Progress Energy

Serial: NPD-NRC-2009-049 10CFR52.79
April 1, 2009

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-0001

SHEARON HARRIS NUCLEAR POWER PLANT, UNITS 2 AND 3
DOCKET NOS. 52-022 AND 52-023
SUPPLEMENT 1 TO RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 017 RELATED TO ACCIDENTAL RELEASES OF RADIOACTIVE LIQUID EFFLUENTS IN GROUND AND SURFACE WATERS

References:
1. Letter from Manny Comar (NRC) to James Scarola (PEC), dated September 25, 2008, "Request for Additional Information Letter No. 017 Related to SRP Section 02.04.13 for the Harris Units 2 and 3 Combined License Application"
2. Letter from James Scarola (PEC) to U. S. Nuclear Regulatory Commission (NRC), dated October 31, 2008, "Response to Request for Additional Information Letter No. 017 Related to Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters," Serial: NPD-NRC-2008-048

Ladies and Gentlemen:

Progress Energy Carolinas, Inc. (PEC) hereby submits a supplemental response to the Nuclear Regulatory Commission's (NRC) request for additional information provided in the referenced letter (Reference 1).

A revised response to the NRC request is addressed in the enclosure. The enclosure also identifies changes that will be made in a future revision of the Shearon Harris Nuclear Power Plant Units 2 and 3 application.

If you have any further questions, or need additional information, please contact Bob Kitchen at (919) 546-6992, or me at (919) 546-6107.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on April 1, 2009.

Sincerely,

Garry D. Miller
General Manager
Nuclear Plant Development

Enclosure

Progress Energy Carolinas, Inc.
P.O. Box 1551
Raleigh, NC 27602

D084
NRO

cc : U.S. NRC Director, Office of New Reactors/NRLPO
U.S. NRC Office of Nuclear Reactor Regulation/NRLPO
U.S. NRC Region II, Regional Administrator
U.S. NRC Resident Inspector, SHNPP Unit 1
Mr. Manny Comar, U.S. NRC Project Manager

**Shearon Harris Nuclear Power Plant Units 2 and 3
Supplement 1 to Response to NRC Request for Additional Information Letter No. 017
Related to SRP Section 02.04.13 for the Combined License Application,
dated September 25, 2008**

NRC RAI #	Progress Energy RAI #	Progress Energy Response
02.04.13-1	H-0439	Revised response enclosed – see following pages
02.04.13-2	H-0440	Revised response enclosed – see following pages
02.04.13-3	H-0441	Revised response enclosed – see following pages

NRC Letter No.: HAR-RAI-LTR-017

NRC Letter Date: September 25, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.13-1

Text of NRC RAI:

The staff requests that the applicant provide a description of the process used to evaluate the conceptual site model of the subsurface environment. The description should include how this process was used as the basis for the calculation of the radionuclide transport in FSAR Section 2.4.13, and how the most conservative conceptual model from the set of plausible conceptual models was applied for the radionuclide transport analysis. Staff also request that the applicant explain how the conservative assumptions employed in the conceptual site model compensate for observed spatial and temporal variability and the resulting uncertainty in describing the sub-surface radionuclide transport analysis.

PGN RAI ID #: H-0439

PGN Response to NRC RAI:

The process for evaluation of the site subsurface hydrologic environment began with a literature review of federal and state hydrologic and geologic information. This information included published regional and local geologic surveys and water resources information. Previous subsurface investigations performed for HNP were reviewed in preparation for HAR's onsite investigations. The HAR site hydrological investigations further characterized the site's potentiometric surfaces, hydraulic gradients, vertical gradients, and flow. Hydraulic conductivity measurements were made for the surficial and bedrock aquifers. Site borings confirmed the structure of the regolith and bedrock. The subsurface information and investigations presented in FSAR Section 2.4.12 were used as the bases of the conceptual radiological models in FSAR Section 2.4.13.

The development of conceptual models recognized the need to accommodate ranges of parametric values applicable to site conditions. Next, the process accepted that the radiological predictions should be conservative. Conversely, it was considered important to be able to demonstrate a significant margin between the effective concentration limit and the predicted maximum radionuclide concentrations at water user locations. Hence, worst-case assumptions are used. Finally, the models were evaluated routinely to gain understanding of the interaction among parameters, assumptions and pathways.

The process focused on two conceptual models that would bound the dose consequences to the surface water and well users from contamination of groundwater. Thus, releases from the failure of a radwaste tank were postulated to occur consistent with USNRC BTP 11-6 assumptions using the worst-case tank radionuclide sources identified for the AP1000. The location of the releases was at the bottom of the auxiliary building below the surficial and bedrock groundwater potentiometric surfaces. Accordingly, the entire release is assumed to enter the surficial or bedrock aquifer.

The process considered public and private users of surface water or groundwater near the site. Contamination of the main reservoir was recognized as a plausible pathway affecting site and public users of surface waters: (1) HAR and HNP use the main reservoir's Thomas Creek branch as a source of raw water for their potable water systems, and (2) Lillington, NC's water supply uses surface waters downstream of the main reservoir's spillway. Contamination of the bedrock aquifer was also considered a plausible pathway affecting water users since domestic wells near HAR derive their supplies from this aquifer.

Site-specific hydraulic head and potentiometric surface conditions were evaluated and showed that contaminated groundwater in the surficial and bedrock aquifers could reach the main reservoir's Thomas Creek branch. Further evaluation established that flow through the surficial aquifer resulted in the shortest plausible travel time to the branch. This observation was used as a benchmark for evaluating various conceptual pathways where groundwater contaminants could ultimately migrate to surface waters.

The process included consideration of possible surface and subsurface pathways for the transport of radionuclides affecting surface water users:

> Groundwater contaminants released to the surficial aquifer resurface in Thomas Creek branch of the main reservoir. In this scenario groundwater moves a relatively short distance to the east of the HAR units. Little dilution occurs due to the small flow and volume in the Thomas Creek branch.
>
> Groundwater contaminants released to the surficial aquifer resurface in the main reservoir. Groundwater is impounded along the diabase dikes to the east of the HAR units, and moving in the direction of decreasing hydraulic head, eventually flows to the main reservoir. The concentrations are further diluted and held-up in the main reservoir.
>
> A small amount of groundwater contaminants released to the surficial aquifer may resurface in the nearby HNP emergency service water canal. Any contaminated water reaching the canal would be diluted and have increased residence time in the auxiliary reservoir prior to spilling to the main reservoir.
>
> Migration of groundwater contaminants released to the bedrock aquifer is constrained along the diabase dikes. Groundwater could leak from the diabase dikes to the main reservoir if the dikes are in hydraulic contact with the reservoir. The time for groundwater to travel to the southeast to the reservoir was expected to be greater than the time for contaminants to flow in the Thomas Creek branch's surface water to the main reservoir. Therefore, the potential radiological impact on surface water users was considered bounded by the Thomas Creek surficial groundwater scenario described above.

The first scenario of the above with groundwater flow from HAR 3 to the Thomas Creek branch was considered the most conservative conceptual model for evaluation of radiological consequences to surface water users. This scenario results in the largest radionuclide concentration at a potential surface water user (HAR raw water intake). This scenario was also used to determine radiological consequences to surface water users at Lillington, NC. Specifically, the radionuclide flux to the branch is diluted in the main reservoir and then further diluted down stream of the reservoir's spillway by the Cape Fear River prior to reaching Lillington. FSAR Section 2.4.13.1.1 qualitatively describes the model; FSAR Section 2.4.13.1.3 describes the analytical model.

Conceptual subsurface pathways considered for transport of radionuclides impacting well users included:

> Groundwater contaminants released to the bedrock aquifer move along the diabase dikes but go to recharge of the fractured bedrock. Migration of groundwater to domestic

wells penetrating the bedrock aquifer three miles to the southeast of HAR (see FSAR Table 2.4.12-202 for well users) is a plausible scenario.

Groundwater contaminants released to the bedrock aquifer migrates directly eastward toward domestic wells two miles from HAR (see FSAR Table 2.4.12-202). The scenario assumes groundwater is not held-up at the dikes, nor does it resurface in the nearby Thomas Creek branch. This scenario is unlikely because releases are expected to migrate along the diabase dikes or resurface at the branch.

The second of the two scenarios above is considered for the most conservative conceptual model for the evaluation of radiological consequences to well users because it is the shortest path despite the first well scenario being more likely. This scenario evaluated the nearest domestic wells to HAR in the direction of possible groundwater movement. FSAR Section 2.4.13.1.2 qualitatively describes the model; FSAR Section 2.4.13.1.3 describes the analytical model.

Spatial variability and uncertainty of site conditions included consideration of backfill, pathways, main reservoir elevation, hydraulic head, and site drainage. Conceptual bases and assumptions used to ensure model conservatism included: (1) straight-line groundwater flow is always assumed to maximize predicted concentration; (2) minimum distances to surface water or water user location are used; (3) soil and weathered rock removed for excavation of the units are used for backfill assuring pre- and post-construction soil properties are similar; (4) maximum applicable values of site hydraulic conductivity and hydraulic heads are used to calculate pore velocities; (5) use of pre-construction hydraulic gradients and pore velocities are conservative since the eventual increase in main reservoir level and installation of engineered drainage ditches will decrease the hydraulic gradients.

The conceptual models compensate for seasonal variability in groundwater levels, gradients and surface water flow. Groundwater level variations are unimportant since the releases are always completely below the potentiometric surfaces of both aquifers: no credit is ever given in the models to releases to unsaturated regions. The direction of groundwater flows are consistently in the same directions due to the high potentiometric head to the north and west of the HAR site and the constant water levels in the auxiliary and main reservoirs. Seasonal variation in dilution are accommodated by (1) not crediting the volume of the Thomas Creek branch and use of a flow that is 2/3 the annual average flow in the branch; (2) use of the minimum annual average spillway flow for dilution in the main reservoir.

Supplemental Response on Potential Groundwater Pathway toward the HNP Emergency Service Water Discharge Canal

The surficial pathway from HAR 2 to the southwest toward the HNP emergency service water (ESW) discharge canal and auxiliary reservoir is not the most conservative case for groundwater transport in FSAR Subsection 2.4.13. This supplement provides further clarification demonstrating that the pathway can be excluded as the most conservative surficial pathway for analysis in Chapter 2.4.13. The clarifications include consideration of hydraulic gradients and transport time.

FSAR Figure 2.4.12-203 gives the general locations of the surficial/overburden observation wells used in this discussion. Exhibit 1 is an annotation from this figure. Quarterly potentiometric surface elevations appear in FSAR Table 2.4.12-206 and distances between wells are computed from the coordinates in FSAR Table 2.4.12-205. The information is summarized in Table 1.

Current HAR 2/3 Site

The surficial/overburden water table at HAR 2 is at approximately Elev. 258.0' based on well MWA-3S data, see Table 1. MWA-3S is located near the center of the reactor containment building and is the nearest well to general area of the postulated spill site. At HAR 2, the water table rises to approximately Elev. 270.1' north and west of the unit as shown by the data from MWA-7S in Table 1.

The waste effluent tanks are located in the west end of the auxiliary building in HAR 2 and 3 about 36 ft below plant grade. Assuming a catastrophic failure of one effluent tank, radionuclides leaked from the HAR 2 auxiliary building are expected to migrate in the surficial/overburden aquifer away from the HNP ESW discharge canal. Table 2 shows that the hydraulic gradients from HAR 2 are always greater to the southeast (MWA-3S to MWA-1S) than toward the southwest (MWA-3S to MWA-2S). Similarly, gradients are always greater to the east (MWA-3S to MWA-4S or MWA-3S to MWA-5S) than toward the southwest (MWA-3S to MWA-2S). The gradients are calculated from the information in Table 1.

The surficial/overburden water table at the HAR 3 auxiliary building is roughly at Elev. 256.4' (MWA-8S). Half of the quarterly observations in Table 1 reveal that MWA-2S near the canal will have a surficial potentiometric elevation higher than HAR 3. The hydraulic gradient data in Table 3 shows that hydraulic gradients from HAR 3 are always greater to the east (for example, MWA-8S to MWA-9S or MWA-7S to MWA-9S) than toward the southwest (MWA-8S to MWA-2S).

HAR 2/3 Future Drainage Ditch

The auxiliary reservoir's elevation of Elev. 252' is unchanged after construction of HAR 2 and 3. Construction of drainage ditches identified in FSAR Subsection 2.4.12.5 and further described in RAI 02.04.12-2 could lower the groundwater elevations by about 5 ft near HAR 2 and 3 safety related structures. It is expected that the net effect of the drainage ditches will result in groundwater flow being directed more easterly but with decreased head, in part due to raising of the main reservoir level to Elev. 240'. For both units, the gradients toward the canal (MWA-3S to MWA-2S and MWA-8S to MWA-2S) are expected to be reduced below the already small values shown in Tables 2 and 3.

Evaluation

The trending information in Table 2 reveals that the groundwater gradients move away from the ESW discharge canal. A more detailed assessment of the localized gradients using triangulation of the potentiometric heads and spatial orientation of wells MWA-1S, MWA-2S and MWA-3S shows that the initial gradient at MWA-3S is greater and more southerly than indicated by Table 2 alone. Table 4 summarizes the local gradients and shows that the gradients do not move toward the ESW canal.

In the unlikely event that some of the contaminants reached the canal, the resulting concentration in the auxiliary reservoir would be much less than the concentrations in the Thomas Creek branch or main reservoir analyzed in the bounding pathway described in FSAR Subsection 2.4.13.1.1.

The minimum transport time from HAR 2 to the ESW discharge canal is about 14 years, see Table 4. This estimate uses the hydraulic conductivity measured at MWA-3S (near the spill location), the shortest travel distance of 170 m between the southwest edge of the auxiliary building and nearest point on the canal, and the localized gradients in Table 4. In all cases the transport time is greater than the 2.3 years for the analyzed release to the main reservoir via the Thomas Creek branch described in FSAR Subsection 2.4.13.1.1. Should any radionuclides reach the ESW discharge canal, they will be additionally held-up and diluted in the auxiliary reservoir prior to spilling to the main reservoir. Thus, the main reservoir concentrations will be less than those entering the reservoir from the Thomas Creek branch.

Groundwater flow near HAR 3 is principally to the east and away from the canal or auxiliary reservoir. Migration of contaminants to the auxiliary reservoir is not plausible.

For both units, the post-construction drainage ditches will make the small amount of groundwater flow more easterly and further reduce the possibility of any leakage toward the ESW discharge canal or auxiliary reservoir.

Supplemental Response on Thomas Creek Branch Flow

The maximum concentrations of radionuclides in the Thomas Creek branch of the main reservoir are reported in FSAR Table 2.4.13-204. The concentrations are determined by assuming that all activity crossing an imaginary plane at the edge of the branch contributes to the branch's concentration. The activity is subsequently diluted by the flow in the branch; no credit is given for dilution by the volume of water within the branch.

The maximum concentrations in the Thomas Creek branch are determined similar to the main reservoir presented in FSAR Subsection 2.4.13.1.3 with two exceptions: (1) the flow Q is the branch flow instead of the main reservoir's dilution flow; (2) the volume V_R is set to zero. The branch flow is taken as 2 cfs although the annual average flow through the branch is 3 cfs. The use of the smaller rate provides additional margin with respect to seasonal flow variations and possible impact on radionuclide concentrations.

The flow rate was determined at the proposed pump house location for HAR 2 and 3 on the Thomas Creek branch. The inflow into the main reservoir through the different creeks is assumed proportional to the corresponding creek's drainage area. The total drainage area of the Thomas Creek branch is 1825 acres above the south culvert.

The pump house shown on FSAR Figure 2.4.1-203 is north of the south culvert. The drainage area between the culvert and pump house is about 75 aces resulting in a net drainage area of 1750 acres (2.7 sq mi) contributing to flow in the Thomas Creek.

The total drainage area for the main reservoir is 70 sq mi (FSAR Subsection 2.4.1.2.1) with an annual average inflow to the reservoir of 78 cfs. The reservoir's inflow is determined from the drainage area and monthly stream flows recorded for USGS's Middle Creek gauging station.

The average annual inflow in the Thomas Creek branch at the pump house is then 3 cfs (78 cfs * 2.7/71). As previously stated, a conservative flow rate of 2 cfs is used to determine the radionuclide maximum concentrations in the Thomas Creek branch.

Supplemental Response on Daughter Nuclides

Daughter and granddaughter nuclides have negligible impact on the AP1000 groundwater transport analysis. The parent nuclides provide a reliable basis for consequence evaluations.

Most nuclides of interest in the groundwater transport analysis are at the left side of the periodic table. The decay chains, should they exist, are characteristically short with many of the nuclides having relatively short half lives. This is in contrast to the actinide and lanthanide series nuclides with high atomic weights at the right side of the periodic table where the radionuclides are more likely to be characterized by long decay chains eventually terminating as stable nuclides. The effluent tank source term includes "left side" actinides (La-140, Ce-141, Ce-143, Pr-143 and Pr-143) but no "right side" actinides. Candidate decay chains are based on those identified in NUREG/CR-5512 and DOE/TIC-1106:

Rb-89 → Sr-89	Mo-99 → Tc-99m →Tc-99	Te-132 → I-132
Sr-90 →Y-90	Ru-103 → Rh-103m	Te-134 → I-134
Sr-91→Y-91m→Y-91	Te-127m → Te-127	Ba-140 → La-140
Y-93 → Zr-93 → Nb-93m	Te-129m → Te-129 → I-129	Ce-143 → Pr-143
Zr-95 → Nb-95m → Nb-95	Te-131m → Te-131 → I-131	Ce-144 → Pr-144m → Pr-144
	Te-131 → I-131	

The Bateman equation is used to calculate daughter and granddaughter activity concentrations as part of a screening process. The parent nuclide concentrations are the effluent hold-up tank activity shown in FSAR Table 2.4.13-201. The parent and progeny are assumed to be unretarded and move at the same speed. A transport time of 2.3 years from FSAR Table 2.4.13-202 is used which corresponds to the minimum time for nuclides to reach the Thomas Creek branch via the surficial aquifer pathway. This pathway also bounds the bedrock pathway.

Only progeny in secular equilibrium with their parent radionuclide have a realistic chance of contributing to dose. Further, the parent's half life must be comparable or longer than the transport time of 2.3 years. If the parent's life half life is short compared to the transport time, then daughter's concentration is too small even though secular equilibrium may exist. All daughter and granddaughter nuclide concentrations are too small to make credible contributions, except for Y-90, Te-127 and Pr-144.

Y-90, Te-127 and Pr-144 are in secular equilibrium with their parent nuclides Sr-90, Te-127m and Ce-144, respectively. Spatially, the progeny concentrations (µCi/cc) are essentially the same as their parents because the short daughter half lives preclude the travel of the daughters any significant distance from where they are produced and then decay.

The progeny of interest have ECLs (µCi/ml) in 10 CFR 20, Table 2 that are at least an order of magnitude greater than their respective parents' ECLs. Thus, the ECL ratios calculated for progeny in Thomas Creek will be at least an order of magnitude less than the parent's contributions. Inspection of Table 2.4.13-204 reveals that the ECL ratios are negligible for parent nuclides Sr-90, Te-127m and Ce-144. The ECL ratios for the daughters will be even smaller. Table 5 summarizes the ECL ratios for parents and progeny. The progeny's contributions are negligible and need not be considered in the groundwater transport analyses.

References

W. E. Kennedy and R. L. Strenge, "Residual Radioactive Contamination from Decommissioning", NUREG/CR-5512, 1992.

D. C. Kocher, "A Handbook of Decay Data for Application to Radiation Dosimetry and Radiological Assessments", US DOE Technical Information Center Publication DOE/TIC-1106, 1981.

Table 1
Surficial Aquifer Water Table Data (ft)

Well	Northing	Easting	Aug	Nov	Feb	May	Average
MWA-1S	686565.2	2012706.8	253.31	253.08	254.03	255.09	253.9
MWA-2S	686443.8	2011686	253.06	258.17	258.65	254.11	256.0
MWA-3S	686910.2	2012316.3	257.12	256.6	260.19	258.03	258.0
MWA-4S	687126.4	2012812.9	253.75	254.07	256.45	254.85	254.8
MWA-5S	687189.6	2013000.5	250.06	253.37	254.81	252.11	252.6
MWA-6S	687568.1	2013443	238.61	238.62	238.29	237.59	238.3
MWA-7S	687499.6	2011203.7	270.41	268.99	269.95	271.13	270.1
MWA-8S	687763.3	2011928.4	257.08	256.06	255.45	257.06	256.4
MWA-9S	687996.6	2012453.3	241.57	244.09	244.65	243.51	243.5
MWA-10S	688247.9	2011681.6	251.36	251.18	260	258.99	255.4
MWA-11S	688614.8	2012942.5	227.11	225.43	232.69	231.46	229.2

Notes:
Locations are from HAR FSAR Table 2.4.12-205.
Water table elevations are from HAR FSAR Table 2.4.12-206.

Table 2
HAR 2 Surficial/Overburden Hydraulic Gradients ft/ft

From	To	Distance	Aug	Nov	Feb	May	Average
MWA-3S	MWA-1S	521	7.3E-03	6.8E-03	1.2E-02	5.6E-03	7.9E-03
MWA-3S	MWA-2S	784	5.2E-03	-2.0E-03	2.0E-03	5.0E-03	2.5E-03
MWA-3S	MWA-4S	542	6.2E-03	4.7E-03	6.9E-03	5.9E-03	5.9E-03
MWA-3S	MWA-5S	739	9.6E-03	4.4E-03	7.3E-03	8.0E-03	7.3E-03
MWA-3S	MWA-8S	937	4.3E-05	5.8E-04	5.1E-03	1.0E-03	1.7E-03
MWA-1S	MWA-2S	1028	2.4E-04	-5.0E-03	-4.5E-03	9.5E-04	-2.1E-03

Note:
Negative gradient means the gradient is toward the "From" well with the potentiometric level higher at the "To" well location.

Table 3
HAR 3 Surficial/Overburden Hydraulic Gradients ft/ft

From	To	Distance	Aug	Nov	Feb	May	Average
MWA-8S	MWA-2S	1342	3.0E-03	-1.6E-03	-2.4E-03	2.2E-03	3.1E-04
MWA-8S	MWA-3S	937	-4.3E-05	-5.8E-04	-5.1E-03	-1.0E-03	-1.7E-03
MWA-8S	MWA-4S	1090	3.1E-03	1.8E-03	-9.2E-04	2.0E-03	1.5E-03
MWA-8S	MWA-5S	1216	5.8E-03	2.2E-03	5.3E-04	4.1E-03	3.1E-03
MWA-8S	MWA-9S	574	2.7E-02	2.1E-02	1.9E-02	2.4E-02	2.3E-02
MWA-7S	MWA-9S	1345	2.1E-02	1.9E-02	1.9E-02	2.1E-02	2.0E-02

Note:
Negative gradient means the gradient is toward the "From" well with the potentiometric level higher at the "To" well location.

Table 4
Transport Times from HAR 2 to ESW Canal

Distance, m	170	Hydraulic K, ft/d	1.2		
Effective porosity	0.1				
	Aug 2006	Nov 2006	Feb 2007	May 2007	Average
Gradient, ft/ft	0.010	n/a	0.013	0.008	0.009
Pore velocity, ft/d	0.120	n/a	0.152	0.102	0.108
Time, yr	13	n/a	10	15	14
Direction	S	n/a	SSE	S	SSE

Notes:
1. N/a - MWA-2S water table elevation greater than HAR-2
2. Average is for four quarters from Table C.1
3. Hydraulic conductivity for MWA-3S from HAR FSAR Table 2.4.12-208

Table 5
Daughter Contributions to Thomas Creek Branch
(Surficial Aquifer)

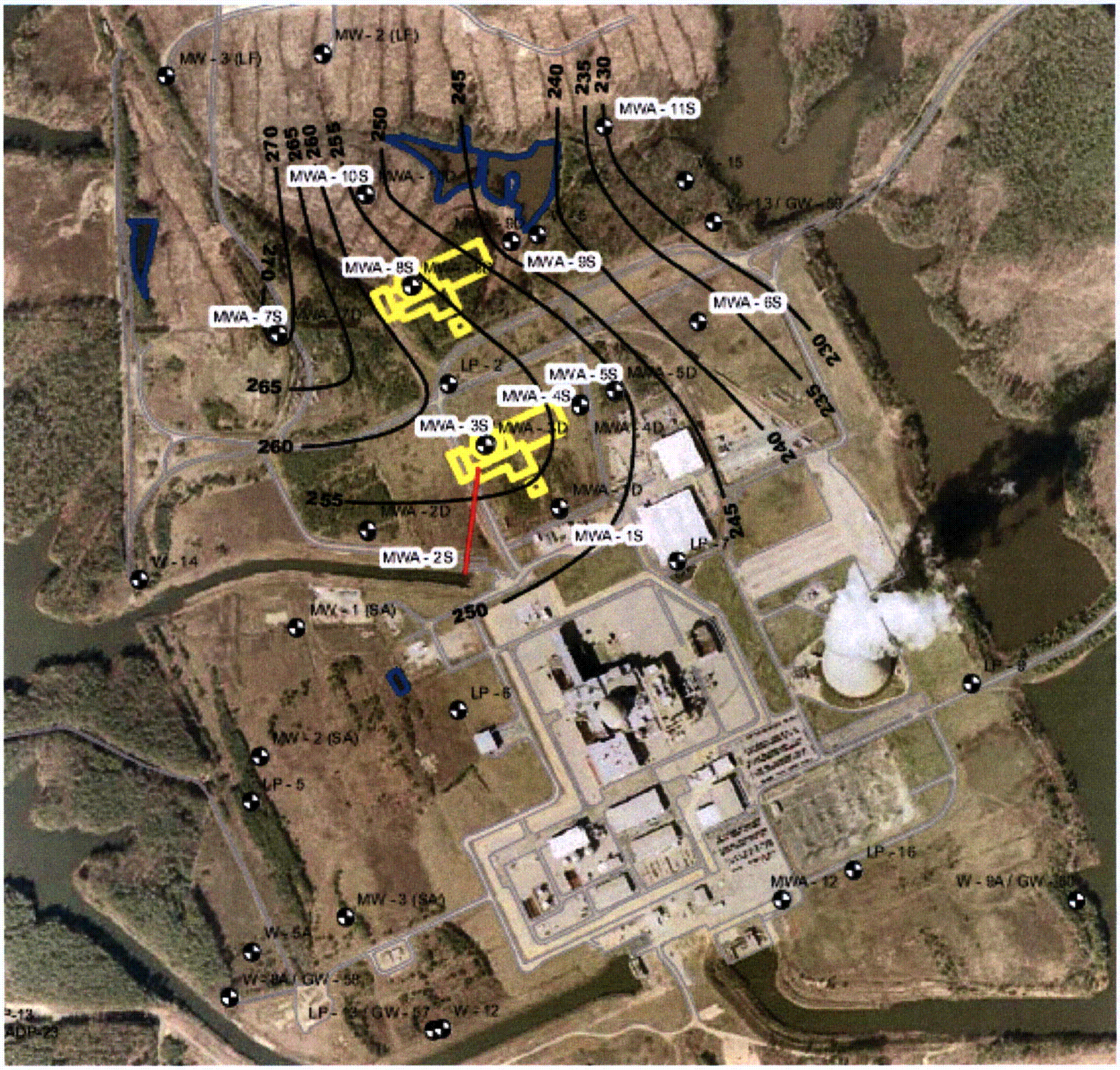
Parent Nuclide	ECL, µCi/ml	Conc, µCi/cc	Ratio Conc/ECL
Sr-90	5.0E-07	6.7E-15	1.3E-08
Te-127m	9.0E-06	2.8E-10	3.1E-05
Ce-144	3.0E-06	1.1E-09	3.7E-04

		Ratio Conc/ECL*	
Daughter Nuclide	ECL, µCi/ml	From Tank	As Daughter
Y-90	7.0E-06	2.56E-97	9.6E-10
Te-127	1.0E-04	0	2.8E-06
Pr-144	6.0E-04	0	1.9E-06

Notes:
Parent data is from FSAR Table 2.4.13-204.
*Y-90 and Pr-144 are also initially present in the waste effluent tank. Their contributions from the tank and as daughters are shown.

Exhibit 1

Monitoring Wells and Nearest Distance from HAR 2 Auxiliary Building to ESW Discharge Canal



Note:
Figure is an annotated from FSAR Figure 2.4.12-203.
Solid line shows nearest distance (170 m) from auxiliary building to ESW discharge canal.

Associated HAR COL Application Revisions:

The following change will be made to the HAR FSAR in a future revision:

Add the following text after the last sentence in FSAR Subsection 2.4.13.1.1:

> Average annual flow in the Thomas Creek branch of the Main Reservoir is greater than 0.057 m^3/s (2 cfs).

Attachments/Enclosures:

None.

NRC Letter No.: HAR-RAI-LTR-017

NRC Letter Date: September 25, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.13-2

Text of NRC RAI:

Values for Kd used in the assessment of the impact of the release of radioactive liquid effluent to the groundwater need to be measured from site-specific sediments and groundwater. Explain why using literature values of Kd is consistent with the requirements for site-specific measurements in 10 CFR 100.20(C)(3).

PGN RAI ID #: H-0440

PGN Response to NRC RAI:

Regulatory Background

10 CFR 100.20(C)(3) states that parameters important to hydrological radionuclide transport must be obtained from on-site measurements.

Regulatory Guide 1.206 does not provide specific guidance but does state that the bases for parameters used in evaluation of accidental releases of effluents in ground and surface waters must be discussed.

Review guidance in NUREG 0800, Section 2.4.13, part III.3, "Characteristics that Affect Transport", states that detailed considerations of site-specific properties are needed unless the uncertainty in a property can be offset by conservatism in the applicant's assessment. Part III.3 advises that site-specific absorption studies may not be needed if any retardation of contaminant migration is negligible.

Rationale for Use of Literature Kd Values

Negligible retardation of radionuclide contaminants by soil or sediment implies no credit for absorption, i.e., a Kd of zero for the contaminant. The HAR groundwater radiological models determined that small values of Kd for Cs and Sr would meet the effective concentration limits (ECLs) of 10 CFR 20, Appendix B.

FSAR Subsection 2.4.13.1.4 describes the determination of the minimum Kd using EPA-402-R99-004. This section identifies minimum values of Kd = 30 ml/g for Cs and 10 ml/g for Sr were determined for the surficial/overburden groundwater path. Similarly, Kd = 10 ml/g and 2 ml/g were determined for the bedrock pathway. The results of the FSAR groundwater radiological analysis, which use these Kd values, are reported in FSAR Subsection 2.4.13.1.5.

Through a sensitivity analysis of the ECLs, reasonable allowances for uncertainties in Kd or site conditions can be demonstrated by changing the Kd to 2 ml/g for Cs and 0 ml/g for Sr. The ECLs are then re-calculated for both pathways and compared to the results reported in FSAR Subsection 2.4.13.1.5:

Groundwater Path Spill to Receptor	ECLs FSAR Subsection 2.4.13.1.5	ECLs Kd = 2 for Cs and Kd = 0 for Sr
Thomas Creek branch	14%	37%
Lillington NC	<0.01%	0.02
Well	0.4%	1%

The tabulation shows that as the ECLs increase they remain, as expected, within 10 CFR 20, Appendix B limits for unrestricted members of the public using groundwater.

EPA-402-R99-004 reported the results of its evaluation of considerable Kd data and regression analyses. The EPA reviewed the correlations and applied expert judgment to identify minimum Kd for Sr and Cs that could be selected based on ranges of soil properties. Representative property ranges for HAR clay content, cation exchange capacity, and pH as required by EPA-402-R99-004's method were used to determine the site-specific Kd values. These values are described in FSAR Subsection 2.4.13.1.4.

To ensure that HAR Kd values obtained from EPA Report 402-R99-004 were conservative minimum values, the Kd values were compared to data in Thibault's compilation referenced in FSAR Subsection 2.4.13.1.4. The EPA-based Kd values used for HAR corresponded to the lower 10th percentile in Thibault's assessed frequency distributions of Kd values for Cs and Sr. This additional assurance combined with the reasonable allowances for uncertainty in Kd values provided a conservative basis for evaluating the accidental releases of a radioactive spill to groundwater at the HAR site.

Validation of Kd Used in HAR FSAR Subsection 2.4.13

Site-specific testing confirmed that the Kd values used in FSAR Subsection 2.4.13's groundwater transport analyses are conservative. Twelve bedrock, six soil, and two diabase dike samples were taken from HAR core borings. In addition, surficial and bedrock groundwater samples from HAR wells were used for preparation of the tracer solutions used in testing. The soil and rock samples are identified in new COL FSAR Table 2.4.13-206. Bore hole locations appear on FSAR Figure 2.5.4-202.

Testing was performed at Argonne National Laboratory for Cs and Sr using ANL's Standard Operating Procedure ACL-264, "Determination of the Distribution Coefficient (Kd) in Soil Samples". Additional Kd tests were performed for information purposes for Co, Mn, Fe, Ag, Te and Ce, although retardation is not credited for these elements in the transport analyses.

Procedure ACL-264 is adapted from ASTM D4319-93, "Standard Test Method for Distribution Ratios by the Short Term Batch Method". ACL-264 identifies several precautions to avoid unrealistically high or low results. Alternate steps are included when the test method may result in unrealistic values. The procedure includes quality control measures such as blank runs, laboratory control standard runs, and reference runs for each of the Kd batches.

The test first determined the concentration of exchangeable ions in soil and rock samples using a potassium nitrate overnight leach of representative samples. Next, a spiking solution was prepared using site water as the solvent for tracer compounds used to test for the elemental Kds. A second set of rock and soil samples (i.e., samples not used in the leach tests) were then saturated for 20 days in the spiking solution to ensure that the adsorbed and solution concentrations were at equilibrium. Final groundwater equilibrated concentrations were measured. Kds were then calculated using the initial concentrations in the soil and rock samples (based on the leach analysis), and the initial and final equilibrated groundwater concentrations.

New COL FSAR Table 2.4.13-206 shows the minimum Kd values for Cs and Sr determined by testing of HAR samples. All Kd values are greater than the analytical Kds for Cs and Sr shown in FSAR Table 2.4.13-202 used in the groundwater surficial and bedrock transport analyses. Therefore, retardation of Cs and Sr credited in the analyses is conservative compared to that occurring in the bedrock and soils at HAR: the radionuclide ECLs reported in FSAR Subsection 2.4.13 for Lillington NC, Thomas Creek Branch and the nearest well remain bounded.

Supplemental Response on Impact of Chelating and Complexing Agents

Chelating and complexing agents effectively increase the solubility of minerals in water. An increase in solubility and a consequential decrease in sorption on to soils can reduce retardation of these nuclides and result in higher concentrations in the groundwater.

A complex is a compound consisting of a metal complex ion(s) and other ions of opposite charge, or a complex ion(s) and a neutral species. The term chelate is used to distinguish complexes formed where the ligand bonds to the metal atom through two or more atoms of the ligand. The important distinction between a chelate and a complex is that a chelate is coordinated to more than one donor site of the ligand, and therefore has much more stability than simple complexes. The increased stability can increase the transport of the chelated-metal cation compared to complexes, which typically dissociate back to free metal cations and ligands after large dilution occurs.

Chemical decontaminants used to remove built-up radioactive activation and corrosion products often use industrial chelating agents to form complexes to transition metals such as Fe, Co, Ni and Mn. Transition metals have several oxidation states, notably +2, +3, +4 and +6 for most transition metals of concern. Strong organic chelating agents of concern are principally amine-polycarboxylic acids (e.g., EDTA, DTPA,), picolinic acid, and to lesser extent citric and oxalic acids used in decontamination processes.

With the exception of cesium and strontium, the HAR groundwater transport analysis in Subsection 2.4.13 does not credit retardation of radionuclides, i.e., Kd = 0 ml/g. All other nuclide concentrations analyzed for the surficial and bedrock aquifer pathways are conservatively bounded by the existing analyses. Thus, chelating agents can only impact the predicted groundwater concentrations of cesium and strontium.

Cesium is an alkali metal. There is little, if any, tendency for cesium to form aqueous complexes in soil and water environments because of the single available Cs^{+} bond site. Thus, the formation of inorganic complexes is not a major influence on cesium speciation and the dominant aqueous species in most groundwater is the uncomplexed Cs^{+} ion. Further, complexation of cesium by common industrial chelates (such as EDTA) is believed to be poor due to their low stabilities and the presence of competing cations (e.g., notably Ca^{+2} and Mg^{+2}) at appreciably higher concentrations in groundwater. Therefore, aqueous complexation is not thought to greatly influence cesium behavior in most groundwater systems.

Chelating of alkaline earth cation Sr^{+2} is not expected to have a major impact. First, there is little tendency for Sr^{+2} to form aqueous complexes with inorganic or organic complexants. Studies of leached groundwater from contaminated sites have shown that essentially all strontium in the leachates existed as uncomplexed Sr^{+2}. Second, Ca^{+2} and Mg^{+2} are important competing cations in much greater concentrations in groundwater than Sr^{+2}. Third, SAR Subsection 2.4.13's groundwater transport analyses uses conservative Kd = 10 ml/g for strontium in the surficial aquifer and Kd = 2 ml/g in the bedrock aquifer. Relaxation of Kd = 0 ml/g for both pathways, which represent worst case chelation for strontium, marginally increases the calculated ECL at the Thomas Creek branch (FSAR Table 2.4.13-203) and nearest well (FSAR Table 2.4.13-205) by less than 0.7 percent; the increase in the ECLs at main reservoir spillway and at Lillington, NC (FSAR Table 2.4.13-204) are less than 0.1 percent. The potential impact of chelating agents on strontium is not significant with respect to the predicted ECLs even under the pessimistic assumption of no retardation.

Naturally Occurring Inorganic and Organic Complexants

Naturally occurring inorganic and humic ligands in soil can form aqueous complexes. Common complexing inorganic ligands in groundwater are carbonates, sulfates, phosphates and chlorides. In general, the inorganic complexes (if formed) tend to increase the potential for transport through groundwater. Conversely, some complexes formed from humic acids readily attach to soil particles and actually retard migration of the complexed cations.

The formation of naturally occurring inorganic and organic complexes is not a major influence on cesium or strontium radionuclide concentration in groundwater at HAR. There is little tendency for Cs^{+} or Sr^{+2} to form aqueous complexes in soil and water environments: uncomplexed Cs^{+} or Sr^{+2} ions are the dominant species in most groundwater. The Kd used for cesium and strontium in FSAR Subsection 2.4.13.1.4 are based on EPA-402-R-99-004 (Reference 2.4-242) guidance which explicitly considered the impact of naturally occurring complexants in developing minimum Kds. Moreover, the confirmatory Kd testing performed for HAR used site groundwater, soil and bedrock samples. The measured Kd test results implicitly include the effects due to naturally occurring complexing agents near HAR.

Usage of Chelating Agents

FSAR Subsection 2.4.13's analysis assumes failure of a waste effluent tank. The waste effluent tanks have the largest volume and potential radionuclide inventory as shown in AP1000 DCD Table 11.2-1. The inventory is due to reactor coolant activity from CVS and sampling systems and miscellaneous leakage.

Chelates and complexing agents are not anticipated to be used during routine operation of the AP1000. Primary chemistry operations of the AP1000 are in accordance with EPRI PWR Primary Water Chemistry Guidelines. As such, the chemicals used on a routine basis are boric acid buffered with 7-lithium hydroxide, gaseous hydrogen, and small amounts of soluble zinc injected as a zinc acetate solution to reduce corrosion product build-up (AP1000 DCD Subsection 9.3.6.2.3.3). Hydrazine or hydrogen peroxide may be injected in small quantities at start-up or during cooldown, respectively (AP1000 DCD Table 5.2-2). The reactor coolant containing these chemicals and their compounds are normally routed through the CVS mixed bed demineralizer and liquid radwaste system vacuum degassifier before being sent to an effluent hold-up tank.

Chelating and complexation agents are not routinely used in other portions of the AP1000 liquid radwaste system, for example, the chemical waste or waste hold-up tanks. If used for decontamination, it is anticipated that the decontamination would be managed by a third-party vendor who would take responsibility for disposal of the agents. Discharge of these agents to or through plant waste systems is not anticipated.

Historically, there has been some use of EDTA in steam generator chemical cleaning and advanced scale conditioning agent evolutions in the nuclear industry. However, these applications are not routine. The use of chelating agents at HAR would need to be reviewed by Progress Energy prior to implementation as would any maintenance activity that would use EDTA or other industrial chelates.

Progress Energy has also determined that EDTA and other chelating agents have not been spilled or released at the HAR or HNP site. PE did determine that trisodium phosphate, a possible weak complexant, has been used to remove calcium and magnesium deposits in boilers at HNP in the 90's. Only small quantities were used and large quantities were never stored on site. There have been no spills of TSP. There is no potential impact from prior TSP usage.

Associated HAR COL Application Revisions:

The following changes will be made to the HAR FSAR in a future revision:

1. Add new FSAR Table 2.4.3-206 which tabulates Kd values for Cs and Sr obtained by testing.
2. Add a subsection to the FSAR:

   2.4.13.1.4.1 Confirmation of HAR Distribution Coefficients

   Kd values for Cs and Sr were confirmed by testing at Argonne National Laboratory of HAR-specific samples (Reference 2.4-2XX). Twelve bedrock, six soil, and two diabase dike samples were taken from HAR core borings. Samples are identified in Table 2.4.13-206 while Figure 2.5.4-202 shows the locations of the bore holes. Surficial and bedrock groundwater from HAR wells MW-3S and MW-3D was used for saturation of samples and preparation of tracer solutions. Table 2.4.13-206 gives the minimum Kd values determined for Cs and Sr. The Kd test results confirm that the Kds in Table 2.4.13-202 used in the groundwater transport analysis are conservative for HAR.

3. Add a subsection to the FSAR

   2.4.13.1.4.2 Chelating Agents and Impact on Groundwater Transport

   Chemical decontaminating agents that remove built-up radioactive activation and corrosion products often use industrial chelating agents to form complexes with transition metals such as Fe, Co, Ni and Mn. Transition metals typically have oxidation states +2, +3, +4 and +6 which allows the complex to form. With the exception of Cs and Sr, the HAR groundwater transport analysis does not credit retardation of radionuclides, i.e., Kd = 0 ml/g. Thus, all other nuclide concentrations analyzed for the surficial and bedrock aquifer pathways are conservatively bounded by the existing analyses.

   Unlike transition metals, aqueous complexing is not thought to greatly influence Cs and Sr behavior in most groundwater systems. Cs and Sr are alkaline and alkaline earth metals, respectively. There is little tendency for Cs or Sr to form aqueous complexes: Cs^+ is mono-valent; studies of leachates from contaminated sites showed essentially all Sr existed as uncomplexed Sr^{+2} (References 2.4-242 and 2.4-2ZZ). Complexing of Sr^+ and Sr^{+2} is believed to be poor because both cations must compete with naturally occurring Ca^{+2} and Mg^{+2} cations which are at appreciably higher concentrations in groundwater.

The confirmatory Kd testing described in FSAR Subsection 2.4.13.1.4 used site groundwater, soils and bedrock samples. The results of the test implicitly included the effects of naturally occurring complexes should they be present near HAR.

The waste effluent tank radionuclide inventory is from reactor coolant received from CVS and sampling systems, and miscellaneous leakage. The use of chelates and complexing agents in the AP1000 reactor coolant system is not anticipated for routine operation. Chemicals involved on a routine basis are boric acid buffered with 7-lithium hydroxide, gaseous hydrogen, and small amounts of soluble zinc injected as a zinc acetate solution to reduce corrosion product build-up (AP1000 DCD Subsection 9.3.6.2.3.3). Hydrazine or hydrogen peroxide may be injected in small quantities at start-up or during cooldown, respectively (AP1000 DCD Table 5.2-2).

Chelating and complexing agents are not routinely used in other portions of the AP1000 liquid radwaste system, for example, the chemical waste or waste hold-up tanks. Historically, there has been some use of chelating agent EDTA in steam generator chemical cleaning and advanced scale conditioning evolutions in the nuclear industry. However, these applications are not routine. The use of chelating agents at HAR would need to be reviewed by Progress Energy prior to implementation as would any maintenance activity that would use EDTA or other industrial chelates.

Progress Energy determined that EDTA and other chelating agents have not been spilled or released at the HAR or HNP site. However, trisodium phosphate (TSP), a possible complexant, has been used to remove Ca and Mg deposits in boilers at HNP in the 90's. Only small quantities were used and large quantities were never stored on site. There have been no spills of TSP. There is no potential impact from prior TSP usage.

4. Add the following references to FSAR Subsection 2.4.16:

2.4-2XX CH2M Hill Technical Memo, Distribution Coefficient (Kd) Measurements with Soil and Water, No.: 338884-TMEM-093, dated March 2, 2009.

2.4-2YY WorleyParsons, "Site-Specific Distribution Coefficients (Kd) for Update of HAR FSAR Subsection 2.4.13, Shearon Harris Nuclear Plant, Units 2 and 3", Report No. HAG-000-X7R-009, March 2, 2009.

2.4-2ZZ R. J. Serne, et al, "Characterization of Radionuclide Chelating Agent Complexes Found in Low-level Radioactive Decontamination Waste," NUREG/CR-6124, March 1996, US Nuclear Regulatory Commission.

Shearon Harris Nuclear Power Plant Units 2 and 3
COL Application
Part 2, Final Safety Analysis Report

Table 2.4.13-206
Minimum Kd Values from Testing of HAR-site Samples [1]

Samples	Lithology[1]	Bore Hole	Sample Depth[1] ft bgs	Minimum Kd Cs ml/g	Minimum Kd Sr ml/g
4	Sandstone	BPA-41	35.6 – 37.6 [2]	3072	52
		BPA-42	52.7 - 53.6		
		BPA-39	77 - 78		
		BCTA-2	48 - 48.7		
4	Siltstone	BPA-16	79.9 - 80.9	7584	48
		BPA-42	30.3 - 31.3		
		BPA-43	35.3 - 36.3		
		BCTA-2	76 – 78 [2]		
4	Shaley Siltstone	BPA-16	141.8 – 144 [2]	3286	71
		BPA-41	124.9 - 126.1		
		BPA-39	61.0 - 61.5		
		BPA-43	87.1 - 88.2		
2	Diabase Dike	BGA-17	39.6 - 40.6	422	18
		BGA-17	68.0 - 69.2		
6	Soils	BPA-16	0	4747	39
		BPA-41	2.5		
		BPA-42	2.5		
		BPA-39	15		
		BPA-43	7.5		
		BCTA-2	3.3		

Notes:

1. From Reference 2.4-2YY
2. The sample depth range includes the duplicate QC sample.

Attachments/Enclosures:

None.

NRC Letter No.: HAR-RAI-LTR-017

NRC Letter Date: September 25, 2008

NRC Review of Final Safety Analysis Report

NRC RAI #: 02.04.13-3

Text of NRC RAI:

Explain how effective porosity values used in the scenarios are representative of the fractured bedrock conditions at the site with implications for contaminant transport. The effective porosity values need to be conservative for the pathline from the tank release location to the receptor location (e.g. surface water body or well location). Spatial variability in effective porosity needs to be considered as the applicant has noted that the fracture density (and therefore effective porosity) could be higher near diabase dikes.

PGN RAI ID #: H-0441

PGN Response to NRC RAI:

An effective porosity of 0.05 (5 percent) is used in the groundwater bedrock linear flow velocity calculation and in the bedrock aquifer transport analysis as shown in HAR FSAR Tables 2.4.12-209 and 2.4.13-202, respectively. The effective porosity is representative for the geologic units associated with the HAR site and the Buckhorn Creek Drainage Basin.

Description of Bedrock Conditions

To explain how effective porosity values are representative of the bedrock conditions at the site with implications for contaminant transport, an understanding of site specific bedrock conditions is required. Regionally, geologic units associated with the Triassic Basin consist of claystone, shale, siltstone, sandstone, conglomerate, and fanglomerate as detailed in HAR FSAR Subsection 2.4.12.1.1. Site investigations at HAR indicate that the bedrock consists predominantly of well-consolidated Triassic siltstones and sandstones interbedded with subordinate shale, claystone, and conglomerate as detailed in HAR FSAR Subsection 2.5.1.2.3. These units have a relatively low primary effective porosity and poorly interconnected pores. Normally, groundwater flows principally along joints, fractures, and bedding planes, which create anisotropic conditions where most water movement is parallel to the strike of the beds.

Exceptions to the Triassic Basin lithology are thin, vertically oriented, diabase dikes. These dikes are characterized by very low primary porosity and generally yield little water. However, the strata adjacent to dikes become fragmented by upward intrusion and secondary porosity is created in the form of fractures. In these areas, groundwater movement through geologic units may be influenced by secondary porosity significantly more than by primary porosity. Locations of diabase dikes associated with HAR 2 and HAR 3 are shown on HAR FSAR Figure 2.5.1-232. It is important to note that five diabase dikes oriented approximately northwest to southeast are located within 0.6 miles on both the west and east side of each proposed unit.

Effective Porosity Values in the Buckhorn Creek Drainage Basin

The effective porosity of the Buckhorn Creek Drainage Basin is established from the results of two field studies performed near HAR. The studies were conducted within the Durham Triassic Basin bedrock approximately 2.8 miles to the southwest (Harding Lawson Associates or HLA) and approximately 3.5 miles to the north-northeast (USGS Professional Paper 1432) of the HAR site, respectively. The effective porosity is shown to be consistent with the ranges provided in the literature for comparable rock.

The HLA study measured effective porosity using 14 physical core samples collected from two boreholes. As shown in Table 1, the effective porosity measurements within the bedrock ranged from 2.5 to 7.2 percent in one borehole and 5.2 to 11.7 percent in the second borehole. The average effective porosity for the 14 core samples is 6.7 percent. In addition to the laboratory measurements of effective porosity, geophysical logging methods were also used in eight boreholes to determine porosity as also shown in Table 1. After completion of field activities, HLA used the site data to develop a hydrogeological model. HLA determined that a formation or effective porosity of 5 percent was appropriate for the model.

USGS Professional Paper 1432 reports on the borehole and physical property analyses used to investigate the lithologic character and subsurface distribution of hydrogeologic units in the Durham Triassic Basin. These objectives were accomplished using borehole-geophysical logging techniques and laboratory analyses of core samples.

Table 2 summarizes effective porosity measurements from the USGS study. The USGS using a synthesis of logging methods determined that the effective porosities of sandstone zones ranged from about 5.3 to 8.5 percent. This range compares favorably with the reported lab measurements for four sandstone core samples (from bedrock at different depths in the same borehole) which showed effective porosities from 2.3 to 12 percent. Logging methods were also used to determine an effective porosity of 6.7 percent in a siltstone region; laboratory measurements ranged from 2.2 to 4.7 percent for three siltstone samples taken at different depths. The average effective porosity for the seven sandstone and siltstone core samples is 5.4 percent, a value comparable to HLA study observations.

Table 3 is a summary of compilations of effective porosities for sandstone, siltstone and shale. The data is indicative of a range of bedrock conditions; it is not Triassic Basin-specific. The effective porosity ranges and averages determined in the HLA and USGS studies fall within the observed ranges for a variety of bedrock conditions.

Secondary Porosity

Fractures in bedrock can result in secondary porosity which contributes to the effective porosity.

The impact of secondary porosity is apparent in the USGS logging data in Table 2. The effective porosity of a 9 m thick zone of fractured bedrock is reported as 11.4 percent. This zone is located in a predominately siltstone region with some sandstone. The zone's effective porosity can be compared to the effective porosities of the sandstone and siltstone zones in Table 2. These zones typically have effective porosities less than 8 percent determined by the same logging methods. Thus, it appears that secondary porosity could increase effective porosity by several percent compared to a location where fracturing of the bedrock is not significant. Although not explicitly included in the porosity estimates used for the Buckhorn Creek Drainage Basin, secondary porosity provides additional margin to the estimated 5 percent effective porosity used in the bedrock groundwater linear flow velocity calculation and bedrock aquifer transport analysis.

Spatial Variability and Conservatism

An effective porosity of 5 percent is considered to be the most-plausible and conservative for a path line from a postulated tank release at HAR 2 or HAR 3 to a receptor location (the main reservoir or an offsite well). The effective porosity is plausible because it represents a combination of geologic units associated with the HAR site and the Buckhorn Creek Drainage Basin. Likewise, spatial variability is considered because local differences due to lithology and geologic units were included in the porosity data.

The effective porosity is conservative because of the margin provided by expected increases due secondary porosity effects. Fractures near diabase dikes or between lithologic units will result in secondary porosities of several additional percent. Secondary porosity provides conservatism because it was not explicitly included in the 5 percent effective porosity value used in FSAR Subsections 2.4.12 and 2.4.13.

Sensitivity Study

The bedrock aquifer transport analysis uses an effective porosity of 5 percent as representative of the Buckhorn Creek Drainage Basin. A sensitivity analysis has been performed using an effective porosity of 2 percent. Two percent is an exceptionally conservative lower limit from Tables 1 and 2 for lithology applicable to the Buckhorn Creek Drainage Basin. The sensitivity analysis uses the bedrock aquifer model described in FSAR Subsection 2.4.13.1.3 and parameters listed in FSAR Table 2.4.13-202, except that the effective porosity was relaxed to 2 percent. The calculated overall ECL at the nearest well location is less than 34 percent of the 10 CFR 20, Table 2 acceptance limit for public water supplies. The parametric study confirms that the bedrock aquifer groundwater concentrations remain well within the acceptance criteria.

Table 1:
Summary of Effective Porosity and Porosity for the Durham Triassic Basin - Harding Lawson Associates (HLA), "GM-1 Pilot Study Report"

Data Source	Porosity Data	Comments
Harding Lawson Associates (HLA), "GM-1 Pilot Study Report," October 27, 1997, Prepared for North Carolina LLRW Management Authority. (FSAR Reference 2.4-238) The study was conducted in the Durham Triassic Basin approximately 2.8 miles to the southwest of the HAR site.	Core measurements: 2.5 - 7.2%	Effective porosity. Core data (8 samples) from bore hole W208. (Figure 5-9)
	Core measurements: 5.2 -11.7%	Effective porosity. Core data (6 samples) from bore hole W205. (Figure 5-9)
	5%	Physical input parameter for site modeling efforts: formation porosity (Table 4-4) The formation porosity for the site was used in the models FLOWDIM and INTERPRET/2 (INT2). As stated on page 4-21, "These input parameters were measured and estimated using available data, or calculated using PVT correlations." Note: The PVT correlations were used only to calculate water viscosity.
	"log-sands": 5 - 10% with some approaching 15%	"log-sands" is defined by the authors as intervals with relatively small amounts of clay minerals and sub-sand-size particles as stated on page 4-13. As stated on page 4-14, "log-sands" generally were easy to differentiate from "log-shales". Porosity values for "log-sands" were reported to be more variable as shown by the range to the left.
	"log-shale": <2%	"log-shales" is defined by the authors as intervals that are more clay-rich and finer-grained as stated on page 4-13.
	Sandstone: 2 - 8% with some approaching 10%	As stated on page 5-14, "it is apparent that there are multiple zones of relatively higher porosity below the base of the weathered zone. The majority of these relatively higher porosity zones correspond to sandstone intervals for which porosities range from 2 to 8 percent." As shown on Table 5-2, the base of the weathered zone ranges from 24 to 36 feet bgs within borings W201 through W208.
	Rock units identified during this study include: Sandstone: 37% Siltstone: 54% Claystone: 6% Conglomerate: 3%	page 5-1

Table 2
Summary of Effective Porosity for the Durham Triassic Basin - U.S. Geological Survey Professional Paper 1432

Data Source	Effective Porosity Data	Comments
U.S. Geological Survey Professional Paper 1432. "Determination of Rock Properties by Borehole-Geophysical and Physical-Testing Techniques and Ground-Water Quality and Movement in the Durham Triassic Basin, North Carolina," 1988. The study was conducted in the Durham Triassic Basin approximately 3.5 miles to the north-northeast of the HAR site. The location is shown on FSAR Figure 2.5.1-230.	11.4%	Average effective porosity from analysis of γ-ray, γ-γ density, neutron and sonic logs from Table 3. Depth to top of porous zone: 189 meters Thickness: 9 meters Table 2 description of zone: fractured. Figure 6 lithology: siltstone with some sandstone
	8.5%	Average effective porosity from analysis of γ-ray, γ-γ density, neutron and sonic logs from Table 3. Depth to top of porous zone: 216 meters Thickness: 18 meters Table 2 description: limy, shaly, and sandstone
	6.8%	Average effective porosity from analysis of γ-ray, γ-γ density, neutron and sonic logs from Table 3. Depth to top of porous zone: 341 meters Thickness: 12 meters Table 2 description: siltstone
	7.9%	Average effective porosity from analysis of γ-ray, γ-γ density, neutron and sonic logs from Table 3. Depth to top of porous zone: 391 meters Thickness: 8 meters Table 2 description: sandstone
	6.7%	Average effective porosity from analysis of γ-ray, γ-γ density, neutron and sonic logs from Table 3. Depth to top of porous zone: 434 meters Thickness: 9 meters Table 2 description: sandstone
	5.3%	Average effective porosity from analysis of γ-ray, γ-γ density, neutron and sonic logs from Table 3. Depth to top of porous zone: 497 meters Thickness: 18 meters Table 2 description: sandy, sandstone, and limy sandstone.

Table 2 (continued)
Summary of Effective Porosity for the Durham Triassic Basin - U.S. Geological Survey Professional Paper 1432

Data Source	Effective Porosity Data	Comments
U.S. Geological Survey Professional Paper 1432. "Determination of Rock Properties by Borehole-Geophysical and Physical-Testing Techniques and Ground-Water Quality and Movement in the Durham Triassic Basin, North Carolina," 1988.	5%	Effective porosity of core samples from Table 6. Depth to core sample: 154 meters Lithology description: sandstone As stated on page 17, "The effective-porosity determinations were made by using a Beckman Gas Pycnometer. The effective porosity is essentially a measure of the connected pore volume. The Beckman technique uses helium gas to impregnate the sample and to measure the volume of the connected pores. The bulk volume is then determined by sealing the sample surface and determining the total volume of the sample. With this technique, measurements of effective porosity are accurate to ±0.05 percent."
	2.3%	Duplicate specimen at 154 meters, same as above.
	8.9%	Effective porosity of core samples from Table 6. Depth to core sample: 157 meters Lithology description: sandstone
	12%	Duplicate specimen at 157 meters, same as above.
	1.3%	Effective porosity of core samples from Table 6. Depth to core sample: 329 meters Lithology description: gray argillite
	4.7%	Effective porosity of core samples from Table 6. Depth to core sample: 330 meters Lithology description: siltstone
	2.2%	Duplicate specimen at 330 meters, same as above.
	2.8%	Duplicate specimen at 330 meters, same as above.
	Ratio of sandstone to shale: 2:3	page 4

Table 3:
Summary of Effective Porosity of General Bedrock

Data Source	Effective Porosity Data	Comments
NUREG/CR-3332. "Radiological Assessment, A Textbook on Environmental Dose Analysis," September 1983, Prepared for Division of Systems Integration Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission.	Sandstone (fine): 2 - 40%	Effective porosity values; Number of analyses: 47; Reported arithmetic mean: 0.21. Table 4.4
	Sandstone (medium): 12 - 41%	Effective porosity values; Number of analyses: 10; Reported arithmetic mean: 0.27. Table 4.4
	Siltstone: 1 - 33%	Effective porosity values; Number of analyses: 13; Reported arithmetic mean: 0.12. Table 4.4
Walton, William C. "Principles of Groundwater Engineering". General specific yield or effective porosity.	Siltstone: 1 - 35%	Specific Yield or effective porosity; Appendix B, Table B.2
	Sandstone: 10 - 40%	Specific Yield or effective porosity; Appendix B, Table B.2
Maidment, David R. "Handbook of Hydrology," 1993. General specific yield or effective porosity.	Sandstone: 5 - 20%	Specific Yield or effective porosity; page 6.16
	Shale: 0.5 - 5%	Specific Yield or effective porosity; page 6.16

Associated HAR COL Application Revisions:

The following change will be made to the HAR FSAR in a future revision:

Add to note d) on FSAR Table 2.4.12-209:

"... and Reference 2.4-238, Table 4-4."

Attachments/Enclosures:

None.