RPP-6908-FP
Revision 0

Vadose Zone Impact Assessment for the 241-S-SX Tank Farms, Conceptual Models and Approach

A.J. Knepp
CH2MHILL Hanford Group, Inc.

Date Published
December 2000

To be Presented at
2000 Fall Meeting of the American Geophysical Union
San Francisco, CA
December 15, 2000

Release Approval 12-18-00 Date

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

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Contractor for the U.S. Department of Energy
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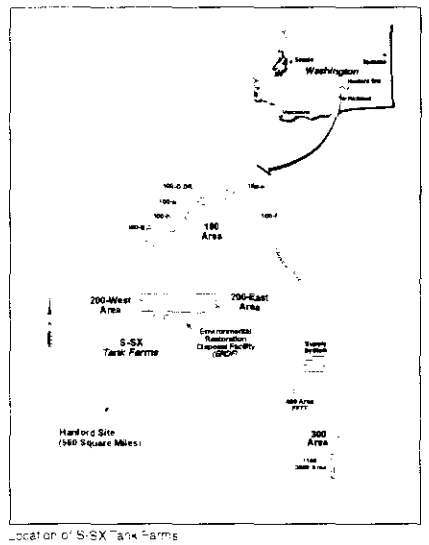
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Preliminary Results of Modeling Vadose Zone Flow at the 241-S-SX Tank Farms, Hanford Site

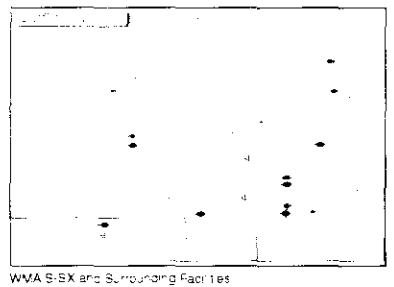
Groundwater/Vadose Zone Integration Project

ABSTRACT

The U.S. Department of Energy (DOE) has initiated a Resource Conservation and Recovery Act (RCRA) Corrective Action process to address the impacts of past and potential future tank waste releases to the vadose zone at the 241-S-SX single-shell tank farms at the Hanford Site in southeastern Washington. The corrective actions include evaluation of impacts to groundwater resources (i.e., the concentration of contaminants in groundwater) and long-term risk to human health (associated with groundwater use). Numerical models have been developed that consider the extent of contamination presently within the vadose zone, contaminant movement through the vadose zone to groundwater, and contaminant movement in the groundwater to points of compliance. Results are included on analysis of laboratory measurements for physical and hydraulic properties for soil samples in the vicinity of the 241-S and 241-SX tank farms, and upscaling of small-scale measurements for soil moisture characteristics. The two-dimensional model considers the accelerated movement of water around and beneath single-shell tanks that is attributed to bare, gravel surfaces and thus enhancing net infiltration of meteoric water (from winter precipitation and snowmelt). Water influx, possibly exceeding 100 mm/yr, is further amplified in the tank farm because of the umbrella effect (i.e., the effect of percolating water being diverted by an impermeable, sloping surface), created by large, 24-m diameter, buried tank domes. The enhanced recharge can potentially mobilize tank leak wastes and result in an earlier arrival of contaminants at the water table. Preliminary modeling results are presented.

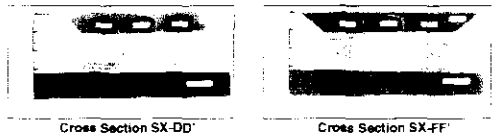


Location of S-SX Tank Farms

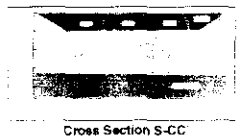


WMA S-SX and Surrounding Facilities

Geologic Cross-Sections



Cross Section SX-DD' Cross Section SX-FF'



Cross Section S-CC'

Timeline estimates for emplacement of interim and closure barriers and the corresponding recharge rates

Condition Simulated	Recharge Estimate (mm/y)
No Barrier [2000-2010]	100
Interim Barrier [2010-2040]	0.5
Closure Barrier (1st 500 yrs) [2040-2540]	0.1
Degraded Closure Barrier (post 500 yrs [2540-3000]	3.5

COMPUTER CODES USED

The computer code used is STOMP (Subsurface Transport Over Multiple Phases), developed by Pacific Northwest National Laboratory. The simulator was specifically designed to provide scientists and engineers from varied disciplines with multidimensional analysis capabilities for modeling subsurface flow and transport phenomena.

Macroscopic Anistotropy Relationships: Polmann (1990)

$$\langle LnK \rangle = \langle LnK_s \rangle - A\langle \psi \rangle - \sigma^2_{LnK_s} A[p - p^2\langle \psi \rangle - \zeta^2\langle \psi \rangle]/(1 + A\lambda)$$

$$\sigma^2_{LnK} = \sigma^2_{LnK_s}[(1 - p\langle \psi \rangle)^2 + \zeta^2\langle \psi \rangle^2]/(1 + A\lambda)$$

$$K_x^{eq} \quad \exp[\langle LnK \rangle + (\sigma^2_{LnK} \quad 2)]$$

$$K_z^{eq} \approx \exp[\langle LnK \rangle + \sigma^2_{LnK} \quad 2)]$$

- $\langle \psi \rangle$ = variance of log-transformed conductivity (relative expected mean deviation)
- $\langle LnK \rangle$ = mean of lnK_s
- $\sigma^2_{LnK_s}$ = variance of lnK_s
- $\langle LnK_s \rangle$ = mean of lnK_s
- p = slope of the β versus lnK_s regression line
- λ = correlation length for lnK_s
- ζ = standard deviation of the residuals of the β versus lnK_s regression
- A = mean slope (β) for lnK_s vs. ψ
- λ = vertical correlation lengths for lnK_s (assumed isotropic in the same manner as that for ψ)
- K_x^{eq} = equivalent unsaturated horizontal conductivity, and
- K_z^{eq} = equivalent unsaturated vertical conductivity

Polmann, D.J. 1990. Application of Stochastic Methods to Transient Flow and Transport in Heterogeneous Unsaturated Soils. Ph.D Thesis. Massachusetts Institute of Technology. Cambridge, MA.

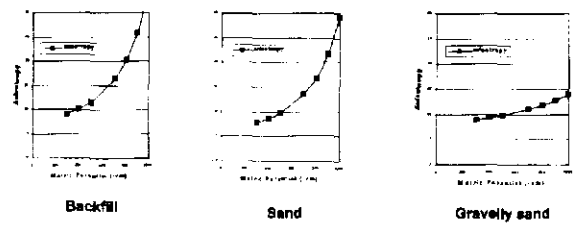
Macroscopic Anistotropy Relationships: Polmann (1990)

Strata	Number of samples	$\langle LnK_s \rangle$	$\sigma^2_{LnK_s}$	p	ζ	λ (cm)	A
Backfill (1)	8	-15.3	1.83	-5.6E-4	5.16E-4	50	0.00415
Sand (2)	12	-14.6	1.50	-7.2E-4	6.55E-4	50	0.00620
Gravelly Sand/Sandy Gravel (3)	11	-14.85	1.94	-2.6E-4	2.50E-4	30	0.00368
Plio-Pleistocene (4)	4	-10.43	1.01	2.4E-3	9.34E-4	50	0.0104
Sandy Gravel (5)	10	-15.76	3.56	-1.1E-4	1.84E-4	30	0.00371

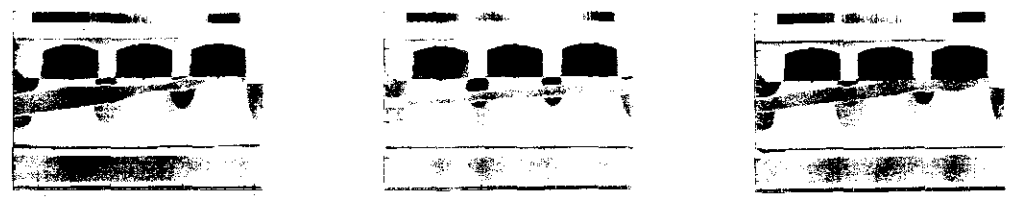
Composite van Genuchten-Mualem Parameters for various strata at the S-SX Tank Farms

Strata	Number of samples	θ_s	θ_r	α (1/cm)	n	l	Fitted K_s (cm/s)
Backfill (1)	8	0.2688	0.0151	0.0197	1.4194	0.5	5.15E-04
Sand (2)	12	0.3819	0.0443	0.0117	1.6162	0.5	9.88E-05
Garvelly Sand/Sandy Gravel (3)	11	0.2126	0.0032	0.0141	1.3730	0.5	2.62E-04
Plio-Pleistocene (4)	4	0.4349	0.0665	0.0085	1.8512	0.5	2.40E-04
Sandy Gravel (5)	10	0.1380	0.0100	0.0210	1.374	0.5	5.60E-04

Calculated macroscopic anisotropy for different strata

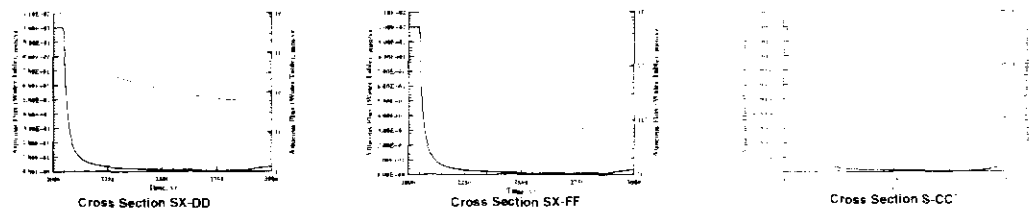


Enhanced Water Movement Around the Tank Domes



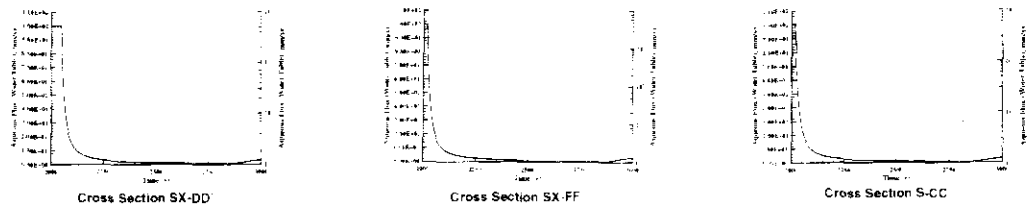
Cross Section SX-DD' Cross Section SX-FF' Cross Section S-CC'

No Barriers: Distribution of Fluxes at the Water Table



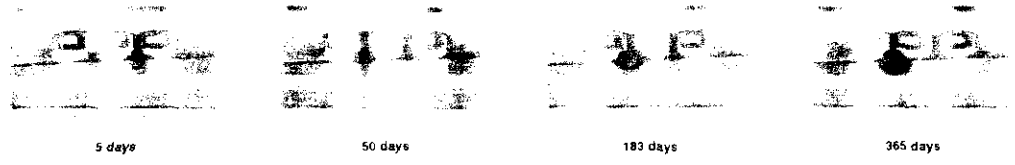
Cross Section SX-DD' Cross Section SX-FF' Cross Section S-CC'

Surface Barriers: Distribution of Fluxes at the Water Table



Cross Section SX-DD' Cross Section SX-FF' Cross Section S-CC'

Saturation Distribution Due to Water Line Leak (25,000 Gallons over 5 days)



5 days 50 days 183 days 365 days

SUMMARY

- A suite of two-dimensional simulations were used to investigate the impact of surface barriers and water line leaks
- The simulations consider the accelerated movement of water around the tank domes and the saturation-dependent anisotropy for the heterogeneous media
- The surface barriers, as expected, reduce magnitude of fluxes to the water table
- The water line leak (25,000 gals over 5 days) was sufficient to saturate the soil near the tanks, but the saturated plume diffused rapidly as it migrated through the vadose zone, having negligible impact below the Plio-Pleistocene layer.

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Raz Khaleel
(509) 376-6903
Fluor Federal Services

Mark White
(509) 372-6072
Pacific Northwest National Laboratory

Phillip Rogers
(509) 372-9234
Jacobs Engineering Group