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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

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BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF

In the Matter of:	)	Docket No. 72-22-ISFSI
	)	
PRIVATE FUEL STORAGE, LLC	)	ASLBP No. 97-732-02-ISFSI
(Independent Spent Fuel	)	
Storage Installation)	)	July 19, 2001

STATE OF UTAH'S RESPONSE AND OPPOSITION TO PFS'S MOTION FOR SUMMARY DISPOSITION OF CONTENTION UTAH O - HYDROLOGY

Contention Utah O asserts that the Applicant has failed to satisfy the environmental review standards of the National Environmental Policy Act of 1969, 42 U.S.C. 4322, et seq ("NEPA") and the substantive requirements of 10 CFR Part 72. The Applicant's motion for summary disposition must fail because neither the record nor the law supports the motion; there are numerous unresolved genuine issues of material fact; and relevant facts not in dispute demonstrate that the DEIS[1] and Environmental Report ("ER") are deficient because they fail to comply with NEPA and Part 72. Thus, PFS is not entitled to judgment as a matter of law. Rather, the undisputed facts show a hearing is unnecessary and the State is entitled to judgment as a matter of law.

This response is supported by the State of Utah's Statement of Disputed and Relevant Material Facts ("Utah Facts") and by the Declaration of Don A. Ostler, attached hereto as Exhibit 1.

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[1] *Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians. . ., Tooele County, Utah*, NUREG-1714 (June 2000) ("PFS DEIS").

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LEGAL DISCUSSION

A. Summary Disposition

Summary judgment "is a drastic and extreme remedy, not to be granted if there is even the slightest doubt as to a factual dispute on any genuine issue of material fact."[2] Because summary judgment – or summary disposition[3] – deprives a party of "its day in court," it is disfavored by the courts[4] and should only be granted where it is quite clear what the truth is and no genuine issue remains for trial.[5] The U.S. Supreme Court has mandated that courts approach such motions with "caution,"[6] which is why courts sometimes call summary judgment the "treacherous shortcut."[7]

The burden on the Applicant is onerous. Advanced Medical Systems, Inc., 38 NRC at 102. To prevail, PFS must demonstrate there are no genuine issues of material fact with respect to any aspect of Utah O relevant to both NEPA and Part 72, and then, that it is also entitled to judgment as a matter of law. Even more onerous is the requirement that the Board draw all reasonable inferences, resolve all genuine factual disputes, and resolve all

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[2] U.S. v. Conservation Chemical Co. 653 F.Supp. 152, 170-171 (W.D. Mo. 1986), *citing* Clausen & Sons, Inc. v. Theo. Hamm Brewing Co., 395 F.2d 388, 389 (8th Cir. 1968); *see also* 10 CFR § 2.749; Long Island Lighting Co. (Shoreham Nuclear Power Station, Unit 1), CLI-86-11, 23 NRC 577 (1986); and Cleveland Electric Illuminating Co. (Perry Nuclear Power Plant, Units 1 and 2), ALAB-443, 6 NRC 741, 755 (1977).

[3] 10 CFR § 2.749. *See* Advanced Medical Systems, Inc. (One Factory Row, Geneva, Ohio 44041), CLI-93-22, 38 NRC 98, 102 (1993) (summary disposition standard is the same as that under Fed. R. Civ. P. 56).

[4] Conservation Chem., 653 F. Supp. at 171.

[5] Poller v. Columbia Broadcasting System, Inc., 368 U.S. 464, 467 (1962).

[6] Anderson v. Liberty Lobby, Inc., 477 US 242, 255 (1986).

[7] *See* e.g., Petition of Bloomfield S. S. Co., 298 F.Supp. 1239, 1242 (D.C.N.Y. 1969), *aff'd on other grounds*, 422 F.2d 728 (2nd Cir. 1970); Elf Atochem N. America, Inc. v. Libbey-Owens-Ford Co., Inc., 894 F.Supp. 844, 849 (1995); Conservation Chem., 653 F.Supp. at 171.

credibility issues of witnesses, in favor of the nonmoving party,[8] *i.e.*, in favor of the State. In light of the above requirements and the numerous complex factual and legal issues presented by Utah O, Applicant's motion must fail.[9]

B. NEPA and NRC Regulations

NEPA requires agencies to analyze the probable environmental effects of major federal actions significantly affecting the quality of the human environment. 42 USC § 4332(C). The purpose is two-fold: to assure that agencies give proper consideration to the environmental consequences of their actions, and to ensure that the public is informed about environmental impacts of such actions.[10] If the agency determines that impacts may occur, a "detailed" EIS must be prepared and different courses of action evaluated.[11]

The test for whether an EIS sufficiently analyzes the environmental effects of a proposed action is the "hard look" or "rule of reason" test.[12] Failure to analyze "every

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[8] Reeves v. Sanderson Plumbing Products, Inc., 530 U.S. 133, 150 (2000), *citing* Anderson, 477 US 242; Sequoyah Fuels Corp. and General Atomics Corp. (Gore, Oklahoma Site Decontamination and Decommissioning Funding), LBP-94-17, 39 NRC 359, 361, *aff'd* CLI-94-11, 40 NRC 55 (1994); Oldham v. West, 47 F.3d 985, 989 (8th Cir. 1995); *quoting* Madewell v. Roberts, 909 F.2d 1203, 1206 (8th Cir. 1990) (resolving witness credibility issues in favor of moving party is inappropriate in ruling on summary judgment).

[9] *See* Elliott v. Elliott, 49 FRD 283, 284 (D.C.N.Y. 1970) (complex cases not appropriately disposed of by summary disposition); U.S. for Use and Benefit of T/N Plumbing & Heating Co. v. Fryd Constr. Corp., 423 F.2d 980, 984 (5th Cir.), *cert. denied*, 400 US 820 (1970) (complicated issues of fact do not lend themselves to disposition of summary judgment). For this reason alone, summary disposition should be denied.

[10] Robertson v. Methow Valley Citizen Council, 490 US 332 (1989); Dubois v. United States Dept. of Agriculture, 102 F.3d, 1273, 1285 (1st Cir. 1996), *cert. denied sub nom* Loon Mountain Recreation Corp. v. Dubois, 521 U.S. 1119 (1997).

[11] Dubois, 102 F.3d at 1285, 1287. *Cf Draft Environmental Impact Statement For Geologic Repository for the Disposal of Spent Nuclear Fuel and High Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, July 1999 ("Yucca DEIS"), pp. 3-31 through 3-59 with PFS DEIS at p. 3-12, lines 28-32.

[12] *See e.g.*, Dubois, 102 F.3d at 1287; Valley Citizens for Safe Environment v. Aldridge, 886 F.2d 458 (1st Cir 1989); All Indian Pueblo Counsel v. United States, 975 F.2d 1437, 1445 (10th Cir. 1992).

significant aspect of the environmental impact of the proposed action"[13]; adequately analyze certain direct and cumulative impacts (10 CFR § 15022.22); disclose that data is missing or unavailable (id. § 15022(a)); collect missing data when the cost of doing so is not "exorbitant"[14]; and reaching a conclusion without sufficient data to do so[15] are all reasons for rejecting an EIS for failing to take the necessary "hard look." *See also* Dubois, 102 F.3d at 1287. Failing to consider every reasonable mechanism which successfully avoids, prevents, mitigates, or reduces pollutant discharges that can contribute to both point and non-point source pollution, and failing to modify designs and practices to reduce pollution and impacts, result in a defective analysis.[16] Finally, NEPA's rule of reason requires the DEIS to assume accidents will occur and evaluate the environmental impacts therefrom.[17]

Part 72 requires the site to be evaluated with respect to effects on populations resulting from both "normal" and "accident conditions" during operation as well as decommissioning, while taking into account usual and unusual regional and site characteristics, *i.e.*, a determination of and compatibility with site-specific characteristics. *See*

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[13] Vermont Yankee Nuclear v. NRDC, 435 U.S. 519, 553 (1978). "The agency need not speculate about all conceivable impacts, but it must evaluate the reasonably foreseeable significant effects of the proposed action... In this context, reasonable foreseeability means that 'the impact is sufficiently likely to occur that a person of ordinary prudence would take it into account in reaching a decision.' ... An environmental effect would be considered 'too speculative' for inclusion in the EIS if it cannot be described at the time the EIS is drafted with sufficient specificity to make its consideration useful to a reasoned decisionmaker." Dubois, 102 F. 3d at 1286 (*citations omitted; emphasis added*).

[14] 40 CFR § 1502.22(a).

[15] 40 CFR §1502.22(a) (must disclose data which is missing or unavailable); 40 CFR § 1502.24 (ensure scientific integrity and describe methodologies).

[16] *See* NEPA; Pollution Prevention Memorandum, 58 Fed. Reg. 6478 (1993).

[17] *See* eg, 40 CFR 1502.22(b) (Reasonably foreseeable impacts includes those with "catastrophic consequences, even if their probability of occurrence is low.").

10 CFR §§ 72.100(a), (b) and 72.122. The site must also be evaluated for environmental conditions and natural phenomena, including man-made phenomena and events to protect the public health and safety. 10 CFR § 72.24(d).

ARGUMENT

A. PFS's Declarants, Trained as Civil Engineers, Are Not Human Health Scientists, Legal Experts, Geochemists or Hydrologists and Their Testimony Regarding Such Is Inadmissible or Alternatively Carries No Weight.

PFS asserts that the joint declaration of H.C.George Liang and Donald W. Lewis expresses "expert" opinions allegedly to demonstrate that the DEIS satisfies NEPA and Part 72 with respect to environmental impacts to surface and groundwater; and that the PFS facility "will have no health and safety impacts on surface water and groundwater." Liang & Lewis Dec., ¶¶ I.A.1 and I.B.4. As the party sponsoring the witnesses, PFS has the burden to demonstrate the witnesses' expertise.[18] Expert qualifications can be established by showing relevant knowledge, skill, experience, training, or education.[19]

With all due respect to the civil engineering education and experience of Liang and Lewis, neither is a medical doctor, human health specialist, or legal expert. To the extent that PFS asserts its declarants are qualified to render a legal opinion on compliance with NEPA and NRC requirements, the State objects because neither declarant is so qualified. Liang & Lewis Dec., ¶¶ I.A.1 and I.B.4. For these reasons, their testimony should only be considered when it pertains directly to their area of expertise: civil engineering.

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[18] Pacific Gas & Electric Co. (Diablo Canyon Nuclear Power Plant, Units 1 and 2), ALAB-410, 5 NRC 1398, 1405, *petition for review denied*, CLI-77-23, 6 NRC 455 (1977).

[19] Duke Power Co. (William B. McGuire Nuclear Station, Units 1 and 2), ALAB-669, 15 NRC 453, 474-75 (1982) (*citing* Fed. R. Evid. 702).

Liang and Lewis have also been put forward as experts in hydrology.[20] Both Liang's and Lewis' training limit their expertise to civil engineering, and in Liang's case, modeling of surface and groundwater flow. *See* Exhibit 3, Liang Tr. at 10-11. Deposition testimony demonstrated declarants' unfamiliarity with geologic formations, formations that produce water, and borehole closure. Liang Tr. at 8-9, 16, and 38; Exhibit 4, Lewis Tr. at 9-25. Also, Dr. Liang's unfamiliarity with the basic hydrogeologic terms "hydraulic conductivity" and "transpiration," and unfamiliarity with geologic field work, indicate he is not an expert in hydrogeology.[21] Liang Tr. at 56-58. Dr. Liang's area of expertise lies in assembling data and information collected by various experts in other fields of hydrology and using that information as input to mathematical equations and programs to model the physical flow of surface and groundwaters.[22] PFS has failed to demonstrate that Dr. Liang's education or experience pertains to any matter outside of the data collection and physical flow, *i.e.*, "groundwater dispersion," areas of hydrology.

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[20] Hydrology, a vast interdisciplinary science, includes meterologic studies (*e.g.*, atomospheric and oceanic studies, weather and storm prediction), surface waters, (*e.g.*, flood modeling, water quality), geology (*e.g.* soil and rock lithology and mineralogy), the physics of water flow (*e.g.*, flow through porous media and fractured media), and geochemistry, (*e.g.*, the chemistry and geochemisty of ground and surface waters). *See* Exhibit 2, R. Allen Freeze & John A. Cherry, Groundwater (Prentice-Hall, Inc. 1979) at xv-xvi (preface).

[21] Hydraulic conductivity is a basic groundwater flow parameter, and an understanding of this term is required to understand hydrogeology. *See, e.g.*, Freeze & Cherry at 29 (comparing the hydraulic conductivity and permeability of common geologic formations); *see also*, Yucca DEIS at 3-50 ("Transmissivity is a measure of how much water an aquifer can transfer and is equal to the average hydraulic conductivity of an aquifer multiplied by the thickness of the aquifer that is saturated.") and at 3-51 (Table 3-14 showing apparent hydraulic conductivities); and NUREG 1567, *Standard Review Plan for Spent Fuel Dry Storage Facilities* (March 2000) § 2.5.5 (Applicant's supporting documents should include information regarding hydraulic conductivity).

[22] Dr. Liang's qualifications do not establish that he is qualified to opine as to the fate and transport of chemical compounds in surface waters, *i.e.*, the complex chemical interactions between organic and inorganic chemical compounds in the soil/rock and dissolved in groundwater.

B. Contention Utah O Presents Genuine Claims that PFS Has Failed to Satisfy.

PFS's Motion asserts that there would be no disputed facts if the opinions of the State's expert are disallowed as alleged "unsupported speculation."[23] Motion at 5. PFS is particularly offended by the State's expert's prior testimony that human error might occur in the design, construction or decommissioning of the facility. Id. at 8. Such assertions are without merit.

Both NEPA and Part 72 require the Applicant to assume accidents can and will happen, and to analyze the potential impacts from these accidents.[24] As described *supra*, the test for determining "reasonably foreseeable" impacts is whether a "person of ordinary prudence" would take it into account.[25] Spills, releases and accidents at industrial facilities are not uncommon. Ostler Dec. ¶ 23. Moreover, an unresolved issue in Contention Utah K relating to credible accidents is whether CRUD and volatile fission products located in the

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[23] Mr. Ostler's opinions are supported by his extensive experience in the area of industrial impacts to surface and groundwater, and by numerous independent sources, including EPA guidance documents, groundwater textbooks, and relevant publications. Thus, his opinions are well within the legal test for admission of expert testimony. In addition, Mr. Ostler's opinion that, in some cases, PFS as well as the DEIS process failed to collect or generate sufficient data to reach a supportable conclusion rests on his expert opinion that at least some relevant data are necessary to reach a scientifically supportable conclusion. Furthermore, an observation that the DEIS process and ER failed to analyze certain potential environmental impacts, or reach a necessary conclusion, is an fact which can be readily verified by perusing the documents in question. Moreover, it is credible that accidental or intentional releases of pollutants or contaminants will occur over the 40 year proposed life of the PFS facility. Ostler Dec. ¶ 23.

[24] *See, e.g.,* 10 CFR § 72.24(d) (evaluation and mitigation of the consequences of accidents); § 72.100(a) (must evaluate "accident conditions" during operation and decommission); § 72.122(b) (SSCs designed to withstand postulated accidents); and 40 CFR § 1502.22 (if data is incomplete and unobtainable, the agency must evaluate reasonably foreseeable "catastrophic consequences, even if their probability of occurrence is low").

[25] PFS's position is tantamount to concluding that a person of ordinary prudence would not take into account accidental spills or releases at an industrial facility, and that the possibility of spills and releases to the soil and groundwater at the PFS facility is so "speculative" that a person of ordinary prudence would not even consider various alternatives or mitigating factors. PFS Motion at 8-9.

gap between the pellet and the cladding would be released after a jettisoned weapon penetrates the canister.[26] In addition, the SAR states "water dripping from shipping casks (*e.g.*, from melting snow)" is collected in the Canister Transfer Building ("CTB") and verified whether or not it is contaminated. SAR at 6.3-1. Nowhere are there any controls to ensure that casks outside the CTB awaiting processing will not drip contaminated water into the soil. As further described in Section C *infra*, there is no supportable evidence to show that the soils at PFS are impermeable, and because the wastewater system, retention pond and improperly filled boreholes will act as pathways to groundwater, the State has presented genuine claims that PFS has failed to satisfy.

NEPA and Part 72 require that accidents both be anticipated and the environmental impacts from accidents be evaluated. A reasonable environmental analysis requires the agency and the Applicant to accept the fact that industrial facilities of all types are subject to human errors and that, during the construction, operation and decommissioning of the 4,000 cask spent nuclear fuel storage facility, human error and misconduct are reasonably foreseeable possibilities over its projected forty year lifetime. To satisfy the minimal requirements of NEPA and Part 72, the DEIS and ER must analyze the human health and safety impacts which may result from accidental releases. If data to evaluate reasonably foreseeable impacts are missing, the DEIS must disclose that fact and obtain such information or explain why it cannot be obtained. 40 CFR § 1502.22. If the cost of obtaining the data is "exorbitant," then NEPA requires the DEIS to assume environmental impacts from a worst case scenario, *i.e.*, impacts which have "catastrophic consequences,

[26] *See*, Utah's January 30, 2001, Response to Summary Disposition of Utah K, Resnikoff Dec. ¶¶ 56-70.

even if the probability of their occurrence is low." Id., § 1502.22(a), (b). The DIES and ER fail to disclose that necessary site specific data are missing, or explain why the data cannot be obtained. *See* Utah Facts ¶¶ 30-35 and 37-45.

In addition, PFS's failure to provide sufficient information is not a reason for barring opposing expert's testimony. *See e.g.* General Electric Co. v. Johnson, 522 U.S. 136 (1997). The burden is on the Applicant to describe its project in sufficient detail, to generate sufficient data, and to analyze the environmental impacts of its actions and of possible accidents. Failure of the Applicant to present sufficient information to "assure the public is informed,"[27] or to allow a greater level of scrutiny, is a deficiency on the part of the Applicant, not the State's expert. The State does not have the burden of proving how an accident may occur – NEPA and Part 72 regulations place an affirmative obligation on the Applicant to assume accidents will occur and to evaluate the impacts accordingly.[28]

Finally, the purpose of rejecting evidence based on unsupported speculation is to prevent experts from testifying to matters which cannot be scientifically supported or are beyond their control, *e.g.*, the Applicant's experts promising that future employees at the site will never have an accident, or will never engage in intentional misconduct, over the lifetime of the facility cannot be supported on generally accepted scientific principles.[29] NEPA and

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[27] *See* Robertson v. Methow Valley, 490 U.S. 332 (1989), *supra.*

[28] Applicant's extensive arguments and attempts to demonstrate it is impossible for accidents to occur are misplaced, and Utah O would be much closer to closure if PFS committed its resources to evaluating the impacts of accidents instead of arguing it has somehow solved the age-old problems of human error, human misconduct, and accidents.

[29] *See e.g.*, Liang and Lewis Dec., ¶¶ 33, 39, 40, 42, 43, 45, 46, 47, 48, 49 (describing aspirations and operating procedures).

Part 72 require the Applicant to assume accidents can and will happen to ensure that the public and decision-makers are informed about the potential environmental impacts of the proposed action. Robertson v. Methow Valley, 490 U.S. 332.

The record before the Board does not support granting PFS's Motion, and, in fact, supports a finding that the deficiencies in the DEIS[30] and ER fail satisfy NEPA and Part 72. *See* Utah Facts at ¶¶ 30-53.

C. Summary Disposition Must be Denied Because Numerous Disputed and Relevant Material Facts Remain Unresolved.

The State and PFS disagree on numerous legal and factual issues including whether site-specific data, currently missing from the DEIS and ER[31], are necessary to satisfy the legal requirements of NEPA and Part 72.[32] The State and PFS also strongly disagree on the interpretation of the general assumptions PFS relies upon to reach its assertion that the soils at the site have a low permeability. Critical to a resolution of these issues is whether the DEIS and ER have adequately characterized the aquifer, the permeability of surface soils and the hydrologic connection between the surface soils and the aquifer.

Hydrologic Connection: Whether the potential impacts expressed in Utah O – environmental impacts[33] from accidental spills and releases at the site; wastewater discharges

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[30] The DEIS contains a scant one page discussion on groundwater quality and chemistry. DEIS §3.2.2.

[31] Utah Facts ¶¶ 1-3, 17-18, 20, 30-35, 37-41, 43-44, and 53.

[32] The DEIS is also deficient for failing to describe the missing data (e.g., defining the aquifer, water quality of the aquifer, soil permeability tests) and explaining why it could not be collected. 40 CFR § 1502.22.

[33] Once the impacts are identified and adequately described, NEPA and Part 72 require an evaluation of mitigating conditions or less damaging alternatives. *See e.g.,* 10 CFR § 72.24(d)(2) and 58 Fed. Reg. 6478 (1993) (CEQ memorandum regarding pollution prevention and mitigation under NEPA).

to the septic systems and percolation from the detention pond – will affect the groundwater pathway to humans or the environment depends upon whether the surface is hydrologically connected to the aquifer under the site. Ostler Dec. ¶ 4. The first step in determining whether a hydrologic connection to groundwater exists is to delineate the permeability characteristics of the surface soils, define the aquifer and its parameters (*e.g.*, hydrologic units, water quality), and then determine whether a hydrologic connection exists between these two areas. Id.

Neither document attempts to define the aquifer, its hydrologic units, or its water quality, as required by NEPA and NUREG 1567 §§ 2.4.5 and 2.5.5. *See* Ostler Dec. ¶¶ 5-10. The DEIS and ER reach a conclusion about the permeability of the surface soils at the site but that conclusion is based solely upon a region-wide estimate, is not supported by any site specific test data, and is inconsistent with the Applicant's own assumptions. Utah Facts ¶¶ 4 and 11; Ostler Dec. ¶¶ 8, 32. Furthermore, the DEIS summarily concludes that the surface soils are of such low permeability that no hydrologic connection exists. Without defining the aquifer and without site-specific data regarding both the surface soils and the aquifer, any conclusion regarding the hydrologic connection is premature and unsupportable. For these reasons, the DEIS and ER fail to satisfy the legal requirements of both NEPA and Part 72.

NUREG 1567, §§ 2.4.5 and 2.5.5, provides guidance for evaluating the subsurface hydrology at ISFSI sites located over an aquifer which is a source of well water. PFS intends to use groundwater from the site as a water supply. *See e.g.*, ER Rev. 13, § 4.5.5. Accordingly, NUREG 1567 provides relevant and appropriate guidance for the PFS site, and the failure of the DEIS and ER to include and evaluate the necessary aquifer data is a material defect in those documents. *See* Utah Facts ¶¶ 20, 29-36, 28-41, 43-45, 48, and 53.

Surface Soils: PFS Material Fact ¶ 3 states, in part: "Percolation into the groundwater from the surface near the PFS site is nonexistent or so insignificant that it can be stated that there is no direct hydrological link between the surface and groundwater in this vicinity." This unabashed statement has no validity in fact or in science and is the nub of PFS's ineffectual site-specific hydrological evaluation. As is apparent from the foregoing statement, PFS assumes it does not have to understand the aquifer or the hydrologic connection between the surface soils and the underlying aquifer if it alleges spills and releases, the septic wastewaters, and the detention pond water, will not migrate through the surface soils.

First, PFS naively maintains that accidental spills and releases will not happen. As described in Section B *supra*, this is incorrect. PFS's laudable goal of "Start Clean - Stay Clean" is no substitute for a rigorous evaluation of potential adverse environmental consequences from PFS's industrial operations. See e.g., Ostler Dec. ¶ 11 and 23. Second, even if accidents do happen, PFS claims the contaminants will not penetrate the surface soils. As support for these propositions, PFS relies on its declarants, Lewis and Liang. *See* e.g., PFS Facts ¶¶ 3, 11, 12, 48, 50, 53, 55-57. As described in Section A *supra*, neither Lewis or Liang have the ability to predict whether or not accidents will occur; nor have they collected site-specific data to support their conclusions. Third, PFS maintains there are no potential contaminant pathways to groundwater. PFS Motion at 3. From PFS's refrain

"Start Clean - Stay Clean," which places total reliance on promises to prevent releases into the environment, PFS assumes, wrongly, it has met the requirements of NEPA and Part 72.

Neither the DEIS nor the ER provide site-specific soil permeability data and it is inappropriate for either Lewis or Liang to reach any site-specific conclusion regarding soil permeability using only region-wide information. *See e.g.*, Utah Facts ¶¶ 3, 4 and 38. First, both the State and the Applicant agree the permeability of the surface soils varies "widely" across the site. Utah Facts ¶ 6. Second, the different types of soils vary across the site. *See* Soil Borehole Logs, SAR, Appendix 2A. Third, the permeability/hydraulic conductivities of the each soil type found at the site can vary by three or four orders of magnitude. Utah Facts ¶¶ 6-7. Accordingly, site-specific data is necessary to reach a scientifically supportable conclusion regarding the soils at the site. Ostler Dec. ¶ 19. Just as importantly, the Applicant's own general assumptions clearly indicate the native surface soils are more permeable than those subsurface soils it intends to utilize as a source of water.[34] This is consistent with the fact that, relative to soils and rocks in general, the types of soils identified at the site have a moderate, not low, hydraulic conductivity/permeability. Ostler Dec. ¶ 7. In addition, PFS's assumed hydraulic conductivity is three orders of magnitude greater than EPA's criteria for a confining layer. Utah Facts ¶ 9.

The pathways to groundwater include spills and release to soils, migration of the sewer-wastewater discharge, improperly filled boreholes, and the retention pond. The

[34] The Applicant assumes the surface soils have a permeability range of 1.4×10^{-4} – 4.2×10^{-4} cm/sec while the permeability of the screened interval in Applicant's test well was estimated to be a less permeable 5.0×10^{-5} cm/sec. *See* Utah Facts ¶ 4; Ostler Dec. ¶ 8. Even Applicant's expert agreed the two permeabilities were of the same "order of magnitude." *See* Liang Tr. at 21-22.

wastewater system is a concern because migration of the wastewater discharge may resurface, either through pumping of groundwater or breaching the surface untreated above the drainfields. Ostler Dec. ¶¶ 16-18. In addition, the ability of the native soils to prevent downward migration of fluids has been adversely affected by the approximately two dozen three-inch plus boreholes drilled through the surface soils and never backfilled or inappropriately backfilled.[35] Utah Facts. ¶ 13. Neither the DEIS nor the ER mention, let alone address, the effect these open and inappropriately backfilled boreholes will have on the hydrologic connection between the surface and subsurface.

The scant and generalized data that PFS has collected does not satisfy the legal requirements of NEPA and Part 72, including NUREG 1567, §§ 2.4.5 and 2.5.5. The State strenuously disputes PFS's premature and unsupportable conclusion that potential spills and releases of radiologics and non-radiologics, discharges from the septic and wastewater systems, and percolation from the detention pond, cannot reach the groundwater pathway or harm human health and the environment. Utah Facts ¶¶ 21-28, 37, and 46-52

D. As a Matter of Law the DEIS and ER Are Deficient and Summary Disposition Should Be Granted to the State and Not to PFS.

If the Board finds that, under NEPA and Part 72, including NUREG 1567, the DEIS and ER are deficient in failing to provide and analyze site-specific information, then as a matter of law, there is no need for a hearing, and summary disposition in favor of the State

[35] Wellhead protection is currently a problem on the Skull Valley Indian Reservation; the Band is under an EPA enforcement action for allowing its drinking water sources to become contaminated and for failing to correct the deficiency. *See* attached Exhibit 5, EPA Second Amended Administrative Order, dated May 2, 2001, and Sanitation Facilities Construction, Skull Valley Band of Goshute Indians, Skull Valley Indian Reservation, dated March 2001.

is warranted.[36] The State requests the Board to hold that there is no genuine dispute that the DEIS and ER are deficient, including but not limited to: failing to note there is missing necessary site-specific soil permeability, aquifer, and water quality data; failing to explain why the data was not collected or cannot be collected, pursuant to 40 CFR § 1502.22; affirmatively reaching various conclusion(s) regarding possible environmental and health impacts, soil characteristics and the hydrologic relationship between the surface and groundwater without sufficient site-specific data to reach any conclusion on these issues; failing to delineate the aquifer and aquifer characteristics under the site as required by NUREG 1567; failing to assume accidents can and may occur; and failing to provide a human health and environmental impact analysis for same. *See* Utah Facts ¶¶ 1-4, 6, 18, 20, 24-25, 27, 30-41, 42-47, 52-53. With these findings, summary disposition in favor of the State is warranted.

CONCLUSION: For the foregoing reasons, the State requests the Board deny PFS's motion and find in favor of the State.

DATED this 19th day of July, 2001.

Respectfully submitted,

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[36] "The weight of authority, however, is that summary judgment may be rendered in favor of the opposing party even though [this party] has made no formal cross-motion under Rule 56." 10A C. Wright, A. Miller, and M. Kane, Federal Practice and Procedures Civil 3d § 2720, Rule 56, at pg. 347 (1998).

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NUCLEAR REGULATORY COMMISSION

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PRIVATE FUEL STORAGE, LLC (Independent Spent Fuel Storage Installation)	)	ASLBP No. 97-732-02-ISFSI
	)	July 19, 2001

STATE OF UTAH'S STATEMENT OF DISPUTED AND RELEVANT MATERIAL FACTS

In support of its Response to PFS's Motion for Summary Disposition of Contention Utah O, the State submits this Statement of Disputed and Relevant Material Facts.

1. Utah disputes the assertion in ¶ 3 of PFS's Statement of Material Facts on Which No Genuine Dispute Exists ("PFS Facts"), which states: "Percolation into the groundwater from the surface near the PFS site is nonexistent or so insignificant that it can be stated that there is no direct hydrological link between the surface and groundwater in this vicinity." The Applicant makes the same or similar statements regarding the soil permeability throughout its Facts. *See e.g.* assertions in PFS Facts ¶¶ 11, 48, 50, 53, 54, 55, 56, 57, 65, 66. The State disputes each and every statement in these paragraphs, and similar statements, which expressly or impliedly suggest the Applicant has demonstrated the permeability of the native surface soils is low enough to prevent surface waters and fluids from migrating downward to the groundwater.

2. The State disputes that the DEIS, the ER, or the Applicant's supporting documents, provide any site-specific soil test data regarding soil permeability at the site. Ostler Dec. ¶ 8-10, 14, 19, and 32-34; *cf Draft Environmental Impact Statement For Geologic Repository For The Disposal of Spent Nuclear Fuel and High Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, July 1999 ("Yucca DEIS"), § 3.1.4.2.2, Table 3-14 (Hydraulic Conductivities specific to site).

3. The State disputes that general assumptions regarding the region-wide permeability of soils of the general type found in Skull Valley, which assumptions are described in the DEIS, the ER, and the Applicant's

supporting documents, are sufficient to reasonably or scientifically support any conclusion regarding the permeability of these soils. Ostler Dec. ¶¶ 6-10.

4. The native surface soils the Applicant believes can function as a confining layer are more permeable than the subsurface soils which the Applicant intends to use as a source of water. The Applicant assumes the site surface soils have a permeability range of 1.4×10^{-4} - 4.2×10^{-4} cm/sec (ER Rev. 2 at 2.5-11 (0.2-0.6 in/hr.)), while the permeability of the screened interval in Applicant's test well was estimated to be a less permeable 5.0×10^{-5} cm/sec. (Stone & Webster, *Determination of Aquifer Permeability From Constant Head Test and Estimation of Radius of Influence for the Proposed Water Well*, Rev. 2, (March 27, 2001) ("Constant Head Test Report") at 5 (attached hereto as Exhibit 6); *see also*, M.S. Bedinger, et al, *Studies of Geology and Hydrology in the Basin and Range Province, Southwestern United States, for Isolation of High-Level Radioactive Waste: Characterization of the Bonneville Region, Utah and Nevada*, U.S. Geological Survey Professional paper 1370-G, 1990 (soils in region approximately 2.3×10^{-5} cm/sec), cited in Constant Head Test Report at 5).

5. The Applicant's expert agrees that the permeabilities of the surface soils at the site and the subsurface water source are of the same order of magnitude. *See* Liang Tr. at 21-22.

6. The Applicant's expert admits the permeability of the soils at the site vary "widely." Lewis Tr. at 25.

7. Published ranges of soil permeabilities/hydraulic conductivities indicate the permeabilities of soils of the type found at the site can vary by three or four orders of magnitude. R. Allen Freeze & John A. Cherry, Groundwater (Prentice-Hall, Inc. 1979), p. 29, Table 2.2 (hydraulic conductivity of silts and clays highly variable). *See* Exh. 2.

8. When compared to the published permeability ranges of other soils and rocks, the assumed permeability of the surface soils has a moderate hydraulic conductivity/permeability. *See*, Exh. 2, Freeze and Cherry, p. 29 (permeability of 1×10^{-4} cm/sec. in middle of range of unconsolidated and consolidated materials). *See also* Ostler Dec. ¶ 15.

9. For a layer of soil to be considered acceptable as a confining layer, EPA guidance requires that the layer have a hydraulic conductivity of 1×10^{-7} cm/sec or less. *See e.g.*, Seminar Publication: *Requirements for Hazardous Waste Landfill Design, Construction and Closure*, EPA/625/4-89/022, Table 1-5, Cover Design, and p. 11 (saturated hydraulic conductivity less than or equal to 1 x

10^{-7} cm/sec.), attached hereto as Exhibit 7; Technical Guidance Document: D. Daniel and R. Koerner, *Quality Assurance and Quality Control for Waste Containment Facilities*, EPA/600/R-93/183, September 1993, p. 39 (hydraulic conductivity of confining clay barrier must be less than 1 x10^{-7} cm/sec), attached hereto as Exhibit 8. Ostler Dec. ¶ 5.

10. The State disputes that the assumed hydraulic conductivity of the native soils (1.4 x 10^{-4} cm/sec – 4.2 x 10^{-4} cm/sec (0.2 - 0.6 in/hr)) satisfies EPA criteria for confining layers, and is in fact more than three orders of magnitude greater in permeability than that permissible for confining layers. *See* ER, Rev. 2 at 2.5-11, and Exhs. 7 and 8. Ostler Dec. ¶¶ 5-6.

11. The Applicant's position appears inconsistent with its responses to Utah's requests for admissions regarding recharge at the Site. *See* Applicant's Objections and Responses to the State of Utah's Tenth Set of Discovery requests Directed to Applicant (March 12, 2001), Response to Request for Admission No. 4. By denying recharge is not occurring at the site, PFS is suggesting there is some recharge occurring at the site.

12. Approximately two dozen, three to six-inch plus diameter boreholes drilled by the Applicant across the site were either not backfilled at all, or backfilled with "soil." *See* Figures 2.6-19, 2.6-21, 2.6-22, 2.6-23 and borehole logs from the Safety Analyses Report ("SAR"), Rev. 6, Appendix 2A (Geotechnical Data), Attachment 1 (the following boreholes were reportedly backfilled with "soil": Boring 1, A-1, A-2, B-4, C-1, C-4, D-2, D-4, E-3, E-4). The SAR borehole logs are silent regarding the following boreholes, and therefore, it is presumed these boreholes were left open: Boring 2, A-3, A-4, B-1, B-2, B-3, C-2, C-3, D-1, D-3, E-1, E-2, CTB-1, CTB-2, CTB-3, CTB-4, CTB-6, CTB-7, CTB-8. Ostler Dec. ¶ 17.

13. The State disputes the Applicant's position that the geotechnical boreholes were "properly sealed so as not to create a link to groundwater at the site." Liang Dec. ¶ 56. Ostler Dec. ¶¶ 16-18. *See Environmental Investigations Standard Operating Procedures and Quality Assurance Manual*, U.S. EPA (May 1996, includes 1977 Revisions), Section 6.10.6, p. 6-17 "Backfilling," (using soil cuttings to backfill borehole <u>not</u> acceptable if boring has breached a 'confining' layer), and Section 6.9 "Well Abandonment," p. 6-14 (" borehole should be sealed in a manner that the well can not act as a conduit for migration of contaminants from the ground surface to the water table . . . the preferred method is to . . . backfill with a cement or bentonite grout, neat cement, or concrete."), excerpts attached hereto as Exhibit 9; Ostler Dec. ¶ 18.

14. The ability of the native surface soils at the site to prevent downward migration of fluids has been adversely affected by the approximately two dozen three-inch plus boreholes drilled through the surface soils and never backfilled, or inappropriately, backfilled. Ostler Dec. ¶ 16; *see also* Exh.9, *EPA Environmental Investigations Manual*.

15. Failing to backfill some geotechnical boreholes and improperly backfilling others at the site have resulted in numerous very high permeability conduits where surface waters can migrate very quickly to the bottom of the boreholes. Ostler Dec. ¶ 16.

16. Groundwater quality under the PFS site may have already been adversely impacted by surface water runoff migrating into the subsurface via the approximately two dozen, improperly closed boreholes across the site. Id.

17. Neither the DEIS, the ER, nor Applicant's supporting documents have evaluated the possible permeability issues, groundwater contamination, and environmental impacts from the boreholes which were either not backfilled, or were improperly backfilled.

18. The State disputes the DEIS, ER, and Applicant's use of assumed permeabilities/hydraulic conductivities for saturated soils. Ostler Dec. ¶ 9.

19. The unsaturated hydraulic conductivity of fine grained sediments can be greater than that of coarse sediments, and it is likely the Applicant's use of assumed saturated soil hydraulic conductivity estimates results in permeability estimates which are lower than those which likely exist at the site. Id.

20. To the extent the DEIS, ER and Applicant assert they have defined any hydrologic zone other than the top of the unconfined groundwater table, the State disputes the assertion in ¶ 11 of PFS Facts, which states that the "depth to groundwater at the site is approximately 125 feet." The single datum point regarding water at the "125 feet" depth is not representative of the capillary fringe zone, perched groundwater in the vadose zone under the site, or of the confined aquifer(s), for which the DEIS and ER provide little or no data. *See* Ostler Dec. ¶¶ 9 and 20.

21. The State disputes the assertions in ¶¶ 37 and 48 of PFS Facts to the extent they imply the septic tank and leach field will be capable of treating anything other than domestic wastes. Ostler Dec. ¶ 12.

22. The Applicant admits the proposed septic systems are not designed to treat anything other than domestic wastes, and possibly some simple biodegradable cleaning agents. Lewis Tr. at 17-19.

23. Many of the hazardous substances to be utilized onsite, including diesel fuel, lubricating oils, cleaning solvents, paint products, pesticides and herbicides (PFS Facts ¶ 22), radionuclides, or other elements or chemical compounds would not be treated in any way by the septic system and will either accumulate in the subsurface, reach groundwater, or return to the surface untreated. Ostler Dec. ¶¶13-15 and 20-22.

24. The State disputes the assertion in ¶ 48 of PFS Facts, which states that the "natural characteristics of the soil in the detention pond will result in very slow seepage rate for any water standing in the pond." The Applicant has no site-specific test data to support this assertion. Id. ¶¶ 27-28.

25. The soil characteristics of the detention pond assumed by Applicant are of a moderately permeable material which varies widely in permeability. *See* Utah Facts ¶¶ 5-7.

26. The integrity of the native soils in the detention pond area may have been breached by either not backfilling, or improperly backfilling, penetration or boreholes drilled across the site. These open and inappropriately backfilled holes provide high permeability conduits for surface waters from the pond to reach below the surface layer and then to groundwater. Ostler Dec. ¶¶ 16-18; *see* Utah Facts ¶¶ 12-16.

27. The State disputes all express and implied assertions in Applicant's documents and PFS Facts (¶¶ 8, 14, 21, 27, 32, 35, 38, 45, 46, 49, 53, 54, 56, 57, 65, 66); *see e.g.*, Liang and Lewis Dec. ¶¶ 33-38, 44, 47, 58) and all similar statements, which indicate there will never be any spills and releases at the site. Ostler Dec. ¶¶ 23, 28 and 34.

28. Industrial sites, including the PFS site, are subject to spills and releases of hazardous substances and hazardous wastes. Id.

29. The PFS facility is located over an aquifer which currently is, and PFS proposes to be, a source of well water. DEIS § 4.2.1.3 "Groundwater"; ER Rev. 13 § 4.3.1 (PFS will use onsite wells for making concrete and for worker use; PFS may also need several wells to meet daily demand).

30. Neither the ER, the DEIS, nor Applicant's supporting documents define the groundwater aquifer(s) beneath the site, the associated hydrologic units, and

their recharge and discharge areas. *See* NUREG 1567, *Standard Review Plan for Spent Fuel Dry Storage Facilities* (March 2000), § 2.4.5; Liang Tr. at 49; Ostler Dec. ¶¶ 29-31.

31. Neither the DEIS, the ER, or any of Applicant's supporting documents provide a description of each hydrologic unit of the aquifer under the site, the potentiometric level, the hydraulic gradient and conductivity, effective porosity, storage coefficient, recharge and discharge areas, and potential for groundwater flow reversal, as well as chemical analysis of each hydrologic unit under the site. *See* NUREG 1567 § 2.5.5 "Subsurface Hydrology."

32. Neither the DEIS, the ER, nor the Applicant's supporting documents provide a sufficiently detailed water table contour map of the site and area surrounding the site, showing recharge and discharge areas, and the location of monitoring wells to detect leakage from storage structures. *See* NUREG 1567, § 2.4.5.

33. Neither the DEIS, the ER, nor the Applicant's supporting documents provide information on monitoring wells, including representative hydrochemical analysis of samples from the aquifer(s) at the site. *See* NUREG 1567 § 2.4.5. Ostler Dec. ¶ 34.

34. Neither the DEIS, the ER, nor the Applicant's supporting documents provide an analysis bounding the potential groundwater contamination from site operations, nor a graph of time versus radionuclide concentration at the closest existing or potential downgradient well. *See* NUREG 1567 § 2.4.5.

35. Neither the DEIS, the ER, nor the Applicant's supporting documents provide a calculated infiltration rate for surface soils at the site. *Cf.* Yucca DEIS § 3.1.4.2.2.

36. The DEIS expressly indicates the Applicant has failed to adequately determine whether sufficient groundwater resources exist for its project. *See* DEIS § 4.2.1.3.

37. The State disputes that the DEIS and ER, or the Applicant's supporting documents, provide any consideration of accidental releases, or a worst case analysis of, releases of radionuclides into surface and groundwater. *See* NUREG 1567 § 2.5.4.9.

38. Applicant's assertion that soils at the proposed PFS facility have a relatively low permeability are not based upon site-specific data, but generally based upon region-wide estimates (Liang Dec. at ¶¶ 20 and 21, citing to an

unpublished and undated USDA Tooele County soil survey and to a 1987 report by Dames and Moore prepared for a proposed Superconducting Super Collider site in the Cedar Mountains); are from general studies prepared for other reasons (id.); or are text book assumptions (Lewis Dec. at ¶ 51 (ground percolation and evaporation assumptions based upon T. William Lambe and Robert V. Whitman, Soil Mechanics (John Wiley & Sons, Inc., 1969) and David D. Houghton, Handbook of Applied Meteorology (Wiley 1985)). Ostler Dec. ¶ 25.

39. The State disputes that the DEIS and ER, or the Applicant's supporting documents furnish adequate site-specific field data to provide adequate input for mathematical models of the flow and transport of possible releases. *See* NUREG 1567 § 2.5.4.9 (site-specific data to be used for modeling through water should be described and referenced). Ostler Dec. ¶ 25.

40. Neither the DEIS, the ER, nor the Applicant's supporting documents present any results of a mathematical model of the flow and transport of releases, the transport capabilities, and potential contamination pathways of the surface and groundwater environments. *See* NUREG 1567 § 2.5.4.9. Ostler Dec. ¶ 25.

41. Neither the DEIS, the ER, nor the Applicant's supporting documents provide the transport characteristics of the aquifers subject to radionuclide contamination, nor ensure that the model and codes used to predict radionuclide migration are appropriate for the site, or ensure that potential future groundwater uses are conservatively estimated. *See* NUREG 1567 § 2.5.5. Ostler Dec. ¶ 25.

42. Unsaturated fine grained soils can have a greater hydraulic conductivity than course grained soils. Ostler Dec. ¶ 9.

43. Neither the DEIS, the ER, nor the Applicant's supporting documents have adequately characterized the soil characteristics across the surface, and under, the site, including determining the unsaturated hydraulic conductivity of the surface soils. Ostler Dec. ¶¶ 14, 15 and 19.

44. Neither the DEIS nor the ER considers the undisputed fact that the soil characteristics, including permeability, vary "widely" across the site. Lewis Tr. at 25.

45. Groundwater modeling is generally required before siting a large industrial facility. Neither the DEIS, the ER, nor Applicant's supporting documents

provide groundwater modeling to predict impacts to water quality, *See* Liang Tr. at 10-11; Ostler Tr. at 30, 72, 77-78; Ostler Dec. ¶¶ 32-34.

46. The State disputes any implied or express assertions by Applicant (e.g., Liang and Lewis Dec. ¶¶ 33, 34, 35,36, 37, 40, 41, 43, 44, 46, 49 68) or statements in the DEIS or ER that the design, construction, operation and decommissioning of industrial facilities such as the PFS facility are not subject to human error or intentional misconduct by disgruntled employees or others. Ostler Dec.¶¶ 11 and 23.

47. The State disputes any express or implied assertion in the DEIS, ER or Applicant's supporting documents that radiologic and non-radiologic chemicals and substances do not have the potential to be spilled or disposed into the septic systems planned to be located onsite. Id.

48. The State disputes any implied or express assertions in the DEIS, ER, or the Applicant's supporting documents that wastes (other than domestic type wastes) disposed in the septic systems will be treated by the septic system. Lewis Tr. at 29; Ostler Dec. ¶¶ 21-22.

49. Septic systems are designed to allow and promote seepage of disposed septic system fluids into subsurface soils. Ostler Dec. ¶ 12.

50. In most properly designed septic systems, wastewater fluids disposed into subsurface soils will migrate downward over the lifetime of the septic system until reaching groundwater. Ostler Dec. ¶ 28.

51. Septic system fluids which do not migrate down to the groundwater table must return to the surface by some mechanism, such as pooling, evaporation, or transpiration. Ostler Dec. ¶ 28; Lewis Tr. at 13.

52. Untreated chemicals or substances which reach groundwater will adversely impact the groundwater quality, creating an exposure pathway for humans, vegetation, and wildlife via downgradient water wells and seeps/springs. Ostler Dec. ¶ 24, 26 and 28.

53. Neither the DEIS, SAR, ER nor Applicant's supporting documents contain any site-specific groundwater quality information regarding perched water, the unconfined aquifer, and any confined aquifers. Ostler Dec. ¶ 33. *Cf*, Yucca DEIS, Table 3-13, p. 3-48; Table 3-17, p. 3-57; subpart "Groundwater Quality," p. 3-41 (collected and analyzed a "wide range of inorganic and organic constituents, as well as general water quality properties" and compared them to EPA & Safe Drinking Water Standards); subpart

"Saturated Zone Groundwater Quality," p. 3-57 (sampling for radioactivity). *See also* NUREG 1567, p. 2-20, § 2.5.5 (independent chemical analyses of groundwater for each hydrogeologic unit to be obtained to compare with applicant's data).

CERTIFICATE OF SERVICE

I hereby certify that a copy of STATE OF UTAH'S RESPONSE AND OPPOSITION TO PFS'S MOTION FOR SUMMARY DISPOSITION OF CONTENTION UTAH O - HYDROLOGY was served on the persons listed below by electronic mail (unless otherwise noted) with conforming copies by United States mail first class, this 19th day of July, 2001:

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of:	)	Docket No. 72-22-ISFSI
PRIVATE FUEL STORAGE, LLC (Independent Spent Fuel Storage Installation)	)	ASLBP No. 97-732-02-ISFSI
	)	July 19, 2001

DECLARATION OF DON A. OSTLER, P.E., IN SUPPORT OF UTAH'S RESPONSE TO SUMMARY DISPOSITION OF CONTENTION UTAH O

I, Don A. Ostler, hereby declare under penalty of perjury and pursuant to 28 USC § 1746, as follows:

1. I am currently employed by the State of Utah, Department of Environmental Quality in the position of Director of the Division of Water Quality. My education and professional experience is summarized in my curriculum vitae, attached as hereto as Exhibit A. I have over 27 years experience in the State of Utah reviewing, revising, and approving hundreds of water pollution control plans from point and non-point sources, reviewing engineering plans and writing surface and groundwater discharge permits, evaluating various industries and their potential to discharge pollutants to surface and groundwaters, and prescribing best available treatment or containment practices. I have also provided testimony before Congressional Committees on water quality issues. The Utah Division of Water Quality is routinely requested to provide data and information to assist agencies prepare Environmental Impact Statements under the National Environmental Policy Act ("NEPA") and to review such documents. These activities are conducted under my supervision.

2. I am experienced in numerous aspects of hydrology, including surface and groundwater quality in the State of Utah, the chemistry of surface and groundwaters; the fate and transport of chemical constituents, including pollutants, in surface and groundwaters; the hydrogeology of soils and unconsolidated geologic formations; compliance with state and federal regulations pertaining to surface and groundwaters; and health and environmental risk assessments. I am familiar with the general hydrology of the various geographical areas of the state of Utah, including Skull Valley.

3. I am familiar with the content of Contention Utah O and the water resources sections of NUREG 1714, *Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah* (June 2000) ("DEIS"), PFS's Environmental Report ("ER"), and Safety Analyses Report ("SAR"). On March 19, 2001, I was named the State of Utah's expert witness on Contention Utah O, and was deposed by the Applicant on April 19, 2001. I have reviewed the Applicant's June 29, 2001 Motion for Summary Disposition of Utah Contention O – Hydrology, as well the Applicant's Statement of Material Facts on Which No Genuine Dispute Exists and all attachments thereto. I provide this declaration in support of the State of Utah's Response the PFS's Motion for Summary Disposition. The following statements in this declaration are based on my experience, training, and best professional judgment.

4. Determining the hydraulic conductivity/permeability of the native soils at the site is a critical first step in determining whether the surface waters at the site are hydrologically connected to groundwater, and whether spills and releases at the site have the potential to reach groundwater.

5. For the native surface soils to act as a low permeability confining layer, they should have a hydraulic conductivity of no greater than 1×10^{-7} cm/sec. and be uniform and continuous across the entire site. This is consistent with EPA Guidance for constructing clay confining layers to minimize infiltration. *See* Exh. 7 to Utah Facts, Seminar Publication: *Requirements for Hazardous Waste Landfill Design, Construction and Closure*, EPA/625/4-89/022; and Exh. 8 to Utah Facts, Technical Guidance Document: D. Daniel and R. Koerner, *Quality Assurance and Quality Control for Waste Containment Facilities*, EPA/600/R-93/183, September 1993.

6. The hydraulic conductivity/permeability which Applicant assumes for the native soils is 1.4×10^{-4} cm/sec. to 4.2×10^{-4} cm/sec (0.2 to 0.6 in/hr. unpublished USDA data). The basis of these assumptions is the generalized USDA soil maps. This information is based upon very little actual soil data to represent a very large land area. Because of the natural variability of soils in nature, it is widely accepted that this information is insufficient to characterize a specific site. Specific soil exploration must be done on the actual site with sufficient coverage to characterize the type and permeability of soils at the site. In addition to the inappropriate use of this generalized information, the Applicant's assumed hydraulic conductivity/ permeability for the site soils is three orders of magnitude greater than that considered acceptable by the EPA for clay confining layers.

7. The soil percolation rate assumed by the Applicant for soils at the site for purposes of its septic system evaluation is 2.64×10^{-6} cm/sec. (0.09 in/day, Lambe 1969). Lewis Dec. ¶ 51 and n. 12. This assumed permeability is much closer to that of an acceptable confining layer or liner than an absorption system. This data indicates that fluids discharged into the subsurface from the septic system will not percolate into the subsurface, as septic systems are designed to operate properly. If the fluids cannot percolate downward because the soil is too impermeable, they will not be treated and will accumulate in the leachfield until they pond at the surface.

8. The Applicant cites to a handbook (Lambe (1969)) for its assumed 0.09 in/day percolation (2.64×10^{-6} cm/sec) rate for its proposed septic system. It is not clear why the Applicant selected this estimate because Lambe also provides much higher hydraulic conductivity rates for silt (1.5×10^{-5} cm/sec) (p. 290), and for sandy clay (1×10^{-4} cm/sec) (Fig. 19.5) and silts (ranging between 1×10^{-4} - 1×10^{-6} cm/sec) (Fig. 19.5). *See* excerpts from T. William Lambe and Robert V. Whitman, Soil Mechanics (John Wiley & Sons, Inc., 1969), attached hereto as Exhibit B. These other general estimates indicate soils of similar type generally will transmit water much more rapidly than the 0.09 in/day assumed of Applicant for its septic system.

9. Based upon information and belief, I assume the Applicant's assumed hydraulic conductivity/permeability rates described above are for saturated soil conditions. The degree of saturation of a soil is important to estimating the ability of a soil to transmit water. Interestingly, soils with low water content, such as those in arid and semi-arid zones, may have a greater hydraulic conductivity than saturated soils of a coarser texture. This paradox arises because the unsaturated hydraulic conductivity of fine soils tends to decrease much less rapidly as pressure head decreases, compared to coarse-texture soils. So soils with associated low intrinsic (saturated) permeabilities can have high unsaturated hydraulic conductivities. A detailed explanation of this phenomenon can be found in Daniel B. Stephens, Vadose Zone Hydrology (CRC) (Lewis Publishers, 1996) at p. 21 (excerpts attached hereto as Exhibit C). For this reason, the hydraulic conductivities/permeabilities assumed by Applicant are likely much less than would actually exist at the site, *i.e.*, the unsaturated native surface soils at the site have a greater ability to transmit water than the estimates Applicant is using.

10. Applicant cites Houghton, 1985, for an evaporation rate of 0.32 in/day. Lewis Dec. ¶ 51 and n. 11. I was unable to locate this estimate in Houghton, but Fig. 16.1 of Houghton indicates a free evaporation rate in the general area of the site of 1200 mm/yr., *i.e.*, 0.13 in/day. *See* Handbook of Applied Meteorology, ed. David D. Houghton (John Wiley & Sons, 1985), excerpts attached hereto as Exhibit D. This 0.13 in/day figure in Houghton is roughly one-third the value used by the Applicant

to estimate the rapidity of evaporation from the site. Without more information, I cannot reconcile the difference, but this is a good example of why site-specific data is important to support a specific project. The Applicant's assumption that rainwater at the site would evaporate quickly before it could infiltrate to groundwater depends in large part on the assumed evaporation rate. The much reduced evaporation rate would significantly increase the rate at which rainwater would penetrate the surface soils and migrate to groundwater.

11. The DEIS and ER fail to adequately 1) determine whether each expected wastestream (*e.g.*, domestic wastewater, cleaning chemicals, laboratory wastes), or potential wastestreams (*e.g.*, diesel, solvents, pesticides and herbicides, etc.) placed in the sewer system will be adequately treated by the septic system; 2) ascertain where the fluids placed in the septic system will end up; and 3) consider the possibility that the many hazardous substances stored or used onsite will be introduced, intentionally or unintentionally, into the septic system during its forty years of operation.

12. Septic systems are designed to introduce wastewaters into the subsurface with the expectation that domestic wastes will be treated by settling in a septic tank, and later, through natural percolation into the subsurface soils. The ultimate disposition of most septic system fluids is usually groundwater.

13. The DEIS and ER assert the surface soils at the site are of a "low permeability" which will act as a confining layer and preclude infiltration of surface waters into the subsurface and to groundwater. I disagree. However, if it were true, it would effectively prevent a septic system from working as they are normally designed, *i.e.*, to accept waters into the subsurface.

14. The DEIS and ER do not present any site-specific soil permeability tests or other site-specific measurement to support any conclusion regarding the native surface soils, *i.e.*, there is insufficient data to come to any supportable conclusion. Soil permeability tests are easily conducted, commonly performed by environmental consultants during facility assessments, and are relatively inexpensive to conduct.

15. The DEIS' and Applicant's conclusions that the soils at the site are "relatively" impermeable is misleading because the permeability of the silty clays and sands identified in samples collected from geotechnical boreholes at the site can vary by many orders of magnitude and are considered moderately permeable in comparison to other soils and rock formations. In addition, for any native soil layer to act as a confining layer, it must be of sufficient thickness, must extend across the entire area to be capped, and be uniformly impermeable across the entire site. The DEIS and SAR indicate the native silts and clays are composed of interfingered lenses and

zones, and therefore, surface waters have the potential to migrate downward much more readily than if the soils were of a uniform soil type.

16. The borehole logs presented in the SAR indicate that approximately two dozen three to six-inch plus diameter boreholes were drilled across the site. In the absence of proper backfilling, these holes will act as conduits for surface waters to migrate directly into the deeper subsurface formations, *i.e.* below 30 feet below ground surface, including the reported 125 foot deep groundwater.

17. Most of the borehole logs in Appendix 2A of the SAR are silent as to backfilling, but those which describe any backfilling activity indicate that "soil," probably the drill cuttings, were shoved down the borehole. This, of course, would not constitute proper backfilling for persons intending to use native soils as a cap or confining layer. *See e.g.* Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, U.S. EPA, (May 1996, includes 1977 revisions), Section 6.10.6 "Backfilling" (the use of soil cuttings to backfill boring not acceptable if boring has breached a 'confining' layer.). *See* Exh. 9 to Utah Facts ("Environmental Investigations Manual").

18. When intending to preserve the integrity of a confining layer, proper backfilling would be the same as for abandoning or sealing drinking or monitoring wells. This would, at a minimum, include sealing the surface soils from the subsurface soil, by backfilling the borehole with a bentonite seal, and a cement and expandable clay (*e.g.* bentonite) mixture. *See* id., Environmental Investigations Manual, p. 6-14, sections 6.9 and 6.9.1 ("When a decision is made to abandon a . . . well, the borehole should be sealed in such a manner that the well can not act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers. To properly abandon a well, the preferred method is to . . . backfill with a cement or bentonite grout, neat cement, or concrete."). The Applicant properly sealed one borehole, CTB-5, when it completed it as a well with a bentonite seal and cement/bentonite mixture.

19. The DEIS, ER, and SAR did not collect or generate the quality and quantity of data necessary to reach a scientifically supportable conclusion regarding certain soil characteristics at the site, the groundwater quality at the site, and the ultimate destination of the wastewater discharged to the septic system. Soil permeability, water quality, and determining where septic fluids, stormwater, and spills will end up are critical to determining whether or not the PFS facility will significantly impact the environment, or present a pathway of contaminant exposure to humans or the environment, *i.e.*, will the contaminants in the wastewater end up untreated in the groundwater table due to moderately high infiltration capacity of the soil; will the

contaminants in the wastewater resurface untreated due to "low infiltration capacity because of the allegedly low infiltration rate of the soil"; or will it properly treat the effluent before it enters the groundwater? The DEIS fails to collect or generate enough site-specific data to conclude where the wastewater will ultimately end up; it only predicts where it will not end up (the groundwater). Without adequate site-specific geologic or environmental engineering data or support, the DEIS merely concludes that the wastewater discharge "may never reach the groundwater" due to an assumed "relatively low" infiltration capacity. DEIS at 4-12. Once the ultimate fate of the wastewater is determined, then the pathways of concern, *e.g.*, groundwater or surface exposure, can be better analyzed.

20. Specific pathways for contaminant migration from the sewer/wastewater system will depend upon the design and construction of the system, and the DEIS does not describe the specific system design and construction, *i.e.*, the general description of PFS's wastewater system precludes anything other than a general response. There are two general pathways of concern. The first is the migration of the sewer/wastewater discharge through the vadose zone to the groundwater, and then the resurfacing of the water, most likely by pumping of the groundwater to the surface for domestic or other use. The second general pathway of concern is resurfacing of the wastewater above the leachfield, *e.g.*, if the leachfield is unable to accept the quantity of wastewater discharged, the contaminants breach the surface untreated. The allegedly low soil permeability assumed by the Applicant suggests the wastewater may pool near the surface where it may come into contact with humans and the environment. However, the Applicant's assumed permeabilities indicate it is much more likely the wastewater will percolate downward into the subsurface. But site-specific data is necessary to reach a supportable conclusion.

21. Whether the system will adequately treat the different contaminants in the wastewater before the wastewater reaches its ultimate destination depends on various factors, including the ultimate destination of the wastewater (*see* discussion above), the organic and inorganic contaminants in the wastestream, and the effectiveness of the soil as a treatment medium. The DEIS fails to adequately address any of these three factors. Therefore, in my opinion the DEIS cannot reach a conclusion that the system will adequately treat the wastewater.

22. A domestic waste septic system which adequately treats simple domestic waste will not adequately treat complex organics, dissolved metals, waste solvents, or radioactive compounds which could potentially enter the wastestream. The DEIS implies, without technical support, that discharging the wastewater into the septic system will somehow result in all contaminants in the wastestream being adequately treated. This is not true.

23. In my 27 years' experience in reviewing practices at industrial facilities, I am aware of numerous incidents where employees have accidentally or intentionally released pollutants or contaminants, or placed same into a septic system. Even companies with best management practices cannot control accidents that occur onsite. Without adequate monitoring systems, PFS will be unaware if such accidents occur. Also PFS does not even have contingency plans or containment systems to address possible accidents. It is credible that a facility operator would assume that spills and releases as a result of human error and misconduct can and do occur at industrial and commercial facilities, such as the PFS facility.

24. Specific pathways for contaminant migration from routine facility operations will depend upon the type of activity taking place. Until specific activities are described in detail by PFS, specific pathways cannot be determined. However, general pathways associated with routine industrial type activities include the spilling and releasing of hazardous substances and hazardous wastes which are used or generated at the facility. Those spills and releases can result from numerous different activities, including accidents during transfers or use of the substance or waste; leaking tanks or storage containers; leaking piping; unauthorized disposal, etc. Once the substance or waste comes in contact with surface soils, the contaminant can also contaminate surface waters, and infiltrate into the subsurface. Subsurface releases may migrate to the groundwater where they may be pumped to the surface via wells, or resurface downgradient as springs or seeps. Humans or wildlife may be exposed to the released substance or waste once it reaches the surface.

25. The DEIS does not adequately describe the transport and ultimate fate of spills and releases of chemical compounds and materials. It merely surmises that a " large fuel spill would be required to adversely impact groundwater quality at the site because the groundwater table is approximately 38 m (125 ft) below the ground surface and soil retention would hold up the liquid." DEIS 4-9. No specific analyses or modeling have been done to support this claim, or any claim, regarding the infiltration of surface waters and spills to groundwater. The DEIS does not conclude that large spills will not occur, only that it would take a large spill to really contaminate the groundwater. Also, cumulative small spills may have an effect similar to that of a large spill. In addition, the conclusion that spills will not migrate downward over time into the groundwater does not address the dissolving of hazardous constituents contained in spilled and released materials into surface waters and the infiltration of these contaminated rainwaters or snow melt waters into the subsurface and groundwater.

26. Specific pathways for contaminant migration from the construction activities will depend upon the specific construction activity taking place. Because the DEIS does not describe the construction activities in detail, a detailed response regarding

pathways cannot be determined until PFS provides a detailed description of construction activities.

27. The DEIS focuses its surface water concerns on the berm which will reportedly be built upgradient of the facility with the purpose of diverting stormwaters during and after construction. Rainwater falling within the facility, along with any spills and releases of hazardous substances and hazardous wastes within the facility area, will reportedly be drained, flushed, or directed downgradient into a retention pond.

28. The DEIS does not describe the transport or fate of the hazardous substances, hazardous wastes, and pollutants which may be released at the facility. The presence of these spills or releases on the surface presents pathways of exposure to humans and the environment through direct exposure and ingestion. The most likely destination of substances that are released to, or leach into, the subsurface is the groundwater directly under the facility. Direct exposure and ingestion of groundwater produced from wells downgradient of the facility, even hundreds of years in the future, are the likely pathways of exposure. Any pond or pooling of water in the desert will attract and expose wildlife to the contaminated water. In addition, the pond will create a hydraulic head which promotes infiltration of the pond water into the subsurface and to the groundwater under the site.

29. Environmental effects or impacts can take two related forms – impacts to water quality and impacts to water quantity. Both can only be analyzed if there is baseline information available by which future water quality and quantity can be compared, and there is a scientific method for predicting how the PFS activities may induce measurable changes. The DEIS does not quantify the current characteristics (quantity and quality) of the aquifer, and its present use and development. Without knowing the present condition of the aquifer and how it is presently being used, the DEIS cannot properly reach a conclusion that the use of the aquifer by PFS, alone or in conjunction with other users, will not adversely affect the present and future use, development, enjoyment, and environmental condition of the Skull Valley area.

30. Whether or not an "effect" on a resource is material depends upon, among other things, the scarcity of the resource and its use. Much of Utah is a desert. Water volume and water quality are often the limiting factors in determining what sustainable uses an area can support. Any water use evaluation must include an evaluation of the importance of the water resource to the present and future use of the area, and how an impact to water quality would affect the area.

31. The DEIS concludes: "It is very likely that little aquifer recharge occurs on the site or elsewhere near the center of the Skull Valley because of low annual precipitation

and because surficial and near surface deposits are silt and clay that have low permeability and inhibit downward percolation of water." DEIS 4-7. Based upon the absence of site-specific data and the limited information regarding the soils in general, there is insufficient data to come to a scientifically supportable conclusion as to recharge in the area of the site, or elsewhere near the center of Skull Valley. However, the general assumptions relied on by PFS,[1] the generally accepted permeability values for the types of soils at the site,[2] the heterogeneity of the soil types across the site,[3] and the wide variability in soil permeability across the site[4] all suggest it is likely there is measurable recharge in the area of the site and Skull Valley, *i.e.*, the naturally occurring surface waters migrate to groundwater at the site.

32. The DEIS fails to present any baseline water quality information to properly analyze and predict whether the proposed facility will adversely affect the current or future water quality (and uses) in the area of the facility, in the area surrounding the facility, and in the Skull Valley basin.

33. The DEIS fails to adequately address the information currently available regarding water quality in the area and in the Skull Valley; whether a baseline study of the water quality is necessary to reach a conclusion whether PFS's facility will affect the water quality in the area and the Skull Valley; whether the current water quality information is sufficient to constitute that baseline or whether additional information is necessary; and if more information is necessary, what quantity and type of information. Information regarding water quality should include the chemical constituents of concern (*e.g* complete chemical analyses), the quality of water necessary for different uses to which the water may be put, and the current and future uses of the water resources in the Skull Valley (*e.g.*, domestic use, livestock, agricultural, wildlife, etc.). In addition, the types of water quality parameters which should be addressed in the DEIS and ER can be found in, among numerous other statutes, for example, the federal Water Pollution Prevention and Control Act, 33 U.S.C. 1251 *et seq.*, and related regulations.

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[1] USDA undated regionwide permeability estimates cited in Liang Dec. ¶ 21, n. 8; Stone & Webster, *Determination of Aquifer Permeability From Constant Head Test and Estimation of Radius of Influence for the Proposed Water Well*, Rev. 2, (March 27, 2001) ("Constant Head Test Report" (Exh. 5 to Utah Facts).

[2] R. Allen Freeze & John A. Cherry, Groundwater (Prentice-Hall, Inc. 1979), Table 2.2, p. 29, Exh. 2 to the State's Response.

[3] *See* SAR Borehole Logs, Appendix 2A (Geotechnical Data), Attachment 1.

[4] Lewis Tr. at 25 (Exh. 4 to the State's Response).

34. The DEIS fails to adequately address the need, or lack thereof, to monitor water quality at or near the proposed facility, for the purpose of determining if the facility is in fact affecting water quality. Various types of hazardous waste treatment, storage and disposal facilities must have extensive groundwater monitoring systems. Even corner gasoline service stations are required to have some type of groundwater monitoring systems to comply with their release detection requirements. In my professional opinion, it is not only reasonable, it is essential, that the PFS nuclear waste facility have in place groundwater monitoring to monitor water quality.

Executed this 19th day of July 2001,

By ______________________________

Don A. Ostler, P.E.

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Executed this 19th day of July 2001,

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PROFESSIONAL EXPERIENCE

Director, Utah Division of Water Quality Utah Department of Environmental Quality	1991 to Present
Executive Secretary, Utah Water Quality Board	1991 to Present
Director, Utah Bureau of Water Quality Utah Department of Health	1987 to 1991
Manager, Permitting and Financial Assistance Sections Utah Bureau of Water Quality	1975 to 1987
Review Engineer, Utah Bureau of Water Quality	1972-1987
Design Engineer, U.S. Bureau of Reclamation Salt Lake City and Denver Colorado	1972
Design Engineer, U.S. Forest Service Salmon, Idaho and Salt Lake City.	1971 to1972

RESPONSIBILITIES

My responsibilities during the last 14 years include the implementation and enforcement of the State's water quality program, which mandate is the protection and improvement of the quality of lakes, streams and groundwater by controlling the discharge of pollutants from both point and non-point sources. Additionally, during my employment with the State of Utah in the past 29 years, I have been responsible for the analysis and review of water pollution control plans from a great variety of sources. To that end, I have reviewed many hundreds of water pollution control plans from a variety of point and non-point pollution sources. This has included engineering plan review and writing surface water and ground water discharge permits. This work routinely requires evaluating activities by various industries and their potential to discharge pollutants to surface and ground water, as well as prescribing best available treatment or containment systems, practices, and technology.

EDUCATION

Masters Degree, Civil Engineering 1975
University of Utah, Salt Lake City, Utah

Bachelors Degree, Civil Engineering 1971
University of Utah, Salt Lake City, Utah

PROFESSIONAL ORGANIZATIONS

Registered Professional Engineer in Utah;
Member of Tau Beta Pi and Chi Epsilon (National Engineering Honorary Fraternities);
President, Vice-President, governing Board Member (1987 to 1992), and current member of National Association of State and Interstate Water Pollution Control Administrators;
Past Chairman (1989), current member, Western States Water Council, Water Quality Committee;
Member, Utah Soil Conservation Commission, 1987 to Present.

TRAINING

Attended countless workshops and seminars, many sponsored by the United States Environmental Protection Agency, relating to current and emerging water quality issues, during my 29 years of employment with the State of Utah.

TESTIMONY

Testified before Congress on water quality issues in 1988-1991.

Soil Mechanics

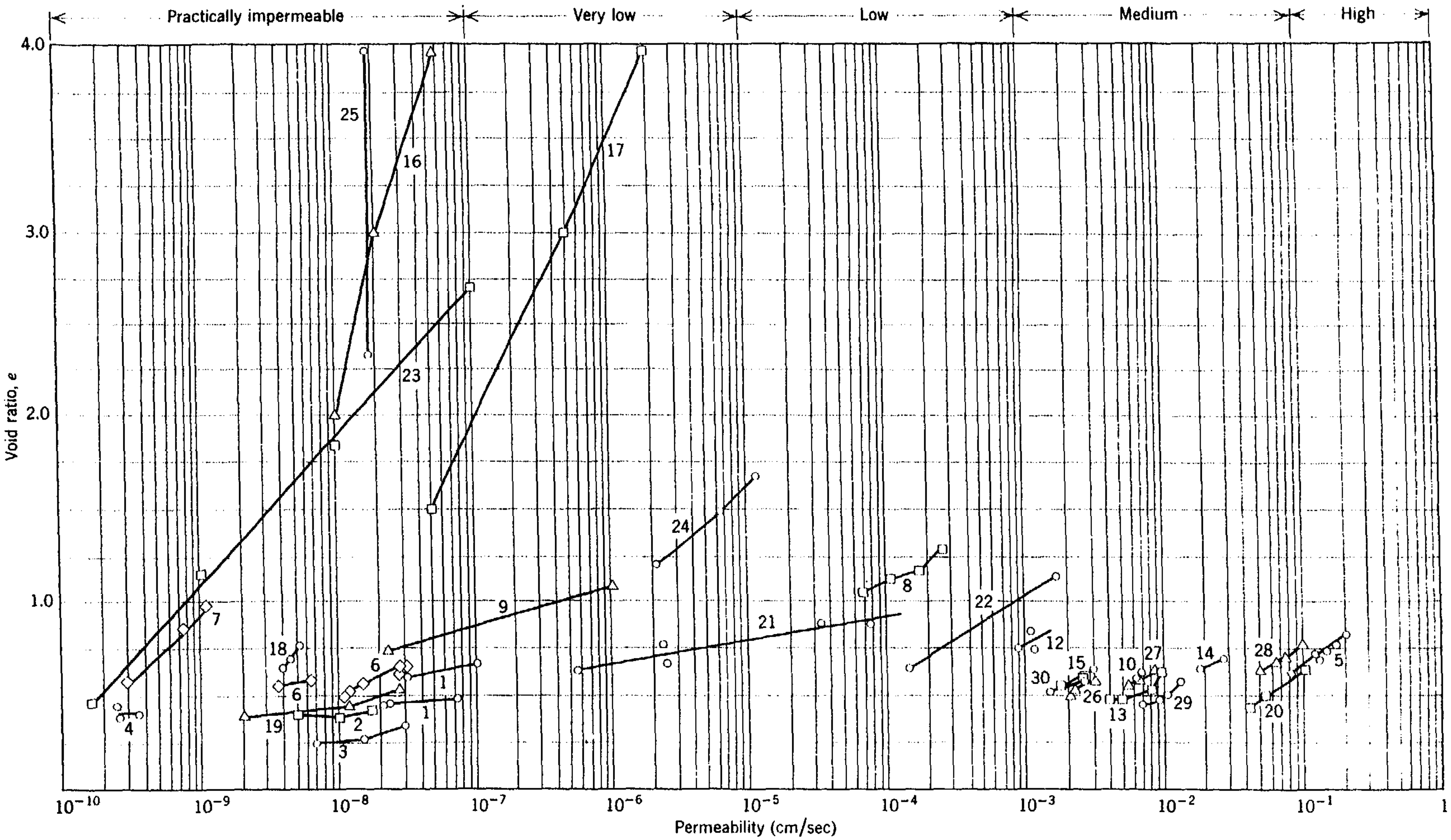
T. William Lambe • Robert V. Whitman

Massachusetts Institute of Technology

1969

John Wiley & Sons, Inc.

New York London Sydney Toronto



Soil Identification Code

1 Compacted caliche
2 Compacted caliche
3 Silty sand
4 Sandy clay
5 Beach sand
6 Compacted Boston blue clay
7 Vicksburg buckshot clay
8 Sandy clay
9 Silt—Boston
10 Ottawa sand
11 Sand—Gaspee Point
12 Sand—Franklin Falls
13 Sand—Scituate
14 Sand—Plum Island
15 Sand—Fort Peck
16 Silt—Boston
17 Silt—Boston
18 Loess
19 Lean clay
20 Sand—Union Falls
21 Silt—North Carolina
22 Sand from dike
23 Sodium—Boston blue clay
24 Calcium kaolinite
25 Sodium montmorillonite
26–30 Sand (dam filter)

Fig. 19.5 Permeability test data.

Table 19.3 Permeability Test Data

Soil	Particle Size, D_{10} (cm)	Permeability (μ/sec)	k/D_{10}^2 (1/sec cm)
Coarse gravel	0.082	1100	16
Sandy gravel	0.020	160	40
Fine gravel	0.030	71	8
Silty gravel	0.006	4.6	11
Coarse sand	0.011	1.1	1
Medium sand	0.002	0.29	7
Fine sand	0.003	0.096	1
Silt	0.0006	0.15	42
		Average =	16

Permeability and particle size data from "Capillarity Tests by Capillarimeter and by Soil Filled Tubes" by K. S. Lane and D. E. Washburn, *Proc. HRB*, 1946.

are treated indirectly or ignored. Unfortunately, the effects of one of the five are hard to isolate since these characteristics are closely interrelated—e.g., fabric usually depends on particle size, void ratio, and composition.

Equation 19.4 suggests that permeability varies with the square of some particle diameter. It is logical that the smaller the soil particles the smaller the voids, which are the flow channels, and thus the lower the permeability. A relationship between permeability and particle size is much more reasonable in silts and sands than in clays, since in silts and sands the particles are more nearly equidimensional and the extremes in fabric are closer together. From work on sands, Hazen proposed

$$k = 100 D_{10}^2 \qquad (19.9)$$

where k is in cm/sec and D_{10} is in cm.

Listed in Table 19.3 are some permeability and particle size test data and the corresponding values of k/D_{10}^2. As shown, the values of K/D_{10}^2 vary from 1 to 42 with an average of 16.

Logic and experimental data suggest that the finer particles in a soil have the most influence on permeability. Hazen's equation, for example, uses D_{10} as "the" diameter for relating particle size and permeability. This relation assumes that the distribution of particle sizes is spread enough to prevent the smallest particles from moving under the seepage force of the flowing water, i.e., the soil must have "hydrodynamic stability." Uniform coarse soils containing fines frequently do not possess hydrodynamic stability. Flow in such soils can wash out the fines and thereby cause an increase in permeability with flow. Particle size requirements to prevent such migration of fines are given in the next section.

The permeability equations indicate that a plot of k versus $e^3/(1 + e)$ should be a straight line. Other theoretical equations have suggested that k versus $e^2/(1 + e)$ or k versus e^2 should be a straight line. There are considerable experimental data which indicate that e versus $\log k$ is frequently a straight line. Figure 19.9 presents experimental data in the form of k versus functions of e. The test data on this sand show that the plot of k versus $e^3/(1 + e)$ and $\log k$ versus e are both

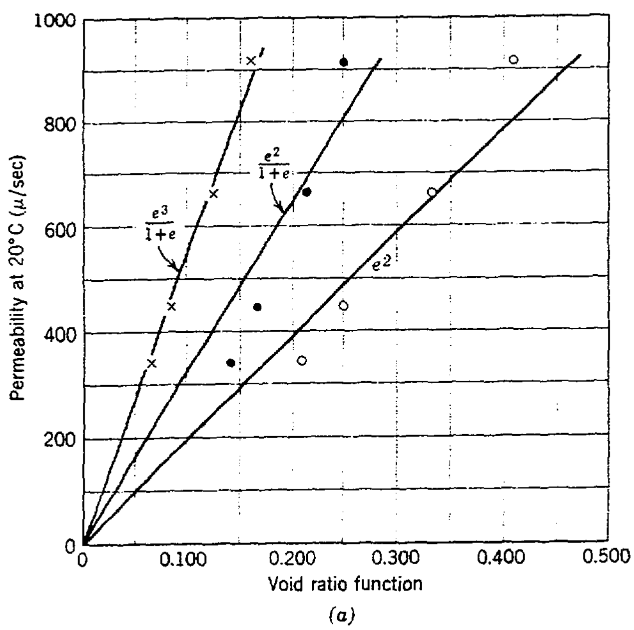


Fig. 19.9 Variable-head permeability test data.

VADOSE ZONE HYDROLOGY

Daniel B. Stephens

Cover illustration by:
Andrea J. Kron
cARTography by Andrea Kron
Los Alamos, New Mexico

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aquifers, and both terms have units of inverse length. In Figure 8, the water stored in unsaturated soil is due to changes in water content as a consequence of infiltration, drainage, capillary effects, or air-drying. In contrast, the specific storage in saturated soil accounts for water and matric compressibility (e.g., Neuman, 1973; Narasimhan, 1979). Later in this chapter, the full matrix storage properties combine compressibility effects with the specific moisture capacity for developing complete flow equations.

IV. DARCY'S EQUATION AND UNSATURATED FLOW PARAMETERS

Perhaps the most widely recognized equation among soil scientists, hydrologists, and petroleum engineers is Darcy's equation. In 1856 Henri Darcy, a French engineer, conducted laboratory experiments on porous filter materials that would be used for a sewage treatment system. These experiments were conducted under fully saturated conditions. Buckingham (1907), a soil scientist, demonstrated that Darcy's equation could be extended to unsaturated conditions as well. Darcy's equation also is used in the petroleum fields and hydrogeology for multiphase flow problems. We begin by discussing the more unfamiliar but more general form of Darcy's equation, which is relevant to a wide variety of fluid flow problems, including nonaqueous phase liquids. Subsequently, we introduce the less mathematically cumbersome equation for the flow of water in the vadose zone.

Darcy's equation for a fluid phase (i.e., liquid or gas), F, can be written as

$$q_{F_i} = -K_F\left(S_F\right)_{ij}\left(\frac{\partial h_F}{\partial x_i} + \rho_{r_F} u_i\right) \quad \textbf{(16)}$$

where q_{F_i} = specific discharge of fluid F in i direction (LT^{-1}), K_F = hydraulic conductivity of phase F (LT^{-1}), S_F = saturation percentage of fluid phase F (L^3L^{-3}), h_F = water height equivalent pressure head of fluid phase F (L), $P_F/g\rho_w$ where P_F = pressure in phase F ($ML^{-1}T^{-2}$), g = gravitational constant (LT^{-2}), and ρ_w = density of pure water (ML^{-3}), x_i = Cartesian space coordinate (i,j = 1, 2, 3) (L), $\rho_{r_F} = \rho_F/\rho_W$ = specific gravity of phase F, and $u_i = \partial z/\partial x_i$ = unit gravitational vector measured positive upward in direction z.

If only water is the fluid of interest, then Darcy's equation is written as

$$q_i = -K(\theta)_{ij}\left(\frac{\partial \psi}{\partial x_i} + \frac{\partial z}{\partial x_i}\right) \quad \textbf{(17a)}$$

where z is positive upward. Where the soil is homogeneous and isotropic, then in three dimensions in an x,y,z-coordinate system, Darcy's equation becomes:

$$q_x = -K(\theta)\frac{\partial \psi}{\partial x} \quad \textbf{(17b)}$$

$$q_y = -K(\theta)\,\frac{\partial \psi}{\partial y} \tag{17c}$$

$$q_z = -K(\theta)\left(\frac{\partial \psi}{\partial z} + \frac{\partial z}{\partial z}\right) = -K(\theta)\left(\frac{\partial \psi}{\partial z} + 1\right) \tag{17d}$$

Darcy's equation simply states that fluid flow is a function of the driving force called hydraulic gradient (pressure and gravity terms in brackets) and a constant of proportionality called the hydraulic conductivity, K. The hydraulic conductivity accounts for the viscous flow and frictional losses that occur as a fluid moves through the porous medium.

A. HYDRAULIC GRADIENT

The hydraulic gradient in the vadose zone exhibits interesting characteristics that contrast markedly with those that hydrogeologists are accustomed to in aquifers. In aquifer systems, flow is primarily horizontal and the regional hydraulic gradient is often in the range of 10^{-4} to 10^{-3}; it is rare that the hydraulic gradient ever exceeds 0.01, although there are exceptions such as where groundwater flows across faults, across aquitards, and very close to pumped wells. But in the vadose zone, hydraulic head gradients near one are common. Unit hydraulic gradients occur in deep vadose zones with uniform texture where the soil-water content is constant with depth. The same is true if the vadose zone is stratified, when the pressure head is averaged over many layers (Yeh, 1989). Where pressure head or mean pressure head does not vary spatially, the gradient of the pressure head ($\partial\psi/\partial z$) is zero. The only component of hydraulic head gradient that one must consider for this case is gravity, and its gradient, ($\partial z/\partial z$), is always unity in the vertical direction when soil-water potential is expressed in units of length. Therefore, the gradient of the total hydraulic head will be one, where the pressure head is everywhere constant. A unit hydraulic gradient indicates that the soil water is flowing vertically downward. When the gradient is unity, the magnitude of the flux, q, equals the hydraulic conductivity, $K(\theta)$.

Although the hydraulic gradient is often near unity, the hydraulic gradient can be many orders of magnitude larger near sharp wetting fronts in dry soils. On the other hand, the hydraulic gradient may also be much less than unity and, in fact, is zero where no flow occurs. Hydrostatic equilibrium is one condition of no-flow flow, but this is not often encountered in the field. Another instance where zero gradient could occur is where a pulse of water percolation downward is halted by an impermeable layer or coarse-textured capillary barrier. Another example is near land surface where there is a plane above which water flows upward due to evapotranspiration and below which flow is downward due to capillary and gravity effects. This plane is usually referred to as the plane of zero flux. From these examples, it is clear that the hydraulic gradient in the vadose zone can vary substantially in response to soil-water dynamics, although in many cases the gradient can be assumed to be near unity in the vertical downward direction, especially below the root zone.

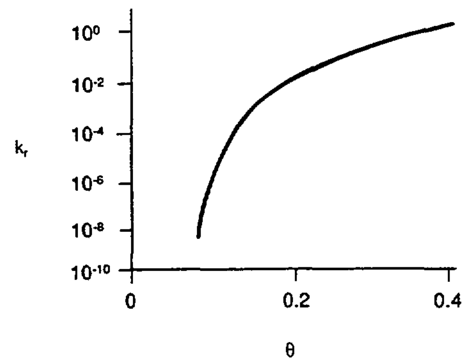

Figure 9 Relative hydraulic conductivity, K_r, vs. water content, θ. Porosity is 0.4 cm^3/cm^3.

B. UNSATURATED HYDRAULIC CONDUCTIVITY AND RELATIVE PERMEABILITY

The following equation further explains how the hydraulic conductivity is a function of the fluid properties, the media properties, and the water content, θ:

$$K(\theta) = \left(\frac{k\rho g}{\mu}\right) k_r(\theta) \tag{18}$$

where k = intrinsic permeability of the medium (L^2), ρ = density of fluid phase P (ML^{-3}), g = gravitational constant (LT^{-2}), μ = dynamic viscosity of fluid ($MT^{-1}L^{-1}$), and $k_r(\theta)$ = relative permeability (dimensionless, ranges from 0 to 1). In Equation 18, the quantity in brackets represents the familiar saturated hydraulic conductivity for isotropic conditions. The relative permeability, sometimes called relative hydraulic conductivity, is a dimensionless parameter that accounts for the dependence of the hydraulic conductivity on pressure head or water content, as shown in Figure 9. The maximum value of relative hydraulic conductivity is one, and at this point the pores are fully saturated with water. But in the field, the vadose zone seldom is fully saturated with water, due to entrapped air. Entrapped air is most likely to occur, for example, below a fluctuating water table or below irrigated fields and intermittently flooded arroyos. Consequently, under field conditions the maximum value of hydraulic conductivity may be only about half of the saturated hydraulic conductivity. Owing to the difficulty to achieve full saturation, the maximum field hydraulic conductivity is sometimes referred to as the satiated hydraulic conductivity.

The relative hydraulic conductivity decreases rapidly with decreasing water content. As drainage progresses, smaller and smaller pores are left holding water. As the water content decreases, the path of water flow becomes more tortuous and the cross-sectional area of water in the pores decreases. In the dry range, the relative hydraulic conductivity becomes very small, so at low water contents, the hydraulic conductivity may be perhaps more than a millionfold smaller than the saturated hydraulic conductivity. At moisture contents as small as a few percent, detailed laboratory experiments have shown liquid phase transport of water can still exist, although at this dry state vapor transport is much more important (Grismer et al., 1986).

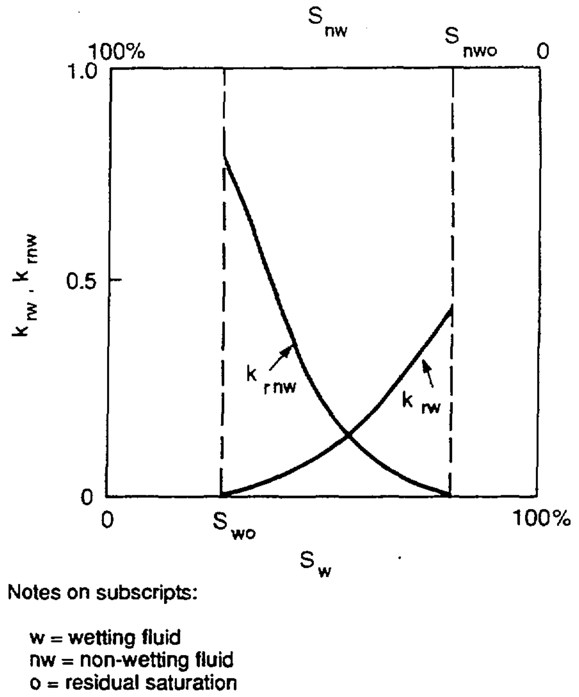

Figure 10 Relative permeability, k_r, vs. saturation, S, for two fluids. Notes on subscripts: w = wetting fluid, nw = non-wetting fluid, and o = residual saturation. (From Bear, 1975.™ With permission.)

Petroleum engineers deal extensively with relative permeability data, but there are important distinctions of interest to soil scientists and hydrologists. Compare the manner in which petroleum engineers sometime represent relative permeability curves (Figure 10) with the soil physicists' perspective (Figure 9). The most significant difference between Figures 9 and 10 is that for the two-phase fluid (e.g., oil and water) system in a petroleum reservoir, each of the phases is shown to reach residual saturation where the relative permeability of a fluid is zero. In contrast, the relative permeability for water in Figure 9 does not usually become zero. In the very dry range of interest to soil scientists and hydrologists, the water may move as thin films. In this state, the relative permeability will be very small, but not actually zero. For most practical problems in reservoir engineering and petroleum production, there is no need to be concerned with film flow. Consequently, relative permeabilities less than about 0.01 or 0.001 are considered negligible in an oil reservoir. Therefore, petroleum engineers often find it more convenient to express unsaturated hydraulic conductivity and relative permeability on an arithmetic scale, whereas soil scientists and hydrologists usually use a logarithmic scale spanning many cycles. Although extensive data exist on capillary properties of oil reservoir rocks, the lower range of the relative permeability test data often does not extend to sufficiently low values to adequately characterize dry conditions. For example, one problem that can arise is in using Darcy's equation to compute recharge. If relative permeability-water saturation curves derived for a petroleum engineering application (e.g., Figure 10) are applied to obtain hydraulic conductivity where field saturation is very low, the recharge may be incorrectly predicted as zero. An understanding of the manner in which petroleum engineers deal with relative permeability can be very important to hydrologists and soil physicists, especially for problems where both soil water and vapor movement

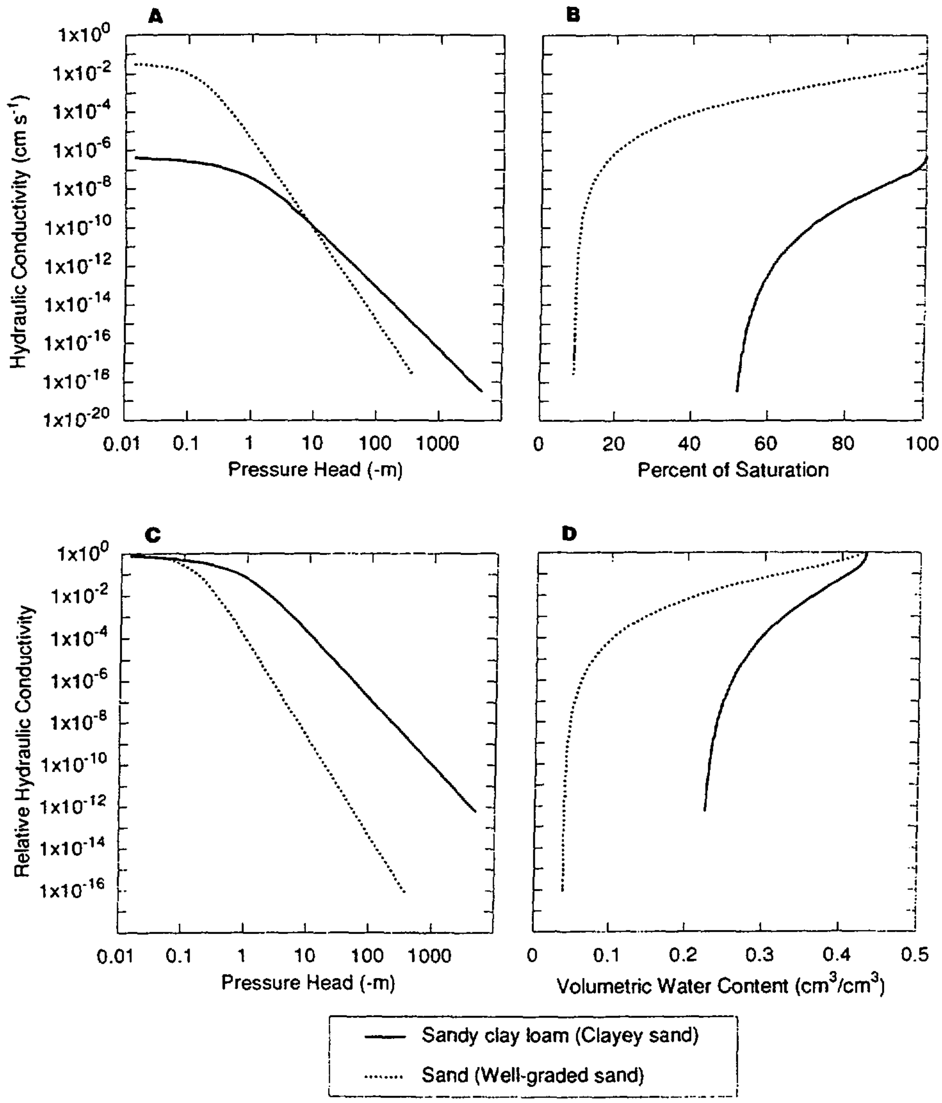

Figure 11 (A) Hydraulic conductivity, K, versus pressure head, ψ, for sand and sandy clay loam; (B) hydraulic conductivity versus water content; (C) relative hydraulic conductivity versus pressure head; and (D) relative hydraulic conductivity versus percent saturation. Water retention curves and specific moisture capacity for these soils are shown in Figure 8.

are significant or for problems of nonaqueous phase liquid migration through the vadose zone.

The hydraulic conductivity of variably saturated media is highly dependent upon soil texture (Figure 11). Hydrogeologists and engineers are well aware of the nature of spatial variability in saturated hydraulic conductivity that is attributed to variability in the intrinsic permeability (Equation 18) of the geologic material. For instance, well-sorted sand typically has a saturated hydraulic conductivity of about 10^{-2} cm/s, whereas clay may have a saturated hydraulic conductivity of about 10^{-6} cm/s. But over the range of water contents likely to be encountered in the vadose zone, the unsaturated hydraulic conductivity of a single soil sample may change by one-million- or one-billion-fold or more. There is even greater variability in the unsaturated hydraulic conductivity among samples of different soil textures.

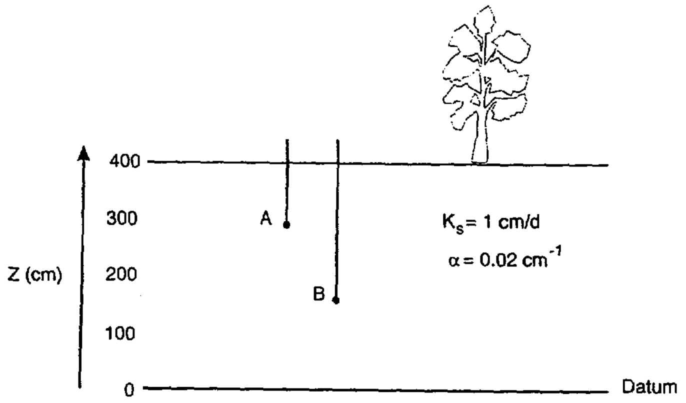

Figure 12 Example to calculate hydraulic gradient, flow direction, and flow rate.

It is especially important to recognize that at low pressure head or water content, the unsaturated hydraulic conductivity of a fine-textured soil may be greater than that of a coarse soil. Figure 11 illustrates this behavior for a sand and loam, with the loam having a greater hydraulic conductivity at pressure heads less than −10 m. This behavior arises because the unsaturated hydraulic conductivity of fine soil tends to decrease much less rapidly as pressure head decreases, in comparison to a coarse textured soil. For most hydrogeologists and engineers, this is a paradox, in that the soil with the highest intrinsic permeability (Equation 18) can have the lowest hydraulic conductivity. However, this fact can be very important in forming conceptual models about vadose zone processes of flow and transport, particularly in heterogeneous or layered media, as we demonstrate in a subsequent chapter discussing vadose zone processes.

The concepts of unsaturated flow presented thus far are summarized in the following example problem. The hypothetical problem is to determine the direction and rate of soil-water flow from *in situ* measurements of pressure head and hydraulic conductivity in a soil having a uniform texture. Figure 12 shows the location of two tensiometers for measuring pressure head. Table 2 indicates the pressure head measurements at the two depths. It has already been determined from laboratory analyses of cores that the saturated hydraulic conductivity is 1 cm/d. We assume that the unsaturated hydraulic conductivity fits the exponential model:

$$K(\psi) = K_s \exp(\alpha\psi) \tag{19}$$

with $\alpha = 0.02\ cm^{-1}$ for this soil. (The exponential model means that on semilogarithmic paper, ln K–ψ fits a straight line having a slope α and an intercept K_s)

To solve this problem, we assume that the flow is vertical and apply Darcy's equation (Equation 17d). We also set the vertical axis as positive upward. The first step to compute the Darcy velocity (specific discharge), q_z, is to determine the hydraulic head gradient from the sum of the pressure head and total head gradients. In our problem, the pressure head decreases upward, so at first glance it may appear that flow is upward. But when the gravitational gradient is added to the pressure head gradient, the total hydraulic head decreases downward (Table 2). Recall it is the gradient of total

Table 2 Pressure Head and Total Head Measurements at Two Depths

	Measured pressure head ψ (cm)	Elevation head Z (cm)	Total head H (cm)
A	–100	300	200
B	–90	200	110

head, not pressure head, that is the water driving force. Consequently, the flow is downward and the magnitude of the total hydraulic head gradient is

$$\frac{dH}{dz} \cong \frac{H_2 - H_1}{Z_2 - Z_1} = \frac{200 - 110}{100} = 0.9 \qquad \textbf{(20)}$$

Note that by our choice of sign convention, the higher subscript refers to the location furthest from the origin.

The second step is to compute the unsaturated hydraulic conductivity. To do this, we determine the mean pressure head in the region between the tensiometers:

$$\frac{\psi_1 + \psi_2}{2} = -95 \text{ cm} \qquad \textbf{(21)}$$

Next, substitute this mean pressure head into Equation 19, along with our previously determined values of K_s and α. The result is $K = 0.15$ cm/d. The third step is to multiply the hydraulic head gradient by the unsaturated hydraulic conductivity to obtain the Darcy velocity:

$$q_z = -K\left(\frac{dH}{dz}\right) = -(0.15)(0.9) = -0.13 \text{ cm/d} \qquad \textbf{(22)}$$

The negative sign indicates flow is in the direction opposite to which z increases, that is, downward.

C. HYSTERESIS IN HYDRAULIC CONDUCTIVITY

When we discussed the soil-water retention curve, we noted that the relationship was hysteretic. As one may expect, the relationship between unsaturated hydraulic conductivity and pressure head also is hysteretic (Figure 13). The simplest explanation for this hysteretic behavior is that at any given pressure head, there is a corresponding value of moisture content on the main wetting curve and a slightly greater moisture content on the main drainage curve. The wetter the soil, the greater the hydraulic conductivity. Therefore, at a particular pressure head, one may find two corresponding hydraulic conductivities, such that the hydraulic conductivity during drainage will be greater than during wetting. Near saturation, entrapped air is the primary cause of hysteresis in hydraulic conductivity. There is little evidence that the unsaturated hydraulic conductivity is hysteretic with respect to moisture content to any practical extent.

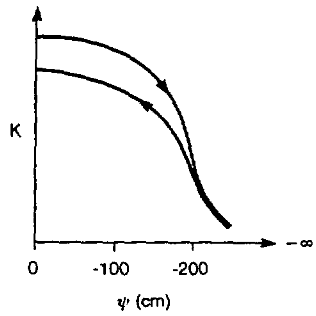

Figure 13 Effect of hysteresis on the hydraulic conductivity, K, vs. pressure head, ψ, relationship.

Problems in which hysteresis may be important to consider involve periods of both wetting and drying, such as can occur during infiltration and subsequent redistribution of a pulse of infiltrated water that is drawn both downward by gravity and capillarity and also upward due to evapotranspiration. As indicated by Rubin (1967) and Hillel (1980), the downward movement of a finite pulse of water cannot accurately be modeled by assigning as input parameters either the wetting or drying unsaturated hydraulic conductivity curves. In both bounding cases, the depth of wetting will be overestimated and the amount of moisture retained near the land surface will be underestimated. However, when the process involves either only wetting or only drying, then it is appropriate to apply the corresponding wetting or drying hydraulic conductivity curve. More is presented about the importance of hysteresis in Chapter 3 on vadose zone processes.

D. ANISOTROPY

Looking back on Equations 16 and 17a presented at the beginning of this section, we subscripted the hydraulic conductivity to indicate that in its most general form the hydraulic conductivity is anisotropic. Anisotropy is a property of the medium that reflects how the hydraulic conductivity varies with direction. That is, measurements of hydraulic conductivity in the vertical direction are different from those in the horizontal direction in an anisotropic medium. By contrast, at any point within an isotropic medium, hydraulic conductivity has the same magnitude in all directions. In a three-dimensional, anisotropic system, hydraulic conductivity is a second-rank tensor or matrix having nine components:

$$K_{ij} = \begin{vmatrix} K_{xx} & K_{xy} & K_{xz} \\ K_{yx} & K_{yy} & K_{yz} \\ K_{zx} & K_{zy} & K_{zz} \end{vmatrix} \qquad (23)$$

The practical significance of this representation is that it allows one to compute the component of water flow in any direction, regardless of the orientation of principal bedding directions. In contrast to an isotropic medium, in an anisotropic system the direction of flow may not be in the same direction as the hydraulic head gradient. The hydraulic conductivity tensor has nine components to account for cases in which the principal coordinate axes and bedding planes are not collinear. However, in many hydrogeologic environments the soil is horizontally stratified, so within the horizontal plane there may be no anisotropy. That is, $K_{yy} = K_{xx}$, and all off-diagonal terms in the conductivity matrix (Equation 23) would be zero, if our coordinate axes are in the horizontal and vertical direction. Consequently, anisotropy in hydraulic conductivity may be represented by the ratio of hydraulic conductivity in the horizontal to vertical direction, K_H and K_V, respectively:

$$A = \frac{K_{xx}}{K_{zz}} = \frac{K_H}{K_V} \tag{24}$$

In most cases, anisotropy is characterized as the ratio of saturated hydraulic conductivities obtained from oriented core samples. At saturation, anisotropy may commonly vary from 2 to 20, but values up to 100 or greater may occur.

In unsaturated media, hydrologists and soil scientists commonly have assumed that the anisotropy at moisture contents less than saturation is the same as at complete saturation. This assumption was questioned by Zaslavsky and Sinai (1981). Theoretical analysis based on stochastic methods (Yeh et al., 1985) suggests that in a steady flow field the anisotropy of a stratified heterogeneous soil should increase as the mean pressure head (and moisture content) of the soil decreases:

$$A(\overline{\psi}) = \exp\left(\frac{\sigma_f^2 + \sigma_\alpha^2\,\overline{\psi}^2}{1 + \overline{\alpha}\lambda_1 \cos\delta_s}\right) \tag{25}$$

where σ_f^2 = variance of ln K_s (dimensionless), σ_α^2 = variance of slope of ln K-ψ (L^{-2}), $\overline{\psi}$ = mean pressure head (L), $\overline{\alpha}$ = mean slope of the ln K-ψ curve (L^{-1}), λ_1 = vertical correlation scale (L), and δ_s = dip of stratification (degrees).

Laboratory experiments have subsequently confirmed that anisotropy is moisture dependent (Stephens and Heermann, 1988; Frederick, 1988). Field and numerical model investigations by McCord et al. (1991) showed that for a uniform dune sand that was nearly isotropic at saturation, the unsaturated anisotropy was as much as 20.

The primary consequence of anisotropy is that subsurface water movement may have strong lateral flow components especially where infiltration occurs into highly stratified, dry soils. We say more about how anisotropy influences flow in the vadose zone in the next two chapters.

E. SOIL-WATER DIFFUSIVITY

The final hydraulic property we discuss here is the soil-water diffusivity, D:

$$D(\theta) = \frac{K(\theta)}{C(\theta)} \tag{26}$$

The soil-water diffusivity embodies both the unsaturated hydraulic conductivity and, through the specific moisture capacity, the soil-water characteristic curve. This parameter is analogous to the hydraulic diffusivity in aquifers and has units of length

HANDBOOK OF APPLIED METEOROLOGY

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from 0.64 to 0.88 (Farnsworth et al. 1982), being greatest in the cooler and more humid climates and least in the arid southwest.

Annual lake evaporation estimates for the entire United States using pan evaporation data were first compiled and mapped by Horton (1943) and have been successively updated by Kohler et al. (1959) and Farnsworth et al. (1982). Annual lake evaporation values presented by Farnsworth et al. (1982) are shown in Figure 16.1. In addition, Farnsworth and Thompson (1982) have published the monthly and annual summaries of pan evaporation for 570 locations in the United States and have estimated pan evaporation using meteorological observations for 196 other locations. They also include coefficients of variation in their results so that a frequency distribution of the evaporation values may be approximated.

Pan evaporation data averaged over several observation sites generally provide reliable estimates of annual lake evaporation. However, on a seasonal or monthly basis, the evaporation from a lake may differ significantly from pan evaporation, not only because of differences in heat storage but also because pan records are highly erratic and the pans themselves have a limited ability to represent conditions of a large free-water surface. The problem with heat storage can be overcome with instrumentation; the latter problem, however, is unalterable.

The Water Budget Method

Conducting a water budget for a lake involves an accounting of all incoming and outgoing water in the lake, including the lake storage, for a given time interval. Evaporation is computed as the residual term in the water budget equation, given as

$$E = P + I - G - O + \Delta S \tag{16.3}$$

where E = volume of lake evaporation during the time interval.
P = precipitation volume over the lake.
I = inflow (runoff) from the lakes watershed.
G = net groundwater seepage from the lake.
O = outflow from the lake.
ΔS = change in lake storage.

Although the components of equation 16.3 are defined here as volumes, the equation is also commonly used with the components expressed as depths of water over the surface area of the lake.

Two aspects of the water budget method cause it to be impractical in most situations. First, because evaporation is computed as a residual term in the water budget, its accuracy is subject to errors in the estimation of the other items in the budget. Frequently, the magnitude of error associated with

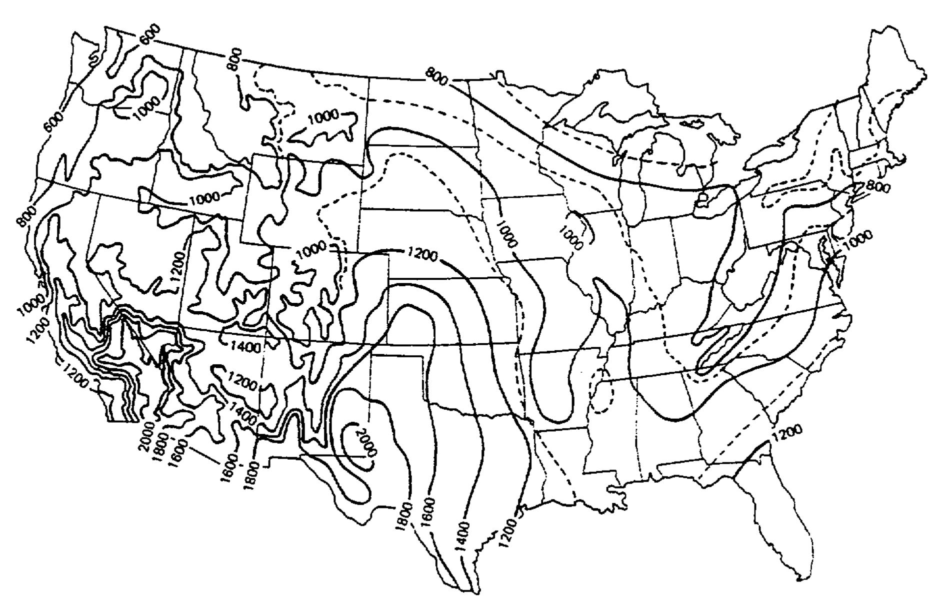

FIGURE 16.1 Annual free-water surface evaporation (in mm). (From Farnsworth et al. 1982.)

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GROUNDWATER

Prentice-Hall, Inc.
Englewood Cliffs, New Jersey 07632

PREFACE

We perceive a trend in the study and practice of groundwater hydrology. We see a science that is emerging from its geological roots and its early hydraulic applications into a full-fledged environmental science. We see a science that is becoming more interdisciplinary in nature and of greater importance in the affairs of man.

This book is our response to these perceived trends. We have tried to provide a text that is suited to the study of groundwater during this period of emergence. We have made a conscious attempt to integrate geology and hydrology, physics and chemistry, and science and engineering to a greater degree than has been done in the past.

This book is designed for use as a text in introductory groundwater courses of the type normally taught in the junior or senior year of undergraduate geology, geological engineering, or civil engineering curricula. It has considerably more material than can be covered in a course of one-semester duration. Our intention is to provide a broad coverage of groundwater topics in a manner that will enable course instructors to use selected chapters or chapter segments as a framework for a semester-length treatment. The remaining material can serve as a basis for a follow-up undergraduate course with more specialization or as source material for an introductory course at the graduate level. We recognize that the interdisciplinary approach may create some difficulties for students grounded only in the earth sciences, but we are convinced that the benefits of the approach far outweigh the cost of the additional effort that is required.

The study of groundwater at the introductory level requires an understanding of many of the basic principles of geology, physics, chemistry, and mathematics. This text is designed for students who have a knowledge of these subjects at the level normally covered in freshman university courses. Additional background in these subjects is, of course, desirable. Elementary calculus is used frequently in several of the chapters. Although knowledge of topics of more advanced calculus is definitely an asset to students wishing to pursue specialized groundwater topics, we hope that for students without this background this text will serve as a pathway to the understanding of the basic physical principles of groundwater flow. Differential equations have been used very sparingly, but are included where we view their use as essential. The physical meaning of the equations and their boundary conditions is held paramount. To avoid mathematical disruptions in continuity of presentation of physical concepts, detailed derivations and solution methods are restricted to the appendices.

Until recently, groundwater courses at the university level were normally viewed in terms of only the geologic and hydraulic aspects of the topic. In response to the increasing importance of natural groundwater quality and groundwater contamination by man, we have included three major chapters primarily chemical in emphasis. We assume that the reader is conversant with the usual chemical symbols and can write and balance equations for inorganic chemical reactions. On this basis, we describe the main principles of physical chemistry that are necessary for an introductory coverage of the geochemical aspects of the groundwater environment. Students wishing for a more advanced treatment of these topics would require training in thermodynamics at a level beyond the scope of this text.

Although we have attempted to provide a broad interdisciplinary coverage of groundwater principles, we have not been able to include detailed information on the technical aspects of such topics as well design and installation, operation of well pumps, groundwater sampling methods, procedures for chemical analysis of groundwater, and permeameter and consolidation tests. The principles of these practical and important techniques are discussed in the text but the operational aspects must be gleaned from the many manuals and technical papers cited throughout the text.

Acknowledgments

The manuscript for this text was reviewed in its entirety by Pat Domenico, Eugene Simpson, and Dave Stephenson. Their comments and suggestions aided us immeasurably in arriving at the final presentation. We are also indebted to Bill Back, Lee Clayton, Shlomo Neuman, Eric Reardon, and Leslie Smith, who provided valuable reviews of portions of the book. In addition, we requested and received help on individual sections from Bob Gillham, Gerry Grisak, Bill Mathews, Dave McCoy, Steve Moran, Nari Narasimhan, Frank Patton, John Pickens, Doug Piteau, Joe Poland, Dan Reynolds, and Warren Wood. In addition, we would be remiss not to recognize the vital influence of our long-time associations with Paul Witherspoon and Bob Farvolden.

We also owe a debt to the many graduate and undergraduate students in groundwater hydrology at U.B.C. and Waterloo who identified flaws in the presentation and who acted as guinea pigs on the problem sets.

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Table 2.2 Range of Values of Hydraulic Conductivity and Permeability

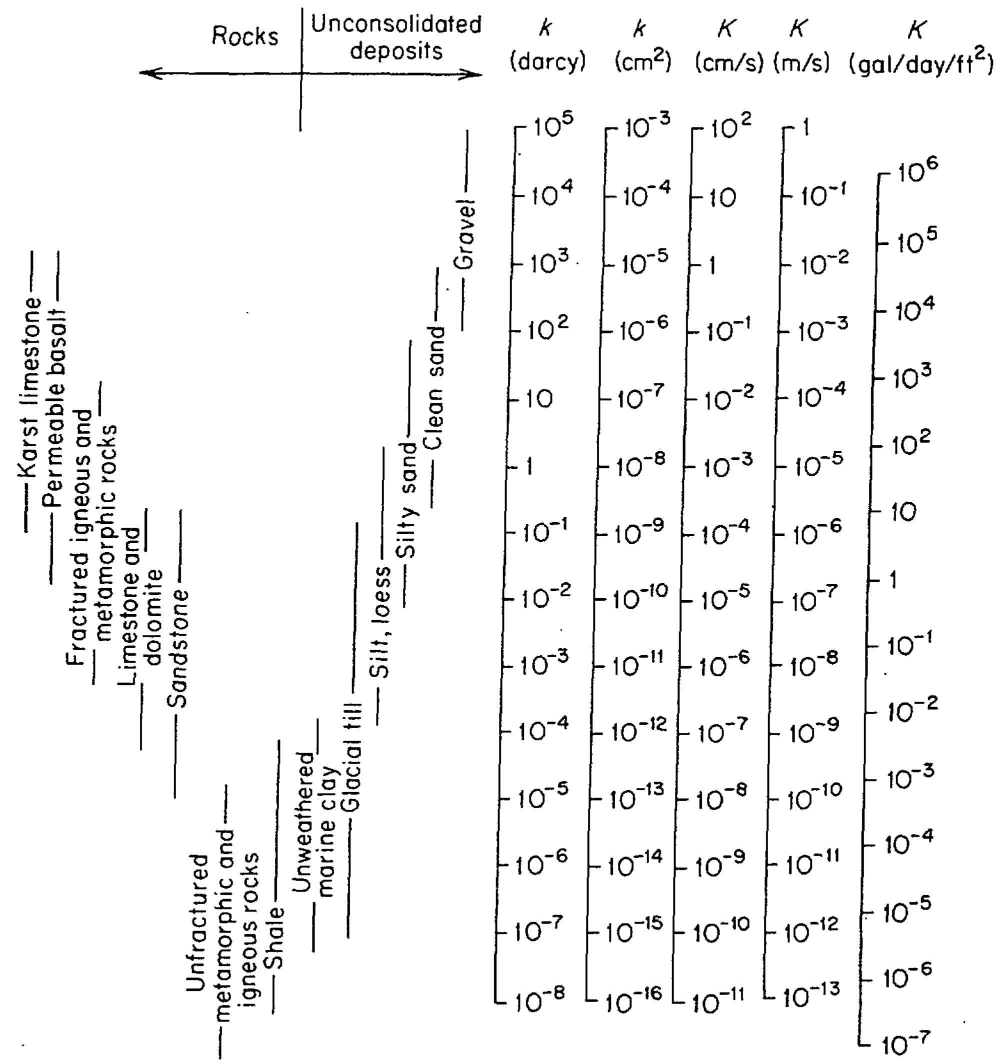

Table 2.3 Conversion Factors for Permeability and Hydraulic Conductivity Units

	Permeability, k*			Hydraulic conductivity, K		
	cm^2	ft^2	darcy	m/s	ft/s	U.S. gal/day/ft^2
cm^2	1	1.08×10^{-3}	1.01×10^{8}	9.80×10^{2}	3.22×10^{3}	1.85×10^{9}
ft^2	9.29×10^{2}	1	9.42×10^{10}	9.11×10^{5}	2.99×10^{6}	1.71×10^{12}
darcy	9.87×10^{-9}	1.06×10^{-11}	1	9.66×10^{-6}	3.17×10^{-5}	1.82×10^{1}
m/s	1.02×10^{-3}	1.10×10^{-6}	1.04×10^{5}	1	3.28	2.12×10^{6}
ft/s	3.11×10^{-4}	3.35×10^{-7}	3.15×10^{4}	3.05×10^{-1}	1	6.46×10^{5}
U.S. gal/day/ft^2	5.42×10^{-10}	5.83×10^{-13}	5.49×10^{-2}	4.72×10^{-7}	1.55×10^{-6}	1

*To obtain k in ft^2, multiply k in cm^2 by 1.08×10^{-3}.

CONDENSED TRANSCRIPT

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	) Docket No. 72-22
	) ASLPB No. 97-732-02-ISFSI
PRIVATE FUEL STORAGE L.L.C.	)
	) DEPOSITION OF:
(Private Fuel Storage Facility)	)
	) **GEORGE H. C. LIANG**
	) **(Utah Contention O)**

Tuesday, April 17, 2001 - 9:14 a.m.

Location: Heber Wells Building

160 East 300 South

Salt Lake City, Utah

Reporter: Vicky McDaniel

Notary Public in and for the State of Utah

CitiCourt, LLC
THE REPORTING GROUP

50 South Main, Suite 920
Salt Lake City, Utah 84144

801.532.3441 TOLL FREE 877.532.3441 FAX 801.532.3414

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
Before the Atomic Safety and Licensing Board

In the Matter of) Docket No. 72-22
) ASLPB No. 97-732-02-ISFSI
PRIVATE FUEL STORAGE)
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)
(Private Fuel Storage) GEORGE H. C. LIANG
Facility))
) (Utah Contention O)

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Notary Public in and for the State of Utah

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A P P E A R A N C E S

For the Intervenor: KURT E. SEEL, ESQ.
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Washington, D.C. 20037-1128
(202) 663-8304

For the NRC: ROBERT M. WEISMAN, ESQ.
U.S. NUCLEAR REGULATORY COMMISSION
Washington, D.C. 20555

Also Present: John Mann

I N D E X

* * *

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P R O C E E D I N G S
GEORGE H. C. LIANG,
having first been duly sworn to tell the truth,
was examined and testified as follows:
EXAMINATION
BY MR. SEEL:
We're here today in the matter of Private Fuel Storage, LLC before the Atomic Safety Licensing Board in a matter to license a nuclear fuel storage facility in Skull Valley.
Q. Would you please state your name and address.
A. My name is George H.C. Liang. My business address is 100 Technology Drive Center, Stoughton, Massachusetts.
Q. My name is Kurt Seel. I'm an assistant attorney general for the State of Utah, and I will be taking your deposition today in the matter of Utah Contention O. Are you familiar with Contention O?
A. Yes.
Q. And it's my understanding you've been named as an expert witness in regards to Contention O.
A. Yes.
Q. Mr. Liang, have you been deposed before? Have you been deposed before? Have you had your

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deposition taken previously?
A. No.
Q. Ever?
A. No -- yes. Ever? I never have a deposition before.
Q. In this or any other matter?
A. Yeah.
Q. In that case, let me explain a little bit of a background. Do you understand how the deposition procedure works? I will be giving you a series of questions for you to answer.
A. Yes.
Q. If there's any ambiguity or if you don't understand the question --
A. Uh-huh.
Q. -- please ask me to clarify the question. Otherwise, I will assume that you understand what's being asked.
A. Okay.
Q. If you want to take a break, please go ahead and ask to take a break, and we will take breaks periodically. Only thing I ask is that you don't take a break while there's a question on the table. In other words, if I ask a question, I ask that you answer that before you ask to take a break.

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A. Okay.
Q. Do you have any questions at this time as to how this is going to proceed?
A. No.
Q. I'm now going to ask you a series of questions that relate to you being an expert and the topics for which you have been put forth as an expert in this matter. What I'm trying to do is find out where you're an expert and then put boundaries on where you're going to be giving expert opinions in this matter, and so that's the purpose behind a lot of these questions.
What is your educational background?
A. My education background, I did my undergrad in Taiwan, National Taiwan University. My major is in civil engineering. Then I did my graduate study at the University of Connecticut at the time where my focus is in the flow mechanics area, and that including hydrology, some other area like groundwater. Then I did my Ph.D. at the University of Connecticut. Focus mainly is wind and wave. I did my thesis in a laboratory wind tunnel 55 feet and then bring wind over the water surface, observe what's the mechanism between the air and the wave and the water.
Q. Since you graduated from University of Connecticut with your Ph.D., what hydrology related jobs

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have you worked on, generally speaking?
A. Oh, since then I've been working with Stone & Webster Engineer Corporation in Boston. Over the years I involve a lot of the project. In the early day, in the '70, '80, mostly in the nuclear project area, which I participate in my amended report including hydrology area, modeling of groundwater. And give you an example, in the Millstone 3 Nuclear Power Station there's one study which I participate is, what happen if a tank rupture in the building area, and then a scenario that hit the ground and the groundwater, how that will disperse into the nearest water body.
And over the years, other nuclear power station also involved, too, like the Shorehan project, Nine Mile 2. And some other, even the fossil plant. Most recent three, four years I'm involved a lot with the siting study of the fossil plant which all involve hydrology -- what happens if a storm come in to runoff, how are we going to control the water quality of the storm runoff before it leaves, and so on.
Q. So are you involved in siting monitoring wells and production wells, things like that?
A. Not really, but at one point we -- Stone & Webster is very diverse company. Not only in the power plant, we also have environmental cleanup. Sometimes

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because so many projects going on, they want some personal resource. I was asked a number of times to look into this so-called monitoring well. Ground well -- at the groundwater well, there was monitoring, and then give some technical input to the specification and so on.
Q. Do you usually look at -- you don't put in the well, or put in the wells yourself --
A. No.
Q. -- but you look at the well logs?
A. No.
Q. You don't look at the well logs?
A. Oh, yeah, I review well log. I have some there that come in. I do -- I did.
Q. Okay. And so you're experienced in well logs, well construction, and pump tests, or other types of aquifer tests?
A. Yes, I involved in -- when I worked with the Stone Webster, yeah. As a matter of fact, I -- most, on this one I also give some supervision to the engineer under me to prepare that kind of spec, like scope of survey and so on.
Q. There is a pump test, a test well in this matter that was installed at the site?
A. Yes.

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Q. And a pump test was done -- or I shouldn't say a pump test. Actually it was a static level test --
A. Right.
Q. -- that was performed on the site. Are you familiar with that well?
A. I reviewed the result. But the actual supervision of that pump test is under my coworkers at Stone Webster.
Q. Do you consider yourself an expert in test well analysis? Is this an area of your expertise that you would -- assuming the data came to you that you could look at it and give an expert opinion on test data from a well?
A. Yes, I consider myself in that -- if it have something, data in -- show me, I review it, yeah.
Q. Are you familiar with different types of geologic formations?
A. Geologic formation area is not my area, because that -- in Stone Webster we have another group of people, geotechnical group. They will do a lot of geological investigation, study, collect data and so on.
Q. For purposes of Contention O, subsurface hydrology, would you consider yourself an expert, then, in which types of formations would produce water in amounts that would be useful to PFS on the site?

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A. I'm not in that area, no.
Q. Surface water modeling?
A. Yes.
Q. Do you do surface water modeling?
A. A lot.
Q. Okay. That would be --
A. But I have to qualify here, because sometimes if our project required -- I mean, we still -- not the latest project. We will formulate our Stone Webster model, but sometimes we using federal government ready available model, surface model and render modeling using.
Q. But you consider yourself an expert --
A. Oh, yeah.
Q. -- in the operation of those government models?
A. Oh, yeah.
Q. Okay. Were you involved in preparing or supervising the environmental report for PFS in this matter?
A. On section, surface hydrology section, yes, in the amended report and Safety Analysis Report.
Q. You also helped prepare or supervise the Safety Analysis Report?
A. Hydrology section.

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Q. Hydrology section?
A. Yeah.
Q. Are you familiar with Contention O?
A. Yes.
Q. And Contention O has many aspects to it regarding environmental impacts. Are you familiar with the environmental impacts analysis that PFS performed?
A. Yeah.
Q. What I want to do next is put some boundaries on where you are an expert in this matter. From what you've told me, sounds like you are an expert on surface water modeling.
A. Uh-huh.
Q. Is that correct?
A. Uh-huh.
Q. You are an expert in groundwater modeling?
A. Yes. As a matter of fact, I wrote an article on that and presented in a symposium. That in my resume on the publication. On the groundwater model to use remediation of hazardous waste site, compare different model.
Q. What about areas of environmental impact as far as degradation of surface or groundwater quality?
A. What do you mean by that, degradation?
Q. Adversely affecting the water quality of groundwater or surface water.

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A. Yeah. As a matter of fact, this is one of the -- when we prepare project report, no matter if it is nuclear or fossil, within Stone Webster scope of work, usually after modeling the ultimate goal is to evaluate what the impact in the environment, because this is always required by federal regulation or NRC guidelines to prepare ER. So modeling is the first step to prepare, but the evaluation impact is the ultimate objective.
Q. Let me continue on that vein. When PFS decided to go out and study the potential environment impacts from its proposed facility, what is the general format for doing it? Is it structure? Does it scope out a whole universe of potential environmental impacts and then decide to go out and collect data on each of those? Or does it take some other approach? You mentioned that modeling was the first step in the process. Isn't there -- are there other steps prior to modeling? How do you decide what it is to model?
A. Let me answer your question. First, when I say those step is not saying that -- of course, you also have to go to the PFS project. But answer your question, say, specific for this, I was bring on board before that process, so those consideration, the

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boundary to this and how it is determined, I did not participate in that decision for this project, Private Fuel Storage project.
Q. So if I understand your answer correctly, the initial scoping as to potential environmental impacts from this project was not something you were involved with?
A. Yes.
Q. Okay. What areas -- what specific environmental impacts were you involved in analyzing?
A. For this project?
Q. For this project.
A. I was brought on board when the question from NRC about the PMF, which also the state have some contention on that subject, PMF.
Q. I'm sorry. What did you say after that? I just didn't hear you.
A. Oh. I was brought on board to work on this project when we received NRC question on the PMF on the Private Fuel Storage site.
Q. Were you involved in any analysis as far as determining contaminant pathways from the applicant's sewer or wastewater system?
A. Will you repeat the question?
Q. Were you involved in analyzing any potential

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environmental effects from the applicant's sewer or wastewater system?
A. Not analyzing, no.
Q. How would you portray your involvement in that?
A. I was involved when they -- when we received the question on the contaminant pathway, then I reviewed the ER, SAR to that subject, what the environmental impact would be.
Q. So your involvement in that analysis was reviewing existing documents that had been prepared by someone else?
A. Yes.
Q. Is that true as well for Utah's contention regarding contaminant pathways from PFS's retention pond?
A. Yes.
Q. You reviewed existing documents regarding that, but you did not actually help prepare those underlying documents?
A. Yes.
Q. Is that true as well for Utah's Contention O regarding potential for groundwater and surface water contamination?
A. Yes.

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Q. Is that true as well for Utah's Contention O regarding effects of applicant's water usage on other well users and on the aquifer?
A. Yes.
Q. And that's true as well for Utah's Contention O regarding impact of potential groundwater contamination on downgrading hydrological resources?
A. Yes.
Q. So if I understand correctly, your expert testimony today on Utah's Contention O would be based upon data and information provided in reports which you didn't prepare or supervise?
MR. GAUKLER: Objection. You may go ahead and answer the question. The objection is unclear. I don't think he testified to that, so...
MR. SEEL: Okay. I'm trying to find out what it is that he can testify to today, and my understanding is he's relying on documents that he didn't help prepare but merely reviewed.
Q. (BY MR. SEEL) Mr. Liang, I'm trying to put some boundaries on what it is you know and what you've done so we can figure out where you're an expert and we can expect you to provide expert testimony, and where you're not an expert and you won't be providing expert testimony on this matter.

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Did you help prepare the environmental report in this matter?
A. I need to -- specifically what area? Environmental covers so many section, so many area. And your question say, do I have to prepare my own report. I cannot answer. All I can only answer, say I prepare hydrology section of the environmental report.
Q. So you helped prepare the hydrologic section of the ER?
A. Yes.
Q. Did you rely on other documents or other information to prepare that section of the ER?
A. We used reference, and based on the scope of what required on the ER, which has NRC Reg guideline, we started to provide input data from the site or from existing literature, and then we decide which model to use. And then after running these all number required by -- all the information resulting, required by the NRC, we prepared the section.
Q. When you were preparing that section of the ER, were you doing it to comply with the NRC regulation?
A. Yes.
Q. Was that NRC regulation --
A. 4.2, Reg Guide 4.2, Environmental Report. That's the reg guide guideline give you what should be

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included in that hydrology section or other section. Very detailed, what you should be use and so on. Reg Guide 4.2 of NRC for all nuclear facility.
Q. In PFS's, Applicant's Responses to Requests for Admissions No. 119 of Contention O, PFS has taken the position, it appears, that there was a lack of a direct hydrological link between groundwater and the surface at the PFS site. Are you familiar with that position?
A. Yes.
Q. PFS's position that there is a lack of a direct hydrologic link between groundwater and the surface?
A. Yes, I'm familiar with that.
Q. Are you able as an expert opinion to respond and answer questions regarding that issue?
A. Yes.
Q. Can you please explain in general terms how PFS reached the conclusion that there was no direct hydrologic link?
A. At the site?
Q. At the proposed site.
A. Yeah. The reason for that is, we -- during the preparation year we did an evaluation and survey, and we haven't found, or only few perennial stream, but

very -- none at the site.

And also we did some soil investigation by geotechnical group and found out that mostly is silt or clay or silty clay. Because there's no surface water at the site, there's hardly any interconnection between -- the link between these two, the surface water and groundwater area. That's my conclusion.

Q. So as I understand your answer, your conclusions or your expert opinions on that are based on two things: low amounts of precipitation and the permeability of the soils at the site?

A. Yeah.

Q. Is there any other factors that might have gone into that decision?

A. Also we think the five-mile radius of the site. We haven't found any permanent water body. The only thing we have found is more reservoir or pond for the irrigation purpose.

Q. We're talking about a hydrologic connection between the surface --

A. And the groundwater.

Q. -- and the groundwater?

A. Right.

Q. Is depth to groundwater a factor that went into your --

A. Yes.

Q. -- conclusion?

A. Yes.

Q. Okay. There was factors: depth to ground water, the permeability of the soils, and the amount of precipitation at the site?

A. Yes.

Q. Based on those three factors, you came to the conclusion that there was no direct hydrological link?

A. Yes.

Q. To use those factors, I assume you had to collect some data of some kind on those three factors?

A. Yes.

Q. Okay. Could you please explain to me the data that was collected regarding the permeability of the soils?

A. The permeability of soil, we have a monitor well, CBT No. 5, which we install a casing two inches, become a monitoring well. The reason that this spot is a boring hole, but later on we decide to install a monitoring well, two-inch diameter. And our geology -- geotechnical group do a so-called constant head pumping test, and then after the data collected, the geotechnical engineers have a calculation, calculated

that permeability is -- I remember is .142 feet per day.

Q. Is that the permeability of the surface soil, or is that the permeability of the soil in the screened area of the well?

A. At the screened area of the area, yeah.

Q. And I understand that PFS is proposing to use a well or series of wells to obtain water for under the site?

A. Yes, that's what I understand.

Q. And that this 0.142 -- was it feet per day?

A. Uh-huh.

Q. -- permeability is sufficient to provide water to the site?

A. Without calculation I cannot answer your question.

Q. I'm sorry?

A. Without calculation.

Q. Well, I guess -- would you consider that permeable enough to water that you would consider using it as a production well?

A. I believe so. But I want to add to it: also depend on how much water you're going to pump from the well. They are related.

Q. So the permeability that we were discussing is at the base of the test well CBT-5?

A. Uh-huh.

Q. It's not the permeability of the surface soils. Is that my understanding?

A. True.

Q. And my understanding, getting back to these three factors, is that the permeability of the surface soils or the permeability of the soils under the site will prevent downward migration of surface waters?

A. Uh-huh.

Q. I have a figure here entitled Figure 2.6-23, entitled Canister Transfer Building Foundation Profile 3-3, looking east. It is from the Safety Analysis Report. Would you please take a look at that.

A. Yeah, uh-huh.

Q. Do you recognize that document?

A. Yes, I have seen the figures.

Q. Would you please describe to me the formations on there that you believe were going to prevent downward migration of surface waters?

A. Oh, that's easy, because on the clay, as we present in the SAR and ER and also in the Safety Evaluation Report prepared by NRC, saying in the Skull Valley the silt permeability is .2 to .6 inch per hour. That's on Safety Evaluation Report page 2-23. But this number was developed by U.S. Department of Agriculture.

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They analyze the soil at the Skull Valley.
On the categories, this so-called soil group classification is clay, silty clay and so on. That permeability, in my expert opinion, is very, very low.
Q. And that was in the Safety Analysis Report?
A. Page 2-23, prepared by NRC. Also presented in our -- I believe in ER.
Q. What was the permeability in the screened area of the test well?
A. Is .142 feet per day.
Q. And the permeability of the surface soils were -- I believe you said 0.2 to 0.6 inches per hour?
A. .2 to .6 inch per hour.
Q. How do those two permeabilities compare to each other?
A. That is the soil test result. The other one is, if you -- someone make the unit the same, then you can compare. I haven't done that.
Q. It's just a conversion of units?
A. Right.
Q. Could you do the conversion for me?
A. Yeah. I need a pen and paper.
So the clay permeability is from .4 feet per day to 1.2 feet per day, the permeability of clay, in comparison with .142 feet per day at 120 feet down.

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It's a range. The clay permeability had a range from .4 feet to 1.2 feet per day. That's my calculation.
Q. The clay ranges between 0.44 feet per day and 1 foot per day?
A. 1.2.
Q. 1.2. Having done the conversion, is there a significant difference between your calculation of the permeability of the surface soils and the permeability of the soils at the bottom of the test well?
A. I didn't get you at first. Will you repeat the question?
Q. Is there a significant difference in the permeability?
A. No. In my engineering, we say this the same magnitude order.
Q. So the soils from which PFS is intending to acquire water is just as permeable or impermeable, depending on how you look at it, as the soils which are going to prevent downward migration of surface water?
A. I won't say that. You see, the production of the water, not only when you heat the aquifer, is not only depend permeability. They are also when so-called transmittability. Because permeability is this way, the transmittability is from horizontal. There's two coefficient in there.

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Q. So this is a heterogeneity in the aquifers? The permeability in the three dimensions differs?
A. No. The permeability is vertical, the transmittability horizontal, coefficient. An aquifer is -- how much water you can do is not only permeability. You have other coefficient also affect the production of the well is the transmittability coefficient.
Q. Are you saying the permeability of the surface soils --
A. Uh-huh.
Q. -- does not determine the ability of it to transmit water?
A. I didn't say that.
Q. Well, let me ask this question, then. What is the difference between permeability and hydraulic conductivity?
A. I don't know that.
Q. Are you familiar with the term "hydraulic conductivity"?
A. I would say no.
Q. I have a document here which is page 5 of Stone and Webster Engineering Corporation calculation sheet entitled Determination of Aquifer Permeability from Constant Head Test, an Estimation of Radius

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Influence for the Proposed Water Well.
A. Uh-huh.
Q. I'd like you to take a look at it and see if you're familiar with that.
MR. GAUKLER: Could you show him the calculation, please. And also I'd like to have the revision of the data and calculations stated for the record.
For the record, it's revision zero, the calculation dated April 22nd, 1999.
A. Yeah.
Q. Mr. Gaukler has raised a good point. I understand that there was a newer revised version part of this document, which we received yesterday.
Here's a revised version of the same document. There's a page 5. Could you look at that as well and confirm your testimony?
A. Same page?
Q. Page 5, yes.
MR. GAUKLER: This is Revision 2, dated March 27, 2001.
A. You only want me to look at page 5?
MR. GAUKLER: If you need to look at the entire document, please do so.
THE WITNESS: Page 5, yeah.

Q. (BY MR. SEEL) There's a symbol on there identified as K.
A. Yeah.
Q. What is the --
A. The K is permeability, meter per second.
Q. What are the units associated with the K?
A. The unit? I said meters per second.
Q. Are those the correct units for permeability?
A. I believe so.
Q. I have an introductory groundwater textbook by the name of Freeze and Cherry. I'd like you to take a look at page 29.
A. Page 29.
Q. At the bottom there's two parameters -- sorry. Look at page 30 -- 29.
A. Twenty-nine.
Q. Two parameters, one identified as permeability and one as hydraulic conductivity.
A. Uh-huh.
Q. What are the units associated with the permeability?
MR. GAUKLER: Use as much of the document, the book, as you need to.
THE WITNESS: Yeah.

A. Okay, I'm finished.
Q. What are the units associated with the parameter of permeability?
A. The table did not show that. The table only show you from one unit how to convert to the other unit. There's a different way to express a unit. But this is so-called conversion factor for permeability. It is not the unit for permeability. So you have a unit, he show this table. If you have foot per second, how to convert to feet per second and so on.
Q. Why would the units change between the conversion? Why would the units between permeability and hydraulic conductivity be different?
A. Hydraulic conductivity, meter per second and then converted feet per second.
Q. But the units are the same. We simply have changed the system of units.
A. Correct, yeah.
Q. We've gone from metric to English.
A. To -- metric to English.
Q. Let's take a different approach. Is permeability, the units of permeability always length over -- excuse me. Are the units for permeability always length squared? It doesn't matter what unit or what type of system you're in, it's always going to be a

length squared?
A. Yes.
Q. And for hydraulic conductivity, will the units always be length over --
A. Length over time.
Q. -- time?
A. Per second. Yup.
Q. Getting back to page 5 of the Stone & Webster document.
A. Uh-huh.
Q. What are the units on permeability?
A. Liter per second.
Q. Are those the correct units for permeability?
A. There is a difference in the textbook and the calculation. The unit differs. But we can check back on the reference weighted formula or reason it from, because there's a reference for this formula, and I believe the formula also define the way, what units should be used in that formula.
Q. The question is, do we have a reference?
A. I would like to have a moment.
Q. Take your time.
A. According to this formula, permeability is expressed in meter per second. I analyzed this formula

by the unit of individual turn. L is lengths of the permeability test section in meter, and then Q is the water flow rate into the well, liter per minute. And then H is height of the water above static equilibrium level in meters.
I just operate the unit and come out -- after I all cancelled this, it came out as length over time.
Q. So it's really not permeability at all, it's hydraulic conductivity?
MR. GAUKLER: Objection. He didn't say that.
Q. I'd like to get back to the three factors that you relied upon to come to the conclusion that the surface soils at the site would prevent the downward migration of surface waters into the aquifer. There were three factors.
A. At the site, yeah.
Q. Correct me if I'm wrong. Those three factors were depth to the water, the groundwater, the low permeability of the soils at the surface, and low amounts of precipitation?
A. Will you repeat? I didn't follow.
Q. I understood there were three factors.
A. Yes.

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Q. The first being depth to groundwater --
A. Uh-huh.
Q. -- the low permeability of soils at the surface --
A. Yeah.
Q. -- and low amounts of precipitation.
A. Yes.
Q. This is from a document I believe you've already looked at. This is page 3.
A. Yes. This is an attachment to the calculation.
Q. And this is well construction log for the test well?
A. Okay.
Q. My understanding from looking at the log -- is that, at the bottom of the borehole --
A. Uh-huh.
Q. -- a sandy silt or silty --
A. Silty sand.
Q. Silty sand?
A. Uh-huh.
Q. And that was where you were going to be acquiring water for your pump well when it was installed?
A. Normally we extract water when we heat this

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water coming out, heat a depth which we have water pumping out. It could be some other location change, maybe deeper or shallower. But at that spot, yes, we will have a silty sand and we heat the water.
Q. This area here, is this sand in the construction log?
A. Yes.
Q. Is that not from the surrounding formation?
A. No. We put it when we install the well.
Q. And then there's this layer here?
A. Uh-huh.
Q. What's that say?
A. 125.5 to 122 elevation we put some bentonite, b-e-n-t-o-n-i-t-e, pellet, p-e-l-l-e-t, seal.
Q. So the bentonite isn't part of the surrounding formation?
A. No.
Q. Why did you put it in?
A. Because you have to seal the well, prevent the water coming in the side, which is a -- circumference is circular.
Q. It's to prevent water from coming up the well?
A. Uh-huh. No, no -- yeah, coming up it. Not -- we pump from here, but we don't want the water --

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without filter, because the sand is acting as a filter action, we don't want the water to come out and then become unfiltered. This sand is prevent this water coming out on the side way. We're actually pumping the water from here.
Q. And this is -- up here, this is cement?
A. Yes.
Q. And this is to prevent groundwater from coming up to the surface, not to prevent surface water from going down into the well?
A. Yeah, Yes. Actually, there's two way. We don't want surface water to -- we don't know what surface quality will be. Actually, it's a two way. We prevent the surface water because we don't want it to come down there. And we don't want the groundwater coming up the side way, you know, which will be -- affect our pumping from here.
Q. So the bentonite seal and cement bentonite placed around the well --
A. Yes.
Q. -- is to prevent water from the surface migrating down, and water from the subsurface --
A. Going up.
Q. -- going up. And that's to preserve the water quality?

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A. That's one of the reasons, uh-huh. I look at that very carefully. And they were confirmed through a Driscoll, author by Driscoll, Groundwater Handbook, the construction of the well.
Q. The construction of the well was to --
A. Is very -- follow the guideline according to the book of Driscoll, Groundwater Handbook. Put the sand and then sealed it by cement and so on.
Q. If they had not put in the seal, would this have punctured this zone of surface silt and clays that PFS asserts will prevent downward migration?
MR. GAUKLER: Objection. What would puncture it? It's not defined.
Q. (BY MR. SEEL) The borehole in which the well is installed.
A. Uh-huh.
Q. It would have punctured that -- step back. If they had not put the seal in place around this well, would it have provided a pathway for surface waters to migrate into the aquifer?
A. I don't understand your question.
Q. What is the purpose behind putting the bentonite and cement bentonite seal in the well?
MR. GAUKLER: Asked and answered. You may answer it again.

A. I already answered. The reason, because we don't want the groundwater coming on the side way, rather than we like water coming up from the well casing itself. That's the reason.
Q. If the bentonite seal and the cement bentonite portion of the well was not there, could surface waters migrate down into the aquifer?
A. No.
Q. If the question is not clear --
A. No, no, surface water would not migrate. If you don't have this sand or the bentonite over there, the surface water will not migrate, no.
Q. Surface waters would not migrate down through this area?
A. Uh-huh.
Q. Why not?
A. Because there's soil surrounding it.
Q. So why bother to put in a bentonite seal at all?
A. Because, as I say earlier, it prevent the water coming up from the side way, not from the casing, the well casing itself.
As I say earlier, the bentonite pellet also let the water stay down so they can go into the -- through the wells the sand have the filter effect, so it

keep the water you pump in from the casing clear. You don't want some sediment or something to come up when you pump the water. This practice also for any residential when you have your own water well supply from your backyard.
MR. GAUKLER: We've been more than an hour. Can we break?
MR. SEEL: Why don't we take a break.
(Recess from 10:25 to 10:41 a.m.)
Q. (BY MR. SEEL) Mr. Liang, I'd like to return to the three factors that PFS relied upon to reach its conclusion that surface soil at the site will prevent the downward migration of surface waters.
I have a document here entitled Figure 2.6-2, Plot Plan and Location of Geotechnical Investigations, Sheet 1 of 2 from the Safety Analysis Report, Revision 8. Would you take a look at it, please.
A. Okay.
Q. There are a number of borehole locations identified on that document.
A. The symbols say "boring location," yes.
Q. Are you familiar with this document?
A. I reviewed the document.
Q. You reviewed this document?

A. Uh-huh. After they present in the ER.
Q. Were you involved at all in the drilling of these boreholes?
A. No. A colleague.
Q. Your --
A. My colleague at Stone Webster.
Q. Colleague?
A. Yeah, my co-worker.
Q. Approximately how many boreholes are located on that map?
A. Based on the symbol -- one, two, three, four; one, two, three, four, five. Four times five is twenty.
Q. Do you know what the diameter of those boreholes were?
A. If my memory right, it's about two inches. I may be wrong. Or one inch.
Q. I'll show you another document entitled Boring Log.
A. Okay, yeah.
Q. Boring B-1.
A. Uh-huh.
Q. Stone & Webster Engineering Corporation, Sheet 1 of 2, dated 8/31/99.
A. Uh-huh.

Q. Please take a look at that.
A. Okay.
Q. In the area identified as methods.
A. Uh-huh. You mean the boring log, yeah. Methods.
Q. Methods. It should identify the -- actually, would you read that section?
A. Drilling soil: 3-1/4 inch inside diameter hollow stem augers. Sampling soil: Two-inch outside diameter split spoon, 24 inches long, 3-inch outside diameter Shelby sampler, S-h-e-l-b-y sampler, 30 inch long. Drilling: Rock.
Q. Thank you. Where it says "3-1/4 inch inside diameter hollow stem augers," does that mean the auger was 3-1/4 inches in diameter?
A. As I understand it, something like this, and then inside diameter means this.
Q. Inside the hollow stem?
A. Uh-huh.
Q. So inside the hollow stem is 3-1/4 inches in diameter?
A. Inside diameter.
Q. So the outside diameter of the auger itself would be more than 3-1/4 inches?
A. True.

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Q. So the borehole was at least 3-1/4 inches?
A. During the drilling, yes.
Q. It would have been at least 3-1/4 inches diameter?
A. Yes.
Q. Would you read the comment section of that document?
A. "No groundwater or bedrock encountered. Backfilled to ground surface with soil, marked with stake."
Q. Do you know why they didn't backfill these boreholes with something other than soil?
A. I don't know. However, based on my expert opinion, why fill with something else?
Q. Well, when PFS drilled their well, they backfilled with a cement bentonite mixture and a bentonite seal.
A. That is because for different purpose.
Q. My understanding is PFS has taken the position that the surface soils are permeable enough to prevent the downward migration of surface waters to the aquifer. Is that correct?
MR. GAUKLER: Asked and answered. You may answer it again.
A. I don't understand. You say pick a

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position. Will you clarify what that means?
Q. PFS has concluded that the surface soils are impermeable enough to prevent the migration of surface waters to the aquifer.
A. With this in the ER or SAR, I forgot, we'd say is very little chance to infiltrate into the ground from the surface water.
Q. What if there were holes punctured in that surface layer? Would those holes act as a pathway for surface waters to migrate to the aquifer?
A. I need some definition of puncture. Because if I say you have a membrane or some soil, then puncture I understand. When you have a soil, I don't know how you define a puncture.
Q. A borehole of a minimum diameter of 3-1/4 inches.
A. If you have a hole in the ground, clear, no obstruction on that hole, you say pathway, I will agree this.
Q. In your expert opinion, would backfilling the boreholes with soil sufficiently seal that zone so they could not act as a pathway for surface waters?
A. Yes, because that soil is pretty much what was coming out in the drilling operation. As a result, those soils just, you know, because you have a hole, so

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those are coming on the side way. After that you fill that, yes.
Q. Disrupting those soils when they were drilled wouldn't affect their permeability?
A. Your question pretty general, because we are doing something on one spot. I don't know that we're going to change. On that hole itself, I would say it could.
Q. When soils are placed back into a borehole, are you familiar with how that process takes place?
A. That's a common practice. I don't know the detail of the process.
Q. Do you know whether the geologist on the rig is the one who fills in the borehole?
A. No.
Q. The driller? The driller's helper?
A. I cannot answer this question, because we have a -- I have a co-worker. He was at the operation when the driller drilled this thing, make sure everything follow the rule procedure or the scope of survey we developed, Stone Webster.
Q. Do you know whether they placed the soils back into the hole and compressed them so that they were the same density as the surrounding soils?
A. No, I don't know this.

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Q. Do you know whether they just shoveled the dirt back in?
A. No, because I was not there.
Q. If the soils weren't placed back in the hole and compressed to the same density as the surrounding materials, would that change the permeability of those soils within the borehole?
A. In my expert opinion, no. If they compact, put back the soil which originally come from the hole, I don't think it will change the permeability. That's only my own expert opinion.
Q. Do you know why the state well drilling regulations require cement or bentonite placed into boreholes instead of just soil cuttings?
A. No, I don't.
Q. Do you know if the original field logs that were taken by the person who logged the hole would indicate how they backfilled those boreholes?
A. I reviewed a couple of the bore logs specifically to ER, CBT No. 5. I didn't read any they described the method to backfill back to the borehole.
Q. Are there boring logs that were handwritten in the field from which this boring log was generated?
A. I know if a technical -- I mean, a geotechnical engineer supervised this, he himself would

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make some field note. And later on after contract completed, he would probably generate log, and then if any discrepancy he will fill in.
Q. But the field logs exist, as far as you know, for these boreholes, the original field logs?
MR. GAUKLER: Objection on what you mean by "original."
MR. SEEL: Handwritten. Unless the driller or the geologist on site somehow through a computer generated that document right there, there must be some underlying documents from which that document is derived.
MR. GAUKLER: Is that a question?
Q. (BY MR. SEEL) In your opinion, do people in the field collect raw data that they write down in a field notebook?
A. This is my understanding. This is general engineering practice.
Q. And it's from those field notebooks that this boring log was derived?
MR. GAUKLER: If you know.
A. I believe so.
Q. Do you know if those field logs have been disclosed to the State of Utah?
A. Not to my knowledge. I don't know anything

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about this.
Q. My understanding is that PFS intends to install at least one sewer system or disposal system of some kind on the site. Is that correct?
A. I think -- I'm not in that area, but my colleague which is in Denver engineered and designed the sewer system. So I don't think I am in the position to answer your question.
Q. Are you familiar that the sewer system will involve liquid disposal to the subsurface?
A. I know the sewer system in general, how it works, yeah.
Q. Is your colleague Mr. Lewis?
A. Wayne Lewis.
Q. He's the individual who would be familiar with the design and operation of the system?
A. Is in my belief, yes.
Q. Would he also be familiar with the ultimate fate of the fluids that are going to be put down in that system? Or would that be the area that you would be familiar with?
MR. GAUKLER: Objection. What do you mean by ultimate fate? Unclear and ambiguous.
Q. Where is the water that's going down the sewer system going to end up?

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A. That is area I'm not in a position to answer, because that is design the sewer engineer would know.
Q. Were you asked to give PFS -- strike that. PFS intends to use water from at least one source through the construction and operation of this proposed facility. Is that correct?
MR. GAUKLER: Object as vague and ambiguous.
Q. Does PFS need water to construct its site?
A. Yes.
Q. Has PFS proposed where it intends to obtain that water?
A. Will you ask this question again?
Q. Has PFS proposed a source for the water it intends to use to construct the site?
A. Yes.
Q. Were you responsible for determining the potential environmental effects from using the water from that source or sources?
A. No. But I reviewed the section which provided by my company colleague.
Q. Are you able to give an expert opinion as to the environmental effects associated with using the water at the site?
MR. GAUKLER: Object. It's unclear when you

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say using the water at the site, the environmental effects of. Are you talking from environmental effects of water use at the site in terms of water being used in the construction process, or water being obtained, environmental effects of water being obtained from some source, i.e., the well?
Q. What are the potential sources of water that PFS is proposing?
A. As I read the ER, they proposed either on site, if they found available quantity of groundwater, or they would truck in from outside source, or for some aspect of the need they would bring in some bottled water.
Q. To determine a potential environmental effect on a source of water, do you need to know where that source is?
MR. GAUKLER: Objection, vague and ambiguous question.
Q. Can you identify for me the exact location of the off-site sources?
A. No, because I'm not involved the original proposal where to get these waters' source outside.
Q. Do you agree that you need to know what the source of the water will be before you can take the next step and analyze what the potential environmental

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effects may be to that source?

MR. GAUKLER: Objection, vague and ambiguous question. You may answer if you can.

A. You have to repeat the question because I don't know if you're talking about outside the -- outside the site or on site or both.

Q. Precisely. How can you determine the environmental effects for using water from the source if you don't know where that source is?

MR. GAUKLER: Objection, ambiguous.

A. I remember ER section have addressed what your question is, but I can't remember exactly where the section or which chapter regarding your question about identify the source of the water come from. And they addressed what kind of impact would be and so on. It's already been addressed in the ER, which I don't know which section it is, because I originally did not participate about this proposal or calculation of how much water used during different phase of the PFS project into construction operation phase.

Q. So you believe the environmental report looks at each potential source of water for this facility and analyzes --

A. Address the impact.

Q. Analyzing the environmental impact for each

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of those --

A. Address the impact, yes.

Q. -- sources?

A. I remember I have read the section, but I can't remember exactly which section. Or during the phase of answer in RAI, NRC request for additional information, I remember. But I don't know which specific question. But this issue had been addressed and answered either in the ER or in the response to NRC RAI about the water source, where it come from, what the impact would be if we choose that way.

Q. Has PFS determined what the aquifer is under the site?

MR. GAUKLER: Objection, vague and ambiguous. Answer if you can.

A. You mean the aquifer of what? Where the aquifer is?

Q. Has PFS determined what constitutes the aquifer under the site?

A. I still don't understand your question: constitute aquifer.

Q. I show you a document.

A. Okay.

Q. It is from NUREG-1567, Section 2, page 2-12, subsection 2.4.5 entitled Subsurface Hydrology.

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A. Uh-huh.

Q. Would you please read that section for me?

A. Paragraph 2?

MR. GAUKLER: Please show him more of the document, please. What NUREG number is that, did you say?

MR. SEEL: 1567.

THE WITNESS: Second paragraph. Under the section --

MR. GAUKLER: We'll get you more of the document.

THE WITNESS: If the site is located --

MR. GAUKLER: Wait till you get more of the document.

THE WITNESS: Okay.

I would like to have the title of the NUREG, what the title of the NUREG 1567. Do you know the title of the NUREG 1567 before I go into the --

MR. SEEL: No, but I can go upstairs and get it for you if you'd like.

THE WITNESS: Okay. So I'm going to read what you request on second paragraph.

MR. GAUKLER: Wait till he gets it.

(Recess from 11:11 to 11:19 a.m.)

THE WITNESS: Okay. Actually it's Review

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Plan, also the Reg Guide 1.17. That is my guess. I just wanted to confirm that. Okay. Let me read to you what you request, the second paragraph.

"If the site is located over an aquifer which is a source of well water, the groundwater aquifer (S) beneath the site, associated hydrological units, and they are recharged and the discharge areas should be described, the results of a survey of groundwater users, well location, source aquifers, water uses, static water levels, pumping rates, and the draw-down should be provided.

A water table contour map showing surface water bodies, decharge and discharge areas, and the locations of monitoring wells to detect leakage from storage structures should also be provided. Information on monitoring wells should include well head elevations, screened intervals, installation methods, and a representative hydrochemical analysis. An analysis bounding the potential groundwater contamination from site operation should be provided. A graph of time versus radionuclide concentrations at the closest existing or potential downgradient well should be included."

Q. In your expert opinion, has PFS performed work that would comply with that paragraph?

A. Some have. Some we plan to do. Because too many mentioned there. I will identify which one we already --
Q. In the first sentence it talked about an aquifer.
A. Yes.
Q. Has PFS determined what the aquifer is?
A. In the ER itself, no, we have not identified the aquifer.
Q. The first sentence states, "If the site is located over an aquifer which is a source of well water." If you've not identified the aquifer yet, could you identify what the source, or the source for well water?
A. We drill a CPT operating well and put a casing on it and we found some groundwater.
Q. Would you please identify those areas in the paragraph in which PFS has --
A. Okay.
Q. -- performed work and those which you indicated that they would be performing in the future?
A. We have done to send either in the SAR or in answer request for additional information from NRC the result of a survey of groundwater user within five-mile radius of the site -- well locations, source aquifer,

water uses, static water levels, pumping rates. We have described in the Skull Valley where the groundwater recharge and decharge area.
That's all.
Q. You indicated that PFS has performed a survey of the groundwater users?
A. Within file-mile radius of the site, yes.
Q. I'm sorry; what was that?
A. Within five-mile radius of the site.
Q. Why did PFS choose five miles?
A. Not only this site, any nuclear facility required to investigate at the radius of five miles.
Q. If there were impacts to the environment or impacts of the aquifer outside of five miles, would PFS have studied that?
A. Not to my knowledge.
Q. PFS did not do an independent analysis as to how far impacts to the aquifer may be caused?
MR. GAUKLER: Objection.
Q. Yeah, it was poorly worded. In your expert opinion, is five miles the outer boundary at which impacts to the aquifer may be observed at the site?
A. I can't answer your question. Will you repeat the question? I'd appreciate.
Q. Is a five-mile radius a reasonable radius to

be looking for impacts?
A. I don't like -- if I don't refer to guideline, in my expert opinion is too conservative. It's more than necessary. But the guideline required it. In my expert opinion, it's too conservative, is more than needed.
Q. And the reasons for it being too conservative are?
A. I don't know. Because that is the -- I don't know this requirement, because the -- what the technical behind the NRC, they said the guidelines saying that you have to have a radius of five miles. I don't know. They may be -- my guess is because of conservatism, because normally a -- well, I shouldn't say that. I will stop here.
Q. Will the use of water at the facility have an environmental impact on the aquifer?
MR. GAUKLER: Objection, vague and ambiguous. Many type of potential of environmental impacts, so if you have any particular ones in mind.
MR. WEISMAN: I'm sorry, Mr. Gaukler. Could you speak up a bit?
MR. GAUKLER: I'm sorry. There's many different types of environmental impacts. What type are you referring to, in general?

Q. (BY MR. SEEL) I'm referring to in general draw-down of the aquifer and the impact it may have on the availability of water resources in the valley.
A. Excuse me? You want me to address that?
Q. Yes.
A. I'd like you to repeat the question.
Q. I'd like to repeat it, too.
A. I don't understand it.
Q. Will the use of water at the facility have an impact on the availability of water resources in the valley?
A. I believe we have addressed the issue based on our 42 years of average annual use of the water if we coming -- withdraw from the well, and what kind of impact on the nearest well user.
Q. PFS is not the only water user in the valley, however. Is that correct?
A. In the valley, yes.
Q. Has PFS done an analysis to determine whether the cumulative impact of all the water users in the valley is having an adverse effect upon the availability of water resources in the valley?
A. We did in one calculation demonstrate that based on those 42 years annual actual rate, if we withdraw that amount from the well aquifer what kind of

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impact would be on the current use of well water.
Q. Will there be sufficient water resources in the valley to satisfy PFS's needs in 40 years?
A. Yes.
Q. And how did you come to that conclusion?
A. Based on that 42 years annual use is 2,040 gallon per year, transfer to 1.42 gallon per minute. And also in other unit is 2.29 acre feet. That kind of compared to the other user or the availability of the aquifer is so insignificant.
Q. Where did you get the data to compare it to these other -- where is the data for these other users in the valley?
A. Oh, we based on those five -- a table or a figure we presented within those five-mile radius.
Q. And you determined that the recharge to the area within the five-mile radius is greater than what is being extracted by those current water users?
A. I base on the -- what available from the aquifer data which I extract an understanding from Hood and Waddell, W-a-d-d-e-l-l, the paper, the publication. I forgot the last name. And they indicate an aquifer in the Skull Valley, how much recharge and decharge quantity.
Q. So is PFS relying solely on the Hood and

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Waddell 1968 report for its conclusions, as to the conclusion that recharged --
A. I believe we answered that question during the answer one of the request for additional information addressed. After Hood publication we have more reason in 1987. Their conclusion is not too much different from Hood. Also, I remind you the State of Utah using Hood for their 1987 to host superconductor, supercolliding project, they also rely on that report.
And we have to conduct some research. There's just no more -- not a more recent publication available.
Q. But PFS is relying on the Hood and Waddell report in coming to this conclusion?
MR. GAUKLER: Objection. Mischaracterizes the witness's testimony.
Q. (BY MR. SEEL) Is PFS relying on anything other than the Hood and Waddell report to come to its conclusion?
MR. GAUKLER: What conclusion are you referring to specifically?
MR. SEEL: The conclusion that the amount of recharge to the aquifer is greater than the amount being used in the valley. If that's not the right conclusion --

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A. We used the Hood information and get the information about charge or recharge of the aquifer.
Q. How much is actually being used in the valley today?
A. I don't know. They said some number in there. I do not memorize the paper.
Q. I understand.
A. So many number.
Q. But if I understand you correctly, PFS is relying on the number in the Hood and Waddell report for its conclusion.
A. If I remember right, talking about 5,000 acre feet compared to what we propose going to draw, 2.29 acre feet. That -- my expert opinion is insignificant.
Q. The question is whether the data from 1968 is still accurate, and my question to you is, why do you feel the data from the 1968 report is still accurate?
A. I have answered already. Because previous question, I don't know which question -- '87, they say another publication concluded. Their study conclusion is not much different from Hood's result.
Secondly, State of Utah using the same report for 1987, their planning of this project.
Q. Was that facility located -- to be located

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in Skull Valley?
A. If I remember right, answer to that question I think is using Skull Valley, yes, the groundwater from the aquifer in the Skull Valley, yes.
Q. Are there any other reasons why you believe the 5,000 acre feet figure included in the Hood and Waddell report is still valid?
A. My conclusion I think based on all available information. Oh, well, that's -- ever since the Hood publication, the balance of the aquifer had not been changed significantly.
Q. If new wells were being put into the aquifer, installed in the aquifer since the Hood and Waddell report, would that change your opinion?
A. That depend on a lot of factor -- how much water individual well will withdraw.
Q. What other factors?
A. That's one of the factors I just mentioned, depending on quantity of individually the withdraw from the aquifer.
Q. Are there any other factors that would go into that determination? Do new wells automatically mean more extraction from the aquifer?
A. Yeah, if you have a new well you just extract from the aquifer, yeah.

Q. So has PFS determined how many new wells have been installed in the aquifer since the Hood and Waddell report?
MR. GAUKLER: I object to this whole line of questioning on lack of relevance. You can answer that question if you know.
A. I don't know.
Q. If the groundwater table is lower, would that have an environmental impact on vegetation in the valley?
A. If the groundwater table is low, I don't know how that interconnected vegetation. I would say no.
Q. Do some types of vegetation extract water from the subsurface out around the groundwater table?
A. I don't know, because I'm not in that area of my study.
Q. Are you familiar with the Hood and Waddell report? Have you read it?
A. I read very casually, not word by word.
Q. Do you know what evapotranspiration is?
A. My understanding of that word means evaporate and escaping to the air.
Q. What does the transpiration part of that term mean?

A. I only know the first part. Transpiration, I don't know what exact mechanism in science.
Q. If the groundwater table is lower in the valley, would that allow saline water from the Great Salt Lake to encroach into the aquifer?
A. I don't know the answer to this question -- to your question.
Q. Is salt water generally denser than fresh water?
A. True.
Q. Are you aware of any areas in the United States where saline water has encroached on fresh water aquifers?
A. Yes.
Q. What areas would those be?
A. Florida.
Q. Do you know what the cause of the encroachment was?
A. I don't know the exact cause, but one thing, the factor which determine is the distance between the aquifer and what the source of salt water. That's a very important factor.
Q. I'm going to hand you a copy of -- I'll hand you all of the Hood and Waddell report. I'd like you to look at page 28. There's a table on use --

A. Twenty-eight, okay.
Q. -- in which there is -- I'd like you to take a look at it so that I can ask you about it.
A. Starts at page 28, right?
Q. Page 28, that's correct.
(Witness reviews document.)
MR. GAUKLER: Are you going to ask specific questions with respect to the table?
MR. SEEL: About the dates on the table and use during those dates.
MR. GAUKLER: He's going to ask a specific question about the table. If you need to look at more of the document, feel free to do so.
THE WITNESS: Okay. The table.
Q. (BY MR. SEEL) My understanding is that -- well, what does the table describe as far as use of water in the Skull Valley?
A. The table is percent of -- is estimated well discharge based mainly on a measurement made during a reconnaissance during 1963 and '65, electrical power consumption, acreage and pumpage, reported by the U.S. Army.
Q. Can you tell me what the total usage of water in 1957 was, according to that table?
A. Total rounded is 3,500. The unit is acre

feet.
Q. Can you tell me what the amount estimated according to the table is in the subsequent year?
A. 1963, no total. 1964, a total of 4,100. In 1965 is 5,000 acre feet.
Q. So between -- if I understand the table correctly, Hood and Waddell estimate that between 1957 and 1965 the amount of water usage in the valley increased by how many acre feet?
A. Nine hundred acre feet.
Q. In 19 -- my understanding is PFS has taken the position that that 5,000 acre feet per year usage rate has not changed since 1968 when the report was written?
A. No. We say change means the available or recharge of the aquifer.
Q. I'm sorry?
A. It's user, amount of use.
Q. I don't understand the difference. Would you explain that to me? Is PFS relying on the 5,000 acre feet per year annual usage rate that Hood and Waddell came up with as being the current usage rate?
A. No, we do not -- I don't believe we used so-called usage, rather than we're using the first page. If you look at the -- let's see, where's the -- right

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here. We present this number in our ER. Estimate every annual groundwater recharge and discharge in the range of 30,000 to 50,000 acre per year. We use that number in our ER, SAR. We did not use this number anywhere, I believe, in our ER or SAR. I may be wrong, but that's my memory. That's what I had read those sections, ER section, SAR section.

Q. Has PFS done any studies as to the current amount of well usage in Skull Valley?

A. Recur amount?

Q. The current amount of water being pumped from wells in Skull Valley.

A. I don't know of -- I don't understand your "recur."

MR. GAUKLER: I object to this whole line of questioning as relevance. You can answer if you can.

Go ahead and rephrase the question.

Q. Has PFS done any studies as to the annual amount of water being pumped from wells in Skull Valley?

A. For all the user.

MR. GAUKLER: Entire Skull Valley, you're talking about?

A. Entire Skull Valley? Not to my knowledge.

Q. Will the amount that's being pumped pump the aquifer dry in 40 years?

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A. I don't understand your question. Forty years, you're referring to Private Fuel Storage project?

Q. That is correct.

MR. GAUKLER: Objection; vague and ambiguous, also lack of relevance.

Q. How do you know there's going to be any water in the aquifer in 40 years?

MR. GAUKLER: Objection, lack of relevance.

A. I don't know answer to this question, your question.

Q. Don't you need to know how much they pumped in order to answer that question?

A. I know how much the PFS will pump, 2.29 acre feet on every -- over 42 years life of the facility.

Q. And how do you know that the aquifer will still be able to produce that much over the course of --

A. My expert opinion is compared to other user, even -- this is insignificant.

Q. Precisely. And those other users are? Where did you get the data about the other users?

A. Within five miles we presented in the ER and SAR. They have quantity use, when they installed the well, how deep of the well, what kind of elevation from the ground surface to the water.

Q. And is the water table dropping in those

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wells?

A. Not significantly, based on the available data to me.

Q. And what about in the rest of the Skull Valley?

A. Oh, I've read a report. They say in the Dugway, they say public water supply. In that particular location is simply water elevation -- I mean, groundwater elevation is significantly buried, reduced because of pumping. But that is 19 miles from the site, as I recall.

Q. So to clarify: the 5,000 acre feet that's being used, that Hood and Waddell says is being used in the valley, may or may not be accurate?

MR. GAUKLER: Objection. This is asked and answered. We've gone over this many times. It's not relevant, and now you should move on to a new topic.

MR. SEEL: If PFS wants to take the position --

MR. GAUKLER: We said we don't rely upon the 5,000 feet. I don't see why you need to come back to it. You've asked this many different ways. I've been very patient. My patience is running out.

A. I'm not in a position to judge the Hood paper to answer that. But I believe their data is very

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accurate, because they are very extensive, very thorough study, based on my technical in this area. Very thorough. One is a hydrologist, one is chemist. One or the other.

Q. And it's a comprehensive inventory of the water, groundwater resources in the valley?

A. Yes.

Q. Would you please turn to the last page of that report.

A. Okay. This is -- 57 is some reference. The last page?

Q. Page 40 of the report entitled "Proposals for Additional Studies." Would you please read the first two paragraphs of that?

A. Page 40, first two paragraphs. "Because Skull Valley has a potential for development, a detailed water resources investigation is needed to refine the estimates given in this reconnaissance. Such a study should include the following considerations:

1. A comprehensive inventory of the water resources of the valley should be made to supplement coverage of this reconnaissance. Detailed data should be obtained on the hydraulic characteristics of existing wells, the discharge characteristics of both the large saline spring in the valley and the large mountain

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springs, the use of water in the valley, and the availability of surface water supply."
Q. Do you agree that the authors of that report seem to indicate that greater level of investigation is required beyond what they did in Skull Valley? Strike that.
Does the statement of the authors correspond with your prior testimony that this was a comprehensive report?
A. At the time I believe that's very comprehensive. As a matter of fact, I did a lot of research before coming here. All the conclusion at end of the paper always recommend something further be done. That's natural. Because nobody can claim, I'm the exhaustive, this is it. Nobody would have the authority saying that.
MR. SEEL: Lunch?
(Lunch Recess from 11:59 a.m. to 1:10 p.m.)

EXAMINATION

BY MR. WEISMAN:
Q. In answering one of the earlier questions, you talked about two parameters, permeability and transmittability.
A. Yes.
Q. I just wanted to make sure that I was clear

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on what the difference between the two of them is. Maybe I can shortcut this just a little bit. I understood from your answer that you measured permeability at the surface from the top down.
A. Uh-huh.
Q. And I'm going to infer from your answer that permeability of a sample of material may vary depending on the direction. You might measure it from the top or from the side, and you might get different answers. Is that correct? So permeability could vary in the X, Y, and Z directions? That's what I'm asking.
A. Yes. The answer is yes.
Q. Okay. So when you answered the question, you said that you measured the permeability from the surface. That's only in the up and down direction, correct?
A. That's our pumping procedure defined, yes.
Q. Okay. So for transmittability, would that be the permeability in a direction parallel to the surface?
A. That is my understanding that the transmittability is the horizontal.
Q. Okay. So that would be -- the only real difference between permeability and transmittability would be the direction of the flow; is that correct?

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A. When you say "only difference," I'm not quite sure.
Q. I mean, they would use the same units. You're measuring the same -- I'm asking if you're measuring the same sort of thing, but the difference is in the direction.
A. Yes.
MR. WEISMAN: Okay. That's the only question I had.
THE WITNESS: Okay.

EXAMINATION

BY MR. GAUKLER:
Q. I had one short, quick question. We've heard a lot of talk about units for expressing permeability --
A. Yes.
Q. -- you just talked about. Is it true that you can express permeability in units of area as the function of time or in your distance over time?
A. Yes. I have seen different textbooks. One textbook expand in the area over time. Some other they're using linear distance over time. Others using area over time.
MR. GAUKLER: Okay.
MR. GAUKLER: No further questions.

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MR. WEISMAN: I think we should go back on quickly for one comment, and that is, Mr. Blake informs me that the term is "transmissibility" and not "transmittability." But I must have heard it wrong.
THE WITNESS: You're correct.
MR. WEISMAN: So with that, I will be done.
MR. SEEL: I may have some follow-up. Just give me a second.

FURTHER EXAMINATION

BY MR. SEEL:
Q. As a follow-up to the questions that were just asked on permeability, and permeability may vary depending on the X, Y, or Z axes, the three dimensions in space, has PFS done any testing to determine whether the permeability in those three dimensions in the test well screened area vary?
A. No.
Q. So they could be -- the permeability in all three directions could be the same?
A. Could be the same, could be different.
Q. How would one go about determining whether they're different or not?
A. I don't know. I don't know the method how to determine the difference.
Q. When dealing with porous media -- and we're

dealing with porous media flow; is that correct?
A. Uh-huh.
Q. Dealing with porous media such as silty sand, would you expect the permeability to differ depending on the dimension?
MR. BLAKE: Dimension or direction?
MR. SEEL: What's that?
A. Yeah, I don't understand dimension.
Q. I guess I'm using dimension as direction.
A. Direction, okay. Will you repeat the question again?
Q. When you did -- let's step back. When you did the pump test, there were certain assumptions built into that pump test formula?
A. Yes.
Q. Was one of those assumptions that you're dealing with porous media?
A. Yes.
Q. Was there another assumption that that porous media is homogenous?
A. Was what?
Q. Homogenous?
A. What does that mean?
Q. Has the same characteristics in all three dimensions.

A. My understanding is we did not go into that assumption, saying that different dimensions is different or vary.
Q. You're experienced in groundwater modeling, are you not?
A. Yes.
Q. Would groundwater models usually assume that the apropos parameter is the same in all three directions?
A. Normally we decide which dimension or direction use depending on what direction you extract the water. Vertically, say, then we're more focused on the vertical direction, the permeability.
Q. I'm sorry, I didn't understand that. I just didn't hear what you said.
A. Normally we focus the permeability dimension is where we -- which direction our water were pumping to. So vertical direction will focus on the permeability in the vertical direction.
Q. Is that what the formula that was used in the static head pump test assumes?
A. Yes, it is.
Q. It does not assume that the aquifer parameters are all the same in all three directions?
A. I don't know the formula will require the --

other than direction of the pumping flow, have to be -- provide as an input for that formula other than the direction you're pumping the -- pumping the water out.
Q. Let's step back to the basics.
A. Okay.
Q. What is the formula based upon? The formula that we use in the static head test, what formula, what physical equation is it based upon?
A. Oh, it's based upon according to what formula is in the Q and then the -- let me see. The head of the -- define in the formula, because we just take out from one of the reference. H is the -- let me see how they defined H.
Q. Is that formula based upon Darcy's law? Are you familiar with Darcy's law for fluid flow through porous media?
A. I know the formula, yes.
Q. Does Darcy's law -- is one of the basic assumptions of Darcy's law that you're dealing with homogenous material of a uniform particulate size?
A. I think that's how the formula based upon, uniform size.
Q. So based of Darcy's law, Darcy's law assumes you're dealing with a medium in which the parameters of that medium are the same in all three directions?

A. When you say medium all the same in all direction is the same group of soil or the size of soil, or what?
Q. Permeability or the ability of fluid to flow.
A. Yeah.
Q. That Darcy's law assumes that the medium flows equally well in each direction.
A. I thought the thousand dollar assumption is what they call homogeneous of the media of the soil. I would say this is the same what you just inferred.
Q. So if the formula in this pump test is based upon Darcy's law --
A. I don't know. I don't know that it is or not, is or is not.
Q. Are you aware of any groundwater flow formula which is not based on Darcy's law that involves porous media?
A. If not homogeneous, is there another similar Darcy's law formula which will apply in homogeneous media of the soil, I don't know.
Q. What are the units for transmissivity?
A. If I remember right, it is area over time.
Q. And you say that is the same as permeability? Is that how I understood your testimony?

A. No. I say permeability can be expressed in terms of area over time or linear over time.
Q. It can be expressed as both?
A. Yes.
MR. SEEL: No further questions.
(Deposition was concluded at 1:23 p.m.)
* * *

C E R T I F I C A T E

State of Utah)
ss.
County of Utah)

I, Vicky McDaniel, a Registered Merit Reporter and Notary Public in and for the State of Utah, do hereby certify:

That the deposition of George H.C. Liang, the witness in the foregoing deposition named, was taken on April 17, 2001, and that said witness was by me, before examination, duly sworn to testify the truth, the whole truth, and nothing but the truth in said cause;

That the testimony of said witness was reported by me in stenotype and thereafter transcribed into typewriting and that a full, true, and correct transcription of said testimony so taken and transcribed is set forth in the preceding pages.

I further certify that I am not of kin or otherwise associated with any of the parties of said cause of action and that I am not interested in the event thereof.

WITNESS MY HAND and OFFICIAL SEAL at Saratoga Springs, Utah, this 23rd day of April, 2001.

Vicky McDaniel, RMR
Utah License No. 87-108580

Case: In the Matter of Private Fuel Storage
Case No.: ASLPB No. 97-732-02-ISFSI
Reporter: Vicky McDaniel
Date taken: April 17, 2001

WITNESS CERTIFICATE

I, George H.C. Liang, HEREBY DECLARE:

That I am the witness referred to in the foregoing testimony; that I have read the transcript and know the contents thereof; that with these corrections I have noted, this transcript truly and accurately reflects my testimony.

PAGE-LINE	CHANGE/CORRECTION	REASON

_____ No corrections were made.

George H.C. Liang

SUBSCRIBED and SWORN to at , this day of , 2001.

Notary Public

In the Matter of Private Fuel Storage
George H. C. Liang * April 17, 2001

CitiCourt, LLC
801.532.3441

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PAGE	LINE	CHANGE/CORRECTION	REASON
5	17	in the fluid mechanics area	typo error
5	21	tunnel 55 feet long and then	typo error
6	4	I have involved in lot of projects	typo error
6	6	I participated in environmental report	typo error
6	9	which I participated in, what happens	typo error
6	10	, and then assume a scenario	typo error
6	11	that the fluid hit the ground and the	typo error
6	14	stations also involved, ..., like Shoreham	typo error
6	18	if a storm occurs, results in runoff,	typo error
6	23	but at one point, I did involve.	typo error
6	24	Webster is a very diverse company.	typo error
7	2	technical personnel resource support	typo error
7	18	I was involved in pumping test when	typo error
7	19	As a matter of fact, I most recently,	typo error
8	14	-- if it has	typo error
8	15	something in well analysis, data came in	typo error
9	8	I mean, we still do lots of modeling	typo error

[continued on next page]

______ **No corrections were made.**

George H.C. Liang
George H.C. Liang

SUBSCRIBED and SWORN to at Stoughton, Norfolk County, Comm. of Massachusetts

______________, this 15th day of May,

2001.

Evelyn S Clegg
my commission expires: 5/24/2002
Notary Public

PAGE-LINE		CHANGE/CORRECTION	REASON
9	9	but not on the latest project.	typo error
9	11	models, surface water model, and run	typo error
9	12	the models.	
9	21	On sections,	typo error
9	22	in the environmental report	typo error
10	20	to use in remediation of	typo error
10	21	different models.	typo error
11	3	the areas when we prepare project report,	typo error
11	22	say those required steps is not saying that I participated in every step on PFS project	typo error
11	23	have to go to the PFS project management.	typo error
11	24	specific for this I was brought on board	typo error
11	25	, so those considerations: the	typo error
12	1	format to do this and how it is determined,	typo error
15	3	I need to know specifically what area?	typo error
15	4	Environmental Report covers so many sections, so many areas.	typo error
15	5	And your question did I help prepare the environmental	typo error
15	6	report? I can not answer. All I can answer: I	typo error
15	7	prepared hydrology section of	typo error
15	13	We used references	typo error
15	14	, which has a NRC Reg guideline	typo error
15	18	by the reg guideline, all the resulting information, required by the	typo error
15	25	That is the reg guide, guideline gives you	typo error
16	2	Very detailed, what you should be used	typo error
16	25	or only few perennial streams,	typo error
17	1	very few, or none at the site.	typo error
17	17	we have found is some reservoirs or ponds	typo error
18	19	well, CBT No.5, which we installed a casing	typo error
21	1	They analyzed the soil at the Skull Valley.	Typo error
22	14	In my engineering experience, we say this	typo error
22	15	order of magnitude.	typo error
22	21	, not only when you hit the aquifer,	typo error
22	22	only depending upon permeability, but also depending upon so-called	typo error
22	24	There are two	typo error
22	25	coefficients in there.	Typo error
23	6	You have another coefficient also affecting	typo error
27	17	back on the reference based formula or the reason it derived	typo error
27	19	I believe the formula also defines the way	typo error
28	1	by the unit of individual terms.	Typo error
28	6	I just calculate the unit and come out --	typo error
28	7	after I cancelled all same units in this calculation,	typo error
29	25	Normally we extract water when we hit this	typo error
30	1	water coming out, hit a depth which	typo error
30	2 & 3	It could be deeper or shallower at some other locations. But at that spot, yes , we	type error typo error
30	4	have a silty sand type of soil and we hit the water.	typo error
31	11	Actually, there are two ways.	typo error
31	12	don't want the surface water to go down	
31	13	surface water quality will be	typo error
32	3	a Driscoll's book, authored by Driscoll,	typo error
32	6	Is very important to follow the guideline	typo error
33	20	Because, as I said earlier, it prevents	typo error
33	23	As I said earlier, the bentonite	typo error
34	1	keeps the water which you pump from the well casing, is clear.	typo error

[continued on next page]

PAGE	LINE	CHANGE/CORRECTION	REASON
34	3	This practice is also for any	typo error
34	4	residential use when you have your own	typo error
35	1	After the information was presented in the ER.	typo error
37	25	You say taken the	typo error
38	5	Were these in the ER or SAR, I forgot, we'd	typo error
38	6	say there is very little chance to infiltrate	typo error
38	25	, you know, because you drill a hole, so	typo error
39	1	those are coming from the side way.	typo error
39	20	everything follow the rule and procedure, or	typo error
40	9	which originally came from the hole	typo error
40	20	specifically in the ER, CBT No. 5	typo error
41	1	make some field notes.	typo error
42	6	colleague who is in Denver	typo error
42	17	It is my belief, yes.	typo error
43	1	That is the area I'm not in a position to	typo error
43	2	answer, because the engineer designed the sewer system would	typo error
44	21	No, because I'm not involved in the original	typo error
45	11	I remember the ER Sections have addressed	typo error
45	14	identify the sources of the water come from.	typo error
45	19	much water used during different phases of	typo error
45	20	project, from construction to operation phase	typo error
48	13	water bodies, recharge and discharge areas,	typo error
49	22	We have done and sent to NRC either in the SAR	typo error
49	23	answering to request for additional information from NRC, the	typo error
50	2	described in the ER: in the Skull Valley where	typo error
50	3	recharge and discharge area.	typo error
51	2	I don't like to go to a five-mile radius.	typo error
51	3	the guideline. In my expert opinion it is too	typo error
51	5	, it's too conservative, and is	typo error
51	9	I don't know. Because that is the guideline.	typo error
51	10	don't know the bases of this requirement, because the guideline what the	typo error
51	11	technical bases behind the NRC's thinking. The guideline	typo error
51	12	saying that you have to cover a radius of five miles. I	typo error
51	14	, because normally a pumping well, I shouldn't	typo error
52	24	based on those 42 years annual average rate,	typo error
53	6	Based on that 42 years annual average use	typo error
53	7	gallon per day, convert to 1.42 gallon	typo error
53	8	unit is 2.29 acre feet per year. That amount	typo error
53	15	within a five-mile radius	typo error
53	23	, how much recharge and discharge	typo error
54	4	the answer to one of the request for	typo error
54	5	we have found one more recent reference published	typo error
54	8	Hood data for their 1987 effort to estimate water needs for hosting the Superconducting	typo error
54	9	Supercollider Project. They also rely on	typo error
55	2	information about discharge or recharge of	typo error
55	20	, I don't know which question. I said in '87,	typo error
55	24	,their proposal planning of hosting SSC project	typo error
56	9	Oh, well, that's the conclusion ever since	typo error
61	10	Current amount?	typo error
61	14	"Current."	typo error
62	14	feet per year over 42 years life of	typo error
63	6	I've read a report. It said in	typo error
63	7	Dugway, there is a public water supply.	typo error
63	8	location was sampled for water elevation changes.	typo error

[continued on next page]

PAGE-LINE		CHANGE/CORRECTION	REASON
63	9	is significantly lowered, and reduced	typo error
63	21	5,000 acre-feet.	typo error
64	2	, based on my technical experience in this area	typo error
64	3	One of the authors is a hydrologist, the other is a chemist	typo error
67	21	textbook expressed in the area over time unit	typo error
72	9	I thought the assumption is	typo error
72	11	would say this is the same as what you just	typo error

CONDENSED TRANSCRIPT

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	) Docket No. 72-22
	) ASLPB No. 97-732-02-ISFSI
PRIVATE FUEL STORAGE L.L.C.	) DEPOSITION OF:
(Private Fuel Storage Facility)	) **DONALD WAYNE LEWIS**
	) **(Utah Contention O)**

Thursday, April 19, 2001 - 3:14 p.m.

Location: Parsons, Behle & Latimer

201 S. Main, #1800

Salt Lake City, Utah

Reporter: Vicky McDaniel

Notary Public in and for the State of Utah

SHEET 1 PAGE 1

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A P P E A R A N C E S

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Washington, D.C. 20555

I N D E X

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P R O C E E D I N G S

DONALD WAYNE LEWIS,
having first been duly sworn to tell the truth,
was examined and testified as follows:

EXAMINATION

BY MR. SEEL:
Q. Would you please state your full name for the record.
A. Donald Wayne Lewis.
Q. Mr. Lewis, my name is Kurt Seel. I'm an assistant attorney general with the State of Utah, and we're here in the matter of Private Fuel Storage license application before the NRC for a spent fuel storage facility located in Skull Valley. This is Contention O. Are you familiar with Contention O?
A. Yes, I am.
Q. And it is my understanding that you've been named as an expert by PFS in regards to certain aspects of Contention O.
A. That is correct.
Q. Would you please describe to me those aspects?
A. It would be the portions of Contention O where there is a concern of source material contaminating the hydrology.

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Q. Would that include the retention pond, retention basin? I'm not sure how you refer to it. The overflow surface runoff retention pond?
A. It could, depending on specifically what you're questioning.
Q. But you would be the person to provide expert testimony on the construction of the pond, the design construction, I guess?
A. No, I'm -- it would be the civil people that would actually design the pond. I would be more involved in what kind of -- if any contaminants would get into the pond.
Q. When you refer to the civil people, who would those be? Are they people that you supervise?
A. No. It would be people that would be my peers, that would be doing the civil design. You're talking about actual design of the pond itself, the way it's laid out?
Q. Correct. Whether it's going to use native soils, an artificial liner, those sorts of characteristics of a pond. That wouldn't be something that you could describe to me?
A. No, I cannot.
MR. GAUKLER: Let's take a break for a second.

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(Witness and counsel consult outside the room.)
A. I need to clarify my last answer.
Q. Go ahead.
A. Okay. When you talk about in terms of design, I'm not the one that designs, you know, makes the size of it or determines what type of fill materials need to be in the detention pond, you know, on the edges and stuff. I can talk to you about what type of percolation we have there, I can talk to you about whether it needs a liner or not, those kind of things. But I don't actually lay the detention pond out.
Q. Okay. I think I understand the difference, but as we get into this, if we get into an area where you don't have personal knowledge or an area you're not an expert in, I assume that you will -- your attorney will bring that to my attention.
A. Yeah.
Q. Are you familiar generally -- well, do you know if a design has actually been -- a specific design has actually been generated, or whether there's only what we call engineering specs? Basically, our goal is to have a pond that will satisfy a 100-year flood located in such-and-such an area, but nothing's actually been drawn on a piece of paper yet?
A. Yes.

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Q. Something has been drawn on a --
A. It has been designed.
Q. Has the state been given a copy of that, do you know?
A. I believe so.
MR. GAUKLER: I believe you've gotten what we had as a preliminary design for sure. I don't know if there's been any subsequent design or not, if we need to update or not, but I'll check.
Q. Do you know if the pond is going to be using native soils? Is there any synthetic liner that's going to be placed in the pond?
A. There will not be any synthetic liners in the pond. I believe it is using native soils, but if they are supplementing those with structural fills, I wouldn't know.
Q. Do you know if they're going to be doing anything to the native soils that would change their percolation characteristics?
A. I'm not aware of any, no.
Q. That's possible that they will be doing something like that?
A. That's actually out of my expertise, but most likely they -- you know, there's nothing structurally that they have to support there, so there

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is no need why they would have to put in like in the center of the bottom of the pond. There would be no reason to add fills that could inhibit percolation. The dike area around the detention pond, they might have to add something there simply to hold the pond together.
Q. So as far as you know, the permeability or percolation characteristics, and if those terms aren't clear to you and you want me to explain more, the permeability or percolation characteristics of the soils in the pond will be essentially the same as the native soils that are located there today?
A. At this point I believe that's what the design is, yes.
Q. Are you also responsible for the design of the septic system?
A. Yes.
Q. I understand it's a wastewater disposal system of some kind. Is that what it is?
A. That would be its technical name.
Q. And there's only one, there's not more than one wastewater disposal system?
A. Well, the wastewater disposal system is just the disposal of wastewater at the facility. In actual design, there are two septic systems that are required to do that. Simply because of the proximity of the

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site, there is one septic system for the Canister Transfer Building and Security Building, and then there's another septic system for the Admin and O&M Building.
Q. They will have two different waste streams going into each of the septic systems?
A. They're -- see, the buildings are separated by, you know, more than a quarter of a mile. So it wouldn't be reasonable to lump them together. So there is one waste stream for the O&M and Admin Building that goes to a septic tank that goes to a drain field, and then quarter of a mile or half a mile away up to the north of that, there is a second one that drains waste from the Canister Transfer Building and Security Building.
Q. Will they be designed to operate the same?
A. In function?
Q. Yes.
A. Yes.
Q. Could you explain how they designed it, just in general terms?
A. In general, they're a gravity-based system that carries the sewage from your toilets, your sinks, basically your restroom, any lunchroom facilities, like a kitchen sink, for example. It carries all those by

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gravity down to a septic tank, and the septic tank allows for the separation between solids and liquids, and the liquids drain out into several perforated pipes into a drain field that allows leaching into the soil.
Q. What are the waste streams -- let's take the first septic system, either one. I don't care which one you choose. Would you please describe the waste stream that PFS intends to put into the septic system?
A. **The only wastes that are going to be in the septic systems are from restrooms and the break room sink.**
Q. What would normally be called domestic waste? I mean, I don't want to put words in your mouth, but human excrement type waste?
A. **Yes.**
Q. Biological waste?
A. **Yes, biological.**
Q. Are there any other waste streams from the lab or from any other source on site that PFS intends to put into the septic systems?
A. **No.**
Q. You mentioned that the waste waters would go into a perforated pipe in a drain field.
A. **Uh-huh.**
Q. And then the waste waters would -- I forget

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the term you used, but I thought it was leach or --
A. **Yeah, leach or percolate into the soil.**
Q. Have you done any tests to determine whether the soils are porous enough or permeable enough to accept the volume of wastewater that you intend to run through the system?
A. **We haven't done any tests, but that's what your perc test determines. And typically any soil, practically, can provide that. It just depends -- it just -- that would in turn determine how large your drain field has to be. So if it has poor percolation, then you have to have a larger drain field, you know, more pipe to distribute.**
Q. What would be the ultimate destination of the wastewater that's put into the leach field? I can explain further if you want. But the groundwater will end up on the surface of the ground or some other location.
A. **The drain field is actually below the surface of the ground, so it's not going to attribute to any surface water. And --**
Q. Let me stop you there for just a second. So none of the water from -- that's in the leach field is going to be brought back up to the surface somehow?
A. **Not unless it's pumped up, no.**

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Q. I'm just trying to -- I just want to, you know, as we're going through make clear.
A. **Yeah.**
Q. I'm trying to find where the wastewater will ultimately end up.
A. **Okay.**
Q. So it's not going to be coming back up to the surface, assuming it operates properly?
A. **Correct.**
Q. What are the other options for this water to end up?
A. **Well, as it percolates into the ground, as we -- there is a certain minimum amount of soil that is required between that and the groundwater in order to provide self-water treatment, if you will, natural treatment of the --**
Q. Filtration of the waters as they migrate downward?
A. **Uh-huh. But it -- you know, it's -- because of the groundwater elevation, it's not going to get that. It's only going to percolate just a few inches into the soil.**
Q. How long is this wastewater system planning to be operational?
A. **For the life of the facility.**

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Q. Would that be 40 years, then?
A. **Yeah.**
Q. You plan to discharge wastewater into the system for a period of 40 years; the water isn't going to come back up to the surface, and it's only going to migrate a couple inches into the soil around the site, around the leach field?
A. **Well, it will be absorbed into the soil.**
Q. Won't it keep absorbing into the soil and migrating further and further from the leach field over the forty-year period?
A. **You mean down into the soil?**
Q. Well, it's not coming to the surface, so it needs to have to go somewhere, I assume. You've got 40 years of discharge going to the subsurface. Eventually you're going to fill up the pore space. Or have you done a --
A. **Just like rain, if it could over -- you know, that molecule of water could eventually find its way, finally, several feet down to groundwater, or it could -- you know, oftentimes the water underneath the ground travels with the slope of the terrain.**
Q. And there's only so much pore space under the ground that you can put water into, and once you fill up that pore space it has to expand into more pore

space; is that correct? I'm just trying to --
A. You mean until the ground becomes saturated?
Q. Saturated, in which case the water has to migrate further out as you continue to put more water into the system?
A. Yeah, but there are other forces that take place. You have evaporation that dries the soil above the ground, you know, so...
Q. Okay, I guess we're getting back to the ultimate destination. So some of that water will come back up to the surface in some form, be it evaporation or something else?
A. Well, the water -- most likely it's going to travel along the slope of the ground. But what you're implying is that the ground is going to saturate around these pipes, and eventually it's going to be basically flooded around all these pipes. And that won't happen, because there are other effects that go on in the soil that would evaporate the water away. Or not necessarily evaporate the water away. I mean, it's going to absorb the water.
Q. I guess I'm trying to figure out the ultimate location for this water, be it the groundwater table, back to the surface, or put into what's sometimes called storage in the pore space of the soil. If

there's another option where this water can go, let me know if there's a fourth or fifth option for where this 40 years of wastewater can ultimately end up. Are those the three options: groundwater, storage in the pore spaces of the soil, and back to the surface?
MR. GAUKLER: In back to the surface, are you including evaporation?
Q. Evaporation, transpiration. Somehow it's leaving the system back to the surface. Are there any other options than those three?
A. Water -- it typically is going to follow the slope of the ground, and it's going to flow in layers along a path that goes down. And that might reach, you know, I don't know. You know, it's going to follow the same path as all the rainwater that travels through there and gets absorbed into the ground.
Q. Will it end up in the groundwater?
A. I don't know. You know, the groundwater is very deep, so I don't know if it's going to end up in the groundwater eventually or not. I don't know what types of -- I don't even know if the soil allows rainwater to eventually percolate into the groundwater. I guess I can't quite answer. You know, I do not know. My expertise does not cover soil conditions enough to where I can answer your specific question.

Q. But the septic system needs to be designed so that it disposes of the water in some manner, otherwise it's going to back up. Is that correct?
A. Uh-huh.
Q. So as part of the proper design for a septic system, don't you need to determine where this water's going to go and how rapidly?
A. Well, that's why you have a minimum distance between the top of the groundwater and where the perforated pipes can be. Ultimately what goes anywhere is just the water. And through filtration, the water that would end up going wherever is going to be purified through natural sources, or through the natural purification process.
Q. That's a different issue, and we can get into that in a minute. I still want to get back to, in order for the system to work properly, don't you have to know where this water's going to end up?
MR. GAUKLER: Objection. I think he's answered that.
If you can add more to what you've already said, go ahead.
MR. SEEL: Are you instructing him not to answer?
MR. GAUKLER: No. I said I think he's

answered it. If he can add more to what he's already said, he's free to go ahead and do that.
A. What I am required to do by the permit requirements is to ensure that I meet certain criteria. None of those criteria deal in determining where the water ultimately goes.
Q. If it comes back up to the surface, wouldn't that be a problem?
A. If the water came back up to the surface?
Q. And it is untreated?
MR. GAUKLER: Objection. I think before we were talking about surface including evaporation, transpiration and evaporation. I think you're probably talking about something different here now. So your question is confusing.
Q. That is correct. I'm talking about the correct operation of a septic system.
A. Uh-huh.
Q. Can you just simply say, we're going to put water in the subsurface and not worry about where it goes, and we know that the system will operate properly?
A. We're going to put water into the system, and we will meet the criteria that for septic tank or septic drain field design which ensures that you have a minimum amount of soil over your perforated pipes and

above the groundwater.
Q. And does that design, does that design presume that the water will migrate downward into the subsurface? Is that how septic systems are designed to operate properly?
A. They are designed so that the amount of soil that occurs between the drain field and, say, groundwater is sufficient enough to purify that water through filtration before it gets to the groundwater.
Q. Let's get to the purification issue. How does a septic system purify -- let's start with the first waste stream, the one you described, these what I'm going to call domestic wastes. But if you have better --
A. That's fine.
Q. You're more familiar with how to describe the waste stream as anticipated at this site. How does the septic system treat or filter or somehow reduce any hazardous characteristics associated with that risk?
A. What the septic drain field does is it provides a large distribution area to distribute the wastewater out into the soil. The system itself does not purify the water, but it allows the -- you know, as it percolates into the ground, then you get natural filtration that purifies the water. And by distributing

that over a large area, we can ensure that no portion of the soil is overloaded.
Q. Does purification -- so the purification treatment is a filtration treatment?
A. Yeah, it's a natural filtration.
Q. Is there any other form of treatment that the system is designed to handle? For example, if things were dissolved in the water, would filtration filter out dissolved constituents in the groundwater, or in the wastewater?
A. Things?
Q. If diesel fuel accidentally got in -- this is theoretical. If diesel fuel accidentally got into the wastewater system, is the septic tank system designed to filter out diesel fuel?
MR. GAUKLER: Objection. There's been no testimony that diesel would get into the septic system.
You can go ahead and answer to the extent you can.
Q. And that's a good point. I'll let you answer.
A. My first line would have been the same. You know, we are designing it so that diesel fuel cannot enter it. But the system is designed for biological wastes.

Q. So it's not designed to treat anything other than biological waste?
A. That is correct.
Q. Is it designed to treat anything that would be dissolved in the wastewater at a molecular level?
A. That was non biological?
Q. Well, even biological. If you had metals dissolved in the water, if you had solvents dissolved in the water, if you had any chemical dissolved in the water, would the septic tank filtration system filter out those molecules?
MR. GAUKLER: Objection, lack of any testimonies of the presence of those things. But you may answer.
A. Again, the facility design is set up to where no solvents or chemicals would be allowed into those, and it -- because it would not treat those particular items. It's not designed to treat those. It's solely designed to treat biological waste.
MR. SEEL: That answers the question.
Do you need a break? I might take a minute to collect my stuff here. Five minutes.
(Recess from 3:40 to 3:48 p.m.)
Q. (BY MR. SEEL) I'd like to step back to the retention pond, and I understand that you have some

expert opinions on that but not necessarily know everything about the pond. Is that correct?
A. That's correct.
Q. I'd like to show you a page, page 4.2-7a from the Environmental Report Revision 7, and I would like you to take a look at this page as much as you need to. Take a look at it. Specifically I'm looking at reference to a percolation rate, but please read as much as you need to put it in context.
A. Okay. "The time for the water that has collected in the basin" --
Q. Oh, I'm sorry. You don't need to read it out loud. I just want you to make sure you've read --
A. Yes.
Q. -- enough of whatever page is there to be familiar with it. There's a sentence that begins "in the unlikely event." Do you see that part?
A. Uh-huh.
Q. Could you read that sentence for me?
A. "In the unlikely event of a 100-year flood, the time for the water that has collected in the basin to be removed by evaporation and ground percolation is approximately 140 days." Keep going?
Q. Please.
A. "Assuming an evaporation rate of 0.32 inches

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per day," reference cited, "and percolation rate of 0.09 inches per day," reference cited.
Q. Do you know, did you assist or supervise in the preparation of this portion of the environmental report?
A. I assisted on it, yes.
Q. Do you know why the percolation rate of 0.09 inches per day was selected?
A. Because the information for that particular locale based on this reference cited that.
Q. This reference is specific to the proposed PFS site?
A. I don't know if it's -- I did not determine what the .09 inches per day is, but based on the information in this book, there are equations that you put in your particular soil characteristics and then you can determine what your percolation rate is.
Q. You didn't go out and do, or a person under you did not go out and perform a test to determine a percolation rate that would be applicable for the site?
A. No, this is based on a book approximation of that percolation rate.
Q. Is this percolation rate consistent with other measurements of the percolation or permeability of soils at the site or in the area that you're aware of?

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A. As far as I'm aware of, yes.
Q. Is this percolation rate consistent with measurements in the test well at the site as far as permeability of the soils at the site?
A. I wouldn't know that.
Q. Do you know whether it's consistent with statements regarding the permeability of surface soils in the area around the site that are elsewhere in the environmental report?
A. I wouldn't know for sure. I didn't determine the numbering.
Q. If there was site-specific information, would that -- regarding the percolation rate of the soils at the site, would you use that in place of a standard reference out of Lambe & Whitman Soil Mechanics, 1969?
A. Yes, we would.
Q. Do you have any plans to do any future tests regarding permeability of soils at the site?
A. Yes, we do.
Q. In regard to the retention pond to specific aspects, or just across the site, sort of in general?
A. I'm not sure. I think it's across the site.
Q. So you wouldn't be going out doing a test to look at the surface soils specifically with the

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retention pond in mind or the septic system in mind or anything else in mind, it would just be a study of the soils at the site?
A. Well, typically those tests are performed in locations where you would -- like the detention pond or the drain field, yes.
Q. But you wouldn't be using a measurement in one location, an assumption in one location and then using a different measurement or different assumption in another location with a different purpose? That was a very poorly worded question and very complex, and why don't we just eliminate that.
MR. GAUKLER: Start over.
Q. (BY MR. SEEL) What I'm trying to get to is, in its documents PFS has referenced different materials, sources for different soil percolation or permeabilities at the site. And they seem to be using different permeability rates depending on whether it's for their aquifer test, whether it's for percolation at the retention pond, whether it's to argue that surface of soils at the site are impermeable enough to prevent downward migrations of spills and releases. What I'm trying to get a handle on is if there is a reason why they seem to be using different permeabilities of these surface soils for different aspects of the facility.

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A. It would determine, or it would be -- it depends on what you're trying to determine. For example, ground surface is going to be different than subsurface depending on the types of soil. What I might have at ground surface at point A could be entirely different than what I have at point B. And so when you determine your percolation, it is based on the types of soil that we have sampled in those areas.
Q. You've collected samples in different areas and performed permeability tests on them?
A. No. What we have done is we've done soil borings of -- all around the site. So we know what types of soils that are there. And so from that you can apply some empirical formulas to get a reasonable estimate of what kind of percolation one could assume at that location.
Q. Is that what was done to come up with this percolation rate of 0.09 inches per day on page 4.2-7 of the Environmental Report Revision 7?
A. Yes, it was.
Q. This number is from a --
A. The percolation rate was determined for the types of soils that would be in the detention pond. So we took soil -- we took soil boring information from the detention pond area and we applied that into the

formulas to determine -- to estimate what kind of percolation you could get, reasonably expect in that area.
Q. And what would those formulas be?
A. I did not do the calculation, but the calculation is based on the formula that was in the Lambe & Whitman soil mechanics book.
Q. And the variability of the soils across the site based on PFS's boring information --
A. Uh-huh.
Q. -- is such that the permeability would vary?
A. It can. I'm not familiar with the soils, all the soil properties across there, but it can vary widely, yeah.
Q. There was future work that you -- stepping back to a prior question. There was work to be proposed in the future or planned to be done in the future regarding soil permeabilities and the like. Is that -- did I understand your -- I can ask the question again, I guess.
Does PFS planned to perform further work at the site regarding soil characteristics, including permeability?
A. PFS is in the process to determine what the permeability is of water from groundwater sources. At

this time there are no percolation tests being performed, but eventually we will perform percolation tests.
Q. Do you know if the percolation rate that is described on page 4.2-7a of Revision 7 of the environmental report, chapter 4, would be sufficient for you to build a properly operating septic system?
A. As I mentioned before, a septic system, the drain field size area that it would take is determined based on the amount of percolation that you get. .09 inches per day is a fairly low percolation. So the drain field size would be large enough so that you could get the amount of percolation that is required to not back up your septic system.
Q. Have you done that analysis yet, how large a drain field that you would need at the site?
A. We've only done a preliminary analysis based on the Uniform Plumbing Code to determine an approximate size. Typically on any type of construction site, that information would be determined by a subcontractor who installs your drain field. They would do a percolation test, and then they would size it to the exact requirements and county criteria at that time.
Q. Part of that rough estimate -- I assume it's a rough estimate, rough calculation?

A. It's an approximation based on the information we have, yes.
Q. What percolation rate did you use? Do you recall?
A. It does not have a percolation rate. What it does, it determines an approximate amount of land, approximate size of the drain field based on the number of people that would be employed at the site.
Q. I'm not sure what -- okay.
A. Explain?
Q. No, that's okay. Is there any other work that's proposed to be done on soil characterization at the site other than this -- I believe you characterized it as more of an aquifer test or a groundwater test?
A. Okay, say that again.
Q. We were talking about future work that's planned to be performed at the site, and we were talking about work that would involve soil characterizations. And I interpreted your answer as that there was some proposed work to be done regarding characterizing a groundwater source or an aquifer source or something like that. Is that correct?
A. We have determined --
Q. Just trying to figure out what future work is planned --

A. What future work?
Q. What future work is planned to be relevant to --
A. Percolation.
Q. Percolation in regards to the septic system and the storm water retention plant.
A. You'd have to do a perc test, physical perc test out there, which we would do.
Q. But it's nothing that's been specifically scheduled; it's just, we will do this sometime in the future? Have you retained a contractor to do that work yet?
A. No.
Q. Oh, thanks.
A. Okay.
MR. SEEL: That's all.
I don't think I have any more questions.

EXAMINATION

BY MR. WEISMAN:
Q. I do have a couple. I just wanted to -- you were talking about a septic system being solely for biological waste.
A. Yes.
Q. Something that was bothering me just a little bit is, you're going to have a housekeeping staff

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that will clean up the restrooms, for instance.
A. Correct.
Q. And they will use some sort of cleaners.
A. Uh-huh.
Q. Where will those cleaners go? Will they also go into the septic system?
A. They could. But cleaners, your typical household cleaners, if you want to call it, janitorial cleaning agents --
Q. Yes.
A. -- are -- what do they call it? Sur --
MR. SEEL: Surfactants.
A. Surfactants.
MR. SEEL: I'm sorry.
A. Surfactants that are -- usually they are -- most often today they're biodegradable. They're not considered hazard waste or hazard materials, and so...
Q. So the septic system is designed to handle those products also?
A. Right.
Q. Okay. I guess my other question is, you mentioned that PFS took some soil borings on the site to determine what kind of -- what the soils were. How deep did those soil borings go?
A. They range. They're all listed in chapter 2

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of the Safety Analysis Report. Some of them were shallow for just determining what kind of soil conditions we had. Some of them are deeper so that we could determine what the groundwater level was at various points around the site. I do not know exactly how deep. You know, some of them were in excess of a hundred feet, some of them were less.
MR. WEISMAN: All right. I don't think I have anything else.
MR. GAUKLER: Let's take a break.
(Recess from 4:05 to 4:08 p.m.)
MR. GAUKLER: Nothing.
(Deposition was concluded at 4:08 p.m.)
* * *

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C E R T I F I C A T E

State of Utah)
ss.
County of Utah)

I, Vicky McDaniel, a Registered Merit Reporter and Notary Public in and for the State of Utah, do hereby certify:

That the deposition of Donald Wayne Lewis, the witness in the foregoing deposition named, was taken on April 19, 2001, and that said witness was by me, before examination, duly sworn to testify the truth, the whole truth, and nothing but the truth in said cause;

That the testimony of said witness was reported by me in stenotype and thereafter transcribed into typewriting and that a full, true, and correct transcription of said testimony so taken and transcribed is set forth in the preceding pages.

I further certify that I am not of kin or otherwise associated with any of the parties of said cause of action and that I am not interested in the event thereof.

WITNESS MY HAND and OFFICIAL SEAL at Saratoga Springs, Utah, this 23rd day of April, 2001.

Vicky McDaniel, RMR
Utah License No. 87-108580

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Case: In the Matter of Private Fuel Storage
Case No.: ASLPB No. 97-732-02-ISFSI
Reporter: Vicky McDaniel
Date taken: April 19, 2001

WITNESS CERTIFICATE

I, Donald Wayne Lewis, HEREBY DECLARE:

That I am the witness referred to in the foregoing testimony; that I have read the transcript and know the contents thereof; that with these corrections I have noted, this transcript truly and accurately reflects my testimony.

PAGE-LINE CHANGE/CORRECTION REASON

_____ No corrections were made.

Donald Wayne Lewis

SUBSCRIBED and SWORN to at ______, this ______ day of ______, 2001.

Notary Public

Case: In the Matter of Private Fuel Storage
Case No.: ASLPB No. 97-732-02-ISFSI
Reporter: Vicky McDaniel
Date taken: April 19, 2001

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PAGE-LINE	**CHANGE/CORRECTION**	**REASON**

✓ **No corrections were made.**

[signature]
Donald Wayne Lewis

SUBSCRIBED and SWORN to at Greenwood Village, Colorado, this 31st day of May, 2001.

My Commission Expires 11/05/2001

[signature] C. Lynn Schwartz
Notary Public

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII

IN THE MATTER OF Skull Valley Band of Goshute Indians 2480 South Main Street, Suite 110 Salt Lake City, Utah 84115 Skull Valley Water System PWS ID #: 4990008 Respondent Proceedings under Section 1431(a) of the Safe Drinking Water Act, 42 U.S.C. §300i(a)	SECOND AMENDED ADMINISTRATIVE ORDER Docket No.SDWA-8-2001-03

STATUTORY AUTHORITY

The following Findings are made and Order issued under the authority vested in the Administrator of the U.S. Environmental Protection Agency (EPA) by Section 1431 of the Safe Drinking Water Act (the Act), 42 U.S.C. §300i, as properly delegated to the Assistant Regional Administrator of the Office of Enforcement, Compliance and Environmental Justice, EPA Region VIII.

JURISDICTION

1. EPA has jurisdiction to issue emergency orders pursuant to the emergency powers provision of the Act, Section 1431, 42 U.S.C. §300i.
2. EPA has primary enforcement responsibility for the Act in Indian country.

FINDINGS

1. The Skull Valley Band of Goshute Indians (Respondent), is a federally-recognized Tribe, and therefore a "person", for federal enforcement, within the meaning of 40 CFR §141.2.

2. Respondent owns and/or operates the Skull Valley Water System located in Tooele County, Utah for the provision to the public of piped water for human consumption.

3. Respondent's water system serves an average of at least 25 individuals daily at least 60 days a year and is therefore a "public water system" within the meaning of Section 1401(4) of the Act, 42 U.S.C. §300f(4), and a "community water system" within the meaning of 40 CFR §141.2.

4. Respondent owns and/or operates a public water system and is therefore a "supplier of water" within the meaning of Section 1401(5) of the Act, 42 U.S.C. §300f(5) and 40 CFR §141.2. Respondent is therefore subject to the requirements of Part B of the Act, 42 U.S.C. §300g, and its implementing regulations, 40 CFR Part 141.

5. Respondent operates a system that is supplied by a surface water source diverted via PVC piping from a creek flowing out of the Indian Hickman Canyon to a 20,000 gallon water storage tank, then into the distribution system of the Skull Valley Community,

consisting of 12 homes and the Pony Express Store, for a total of 13 service connections, serving approximately 30 persons per day, therefore meeting the definition of public water supply as defined at 40 CFR §141.2.

6. 40 CFR §141.63(b) imposes and defines the acute Maximum Contaminate Level (MCL) for total coliform bacteria as a fecal coliform positive or E. coli positive repeat sample, or any total coliform positive repeat sample following a fecal coliform positive or E. coli positive routine sample. EPA has determined, based on water quality sampling of the surface water, that a threat to human health is present in the drinking water. The sampling results include, but are not limited to, the following: (a) total coliform and fecal coliform positive water quality monitoring results collected on July 15, 1999 by the Tribe, (b) total coliform and E. coli positive water quality monitoring results collected on July 31, 2000 by the Indian Health Service (IHS), (c) total coliform positive water quality monitoring results collected on December 1, 2000 by EPA, and (e) documentation concerning the use of unfiltered, un-disinfected surface water collected during EPA's sanitary survey conducted November 7, 2000, that the present bacteriological quality of the Skull Valley Water System drinking water may present an

imminent and substantial endangerment to the health of persons. Furthermore, the monitoring results in July, 1999 and July, 2000 exceeded the acute MCL for total coliform bacteria, in violation of 40 CFR §141.63(b).

7. Fecal coliform and E. Coli are bacteria whose presence indicate that the water may be contaminated with human or animal waste. Microbes in this waste can cause diarrhea, cramps, nausea, headaches, or other symptoms. These bacteria can pose a special health risk to infants, young children, and people with severely compromised immune systems.

8. This Order and the requirements set forth herein are necessary to ensure adequate protection of public health based on EPA's enforcement responsibility for the Act in Indian country.

9. To date, the State of Utah has not acted to protect the health of the individuals served by the Water System because it is not authorized to do so under the Act.

10. Local authorities have not acted to protect public health.

11. The Tribal government has not acted to protect public health.

<u>EMERGENCY ADMINISTRATIVE ORDER</u>

1. Respondent shall continue to provide notice in the affected area to the public of the E. coli violation and the requirement to boil water. This public notice

shall be posted in conspicuous locations throughout the area served by the water system; and hand delivered to persons served by the water system. The notice must remain in place until written notification is received by EPA. Upon the effective date of this Order, Respondent shall comply with the publication notification requirements at 40 CFR § 141.201 et seq. following any future NPDWR violation. Respondent shall submit a copy of the public notice to EPA within 10 days of completion of the public notice, as required by 40 CFR § 141.31(d). The public notice shall include the following information:

a. The requirements specified in 40 CFR §141.205 include:

(1) A description of the violation, including the contaminant of concern, and the contaminant level;

(2) When the violation or situation occurred;

(3) Any potential adverse health effects from the violation or situation (see section b. below);

(4) The population at risk, including subpopulations particularly vulnerable if exposed to the contaminant in their drinking water;

(5) Whether alternative water supplies should be

used (see section b. below);

(6) What actions consumers should take, including when they should seek medical help, if known (see section b. below);

(7) What the system is doing to correct the violation or situation;

(8) When the water system expects to return to compliance or resolve the situation;

(9) The name, business address, and phone number of the water system owner, operator, or designee of the public water system as a source of additional information concerning the notice; and

(10) A statement to encourage the notice recipients to distribute the public notice to other persons served.

b. Mandatory health effects language as specified in 40 CFR §141.205(d)(1), Appendix B to Subpart Q of Part 141. This language is as follows:

Inadequate treated water may contain disease-causing organisms. These organisms include bacteria, viruses, and parasites which can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.

Coliforms are bacteria that are naturally present in the environment and are used as an indicator that other, potentially-harmful, bacteria may be present. Coliforms were found in more samples than allowed and this was a warning of potential problems.

Fecal coliforms and E. Coli are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause short-term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms. They may pose a special health risk for infants, young children, and people with severely compromised immune systems.

"UNTIL FURTHER NOTIFIED, ALL WATER USED FOR DRINKING, BRUSHING TEETH, COOKING, MAKING ICE, WASHING DISHES, OR USED FOR HUMAN CONSUMPTION, ETC., SHALL BE BOILED FOR AT LEAST ONE (1) MINUTE, AT A ROLLING BOIL, BEFORE USE, ALL STORED WATER, DRINK OR ICE MADE RECENTLY FROM THIS SUPPLY SHALL BE DISCARDED."

2. Respondent must continue to provide the boil water notice until EPA Region VIII provides written notice to discontinue.

3. Respondent shall provide a continuous supply of bottled drinking water from a licensed bottled water distributor to all water users of the Skull Valley Water System, as needed, until:

a) Respondent installs filtration and continuous disinfection equipment designed to meet all the treatment requirements for giardia and virus removal and/or inactivation consistent with the requirements of the Surface Water Treatment Rule (SWTR), and thoroughly cleans, flushes, and disinfects the entire water system including all service lines and storage tanks;

or

b) Respondent makes all improvements to the previously used ground water source necessary to bring this water source back in service, including: thorough disinfection of the entire water system, cleaning and flushing of all service lines and storage tanks, and permanently and physically disconnecting all connections to the surface water source.

4. Within 5 days of the effective date of this Emergency Administrative Order, Respondent shall certify, in writing, that it intends to comply with all provisions of this Order. This response shall include a statement as to which option, 3(a) or 3(b) the Tribe intends to pursue and include a schedule for implementation of the selected option. Thereafter, Respondent shall submit monthly progress reports to EPA indicating progress toward completion of the selected option. Progress reports shall be submitted to the EPA contact indicated below and each month postmarked no later than the 15th of each month.

5. If Respondent selects option 3(a), the first required monthly progress report shall include an engineering assessment, conducted by a qualified individual, of the feasibility of utilizing the Indian Hickman Creek as a permanent water source including a discussion of the following elements: flow and capacity of the Indian Hickman Creek; water quality of the Indian Hickman

Creek; and a preliminary economic evaluation of the costs associated with the purchase, installation, and long-term operation and maintenance of filtration and disinfection treatment of the proposed surface water source. All improvements necessary to meet the treatment requirements for giardia and virus removal and/or inactivation consistent with the requirements of the Surface Water Treatment Rule (SWTR) shall be completed not more than one year after the original effective date of the Emergency Order, November 9, 2000.

6. If Respondent selects option 3(b), all improvements to the ground water system, including thorough disinfection, cleaning and flushing of the entire system, and physical removal of all existing connections to the surface water source, necessary prior to placing the ground water well back in service must be completed May 31, 2001.

7. Upon the effective date of this Emergency Order, Respondent shall comply with the National Primary Drinking Water Regulations (NPDRWs) 40 CFR Part 141, as applicable to community public water systems. Depending on the option selected, 3(a) or 3(b), these requirements may include the filtration and disinfection requirements of the Surface Water Treatment Rule, 40 CFR part 141, Subpart H.

8. Unless otherwise specified, all reports and notifications herein required shall be submitted to:

Greg Gholson
US Environmental Protection Agency
Drinking Water Branch (8ENF-T)
999 18th Street Suite 300
Denver, Colorado 80202-2466
Telephone (800)227-8917 X 6334 or (303) 312-6334

GENERAL PROVISIONS

1. This Order does not constitute a waiver, suspension, or modification of the requirements of 40 CFR §141.1 et seq., or the Safe Drinking Water Act, which remain in full force and effect. Issuance of this Order is not an election by EPA to forgo any civil or criminal action otherwise authorized under the Act.
2. Violation of any term of this Order instituted under Section 1431(a) of the Act, 42 U.S.C. § 300i(a), may subject the Respondent to a civil penalty of not to exceed $15,000 for each day in which such violation occurs or failure to comply continues, assessed by an appropriate U.S. District Court under Section 1431(b) of the Act, 42 U.S.C. § 300i(b).
3. Violation of any requirement of the SDWA or its implementing regulations instituted under Section 1414(b), 42 U.S.C. §300g-3(b), may subject Respondent to a civil penalty of not more than $27,500 per day of violation assessed by an appropriate U.S. District

Court under Section 1414(b) of the Act, 42 U.S.C. §300g-3(b).

4. The effective date of this Order shall be the date of issuance.

Issued this 2nd day of MAY, 2001.

Carol Rushin,
Assistant Regional Administrator
Office of Enforcement, Compliance and Environmental Justice

SANITATION FACILITIES CONSTRUCTION
SKULL VALLEY BAND OF GOSHUTE INDIANS
SKULL VALLEY INDIAN RESERVATION

PROJECT NO. PH 01-S02
PUBLIC LAW 86-121

DATE OF DOCUMENT:
March 2001

INTRODUCTION

The Skull Valley Band of Goshute Indians submitted a Project Proposal to the Indian Health Service (IHS) in February 2001 requesting assistance in improving the Skull Valley water supply on the Skull Valley Indian Reservation. In response to the Project Proposal and because unsafe water supplies and sewage disposal facilities contribute to the high incidence of infectious diseases, the IHS, an Agency of the U.S. Public Health Service, has been authorized under Public Law 86-121 to construct sanitation facilities for American Indians and, therefore, will provide for the design and construction of the facilities described in this Project Scope.

This document contains a preliminary evaluation, recommendations, and cost estimates to provide the Reservation with a safe water source.

EXISTING SANITATION FACILITIES

Water Supply: The Skull Valley community water system consists of a well, 648 feet of 6-inch and approximately 3,850 feet of 4-inch PVC water distribution pipe, and a 13-foot diameter, 22-foot high, 20,000-gallon standpipe. There are four flush valves on the distribution piping.

The well was drilled to 650 feet in 1976 and is 8 inches in diameter. The well is housed in an 8-foot by 8-foot building. Some of the valves on the plumbing tree are inoperable and there is no water meter. The water system does not include disinfection equipment and the pump control system only works in manual mode. When operating, the system serves eight homes and the Pony Express tribal store.

At present, the water system is connected to a nearby irrigation system that has a surface water source. This source is considered non-potable because it is unfiltered and untreated. At this time, the Tribe is providing bottled drinking water to the water system customers.

The Tribe connected the water storage tank to the irrigation system as a temporary water supply when an electrical surge damaged the well pump and phase monitor. The Tribe has since replaced the well pump and damaged phase monitor, but has not brought the well back on line. It is estimated that the pump will produce 25 gallons per minute.

RECOMMENDED FACILITIES

Water Supply: The well will be disinfected and brought back into service. A complete chemical analysis of the well water will be completed to verify that water quality has not deteriorated. The water tank and distribution system will be physically disconnected from the surface water source and disinfected. A hypochlorinator will be installed in the pumphouse to disinfect the well water. The pumphouse plumbing tree will be replaced and the new plumbing tree will include a water meter.

Other pumphouse improvements will include a new door and a new light fixture. The chain-link fence around the pumphouse will be repaired and the well pump controls will be modified for automatic operation to keep the tank full, and to run the hypochlorinator when the well pump is running. As funding allows, some of the flush valves will be replaced with fire hydrants.

It is also proposed under this project that utility management training, disinfection equipment training, and operation and maintenance training be provided for the Tribal utility organization.

ESTIMATED COST OF RECOMMENDED FACILITIES

WATER SUPPLY	Quantity	Unit Cost	Total Cost
1. Well & system disinfection	1 JOB	L.S.	$ 3,500
2. Disconnect surface source	1 JOB	L.S.	1,000
3. Water quality analysis	1 JOB	L.S.	2,500
4. Hypochlorinator	1 EA	$2,500	2,500
5. Pumphouse/fence upgrades	1 JOB	L.S.	3,000
6. Pump control upgrades	1 JOB	L.S.	6,000
7. Fire hydrants	3 EA	$2,500	7,500
SUBTOTAL			$26,000
+10% TECHNICAL SUPPORT			2,600
+5% CONTINGENCIES			1,300
TOTAL			$29,900
ROUNDED TO THE NEAREST THOUSAND			$30,000

Total Cost Per Unit = $30,000 ÷ 8 = $3,750

OPERATION AND MAINTENANCE (O&M)

The Tribe will be responsible for O&M upon completion of the project. Operation and maintenance costs are paid for out of the Tribe's general fund. The Tribe will receive O&M training during the project and following the project.

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STONE & WEBSTER, INC.

CALCULATION SHEET

5010.64

CLIENT & PROJECT **PRIVATE FUEL STORAGE, LLC – PFSF**	PAGE 1 OF 8 + 8 pages of attachments
CALCULATION TITLE **DETERMINATION OF AQUIFER PERMEABILITY FROM CONSTANT HEAD TEST AND ESTIMATION OF RADIUS OF INFLUENCE FOR THE PROPOSED WATER WELL**	QA CATEGORY (✓) ☐ I NUCLEAR SAFETY RELATED ☐ II ☑ III ☐ (other)

CALCULATION IDENTIFICATION NUMBER

JOB ORDER NO.	DISCIPLINE	CURRENT CALC NO	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
05996.02	G(B)	15		N/A

APPROVALS - SIGNATURE & DATE

PREPARER(S)/DATE(S)	REVIEWER(S)/DATES(S)	INDEPENDENT REVIEWER(S)/DATE(S)	REV. NO. OR NEW CALC NO.	SUPERSEDES CALC NO. OR REV NO.	CONFIRMATION REQUIRED ☑ YES	NO
Original signed by: DLAloysius / 4-22-99	Original signed by: JCShiau / 4-22-99	Original signed by: JCShiau / 4-22-99	0	N/A		✓
Original signed by: TYChang / 12-16-99	Original signed by: JCShiau / 12-16-99		1	0		✓
Thomas H. Chang TY Chang /3-27-01	J.C. Shiau JC Shiau /3-27-01		2	1	✓	

DISTRIBUTION

GROUP	NAME & LOCATION	COPY SENT (✓)	GROUP	NAME & LOCATION	COPY SENT (✓)
RECORDS MGT. FILES (OR FIRE FILE IF NONE)	JOB BOOK R4.2G	ORIG			
	FIRE FILE	☑			
Geotechnical	PJTrudeau 100/3	☑			

STONE & WEBSTER, INC.

5010.65 CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				PAGE 5
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
05996.02	G(B)	15-2	N/A	

As presented on Pages 28-31 of Calculation 05996.01-P-002, Rev. 5 (copies are included in Attachment B), the maximum anticipated withdrawal rate for the proposed PFSF water well will be approximately 10,000 gal/day (6.94 gpm or 11.2 ac-ft/yr) during the first nine months of operation and will decrease thereafter. Over a 42-year period (Year 2000 through 2042), the average withdrawal rate from the well will be approximately 2,040 gal/day (1.42 gpm or 2.29 acre-ft/yr). It should be noted that six existing wells within five miles of the site have water rights ranging from approximately 11 to 1,600 acre-ft/yr (refer to Geotechnical Sketch 05996.02-GSK-B-27-1). This information and additional details on these wells are included in the response to comments on Nuclear Regulatory Commission RAI No.1, Safety Analysis Report (SAR), Question 2-3.

HYDRAULIC CALCULATIONS

Aquifer Permeability

Aquifer permeability was estimated using the following equation (CANMET, 1977):

$$K = (5.833 / \pi L)\ (Q / h)\ (10^{-5})$$

where,

- K = permeability (meters/sec)
- L = length of permeable test section (meters)
- Q = water flow rate into well (liters/min)
- h = height of water above static, equilibrium level (meters)

Input parameters to the equation, which were collected during the field test (see Attachment A), included:

- L = 152.0 ft - 125.5 ft = 26.5 feet or 8.1 meters = total length of sand pack around and above the well screen. (Note: the total length of the sand pack was used as opposed to the screen length since the sand pack would have a permeability at least two orders of magnitude greater than the surrounding native deposits.)
- Q = 44.9 gallons over 20 minutes = 2.25 gpm or 8.50 L/min.
- h = 124.5 ft + 2.8 ft (casing height above grade) = 127.3 feet or 38.8 meters.

The above numbers yield a permeability of 5.0×10^{-7} m/sec (5.0×10^{-5} cm/sec or 0.142 ft/day).

The above permeability result compares favorably with a regional study of the adjacent Bonneville Region (Bedinger et al., 1990) that indicated that the fine-grained basin fill deposits had a permeability of approximately 2.3×10^{-5} cm/sec.

United States
Environmental Protection
Agency

Technology Transfer EPA/625/4-89/022

EPA

Seminar Publication

Requirements for Hazardous Waste Landfill Design, Construction, and Closure

Table 1-5. Cover Design

Vegetative Cover
- Thickness ≥ 2 ft
- Minimal erosion and maintenance (e.g., fertilization, irrigation)
- Vegetative root growth not to extend below 2 ft
- Final top slope between 3 and 5% after settlement or subsidence. Slopes greater than 5% not to exceed 2.0 tons/acre erosion (USDA Universal Soil Loss Equation)
- Surface drainage system capable of conducting run-off across cap without rills and gullies

Drainage Layer Design
- Thickness ≥ 1 ft
- Saturated hydraulic conductivity ≥ 10^{-3} cm/sec
- Bottom slope ≥ 2% (after settlement/subsidence)
- Overlain by graded granular or synthetic filter to prevent clogging
- Allow lateral flow and discharge of liquids

Low Permeability Liner Design

FML Component:
- Thickness ≥ 20 mil
- Final upper slope ≥ 2% (after settlement)
- Located wholly below the average depth of frost penetration in the area

Soil Component:
- Thickness ≥2 ft
- Saturated hydraulic conductivity ≤ 1 x 10^{-7} cm/sec
- Installed in 6-in lifts

- Summary of CQA activities for each landfill component.

This report must be signed by a registered professional engineer or the equivalent, the CQA officer, the design engineer, and the owner/operator to ensure that all parties are satisfied with the design and construction of the landfill. EPA will review selected CQA reports.

The CQA plan covers all components of landfill construction, including foundations, liners, dikes, leachate collection and removal systems, and final cover. According to the proposed rule (May 1987), EPA also may require field permeability testing of soils on a test fill constructed prior to construction of the landfill to verify that the final soil liner will meet the permeability standards of 10^{-7} cm/sec. This requirement, however, will not preclude the use of laboratory permeability tests and other tests (correlated to the field permeability tests) to verify that the soil liner will, as installed, have a permeability of 10^{-7} cm/sec.

Summary of Minimum Technology Requirements

EPA's minimum technology guidance and regulations for new hazardous waste land disposal facilities emphasize the importance of proper design and construction in the performance of the facility. The current trend in the regulatory programs is to develop standards and recommend designs based on the current state-of-the-art technology. Innovations in technology are, therefore, welcomed by EPA and are taken into account when developing these regulations and guidance.

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2. LINER DESIGN: CLAY LINERS

Introduction

This chapter discusses soil liners and their use in hazardous waste landfills. The chapter focuses primarily on hydraulic conductivity testing, both in the laboratory and in the field. It also covers materials used to construct soil liners, mechanisms of contaminant transport through soil liners, and the effects of chemicals and waste leachates on compacted soil liners.

Materials

Clay

Clay is the most important component of soil liners because the clay fraction of the soil ensures low hydraulic conductivity. In the United States,however, there is some ambiguity in defining the term "clay" because two soil classification systems are widely used. One system, published by the American Society of Testing and Materials (ASTM), is used predominantly by civil engineers. The other, the U.S. Department of Agriculture's (USDA's) soil classification system, is used primarily by soil scientists, agronomists, and soil physicists.

The distinction between various particle sizes differs between ASTM and USDA soil classification systems (see Table 2-1). In the ASTM system, for example sand-sized particles are defined as those able to pass a No. 4 sieve but not able to pass a No. 200 sieve, fixing a grain size of between 0.075 millimeters (mm) and 4.74 mm. The USDA soil classification system specifies a grain size for sand between 0.050 mm and 2 mm.

The USDA classification system is based entirely upon grain size and uses a three-part diagram to classify all soils (see Figure 2-1). The ASTM system, however, does not have a grain size criterion for classifications of clay; clay is distinguished from silt entirely upon plasticity criteria. The ASTM classification system uses a plasticity diagram and a sloping line, called the "A" line (see Figure 2-2) to distinguish between silt and clay. Soils whose data points plot above the A line on this classification chart are, by definition, clay soils with prefixes C in Unified Soil Classification System symbol. Soils whose data points plot below the A line are classified as silts.

Table 2-1. ASTM and USDA Soil Classification by Grain Size

	ASTM	USDA
Gravel		
	4.74 (No. 4 Sieve)	2
Sand		
	0.075 (No. 200 Sieve)	0.050
Silt		
	None (Plasticity Criterion)	0.002
Clay		

EPA requires that soil liners be built so that the hydraulic conductivity is equal to or less than 1 x 10^{-7} cm/sec. To meet this requirement, certain characteristics of soil materials should be met. First, the soil should have at least 20 percent fines (fine silt and clay sized particles). Some soils with less than 20 percent fines will have hydraulic conductivities below 10^{-7} cm/sec, but at such low fines content, the required hydraulic conductivity value is much harder to meet.

Second, plasticity index (PI) should be greater than 10 percent. Soils with very high PI, greater than 30 to 40 percent, are sticky and, therefore, difficult to work with in the field. When high PI soils are dry, they form hard clumps that are difficult to break down during compaction. On the Gulf Coast of Texas, for example, clay soils are predominantly highly plastic clays and require additional processing during construction. Figure 2-3 represents a collection of data from the University of Texas laboratory in Austin showing hydraulic conductivity as a function of plasticity index. Each data point represents a separate soil compacted in the

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QUALITY ASSURANCE AND QUALITY CONTROL FOR WASTE CONTAINMENT FACILITIES

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2.2.1.4 Maximum Particle Size

The maximum particle size is important because: (1) cobbles or large stones can interfere with compaction, and (2) if a geomembrane is placed on top of the compacted soil liner, oversized particles can damage the geomembrane. Construction specifications may stipulate the maximum allowable particle size, which is usually between 25 and 50 mm (1 to 2 in.) for compaction considerations but which may be much less for protection against puncture of an adjacent geomembrane. If a geomembrane is to be placed on the soil liner, only the upper lift of the soil liner is relevant in terms of protection against puncture. Construction specifications may place one set of restrictions on all lifts of soil and place more stringent requirements on the upper lift to protect the geomembrane from puncture. Sieve analyses on small samples will not usually lead to detection of an occasional piece of oversized material. Observations by attentive CQC and CQA personnel are the most effective way to ensure that oversized materials have been removed. Oversized materials are particularly critical for the top lift of a soil liner if a geomembrane is to be placed on the soil liner to form a composite geomembrane/soil liner.

2.2.1.5 Clay Content and Activity

The clay content of the soil may be defined in several ways but it is usually considered to be the percentage of soil that has an equivalent particle diameter smaller than 0.005 or 0.002 mm, with 0.002 mm being the much more common definition. The clay content is measured by sedimentation analysis (ASTM D-422). Some construction specifications specify a minimum clay content but many do not.

A parameter that is sometimes useful is the activity, A, of the soil, which is defined as the plasticity index (expressed as a percentage) divided by the percentage of clay (< 0.002 mm) in the soil. A high activity (> 1) indicates that expandable clay minerals such as montmorillonite are present. Lambe and Whitman (1969) report that the activities of kaolinite, illite, and montmorillonite (three common clay minerals) are 0.38, 0.9, and 7.2, respectively. Activities for naturally occurring clay liner materials, which contain a mix of minerals, is frequently in the range of $0.5 \leq A \leq 1$.

Benson et al. (1992) related hydraulic conductivity to clay content (defined as particles < 0.002 mm) and reported the correlation shown in Fig. 2.11. The data suggest that soils must have at least 10% to 20% clay in order to be capable of being compacted to a hydraulic conductivity $\leq 1 \times 10^{-7}$ cm/s. However, Benson et al. (1992) also found that clay content correlated closely with plasticity index (Fig. 2.12). Soils with PI >10% will generally contain at least 10% to 20% clay.

It is recommended that construction specification writers and regulation drafters indirectly account for clay content by requiring the soil to have an adequate percentage of fines and a suitably large plasticity index -- by necessity the soil will have an adequate amount of clay.

2.2.1.6 Clod Size

The term *clod* refers to chunks of cohesive soil. The maximum size of clods may be specified in the construction specifications. Clod size is very important for dry, hard, clay-rich soils (Benson and Daniel, 1990). These materials generally must be broken down into small clods in order to be properly hydrated, remolded, and compacted. Clod size is less important for wet soils -- soft, wet clods can usually be remolded into a homogeneous, low-hydraulic-conductivity mass with a reasonable compactive effort.

Environmental Investigations Standard Operating Procedures and Quality Assurance Manual

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The following development procedures are generally used to develop monitoring wells:

1. Pumping;
2. Compressed air (with the appropriate organic filter system);
3. Bailing;
4. Surging;
5. Backwashing ("rawhiding"); and
6. Jetting.

These developmental procedures can be used, individually or in combination, in order to achieve the most effective well development. Except when compressed air is being used for well development, sampling can be initiated as soon as the ground water has re-equilibrated, is free of visible sediment, and the water quality parameters have stabilized. Since site conditions vary, even between wells, a general rule-of-thumb is to wait 24 hours after development to sample a new monitoring well. Wells developed with compressed air normally should not be sampled for at least 48 hours after development so that the formation can dispel the compressed air and restabilize to pre-well construction conditions. The selected development method(s) should be approved by a senior field geologist before any well installation activities are initiated.

6.9 Well Abandonment

When a decision is made to abandon a monitoring well, the borehole should be sealed in such a manner that the well can not act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers. To properly abandon a well, the preferred method is to completely remove the well casing and screen from the borehole, clean out the borehole, and backfill with a cement or bentonite grout, neat cement, or concrete. In order to comply with state well abandonment requirements, the appropriate state agency should be notified (if applicable) of monitoring well abandonment. However, some state requirements are not explicit, so a technically sound well abandonment method should be designed based on the site geology, well casing materials, and general condition of the well(s).

6.9.1 Abandonment Procedures

As previously stated the preferred method should be to completely remove the well casing and screen from the borehole. This may be accomplished by augering with a hollow-stem auger over the well casing down to the bottom of the borehole, thereby removing the grout and filter pack materials from the hole. The well casing should then be removed from the hole with the drill rig. The clean borehole can then be backfilled with the appropriate grout material. The backfill material should be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method). The top 2 feet of the borehole should be poured with concrete to insure a secure surface seal (plug). If the area has heavy traffic use, and/or the well locations need to be permanently marked, then a protective surface pad(s) and/or steel bumper guards should be installed. The concrete surface plug can also be recessed below ground surface if the potential for construction activities exists. This abandonment method can be accomplished on small diameter (1-inch to 4-inch) wells without too much difficulty. With wells having 6-inch or larger diameters, the use of hollow-stem augers for casing removal is very difficult or almost impossible. Instead of trying to ream the borehole with a hollow-stem auger, it is more practical to force a drill stem with a tapered wedge assembly or a solid-stem auger into the well casing and extract it out of the borehole. Wells with little or no grouted annular space and/or sound well casings can be removed in this manner. However, old wells with badly corroded casings and/or thickly grouted annular space have a tendency to twist and/or break-off in the borehole. When this occurs, the well will have to be grouted with the remaining casing left in the borehole. The preferred method in this case should be to pressure grout the borehole by placing the tremie tube to the bottom of the well casing, Double Filter Pack

The borehole is advanced to the desired depth. As with the "inner filter pack" the well screen is filled with filter pack material and the well screen and casing inserted until the top of the filter pack is at least 6 inches below the water table. Filter pack material is poured into the annular space around the well screen. This type temporary well construction can be very effective in aquifers where fine silts or clays predominate. This construction technique takes longer to implement and uses more filter pack material than others previously discussed.

Well-in-a-Well

The borehole is advanced to the desired depth. At this point, a 1-inch well screen and sufficient riser is inserted into a 2-inch well screen with sufficient riser, and centered. Filter pack material is then placed into the annular space surrounding the 1-inch well screen, to approximately 6 inches above the screen. The well is then inserted into the borehole.

This system requires twice as much well screen and casing, with subsequent increase in material cost. The increased amount of well construction materials results in a corresponding increase in decontamination time and costs. If pre-packed wells are used, a higher degree of QA/QC will result in higher overall cost.

6.10.6 Backfilling

It is the generally accepted practice to backfill the borehole from the abandoned temporary well with the soil cuttings. Use of cuttings would not be an acceptable practice if waste materials were encountered or a confining layer was inadvertently breached. If for some reason the borehole cannot be backfilled with the soil cuttings, then the same protocols set forth in Section 6.9 should be applied. Section 5.15 should be referenced regarding disposal of IDW.