated Impact No. 1343	Changed the reference from "10 CFR Part 20, Appendix B, Table II, Column 2" to "10 CFR Part 20, Appendix B, Table 2, Column 2."
17.	Editorial	Changed "Reference 25" to "Reference 24."
18.	Current secondary review branch	Changed SRB to PERB.
19.	Current secondary review branch	Changed SRB to PERB.

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Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
20.	Integrated Impact No. 1343	Changed the reference from "10 CFR Part 20, Appendix B, Table II, Column 2" to "10 CFR Part 20, Appendix B, Table 2, Column 2."
21.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
22.	SRP-UDP format item	Converted 2900 feet to 880 meters and placed the English units in parentheses.
23.	SRP-UDP format item	Converted centimeters to 15 micrometers and placed the English equivalent in parentheses.
24.	Integrated Impact No. 1343	Changed the reference from "10 CFR Part 20, Appendix B, Table II" to "10 CFR Part 20, Appendix B, Table 2."
25.	Editorial	Corrected the reference to "Section 15.7.3."
26.	SRP-UDP format item	Added to EVALUATION FINDINGS that refers to design certification reviews, 10 CFR Part 52.
27.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
28.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
29.	Editorial	Transposed the words "published" and "data" as shown.
30.	Editorial	As explained in "References That Could Not Be Validated," the NRC Dispersion Workbook was published as NUREG-0868.
31.	Editorial	As explained in "References That Could Not Be Validated," this reference is obsolete and has been superseded by Reference 8. Accordingly, it has been deleted and so noted. Renumbered subsequent references.
32.	SRP-UDP format item	As explained in detail in "References That Could Not Be Validated," this reference has been superseded by ANS 2.17.
33.	Editorial	Added 10 CFR Part 20 to REFERENCES.

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Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
1343	Updated references to 10 CFR Part 20.	III (2 places); IV