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FINAL REPORT

INDEPENDENT TECHNICAL REVIEW OF N SPRINGS EXPEDITED RESPONSE ACTION PROPOSAL HANFORD SITE

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Prepared For:

Westinghouse Hanford Company

Prepared By:

ADVANCED SCIENCES, INC.

FEBRUARY 22, 1994

FINAL REPORT

INDEPENDENT TECHNICAL REVIEW OF N SPRINGS EXPEDITED RESPONSE ACTION PROPOSAL HANFORD SITE

Prepared for:

Westinghouse Hanford Company
P.O. Box 1970
Richland, Washington 99352

Prepared by:

Advanced Sciences, Inc.
1777 Terminal Drive
Richland, Washington 99352

February 22, 1994

EXECUTIVE SUMMARY

This report presents the results of an independent third-party technical review of DOE/RL-93-23, N Springs Expedited Response Action (ERA) Proposal, Revision 0 (DOE RL, 1994). The objective of the technical Review Board was to obtain independent, third-party expert opinions on the technical adequacy of the document and its conclusions. The ultimate objective of the technical review is to improve the cost-effectiveness and defensibility of alternatives for the Expedited Response Action (ERA) for reduction of strontium-90 (^{90}Sr) from the N Springs into the Columbia River near the N Reactor at the Hanford Site.

The Review Board was composed of qualified, nationally recognized, experts in the disciplines of geology, hydrology, and civil/environmental engineering with expertise in grout curtains, slurry walls, and ion exchange and reverse osmosis treatment technologies. The Board reviewed the N Springs ERA Proposal, as well as three other N Springs-related documents.

As a result of the technical review the Board found strong, clear consensus on the following concerns:

1. The presentation of existing concentrations of ^{90}Sr in ground water and soils at and near the N Springs site is confusing, because the location and timing of concentrations in both ground water and soil are not well documented in the ERA Proposal.

2. The goal of significant reduction of ^{90}Sr flux to the Columbia River by separation of ^{90}Sr from pumped ground water during the 10-year ERA duration would result in insignificant total mass removal due to the natural immobility of ^{90}Sr.

3. The report provides an adequate description of the various candidate alternatives available to meet the ERA Proposal goal for reduction of ^{90}Sr flux to the Columbia River.

4. Technological uncertainties, especially in the pump-and-treat alternatives, resulted in the inability of the authors of the ERA Proposal to conclusively select a preferred alternative. The Review Board's opinion is that the alternative with the least amount of technological and cost uncertainty (vertical barrier using a slurry wall) could have been selected as the preferred alternative. In addition, the Review Board agreed that the effectiveness of the pump-and-treat alternative was incorrectly assessed in its capability to remove ^{90}Sr from the ground water and soils at the site.

5. It is the Review Board's opinion that estimated costs of the alternatives were not judged on relative terms, because the more complex alternatives, that is pump and treat and hydraulic control, will cost substantially more to construct and operate at nuclear facilities than in non-nuclear settings.

The Review Board also made the following recommendations:

1. The Review Board recommends a clear and quantitative statement of the goal of the ERA Proposal be established.

2. The objectives of an ERA Proposal, that is, to select a cost-effective alternative for meeting the ^{90}Sr flux goal and, to the extent practical, contribute to the effective performance of any final action, should be strictly followed.

3. The Review Board recommends that the most cost-effective alternative be selected from among the 12 alternatives presented in the report. This alternative appears to be some form of the vertical barrier (Alternative 3), with supplementary monitoring wells near the ends of the barrier. Additional analyses should be undertaken to provide definitive design data for the barrier.

Table of Contents

1.0 INTRODUCTION

Westinghouse Hanford Company (WHC), on behalf of the U. S. Department of Energy, Richland Operations Office (DOE RL), has undertaken an Expedited Response Action (ERA) as an interim action proposed to significantly reduce the flux of strontium-90 (^{90}Sr) to the Columbia River from the N Springs near the N Reactor at the Hanford Site. The principal objective of the N Springs ERA Proposal (DOE RL, 1994) is to evaluate various action alternatives and recommend a response that best meets the selection criteria as prescribed by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, including demonstration of cost effectiveness. The methodology used for evaluation, cost analysis, and alternative recommendation is the engineering evaluation/cost analysis (EE/CA). The goal of the ERA Proposal is to analyze and recommend an expedited response action and not to recommend final remediation of the contaminated ground water discharging to the Columbia River at the N Springs. The regulatory driver for the ERA is the Milestone M-14 Settlement of the Proposed 100-N Springs Expedited Response Action Plan (WHC, 1992).

This report describes the results of an independent third-party technical review of the N Springs ERA Proposal published by DOE RL (1994). Advanced Sciences, Inc. (ASI) identified and retained qualified, nationally recognized experts to serve on the Review Board and documented the findings of the Board.

This report is organized into three sections. Section 1 is the introduction describing the objectives of the Review Board and the approach used to meet those review objectives. Section 2 presents the comments, suggested corrections, conclusions, and recommendations of the Review Board. Section 3 provides selected references used as a basis for the review comments, corrections, conclusions, and recommendations. Appendices to this report contain the resumes of the Board members and detailed comments received from the individual Board members.

1.1 OBJECTIVES OF N SPRINGS EXPEDITED RESPONSE ACTION PROPOSAL

The objectives of the N Springs ERA Proposal were to identify, screen, and compare alternatives that eliminate or substantially reduce the flux of ^{90}Sr to the Columbia River. The goal of the proposal is to recommend a cost-effective alternative(s) that meets the ERA objectives. Additionally, the ERA should, to the extent practical, contribute to the effective performance of any final actions. Therefore, the ERA would be reevaluated as planning in the 100-N Area proceeds (DOE RL, 1994).

1.2 OBJECTIVES OF INDEPENDENT REVIEW BOARD

The objective of the Review Board was to obtain independent, third-party expert opinions on the technical adequacy of the ERA document and conclusions. During this process, the Board reviewed the N Springs ERA Proposal (DOE RL, 1994) along with selected background documents referenced in the ERA. The ultimate objective of the technical reviews is to improve the cost effectiveness and defensibility of decisions on the suitability of alternatives for the ERA.

1.3 APPROACH

To achieve the stated objectives, the performance of the Review Board consisted of (1) identifying and selecting qualified experts to serve as Board members; (2) reviewing the N Springs ERA Proposal document and related background documents; (3) meeting and discussing issues related to the ERA Proposal with WHC and IT Corporation (authors of the document); (4) obtaining written comments from the Board members both individually and collectively; and (5) presenting report findings to WHC. This section describes the selection of Board members and the documents reviewed. The comments, corrections, conclusions, and recommendations of the Board are summarized in Section 2.0. Resumes of individual Board members are given in Appendix A. Viewgraphs used in the report-findings presentation are presented in Appendix B. Individual comments are attached as Appendices C through G.

1.3.1 Review Board Selection

The selection of the Review Board consisted of identifying qualified scientists and engineers who are not members of the organizations that completed the ERA work being reviewed. Board members were selected from the following technical disciplines: (1) geology; (2) hydrology; and (3) civil/environmental engineering. Specific expertise within the above disciplines included those related to vertical walls (grout curtains and slurry walls) and pump-and-treat (ion exchange and reverse osmosis) technologies.

Based upon the above disciplines and specific expertise, the Review Board members were selected as follows:

Anthony S. Burgess, Ph.D., P.E., Hydrogeology/Geotechnical Engineering

Wade E. Hathhorn, Ph.D., Civil Engineering/Hydrogeology

James R. Kunkel, Ph.D., P.E., P.H., Hydrology and Civil/Environmental Engineering

Richard A. Millet, P.E., Civil/Geotechnical Engineering

Martin Vorum, P.E., Chemical/Environmental Engineering

Appendix A contains the resumes for the Review Board members selected. Dr. Kunkel was selected by the Board members as chair and was responsible for coordinating the receipt of comments from the individual Board members and preparing the draft of the Board's report.

1.3.2 Documents Reviewed

The Board met collectively on February 7 and 8, 1994 to review and discuss selected documents, held a conference telephone call on February 15, 1994 to discuss draft individual comments and the documents, and met collectively on February 21, 1994 to discuss the draft final report and prepare the presentation to WHC held on February 22, 1994. The Board members were provided the following documents for review and background information:

Connelly, M. P., J. D. Davis and P. D. Rittman, 1991, *Numerical Simulation of Strontium-90 Transport from the 100-N Area Liquid Waste Disposal Facilities*: Report prepared by Westinghouse Hanford Company for the U. S. Department of Energy, Office of Environmental Restoration and Waste Management, WHC-SD-ER-TA-001, Revision 0, April, 61 pages, 1 appendix.

U. S. Department of Energy, Richland Field Office (DOE RL), 1994, *N Springs Expedited Response Action Proposal*: DOE/RL-93-23, Revision 0, January, 10 Sections, Appendix A.

Thompson, K. M., 1991, *Hanford Past-Practice Strategy*: DOE/RL-91-40, Revision 0, U. S. Department of Energy, Richland Field Office (DOE RL), November, 31 p., 2 attachments.

Westinghouse Hanford Company (WHC), 1992, *M-14 Settlement - Proposed 100-N Springs Expedited Response Action*: Letter from W. L Johnson, Westinghouse Hanford Company to R. D. Izatt, U. S. Department of Energy, Richland Field Office, October 19, 1992, Correspondence No. 9257492D, 3 p., 2 enclosures.

Although the N Springs ERA Proposal (DOE RL, 1994) constitutes the primary document reviewed, the other documents were made available by WHC as background information. These supplemental background documents were not reviewed for technical adequacy but rather served as useful background information and data for the N Springs ERA Proposal technical review.

2.0 SUMMARY OF REVIEW BOARD FINDINGS

2.1 COMMENTS AND SUGGESTED CORRECTIONS

The independent Review Board members submitted individual comments which are presented in Appendices C through G. The comments may be categorized according to the following: (1) lack of a clear goal commensurate with an ERA; (2) uncertainties in estimating the effectiveness of the alternatives to meet the assumed goal; and (3) uncertainties in the cost estimates for the alternatives. A summary of the Review Board member's comments related to these three comment areas are summarized in this section. Where appropriate, suggested corrections related to the comments are included. This section is intended only to provide an overview of the member's comments. In most cases these comments constitute a consensus of the Technical Review Board.

2.1.1 Lack of a Clear Goal Commensurate with an ERA

The primary goal presented in the N Springs ERA Proposal (DOE RL, 1994) is to eliminate or significantly reduce the flux of strontium-90 (^{90}Sr) to the Columbia River through the N Springs. Further, the Proposal states that "significant reduction" was considered to be at least 50 percent of the ^{90}Sr concentrations greater than 1,000 pico-Curies per liter (pCi/L). At first glance, these appear to be consistent statements of the same goal. However, as pointed out in the individual review comments (Appendices C through G), applying a goal of reducing ground-water concentrations of ^{90}Sr may not directly or efficiently serve to limit flux to the River, and may prove costly to achieve, whatever the ongoing flux may be. Therefore, the Review Board concludes that (1) reduction of concentrations by separation of ^{90}Sr from pumped ground water during the 10-year ERA duration would result in insignificant total mass removal due to the natural immobility of the ^{90}Sr as discussed below, and (2) the ground-water concentration data are not well documented in the ERA Proposal, so that it cannot be concluded what the impact on flux would be by attacking the presently described ^{90}Sr concentration distributions.

This highlights the question as to whether the ERA intent is to provide actual ^{90}Sr removal, or to simply prevent its dispersal into the River as is traditionally consistent with non-time-critical ERAs. The Review Board recommends the latter objective. This issue is important when it is noted that the actual removal of ^{90}Sr using the pump-and-treat alternative is between less than one to, at most, two percent of the total mass (corrected for decay) of contaminant in the soil and ground water at the site. Therefore, it would appear that not only is the goal of removal of ^{90}Sr concentrations to achieve the reduction of doubtful value, but the whole concept of removal of ^{90}Sr mass appears to be a goal not commensurate with expedited response actions, because it is a complex scheme not traditionally allowed under standard ERA proposals (Thompson, 1991). The Review Board proposes that the goal of reduction of ^{90}Sr flux to the Columbia River be retained but that this goal should be achieved using non-time-critical methods typical of ERAs.

In addition, the maximum contaminant level (MCL) for ^{90}Sr is ill-defined in the N Springs ERA Proposal. It is unclear whether the existing MCL for ^{90}Sr of 8 pCi/L or the proposed MCL of 42 pCi/L is being used as the standard for discharging water to the River.

2.1.2 Uncertainties in Estimating the Effectiveness of the Alternatives

The proposed N Springs ERA alternatives consist of four types: (1) no action; (2) pump and treat; (3) vertical barrier; and (4) hydraulic control. Within the pump-and-treat alternative, two pumping options, two treatment options, and four disposal options, for a total of eight alternatives, are examined. Within the vertical-barrier alternative, two locations were examined. Therefore, a total of 12 alternatives were investigated. The no-action alternative (Alternative 1), which was used as a baseline to judge the effectiveness of all other alternatives, was based upon model runs for hydrologic conditions which no longer exist at the site. Model-predicted concentration of ^{90}Sr in the ground water appear to be higher than those generally observed. Therefore, there is much uncertainty in the magnitude of the problem.

The pump-and-treat alternative(s) (Alternative 2) received the most attention by the Review Board members. Technical feasibility/applicability of this alternative(s) was discussed at length, as were the costs related to this alternative(s). The cost aspects of this alternative(s) are discussed in the next section. Several technology-specific issues were raised by the Review Board about the pump-and-treat alternative. Assuming that the goal of the ERA Proposal is reduction of ^{90}Sr flux to the River and not reduction of ^{90}Sr mass remaining in the soil, these issues included: (1) the potential inability of this alternative to achieve a net reduction of ^{90}Sr flux to the Columbia River of 50 percent, and (2) the potential inability of both ion exchange (IX) and reverse osmosis (RO) to reduce treated water ^{90}Sr concentrations to the proposed MCL of 42 pCi/L. Because of these and other uncertainties in the pump-and-treat alterative(s), this method of flux reduction may, in fact, become a very expensive hydraulic control alternative.

The vertical-barrier alternative(s) (Alternative 3) also received much attention from the Review Board. The effectiveness of the vertical barrier was reported in the N Springs ERA Proposal to range from 71 to 100 percent reduction in ^{90}Sr flux to the River. It is unlikely that 100 percent reduction can be achieved over the 10-year performance period of the vertical barrier. However, its effectiveness was agreed upon to be high and very effective in meeting the goal of the ERA Proposal, because ^{90}Sr is highly sorptive and the vertical barrier would greatly reduce the flux of contaminants to the River. The Review Board members generally agreed that the fewest uncertainties, in terms of inability to meet the ERA goal, rested with the vertical-barrier system--particularly a single-auger, deep, soil-mixing technology. The Review Board also believes that a grouted-interlock, sheet-pile wall should be reassessed for constructability. The sheet-pile wall system appears to offer significant advantages, because of limited access to the River bank. One of the issues associated with the vertical barrier was the feasibility of constructing a vertical barrier very near (within 50 feet of) the Columbia River. If the vertical barrier were constructed 100 feet or further from the River, flushing of ^{90}Sr into the River during the first year(s) of operation may reduce the effectiveness of the barrier during those years. Continued releases of ^{90}Sr from the soils between the barrier and River will occur. This is a result of the daily and seasonal fluctuations in water level in the River. Thus, over the short term, the barrier may be significantly less effective than estimated and will depend upon the location of the barrier relative to the River.

The hydraulic-control alternative (Alternative 4) was judged by the Review Board to be generally less likely to control the flux of ^{90}Sr to the Columbia River, because of the large uncertainties in the hydrogeologic characteristics of the site. On the other hand, the highly sorptive nature of ^{90}Sr is a benefit to this alternative assuming that hydraulic control can be achieved with a reasonable number, location, and operational complexity of wells. Overall, this alternative appeared to the Review Board members to be very risky.

From a technological viewpoint and in the spirit of ERA proposals, the Review Board generally agreed that the least complex alternative and potentially the most reliable is the vertical barrier.

One or more monitoring wells could be installed at the ends of the barrier to track the reliability of the system. The general consensus of the Review Board was that some variation of the vertical barrier, as presented in the N Springs ERA Proposal, would potentially provide the necessary reduction of ^{90}Sr flux to the Columbia River until a final remedial-action alternative could be selected.

2.1.3 Uncertainties in the Cost Estimates for the Alternatives

The "relative" cost estimates for the alternatives were derived from vendor quotes, WHC labor rates, and assumed typical "environmental"-project costs rather than permanent nuclear-project costs. The Review Board generally felt that the assumption of a typical environmental project is in serious error. The costs for the more complex alternatives, such as pump and treat and hydraulic control, could not be adequately compared with other alternatives such as the vertical barrier using the environmental-project assumption at the Hanford Site. For example, although the costs for slurry wall installation may be similar for both nuclear and non-nuclear facilities, those for water treatment equipment as well as operation and maintenance would have large variations between nuclear and non-nuclear applications. It is unlikely that RO plants at the Hanford site could be operated remotely by computer from offsite, as proposed by at least one of the vendors. The Review Board felt that more attention should have been given to reduction in the cost uncertainties in order to give more realistic benefit-cost analysis results. Suggested benefit-cost analyses should include a comparison of alternatives using cost per Curie-year for net ^{90}Sr flux reduction to the Columbia River, where the cost is the present value worth of a given alternative. Consequently, the Review Board concluded that the vertical barrier alternative was not fairly compared in terms of the uncertainty (capital costs, operation and maintenance costs, potential waste disposal costs) in the costs of other alternatives.

The report conclusions and recommendations do not favor a single preferred alternative for implementation for the N Springs ERA Proposal. The report concludes that the preferred alternative cannot be confidently recommended in light of the technical and cost uncertainties. The preferred alternative is actually further study of 10 of the 12 originally proposed alternatives. The opinion of the Review Board is that a single preferred alternative should be recommended in the report and additional studies undertaken, if necessary, to construct this alternative.

2.2 CONCLUSIONS AND RECOMMENDATIONS

Based upon review of the N Springs Expedited Response Action Proposal (DOE/RL-93-23), Revision 0 (DOE RL, 1994), the technical Review Board offers the following conclusions and recommendations.

2.2.1 Conclusions

1. The presentation of existing concentrations of ^{90}Sr in ground water and soils at and near the N Springs site is confusing, because the location and timing of concentrations in both ground water and soil are not well documented in the ERA Proposal.

2. The goal of significant reduction of ^{90}Sr flux to the Columbia River by separation of ^{90}Sr from pumped ground water during the 10-year ERA duration would result in insignificant total mass removal due to the natural immobility of ^{90}Sr.

3. The report provides an adequate description of the various candidate alternatives available to meet the ERA Proposal goal for reduction of ^{90}Sr flux to the Columbia River.

4. Technological uncertainties, especially in the pump-and-treat alternatives, resulted in the inability of the authors of the ERA Proposal to conclusively select a preferred alternative. The Review Board's opinion is that the alternative with the least amount of technological and cost uncertainty (vertical barrier using a slurry wall) could have been selected as the preferred alternative. In addition, the Review Board agreed that the effectiveness of the pump-and-treat alternative was incorrectly assessed in its capability to remove ^{90}Sr from the ground water and soils at the site.

5. It is the Review Board's opinion that estimated costs of the alternatives were not judged on relative terms, because the more complex alternatives, that is pump and treat and hydraulic control, will cost substantially more to construct and operate at nuclear facilities than in non-nuclear settings.

2.2.2 Recommendations

1. The Review Board recommends a clear and quantitative statement of the goal of the ERA Proposal be established.

2. The objectives of an ERA Proposal, that is, to select a cost-effective alternative for meeting the ^{90}Sr flux goal and, to the extent practical, contribute to the effective performance of any final action, should be strictly followed.

3. The Review Board recommends that the most cost-effective alternative be selected from among the 12 alternatives presented in the report. This alternative appears to be some form of the vertical barrier (Alternative 3), with supplementary monitoring wells near the ends of the barrier. Additional analyses should be undertaken to provide definitive design data for the barrier.

3.0 REFERENCES

Thompson, K. M., 1991, Hanford Past-Practice Strategy, DOE/RL-91-40, Revision 0, U. S. Department of Energy, Richland Field Office (DOE RL), November, 31 p., 2 attachments.

U. S. Department of Energy, Richland Field Office (DOE RL), 1994, N Springs Expedited Response Action Proposal, DOE/RL-93-23, Revision 0, January, 10 Sections, Appendix A.

Westinghouse Hanford Company (WHC), 1992, M-14 Settlement - Proposed 100-N Springs Expedited Response Action, Letter from W. L Johnson, Westinghouse Hanford Company to R. D. Izatt, U. S. Department of Energy, Richland Field Office, October 19, 1992, Correspondence No. 9257492D, 3 p., 2 enclosures.

APPENDIX A

RESUMES OF REVIEW BOARD MEMBERS

Anthony S. Burgess

Golder Associates

Education B.Sc., Geology, University of Durham, United Kingdom, 1966.
Ph.D., Geology (Engineering Geology and Geohydrology), University of Durham, United Kingdom, 1970.

Affiliations Professional Engineer; Washington, Oregon and Ontario.
Association of Groundwater Scientists and Engineers.
Water Environment Federation.

Positions

1984 to date	**Golder Associates** *Principal* *Principal-In-Charge, Environmental Sciences Group*	**Redmond, Washington**
1979 - 1984	**Acres Consulting Services** *Head, Technical Development Department*	**Niagara Falls, Canada**
1977 - 1979	**Acres Consulting Services** *Senior Geotechnical Engineer*	**Niagara Falls, Canada**
1973 - 1977	**Crippen Acres Engineering** *Site and Office Geotechnical Engineer*	**Winnipeg, Canada**
1972 - 1973	**Geocon, Frederiction** *Senior Soils Engineer*	**New Brunswick, Canada**
1970 - 1972	**Ove Arup and Partners** *Soils/Geological Engineer*	**London, U.K.**

Professional Summary

Dr. Burgess is a Principal at Golder Associates Inc. with a wide variety of geotechnical experience in North America and overseas. Technical responsibilities have included theoretical analyses, design and site engineering in soil and rock mechanics, engineering geology, hydrogeology, and northern engineering. Project assignments have included hydroelectric development, underground facilities, marine structures, oil field development from artificial islands, commercial and industrial development, hazardous and radioactive waste, and groundwater contamination.

Experience in Hydrogeology and Environmental Projects

1991 - 1992 Technical support to attorneys; groundwater contamination and closure of landfill, Hansville, Washington.

1991 - 1992 Principal-in-charge of consultant team retained by PLP group for MTCA RI/FS, Landsburg Mine, Washington.

1990 - 1992 Technical reviewer for Golder subcontract, Westinghouse Hanford, for work plans, RI/FS reports and risk assessments.

1992 Testimony at Shoreline Hearing for gravel pit expansion, Yakima, Washington.

1992 Project Manager for risk assessment of release of Bunker C fuel oil to karstic bedrock, The Pas, Manitoba.

1992 Project Manager for study of impacts to aquifer from discharge of storm water to sumps, Portland, OR.

1991 - 1992 Project Manager, MTCA closure of trench containing wood treating wastes.

1991 Review of hydrogeological impacts of proposed oil pipeline from west of Port Angeles to the Canadian Border.

1991 - 1992 Technical review of groundwater modeling of releases from hazardous waste facility, Munchehagen, Germany.

1991 Technical review of feasibility study for oil production facility with arsenic contamination Elk Hills, California.

1991 Expert witness, release of petroleum hydrocarbons to soil and groundwater, Kent, Washington.

1990 - 1991 Groundwater monitoring plan and semiannual review of monitoring data, Columbia Ridge Landfill, Arlington, Oregon.

1990 - 1991 Project Director for investigation and preparation of corrective action plans for multi-tenant site, Portland, Oregon.

1990 - 1991 Technical assistance for review of investigation data and soil gas survey at site with chlorinated solvent contamination in groundwater, Mountain View, California.

1990 - 1991 Technical review of interceptor well system for groundwater containing solvents and arsenic, Industriplex, Woburn, Massachusetts.

1990 - 1991 Technical support to attorneys; litigation of responsibility for releases of chlorinated solvents to soil and groundwater, Visalia, California.

1990 - 1991 Technical review of investigation and proposed remediation, wood treating facility, Marysville, California.

1990 - 1991 Expert witness testimony, extent of contamination and estimate of remediation costs, petroleum and solvent recycling facilities, Tacoma, Washington.

1990 Technical manager, preparation of contract documents for low temperature thermal treatment for hydrocarbon contaminated soils, March AFB, California.

1989 - 1990	Technical review of risk assessment of soil, surface water and groundwater releases, Canada Creosote, Calgary.
1989	Technical review and assistance for RCRA facilities investigation of disposal well, Anacortes, Washington.
1988 - 1989	Project Director for environmental services contract, Westinghouse Hanford Company; task order assignments included RI/FS work plan preparation for hazardous and mixed waste sites, RCRA Part B Permit applications, process waste water treatment and disposal alternatives evaluation, health and safety training, sampling plans, QA/QC procedures development.
1988 - 1989	Technical responsibility for evaluation of remedial action alternatives, Expo 86' site, Vancouver, B.C., contaminated with coal tar wastes, (PAHs, cyanide and heavy metals).
1987 - 1989	Project Director for investigation, evaluation of remedial alternatives and implementation of interim remedial actions including groundwater pumping and biological treatment, and soil vapor extraction, paint manufacturing facility, Santa Clara, California.
1987 - 1989	Development of groundwater monitoring plan using stochastic approach, Arlington, Oregon.
1985 - 1989	Project Manager for analysis and interpretation of groundwater contamination by VOC's, including preparation of IRM report and design and construction management of slurry wall/groundwater extraction systems at a semiconductor manufacturing facility, California.
1987 - 1988	Project Director for investigation, remedial alternatives evaluation, and soils cleanup of cyanide and solvent releases, metal fabrication plant, Napa, California.
1988	Technical review for attorney of stream erosion attributed to quarrying operations, Oakland, California.
1987	Technical assistance for investigation and remedial alternatives evaluation, PCB spill in fractured dolomite aquifer, Smithville, Ontario.
1987	Review for attorney of investigation results, chlorinated solvent spills, Tacoma, Washington.
1984 - 1987	Program Manager of contract for Washington Department of Ecology for remedial investigations and feasibility studies of abandoned hazardous waste sites including:
	Colbert Landfill, Spokane; groundwater contamination of organic solvents.
	Restover Truckstop, Tumwater; groundwater contamination by gasoline and diesel.
	Northside landfill, Spokane; contamination of sole source aquifer by landfill leachate, including organic solvents.
	Greenacres Landfill, Spokane; geophysical survey and hydrologic budget for site contaminating nearby well with organic solvents.

North Market Street, Spokane; preliminary assessment of area experiencing groundwater contamination by petroleum products.

Ellisforde (Tibbs) Landfill; preliminary investigation for groundwater contamination by pesticides.

B&L Woodwaste Landfill, Fife; evaluation and conceptual design and cost estimate for interim action.

1986	Expert testimony, gasoline spill, Nome, Alaska.
1986	Review for attorney of soil contamination by PAH's, Seattle, Washington.
1984 - 1986	Review and analyses of hydrogeological characterization for RCRA Part B Permit Application for hazardous waste disposal facility, Oregon.
1985	Project Manager for geophysical and hydrogeological investigation of volatile organic solvent contamination, McChord AFB, Washington.
1985	Technical review of groundwater studies at chemical plant, Soda Springs, Idaho.
1985	Project Manager for leachate management study, Vashon Landfill, Washington.
1984 - 1985	Project Manager for engineering design study of coal tar pond, Sydney, Nova Scotia, including surface and groundwater evaluation and sampling, assessment of releases of PAH's to harbor, and development of remediation alternatives.
1984	Specialist, technical input on hydrogeological aspects of investigation and design of landfill for City of Anchorage, Alaska.
1984	Project Manager for review of geological and geohydrological data from Hooker Chemical "S" area site, Niagara Falls, New York, for Environment Canada.
1984	Technical input to investigation of groundwater contamination from aircraft fuel spill, Fredericton, New Brunswick.
1983	Technical supervision of investigation and implementation of control measures for groundwater contamination from gasoline service station, Saint John, New Brunswick.
1982	Technical supervision of pumping test and analyses for pit dewatering study, Wabush Mine, Labrador.
1982	Direction of modeling of groundwater flow and temperature to determine effects of changes in river temperature on salmon spawning habitats, Susitna River, Alaska.
1981	Technical review of geohydrological studies of abandoned, operating, and proposed solid waste sites, Burlington, Ontario.

1981	Technical support and review for hydrogeological and geotechnical characterization of radioactive residue storage site, Lewiston, New York.
1980	Technical input for evaluation of groundwater contamination from coal pile, and recommendations for mitigating measures, Dunkirk, New York.
1980	Field supervision and analysis of pumping test, uranium tailings stabilization project, Uravan, Colorado.
1979	Technical input for geohydrological evaluation for effect of coal tar disposal, Plattsburgh, New York.
1979	Technical responsibility for geohydrological characterization of Bayou Choctaw Salt Dome, Louisiana, for strategic petroleum reserve program.
1979	Review of study of low temperature thermal energy storage in aquifers, southern United States.
1979	Technical responsibility for geohydrological analysis for environmental impact study, proposed open pit copper mine, British Columbia.
1979	Site data collection and analyses of groundwater inflow for operating lead-zinc mine in karstic limestone, Daniels Harbour, Newfoundland.
1978	Review of field investigation and analyses to determine seepage losses for tin dredging operation, Jacunda, Brazil.
1978	Technical supervision of field work and analyses for groundwater studies in support of investigation and remediation of radon contamination in house basements, Elliot Lake, Ontario.
1978	Technical review of pumping tests performed for dewatering study, light rail transit tunnel study, Buffalo, New York.
1978	Site inspection and recommendation for mitigative measure for gasoline leakage into groundwater, Jordan Station, Ontario.
1977	Finite element modeling of groundwater flow around proposed radioactive waste repository, Sweden.
1976	Analysis of potential abutment seepage conditions and cutoff design, Limestone Generating Station, Manitoba.
1973	Field supervision and preliminary analyses of pumping test data, municipal water supply well, Lameque, New Brunswick.

Experience in Permafrost and Northern Engineering

1986 Expert testimony, permafrost thaw and building settlement in relation to gas spill, Nome, Alaska.

1984 Technical supervision of analyses for covered heap leach pad on permafrost, Northwest Territories.

1982 Project Technical Manager for analysis of thaw and resulting deformation and stress effects around multi-well oil production clusters, Beaufort Sea Artificial Islands.

1981 Project Technical Manager for thermal and stress analyses of thaw around single oil production well, Beaufort Sea.

1981 Technical supervision of analyses of thaw from waste heat rejection, proposed LNG dock and loading facility, Melville Island, Northwest Territories.

1976 Analysis of forces on coffer dams and ride-up due to river ice jams, Nelson River Limestone Project, Manitoba.

1973 Site Geotechnical Liaison Engineer for construction of dykes on discontinuous permafrost, Long Spruce Generating Station, Manitoba.

Experience in Soil Mechanics and Foundations

1993 Expert testimony on soil stockpile characteristics, construction claim defense, Renton, WA.

1982 Technical supervision of terrain evaluation using air photos and drilling for industrial "Energy Park," Bruce Nuclear Power Station, Ontario.

1981 Technical supervision of analyses of consolidation and negative skin friction effects on well casings beneath artificial islands, Beaufort Sea.

1973 Analyses of foundation stability of highway embankment of soft clay, Saint John, New Brunswick.

1972 Site investigation and recommendation for school and housing developments, Moncton, New Brunswick.

1972 Site investigation and terrain evaluation for proposed industrial park, Saint John, New Brunswick.

1972 Supervision of drilling from barge in Bay of Fundy for waste water outfall, Saint John, New Brunswick.

1971 Supervision of site investigation and caisson load test for large hospital development, Glasgow, U.K.

1971 Block sampling from augured shaft, site investigation drilling, laboratory test analysis and finite element modeling of deep excavation in clay, London, U.K.

1971 Site investigation and foundation design recommendation for mail sorting facility, Washington, U.K.

1970 Supervision of site investigation and caisson design for hospital, London, U.K.

1970 Analysis of site investigation data and design of piling for dock facility, Chittagong, Bangladesh.

Experience in Engineering Geology and Rock Mechanics

1984 Technical review of analyses and proposed rock support, Chamera Hydroelectric Development, India.

1981 Site supervision and analysis of in situ stress tests in exploratory audit, Saudi Arabia.

1980 Technical review of analyses and support estimates for caverns for compressed air energy storage facility, Maryland.

1976 Stability analysis for channel rock plug, Churchill River Diversion, Manitoba.

1975 Review of rock conditions and blasting for control structures, Missi Falls and Notgi, Churchill River Diversion, Manitoba.

1974 Site Geotechnical Engineer responsible for design of open cut rock support, Long Spruce Generating Station, Manitoba.

1973 Site geotechnical engineer reviewing blasting procedures and vibration monitoring, powerhouse and spillway excavations, Long Spruce Generating Station, Manitoba.

1973 Review of geological data, air photo interpretation and site investigation for sand and gravel resources in Saint John area, New Brunswick.

1971 Design of investigation and site supervision of grouting programs for old mine workings, Glasgow and Leeds, U.K.

Experience in Modeling and Systems Analysis

1983 Project Manager for software developments for sonar transducer modeling, Canadian Department of Defense.

1982 Technical supervision and review of thermal and stress analyses for high temperature, high pressure viscometer, Ontario Research Foundation.

1982 Project Manager for study of ship hull vibration, Canadian Department of Defense.

1981 Technical review of risk reliability study, LNG liquification plant, Melville Island, Northwest Territories.

1981 Technical supervision of static and seismic analyses of silo containing radioactive residues, Lewiston, New York.

1980 Technical review of modeling of penstock, turbine, generator, and draft tube to investigate system instability, Tarbela, Pakistan.

1978 Technical input to analyses of ground source heat pumps, Canada.

Experience in Radioactive Waste

1991 Technical manager for risk assessment of potential release of radioactive liquid wastes, Idaho Falls National Engineering Laboratory, Idaho.

1990 - 1991 Technical review of RI/FS work plans and reports for mixed waste facilities, Hanford, Washington.

1988 - 1989 Project director for environmental services contract, Westinghouse Hanford Company, including Part B Application for low-level waste burial grounds.

1985 - 1986 Technical review of RCRA Part B Application, Hanford, Washington.

1985 - 1986 Project Manager for development of mathematical models for flow in fractured rock, Battelle, OCRD.

1985 Technical review of tracer test for basalt, Hanford, Washington.

1984 - 1985 Technical review of in situ test plan report for salt repository, Battelle, ONWI.

1984 - 1985 Technical supervision of study of processes to be considered in siting Monitored Retrieval Storage (MRS) facility.

1984 Technical review of test shaft facility for repository in Tuff, Nevada.

1982 Project Manager for design studies of multi-level crystalline rock repository, Atomic Energy of Canada Limited.

1980 Technical supervision of seismic analyses for uranium tailings dam, Uravan, Colorado.

1978 Project Engineer for design study for single level repository in crystalline rock, Atomic Energy of Canada Limited.

1978 Review of state-of-the-art pluton hydrology and modeling concepts, relative to radioactive waste disposal, Atomic Energy of Canada Limited.

1978 Preparation of reverse well and island disposal concepts for Draft Generic Environmental Impact Statement for Commercially Generated Radioactive Waste, U.S. DOE.

1978 Technical input to hydrogeological hazard assessment of shale grout injection of high-level waste, West Valley, New York.

1977 Finite element modeling of groundwater flow around proposed radioactive waste repository, Sweden.

Experience in Dams and Hydroelectric Development

1988 Technical input to geotechnical and hydrological evaluation of siting and design, small hydro sites, Baker Lake and Nooksak River, Washington.

1984 Technical supervision of stress analyses for underground powerhouse, Chamera, India.

1983 Technical supervision of stress analysis using finite element methods to investigate cause of cracking in powerhouse, Mactaquac, New Brunswick.

1982 Technical review of static and dynamic analyses for Karun 2 concrete arch dam, Iran.

1981 Technical input and review of analyses to study effect of spillway vibration on powerhouse, Nipawin, Saskatchewan.

1981 Technical supervision of static and dynamic analyses, Watana Dam (earth/rockfill) and Devil Canyon Dam (concrete arch), Susitna River.

1979 Site investigation at existing dam for redevelopment, Oswego, NY.

1976 Feasibility level designs at various sites for flood control dams, Red Deer River, Alberta.

1974 - 1976 Site visits during construction to review engineering geology data, Notigi, South Bay Channel and Missi Falls, Manitoba.

1973 - 1974 Review of foundation instrumentation results, Kettle Generating Station, Manitoba.

1973 - 1974 Site geotechnical engineering, Long Spruce Generating Station, Manitoba, including coffer dam construction, rock excavation, grouting, earth dam construction and dykes on permafrost.

1972 Site investigation of dam to determine cause of settlement of crest, Musquash Dam, New Brunswick.

Publications and Presentations

Burgess, A.S., "Groundwater Monitoring for Contaminant Detection" International Society for Soil Mechanics and Foundation Engineering Rio de Janeiro, Brazil, August 1989.

Burgess, A.S., "Investigation of Contaminated Sites" Keynote Speaker Canadian Geotechnical Society 1st Environmental Geotechnics Conference Montreal 1991.

Burgess, A.S., "The ABC's of Groundwater Science" A course for lawyers and managers, Executive Enterprises, Inc., Washington D.C., San Franisco, Denver 1990-92.

Burgess, A.S., Patrick, G.C., "Control and Remediation of Solvent Releases in the Santa Clara Valley" ENSOL 90' Conference.

Corser, P., Burgess, A.,"Costs of Permitting, Design and Construction of RCRA Subtitle C Facilities". Conference presentation in May of 1990.

Patrick, G.C., Burgess, A.S., "Field Studies of Nonaqueous Phase Liquids at two Sites in California's Santa Clara Valley" Conference on Subsurface Contamination by Immiscible Fluids, Calgary, Alberta, Canada April 18 - 20, 1990.

Burgess, A.S., Leonard, M.S., and Laird, G.S., "Design and Construction of a Soil Bentonite Slurry Wall Around an Operating Facility Superfund Site," Proceedings: Second International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, June 1-5, 1988.

Burgess, A.S., Curtis, D.D., N. Pui, and D. Mitchell, "Extraction of Oil Through Permafrost Related Problems, Controlling Mechanisms and Recent Research," International Permafrost Conference, Fairbanks, Alaska, April 1983.

Burgess, A.S., Curtis, D.D., and Laut, S.W., "Exploring for Oil Through Offshore Permafrost, "Northern Miner, December 1983.

Thompson, S.N., Burgess, A.S., and O'Dea, D., "Coal Tar Containment and Cleanup, Plattsburgh, New York," Hazardous Materials Control Research Institute, 4th National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D.C., October 1983.

Burgess, A.S., "Seismic Considerations for the Susitna Hydroelectric Project," Regional Seminar on Earthquake Fundamentals for Alaska, October 1982.

Ratigan, J.L., Osnes, J.D., Brandshaug, T., and Burgess, A.S., "Temperature History for CANDU Reprocessing Waste and Immobilized Fuel in an Underground Vault in Plutonic Rock ," U.S.Symposium on Rock Mechanics, Cambridge, Massachusetts, June 1981.

Burgess, A.S., Charlwood, R.G., Ratigan, J.L., Card, E., and Ohta, M., "A Disposal Center for Immobilized Nuclear Waste: Conceptual Design Study," Atomic Energy of Canada Limited 6415, February 1980.

Burgess, A.S., Charlwood, R.G., Ratigan, J.L., Card, E., and Ohta, M., "A Disposal Center for Irradiated Nuclear Fuel: Conceptual Design Study," Atomic Energy of Canada Limited 6415, February 1980.

Burgess, A.S., "Modeling of Groundwater Flow in Fractured Rocks for Radioactive Waste Repository Studies," Proceedings: Work ship Numerical Modeling Thermo hydrological Flow in Fractured Rock Masses, Berkeley, California, (LBL 11566), 1980.

Burgess, A.S., Charlwood, R.G., and Mahtab, A., "Geological Engineering Aspects of Conceptual Design of Radioactive Waste Vault in Hard Crystalline Rock," The Canadian Mining and Metallurgical Bulletin, July 1980.

Burgess, A.S., and Charlwood, R.G., "Immobilized Fuel and Reprocessing Waste Vaults: Design Criteria and Synthesis of Thermal-Rock Mechanics Analyses," Atomic Energy of Canada Limited TR58, January 1979.

Burgess, A.S., and Skiba, E., "Immobilized Fuel Vault: Container Near-Field Thermal-Rock Mechanic Analyses," Atomic Energy of Canada Limited TR49, January 1979.

Burgess, A.S., and Sandstrom, P.O., "Immobilized Fuel Vault: Design Concepts and Layouts," Atomic Energy of Canada Limited TR59, March 1979.

Burgess, A.S., and Sandstrom, P.O., "Reprocessing Waste Vault: Design Concept and Layouts, "Atomic Energy of Canada Limited TR60, March 1979.

Burgess, A.S., Skiba, E., and Charlwood, R.G., "Analyses of Groundwater Flow Around a High-Level Waste Repository in Crystalline Rock," OECD Nuclear Energy Agency, Paris, France, March 1979.

Burgess, A.S., "Design Concepts for Underground Disposal of Irradiated CANDU Fuel and Reprocessing Wastes in Crystalline Rocks," Canadian Nuclear Association 19th Annual Conference, Toronto, Canada, June 1979.

Burgess, A.S., Codrington, J.B., Skiba, E.L, and Cane, D., "Canadian Work on Ground Heat Source Heat Pumps," Nordic Symposium on Earth Heat Pump Systems, Goteborg, Sweden, October 1979.

Burgess, A.S., Ratigan, J.L., and Stille, H., "Geohydrological Aspects of a Conceptual High-Level Waste Repository in Crystalline Rock," 31st Canadian Geotechnical Conference, Winnepeg, 1978.

Burgess, A.S., and Charlwood, R.G., "Immobilized Fuel and Reprocessing Waste Vaults: Design Specification and Scope of Work," Atomic Energy of Canada Limited TR47, April 1978.

Burgess, A.S., and Sandstrom, P.O., "Immobilized Fuel and Reprocessing Waste Vaults: Preliminary Design Concepts," Atomic Energy of Canada Limited TR49, May 1978.

Burgess, A.S., Charlwood, R.G., McCreath and Mahtab, "Geological Engineering Factors in the Design of a Radioactive Waste Repository in Hard Crystalline Rock," Canadian Geoscience Council Forum, October 1978.

Burgess, A.S., Edwards, A., Beukens, R., and Allen, G., "Use of Tailings as Back fill in Uranium Mines," CNA 18th Annual International Conference, Ottawa, June 1978.

Burgess, A.S., Keil, L.D., Neilsen, L.M.N., and Koropatnick, L.A., "Blast Vibration Monitoring of Rock Excavations," Canadian Geotechnical Journal Vol. 14, No. 4, 1977.

Burgess, A.S., Stille, H., and Lindblom, U., "Regional Groundwater Flow Analyses," Groundwater Movements Around a Repository: Karnbranslesakerhet, Stockholm, September 1977.

Stille, H., Burgess, A.S., and Lindblom, U.E., "Geological and Geotechnical Conditions, "Groundwater Movements Around a Repository: Karnbranslesakerhet, Stockholm, September 1977.

Ratigan, J.L., Burgess, A.S., Skiba, E.L., and Charlwood, R., "Repository Domain Groundwater Flow," Groundwater Movements Around a Repository: Karnbranslesakerhet, Stockholm, September 1977.

Burgess, A.S., "Engineering Geology and Geohydrology of the Magnesian Limestone of North England (Ph.D. Thesis)," University of Durham, England, 1970.

Burgess, A.S., and Russell, M.J., "Tectonic Comparison of North Atlantic and Middle East Rifting," Nature, Vol. 222, June 1969.

Burgess, A.S., Attewell P.B., and Aucott, J.W., "Computerized Data Processing from an X-Ray Texture-Goniometer," Mineral Magazine, Vol. 37, No. 287, September 1969.

Vita for

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Education

Ph.D., Civil Engineering, University of Texas at Austin, 1990
M.S., Civil Engineering, University of Wyoming, 1986
B.S., Civil Engineering, University of Nevada, Reno, 1984 (w/ High Distinction)

Honors and Awards

University of Illinois at Chicago:
Nominee, Silver Circle Award for Teaching Excellence, 1992

University of Texas at Austin:
Endowed Presidential Scholarship 1988, 1989, 1990

University of Nevada, Reno:
Civil Engineering Student of the Year 1984; Alan Ladd Johnston Scholarship; Major Max C. Fleischmann Scholarship; Royal D. Hartung Education Scholarship; Virginia M. Johnson Scholarship

Publications

Refereed Papers:

Hathhorn, W. E. and R. J. Charbeneau (1994). "Stochastic Fluid Travel Times in Heterogeneous Porous Media," *J. Hydraulic Engr.*, ASCE, 120(2), pp. 134-146.

Hathhorn, W. E. (1994). "A Second Look at the Method of Random Walk," submitted to J. of Contaminant Hydrology.

Tung, Y.K. and W. E. Hathhorn (1990). "Stochastic Waste Load Allocation," *Ecological Modeling*, 51, pp. 29-46.

Hathhorn, W. E. and Y. K. Tung (1989). "Bi-objective Analysis of Waste Load Allocation Using Fuzzy Linear Programming," *Water Resource Management*, 3, pp. 243-257.

Tung, Y. K. and W. E. Hathhorn (1989). "Determination of the Critical Locations in a Stochastic Stream Environment," *Ecological Modeling*, 45, pp. 43-61.

Tung, Y. K. and W. E. Hathhorn (1989). "Multiple-Objective Waste Load Allocation," *Water Resource Management*, 3, pp. 129-140.

Hathhorn, W. E. and Y. K. Tung (1988). "Assessing the Risk of Violating Stream Water Quality Standards," *J. of Environmental Management*, 26, pp. 321-338.

Tung, Y. K. and W. E. Hathhorn (1988). "Probability Distribution for Critical DO Location in Streams," *Ecological Modeling*, 42, pp. 45-60.

Tung, Y. K. and W. E. Hathhorn (1988). "Assessment of Probability of Dissolved Oxygen Deficit," *J. of Environmental Engineering*, ASCE, 114(6), pp. 1421-1435.

Additional Journal Papers in Preparation:

Hathhorn, W. E. (1994). "A Discussion of Model Error in the Use of the Advection-Dispersion Equation: I. The Uncorrelated Framework." in preparation.

Hathhorn, W. E. (1994). "A Discussion of Model Error in the Use of the Advection-Dispersion Equation: II. The Correlated Framework." in preparation.

Proceedings:

Hathhorn, W. E. (1994). "An Analytic Quantification of the Fluid Passage Time Problem in Heterogeneous Porous Media" submitted to *The Proceedings of the Fourteenth Annual Hydrology Days,* Apr. 5-9, Ft. Collins, CO.

Hathhorn, W. E. (1993). "A Review of Fluid Movement in Compacted Clays: The Case of Macropore Flow" in *Engineering Hydrology: Proceedings of the Symposium,* ASCE, July 25-30, San Francisco, pp. 473-478.

Hathhorn, W. E. and Y. K. Tung (1989). "Water Quality Assessment in a Stochastic Stream Environment" in *Environmental Engineering: Proceedings of the 1989 Specialty Conference,* ASCE, July 10-12, Austin, Texas, pp. 600-607.

Technical Reports and Theses:

Hathhorn, W. E. (1990). "Diffusion Theory and the Fluid Passage Time Problem in a Porous Media," Ph.D. Dissertation, Department of Civil Engineering, The University of Texas at Austin.

Hathhorn, W. E. (1988). "Enhanced Methodology for the Response to a Chemical Spill," prepared for the Union Carbide Co., Department of Civil Engineering, University of Texas at Austin, February.

Hathhorn, W. E. (1988). "Regulatory Investigative Treatment Zone Model (RITZ-UT): A User's Manual," prepared for the Department of Civil Engineering, University of Texas at Austin, August.

Hathhorn, W. E. (1986). "Optimal Waste Load Allocation in a Stream Environment Under Uncertainty", M. S. Thesis, University of Wyoming.

Presentations

"An Analytic Quantification of the Fluid Passage Time Problem in Heterogeneous Porous Media," to be presented at the Fourteenth Annual Hydrology Days, Ft. Collins, CO., Apr. 5-9, 1994,

"A Statistical Discussion of Model Error in the Use of the Advection Dispersion Equation," to be presented at the 1994 Pacific Northwest/Oceania Conference: Assessment of Models for Groundwater Resources Analysis and Management, Oahu, Hawaii, Mar. 21-23, 1994.

"The Tradeoff Between the Desired Hydraulic Properties and the Risk to Contamination During Artificial Recharge," Regional Seminar on the Potential for Artificial Recharge of Groundwater, University of Jordan, Amman, December 13-15, 1993.

"A Review of Fluid Movement in Compacted Clays: The Case of Macropore Flow," International Symposium on Engineering Hydrology, ASCE National Conference on Hydraulic Engineering, San Francisco, July 25-30, 1993.

"Hydrogeologic Performance Assessment: The Fluid Passage Time Problem," Invited Lecture, University of Illinois at Urbana, Urbana, Illinois, October 16, 1991.

"Hazardous Waste Management: Research Perspectives and Objectives," Invited Lecture, Idaho State University, Pocatello, Idaho, September 20, 1991.

"Stream Water Quality Assessment Under Uncertainty," National Conference on Environmental Engineering, ASCE Austin, Texas: July 10-12, 1989.

"Multiobjective Waste Load Allocation Using Fuzzy Linear Programming", Annual Conference Rocky Mountain AWWA-WPCA, Breckenridge, Colo.: Sept. 7-10, 1986.

Professional Committees & Activities

Member, ASCE's Task Commitee on Groundwater Modeling Review, 1992-93
Member, ASCE Technical Committee on Probabilistic Methods in Hydrology
Participating Member, ASCE Technical Committee on Groundwater Hydrology
Reviewer, J. of Environmental Engineering, ASCE, 1992-93
Reviewer, J. of Hydraulic Engineering, ASCE, 1993
Reviewer, J. of Computing in CE, ASCE, 1993
Reviewer, J. of Geotechnical Engineering, ASCE, 1994.
Reviewer, Soil Science Society of America Journal, SSSA, 1993

Professional Experience

Assistant Professor, Department of Civil & Environmental Engineering, Washington State University: Sept. 1992 - present

Research Consultant/Temporary Employee, Energy Systems Division, Argonne National Laboratory, Argonne, Illinois: Oct. 1991 - present

Assistant Professor, Department of Civil Engineering, Mechanics and Metallurgy, University of Illinois at Chicago: Sept. 1990 - Aug. 1992

Graduate Research and Teaching Assistant, Department of Civil Engineering, University of Texas at Austin: Jan. 1987 - Aug. 1990

Graduate Research Assistant, Department of Civil Engineering, University of Wyoming: Sept. 1985 - Dec. 1986

Technical Aid, U.S.D.A.- ARS, Arid Research Center, Tucson, Az.: Summer 1985

Instructor, Department of Civil Engineering, The University of Arizona: Spring, 1985

Administrative Experience

Coordinator of the Environmental Subsurface Program, Washington State Univerisity

Coordinator of Departmental Graduate Studies Program in Environmental/Water Resources Engineering, University of Illinois at Chicago

Coordinator of Army Corp of Engineers HEC-2 Short Course, August 12-14, 1991

Teaching Experience

Undergraduate Courses in:

- Hydraulic Engineering and Hydrology
- Hydraulic Engineering Lab
- Introduction to Environmental Engineering
- Groundwater Hydrology
- Surveying
- Senior Design

Graduate Courses in:

- Hazardous Waste Engineering
- Advanced Groundwater Hydraulics
- Subsurface Contaminant Transport

Professional Memberships

American Geophysical Union; American Society of Civil Engineers; National Water Well Association; Soil Science Society of America; Phi Kappa Phi; Tau Beta Pi

JAMES R. KUNKEL, Ph.D., P.E.

EDUCATION:

PhD, Hydrology & Water Resources, The University of Arizona, 1974.
MS, Civil Engineering, The University of Connecticut, 1969.
BS, Civil Engineering, St. Martin's College, 1967.

OSHA Hazardous Waste Operations Training Course, 24-Hours, 1990.
Supervisory Health and Safety Training, 8-Hours, 1989.
First Aid and CPR Training, 8-Hours, 1990.
First Aid, 4-Hour Refresher, 1993.
CPR Training, 4-Hour Refresher, 1993.
Self Rescuer Training, 1991.

CAPABILITY SUMMARY:

9413225.2954

Dr. Kunkel has 27 years of theoretical and practical experience in hydrology and water resources engineering for a wide range of projects. Dr. Kunkel is familiar with RCRA and CERCLA regulations and has participated in characterization of both hazardous and mixed waste sites. He has done research on disposal of high level nuclear waste and site characterization for nuclear waste disposal. His specific experience with grout curtains, slurry walls, ion exchange and reverse osmosis systems includes: (1) analysis of grout curtain performance related to ground-water flow for a waste soil tank leak in the Parachute Creek alluvium near Parachute, Colorado; (2) analysis of grout-curtain cutoff walls and pumping wells to control contaminant plumes at the Rocky Flats Plant near Denver, Colorado; (3) a study of reverse osmosis and mechanical evaporation for concentration of mixed wastes at the Rocky Flats Plant near Denver, Colorado; and (4) participation in the ongoing HRA-EIS at the Hanford Site near Richland, Washington.

His groundwater hydrology experience has included installation and monitoring of wells for water levels and water quality. Dr. Kunkel has designed and performed pumping and tracer tests in porous media and fractured rock to estimate hydraulic and transport characteristics. He has written a discrete fracture model to simulate flow and chemical transport in fractured media. Dr. Kunkel has directed groundwater and soil investigations for design of rapid infiltration basins for treatment of nitrogen and phosphorus in treated, secondary domestic wastewater. He has also written an empirical unsaturated flow model for water balance estimates of reclaimed waste disposal piles. His groundwater capabilities also include investigation and analysis of hydrologic conditions related to hazardous waste and nuclear waste sites.

Dr. Kunkel has designed and installed monitoring equipment for vadose (unsaturated) zone studies in many types of soils including clay soils and gravel soils. He also has supervised the collection of vadose zone soil samples for laboratory testing of moisture characteristic curves, unsaturated hydraulic conductivity and other physical and chemical analyses.

He has participated in closure plans for nuclear and mixed waste facilities. He has studied various aspects of "zero-discharge" from federal nuclear facilities as part of State and Federal agreements, including conceptual design of water facilities. His federal facilities experience has included selected projects in the states of Colorado, Washington and Idaho. He has planned, supervised, and analyzed the collection of surface-water data, ground-water data and vadose zone soil physical and chemical data for characterization of contaminated sites and for monitoring at federal facilities.

Dr. Kunkel conducted research on dispersion and flow and transport in basalts as part of a three-year program for the U.S. Nuclear Regulatory Commission (NRC). The research investigated new field methods for obtaining dispersivity in saturated fractured rock at a research well field near Spokane, Washington. Results of the research have been published by the NRC in a series of NUREG reports. He wrote a discrete fracture model to calculate dispersion in fractured rock. Dr. Kunkel also did research work on ground water hydrologic techniques associated with coal-bed methane recovery. He has written or helped write several corporate software packages for analysis of pumping and slug test data and selection of pumps for wells. This research was for the Gas Research Institute (GRI).

Dr. Kunkel is on the adjunct faculty in the Department of Geology and Geological Engineering. He teaches graduate courses on flow and transport in fractured rock, and unsaturated zone hydrology. He is advisor to a doctorate-level graduate student on flow and transport in variably saturated media. He currently has research projects related to contaminant transport in variably saturated fractured rock, and field measurement of recharge in variably saturated geologic media. He is currently participating on an independent review team, with other School of Mines faculty, related to analysis of the adequacy of work plans and statistical analyses of soil and water data related to a Superfund site southwest of Denver, Colorado.

He has analyzed surface and groundwater rights in Colorado and New Mexico including change of point of diversion and type of use. His studies have resulted in augmentation plans and probabilistic estimates of when a given water right may be in priority. He has used several consumptive use models to estimate water depletions for agricultural crops as well as natural vegetation. Examples of his specific experience include estimates of changes in hydrologic components (runoff, evapotranspiration, recharge, etc.) due to construction of industrial facilities near Parachute, Colorado; return flows from use of non-tributary groundwater rights in the Cherry Creek Basin; probabilistic analysis of undeveloped streamflows in the South Platte River basin between Waterton and the Nebraska state line; and potential for using mine dewatering as a source of industrial water supply in New Mexico. Dr. Kunkel has testified in Colorado Water Court and at numerous administrative and public hearings regarding the results of his analyses.

Dr. Kunkel has done monitoring and modeling for urban runoff and evaluated the outputs of non-point source pollution on streams, reservoirs and lakes. He has developed information for water discharge permits under State and Federal regulations. He has done water resources planning, design, and operational studies for over 50 tailing, flood control, recreational, and water supply dams; water-quality modeling of recreational and water supply reservoirs including temperature stratification, dissolved oxygen, and dissolved solids profiles; and water-quality modeling of streams including temperature, dissolved oxygen, nutrients, and other selected conservative and non-conservative constituents. He has applied a dam-break flood model to several different types of dams, including tailings dams. His design experience includes diversion, decant, and spillway systems for waste impoundments, tailing dams, water supply dams, municipal solid waste disposal areas, and other solid waste disposal areas. Dr. Kunkel has worked on 10 flood insurance studies involving river hydraulics. He has used most of the available public domain surface water hydrologic and hydraulic models including, but not limited to, the HEC models and the SCS models.

Dr. Kunkel has done analyses of water supply systems for municipal, industrial, and agricultural use. He has participated in water rights and water supply analyses for five North Central New Mexico pueblos and a water resources inventory for the Mescalero Apache Tribe in Mescalero, New Mexico. His design experience includes plans and specifications for a $7 million pumping and pipeline facility in association with off-channel storage of water from the Yellowstone River, analysis of the primary pumping facility and force main for Ridges Metropolitan District near Grand Junction, Colorado. Dr. Kunkel has designed large-diameter water-supply wells for domestic water supply for Willows Water District near Denver, Colorado. He has analyzed and designed over 10 water storage facilities for municipal, industrial, and irrigation water supply in the western United States.

PROFESSIONAL EXPERIENCE:

ASI, Senior Principal Engineer, 1992 - Present
ASI, Senior Hydrologist/Project Manager, 1989 - 1992

Colorado School of Mines, Adjunct Associate Professor, 1989 - Present

In-Situ Inc., Senior Hydrologist, 1983 - 1989

Woodward-Clyde Consultants, Assistant Chief of the Water Resources Division, 1976 - 1983.

William Matotan & Associates, Engineers, Project Manager, 1974-1976.

Mexican Agriculture and Water Resources Ministry, Mexico, D.F., Hydrologic Consultant to the Papaloapan River Basin Commission, 1972 - 1974.

Pima County Highway Department, Civil Engineer, 1969 - 1972.

PROFESSIONAL REGISTRATIONS/ AFFILIATIONS:

Registered Professional Engineer, Civil Engineering, - Colorado, Wyoming, New Mexico, and Washington.

Registered Professional Hydrologist, (American Institute of Hydrology)

Member, American Society of Civil Engineers

Member, American Water Resources Association

Member, Colorado Ground Water Association

PUBLICATIONS: Dr. Kunkel has authored or co-authored over 16 papers and technical publications, over 90 major consultant reports, and has made over 30 oral presentations at technical meetings, symposia, university seminars, training courses, public meetings and litigation proceedings. His publications include the streamflow and sediment discharge characteristics of the Piceance Basin, on assessing water resources development alternatives in the South Platte River Basin, on water balance and water quality at an oil-shale retorting facility, on calculation of dispersivity in saturated, fractured rock, on assessment of urban runoff water quality characteristics and on unsaturated zone monitoring and statistical data analyses. He was elected to *Who's Who Among Students in American Colleges and Universities* in 1966.

SECURITY CLEARANCE: DOE "Q" Clearance (1991-1994) Inactive, DoD Secret Clearance (1990-1993) Inactive.

JAMES R. KUNKEL, Ph.D., P.E.
BIBLIOGRAPHY
(STATUS AS OF JANUARY 28, 1994)

I. TECHNICAL PUBLICATIONS

Vadose-Zone Monitoring, Sanitary Treatment Plant Sludge-Drying Beds, Rocky Flats Plant, Golden, Colorado (with J. Scott Thompson), *Proceedings of the ASCE Water Resources Planning and Management Division, 21st Annual Conference*, May 23-26, 1994, Denver, Colorado, (in press).

Surface-Water Quality Assessment, Woman Creek Priority Drainage Site Characterization, Rocky Flats Plant near Golden, Colorado (with T. D. Steele, T. D. Smart, and E. C. Mast), *Proceedings of the 1994 Annual Meeting of the American Institute of Hydrology - "Toxic Substances in the Hydrologic Sciences"*, April 10-14, 1994, Austin, Texas (in press).

Biodiversity and Water-Resources Development, Cuatro Ciénegas Region, Coahuila, México, *Proceedings of the AWRA-Colorado Section 1994 Annual Symposium*, March 18, 1994, Denver, Colorado (in press).

Chemical-Constituent Load Removal Efficiency of an Urban Detention Pond/Wetlands System in the Denver Metropolitan Area, Colorado (with T. D. Steele, B. Urbonas, and J. Carlson) in F. Pierce Linaweaver [Editor], *Environmental Engineering, Saving a Threatened Resource - In Search of Solutions*: Proceedings of the Environmental Sessions at Water Forum '92, American Society of Civil Engineers, New York, NY, pp. 352-357.

A Field-Tracer Test for Estimating Dispersion Coefficients in Saturated, Fractured Media (with S. C. Way). *Proceedings of the Symposium on Fractured and Jointed Rock Masses*, Conference of the International Society for Rock Mechanics, June 3-5, 1992, Lake Tahoe, California, Preprint pp. 717-722.

Computer-Aided Characterization of Wellfield-Testing Results in Basalts (with J. A. Paschis, T. D. Steele, and L. B. Hall). *Proceedings of the International High Level Radioactive Waste Management Conference*, April 12-16, 1992, Las Vegas, Nevada, v. 1, pp. 475-480.

Trace-Metal Concentration Changes in Urban Stormwater Runoff Routed Through a Detention Pond and Wetlands in the Denver Metropolitan Area, Colorado (with T. D. Steele). *Proceedings of the Colorado Water Engineering and Management Conference/Symposium*, March 2-3, 1992, Aurora, Colorado, pp. 303-310.

A Comparative Assessment of Nutrient-Biological Conditions in Selected Reservoirs in the Denver Metropolitan Area, Colorado (with T. D. Steele, R. C. Averett, and W. F. Lorenz). *Proceedings of the AWRA Symposium on Urban Hydrology*, M. E. Jennings, Editor, November 4-9, 1990, Denver, Colorado, pp 89-98.

Shop Creek Stormwater Quality Enhancement Project (with K. Wegener and J. T. Wulliman). *Proceedings of the ASCE National Conference on Hydraulic Engineering*, San Diego, California, July 30-August 3, 1990.

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BIBLIOGRAPHY
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I. TECHNICAL PUBLICATIONS (CONTINUED)

Computerized Urban Runoff Water-Quality Data Handling Begins with Electronic Data Collection and Laboratory Reporting (with T.D. Steele). *Proceedings of the International Symposium on the Design of Water Quality Information Systems*, Edited by R. C. Ward, J. C. Loftis, and G. B. McBride. Information Series No. 61, Colorado State University, Fort Collins, Colorado, pp. 318-336, October 1989.

Flow of Groundwater and Transport of Contaminants through Saturated Fractured Geologic Media from High-Level Radioactive Waste (with T.D. Steele, S.C. Way, R.A. Koenig and others). Report prepared for the U.S. Nuclear Regulatory Commission, NUREG/CR-5391, June 1989.

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JAMES R. KUNKEL, Ph.D., P.E.
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II. PRESENTATIONS

"Soluciones Analíticas para el Transporte de Gasolina en la Zona Vadosa" (Analytical Solutions for Gasoline Transport in the Vadose Zone), Seminar presented to the faculty and graduate students of the Universidad Autónoma Agraria Antonio Narro, Saltillo, Coahuila, MEXICO, June 16, 1993.

"Restoration of Petroleum Hydrocarbons and Organic Chemicals in Soils and Ground Water," ECOMEX '92 Seminar on Soil/Groundwater Remediation Technology -- New Remedies for Old Problems, Alliance for International Environmental Studies, Inc., Mexico, D.F., MEXICO, July 28, 1992.

"Case Study of a Petroleum Hydrocarbon Remediation Site, Puerto Rico Air National Guard," ECOMEX '92 Seminar on Soil/Groundwater Remediation Case Studies, Alliance for International Environmental Studies, Inc., Mexico, D.F., MEXICO, July 29, 1992..

Chemical-Constituent Load Removal Efficiency of an Urban Detention Pond-Wetlands System in the Denver Metropolitan Area, Colorado (with T. D. Steele and B. Urbonas). Paper Presented at the North American Lake Management Society, 11th International Symposium, "Lake, Reservoir, and Watershed Management in a Changing Environment," November 11-16, 1991, Denver, Colorado.

Short Course on Environmental Concepts, Planning, and Regulations Related to the Mineral Industries. Three, 2-hour Lectures on: (1) Design Storm/Flood for Sizing of Hydraulic Structures - Applications to Mining; (2) Estimation and Control of Water and Wind Erosion; and (3) Water Quality and Mining. One, 2-hour Lecture on Hydrologic Monitoring Related to Mining was Prepared but Presented by Dr. T. D. Steele. Short Course Conducted by the Department of Environmental Sciences and Engineering, Colorado School of Mines for the Director General of Mines, Government of Mexico. May 20, 21, 22 and 27, 1991.

Shop Creek Stormwater Quality Enhancement Project (with K. Wegener and J. T. Wulliman). Paper Presented at the 26th Annual AWRA Conference "The Science of Water Resources: 1990 and Beyond." November 4-9, 1990. Denver, Colorado.

Monitoring Wells in Saturated and Unsaturated Porous Media and Fractured Rock. 3-Hour Guest Lecturer for Graduate Hydrology Course (GEGN 574A). Colorado School of Mines, Golden, Colorado, April 17, 1990.

Application of Data-Logger/Pressure-Transmitter/Conductivity-Probe Instrumentation in Long-Term Salt-Tracer Studies in a Fracture, Saturated Geologic Medium (with J.A. Paschis, R.D. Koenig and T.D. Steele). Paper Presented at the NWWA Conference on Field Techniques for Quantifying the Physical and Chemical Properties of Heterogeneous Aquifers, Dallas, Texas, March 20-23, 1989 (abstract published in Conference Program).

Introduction to Flow and Transport in Fractured Geologic Media. 3-Hour Guest Lecturer for Graduate Hydrology Course (GEGN 581A). Colorado School of Mines, Golden, Colorado, November 28, 1988; November 13 and 27, 1989.

II. PRESENTATIONS (CONTINUED)

Ground-Water Modeling. Presentation to Marathon Oil Company at the Ground-Water Workshop, Denver, Colorado November 1-3, 1988.

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Historical and Future Undeveloped Streamflows, South Platte River, Colorado (with T.D. Steele). Paper Presented at the AWRA 18th Annual Meeting, San Francisco, California, October 10-15, 1982 (abstract published in Conference Program).

Ground Water/Surface Water Interactions, One-day Lecture as part of the U. S. Geological Survey Training Course: Hydrologic Techniques for International Participants, June 21-August 13, 1982, Denver, Colorado.

JAMES R. KUNKEL, Ph.D., P.E.
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(STATUS AS OF JANUARY 28, 1994)

II. PRESENTATIONS (CONTINUED)

Water Use and Development Alternatives, South Platte River Basin, Colorado (with T.D. Steele, C.S. Curtis and W.B. Lord). Paper Presented at the ASCE Western Conference on Water and Energy: Technical and Policy Issues, Fort Collins, Colorado, June 27-30, 1982 (abstract published in Symposium Proceedings, p. 450).

Prediction of Dam-Break Floods. Paper Presented at the Colorado Natural Hazards Research Meeting, Lakewood, Colorado, April 1981.

Modeling of a Tailings Dam Failure (with R.S. Lytle). Paper Presented at the National Weather Service Dam-Break Model Symposium/Workshop, Tulsa, Oklahoma, October 15-19, 1979.

Public Law 92-500 and the Wastewater Treatment Plant Operator. Presented before the Central Section, New Mexico Water Supply and Pollution Control Association, Albuquerque, New Mexico, December 10-12, 1975.

III. OTHERS

Analysis of a Multipurpose Water Resource System in Southeastern Mexico. Ph.D. Dissertation, The University of Arizona Department of Hydrology and Water Resources. 1974.

Dr. Kunkel also has authored or co-authored over 90 engineering and hydrology reports for public and private clients. Many of these reports were submitted for review to federal, state and local regulatory agencies.

IV. THESES PREPARED UNDER DR. KUNKEL

Predicting Flow Characteristics of a Lixiviant in a Fractured Rock Mass, Thesis by Nadia C. Miller submitted in partial fulfillment of the requirements for the degree of Master of Science (Engineering Ecology), Colorado School of Mines, Golden, Colorado, April 9, 1992.

Estimation of Groundwater Recharge using Neutron Probe Moisture Readings near Golden, Colorado, Thesis by Nicolas J. Kiusalaas submitted in partial fulfillment of the requirements for the degree of Mater of Science (Geological Engineer), Colorado School of Mines, Golden, Colorado, November 12, 1992.

Study of Hydraulic Properties and Recharge of the Unsaturated Alluvial Aquifer at the Rocky Flats Plant, Jefferson County, Colorado, Master's Report submitted by Laurie A. Host in partial fulfillment of the requirements for the Degree of Master of Science in Environmental Science, University of Colorado, Denver, Colorado, November 17, 1993.

RICHARD A. MILLET

project director
water resources
tunnels
slurry wall construction
heavy civil construction

EDUCATION

Rensselaer Polytechnic Institute, Troy, New York: M.S., Civil Engineering, 1964
Rensselaer Polytechnic Institute, Troy, New York: B.S., Civil Engineering, 1962

REGISTRATION

Registered Professional Engineer: Alabama, California, Colorado, Illinois, Ohio, New Jersey, New York, North Carolina, Virginia, Washington, and West Virginia
Registered Geotechnical Engineer: California

PROFESSIONAL HISTORY

Woodward-Clyde Consultants, Staff Engineer to Executive Vice President and Managing Principal, 1966 to date
U.S. Army Corps of Engineers, OIC Engineering Material Section, U.S. Army Engineering School, Fort Belvoir, Virginia, 1964-1966
Rensselaer Polytechnic Institute, Troy, New York, Research Engineer, 1962-1964

REPRESENTATIVE EXPERIENCE

Mr. Millet has been responsible for geotechnic studies pertinent to design and construction of dams, tunnels, canals, nuclear and fossil power stations, industrial plants and facilities, highways, railroads, and bridges.

Mr. Millet has had extensive experience in the design and analysis of earth, rockfill, and tailing dams. His studies for such projects have included: establishing geotechnic, geologic and hydrologic design criteria; evaluation and selection of alternative dam sites; establishing field exploration of dam foundation conditions and potential borrow sources; evaluation and utilization of potential borrow sources; evaluation of embankment and foundation seepage and stability conditions; design of embankment sections; design of spillway and appurtenant structures; preparation of contract documents (plans and specifications); and design review and inspection during construction. He is currently Chairman of the U.S. Congress on Large Dams (USCOLD) Technical Committee on Dam Foundations.

Representative dam assignments include: Los Vaquerous Dam, Merrill Creek Reservoir Dam, Glendola Dam, Amos Dam, Sporn Dam, Lake Forest Dam, Lake Arrowhead, Lake Pinehurst, and Berne Reservoir Dam. These dams range in size from 65 to 500 feet and typically are in excess of 100 feet.

Mr. Millet was project sponsor for Woodward-Clyde services to Metropolitan Water District of Southern California for a multiphase planning study to establish a new terminal water storage facility (Eastside Reservoir) in Riverside County, California. The project began with the screening of 15 potential sites and was completed with the selection of two alternative sites for an 800,000-1,000,000 acre-ft storage facility. Issues addressed in this study included: seismic geology; earthquake engineering; alternative embankment cross sections (location and design); static and dynamic stability assessment; dam leakage; reservoir leakage; borrow utilization; constructability; and cost estimation.

Mr. Millet has been a leader in the use of cutoff walls for dams constructed by the slurry trench technique. In 1973 he designed and implemented the first U.S. application of a cement-bentonite cutoff wall at the Lake Arrowhead Dam in Georgia. Since that time, Mr. Millet has participated in the design and construction of over 15 cutoff walls constructed by the slurry wall technique including soil-bentonite, cement-bentonite, plastic concrete and concrete walls ranging in depth from 20 to 165 feet.

In addition to slurry wall cutoffs, Mr. Millet has considerable experience in the use of grouting techniques to seal previous rock and soil formations, including Karstic rock formations. Most recently, Mr. Millet designed the extensive (12 rows) cement-grouting program successfully implemented for the heavily weathered granitic foundation of the Merrill Creek Reservoir Dam.

Mr. Millet has also lead post-construction, geotechnic and hydrologic evaluations, and inspections of dams. Representative assignments include over 100 dams for: American Electric Power Service Corporation in Virginia, West Virginia, Ohio, Michigan and Kentucky; Diamondhead Corporation in North Carolina, Georgia, Louisiana, Oklahoma and New York; and American Waterworks Service Corporation in the Northeast.

In addition to his work on dams, Mr. Millet has had significant experience in geotechnic studies for tunnels associated with dam outlet works, and water diversion and transportation systems, including geologic exploration, support requirements, instrumentation and construction consultation. Representative assignments include: Glenwood Canyon I-70 vehicular tunnel, Colorado; East 63rd Street subway hard ground tunnels and shafts and Archer Avenue subway soft ground tunnels, New York City, New York; Amos Dam diversion tunnel, West Virginia; Lake Thistle, Utah, drop inlet and emergency and permanent drainage tunnel; Stanley Canyon, Colorado, drop inlet and diversion tunnel; and Tablachaca landslide drainage tunnels, central Andes, Peru.

While with the U.S. Army Engineering School in Fort Belvoir, Virginia, Mr. Millet was responsible for all instrumentation in soil engineering, engineering geology, bituminous paving, and plain and reinforcement concrete.

AFFILIATIONS

American Society of Civil Engineers (Fellow)
American Society for Testing and Materials
Chi Epsilon
Tau Beta Pi
Society of American Military Engineers
United States Congress of Large Dams
American Consulting Engineers Council

PUBLICATIONS

A list of selected publications is available upon request.

SELECTED PUBLICATIONS

A holistic approach to identifying causes of failure in the providing of geotechnical and environmental consulting services (with D.C. Moorhouse). Journal of Management in Engineering, ASCE, Vol. 10, No. 3. May, 1994.

Contractor quality control. The Military Engineer, No. 549. May - June, 1992.

U.S.A. Practice slurry wall specifications 10 years later (with J-Y Perez and R.R. Davidson). American Society for Testing and Materials, ASTM STP 1129. 1992.

Matrix evaluation of structural grouting of rock (with R.L. Engelhardt). Proceedings, American Society of Civil Engineers Specialty Conference on Grouting in Geotechnical Engineering. February, 1982.

Current USA practice: slurry wall specifications (with J-Y Perez). Journal of the Geotechnical Engineering Division, ASCE 107 (GT8), 1041-1056. 1981.

Comparison of finite element predictions of horizontal elastic rock movements to field measurements in an excavation in New York City (with A.J. Ciancia and L.C. Dorrler). Presented at the 20th symposium on Rock Mechanics. Austin, Texas. June 4-6, 1979.

Bedrock verification program for Davis-Besse nuclear power station (with D.C. Moorhouse). Proceedings, American Society of Civil Engineers Specialty Conference on Structural Design of Nuclear Plant Facilities. December 1, 1973.

Use of geophysical methods to explore solution susceptible bedrock -- Davis-Besse nuclear power station (with D.C. Moorhouse). Woodward-Clyde Consultants, Geotechnical Bulletin V, No. 2. 1971.

9113225.2966

MARTIN VORUM, P.E.

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(303) 789-0848

EXPERIENCE SUMMARY: ANALYSIS, DESIGN, AND MANAGEMENT

Offering over 20 years of professional accomplishment in technical analysis, design and project management, and staff supervision in resource recovery, manufacturing, environmental compliance, and remediation industries. Recognized for the ability to characterize problems; synthesizing efficient solutions; attention to detail; and developing "nuts and bolts" answers which increase safety, effectiveness, productivity, and profitability. Most recent activities have centered on the evaluation, design, installation, and operation of diverse technologies for remediation systems. Several activities that pertain specifically to the management and remediation of water include:

- Analysis and testing of reverse osmosis effectiveness at high brine concentrations.
- Analytical modeling of groundwater brine chemistry (geothermal).
- Recovery of metal/solvent contaminated groundwater.
- Analysis of solution data for hydrometalurgical extraction systems.
- Detailed analysis of mechanical, chemical, and thermodynamic design factors in industrial process systems, including separation methods.
- HAZOPS and operability analyses for complex process systems.
- Quality control for design and construction.

Career Overview and Education

Served as a **Senior Project Manager** at Waste-Tech Services, 1992-1993, supervising the work of four projects managers. **Project Supervisor** and **Project Manager** for Canonie Environmental Services Corp, 1987-1992.

Provided services as an **Independent Consultant** in process design for gold mills and geothermal power plants in 1986 and 1987.

From 1976-1986, served as a **Process Engineer** with Stearns Roger Corporation (1981-1986), a major engineering/construction firm in the oil, gas, and petrochemical fields; and with Coury & Associates, Inc. (1976-1981), a specialty consulting firm in the geothermal and desalination fields.

Bachelor of Science in **Chemical Engineering**, University of Houston, 1975.
Professional Engineer: Colorado, Chemical Engineering
Graduate studies in **Biochemical Engineering**, Colorado State University, 1985.

Relevant Project Experience

ENVIRONMENTAL SERVICES: SITE REMEDIATION, WASTE MINIMIZATION

1. Wastewater Treatment Optimization (Metals Removal from Water) -- Managed trouble-shooting for printed circuit electroplating. Recommended changes in conditions and control produced successful operation at nominal cost.

2. Central Groundwater Extraction System (Recovery, Control, Treatment) -- Managed design through startup of extraction system for pump-and-treat operation at Seattle Superfund site. The system used a central vacuum unit to raise 225 gallon-per-minute water flow from 206 shallow wells on 17 acres. Contaminants were metals, VOCs.

INDUSTRIAL PROCESSES: OIL, GAS, PETROCHEMICALS

3. HAZOPs Analyses of Gas/Oil Production Units (HAZOPS Design Analysis) -- Performed detailed design analysis for operations planning; quantified potential hazards and control faults. Documented plant operating instructions and trained operators.

4. Plant Construction Checkouts (Detailed Design Quality Control) -- Inspected construction for conformance with plans and potential design errors in complex industrial plants.

GEOTHERMAL ENERGY

5. Redesign of Processes (Technology Design, Water Treatment) -- Designed revamps of conventional process technology for restricted conditions available from alternate energy sources. Managed consulting contract/budget; performed design and cost estimating.

6. Analytical Modeling of Geochemistry (Groundwater Chemistry) -- Formulated and programmed quantitative model of vapor/liquid/solute chemistry for geothermal brines. Model accurately predicted flow and scaling conditions in brine production systems.

7. Pilot Tests of Hydrogen Sulfide Removal (Technology Design, Water Chemistry) -- Designed, and managed procurement and operations of a reboiler system to decontaminate geothermal steam. Project demonstrated high efficiency separation and heat transfer.

MINERAL PROCESSING

8. Gold Mill Capacity Expansion (Metals-in-Water) -- Reviewed plant expansion criteria for a conversion from Zadra to AARL carbon stripping process. Study of kinetic data indicated plant productivity could be greatly increased primarily by altering conditions and flow rates, without adding full proportional volumes of tankage and carbon columns. Client realized major cost savings for the plant revamp.

DESALINATION

9. Pilot Testing of Silica Control (<u>Reverse Osmosis, Metals Removal</u>) -- Designed and operated a 25,000 gallon-per-day reverse osmosis system, which demonstrated that recovery of clean water could surpass 80 percent long term, versus rule-of-thumb design approach that limited the applied membrane efficiency to 50 to 70 percent range.

Partial List of Publications

Vorum, M., "SoilTech ATP System for Dechlorination of PCBs; Wide Beach Superfund Project." Incineration Conference, Knoxville, TN, May 1991.

Vorum, Ritcey, R.M., "SoilTech ATP System: Pyrolytic Decontamination of Oily RCRA and TSCA Wastes." HazTech Int'l '91 Conference, Houston, TX, Feb. 1991.

Vorum, Shuck, D.L., Shanks, R., "High-Rate in Situ Soil Aeration for VOC Remediation." Conference Proceedings, Colorado Hazardous Waste Management Society, Denver, CO, Fall 1989.

Coury, G.E., Vorum, "Removing H2S from Geothermal Steam." Chemical Engineering Progress, September, 1978.

Vorum, Coury, "Nonelectric Utilization of Geothermal Energy in the San Luis Valley, CO." U.S. DOE Idaho Operations, Report IDO/1623-3, February, 1978.

APPENDIX B

PRESENTATION VIEWGRAPHS

9413225.2972

INDEPENDENT TECHNICAL REVIEW OF N SPRINGS EXPEDITED RESPONSE ACTION PROPOSAL HANFORD SITE

Prepared by:

ADVANCED SCIENCES, INC.

Prepared for:

Westinghouse Hanford Company

February 22, 1993

N SPRINGS INDEPENDENT REVIEW BOARD GOALS

- PROVIDE INDEPENDENT TECHNICAL REVIEW OF DOE/RL-93-23, "N SPRINGS EXPEDITED RESPONSE ACTION PROPOSAL," REVISION 0
- ANALYZE TECHNICAL ADEQUACY OF DOCUMENT AND CONCLUSIONS

ADVANCED SCIENCES, INC.

9413225.2974

N SPRINGS REVIEW BOARD

- ANTHONY S. BURGESS, PH.D., P.E.
  HYDROGEOLOGY/GEOTECHNICAL ENGINEERING
- WADE E. HATHHORN, PH.D.
  CIVIL ENGINEERING/HYDROGEOLOGY
- JAMES R. KUNKEL, PH.D., P.E., P.H.
  HYDROLOGY AND CIVIL/ENVIRONMENTAL ENGINEERING
- RICHARD A. MILLET, P.E.
  CIVIL/GEOTECHNICAL ENGINEERING
- MARTIN VORUM, P.E.
  CHEMICAL/ENVIRONMENTAL ENGINEERING

ADVANCED SCIENCES, INC.

9413225.2975

DOCUMENT REVIEWED

U. S. Department of Energy, Richland Field Office (DOE RL), 1994, N Springs Expedited Response Action Proposal, DOE/RL-93-23, Revision 0, January, 10 Sections, Appendix A.

ADVANCED SCIENCES, INC.

9413225.2976

BACKGROUND DOCUMENTS

Connelly, M. P., J. D. Davis and P. D. Rittman, 1991, Numerical Simulation of Strontium-90 Transport from the 100-N Area Liquid Waste Disposal Facilities: Report prepared by Westinghouse Hanford Company for the U. S. Department of Energy, Office of Environmental Restoration and Waste Management, WHC-SD-ER-TA-001, Revision 0, April, 61 pages, 1 appendix.

Thompson, K. M., 1991, Hanford Past-Practice Strategy, DOE/RL-91-40, Revision 0, U. S. Department of Energy, Richland Field Office (DOE RL), November, 31 p., 2 attachments.

ADVANCED SCIENCES, INC.

9413225.2977

BACKGROUND DOCUMENTS (Cont'd)

Westinghouse Hanford Company (WHC), 1992, M-14 Settlement - Proposed 100-N Springs Expedited Response Action, Letter from W. L. Johnson, Westinghouse Hanford Company to R. D. Izatt, U. S. Department of Energy, Richland Field Office, October 19, 1992, Correspondence No. 9257492D, 3 p., 2 enclosures.

ADVANCED SCIENCES, INC.

9413225.2978

SUMMARY OF REVIEW BOARD FINDINGS

- LACK OF A CLEAR GOAL COMMENSURATE WITH AN ERA
- UNCERTAINTIES IN ESTIMATING THE EFFECTIVENESS OF THE ALTERNATIVES
- UNCERTAINTIES IN THE COST ESTIMATES FOR THE ALTERNATIVES

ASI ADVANCED SCIENCES, INC.

9413225.2979

REVIEW BOARD CONCLUSIONS

- EXISTING CONCENTRATIONS OF ^{90}Sr IN GROUND WATER AND SOILS ARE NOT WELL DOCUMENTED IN THE ERA PROPOSAL

- THE GOAL OF SIGNIFICANT REDUCTION OF ^{90}Sr FLUX TO THE COLUMBIA RIVER THROUGH REDUCTION OF AT LEAST 50 PERCENT OF THE ^{90}Sr CONCENTRATIONS GREATER THAN 1,000 pCi/L IS ARBITRARY AND LED TO DEFINITION OF REMEDIAL TECHNOLOGIES WHICH MAY NOT BE CAPABLE OF PROVIDING SUCH REDUCTION

ADVANCED SCIENCES, INC.

REVIEW BOARD CONCLUSIONS (Cont'd)

- THE ERA PROPOSAL PROVIDES AN ADEQUATE DESCRIPTION OF THE VARIOUS CANDIDATE ALTERNATIVES
- TECHNOLOGICAL UNCERTAINTIES RESULTED IN THE INABILITY OF THE AUTHORS OF THE ERA PROPOSAL TO CONCLUSIVELY SELECT A PREFERRED ALTERNATIVE

ADVANCED SCIENCES, INC.

9413225.2981

REVIEW BOARD CONCLUSIONS (Cont'd)

- THE ALTERNATIVE WITH THE LEAST TECHNOLOGICAL AND COST UNCERTAINTY (VERTICAL BARRIER) SHOULD HAVE BEEN SELECTED AS THE PREFERRED ALTERNATIVE
- THE EFFECTIVENESS OF THE PUMP-AND-TREAT ALTERNATIVE WAS INCORRECTLY ASSESSED IN ITS CAPABILITY TO REMOVE ^{90}Sr FROM GROUND WATER AND SOILS AT THE SITE

ASI ADVANCED SCIENCES, INC.

REVIEW BOARD CONCLUSIONS (Cont'd)

- ESTIMATED COSTS WERE NOT JUDGED ON RELATIVE TERMS. THE MORE COMPLEX ALTERNATIVES, THAT IS PUMP AND TREAT, WILL COST SUBSTANTIALLY MORE AT A DOE SITE THAN AT NON-DOE SITES

ADVANCED SCIENCES, INC.

REVIEW BOARD RECOMMENDATIONS

- A CLEAR AND QUANTITATIVE STATEMENT OF THE GOAL OF THE ERA PROPOSAL NEEDS TO BE ESTABLISHED
- STRICTLY FOLLOW THE ERA PROCEDURE FOR RECOMMENDING THE MOST COST-EFFECTIVE ALTERNATIVE FOR MEETING THE ^{90}Sr FLUX GOAL AND, TO THE EXTENT PRACTICAL, CONTRIBUTE TO THE EFFECTIVE PERFORMANCE OF ANY FINAL ACTION

ASI ADVANCED SCIENCES, INC.

REVIEW BOARD RECOMMENDATIONS (Cont'd)

- THE VERTICAL BARRIER WITH SUPPLEMENTARY MONITORING WELLS NEAR THE ENDS OF THE BARRIER APPEARS TO BE THE MOST COST-EFFECTIVE ALTERNATIVE

ADVANCED SCIENCES, INC.

APPENDIX C

COMMENTS OF ANTHONY S. BURGESS

N SPRINGS EXPEDITED RESPONSE ACTION PROPOSAL

COMMENTS BY ANTHONY S. BURGESS

1. GENERAL

The project would benefit from a more formal decision analysis approach, including the explicit incorporation of uncertainty in both performance and costs. Currently, the objectives and criteria are not well defined, nor is it apparent which stakeholders have been involved in their selection.

By using a more formal approach, real data needs can be identified. Thus, further data collection and analyses would only be performed where improved knowledge has the potential for modifying a decision. The proposed schedule (Figure 9-1) identifies an "Action Memorandum". It is recommended that this be used to re-evaluate the issues identified in this review, and to provide the basis for further data collection and analysis.

It is understood that risk assessments based on estimates of release of Sr-90 to the Columbia River show that concentrations and fluxes are below what would normally be considered action levels. Nevertheless DOE has agreed to proceed with an ERA to significantly reduce the Sr-90 flux. What would be considered a de minimus flux? What is a realistic estimate of the current flux? How (and when) will risks associated with construction of an ERA be evaluated against the risks posed by no action?

Present worth cost estimates are based on a discount factor of 10 per cent. This is high: values of real discount factors (interest rate minus inflation rate) of 3 to 5 per cent may be more realistic. A high discount rate favors alternatives which are O&M loaded, relative to alternatives which involve high capital expenditure. As with other cost factors, it is recommended that uncertainty in the discount factor be explicitly included in any analyses.

There are a number of inconsistencies in the costs presented in various sections of the report. For example, Table 7-1 and the similarly titled table in Appendix A page A-7 show different costs. Also the cost evaluation tables in Section 6 are not always consistent with similar tables in Appendix A. A careful check of all costs and their reporting should be performed.

2. SPECIFIC

Comment 1 Section 2.2.3 and associated figures. The text notes that the most recent springs data show Sr-90 concentrations of 11,000 pCi/L. These data are not reflected on Figure 2-8. This has significance in relation to the calibration of the model for initial Sr-90 concentrations in the groundwater and subsequent use for estimating groundwater concentrations during operation of the pump and treat system (see Comment 10).

Recommendation. Post the concentrations measured in the springs wells. Asterisk values not used in the contouring and add note to that effect.

Comment 2 Figures 2-4 and 2-8. We understand from our meeting with WHC and IT that both Figure 2-4 and Figure 2-8 include only wells screened within approximately 15 feet of the water table. These were specifically selected since deeper wells show much lower concentrations of Sr-90.

Recommendation. Add notes to the figures that only water table wells with screen lengths less than 15 feet were used.

Comment 3 Section 2.2.3. There appears to be sufficient data available (concentrations, groundwater gradient, estimates of hydraulic conductivity, cross sectional area of flow) to make an estimate of the current flux of Sr-90 into the Columbia River. Since the stated primary objective is to eliminate or reduce the flux of Sr-90 to the Columbia River, it is important to document the methodology by which the flux will be calculated, and to calculate the flux for current conditions, as the baseline against which progress can be measured.

Recommendation. Propose a methodology for calculating the flux and make an estimate of the flux for current conditions.

Comment 4 Section 3.3 and Table 3-3. It is unclear whether the current MCL for Sr-90 (8 pCi/l) or the proposed (42 pCi/l) will be used as the standard for the discharge of treated water.

Recommendation. Clarify

Comment 5 (Section 5.0). Hydraulic control can also be accomplished by injection of clean water along the river bank. It would enhance flushing in the short term (and also the flux of Sr-90 to the river) for the section of the aquifer between the river and the line of injection wells. Limited areas of the aquifer which are currently uncontaminated would become contaminated. Also the system would require operation for an indefinite period. However, it would not require any water treatment.

Recommendation. Add this alternative (injection wells) to the list, although it will likely be screened out under the "protectiveness" criterion.

Comment 6 Section 5.2.4.3. Is there any record of the use of sheet piling at Hanford, for example construction of water intakes? Section 2.1.5.2.2 indicates that the cobble-boulder unit occurs at or near the top of the Hanford Formation. If the wall were installed as close to the springs as possible, this would be at the base of the Hanford Formation and into Unit E of the Ringold. According to Sections 2.1.5.2.1 and 2.1.5.2.2, these are pebble-cobble (Hanford) and fluvial gravels (Unit E of Ringold). These lithologies should not present problems for sheet piles with sufficiently heavy section. There have been recent developments of sheet piles with groutable interlocks, which have been used successfully on hazardous waste sites.

Recommendation. Retain sheet piling as an alternative until field testing indicates that conditions are such that driving would not be feasible.

Comment 7 Section 5.2.4.4. The freeze wall appears to be rejected because it would require drillholes on a spacing of 6-7 feet. However, the in-situ soil mix wall requires holes at a spacing of about 4 feet, assuming a 5 feet diameter mixed column with minimum overlap. Instead of drillholes for the freeze wall, could hollow driven steel pipe piles be used?

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Recommendation. Reconsider freeze wall and reasons for elimination. It is probably justifiable to reject on the basis of innovative and untried technology for hazardous waste sites.

Comment 8 Section 6. There are four primary criteria (technical feasibility, cost considerations, institutional considerations, and environmental impacts) used to evaluate the alternatives. Each of these criteria includes up to ten sub criteria. There is no attempt to indicate any relative weighting between the sub criteria, or even between the criteria. A number of the sub criteria appear more than once. For example, "present worth" will include both "capital" and "operating and maintenance" costs, and should not be included as a separate sub-criterion. No definitions are given for the criteria. Therefore the evaluations presented in the Tables 6-2 through 6-27 do not have any yardstick against which they can be objectively measured and compared.

Recommendations. From discussions with WHC and IT staff, it appears that the alternative may be better selected by application of the following rules/criteria:

1. achieve the removal action objective of a minimum of 50 per cent reduction in the flux of Sr-90 to the river
2. provide the lowest \$/(Ci/year) net flux reduction where the cost is the present worth of the alternative
3. ability to comply with ARARs

For each of the above, the relative importance can be expressed by means of a weighting factor. The method by which alternatives will be evaluated for each of the criteria should be defined. For example, the reduction in flux must be a net reduction, including the discharge of Sr-90 back to the river from a pump and treat operation. Uncertainty in the evaluation of alternatives must be explicitly expressed. Additional data collection, analysis and testing can then be based on a defined need to reduce the uncertainty in a particular evaluation.

Comment 9 Section 6.0 p 6-3. The text states that the cost estimates are +50% to -30%. However, it is unlikely that the cost estimates are within this range. For example, in section 6.2.3.2.1, it is noted that there is almost an order of magnitude difference in estimates from vendors, for the O&M costs for reverse osmosis. The text indicates that cost estimates are based on an "environmental" rather than a "nuclear" setting. Given the nature of the contaminants, the probable high profile of the project and the very fact that it is at the Hanford site, it appears likely that the costs are underestimates, and may not be within +50%. Different alternatives may have different cost estimating errors and uncertainties attached. Therefore they cannot be neglected on the basis that the evaluation of costs is on a relative rather than an absolute basis.

Recommendation. The cost estimates should be based on nuclear facility experience. Uncertainty in cost estimates should be explicitly included in the evaluation, with documentation of the reason for the uncertainty. In this way the need for additional activities can be appropriately identified and focussed.

Comment 10 Section 6.1 The PORFLO-3 model was originally developed to estimate the contaminant flux to the river during and following operation of the disposal cribs. Predicted concentrations of Sr-90 in the groundwater appear to be higher than generally observed. Modeled values are typically 1000 to 6000 pCi/l (Figure 6-1)compared with measured values of about 1000 to 1500 pCi/l (Figure 2-8), except for the concentrations in well N-8T and some sampling points immediately adjacent to the springs. It may have been appropriate to use a model which produced conservative estimates of the flux to the river, when that was the objective. However, when comparing alternatives, it is important to use best estimate realistic assumptions. If this is not done, an alternative may appear to offer a substantial reduction in the flux because the no action alternative overestimates the flux.

Recommendation. Additional groundwater modeling is required, and should be designed to specifically address the alternatives in an unbiased manner.

Comment 11 Section 6.2. From the PORFLO-3 analyses it appears that a five well system will reduce the flux approximately 96 per cent compared with the no action alternative. Because of the geometry of the system, as the pumping rate is increased to reduce the flux from the springs, there is more dilution and lower Sr-90 concentrations in the pumped water. Paradoxically, this may result in a net increase in flux to the river because of the allowable concentration in the discharge. Concentrations of the pumped groundwater are not given in the document. However, from Figure 6-3, it appears that concentration would be in the range of 100 to 500 pCi/l. As noted above in Comment 10, the model may overestimate the initial groundwater concentrations by a factor of about five. Concentrations in the pumped wells may therefore be as low as 20 to 100 pCi/l. Averaging over the five wells, the net concentration may therefore be about 60 pCi/l. If the allowable concentration for discharge to the Columbia River is 42 pCi/l, then the net reduction in flux to the Columbia River will only be about 30 per cent. This alternative would therefore not meet the objective of achieving a net reduction of Sr-90 flux of at least 50 per cent.

Recommendation. Further evaluation of this alternative is required using realistic Sr-90 groundwater concentrations. In addition, low volume "surgical" pumping from the area of highest concentration may be much more effective in reducing the net flux and avoiding excessive dilution.

Comment 12 Section 6.2.2 The text states that "Pump and treat may contribute to final remediation". However, in terms of the activity removed relative to the total inventory, it will be insignificant. Connelly (1991) calculates the cumulative inventory of Sr-90 as of January 1 1988 to be 1900 Ci for 1301-N facility and 210 Ci for 1325-N facility, for a total of 2110 Ci. For five extraction well operating at a total of 300 gpm for 10 years, with a pumped water concentration for Sr-90 of 500 pCi/l (a conservative [high] estimate), a total of about 3 Ci will be removed. Over the same 10 year period natural decay of the Sr-90 will result in a decrease in the inventory by 22%.

Recommendation. Delete the sentence referenced above since it implies that pump and treat is much more effective than it actually is. This may lead to it being favored over other alternatives.

Comment 13 Section 6.2.3 As noted above, the cost uncertainties appear to be greater than -30 to +50 per cent.

Recommendations. Review all cost estimates and explicitly include uncertainty.

Comment 14 Section 6.3.1. As noted in this section, for a vertical barrier wall to be effective it must be located as close as possible to the springs themselves. In this way, flushing of contaminated soil by diurnal and seasonal fluctuations in river level will be reduced.

Recommendation. More study of the flushing of Sr-90 is required before the use of a barrier wall can be confirmed as effective over the ten year span of the ERA. Analytical methods may be appropriate for evaluation of the effect of locating the barrier wall at different distances from the river. For example a solution presented in Freeze and Cherry p494 et seq may be used to quantify the flow out of the river bank following a step change in water level on the boundary.

Comment 15 Section 6.3.1. As noted above, there may be a significant advantage in locating the wall as close to the river as possible. However, the topography of the riverbank as depicted on Figure 6-8 may not be representative of the complete wall length. From a review of site topographical maps, and as shown in the cross section on Figure 8 in Connelly (1991), the bank may be both steeper and higher in some areas before a possible construction bench is reached.

Recommendation. Use available site topography to layout wall alternatives and confirm that they are all feasible from a construction perspective. Also consider the use of grouted interlock sheet piles. In areas of difficult access, it may be possible to pitch and drive sheet piles close to the springs where barrier wall installation would not be feasible.

Comment 16 Section 6.3.1. It is noted that the model does not account for flux which may flow around the ends of the wall.

Recommendation. While the wall can always be lengthened following these analyses, the length of the wall is a fundamental parameter for any cost comparison. These analyses should therefore be completed for this stage of the decision making.

Comment 17 Section 6.3.1.2. In areas where a 100 ft deep wall is required, the upper section may be through bouldery ground making installation by soil mixing difficult.

Recommendation. Consider using a conventional slurry wall trench excavated with an extended boom backhoe down to about 50 ft. The deep soil mixing could then be performed through the slurry filled trench. The ability to accurately locate overlapping deep mixing zones through the slurry would require careful evaluation.

Comment 18 Sections 6.3.1.1 and 6.3.1.2. It is not clear from the descriptions of both of these methods whether the need for any special procedures have been included for excavation through radioactive materials. For a slurry wall, for example, any bentonite slurry would potentially become contaminated.

Recommendations. Review construction procedures and identify where additional measures may be required which would significantly increase construction costs, and include as appropriate in the cost estimates.

Comment 19 Table 6-5. Evaluation of "Demonstrated performance and reliability under similar conditions" is missing from this table.

Recommendation. Add to table.

Comment 20 Section 6 Cost Evaluation Tables. These tables are not all consistent with similar tables in Appendix A. For example, in Table 6-8, the present worth for the five well extraction system is reported as $1.77M. The detailed table in Appendix A page A-10 gives the present worth as $1,721,326.

Recommendation. Undertake a comprehensive check of all costs and consistency in different sections of the report.

Comment 21 Section 7.1.1. No discussion is presented with regard to the ability of the pump and treat alternative to meet the MCL for Sr-90 of 42 pCi/l for the treated water discharge.

Recommendation. Add discussion on the treatment capability.

Comment 22 Section 7.2. The cost benefit analysis does not adequately reflect the uncertainty in both the costs and per cent reduction of Sr-90 flux. No analyses were performed that confirmed that the wall at the river would result in a 100 per cent reduction in the flux.

Recommendation. Include uncertainty in the analyses, for example, by replacing the points plotted on Figure 7-1 by bars representing a range.

Comment 23 Section 8.0. The reasons for undertaking the additional analyses and data collection are not adequately presented. As noted above, data should only be collected which is necessary to evaluate an alternative, and which would change a decision as to which is the preferred alternative.

Time consistent groundwater and spring sampling. The rate of migration of Sr-90 for the current conditions may be as low as one meter per year. Sampling monitoring wells at the same time is therefore unlikely to be critical. Spatial variability will probably be greater than temporal variability. However, more complete sampling of concentrations, groundwater elevations, and fluxes at the springs may be important to quantify diurnal flushing.

Subsurface characterization. The sampling proposed is unlikely to add anything significant to knowledge of the confining layer. Why are these data needed, and will the proposed program provide the needed data to reduce uncertainty? Why two borings and not four?

Recommendation. A more critical analysis of data needs should be undertaken, based on decision analyses and the value of data.

Comment 24 Appendix A. As noted above, there are inconsistencies between costs presented in various sections of the report.

Recommendation. Perform detailed check of costs and consistencies.

APPENDIX D

COMMENTS OF WADE E. HATHHORN

Review of:

N Springs Expedited Response Action Proposal

(DOE/RL-92-23, Revision 0)
U.S. Department of Energy
Richland, Washington 99352

By:

Dr. Wade E. Hathhorn
Clearwater Consultants, Ltd.
(and Washington State University)
Pullman, Washington 99163

Summary: A technical review is given of the U.S. DOE's report for the N Springs Expedited Response Action Proposal. An attempt was made to exclude such external factors as outside political agendas, conclusions from previous versions of the text, and various regulatory pressures in making a purely impartial, objective review of the document. Faced with a proposed primary ERA goal of significantly reducing the flux of Strontium-90 to the Columbia River from the 100-N Reactor cribs, a recommendation is made to proceed with the report's alternative for a slurry wall to be developed near the River's edged. In making that conclusion, evidence is cited for the immobility of Sr-90 in groundwater systems and the likely ineffective result which would be achieved through pump-and-treat measures. Moreover, the immobility of Sr-90 is a benefit to the wall, wherein a small extension of the bulk contaminant path length created by the wall would result in a greatly increased travel times and lower plume concentrations due to natural radioactive decay. On a pure benefit/cost assessment, the slurry wall provides the greatest long-term reduction in Sr-90 flux to the River at minimal cost .

Relevant Background: It is of interest to begin by citing a few relevant facts regarding the site and its history. The identified chemical of potential concern (COPC) is Strontium-90, herein referred to as Sr-90. Generated from the operation of the 100 N Reactor, the Sr-90 was released into the subsurface through two primary liquid waste disposal facilities (LWDF): the 1301-N and 1325-N cribs. Between 1964 and 1990, the two cribs were used to infiltrate approximately 12.4 million liters of liquid material yielding a total (decay corrected) Sr-90 subsurface release inventory of 1,760 Ci (ref. Table 2-2: p. 2T-2). Citing Hartman and Lindsay (1993), it is noted that the Sr-90, with a half-life of 28.1 years, remains principally fixed to the soils directly beneath the two cribs and along a soil layer marking the water table between the cribs and the Columbia River. In 1993, the maximum Sr-90 concentration measured in the underlying groundwaters was approximately 11,000 pCi/l, located at the N-8T monitoring well. Other points of significant concentration included those at seeps 2, 3, 4, and 11 (ref. Figures 2-2 and 2-10: pp. 2F-2 and 2F-10, respectively).

Review of Sections 1 and 2: My only notable comment here was a personal note of the highly heterogeneous structure described for the contaminated lithologies and a criticism of the lack of informational detail used in constructing the 1993 Sr-90 activity shown in Figure 2-8. In particular, Figure 2-8 has seemingly excluded direct depiction of the most severely contaminated areas, namely those identified around monitoring well N-8T and seeps 3 and 4 which are not shown. After interviewing the authors of the ERA report, evidence was made available which suggested the Sr-90 "plume" may have bifurcated (or branched) around a low-permeable lens located between the 1301-N trench and the Columbia River, producing a "multi-fingered" plume front at river's edge. Now, it is important to point out that this conclusion is only conjecture on my part. Nevertheless, the bimodal distribution of groundwater concentrations shown in Figure 2-10 and the strong lithologic heterogeneities indicated at this site suggest a complex shape to the actual plume which is emanating from the cribs. Such a conclusion is important in that the spatial complexity of a plume may have a significant influence on the final action technology chosen to carry out the ERA plan.

Review of Section 3: There a few points of particular interest here, namely the primary and secondary objectives identified for the ERA. Quoting (p. 3-2, section 3.3), "The primary objective of the N Springs ERA is to eliminate or significantly reduce the flux of Strontium-90 to the Columbia River through the N Springs.... A secondary objective of the ERA is to implement a removal action that will be compatible with future remedial actions planned for the operable unit and will contribute to the efficient performance of the final remedial action to be taken." Several operative words were identified here which included: "significantly reduce" and "compatible" "removal action." As noted by the authors of the report, an arbitrary goal of significant Sr-90 flux reduction was set at 50% of it current value, while the notion of delineating those potential remedial technologies constituting a compatible removal action remained undefined.

Accordingly, questions remain as to whether or not the intent of the N Springs ERA was to provide for actual, forced mass removal at the site or to permit the use of technologies which only prevented the spread of mass (e.g. those permitted under traditional non-time-critical ERA's). This issue becomes important when noting that the proposed technologies selected for site action include: (i) pump-and-treat or (ii) a deep-mixed slurry wall. In the case of pump-and-treat, mass is actually physically removed from the site via groundwater pumpage, while a slurry wall will only abate the transport of mass in place. If immediate forced mass removal were required, then only the pump-and-treat technology would meet this demand. Yet, the use of such "complex" schemes are traditionally not allowed under standard ERA permitting (Thompson, 1991). Thus, I believe there is significant confusion reported regarding the objective of this ERA and the corresponding technological limitations permissible under that permit. A few additional statements by the authors in section 3.3 may be helpful in clarifying these points and, in particular, the stated goals of the ERA.

Review of Section 4: I have no significant comments for Section 4. Irrespective of the confusion noted in Section 3, the technologies selected for investigation seemed reasonable.

Reveiw of Section 5: Knowing that the disputed selection of a proposed ERA for the N Springs Site surrounds either: (i) pump-and-treat or (ii) a slurry wall, I will reserve my comments for Section 5 to be directed principally at these two technologies alone. First, with respect to pump-and-treat, I took great exception to its noted technological feasibility. Here, the mention of the extremely large relative retardation factor for Sr-90 was omitted. Citing Connelly et al. (1991), the actual retardation of Sr-90 within the

Ringold aquifer is on the order of 120. Physically, the magnitude of this number defines the relative mobility of the contaminant in the soil-water environment of the subsurface. In this case, the Sr-90 is thought to be highly sorbed onto the soil solids. Moreover, with such a large retardation factor, one would expect the Sr-90 to be virtually immobile in the groundwater under pump-and-treat activity. Without that mobility, the Sr-90 could not be recovered by simple pumpage. Operationally, the outcome of such an approach would yield the displacement of a tremendous amount of water without significant mass recovery. Here, the technology's effectiveness would be reduced to one of simple hydraulic control without a significant reduction in plume strength. Given the typical costs of remediating the pumped water, the use of pump-and-treat technology poses an expensive means of providing nothing more than mass transport reduction through hydraulic control without effective mass recovery. This fact is a serious negative point that should be noted for any pump-and-treat system that is being proposed for application to strongly sorbed contaminants. In fact, after lengthy pumpage, the Sr-90 would be expected to remain as a large distributed source of groundwater contamination around the cribs. It is further belived that even after a decade of pump-and-treat within the proposed ERA compliance period, the Sr-90 flux into the river would continue at its current intensity upon cessation of the operation. The only significant reduction in source strength for the Sr-90 plume would be derived from its natural radioactive decay. This fact is further discussed in my comments for Section 6.

With respect to vertical barriers and, in particular slurry walls, Section 5 presents poor discussion of the technology's utility for a particular use. For example, if the ERA demands that forced, mass recover action be taken, slurry walls will simply not satisfy that demand. If, however, mass reduction is permitted through the retention of the plume and its eventual degradation through natural radioactive decay, then the slurry wall may be an effective alternative, particularly for the strongly sorbed Sr-90 contaminants. Here, the forced deviation of the plume's path may constitute an increase in travel time to the river which spans a number of half-lives for the contaminant. Thus, a wall which would cause the core of the plume's path to be nominally lengthened would not only significantly reduce the direct mass flux to the river but would also permit significant natural reduction of the mass within the plume through radioactive decay. Yet, the goal of the ERA and the eventual remediation of the site are not incorporated into the discussion. A fact which, in my opinion, is extremely germane to the selection and viability of this technology. Furthermore, the difficulty in siting the wall and the determination of its length are not clearly discussed. Such factors are directly affected by knowledge of the plume's shape and primary location, each of which are admittedly ill-defined in the earlier sections of the report.

Review of Section 6: One of my principal concerns at the outset of this section was the potential for the reported results to be misinterpreted as being some indication of what actually might be occurring at the site in the year 2002. In particular, it should be noted that the plumes shown throughout this section are only generalizations for a given parameterization of the computer model (PORFLO-3). This statement, however, should not be interpreted as a condemnation of the modeling itself, rather the way in which the results may be interpreted by readers as a reflection of actual plume behavior. Such interpretations are simply not justifiable given the complexity of the hydrogeology at the site and the rather simple modeling parameterization used in predicting those outcomes (Connelly et al., 1991). The utility of the modeling results shown lie in the comparative analysis presented of the effects produced by separate response action plans. Although the report attempts to make this point clear, I want to reemphasize this fact as preface to my comments for Section 6.

In examining the results of Section 6, it is apparent that each of the action plans does little to actually reduce the relative concentration of the plume by the year 2002. Comparative analysis of the plumes generated for each of the active plans reveals a final plume strength which is almost identical to that of the no action case (e.g. Figures 6-1 and 6-3). This fact is due to the relatively large effective retardation factor noted for Sr-90. In all cases, there is little, if any, noticeable displacement of the Sr-90 over the ten-year action period. This result may seem surprising at first, but upon further thought we know the mass will remain strongly attached to the soil. To elaborate on this point, consider the following estimate of expected mass recovery that would have occurred over the ten-year period in the proposed five pumping well scheme presented on page 6-7 of the report. By the year 2002, the five wells (each pumping at 330 m^3/day) will produce approximately 6.2 billion liters of water. If we assume an average aqueous Sr-90 concentration of 500 pCi/l for that pumped water (see Figure 6-3, p. 6F-3), then 3.1 trillion pCi will be recovered. However, that's only 3.1 Ci. Ignoring radioactive decay, this is a small fraction (<1%) of the original 1,760 Ci of Sr-90 reportedly released. This result, unfortunately, is not presented in the report.

As I indicated earlier in my discussion, the relatively large retardation factor for Sr-90 is an element that must considered directly in the selection of a given action alternative. For pump-and-treat, the effect would be one of reducing the technology to nothing more than a costly means of hydraulic control. Even if the pumped water contained 500 pCi/l Sr-90 (a value which may be unreasonably high given the dilution which is likely to occur from the pumpage of seepage from the river), this concentration amounts to only about 0.2 parts per billion. The resulting mass recovered over the ten years of pumping would be minimal.

On the other hand, the highly sorptive feature of Sr-90 is a benefit to the effectiveness of both a slurry wall or simple (up-gradient) hydraulic control. However, given the additional hydrogeologic complexity of the site, the effectiveness of hydraulic control in reducing the Sr-90 flux to the river by 50% is unclear. A great deal of uncertainty remains as to the actual hydrogeology at the site and the impending Sr-90 plume's true shape. Here, it should be explicitly clear that the modeling results presented in the report are nothing more than idealized renderings of a fictitious hydrogeologic environment. The report's depiction of plume symmetry and the "smooth" spatial distribution of mass should not be interpreted as fact. By contrast, the more likely scenario is the occurrence of a relatively complex plume geometry whose evolution is being controlled by local heterogeneities in hydraulic conductivity and sorption. This noted hydrogeologic complexity raises serious questions regarding the ability to design an effective up-gradient hydraulic control system. In particular, the number and placement of wells required to satisfy the stated design criteria would be subject to appreciable uncertainties. Moreover, from a practical viewpoint, if one (or more) of the wells were to become contaminated (as a result of drawback or the inclusion of a unknown source), then the discharge water will likely have to be treated, resulting in substantial cost increases for the system. Accordingly, I concur with the report's conclusion that simple hydraulic control is too risky with respect to its design and actual operating effectiveness.

Hence, a slurry wall remains as my final candidate for the ERA plan. A slurry wall has the particularly positive attribute of being practically free from post-constructed operation and maintenance. Once in place, the wall resides as a stable barrier preventing direct flow and mass transport to the river. Moreover, based on a pure benefit/cost assessment, the slurry wall provides the greatest Sr-90 flux reduction per dollar spent (see Table 7-1 and Appendix A-7). Nevertheless, in the report, questions were raised as to its actual effectiveness, particularly with respect to the possibility of mass flux around its ends. This issue should be of little concern. Again noting that the retardation factor for Sr-90 is very large, the expected mass flux around the end of the wall should be small provided the wall intercepts the portion of the plume which has Sr-90 concentrations in excess of 100 pCi/l. Thus, the principal questions remaining for the wall are those regarding its placement and length. Such questions of alignment are critical factors not only to the overall cost of the wall (as the soil horizon is more shallow along the river bank) but also to the amount of Sr-90 which may be lost to the river located between the wall and the river's edge. Moreover, the wall's design is also largely dependent on knowing where the Sr-90 plume is located. The issue over hydrogeologic uncertainty at the site (as noted in my previous discussion of hydraulic control systems) is again raised here. As a minimum, a more detailed examination of the current contaminant along the river's edge adjacent to the cribs would have to be performed through additional monitoring wells and geophysical loggings.

Review of Sections 7 and 8: The review of Sections 7 and 8 are discussed indirectly in the paragraphs above. The only critical comment for Section 7 was that the cost figures given were inconsistent throughout the report. It was assumed the corresponding numbers in the appendix A were the most accurate of those provided.

Conclusions and Recommendations: Upon careful review of the material presented in the N Springs ERA proposal, it was concluded the authors of the report had done a reasonably accurate and reliable job of presenting the facts as they applied to the discussion of the various alternative actions presented. The single most important negative comment I had of the report was its exclusion of relevant discussion regarding the immobility of Sr-90 in groundwaters. This fact would have clearly made the use of pump-and-treat technology an infeasible option since little, if any, significant quantity of Sr-90 would actually be removed from the site during that operation. Although pump-and-treat would provide a high profile response both in terms of political and environmental favor, the plan in my opinion would be an expensive failure. In the end, you would have moved vast quantities of water but done very little to actually improve existing water quality over that which would be produced under the no action plan.

Thus, faced with objectives of the ERA itself, the most cost effective and potentially reliable alternative is to build a slurry wall. In doing so, the actual design will require improved characterization of the Sr-90 plume, including better resolution of its location and contaminant strength along the river. The principal features of this design will include the siting and sizing of the wall. The length of the wall may be shortened with the inclusion of a single, periodically operated pumping well (and treatment system) located along the down-gradient end of the wall. The well could be operated intermittently at times when the concentration of Sr-90 in the groundwater moving around the wall's end exceeds a predefined monitored level, for example 100 pCi/l. In the end, a benefit/cost assessment would have to be made to determine the actual feasibility of such an alternative.

Nevertheless, it seems reasonable to conclude that some variation of the slurry wall idea would potentially provide resolution of the problem at a minimal costs.

References:

Connelly, M. P., J. D. Davis, and P. D. Rittmann (1991). Numerical Simulation of Strontium-90 Transport from the 100-N Area Liquid Waste Disposal Facilities, Report No. WHC-SD-ER-TA-001, Westinghouse Hanford Co., Richland, Washington, 62 p.

Hartman, H. J. and K. A. Lindsey (1993). Hydrogeology of the 100-N Area, Report No. WHC-SD-EN-EV-027, Westingthouse Hanford Co., Richland, Washington.

Thompson, K. M. (1991). Hanford Past-Practices Strategy. Report No. DOE/RL-91-40, U.S. Dept. of Energy, Richland Operations Office, Richland, Washington, 31 p.

APPENDIX E

COMMENTS OF JAMES R. KUNKEL

February 17, 1994

Mr. Reed A. Kaldor
Project Director
Advanced Sciences, Inc.
1777 Terminal Drive
Richland, Washington 99352-4952

Subject: Comments of James R. Kunkel, Independent Technical Review of the N Springs Expedited Response Action Proposal, Hanford Site
ASI Project No. 9848.101

Dear Mr. Kaldor:

This letter report presents the results of my technical review of DOE/RL-93-23, N Springs Expedited Response Action Proposal, Revision 0 (DOE RL, 1994). The objective of the technical review was to analyze the technical adequacy and conclusions of the document and to improve the cost-effectiveness and defensibility of alternatives for the Expedited Response Action (ERA) Proposal for reduction of strontium-90 (^{90}Sr) from the N Springs into the Columbia River near the N Reactor at the Hanford Site. I understand that these comments will be incorporated into a final report prepared by ASI along with technical review comments by others. This final report will be submitted to Westinghouse Hanford Company (WHC) on February 22, 1994. I further understand that the final report containing the review comments will become part of the public record concerning the N Springs ERA Proposal, which currently is being circulated for public comments.

INTRODUCTION

Westinghouse Hanford Company, on behalf of the U. S. Department of Energy, Richland Field Office (DOE RL), has undertaken an ERA as an interim action proposed to significantly reduce the flux of ^{90}Sr to the Columbia River from the N Springs near the now inactive N Reactor at the Hanford Site. The goal of the ERA is to analyze and recommend an expedited response action and not to recommend final remediation of the contaminated ground water discharging to the Columbia River at the N Springs (DOE RL, 1994).

This letter report is divided into three sections: an introduction, comments and discussion of the N Springs ERA Proposal by report section, and conclusions and recommendations. The comments in this review letter are my own and, although discussed with other members of the review board, do not necessarily represent consensus among other reviewers. The basis for my comments focus upon the standardized cost-effectiveness analysis approach, first formally proposed by Kazanowski (1968) and, since then, applied to water-resources systems by others authors (see, for example, Chaemsaithong and others, 1972; Drobny and others, 1971; Kunkel, 1974). The cost-effectiveness methodology is an extension of engineering economic analysis, in which alternative plans are compared using both cost and non-cost measures of effectiveness. Therefore, the standardized cost-effectiveness methodology permits the selection of an alternative which is not necessarily the least-cost option, based upon non-cost measures of effectiveness, such as loss of human life or effectiveness of water-quality treatment.

While the N Springs ERA constitutes the primary document reviewed, other documents were made available by WHC as background information. These documents included the 100-N Area ^{90}Sr Modeling by Connelly and others (1991), the M-14 Agreement (WHC, 1992), and the Hanford Past-Practices Strategy (Thompson, 1991). These supplemental background documents were not reviewed for technical adequacy but rather served as useful background information and data for the N Springs ERA Proposal (DOE RL, 1994) technical review.

COMMENTS AND DISCUSSION

Comments and discussion regarding the N Springs ERA Proposal (DOE RL, 1994) are made by report section. The report contains 10 sections: Section 1 - Introduction; Section 2 - Site Description; Section 3 - Removal Action Objectives Development; Section 4 - Identification of Removal Action Technologies; Section 5 - Screening of Removal Action Technologies; Section 6 - Detailed analysis of Removal Action Alternatives; Section 7 - Comparative Analysis of Removal Action Alternatives; Section 8 - Preferred Alternative; Section 9 - Schedule; and Section 10 - References.

Comments Related to Section 1 - Introduction

No Comments.

Comments Related to Section 2 - Site Description

In the subsection discussing the ground-water flow (Section 2.1.7.2.2) and N Springs (Section 2.1.7.2.3), not all the wells mentioned in the text are shown on figures related to this section. This omission makes the understanding of the ground-water and N-Springs flow regimes difficult. I would suggest that the authors check the correspondence between well numbers in the text and those on figures so that the reader has a complete picture of the data available and the analyses being undertaken. This comment applies to other subsections within the section as well.

In the subsection on ground-water contaminants (Section 2.2.3), it is stated, by referencing Hartman and Lindsey (1993), that the ^{90}Sr in the ground water appears to be limited to the upper part of the unconfined aquifer. This is a significant condition, relative to possible removal-action alternatives. In addition, the authors state that diesel fuel and other petroleum products have been present at the water table in the 100-N Area. This also is significant in the effectiveness of removal-action alternatives.

At the end of Section 2.2.3, the authors indicate that the most recent spring data available (for the year 1992) indicated ^{90}Sr concentrations of approximately 11,000 pico-Curies per liter (pCi/L). If this is the case, it would appear that ground-water ^{90}Sr concentrations feeding the springs also would be at least 11,000 pCi/L. However, Figure 2-6 indicates the highest ground-water ^{90}Sr concentration to be 8,980 pCi/L for February 1990 and Figure 2-8 indicates the highest ground-water ^{90}Sr concentration to be 1,580 pCi/L for February and March 1993. This inconsistency deserves to be addressed.

<u>Comments Related to Section 3 - Removal Action Objectives Development</u>

In the section on chemicals of potential concern (Section 3.1), the authors indicate that sulfates and hydrocarbons in the ground water may cause additional evaluation and design for the removal-action alternatives. This concern appears to have been dropped later in the report when the alternatives were analyzed. No reason was given in the report for this omission

The removal-action objectives section (Section 3.3) indicates that the goal of the removal action is to reduce the ^{90}Sr by at least 50 percent for concentrations greater than 1,000 pCi/L. It would appear that a better goal would be at least 50 percent reduction in ^{90}Sr flux to the Columbia River rather than merely a reduction in concentration alone. In fact, the Executive Summary section of the report indicates that the goal is a reduction of ^{90}Sr flux to the River. I suggest that Section 3.3 be reworded to indicate a goal of flux reduction rather than a concentration reduction for ^{90}Sr.

Section 3.3 also indicates that the existing maximum contaminant level (MCL) for ^{90}Sr is 8 pCi/L and that extracted contaminated water would be treated to the MCL prior to disposal. This section also infers that tritium (^{3}H), which also occurs in the ground water at concentrations higher than the existing MCL of 20,000 pCi/L, would require a waiver for disposal, because no tritium-removal technology currently exists. However, the MCLs shown on Table 3-3, and subsequently used in the report, indicate that the proposed MCLs of 42 pCi/L for ^{90}Sr and 69,040 pCi/L for ^{3}H would be used for the removal-action objectives. It is not explicitly stated whether the existing or proposed MCLs are being used.

If the proposed MCL for ^{3}H (69,040 pCi/L) is used, it is doubtful if existing concentrations of ^{3}H discharging to the Columbia River from the N Springs is higher than the MCL based upon tritium concentrations presented on Figures 2-7 and 2-9. Therefore, it is not clear if a tritium concern actually exists at the N Springs. I suggest this issue be clarified in the report.

Comments Related to Section 4 - Identification of Removal Action Technologies

No comments. This section appears to take into consideration all applicable technologies.

Comments Related to Section 5 - Screening of Removal Action Technologies

No comments. This section adequately screens the applicable removal-action technologies.

Comments Related to Section 6 - Detailed Analysis of Removal Action Alternatives

The alternatives consist of four basic types: (1) no action; (2) pump and treat; (3) vertical barrier; and (4) hydraulic control. Within the pump-and-treat alternative, two pumping options, two treatment options, and four disposal options, for a total of eight alternatives, are examined. Within the vertical barrier alternative, two locations were examined. Therefore, a total of 12 alternatives were investigated. The no-action alternative (Alternative 1) describes a ground-water model application by Connelly and others (1991) which serves as the basis for assessing if all alternatives, except hydraulic control, meet or exceed the goal of reducing the ^{90}Sr flux to the Columbia River by at least 50 percent. The report admitted that the model used was calibrated under ground-water conditions which are not now present in the 100-N Area. For example, the ground-water mound which developed during disposal of water while the N-Reactor was operational no longer exists. However, each alternative was analyzed using the model and the results should be representative for each alternative. The no-action alternative indicated that over the next ten years (the time frame of the study), approximately 12.6 Ci of ^{90}Sr would be discharged to the Columbia River through the N Springs. Thus, the goal of reducing this flux to 6.3 Ci or less was the effectiveness criterion (e.g., 50 percent ^{90}Sr flux reduction) desired for each of the removal-action alternatives. All alternatives, except the no action alternative, meet or exceeded this effectiveness criterion.

Uncertainties in the effectiveness of the removal-action alternatives are well presented, but result in the authors of the report being unable to recommend a preferred alternative. As a result, 10 of the 12 original alternatives are retained for further study. This is clearly not in the spirit of the ERA process, based upon an engineering evaluation/cost analysis (EE/CA). The uncertainties fall into several categories which include uncertainties in (1) the physical and chemical parameters used to calibrate the ground-water flow and transport model, (2) the ability of the treatment alternatives to treat withdrawn ground water to a ^{90}Sr concentration of 42 pCi/L, and (3) the costs used in assessing the removal-action alternatives. The following examines primarily the costs used in the assessment but also evaluates the effectiveness of the alternatives, based upon my professional experience with similar studies at DOE sites.

Alternative 2 - Pump and Treat

The eight pump-and-treat alternatives' analyses appear to be adequate from the standpoint of use of the best available physical parameters. The pump-and-treat alternatives were estimated by the authors to reduce the flux of ^{90}Sr to the River from 12.6 Ci/yr to between 0.3 and 4.2 Ci/yr (a reduction range of between 67 and 98 percent) depending upon whether three or five wells were used for extraction of ground water. It should be pointed out that relative to the total estimated quantities of ^{90}Sr in the ground water and soil (approximately 1,760 Ci as of the year 1990), very little (most likely less than 2 percent over the 10-year life of this alternative) ^{90}Sr would be removed by the pump-and-treat system, because much of the ^{90}Sr is adsorbed to soils in the vicinity of the water table. It should be pointed out that, in my opinion, for the pump-and-treat alternatives, a single well pumping ground water to a treatment unit, probably would meet the effectiveness criteria. This aspect is not mentioned in the report.

Much uncertainty appears to occur in the ability of the ion exchange (IX) and reverse osmosis (RO) treatment technologies to reduce ^{90}Sr concentrations in the extracted ground water to 42 pCi/L. The report recommends that pilot-plant studies be done to evaluate the effectiveness of both IX and RO treatment relative to ^{90}Sr removal. The costs for the eight pump-and-treat alternatives were obtained from vendor quotes. The equipment costs for RO units (Appendix A of the report) indicated a unit cost of between $2,000 and $3,000 per gallon per minute (gpm) of treatment capacity. My experience with RO units at the Rocky Flats Plant near Denver (ASI, 1991b; 1991c) indicates that RO capital costs at a DOE facility may be on the order of $20,000 to $30,000 per gpm of treatment capacity, because of the increased costs of installation at such a facility. Although my experience has been with "permanent" RO facilities rather than the "temporary" RO units assumed in the N Springs report, I judge that if the required life of the pump-and-treat system is to be 10 years, then a more "permanent" facility may be warranted. An RO unit purchased and operated to treat ground water from an *in-situ* uranium mine in the Bison Basin of Wyoming had capital costs of $12,500 per gpm of treatment capacity (Catchpole and others, undated). Therefore, it appears that the capital costs used in the report for RO treatment may be biased low. This would significantly increase the costs for these alternatives. Capital costs shown in the report for vapor compression evaporation (VCE) also were taken from vendor quotes and were on the order of $17,000 to $24,000/gpm of water evaporated. My experience with VCEs at the Rocky Flats Plant (ASI, 1991d) indicates similar capital costs of up to $50,000/gpm of water evaporated. The Rocky Flats Plant VCE study assumed steam-driven turbines rather than electricity-driven systems assumed in the ERA Proposal report. Thus, the VCE capital costs associated with this alternative also appear to be slightly low but not as significant as the RO capital costs. In addition, no temporary storage facilities to provide uniform flow rates to the treatment units and to temporarily store water during maintenance were included in the report cost estimates.

Operation and maintenance (O&M) costs presented in the report for RO units are on the order of $1.00/1000 gallons of water treated. One vendor quote in the report indicated an O&M cost of between $30 and $50/1000 gallons of water treated. This appears to be very high. The Bison Basin RO O&M costs were on the order of $6.20/1000 gallons (Catchpole and others, undated). O&M costs for RO units at Rocky Flats Plant have generally fallen into the range of $3.00/1000 gallons of water treated (ASI, 1988; 1991a). Therefore, the O&M costs used in the report may be significantly less than typical historical RO O&M costs at other DOE facilities. O&M costs for VCE systems are largely unknown. While Rocky Flats Plant has a VCE system, it has not been in operation enough to provide reliable O&M costs. The VCE O&M costs used in the report were approximately $3.90/1000 gallons of evaporated water. My experience indicates that at DOE facilities these O&M costs may be higher than those estimated in the ERA Proposal report.

Based upon the above costs estimates, it appears that the RO/VCE treatment component of the pump-and-treat alternatives is significantly under-priced, both with respect to capital costs and O&M costs. This also may be the case for the IX/VCE treatment component as well; however, less uncertainty exists in the IX treatment because the N Springs ERA report indicates it has been used at the Oak Ridge DOE site.

Alternative 3 - Vertical Barriers

The effectiveness of the two barrier (slurry)-wall alternatives ranged from 71 percent to 100 percent reduction of ^{90}Sr flux to the Columbia River. These flux-reduction estimates are suspect, because no estimates of the flux around the ends of the slurry wall (end effects) were estimated. It would appear, that although the ^{90}Sr flux rate to the River is greatly reduced, it will not be completely cut off over the 10-year life of this alternative. However, this alternative is attractive, because it constitutes a one-time capital cost expenditure with no annual O&M costs. It could also fit into future remediation alternatives for the 100-N Area. However, no costs were presented to account for removal of the slurry wall if such removal is required under CERCLA. I judge that the probability of removal of the wall in the future is small. The long-term impacts of leaving the barrier wall in place should be addressed more thoroughly in the ERA Proposal. The rationale for the slurry wall is based upon the assumption that it would induce a very flat hydraulic ground-water gradient and, along with the existing soils, would provide retardation (assumed in the report to be 120) sufficient to reduce the flow of water and resulting flux of ^{90}Sr to the Columbia River. If, after installation, the slurry wall is shown to provide less effectiveness than assumed, a pumping (injection or extraction) well(s) could be installed to more actively control hydraulic gradients.

Alternative 4 - Hydraulic Control

The hydraulic-control alternative assumed placement of a line of pumping wells in uncontaminated areas of 100-N Area behind the ^{90}Sr plume to pump "clean" water and flatten the ground-water gradient to the River, thus reducing the flux rate to the River by up to 50 percent. This alternative was shown to be the least cost of the alternatives considered but has many uncertainties related to water pumping rates and control of pumping. The same effect could have resulted from pumping Columbia River water into a line of wells located at the edge of River near the N Springs. This hydraulic-control alternative would have the same effect as the slurry wall and may be less expensive over the 10-year project life. The same uncertainties exist for this alternative as for the slurry wall relative to end effects; however, because this alternative is not a completely passive system, more control would be available by adjusting well-pumping rates or adding additional wells, if needed.

The costs given in the Section 6 cost tables for each alternative (Tables 6-8 through 6-14, 6-21, and 6-25) do not reflect the costs presented in Appendix A of the report. I have assumed that the costs in Appendix A are correct, because the present values in Appendix A reflect the correct time frame (10 years) and discount rate (10 percent) indicated in the report.

Comments Related to Section 7 - Comparative Analysis of Removal Action Alternatives

The key elements in this section are Figure 7-1 (Cost Benefit Analysis of Alternatives) and Table 7-1 (Cost Comparison of Alternatives). It should be noted certain values in Table 7-1 are in error and this table should be replaced with the correct costs (also shown on Figure 7-1) as shown in the table on Page A-7 of Appendix A. Although the table on Page A-7 does not show the cost of the slurry wall located 100 feet from the River, these costs appear to be correct as shown in Table 7-1.

Figure 7-1 indicates that the least-cost alternative is Alternative 4 - Hydraulic Control and the most effective alternative, from the criterion of reduction of ^{90}Sr flux to the River, is either the slurry wall (Alternative 3) near the River or the 5-well pump-and-treat system (Alternative 2). Because, in my opinion, the costs for the treatment components of the pump-and-treat alternatives are significantly undercosted for a DOE facility, these alternatives are less attractive than either the slurry wall or hydraulic-control alternatives. If fact, from a purely cost-benefit standpoint, it may be difficult to justify any form of pump and treat for the ERA. Although some form of pump and treat may be selected for the final contaminant removal action in the 100-N Area, it does not appear to be supported through the EE/CA for this ERA Proposal. In addition, the impacts of the sulfate and petroleum contaminant plumes on the treatment component of the pump-and-treat alternatives are not addressed, causing large uncertainties in both the performance and costs of the treatment technologies.

Although the slurry wall may not have a 100-percent effectiveness, as shown on Figure 7-1, it would be as effective as pump and treat using a 3-well extraction system. Also, it appears that fewer uncertainties exist in the slurry wall than in the pump-and-treat alternatives.

<u>Comments Related to Section 8 - Preferred Alternative</u>

No preferred alternative is recommended in the report. Rather, both the slurry wall and pump-and-treat alternatives (comprising 10 of the 12 original alternatives) are recommended as the preferred alternatives, subject to additional studies designed to reduce the uncertainties in the physical and chemical parameters of the ground-water system. In my opinion, much more effort needs to be placed on the cost-estimation aspects associated with the ERA Proposal. Because the ERA is an expedited, and by definition, not the final action for the site, one of the least-cost alternatives should be recommended as the preferred alternative. It appears that the alternative with the least uncertainty is the slurry wall, which is still one of the least-cost alternatives, assuming that realistic Hanford Site treatment costs are used for the pump-and-treat alternatives.

<u>Comments Related to Section 9 - Schedule</u>

No comments.

<u>Comments Related to Section 10 - References</u>

No comments.

CONCLUSIONS AND RECOMMENDATIONS

Based upon my review of the N Springs Expedited Response Action Proposal (DOE/RL-93-23), Revision 0, (DOE RL, 1994), I offer the following conclusions and recommendations.

<u>Conclusions</u>

1. Minor inconsistencies exist in the report relative to concentrations of ^{90}Sr in the ground water in the 100-N Area in the vicinity of the N Springs.

2. The goal of the ERA should be removal of 50 percent of the ^{90}Sr <u>flux</u> to the Columbia River rather than removal of 50 percent of the ^{90}Sr <u>concentration</u> higher than 1,000 pCi/L.

3. The specific MCLs used for treatment goals for extracted water from the pump and treat alternatives are not explicitly stated in the report. Are the existing or proposed MCLs being used?

4. Tritium may not be an issue if the proposed MCL of 69,040 pCi/L is used.

5. Many uncertainties exist in the costs and effectiveness of the proposed removal-action alternatives. These uncertainties fall into three categories: (1) the physical and chemical parameters used to calibrate the ground-water flow and transport model; (2) the ability of the treatment alternatives to effect a ^{90}Sr concentration equal to specific MCLs; and (3) the costs used in assessing the removal-action alternatives, especially the treatment components of the pump-and-treat alternatives.

6. RO capital costs for DOE facilities appear to be underestimated by up to 10 times in the report, causing the treatment component of the pump-and-treat alternative to be much more expensive than assumed in the ERA Proposal. VCE capital costs also are underestimated relative to DOE sites but only by a factor of less than 2. Operation and maintenance costs for RO and VCE treatment is underestimated by a factor of 6 or more relative to both historical commercial (non-DOE) and DOE operation and maintenance costs for similar facilities.

7. No preferred alternative was presented, even though the EE/CA process is supposed to recommend a preferred alternative for the ERA. Instead, 10 of the 12 original alternatives are presented as the preferred alternatives, pending further study.

<u>Recommendations</u>

1. More realistic ground-water concentrations of ^{90}Sr, and perhaps ^{3}H, based upon all well data available, should be presented in the ERA report.

2. The goal of the ERA should be clearly presented in Section 3 as a 50 percent reduction in ^{90}Sr <u>flux</u>.

3. The MCLs which are to be used should be clarified. This will have impacts regarding the treatment-technology capabilities for the pump-and-treat alternatives and also may make tritium a non-issue relative to N Springs discharges to the Columbia River.

4. Emphasis should be placed on realistic costs for the pump-and-treat alternative(s), as well as other alternatives, in an effort to clearly identify a preferred alternative. This should be done prior to other activities recommended in Section 8 of the ERA Proposal report. It is understood that better costs may be dependent upon treatability studies for the treatment alternatives. At a minimum, additional analysis and refinement of costs, and treatability studies should be done as a part of the preferred alternative selection.

5. A preferred alternative should be selected and implemented as soon as possible, based upon a defensible cost-effectiveness analysis. This should include realistic costs for DOE facilities.

If you have questions for desire additional information regarding this letter, please call.

Yours truly,

James R. Kunkel, Ph.D., P.E.
Senior Principal Engineer

Reviewed by:

Timothy D. Steele, Ph.D.
Manager, Water Resources/Physical Sciences Department

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APPENDIX F

COMMENTS OF RICHARD A. MILLET

February 17, 1994

Mr. Reed A. Kaldor
Project Director
Advanced Sciences, Inc.
1777 Terminal Drive
Richland, WA 99352-4952

Re: "N-Springs" Expedited Response Action (ERA) Proposal

Dear Mr. Kaldor,

In accordance with the contract between Westinghouse Hanford Company and Advanced Services, Inc. (ASI) and the subagreement between ASI and Woodward-Clyde Federal Services (WCFS), you have requested that I participate on an Independent Review Board to critique the referenced Proposal. It is understood that this Proposal was prepared by the IT Corporation on behalf of Westinghouse Hanford Company.

On February 7 and 8, 1994, I participated in meetings at your Richmond, Washington offices. During these meetings, I had the opportunity to discuss the subject Proposal and to meet with both the management and the technical staff of IT Corporation, Westinghouse Hanford Corporation, and other members of the Independent Review Board. In addition, copies of various background reports and documents were made available for my review.

My understanding of the primary objective of the ERA is to eliminate, or significantly reduce, the flux of Strontium-90 being released into the Columbia River from the N-Springs in the 100N Area. In turn, the objective of the N-Spring Independent Review Board (as defined by R.P. Henckel of Westinghouse Hanford Company during his briefing to the Independent Review Board on February 7, 1994) is to provide independent technical review of DOE/RL-93-23, *N-Springs Expedited Response Action Proposal, Revision 0,* by analyzing the technical adequacy of the documents and the conclusions.

Subsequent to our meetings in Richmond, I have reviewed the ERA Proposal and the references provided. The following text provides my opinions and conclusions. Since my expertise is Geo-Civil Engineering, my comments will tend to focus in that area.

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OVERVIEW

In light of the very short time fuse given IT Corporation, I believe the ERA proposal to be comprehensive, thorough, and generally well done. Specific comments by Report Section follow:

SECTION 1.0 - INTRODUCTION

No comments.

SECTION 2.0 - SITE DESCRIPTION

Section 2.0 appears to accurately summarize available existing data. Obviously, there was not time available to collect new data or fill data gaps (e.g. longer term pumping tests, test borings to supplement aquifer stratigraphy, etc.). These data should be obtained prior to final remedial action.

SECTION 3.0 - REMOVAL ACTION OBJECTIVES DEVELOPMENT

This section clearly states the objective of the ERA is to eliminate or significantly reduce (i.e. a 50% reduction) the flux of Strontium-90 into to the Columbia River from the N-Springs. A secondary objective of the ERA is to implement an action that will be compatible with future remedial action(s) and contribute to its (their) efficient performance.

SECTION 4.0 - IDENTIFICATION OF REMOVAL ACTION TECHNOLOGIES

I generally agree with the technologies identification. There are no significant omissions.

SECTION 5.0 - SCREENING OF REMOVAL ACTION TECHNOLOGIES

I am in general agreement with the process employed to screen technologies and with the results of process; i.e. inappropriate technologies were eliminated and appropriate technologies were accepted for further study.

SECTION 6.0-DETAILED ANALYSIS OF REMOVAL ACTION ALTERNATIVES

The following comments address specific issues/text in Section 6:

The four main selection criteria on page 6-1 are acceptable.

The following comments address specific technical issues:

- Groundwater Modeling

  The groundwater and transport (PORFLO-3) modeling done, seem reasonable appears reasonable. Due to the limited field data verification available, however, the results of this modeling should be considered on a relative comparative basis among the alternatives rather than on an absolute basis. One specific comment relates to the ability of the model to predict the outcome of flow around the ends of the slurry wall barrier. It would appear that an order of magnitude estimate of the flux around the ends of the wall could be made based upon the existing modeling data, whereas the report leaves this issue as a significant open question.

- Vertical Barrier Wall

  The location and alignment of the proposed vertical barrier wall system does not seem to be well engineered. In reviewing the available topography along the proposed general alignment, several issues were identified (see Figure 1): 1) the wall must be about 200 feet from the river to reach the near-level (elevation 135 to elevation 140) highlands above the river, at this location the required depth of a barrier wall will be about 100 feet; 2) at 100 feet from the river the barrier wall is located on a slope typically ranging from 2 horz. to 1 to 3 horz. to 1 and the required depth of the wall ranges from 60 feet to 80 feet; and 3) at 50 feet from the river the barrier wall is located on the same slope (in some locations on or near an access road) and the required depth of the wall ranges from 40 feet to 50 feet. The depths for a wall 50 feet and 100 feet from the river will greatly reduce the required square footage of wall needed to be constructed, compared to the quantities used in the Expedited Response Action (ERA) proposal.

Regarding the barrier wall types, I concur with the use of the single auger deep soil mixing technology for construction of the barrier wall. In addition, I believe that a steel sheet pile wall with grouted waterlocks should be revisited, especially for the shallower wall needed at 50 feet and 100 feet from the river.

For the soil-mixing wall, however, at the upland locations, it is not clear that the plan was to stop soil mixing at an appropriate level above the water table (i.e. 10 ft) or that grout mixing would continue to the ground surface. The back-up pricing schedule included in Appendix A seems to indicate the latter (see Appendix A, page A-27). The mixing and the introduction of cementatious material can be stopped at an appropriate elevation above the groundwater surface, and thus, the cost of the wall could be reduced.

In addition to the single-auger systems, high pressure jet grouting could be used to construct the barrier wall. This technique has the advantage of allowing more precise maintenance of the physical alignment of the wall. This technology which is provided by Haliburton Companies, has the disadvantage that some drill cuttings come to the surface and the risk of the high pressure jet not penetrating or cutting through some in-situ soils, and thus, possibly creating windows. (If further interest in this technique exists, I suggest you contact Mr. Paul Pettit of Haliburton at 713/561-1560.)

- Table 6-20 - "Technical Feasibility Evaluation for Slurrywall Alternatives"

    - Operation/Maintenance Requirements

      The table indicates "a vegetative cap may be required". Such a cap would not be required, especially if the mixed-in-place wall stops below the ground surface.

    - Environmental Effects on Performance

      The table indicates "groundwater flow has the potential to deteriorate the wall over time." During the 10-year project life, there is likely no deterioration of a competently installed wall.

    - Sensitivies and Uncertainties

      The table makes no mention as to the potential difficulties associated with cobbles/boulders in constructing the wall and no discussion of the significant savings that could occur if the permitting issues associated with installing the wall in the flood plain could be resolved.

SECTION 7.0 - COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

Even recognizing the real enviro-political pressures that the Hanford facilities face, this Section of the report does not follow the objectives and criteria of the ERA. Table 7-1 would seem to clearly indicate that the barrier wall is the most cost-effective solution resulting in the least impact and no required discharges. The pumping systems do not address the uncertainty of the alluvial aquifer. Erratic stratigraphy introduces the possibility that hydraulic short circuits exist, and therefore, discharges to the springs may be unaffected by a 3 or 5 pump scheme. The possibility exists that supplemental wells would be required to achieve the desired objectives. The barrier wall deals much more positively with these stratigraphy issues by physically cutting throughout all zones of alluvium.

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Based upon: (1) my previous comments on the reduced cost of a less than full height mixed wall and/or the movement of the wall toward the river which would reduce the required height; and (2) the potential for dramatic increases in the true operating costs for a pump and treat system on the Hanford facility (my understanding based on labor and shift costs associated with work at a Hanford "nuclear facility"), it appears the cost benefit analysis would move even further in supporting a barrier wall alternative.

In this regard, I would like to offer a suggested alternative which may incorporate the "best of both worlds". I would suggest consideration of evaluating the use of a shortened barrier wall (1500 to 2000 feet) coupled with the installation (but not pumping) of two wells, one located at each end of the barrier wall. These wells would be monitored, but not pumped, until and/or unless strontium levels in the wells show above criteria concentrations. The cost of this alternative could be less than the alternatives currently being considered, and positive control would be obtained over the strontium flux rate to the N-Springs (see Figure 2 for a sketch of the alternative).

Finally, I have several specific editorial comments and/or corrections to Section 7 text. The use of the word "wall" on page 7-1, Section 7.1.1.1., seventh sentence beginning "In addition, the location...", is confusing. The pumping alternatives do not create a wall, only the slurry barrier does that.

The hydraulic control alternative on page 7F-1, Figure 7.1, could be interpreted as the best solution. In discussions with IT staff, additional limitations and uncertainties were orally presented which are not completely described in the text. I suggest text in this area be augmented.

The "wall at the river" on page 7F-1, Figure 7.1, is shown to be 100 percent effective. Nothing is 100 percent effective, and this concept should be appropriately corrected as it reduces the credibility of the report.

There appears to be some mathematical inconsistencies in the present worth values in Table 7-1, on page 7T-1, Appendix A, and in tables of costs presented in Section 6.0.

SECTION 8.0 - PREFERRED ALTERNATIVES

My comments on Section 7.0 address my overall comments regarding the preferred alternatives. Although uncertainties do exist, I believe the modified barrier wall coupled with the non-pumping back-up wells could be implemented after gathering supplemental field verification information.

SECTION 9.0 - SCHEDULE

The schedule seems to be complete, but if a definitive alternative can be selected, some time could be saved in implementing the solution. If the suggested shortened barrier wall plus non-pump wells were selected, the water treatability studies could be done in parallel with construction of the wall. Pumping, if needed, would not take place for at least several years. This process would allow time to select the water treatment technology, complete its design, and have procurement on ready standby.

If you have questions or desire additional information, please call.

Yours truly,

Richard A. Millet, P.E.
Chief Practice Officer

FIGURE 1
TYPICAL VERTICAL BARRIER LOCATIONS

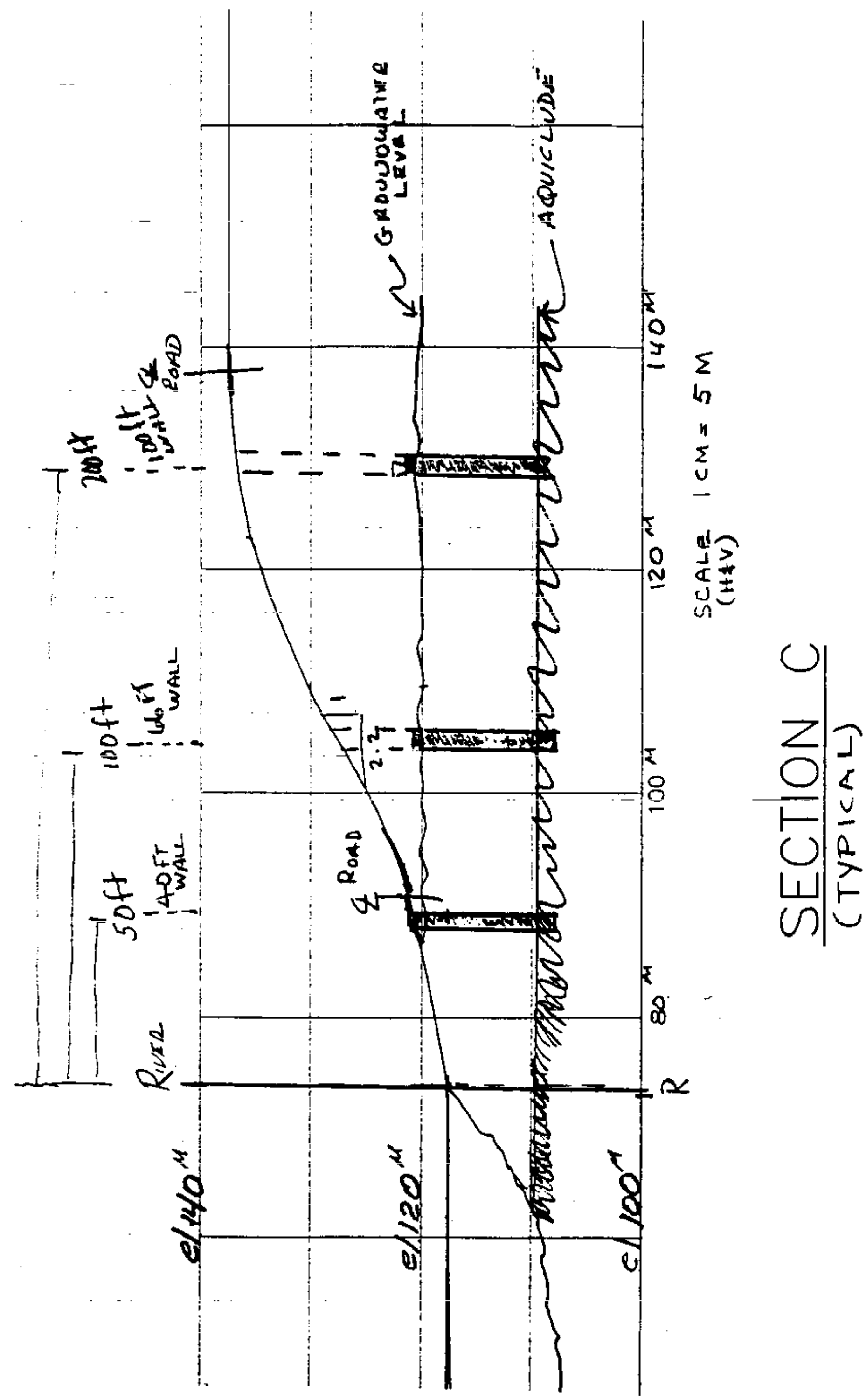
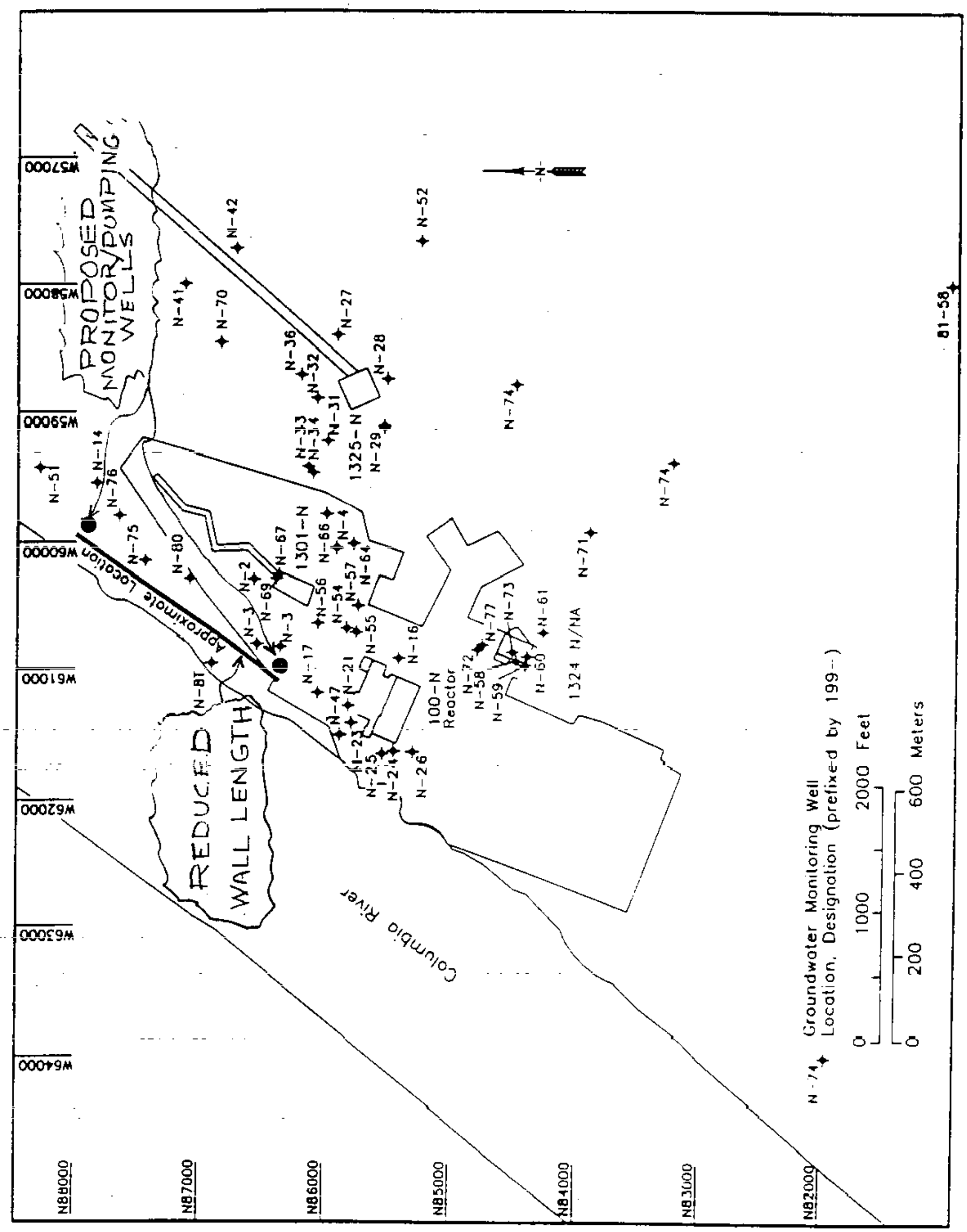


FIGURE 2
PROPOSED COMBINATION ALTERNATIVE



APPENDIX G

COMMENTS OF MARTIN VORUM

REVIEW OF "N SPRINGS EXPEDITED RESPONSE ACTION PROPOSAL"

SUBJECT DOCUMENT -- DOE/RL-93-23; REVISION 0

ASI PROJECT/TASK: 9848.101

CONTRACT NAME: WESTINGHOUSE HANFORD CORPORATION

Review Notes by Martin Vorum

February 18, 1994

1.0 PURPOSE

On February 7, 1994, a review was begun by Advanced Sciences, Inc. (ASI) to assess the methodology and results of a study by Westinghouse Hanford Corporation (WHC) that culminated in the subject report: **N Springs Expedited Response Action Proposal.** The Proposal for the Expedited Response Action (ERA) was issued January 1994 by the United States Department of Energy (DOE), Richland, Washington. The Proposal addresses groundwater cleanup issues for the "N Area" of the DOE Hanford Federal Facility (the Site), located adjacent to the city of Richland.

This submittal presents notes on the portion of the review by Martin Vorum for ASI. The primary focus of the author is on the extraction, treatment, and disposal of groundwater from the N Area. General comments are made concerning the data on groundwater hydrology phenomena as they affect the potential scope and performance of water treatment systems.

2.0 BACKGROUND

This review addresses the findings written into the ERA Proposal and the implications of those findings regarding the Proposal's implementation. The following comments briefly outline the bases of this review.

The ERA for the N Site groundwater is mandated in agreements between the parties operating the Hanford Site, and those responsible for oversight of environmental issues and activities on the Site. Among other documents, this review covers the subject ERA Proposal and the plan that guided its development: **100-N SPRINGS EXPEDITED RESPONSE ACTION PROJECT PLAN**, (ID Number WHC-SD-EN-TPP-002, Rev. 0, September 25, 1992). From those two documents, in particular, we understand that the goals for developing the ERA Proposal and for its implementation include:

- Describe the Site characteristics;
- Identify the tasks to complete the ERA Proposal;
- Identify critical ERA design and implementation tasks;
- Describe alternatives to be considered to perform the ERA, and the screening process applied to those alternatives.
- Define a project schedule (for implementing the ERA Proposal).

Through the Proposal, the DOE intends to conduct an ERA to "substantially reduce the Stontium-90 (Sr^{90}) transport into the (Columbia) River through the groundwater pathway." In developing the ERA Proposal, its authors determined that the modeling of the Site hydrogeology and the data on water treatment technologies were insufficient for resolution of the detailed implementation plan. Therefore, the ERA Proposal necessarily includes completing the information to select a preferred alternative at N Springs. The detailed design and near-term implementation of the ERA are also contemplated in the Proposal. The shortfall in hydrologic and water treatment engineering data left the following questions:

- To what degree will the various options for groundwater management reduce Sr^{90} flux to the river? Significantly, does more accurate geohydrology modeling support the "No Action" ERA alternative?
- For active flux management by extraction and treatment, what flows must be used as treatment design bases?
- What are the performance capabilities of the available water treatment alternatives?
- Which disposal option for treated ("clean") water is acceptable?

3.0 SUMMARY OF REVIEW FINDINGS AND RECOMMENDATIONS

This reviewer agrees that it is premature to select any of the removal alternatives to implement for the ERA Proposal. The objectives for managing the N Area groundwater are ambiguous. Therefore, the criteria for evaluating any alternative are uncertain: e.g., the Proposal names a flux reduction for Sr^{90} to the Columbia River by 50 percent, but the discussion of ERA alternatives focuses on 95-plus percent removal. Specific objectives must be set in order to qualify the choice of alternatives.

The technical data are weak on the groundwater movement and quality, and on treatment capabilities and costs. In summary these specifics must be addressed:

The groundwater regime modeling must be refined to quantify the potential effectiveness of active management. Regarding the pump-and-treat alternatives, their component systems cannot be sized without the fundamental information on their necessary capacities. As noted in the ERA Proposal, costs for treatment are proportionally affected by capacity.

The knowledge of treatment effectiveness is insufficient to determine whether target water qualities for the Site can be achieved at "reasonable costs." Even assuming possible capacities, the details of system design to achieve strontium removal are unknown, and the costs of secondary waste management and disposal are highly uncertain; estimated disposal costs are significant and could be higher.

To address narrowly the technical questions of water treatment effectiveness, it is suggested that two variations on the water treatment alternatives be considered (depending on resolution of objectives, though):

- It may be necessary to run ion exchange (IX) in series with reverse osmosis (RO), in effect de-ionizing the RO permeate, in order to meet the exacting water disposal standards.

- Chemical methods applied to other radionuclides, for example radium, to meet water standards may be effective by analogy for strontium isotopes: e.g., precipitated barium sulfate acts as a "getter" to adsorb soluble radium, even below the equilibrium solubility limit of radium sulfate.

4.0 ISSUES RE. OBJECTIVES AND TECHNICAL FEASIBILITY OF ERA PROPOSAL

ERA OBJECTIVES: REDUCING Sr^{90} FLUX TO RIVER

4.1 As noted in the Comparitive Analysis, page 7-6, the slurry wall and hydraulic control alternatives could cause clean aquifer material to become contaminated. In the context of the objectives of the ERA and ultimate site cleanup, this potential should be characterized as both temporary and self-correcting.

4.2 This author contacted S.M. Robinson (principle author of a 1990 paper referenced in the Proposal) on ion exchange studies for the Oak Ridge National Laboratory (ORNL). There is a parallel for the Hanford Site regarding the issues of strontium cleanup in the ORNL experience: ORNL is permitted to discharge treated water to a stream which flows to a lake, meeting standards of the National Pollutant Discharge Elimination System (NPDES) set at 11 becquerels per liter, equivalent to about 300 picoCuries per liter, or roughly 7 to 37 times the standard contemplated for the Hanford Site treated water.

Recommend re-evaluating the target discharge limits for the Site: are they unreasonably and impractically stringent?

GENERAL ISSUES FOR N AREA ACTIVE GROUNDWATER MANAGEMENT

4.3 Given the significant uncertainties described in the ERA Proposal, the statement of Section 7.1.1.3 is overly broad. We cannot know or even judge which, if any, of the alternatives can meet the as-yet unquantified reduction in Sr^{90} flux to the river. Therefore, performance and reliability are not yet capable of being compared in meaningful terms.

Recommend re-wording to acknowledge uncertainties.

4.4 The Proposal cites petroleum and sulfate contamination of the vadose zone soils and the groundwater (Sections 2.2.2/2.2.3). This should be considered in better evaluating groundwater flows for the pump-and-treat or hydraulic control options; heavy metals should also be considered with better data on the existing groundwater quality. Care should be taken to ensure that solid wastes derived from the pumped water would not be classified as "mixed waste" as a result of combined contaminants -- that may result in much higher net disposal costs than the assigned $63 per cubic foot of solids.

4.5 The development of the ERA Proposal was intended to result in selecting a preferred removal alternative, but the uncertainties on precise site conditions and potential performance of the active alternatives precluded making such selection. The Proposal generally defines a followup selection process. This is appropriate given current information, but wording on page 6-2 suggests the Proposal is reporting a selection. On page 8-1 the Proposal states additional information "may" be needed to implement one preferred option.

It would help all readers for the Proposal to state more plainly and consistently in Sections 6.0, 7.2 and 8.0 that the overall action objectives and specific options' effects require further definition before it is possible to select and implement one ERA option.

4.6 Section 6.2.1.3.3 suggests reinjecting treated water upgradient of the extraction wells of a pump-and-treat system to achieve containment through recycle of contaminants, principally tritium. This is a questionable solution because of the implied need to maintain a growing subsurface reservoir of water sufficient to realize the natural decay cited in the description. The recycle option faces significant practical hurdles.

TECHNOLOGY-SPECIFIC ISSUES

4.7 The abilities of reverse osmosis and ion exchange technologies to achieve Sr^{90} target values are indeed subject to question (1,2,3,4,5). For perspective, the target treated water qualities of either 8 or 42 picoCuries per liter (pCi/L) beta emissions due to strontium correspond to <u>extremely</u> low Sr^{90} mass concentrations of roughly 10^{-07} parts per billion (ppb). At these levels the performance of RO membranes (rejection) and IX media (capture of strontium) are not generally known in industry. For ion exchange, there will be significant adsorptive competition principally from calcium, magnesium, and iron, because they exist in the groundwater at concentrations roughly 1 million to 10 million times the probable range of Sr^{90} concentrations entering a treatment system. There are some case-specific applications not widely reported (6). For the Hanford Site, data will have to be developed empirically.

As a result, the technical uncertainty affects the two major cost factors for either RO or IX:

1. The design and scale of the treatment system needed to achieve the target water quality values.

2. The amount of solid wastes that will actually be generated in the form of spent RO membranes (due to accumulated low-level radioactive contamination) or spent IX media (due to fouling by competing, dominant species calcium, magnesium, and iron, that should be adsorbed several orders of magnitude faster than Sr^{90}).

It would appear, therefore, that the RO and IX secondary waste solids disposal rate of nearly 1 cubic yard per day (assigned in the ERA Proposal costs) is highly sensitive to the ongoing evaluation. It plays a significant role in the costs estimated to date -- roughly $0.5 million per year for a 300 gpm system. This would increase or decrease roughly in proportion to treatment efficiences experienced in eventual practice.

Anticipating the difficulty of achieving the extreme strontium treatment levels proposed, it has been suggested (7) that two variations on the treatment design alternatives are worth consideration:

- Radium can be co-precipitated from water to meet its respective drinking water Maximum Concentration Limits (MCLs) in the presence of suspended barium sulfate solid. By analogy, strontium may exhibit the same behavior. The benefits would be two-fold: Barium sulfate is relatively insoluble, and so would only necessitate the maintenance of low amounts of dissolved barium and sulfate in the water. Secondly, this may mitigate the very costly burden of disposing spent adsorbent media if IX were the primary treatment.

- RO might serve as a general desalting treatment step, followed by IX (of the RO permeate) to effectively de-ionize the water. This may allow IX to meet the treatment goals, while not consuming quantities of media as would occur for IX as a single step treatment. However, this invokes the potential complications and costs of both RO and IX.

4.8 Silica was not identified in the background water data in Table 2-4. Silica could play a significant role in limiting the RO system recovery levels. The study assumed 90 percent production of treated water by RO. Modest differences in RO efficiency -- say achieving only 70 to 80 percent recovery -- would dramatically increase the size and operating costs for secondary waste treatment, assumed to be by evaporation. As a cascade effect this may also increase the difficulty of achieving water quality due to inherent salt carryover in evaporation systems.

This factor should be considered in the further technology evaluation.

4.9 Similarly, background levels of carbonate/bicarbonate species were not named. Carbonate scaling was appropriately mentioned as a possible limiting factor for RO efficiency, and would have an effect similar to silica on the costs of secondary waste treatment.

4.10 Regarding the disposal of (clean) treated water from a pump-and-treat system, Proposal Section 5.2.3.2 cites a ban on "liquid effluent releases" into cribs on the Site under the Tri-Party Agreement Milestone M-17. Crib disposal then would require a waiver, according to the Proposal, which implies uncertainty, or at least additional negotiation effort and time.

Does the term "effluent" actually apply to rigorously treated water, or more correctly to the past practices of disposing of untreated or minimally treated water specifically to achieve soil column adsorption of waste constituents? The answer could streamline the selection and approval process.

4.11 The Proposal cites flocculation/sedimentation/filtration to remove suspended solids as pre-treatment for either water treatment option, and costs are ostensibly included in the RO/IX capital costs.

The background groundwater data also show combined dissolved calcium, magnesium, and iron concentrations 5 to 7 orders of magnitude greater than estimated Sr^{90} concentrations in the raw water subject to treatment. The detailed evaluations of IX technology, in particular, should consider chemically precipitating these species in the pre-treatment section. This may yield savings due to reduced IX media consumption if the non-target metals inevitably will wind up in the solid wastes. The surplus of calcium and magnesium over strontium would still be very large. A 1988 paper by Robinson et al discusses this approach, but not in the context of this project's minute Sr^{90} levels. Given the uncertainties about IX selectivity for Sr^{90}, the differences in secondary waste disposal may be significant.

4.12 Section 6.2.1.2.1 cites IX application for cobalt colloid removal. The Proposal does not otherwise indicate cobalt is among the Chemicals of Potential Concern (COPC).

5.0 ERA PROPOSAL COMBINED COST ISSUES

MAJOR COST ISSUES

The following comments are given in order of the author's view of relative importance to the realization of ERA objectives and correct determination of costs.

5.1 The Proposal refers to achieving "cost effectiveness," "reasonable costs" (both on page ES-1), and "optimizing ... resources ... (and) degree of benefit" (pages 1-1, 1-2). The criteria and methods for determining effectiveness and optimization are not stated, however. In particular, we understand that the desired or necessary degree of reduction in flux of Sr^{90} to the river is not yet established, and that risk assessment work for the Site may support relatively modest flux reductions, compared to the 90-plus percent reductions estimated for some ERA alternatives.

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This author strongly recommends that the Proposal place a top priority on resolving a target flux reduction. Without this, one cannot set a performance threshold for the ERA alternatives, and "reasonable" or "optimized" costs cannot be determined.

5.2 Page 6-3 of the Proposal states the assumption that costs will not correspond to the design and operating standards that would be required if the ERA systems were "installations of permanent nuclear facilities." This assumption has major cost-multiplying effects, and every effort should be made to ensure that the design criteria of a pump-and-treat approach, if selected, avoid invoking such costly standards.

5.3 The Proposal defines the estimated costs as "relative" on page 6-3. The costs for ongoing (groundwater) monitoring and Site access control are assumed to apply to all ERA alternatives (page 6-3), and such costs are not included in the estimates used in the Proposal (page 6-6). This is consistent and supports the relative comparison of costs for all options against a "zero-baseline" reference of Alternative 1, the No Action approach. However, this definition of baseline also causes the cost comparison to slightly overstate the relative cost differences between options, depending on the magnitude of costs imbedded in the baseline.

It would be useful and prudent to identify the assumptions on the Section 6 cost tables; in the text and cost tables of Section 7 (Comparitive Analysis); and in the bases listed in Appendix A (Cost Estimates).

5.4 Comparitive costs of off-site disposal of low-level wastes were obtained (6) at $30 to $300 per cubic foot. The Proposal used a basis of $63 per cubic foot. (These comparitive rates do not include shipping.) Thus, the estimate for onsite solid waste disposal is at the low end of available commercial fees, discounting shipping for a common basis. The Proposal indicated rates may change -- this factor should be tracked closely because it is already a major cost component.

5.5 Section 7.1.2 of the Proposal states that pump-and-treat costs are most sensitive to pumping capacity, followed by disposal type (for the treated water). The quantitative comparisons listed on page 7-3, however, indicate that the choice of a disposal option could have greater impact (worst case, as high $8 to $10 million) on cost than would the capacity range for the assumed pumping rates of 150 to 300 gallons per minute (gpm). This case occurs if the 200 Area is selected for treated water disposal. By inference, the relative sensitivity would also hold for somewhat higher capacities, too.

Excluding the high-cost 200 Area disposal option, the difference in costs of alternatives due to other disposal options ranges only from about $0.8 million to $2.8 million within consistent alternatives. Thus, the disposal option potentially represents the least cost-sensitive factor for pump-and-treat alternatives.

5.6 This author has not performed a cost estimate for the alternative of using new cribs for treated water disposal systems. However, for a capacity of 150 to 300 gpm of water meeting Drinking Water MCLs, a disposal crib cost of $1.7 million seems excessive.

5.7 The Proposal uses a unit cost of $1527 per foot of depth for extraction and reinjection wells for the pump-and-treat alternatives. This is about an order of magnitude greater than comparable unit costs in similar geologic settings, but in non-DOE site settings (8) -- i.e., non-radioactive mine tailings or drainage sites.

Is that scale of multiplier appropriate for the Hanford site setting, given the available background data on soil and water contamination? (Note that the proposed wells would be installed in locations away from the highest contamination profiles in the 100 Area.)

5.8 In the cost breakdowns in Appendix A, the RO alternative costs do not include installation, corresponding to those given for IX, comprising shipping, installation, and piping, with associated materials and labor.

5.9 Annual maintenance costs for water disposal at the 200 Area are assumed at 3 percent of capital, excluding the cost of the crib. The resultant value then is driven by the cost of the nearly 9-mile pipeline from Area 100. Is this percentage justified for that kind of base capital cost -- i.e., a simple pipeline?

5.10 The capital costs for hydraulic control include a 16-inch transfer pipe to the river. For the assumed capacities, 16 inches is extremely generous for pipe size. What is the discharge point? The Proposal also gives a discharge pipe length of 8000 feet. Perhaps a good fraction of this line's estimated $698,087 cost could be saved using different bases.

MINOR COST ISSUES

Following are discrete design and estimating issues that could result in cost savings that each amount to small percentages of the total costs of ERA implementation, but which also could amount to meaningful savings that should be captured:

5.11 Buried piping from extraction wells (for either the hydraulic control or the pump-and-treat alternatives) and from a treatment system to the various potential disposal locations: if not an obstruction to traffic in the area, piping could be installed at the surface less expensively, while still providing protection against freezing in the event of system power interruptions in cold weather.

5.12 Is the use of stainless steel well casings required or technically justified?

5.13 Drums were omitted from the disposal costs given for the IX alternative.

5.14 Mixers for feed equalization tanks: probably of insignificant benefit relative to any realistic potential swings in net groundwater compositions during operation of the extraction wells.

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