PREFACE

In the last decade, knowledge about the region beneath the Hanford Site Tank Farms has increased tremendously. Single-shell tanks and pipelines have released contamination into the ground. In the mid 1990s, cesium-137 was found 30 to 50 feet away from the bottom of tanks. The then-current understanding was that it should have moved just a few feet. There were concerns that waste from Hanford's large underground storage tanks was moving faster than the Hanford scientists thought and that large amounts of this waste would soon be in the groundwater on its way to the Columbia River. There were serious concerns because the waste in Hanford's underground tanks is radioactive and extremely hazardous.

After a decade of field, laboratory, and computer modeling, our understanding has greatly improved. We now understand why the cesium was found so far from the tanks. During the early stages of the leak, the sodium in the waste overcomes the natural tendency of the soil to chemically react with the cesium, allowing the cesium to move freely until the natural chemistry reasserts itself. We have a much better understanding of the geology underlying the 200 Areas Central Plateau and the processes which formed it. We have developed a better understanding of how moisture moves in the subsurface. This moisture movement takes the contaminants that escape the tanks down to the groundwater. We have developed additional supporting information needed to predict future contaminant movement and their impacts. We have drilled through the zones of largest contamination and found that the vast majority of the tank waste plumes end far above the groundwater. Nevertheless, new groundwater wells show mobile radionuclide concentrations over a hundred times greater than the drinking water standard (e.g., technetium-99). And for the first time, we have detailed, robust, quantitative risk assessments of what all of our understanding means. And, most important, we have begun to remediate the tank farms by installing berms and gutters and implementing other interim corrective measures.

This report describes what we have learned and how we have incorporated the data and information into a system of knowledge. The report incorporates data and information developed not only by the Tank Farm Vadose Zone Program, but also by staff supporting the Integrated Disposal Facility and others. This first tier (contained in Chapters 1 to 33) summarizes the knowledge in a way that a nontechnical reader can follow the discussion. The second tier (contained in Appendices A through N) provides a technical reader with more details, even though the discussion is not in the area of his expertise. The final tier is geared toward the specialist in each subfield, so that the state of knowledge can be independently judged.

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NOTES TO THE READER

The following information is provided to assist the reader in understanding the technical data and format of this report.

1. Structure of the RCRA Facility Investigation Report for Hanford Single-Shell Tank Waste Management Areas

This report covers an extremely large amount of technical material. The general approach is to divide the report into a number of volumes, or tiers. Partially, this is because of its size. More important, the report is divided into a number of tiers because of the different audiences for this report (Table 1). Because this first tier is written for a non-technical audience, the emphasis is on presenting information through figures, photographs, and tables, rather than text. In Tier 2, there is more emphasis on textual descriptions and data summaries that support our understanding of the system. Tier 3 provides a reference shelf of key Hanford documents related to Tank Farm Vadose Zone activities.

Table 1. Audiences for this Report

Audience	Purpose of Section
Non-technical	Tier 1: Provides informal summaries of background information, project results, state of knowledge (including values of key parameters), and path forward
Technical, but not expert in area covered	Tier 2: Provides technical information for professional audiences. a. Provides detailed description of state of knowledge, work accomplished since publication of respective field investigative reports, and the path forward. b. Provides the Field Investigation Reports for Waste Management Areas A/AX, C, and U.
Technical, expert in area covered	Tier 3: Provides documents already published. a. Data packages (written in conjunction with Tier 1 and Tier 2 of this report) intended for subject matter experts. b. Major documents separately published that will be useful to the technical reader.

Each chapter, appendix, and data package is written by one or more Hanford Site experts in that discipline. For disciplines that occur in various volumes, the same team produces the section at each level of detail. Table 2 gives the key authors for each area of expertise.

2. Definitions of Terms

A number of terms are conventionally abbreviated in this document (e.g., waste management area is expressed as WMA). Abbreviated terms are spelled out on their first use, and as a convenience for the reader, a list of acronyms and abbreviations with their definitions can be found following the Tables of Contents in the main document and in each appendix. A glossary of terms can be found in Chapter 32. For readers using the electronic version, hyperlinks can be used to take readers from technical words and phrases to their definition.

Table 2. Layout of the RCRA Field Investigation Report (Page 1 of 2)

Area	Summary	Detailed	Data Package	Author(s)
Introduction				
Introduction	1			F. Mann
Existing Contamination	2			F. Mann
Facility Description	3			F. Mann and D. Myers
Project Results				
History of the Project	4			F. Mann
Major Accomplishments	5			F. Mann
Summary of New Work	6	J		D. Myers and F. Mann
Field Activities and Results	7			F. Mann
Laboratory Results	8			C. Brown
Inventory	9			F. Mann
Simulations	10			F. Mann
Interim Measures	11	K		F. Anderson
Planned Corrective Measures Study	12			J. Field
Associated Science Activities	13			M. Freshley
Technology Development	14			F. Mann
State of Knowledge				
Risk Assessment Requirements	15			F. Mann
Conceptual Model	16	A		M. Wood
Inventory	17	B		F. Mann
Recharge	18	C	I	M. Fayer
Contaminant Release	19	D	II	W. Deutsch
Geology	20	E	III	S. Reidel and M. Chamness
Hydrology	21	F	IV	R. Khaleel
Geochemistry	22	G	V, VI	K. Cantrell
Groundwater Contamination	23	H	VII	D. Horton
Hanford Site Groundwater Model	24			F. Mann
Dosimetry	25		VIII	P. Rittmann
Computer Models	26			F. Mann
Future Impacts	27			F. Mann
Cumulative Impacts	28			F. Mann

Table 2. Layout of the RCRA Field Investigation Report (Page 1 of 2)

Area	Summary	Detailed	Data Package	Author(s)
Future Work				
Data Gaps	29		IX	F. Mann
Path Forward	30			F. Mann
End Material				
Preparers	31			All
Glossary	32			F. Mann
References	33			All
Field Investigation Reports				
WMA C & A-AX FIR		L		M. Connelly
WMA U FIR		M		M. Connelly
Conclusions and Recommendations		N		F. Mann

a. Sections having detailed descriptions are in Appendices A through N.

To avoid confusion, the letter I is not used to identify the appendices.

Data Packages have been issued separately from the RCRA Facility Investigation Report:

I. Recharge Data Package. Fayer 2007, M.J. Fayer and J.M. Keller, *Recharge Data Package for Hanford Single-Shell Tank Waste Management Areas*, PNNL-16688, Pacific Northwest National Laboratory, Richland, Washington, September 2007.

II. Release Data Package. Deutsch 2007, W.J. Deutsch, K.M. Krupka, and K.J. Cantrell, *Contaminant Release Data Package for Residual Waste in Single-Shell Hanford Tanks*, PNNL-16748, Pacific Northwest National Laboratory, Richland, Washington.

III. Geology Data Package. Reidel 2007, S.P. Reidel and M.A. Chamness, *Geology Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*, PNNL-15955, Pacific Northwest National Laboratory, Richland, Washington.

IV. Hydrology Data Package. Khaleel 2007, R. Khaleel, *Far-Field Hydrology Data Package for the RCRA Facility Investigation (RFI) Report*, RPP-RPT-35222, Rev. 1, CH2M HILL Hanford Group, Inc. Richland, Washington.

V. Geochemistry Data Package. Cantrell 2007, K.J. Cantrell, J.M. Zachara, P.E. Dresel, K.M. Krupka, and R.J. Serne, *Geochemical Process Data Package for the Vadose Zone in the Single Shell Tank Waste Management Areas at the Hanford Site*, PNNL-16663, Pacific Northwest National Laboratory, Richland, Washington, September 2007.

VI. Characterization Data Package. Cantrell 2007, K.J. Cantrell, C.F. Brown, R.J. Serne, and K.M. Krupka, *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site*, PNNL-17154, Pacific Northwest National Laboratory, Richland, Washington.

VII. Dosimetry Data Package. Rittmann 2007, P.D. Rittmann, *Exposure Scenarios and Unit Dose Factors for the Hanford Tank Waste Performance Assessment*, HNF-SD-WM-TI-707, Rev. 5, Fluor Government Group, Inc., Richland, Washington.

VIII. Current Groundwater Contamination Data Package. Horton 2007, D.G. Horton, *Past and Current Groundwater Flow and Contamination at Single-Shell Tank Waste Management Areas*, PNNL-15837, Pacific Northwest National Laboratory, Richland, Washington, April 2007.

IX. Data Gaps. Mann 2007, F.M. Mann, M. Connelly, D.A. Myers, T.E. Jones, R. Khaleel, M.I. Wood, M.D. Freshley, and R.J. Serne, *An Evaluation of Hanford Site Tank Farm Subsurface Contamination, FY 2007*, RPP-33441, CH2M HILL Hanford Group, Inc., Richland, Washington, June 2007.)

3. Reference Citations

Throughout the text of this report, reference citations are presented where information from the referenced report was used. These reference citations are, for the most part, contained within parentheses. This identification corresponds to the reference list at the end of each chapter and the complete reference list in Chapter 33. For each appendix, a separate reference list can be found at the end of the appendix.

4. Chemical Elements and Radioactive Isotopes

Many chemical elements and radioactive isotopes are referenced in this report. Examples of the chemical elements are cesium, strontium, and uranium; isotopes are expressed after the element name (e.g., cesium-137). To save space in tables and illustrations, elements and isotopes may appear in abbreviated form (e.g., Cs-137).

5. Scientific Notation

Scientific notation is used in this report to express very large or very small numbers. For example, the number one million could be written in scientific notation as 1.0E+06 (or 1.0×10^6) or in traditional form as 1,000,000. Translating from scientific notation to the traditional number requires moving the decimal point either right or left from the number being multiplied by 10 to some power, depending on the sign of the power (i.e., negative power move left or positive power move right).

6. Units of Measure

Information derived from historical or referenced sources is presented in the units cited in the reference. Field and laboratory data are presented in the units as measured in the field or reported by the laboratory. The approximate customary measurements are shown in parentheses directly following the use of many of the metric measurements. For example, a distance presented as 10 meters (m) is followed by 33 feet (ft) or vice versa. This example is often presented in the text as: 10 m (33 ft).

7. Electronic Viewing Option

An electronic version of this report is available. The reader is encouraged to utilize the electronic version to view the graphics particularly. Throughout the report, graphics make use of color to convey information, and when the report is printed, the color differences may be lost.

Hyperlinks are used extensively in Tier 1 to allow the reader to go to cited material. Hyperlinks connect

- citations to a RCRA Field Investigation (RFI) Report section to that section
- citations to a figure or table to that object.

8. Well Numbering and Identification

Several well-numbering methods exist on the Hanford Site, leading to confusion in identifying those structures on various maps and cross-referencing them in this report. Three numbering methods are used here:

- Tank Farm System – In this method, drywells are numbered to identify the tank farm, associated tank, and the clock position of the well relative to the tank. The tank farm numbers are A=10, AX=11, B=20, BX=21, BY=30, C=40, S=50, SX=51, T = 50, TX = 51, TY =52, and U=60; each tank is assigned a two-digit number corresponding to its official number (101 = 01, 102 = 02, etc.); and the two-digit clock position numbers are based on north as 12 o'clock (for example, south would be 06).

  Example: well 50-01-12 is north of tank T-101.

  Many farms have drywells drilled along the peripheries. These wells are noted by the tank farm number, followed by "00", and then the clock position related to the entire farm.

  Example: drywell 51-00-10 is at the 10:00 position on the periphery of the TX tank farm.

  Use of the tank farm numbering system is common because it permits the reader to readily visualize the spatial position of a given well relative to the tank it monitors.

- Hanford Site Well Numbering – In this method, based on the Hanford Site 200 Areas Well-Number protocol, each well is assigned a number based on the Hanford area in which the well exists (for example, 299 = well in either of the 200 Areas), followed by a number designating the survey sheet on which it can be found (for T, TX, and TY, these are sheets W10, W11, and W15, respectively), and finally a number based on the sequential order in which the well was drilled.

  Example: The well just south of Tank SX-113 is labeled 299-W23-19.

- Washington Department of Ecology Start Card Number – In this method, every well drilled on the Hanford Site has a tracking number assigned by the Washington State Department of Ecology. Wells drilled solely for the purpose of collecting soil samples and decommissioned after those samples were collected, often have only this number. The number is alphanumeric, such as C3104. All characterization boreholes, not extending to groundwater, drilled by the Groundwater Protection Program have only this number assigned.

  Example: One of the boreholes is designated C3104.

Every effort has been made to minimize confusion by including the name 'well' or 'borehole' with the unit-identifying number.

9. Relationship with Other Efforts

A number of programs and projects provide "information for the single-shell tank (SST) waste management areas (WMAs) that support SST retrieval and closure." Some of these are the responsibility of the tank farm contractor (CH2M HILL Hanford Group, Inc.); some are the responsibility of other Hanford Site contractors; while still others are the responsibility of the U.S. Department of Energy.

10. RCRA Corrective Actions Project

The RCRA Corrective Actions Project (managed by CH2M HILL Hanford Group, Inc.) is responsible for characterizing the sediments in the SST farms, for analyzing the long-term risks from contaminated sediments, for implementing remediation of sediments and facilities in those farms external to the tanks, and for providing information supportive of tank waste retrieval and farm closure. The RCRA Facility Investigation Report is part of the RCRA Corrective Action Project. The RCRA Facility Investigation Report activity will rely heavily on work previously performed and planned to be performed by the RCRA Corrective Actions Project. Many of those leading the preparation of sections for the RCRA Facility Investigation Report are leading or supporting the corresponding activities for the Corrective Actions Project.

11. Relationships with Other Efforts

A number of programs and projects provide information that supports this effort. Many of these are the responsibility of the CH2M HILL Hanford Group, Inc. Some are the responsibility of other Hanford Site contractors. Finally, some are the responsibility of U.S. Department of Energy-Headquarters.

a. RCRA Corrective Actions Program. The RCRA Corrective Actions Program (managed by CH2M HILL Hanford Group, Inc.) is responsible for

- characterizing sediments contaminated by tank farm releases
- understanding how the waste moved in the past and will move in the future
- estimating future impacts from the waste
- implementing interim measures to reduce the impacts of the waste
- providing information to the tank waste retrieval and tank farm closure activities to optimize their activities.

This RCRA facility investigation report is part of the RCRA Corrective Actions Program. Many of the authors of this report are part of the RCRA Corrective Actions Program team.

b. Single-Shell Tank Performance Assessment. The single-shell tank performance assessment (SST PA) activity (managed by CH2M HILL Hanford Group, Inc.) is responsible for producing long-term risk assessments (and collecting associated data) resulting from the past operations of the SST farms, from the retrieval of tank waste, and from the closure of the farms. The RCRA Facility Investigation Report activity is tightly coordinated with the SST PA effort. Some activities formerly controlled by the SST PA effort (e.g., data packages) will serve both the SST PA and this RCRA Facility Investigation Report effort. The intent is to have one data/information base for the calculation of long-term impacts from tank farm operations.

The RCRA Facility Investigation Report activity will perform no computer simulations, but will, instead, rely on the efforts of the SST PA activity. The lead of the SST PA is an active member of the team producing this RCRA Facility Investigation Report.

c. Integrated Disposal Facility Performance Assessment. The Integrated Disposal Facility Performance Assessment (IDF PA) activity (managed by CH2M HILL Hanford, Inc.) is responsible for producing the long-term risk assessment for the Integrated Disposal Facility, Hanford's newest disposal facility. Much of the geotechnical data and information needed for uncontaminated sediments can (and will) be taken from the IDF PA activity. Again, the technical leads for many of the sections have also served as leads for the corresponding IDF PA tasks. The leader of the RCRA Facility Investigation Report activity is also the leader of the IDF PA activity.

d. Tank Closure Project. The Tank Closure Project (managed by CH2M HILL Hanford, Inc.) is responsible for retrieving waste and closing the SSTs and their associated WMAs. Information from the tank farm organizations are discussed when it has a direct bearing on long-term environmental or human-health impacts from retrieval or closure. Other information (e.g., sequence and schedule of tank waste retrieval) is considered operational detail and is not included in the main part of this report.

e. Groundwater Remediation Project. The Groundwater Remediation Project, often called the "Integration Project" after its initial name (Hanford Groundwater/ Vadose Zone Integration Project), is the leader of the Hanford Site effort on characterization and risk analysis for the vadose zone and groundwater. The Groundwater Remediation Project (managed by the Management and Integration Contractor, Fluor Hanford, Inc.) also has the responsibility

- to monitor groundwater
- to characterize the vadose zone under past liquid discharge sites (e.g., cribs and trenches)
- to remediate groundwater and the waste sites.

The RCRA Facility Investigation Report team has worked closely with the Groundwater Remediation Project.

f. Hanford Site Environmental Surveillance Program. The Hanford Site Environmental Surveillance Program (managed by Pacific Northwest National Laboratory) takes field and laboratory measurements of contamination in the various media (e.g., soil, air, water) in and around the Hanford Site. The program produces annual reports on its findings (e.g., *Summary of the Hanford Site Environmental Report for Calendar Year 2005.*) The annual Hanford Site Groundwater Monitoring Report is now the responsibility of the Groundwater Remediation Project.

g. Remediation and Closure Science Project. One important goal of the Integration Project is to bring the best science to bear on the resolution of key Hanford Site environmental issues, including strong participation from the U.S. Department of Energy's national laboratories and universities. This project (managed by Pacific Northwest National Laboratory) is tightly coordinated with the Tank Farm Vadose Zone Project effort and has contributed significant insights.

h. Environmental Management Science Project. Through the efforts of the Integration Project and the Radiation and Closure Science Project, U.S. Department of Energy Headquarters (through the Environmental Management Science Program [EMSP]) has also contributed significantly. The EMSP initially awarded 31 grants (approximately 25 million dollars) that were directed toward vadose zone problems, most of which were focused on Hanford Site problems. Additional grants have since been awarded, and the results of all the efforts have been incorporated into the specific tank farm field investigation reports.

i. Hanford River Corridor Project. The Hanford River Corridor Project (managed by Washington Closure Project) has the responsibility for remediation of vadose zone areas outside of the 200 Areas central plateau. Relatively little data created from that project are included in this report.