UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of:	)	
	)	
Interim Storage Partners	)	Docket No. 72-1050
	)	
(WCS Consolidated Interim Storage Facility)	)	
	)	

PETITION OF PERMIAN BASIN LAND AND ROYALTY ORGANIZATION AND FASKEN LAND AND MINERALS FOR INTERVENTION AND REQUEST FOR HEARING

Pursuant to 10 CFR 2.309 Petitioners Permian Basin Land and Royalty Organization (PBLRO) and Fasken Land and Minerals (Fasken) hereby respectfully petition for intervention and request a hearing in the above-captioned matter.

I. FASKEN AND PBLRO HAVE STANDING TO REQUEST A HEARING

Fasken and PBLRO have bases to intervene pursuant to both of the NRC's recognized legal frameworks for analyzing standing based on radiological injury: traditional standing and the proximity presumption. *U.S. Army Installation Command* (Schofield Barracks, Oahu, Hawaii, & Pohakuloa Training Area, Island of Hawaii, Hawaii), LBP-10-4, 71 NRC 216, 228 (2010). PBLRO is an association formed in response and opposition to the proposed CISFs. In Andrews County, Texas (ISP WCS CISF) and Lea County, New Mexico (Holtec CISF). (Boyd Declaration, para. 2). Members of PBLRO, which includes Fasken, are oil and gas producers and royalty owners which have long-term economic, social and environmental interests in the Permian Basin. (Id.). PBLRO's purpose is to advocate on behalf of oil and gas producers and land and royalty owners who have substantial economic interests that are jeopardized by the proposed CISF. (Id.) The potential for harm to Fasken's interests parallels the potential for harm to other members of PBLRO. (Taylor Dec., paras. 6, 13-14). No other petitioner/party can adequately represent the interests of Fasken and the oil and gas producers and land and royalty owners in PBLRO. As set forth below, Fasken and PBLRO have met the requirements to establish standing.

A. Fasken and PBLRO Have Standing Pursuant to Traditional Standing Doctrine

Traditional standing anticipates injury-in-fact, causation, and redressability. *Pac. Gas & Electric Co*., LBP-02-23, 56 NRC at 426 (2002). Fasken and PBLRO satisfy the traditional standing requirements because harm to its members who live, work and travel on or along transportation routes that ISP plans to use to transport spent nuclear fuel to the CISFs. *In the Matter of Duke Cogema Stone & Webster,* (Savannah River Mixed Oxide Fuel Fabrication Facility), LBP-01-35, 54 NRC 403, 417 ("[U]nwanted doses of ionizing radiation" from shipments of nuclear fuel transported "over the same public highways the Petitioners' members travel" established standing because "incident-free shipping of plutonium provides a dose of ionizing radiation, albeit small, to anyone next to the transport vehicle and a minor exposure to radiation, even one within regulatory limits, is sufficient to state an injury in fact.").

Furthermore, there is a risk of radiologic harm from an accident caused by shipments of spent nuclear fuel being transported to the CISF. *See e.g.,* WCS Environmental Report 4-15 (noting that rail casks could release radioactivity in "exceptionally severe accidents"). Highways in the area near the WCS CISF are unsafe due to the increased traffic from the oil boom which creates a risk that accidents involving radioactive waste shipments are also likely. *See e.g.,* New Mexico GOP Governor Hopeful: Toll Roads for Oil Traffic, Associated Press, KTBS (Aug. 21, 2018), https://www.ktbs.com/news/business/newmexico-gop-governor-hopeful-toll-roads-for-oil-traffic/article_e8f4a10a-2542-5a9a-b64ed0e6448c7bc8.html. Fasken and PBLRO members also may not be able to avoid radiological harm while travelling in the Permian Basin. The choice of routes is limited, and travelers in the vicinity of the proposed site may be unable to avoid radiological exposure and injury. *See Duke*, LBP-01-35, 54 NRC at 415. Moreover, ISP plans to use the Texas and New Mexico Railway between Monahan, Texas and Eunice, New Mexico to transport spent fuel to the site. *See* WCS Environmental Report at 4-8. This railway runs within a few hundred feet of Highway 18 for approximately 40 miles. Use of these anticipated routes and methods of transport virtually assure that Fasken employees and members of PBLRO will be in close proximity to routine shipments of spent nuclear fuel and thereby ensure members and employees will be exposed to unwanted radiation. Fasken and PBLRO have standing to request dismissal of the WCS application through employees and members:

- Tommy Taylor, who regularly travels on roads and highways around the WCS CISF, including Highway 176 which parallels the Texas and New Mexico Railway for approximately 40 miles. *See* Exhibit 1, para 3.
- D.K. Boyd, who travels once a week on Highway 18 for business related purposes on his ranch and to access his residence. The Texas and New Mexico Railway also runs through 5.5 miles of D.K's ranch which D.K. and his family frequently and regularly cross to conduct their cattle operations. *See* Exhibit 2, para. 7.

As oil and gas producers and land and royalty owners, Fasken and PBLRO also have traditional standing based on CISF's adverse impacts on property values. *See Kelley v. Selin*, 42 F.3d 1501, 1509–10 (6th Cir. 1995) ("Petitioners are clearly asserting a threatened injury. The injury can be fairly traced to respondents' actions since petitioners allege that it is the storage of spent nuclear fuels in the VSC–24 cask that has the potential to interrupt enjoyment of their lakefront property and to diminish its value. Finally, a decision in their favor could redress the threatened harm."); *see also Louisiana Energy Servs., L.P.* (Claiborne Enrichment Ctr.), CLI-98-3, 47 N.R.C. 77 (1998). Close proximity to nuclear facilities and transportation routes for spent nuclear fuel may decrease property as soon as a nuclear facility is licensed. And a radiological release that interferes or precludes continued production in the Permian Basin implicates the interests of Fasken and PBLRO. Accordingly, Fasken and PBLRO have standing to intervene and participate in hearings related to the subject CISF application through members:

- Tommy Taylor, who is the Vice President of Fasken Management. LLC which owns leasehold property where oil and gas extraction and production activities are conducted. *See* Exhibit 1, para 1 & 3.
- D.K. Boyd who owns Frying Pan Ranch which is used for oil and gas operations, cattle operations, and for residency. *See* Exhibit 2, para 5 & 7-8.

B. Fasken and PBLRO Meet Standing Requirements Under the Proximity Presumption

NRC recognizes standing may be based on the proximity presumption. *Tennessee Valley Auth.* (Sequoyah Nuclear Plant, Units 1 & 2; Watts Bar Nuclear Plant, Unit 1), LBP-02-14, 56 NRC 15, 3 (2002) ("This so-called proximity or geographical presumption 'presumes a petitioner has standing to intervene without the need specifically to plead injury, causation, and redressability…' "); *Armed Forces Radiobiology Research Inst.* (Combalt-60 Storage Facility), ALAB–682, 16 NRC 150, 154 (1982) (The "proximity to a large source of radioactive material establishes petitioner's interest."). Where the "nature of the proposed action and the significance of the radioactive source" create an "obvious potential for offsite consequences," the NRC applies a presumption of standing to individuals residing, owning property, or having frequent and regular contacts within the radius of those potential offsite consequences. *Consumers Energy Co.* (Big Rock Point Indep. Spent Fuel Storage Installation), CLI-07-19, 65 NRC 423, 426 (2007) (quoting Exelon Generation Co. (Peach Bottom Atomic Power Station, Units 2 & 3), CLI-05-26, 62 NRC 577, 580-581 (2005)); see also Kelley v. Selin, 42 F.3d 1501 (6th Cir. 1995); USEC, Inc. (Am. Centrifuge Plant), CLI-05-11, 61 NRC 309 (2005).

Fasken has oil and gas interests approximately eighteen miles from the proposed WCS CISF site. (Taylor Declaration, para. 3) PBLRO member D.K. Boyd has property within four miles of the WCS CISF site. (Boyd Declaration, para. 4). These distances meet the proximity test for standing.

The determination of the radius "beyond which . . . there is no longer an 'obvious potential for offsite consequences'" is made on a case-by-case basis. *Exelon Generation Co. LLC & PSEG Nuclear, LLC* (Peach Bottom Atomic Power Station, Units 2 & 3), CLI-05-26, 62 NRC 577, 580-81 (2005). Licensing Boards have found standing based on proximity to spent nuclear fuel ranging from 4,000 feet to 17 miles that both Fasken and PBLRO satisfy. *Private Fuel Storage, LLC* (Independent Spent Fuel Storage Installation), LBP-98-7, 47 NRC 142 (1997); *Pac. Gas & Elec. Co.,* LBP-02-23, 56 NRC at 428; *See also Vermont Yankee Nuclear Power Corp.* (Vermont Yankee Nuclear Power Station), CLI-00-20, 52 NRC 151, 163-64 (2000) (6 miles sufficient for standing in license transfer proceeding). The standard for assessing the potential for offsite consequences is whether the consequences are plausible, not whether consequences are probable or likely. *Cfc Logistics, Inc.*, LBP-03-20, 58 NRC 311, 320 (2003) citing *Ga. Inst. Of Tech*. (Georgia Tech Research Reactor) CLI-95-12, 42 NRC 111 (1995) (Commission found standing based on a "plausible scenario, albeit a highly unlikely one, in which three independent redundant safety systems—all designed to function under normal circumstances—could simultaneously fail in a research reactor."). It is plausible that radiological harm would impact Fasken's interests situated eighteen miles from the WCS CISF and PBLRO member D.K. Boyd's property four miles from the site as well.

The potential for offsite consequences from the WCS CISF is "obvious" due to the extraordinary volume of spent nuclear fuel anticipated for its facility. ISP proposes to store 40,000 MTU of spent nuclear fuel at the WCS CISF—a quantity that is more than half of the spent nuclear fuel existing in the United States. WCS Environmental Report at 4-9. Further, ISP recognizes at least one plausible scenario that would result in off-site consequences from storage of spent nuclear fuel at the WCS CISF. WCS Safety Analysis Report at 12-2 ("Analyses are provided for a range of hypothetical accidents, including those with the potential to result in a total effective dose equivalent of greater than 5 Rem outside the owner controlled area or the sum of the dose equivalent specified in 10 CFR 72.106.").

Fasken and PBLRO have standing to warrant granting intervention status and hearing participation based on the proximity presumption because Fasken and PBLRO members own property and have frequent and regular contacts within the radius of potential obvious offsite consequences of the ISP CISF, including:

- Tommy Taylor, who spends time on leasehold properties owned by Fasken that are within 18 miles of the WCS CISF. *See* Exhibit 1, para. 3.
- D.K. Boyd, who owns Frying Pan Ranch which is located 4 miles from the WCS CISF at its nearest point. *See* Exhibit 2, para. 4.

C. Fasken and PBLRO Have Properly Established Representational Standing Requirements

To establish representational standing, an organization must show that at least one of its members will be affected by the proceeding, that the identified members would have standing to intervene on their own, and that these members have authorized the organization to request a hearing on their behalf. *Sequoyah Fuels Corp. and General Atomics* (Gore, Oklahoma Site), CLI- 94-12, 40 NRC 64, 72 (1994) (citing *Houston Lighting and Power Co.* (Allens Creek Nuclear Generating Station, Unit 1), ALAB-535, 9 NRC 377, 389–400 (1979)) ("An organization seeking representational standing on behalf of its members may meet the 'injury-in-fact' requirement by demonstrating that at least one of its members, who has authorized the organization to represent his or her interest, will be injured by the possible outcome of the proceeding"). Additionally, the interest that the representative organization seeks to protect must be germane to its own purpose, and neither the asserted claim nor the required relief must require an individual member to participate in the organization's legal action. *Consumers Energy Co.* (Palisades Nuclear Plant), CLI-07-18, 65 NRC 399, 409 (2007).

Here, Fasken's purpose is to assure that the licensing decision adequately protects the interests of Fasken and other PBLRO members in an environment free from radiation fm the proposed CISF and other hazards associated with CISFs and to protect the economic interests of Fasken and PBLRO to which Fasken belongs. (Exhibit 1, para. 16). PBLRO's purpose is to oppose CISFs in Andrews County, Texas and Lea County, New Mexico and to support its members', including that of Fasken's, long-term economic, social and environmental interests in the Permian Basin. (Exhibit 2, para. 2). Fasken and PBLRO have thus demonstrated that the interests they seek to protect are germane to each organization's purposes. Fasken and PBLRO have both identified members who will be affected by the proceeding and who also have standing to intervene on their own accounts based on both traditional standing and the proximity presumption.[1] Tommy Taylor and D.K. Boyd have authorized both Fasken and PBLRO to request a hearing on their behalf. (Exhibit 1, para. 16); (Exhibit 2, para. 16). Thus, Fasken and PBLRO have met the requirements of representational standing.

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[1] *See* Exhibit 1, para. 3 (employment duties and personal reasons require Taylor to travel to and spend time in the area of the proposed CISF); *see also* Exhibit 2 (owns land and interests within four miles of the proposed CISF).

II. FASKEN-PBLRO CONTENTIONS

Pursuant to 10 C.F.R. § 2.309(f), a petitioner's contentions must: (1) provide a specific statement of the issue of law or fact to be raised or controverted; (2) provide a brief explanation of the basis for the contention; (3) demonstrate that the issue raised in the contention is within the scope of the proceeding; (4) demonstrate that the issue raised in the contention is material to the findings the NRC must make to support the action that is involved in the proceeding; (5) provide a concise statement of the alleged facts or expert opinions which support the petitioner's position on the issue and on which the petitioner intends to rely at hearing, together with reference to specific sources and documents on which the petitioner intends to rely; (6) provide sufficient information to show that a genuine dispute exists with the licensee on a material issue of law or fact.

The NRC has made clear that the burden on a petitioner in stating its contentions is not heavy. In *Dominion Nuclear Conn., Inc.* (Millstone Nuclear Power Station, Unites 2 & 3), CLI-01-24, 54 NRC 349 (2001), the NRC describes the admissibility standards as "insist[ing] upon some 'reasonably specific factual and legal basis' for the contention." *Id.* at 359. Petitioners are required only to "articulate at the outset the specific issues they wish to litigate." *Id.*

The NRC courts have also made clear that the burden of persuasion is on the licensee, not the petitioner. The petitioner only needs to "com[e] forward with factual issues, not merely conclusory statements and vague allegations." *Northeast Nuclear Energy Company*, 53 NRC 22, 27 (2001). The NRC described the threshold burden in stating a contention as requiring a petitioner to "raise any specific, germane, substantial, and material factual issues that are relevant to the … request for a license…and that create a basis for calling on the [licensee] to satisfy the ultimate burden of proof." *Id.* Also, in *Vermont Yankee Nuclear Power Corp. v. NRDC,* 435 U.S.

519, 554 (1978), the United States Supreme Court affirmed the NRC in finding that the proper standard to apply required intervenors to simply make a "showing sufficient to require reasonable minds to inquire further," a burden the NRC found to be significantly less than that of making a prima facie case.

A. CONTENTION NO. 1:

The Applicant's proposed CISF is not needed to ensure safe storage of SNF, even for indefinite durations.

i. Basis for Contention

This contention is within the scope of the proceeding because it deals with the completeness and accuracy of information in Applicant's Environmental Report (ER).[1] The Applicant's assessment of the need for a CISF is summarized in its ER at Sec. 1.1. It characterizes a national "strategic need" for the CISF by allowing an "orderly transfer" of SNF from reactors around the country to a "safer and more secure centralized storage location." This assertion implies an away from reactor (AFR) CISF is needed because SNF stored at reactor locations is not safe. This conflicts with the NRC's findings in the Waste Confidence Rule as expressed in NUREG-2157.

ii. Facts Upon Which Petitioner Intends to Rely in Support of This Contention

NUREG-2157 is the Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel (GEIS).[2] The GEIS discusses at-reactor SNF handling and storage at Section 2.1.2.. The GEIS anticipates that SNF at-reactor storage in spent fuel pools and on-site ISFSIs is an acceptable means to manage SNF. [3] This is borne out by, *inter alia*, the NRC's continued

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[1] 10 CFR § 72.11

[2] https://www.nrc.gov/docs/ML1418/ML14188B749.pdf

[3] GEIS sec. 2.1.2.2

licensing of at-reactor ISFSIs for SNF management.[4] The GEIS indicates that at-reactor SNF storage could continue safely indefinitely.[5] Nowhere does Applicant contradict NRC that on-site SNF storage is safe and secure, even for an indefinite duration.

Applicant's asserts that an AFR ISFSI is a "safer and more secure" method than storage at reactor sites but does not provide any factual support for its statement. There is no comparative analysis, either generic or site-specific, that supports the claim that ISP's CISF is safer and more secure alternative than CISFs at reactor sites. Its discussion regarding the no-action alternative identifies no "needs" that undermine the NRC's conclusion that at-reactor storage for even indefinite durations is safe.[6] The "needs" for an AFR ISFSI, as argued by Applicant, are actually preferences that mainly accommodate reactor owners.[7] And this applies to fiscal/financial arguments, as well. It may be the case that reactor owners financial considerations and the Department of Energy's fiscal considerations point to a preference for AFR SNF storage. But Applicant presents no case that accommodating financial and fiscal preferences are needs.

The preference of reactor operators may be for SNF management at AFR facilities. But Applicant conflates "needs" with preferences of reactor operators. For example, the Applicant notes in its ER that "[M]any policymakers and stakeholders in the communities that host shutdown reactors <u>want</u> to have the SNF removed to complete decommissioning of the site and to allow for more beneficial uses of the land."[8] Applicant does not otherwise identify a need for

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[4] Id.
[5] GEIS sec. 2.2.3
[6] ER sec. 2.1
[7] ER sec. 1.1
[8] Id. (Emphasis added)

AFR storage except related to decommissioning; and that putative need is not supported by the ER or the GEIS.

Applicant asserts that its CISF is needed to accommodate decommissioning. But Applicant concedes that decommissioning has proceeded at nine reactors and does not cite circumstances that required the nine reactors to seek the services of an AFR CISF.[9] And for future decommissioning, Applicant cites no information that suggests that unless an AFR CISF is available decommissioning will be hampered. In short, there is no identified need for an AFR CISF to allow present or future decommissioning activities.

The NRC anticipates that SNF will be managed at reactor sites. The GEIS recognizes that nuclear plants are facing decommissioning and at-reactor storage is not only expected, the NRC has adopted specific nomenclature to describe it.

> During major decommissioning activities , the licensees will transfer spent fuel from spent fuel pools to either an at-reactor or away-from-reactor ISFSI. When decommissioning of the reactor and related facilities is completed and the at-reactor ISFSI is the only spent fuel storage structure left onsite, the facility is referred to as an "ISFSI-only site." Existing ISFSI-only sites include Big Rock Point, Haddam Neck, Fort St. Vrain, Maine Yankee, Rancho Seco, Trojan, and Yankee Rowe.[10]

The NRC has not expressed a preference for AFR CISF for SNF storage let alone designated it as a need inherently superior to at-reactor storage. Further, the GEIS does not differentiate between the efficacy of at-reactor CISFs and AFR CISFs for long-term SNF storage. For example, the GEIS states regarding long-term management of SNF that "[C]ontinued storage activities include replacing the storage facility (for either an at-reactor or an away-from reactor

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[9] Decommissioning of the nine reactors did not include transporting SNF from the reactors. Per the GEIS spent fuel may remain on-site indefinitely. GEIS sec. 2.1.2.2.

[10] Id. (Emphasis added)

ISFSI), the DTS, and the spent fuel canisters and casks."[11] This reflects a regulatory recognition that both modes of storage require component replacement for long-duration storage.

A comparison of the respective summaries for at-reactor storage and AFR storage reinforces that AFR storage is not needed for safe SNF management. For at-reactor SNF storage the GEIS states:

> The impact determinations for at-reactor storage for each resource area for each timeframe are summarized in Table 4-2. For most of the resource areas, the impact determinations for all three timeframes are SMALL. Continued storage is not expected to adversely affect special species and habitats. For accidents (design basis and severe) and terrorism considerations, the environmental risks of continued storage are SMALL. However, for a few resource areas, impact determinations are greater than SMALL and varied for the three timeframes. For the long-term storage and indefinite storage timeframes, during which ground-disturbing activities may occur, impacts on historic and cultural resources range from SMALL to LARGE. The impacts from management and disposal of nonradioactive waste would be SMALL for both the short-term and long-term timeframes but SMALL to MODERATE for indefinite storage.[12]

For AFR SNF storage the GEIS states:

> The impact levels determined by the NRC in the previous sections for away-from-reactor dry cask storage of spent fuel are summarized in Table 5-1. For most impact areas, the impact levels are denoted as SMALL, MODERATE, and LARGE as a measure of their expected adverse environmental impacts. In other impact areas, the impact levels are denoted according to the types of findings required under applicable regulatory or statutory schemes (e.g., "disproportionately high and adverse" for environmental justice impacts). For a number of the resource areas, the impact determinations for all three timeframes are SMALL. For air quality and terrestrial ecology, there is the potential for a MODERATE impact during the construction of the ISFSI. For environmental justice, special status species and habitats, and historic and cultural resources, the results are highly site-specific. While it is possible the ISFSI could be built and operated with no noticeable impacts on these resources, a definitive conclusion cannot be drawn in this GEIS. For socioeconomics (taxes), aesthetics, and traffic, there are impacts that could be greater than SMALL that will continue throughout the existence of the ISFSI. The tax impacts are beneficial in nature. Finally, there is the potential for a MODERATE impact from the disposal of nonradioactive

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[11] GEIS, sec. 2.2.2.2

[12] GEIS, sec.4.20

> waste in the indefinite timeframe if that waste exceeds the capacity of nearby landfills.[13]

These summaries for at-reactor storage and AFR storage do not indicate, in any manner, that AFR storage is needed in order to manage SNF safely. Suggestions by the Applicant that AFR storage is safer and more secure than at-reactor storage are unjustified and do not support a need for the proposed facility.

Applicant has not presented a case to support that the proposed CISF will further the overarching need to establish a permanent repository. In fact, Applicant ignores that aspect of SNF management. Given the premise that permanent repository capacity is needed it follows that Applicant is obliged to inform the Commission precisely how establishing its CISF would further the objective of establishing a permanent repository. Further, given that permanent repository capacity is not expected before 2048[14] and the regulatory authority to allow SNF to remain at a CISF indefinitely[15]Applicant is obliged to address the why its proposed facility in Andrews County will not become a de facto permanent SNF storage facility.

There is no evidence that the proposed CISF will further the cause of establishing a permanent repository, based on the history of SNF management. Rather, the CISF may be viewed as a diversion from establishing a permanent repository. The Applicant's implicit unsupported notion that somehow its CISF is an essential link to achieving the primary objective of the Nuclear Waste Policy Act to effect permanent repository capacity is actually contrary to the logic of the Act. Applicant contends that the Blue Ribbon Commission (BRC) that studied the problem of SNF management supports its proposal for a CISF. However the BRC

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[13] GEIS sec. 5.20
[14] ER sec. 1.1
[15] NUREG-2157 § 2.2.3

specifically recognized that a CISF will not be an effective SNF management program unless it is coupled with an effective permanent repository policy. The BRC was clear about this imperative.

> The salient point for purposes of this discussion is that the challenge of siting one or more consolidated storage facilities cannot be separated from the status of the disposal program. Many states and ommunities will be far less willing to be considered for a consolidated storage facility if they fear they will become the de facto hosts of a disposal site. This means that a program to establish consolidated storage will succeed only in the context of a parallel disposal program that is effective, focused, and making discernible progress in the eyes of key stakeholders and the public. A robust repository program, in other words, will be as important to the success of a consolidated storage program as the consolidated storage program will be to the success of a disposal program. Progress on both fronts is needed and must be sought without further delay.[16]

The Department of Energy's 2013 *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* echoed the BRC's concerns about an interim storage plan untethered from a permanent repository. While DOE endorsed the BRC's recommendation that the government should pursue consolidated interim storage of spent fuel it recognized "that a linkage between opening an interim storage facility and progress toward a repository is important so that states and communities that consent to hosting a consolidated interim storage facility do not face the prospect of a de facto permanent facility without consent."[17]

Moreover, Applicant has not addressed the statutory requirement that construction of a CISF may not commence before a license for a permanent repository has been issued.[18]To the extent that a license for the WCS CISF issues it will not authorize any meaningful SNF management in a CISF unless a permanent repository license has been issued. This underscores the inherent relationship between a proposed CISF and the need to establish a permanent

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[16] BRC Report, pg. 40

[17] DOE *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*, p. 5.

[18] 42 USC § 10168(d)(1)

repository. In any event, the statutory predicate of requiring licensure of a permanent repository is further support that the Applicant's proposal is an exercise in futility unless and until a permanent repository is licensed. The failure to discuss the restriction in 42 USC 10168(d)(1) is a material omission from Applicant's ER.

Applicant's ER has not dealt with the relationship between progress toward a permanent repository and the prospect that the proposed CISF will become a de facto permanent SNF facility. The BRC and the DOE's *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* could not be clearer about the inherent relationship between progress toward a permanent repository and the acceptability of a proposed CISF. Applicant's failure to address this relationship is a material omission from its ER.[19]

B. CONTENTION NO. 2:

ISP's SAR fails to provide adequate data regarding active and abandoned oil and gas wells and borings on and near the WCS site, contrary to the requirements of 10 C.F.R. 72.103.

i. Basis for Contention

This contention is within the scope of this proceeding because it concerns ISP's SAR and whether the SAR has met the site suitability requirements as required for an application under 10 C.F.R. § 72.103.

Applications for dry cask modes of storage east of the Rocky Mountain Front (east of approximately 104° west longitude) are "…acceptable if the results from onsite foundation and geological investigation, literature review, *and regional geological reconnaissance* show no unstable geological characteristics, soil stability problems, or potential for vibratory ground motion at the site…." 10 C.F.R. § 72.103(a)(1) (emphasis added).

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[19] 10 C.F.R. § 72.11.

Over the course of time, there have been a total of 4,947 well bores drilled in Texas and New Mexico within a 10-mile radius of the WCS site;[20] a fact that ISP has failed to mention and thus failed to investigate in its Safety Analysis Report (SAR). Furthermore, out of the 4,947 wells, 905 are abandoned wells.[21] There could also be a presence of orphan wells[22] near the site as well. ISP has failed to investigate the presence of active and abandoned oil and gas wells and borings in the region, and the effect these wells could have on the stability of the site. Thus, ISP's SAR is insufficient to meet the requirements under 10 C.F.R. § 72.103(a)(1) that an applicant investigate regional geological characteristics for instability.

ii. Facts Upon Which Petitioner Intends to Rely in Support of This Contention

Contentions regarding an SAR's assessment—or lack thereof—concerning the presence of oil and gas wells and borings on and near a site "raise[] an issue that is material to the findings the NRC must make" in granting an application.[23]

The *Exelon* case differs slightly from our case in that the Exelon application sought the NRC's approval for one or more nuclear power reactors.[24] While reactors and ISFSI's are regulated by different Parts, the standards and circumstances regarding site suitability are similar in nature. The site suitability conditions in *Exelon* were governed by 10 C.F.R. 100.20(b) and 100.21(e).[25] In comparing regulations from the *Exelon* to this case, sub-section 100.20(b) is the

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[20] Declaration of Aaron Pachlhofer, P.G., pg. 6. (hereinafter referred to as "Exhibit 3")

[21] *Id.*

[22] Only historical drilling records and maps kept by individual companies can locate orphan wells. The Texas Railroad Commission's public mapping records will not contain information related to whether an orphan well is present in a certain location. *Id*. at pg. 6-7.

[23] *In the Matter of Exelon Nuclear Texas Holdings, LLC* (Victoria County Station Site), LBP-11-16, 73 N.R.C. 645, 669 (2011) (hereinafter *Exelon*).

[24] *Id*. at 650.

[25] *Id.* at 669.

only sub-section relevant to 72.103.[26] Sub-section 100.20(b) states that when determining the acceptability of a site for a stationary power reactor, the NRC will take into consideration "[*t]he nature and proximity of man-related hazards* (e.g., airports, dams, transportation routes, military and chemical facilities)… [in] determining whether a plant design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low." (emphasis added). Similarly, but more generally, sub-section 72.103(a)(1) states that an application for a dry cask ISFSI is acceptable "if the results from onsite foundation and geological investigation, literature review, and *regional* geological reconnaissance show no unstable geological characteristics…." (emphasis added). While the language in Part 72 is more general than the language in Part 100, Part 72's "regional" analysis would encompass the need to analyze the presence of oil and gas wells and borings holes on and around the site.

Aside from a few statements indicating that "drilling for and production from oil and gas wells" were land uses within a few miles of the WCS CISF,[27] ISP's SAR fails to admit the presence of the nearly 5,000 wells located within 10 miles of the site, and thus completely fails to analyze the regional geography as required under 10 C.F.R. § 72.301(a)(1). Given that older well bores pre-dating 1967 may have little or no information determining whether they have been properly plugged and abandoned,[28] and given the presence of 905 abandoned wells not including any unknown orphan wells, it is imperative that the SAR analyze the risk that these abandoned wells will pose on the geological stability of the site. Additionally, these abandoned wells should be analyzed as potential pathways to groundwater.

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[26] 10 C.F.R. 100.21(e) deals with the application site criteria for "[p]otential hazards associated with nearby transportation routes…" and thus is not applicable in this case.

[27] SAR, p. 2-2.

[28] Exhibit 3, pg. 6.

C. CONTENTION NO. 3:

The Applicant’s Emergency Response Plan (ERP) Fails to Address How Licensee Will Protect the Facility from Credible Fire and Explosion Effects Including Those that are Caused by Aircraft Crashes.

i. Basis for Contention

This contention is within the scope of this proceeding because it concerns the WCS ERP and whether it has established that the facility is designed to continue to effectively perform its safety functions under all credible fire and explosion exposure conditions pursuant to the requirements of 10 C.F.R. § 72.122(c).

Applications for ISFSIs that are not located on the site of a nuclear power reactor must be accompanied by an Emergency Plan that includes, among other things, “[f]acility description … identification of each type of radioactive materials accident … classification of accidents … [and a] brief description of the means of mitigating the consequences of each type of accident, including those provided to protect workers onsite, and a description of the program for maintaining the equipment.”[29] Furthermore, the overall requirements for an ISFSI’s design criteria includes protection against fires and explosions and to minimize and control the release of radioactive material to the environment.[30] More specifically, an ISFSI “…must be designed and located so that [it] continue[s] to perform [its] safety functions effectively under credible fire and explosion exposure conditions.”[31] Furthermore, structures, systems, and components (SSCs)

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[29] 10 C.F.R. § 72.32(a).
[30] 10 C.F.R § 72.122(c).
[31] *Id.*

important to safety must be designed and located so that they can "continue to perform their safety functions *effectively* under credible fire and explosion exposure conditions."[32]

The on and off-site procedures listed in the ERP to prevent fires and explosions do not comply with 10 C.F.R. § 72.122 which requires that suppression systems "be designed and provided with sufficient capacity and capability to minimize the adverse effects of fires and explosions on SSCs". ISP relies on outside assistance to handle catastrophic fires and explosions, and does not specify how their current suppression systems will effectively mitigate fires and explosions until help arrives. Furthermore, the ERP does not describe the on-site means of mitigating a credible airplane crash contrary to the requirement that that each license for an ISFSI "include *technical specifications*…to guard against the uncontrolled release of radioactive materials."[33]

ii. Facts Upon Which Petitioner Intends to Rely in Support of This Contention

The WCS ERP was developed to include radiological and non-radiological "emergency incidents that are deemed credible when hazard analyses are applied to routine operations of the facility."[34] Two out of the twelve credible incidents WCS cites includes fires and explosions; additionally, WCS identifies airplane crashes as a third credible incident.[35] The ERP defines an airplane crash as "[a] plane crash on Facility property" in which the "plane crash impact[s] a hazardous material or radiologically controlled area." *Id.* Unlike a malevolent air-based attack, which the NRC and multiple courts have determined "other federal agencies [namely the FAA]

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[32] NUREG-1567, pg. 6-7 (emphasis added).

[33] 10 C.F.R. § 72.44(c)(1)(i). (emphasis added).

[34] WCS Consolidated Emergency Response Plan, Revision 03-15-2017 at pg. 5. (Accession No. ML17082A054) (hereinafter referred to as "ERP")

[35] *Id.* at 59.

[are better] able to actively protect against,"[36] the presence of a credible fire and explosion incident in an ERP requires assurance that the facility can perform its safety functions effectively and with sufficient capacity and capability to minimize adverse effects of credible conditions.[37] The U.S. Supreme Court in *Metro Edison Co. v. People Against Nuclear Energy,* which was cited and analyzed by *San Luis Obispo Mothers for Peace v. NRC*, explains that in order to fall within NEPA's impact-statement requirement, an agency's action and the environmental effect at issue requires "a reasonably close causal relationship between a change in the physical environment and the effect at issue."[38] Moreover, a governing body "must look to the underlying policies or legislative intent in order to draw a manageable line between those causal changes that may make an actor responsible for an effect and those that do not." *Id.* at f.n. 7.

Applying the standard in *Metro Edison,* the ERP's inclusion of an airplane crash as a credible incident requires compliance with requirements of sub-section 72.122(c). ISP has not adequately indicated that the facility could perform its safety functions effectively against a catastrophic airplane crash nor has it shown that the facility has the capability to minimize the effect that an airplane crash would have on the surrounding environment. Considering WCS included the potential for an airplane crash as a credible incident, the application cannot be

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[36] *See Pub. Citizen v. Nuclear Reg. Com'n.,* 573 F.3d 916, 922 f.n. 5 (9th Cir. 2009) (reiterating the NRC's consistent position that the new design features "will result in a margin of safety *far* beyond that required to achieve reasonable assurance of public health and safety," and that the responsibility of preventing the impact of large commercial aircraft rests with the federal government as it is a beyond-design-basis event).

[37] 10 C.F.R. § 71.122(c)

[38] 460 U.S. 766, 774, 103 S. Ct. 1556 (1983); *See also City of Dallas, Tex. v. Hall*, 562 F.3d 712, 723 (5th Cir. 2009) (holding that when the federal action "[did] not effect a change in the use or character of land or in the physical environment" NEPA analysis was not required.); *Found. On Econ. Trends v. Lyng,* 943 F.2d 79, 90 (D.C. Cir. 1991) (holding that the alleged inadequacies in the USDA's preservation work—i.e. federal action—was not the proximate cause of degradation of genetic diversity threatening the food supply, and was thus "too attenuated.").

approved by the NRC until ISP shows that it is equipped with sufficient capacity and capability to effectively minimize the adverse effects to the facility and the surrounding area that an airplane crash impacting hazardous and radioactive material may cause.

WCS' on-site methods for mitigating various credible incidents including spills, releases, and on-site transportation accidents includes providing personal protective equipment to personnel, including "safety glasses, gloves, boots, Tyvek suits, full-face respirators and self-contained breathing apparatus." ERP, at 27. The ERP also describes mitigation tactics for on-site transportation accidents, which among other things, includes the "…release of hazardous and/or radioactive materials to the environment." *Id.* at 30. The ERP specifies that there will be trained personnel selected to use "[p]ortable fire extinguishers and extended pressurized water hoses" for on-site transportation accident emergencies. *Id.* The site will also use stationary automatic sprinklers and water spray systems. *Id.* at 40. WCS also has equipment available on-site to erect temporary berms across drainage ditches and around emergency areas as may be required for water control. *Id.* at 29. That being said, the berms are not permanently placed, which requires that time be taken for them to be set up before trained on-site personnel can begin containing and extinguishing a fire and/or explosion resulting from an airplane crash. While contaminated water may either be treated on site per applicable permits or can be taken off-site to an authorized facility if contaminated,[39] the added time of setting up the berms before on-site personnel can have the capability to extinguish a fire or explosion would increase the amount of radioactive material released in the environment.

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[39] *Id.* at 29.

ISP also fails to consider the size, velocity, weight, and fuel loads of different aircraft when assessing the hazards an airplane crash would have on the site.[40] The failure to consider these factors makes it impossible to determine whether the mitigation measures will be adequate. To meet license application requirements in this regard requires ISP to consider the damage effects to the facility caused by a range of aircraft including large commercial planes. This is a material omission from ISP's application and violates 10 CFR § 72.11.

The ERP generally states that "[i]f an on-site accident involving contamination of property and facilities occurs, WCS will deploy equipment to clean up the release and decontaminate the site." *Id.* While the ERP does indicate access to portable spill control and decontamination equipment[41] it makes no specific reference to what equipment will be used or how effectively the equipment will minimize the adverse effects of an extreme fire or explosion. Other than the use of stationary automatic sprinklers and trained personnel using fire extinguishers and extended pressurized water hoses, the ERP fails to specifically state how their on-site emergency equipment will effectively minimize the adverse effects of an extreme fire or explosion caused by an airplane crash, including a large commercial aircraft, and thus does not satisfy the requirements of 10 CFR § 72.122(c) or NUREG 1567 § 2.5.2.

In the event of a catastrophic fire, the ERP relies on off-site assistance for fire and explosions from both the Andrews County Volunteer Fire Department (ACVFD), located 30 miles from the site, and Eunice, New Mexico Volunteer Fire Department, located 6 miles from

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[40] NUREG-1567 § 2.5.2 states that applicants should consider these specific factors when a facility is near an airport. Midland International Airport is approximately 50 miles to the WCS site. Andrews County Airport-E11 in Andrews, TX is a local airport which is approximately 32 miles from the WCS site by air. Lea County Regional Airport in Hobbs, NM is a larger domestic airport which is approximately 19 miles from the site by air.

[41] ERP, at 40.

the site. *Id.* at 22. In the event of a catastrophic fire, the Andrews and Lea County Sheriff's Departments, Texas Department of Public Safety and/or the New Mexico State Police are responsible for directing traffic along Highway 176 and evacuating any of the general public surrounding the facility that may be affected by windblown or gaseous wastes. *Id.* at 29. While the ACVFD has a suppressant foam producing truck, the ACVFD can only respond in approximately 30 minutes. *Id.* The Eunice Fire Department may also respond to a catastrophic fire or explosion and has worked with the Andrews firefighting team often in the field, but WCS has not indicated that the Eunice Fire Department has a suppressant foam producing truck. *Id.* Radiological response training has been offered to the Andrews Fire Department and Eunice Fire Department,[42] however, to sufficiently mitigate a catastrophic fire or explosion resulting from an airplane crash, it is unknown due to ISP's omission, and unlikely that the facility could extinguish the fire and mitigate the release of gaseous and/or radioactive fumes until the ACVFD arrived with its suppressant foam producing truck, which at the earliest would be 30 minutes after the credible incident occurred.

It is required that an analysis and evaluation of the design and performance of an ISFSI assessing the impact on public health and safety include a determination of "[t]he adequacy of structures, systems, and components provided for the prevention of accidents and the mitigation of the consequences of accidents, including natural and *manmade phenomena* and events." 10 C.F.R. § 72.24(d)(2) (emphasis added). Moreover, controlling bounds for external events for "'design basis' (accident level) loads" in NUREG-1536 includes "extreme *credible* external *man-induced* events used for deriving design bases on the basis of analysis of human activity in

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[42] ERP, pg. 29.

the region taking into account the site characteristics and associated risks."[43] Considering stationary sprinklers, portable fire extinguishers, water hoses, and unspecified spill and contamination control equipment are the only on-site suppression systems available, it is unlikely, and ultimately unknown that the site's suppression system is designed and capable to minimize the adverse effects resulting from catastrophic fires and explosions resulting from, for example, an airplane crash.

Many regulations and guidance documents regarding mitigation of exposure to radioactive material imply that time is of the essence.[44] Guidance further dictates that proposed operations should reflect incorporation of "as low as (is) reasonably achievable" (ALARA) principles in operational procedures.[45] To effectively incorporate ALARA principles applicants must make

> "every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest."[46]

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[43] NRC Guidance, *Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility*, NUREG-1536, Table 3-2 (Loads and Their Descriptions), pg. 3-44 (emphasis added).

[44] *See* 10 C.F.R. § 72.126 (the criteria for radiological protection includes "*[m]inimiz[ing] the time* required to perform work in the vicinity of radioactive components) (emphasis added); 10 C.F.R. § 20.1702 ("[w]hen it is not practicable to apply process or other engineering controls to control the concentrations of radioactive material in the air to values below those that define an airborne radioactivity area…the licensee shall…limit intakes by one or more of the following means:…[*l*]*imitation of exposure times*) (emphasis added); NUREG-1567, at 15-14 (reviewer should verity that the SAR defines the physical parameters associate with off-normal events, including:…alarms and *response times for corrective action*) (emphasis added).

[45] NUREG-1567 at 11-9.

[46] NRC website definitions (available at https://www.nrc.gov/reading-rm/basic-ref/glossary/alara.html) (citing 10 C.F.R. § 20.1003).

Detailed plans and procedures should be developed in accordance with Regulatory Guide 8.8, which should consider inclusion of tested contingency procedures for potential off-normal occurrences.[47] Regulatory Guide 8.8 states that "[c]onsequently, the basic variables that can be controlled to limit doses from internal exposures are those that limit (1) *the amount of contamination*, (2) *the dispersal of the contamination*, and (3) the length of time that personnel must spend in contaminated areas.[48] Analogously, limiting the dose to external exposures would consider the same variables. Because the effects of an aircraft crashes have not been presented by the Applicant it is uncertain whether the WCS site could, on its own, limit the dose variables regarding the amount and dispersal of contamination released during a catastrophic fire and explosion. Accordingly, ISP also fails to demonstrate that it can meet either the ALARA standards or 10 C.F.R. § 72.122(c).

As mentioned, reliance on a suppressant foam producing truck that is approximately 30 minutes away from the site does not reflect adherence to ALARA principles; nor does it adhere to the multiple regulations and guidance documents that imply sites need to limit the amount of exposure to radioactive material. Given that the suppressant foam producing truck is available the state of technology here is not at issue. The economics of having a truck on-site—or at the very least, much closer than 30 minutes away—in relation to the benefits to public health and safety is clear. Considering the truck would have the highest probability of preventing a catastrophic fire in relation to the current on-site mitigation equipment WCS proposes to use, having a truck on-site, or the presence of some other mitigating mechanism must be implemented on-site in order for WCS to comply with the ALARA standard.

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[47] NUREG-1567, § 11.4.1.3.

[48] NRC Guide 8.8, "Information Relevant to Ensuring That Occupations Radiation Exposures At Nuclear Power Stations Will Be ALARA" pg. 8.8-4 (June 1978) (emphasis added).

At this point, until WCS can describe in detail that their portable spill and contamination control equipment is capable of effectively minimizing the adverse effects of a catastrophic fire resulting from a plane crash without having to wait on assistance from ACVFD's suppressant foam producing truck, the requirements of 10 C.F.R. § 72.122(c) will not be met.

D. CONTENTION NO. 4:

ISP has failed to adequately discuss and evaluate the impact the proposed site will have on the environment and has also failed to include adverse information specifically relating to potential of waste-contaminated groundwater traveling to aquifers and other groundwater formations located below and around the proposed site.

i. Basis for Contention

The potential for radiological and other environmental impacts on a region must be evaluated pursuant to subpart A, part 51 of title 10.[49] As required by this section, "[an] environmental report shall contain a description of the…environment affected, and discuss…[t]he impact of the proposed action on the environment."[50] The information submitted pursuant to paragraph (b) "should not be confined to information supporting the proposed action but should also include adverse information" as well.[51] Contrary to the requirements of 10 C.F.R. § 51.45, WCS has failed to adequately evaluate the potential for radiological and other environmental impacts on the environment based on the proposed action and has also failed to include adverse information regarding the proposed action. Thus, this contention is within the scope of these proceedings.

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[49] 10 C.F.R. § 72.90(e).

[50] 10 C.F.R. § 51.45(b)(1).

[51] 10 C.F.R. § 51.45(e).

More specifically, pursuant to NUREG-1567, any site located over an aquifer that is a source of well water should consider "[a]n analysis bounding the potential groundwater contamination from the site operations." NUREG-1567 § 2.4.5.[52] The SAR should contain "adequate information for an independent review of all subsurface hydrology-related design bases and compliance with dose radiological exposure standards." *Id.* There are aquifers and formations present in the subsurface throughout the WCS area, which are also exposed within the excavation walls at the WCS llrw facility.[53] Of these formations, one provides well water to the city of Midland, TX.[54] The SAR fails to provide an analysis bounding the potential groundwater contamination from site operations, and therefore fails to meet the requirements of 10 C.F.R. § 51.45(b)(1).

ii. Facts Upon Which Petitioner Intends to Rely in Support of This Contention

ISP contends that the method of storage (i.e. dry cask) and the nature of the canisters precludes the possibility of groundwater contamination from the operation of the WCS CISF.[55] WCS states that an airplane crash impacting hazardous material on the facility is a credible incident, but fails to consider as directed by NUREG-1567 § 2.4.5 the potential of casks releasing radioactive material upon impact of large, fully-fueled aircrafts.[56] Furthermore,

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[52] Post-construction environmental reports made during a "license renewal term" require an applicant to assess the impact of any documented inadvertent releases of radionuclides into groundwater—including aquifers—and the projected impact such release had on the environment. *See* 10 C.F.R. § 51.53(c)(3)(ii)(P). This directly correlates to NUREG-1567's guidance that applicants should consider potential groundwater contamination for sites located over aquifers as part of their design basis analysis in an SAR.

[53] Exhibit 3, pg. 4.

[54] *Id.*

[55] SAR at 2-21.

[56] Fasken and PBLRO argue in Contention No. 3 that ISP also does not fulfill the requirements of 10 C.F.R. § 72.122(c) which require an ISFSI to be designed to perform its safety functions effectively under credible fire and explosion exposure conditions.

environmental reports must contain "an analysis of the *cumulative impacts* of the activities…in light of the preconstruction impacts."[57] While Section 9.4.2.1 of NUREG-1567 states that "confinement calculation of the doses under normal off-normal and accident conditions is unnecessary for storage casks having closure lids that are designed and tested to be 'leak tight,'" WCS still has a duty under 10 C.F.R. § 72.122(c) and NUREG-1567 § 2.4.5 to ensure the ISFSI is designed to effectively protect against the release of radioactive material involving credible incidents, which includes airplane crashes.[58] Since WCS concedes this credible incident, Movants rely on Section 2.4.5 of NUREG-1567 which states that any site located over an aquifer that is a source of well water should consider "[a]n analysis bounding the potential groundwater contamination from the site operations."

ISP's SAR also states that the shallowest water bearing zone at the WCS CISF is about 225 feet deep.[59] However, the Ogallala Formation "is present in the subsurface along the north and east sides of the WCS-Flying "W" Ranch at a depth of 45-105 ft."[60] The SAR also states that the closest downgradient drinking water well is located approximately 6.5 miles to the east of the proposed WCS CISF and that the Ogallala, Antlers, and Gatuña (OAG) aquifers are "largely unsaturated" beneath the WCS.[61] To the contrary, cross-formational groundwater is known to exist between the Ogallala and the Antler Formations.[62] Even if the OAG aquifers are "largely

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[57] 10 C.F.R. § 51.45(c); *See also In the Matter of N. States Power Co.* (Prairie Island Nuclear Generating Plant Indep. Spent Fuel Storage Installation) 76 NRC 503, 513 (2012) (instructing applicants to "[d]iscuss any past, present, or reasonably foreseeable future actions which could result in cumulative impacts when combined with the proposed action.").

[58] WCS Consolidated Emergency Response Plan, Revision 03-15-2017 at pg. 5 (stating an airplane crash is a credible incident and defining the crash as an "airplane crash impacting a hazardous material or radiologically controlled area.") (Accession No. ML17082A054)

[59] SAR at 2-21.

[60] *See* Exhibit 3, pg. 4, f.n. 3 (citing Exhibit 4).

[61] SAR at 2-21.

[62] Exhibit 3, pg. 4.

unsaturated", this doesn't detract from the fact that they are still aquifers situated below the vicinity of the WCS site. Thus, pursuant to NUREG-1567 § 2.4.5, ISP should analyze the potential for radiological and other environmental impacts based on WCS's location above an aquifer.

The SAR further states that the local Ogallala aquifer "contains fresh to slightly saline water" and that "[t]he Ogallala Formation, *if present*, is not water bearing in the WCS CISF area."[63] The purpose of an SAR is to provide specific and adequate information regarding a site's features regarding the installation;[64] the analysis is not meant to accommodate "ifs" related to the same. As mentioned, the Ogallala formation is present in the subsurface along the WCS Flying "W" Ranch.[65] Contrary to the SAR's findings, "[g]roundwater [has been] found in 3 borings that penetrated the Ogallala" along the north and east sides of the WCS-Flying "W" Ranch, it is "present…beneath the WCS site itself," and "cross-formational groundwater is known to exist between [the Antler and the Tertiary Ogallala] formations.[66] ISP's statement regarding "if" the Ogallala formation is present or not bolsters this contention's premise that the SAR has not adequately described the potential for groundwater contamination. ISP's equivocal characterization of the aquifers in the area of the proposed facility is an inadequate basis to conclude that groundwater is not present.

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[63] SAR at 2-22 (emphasis added).

[64] The objective of NUREG-1567 is to "ensure that the applicant has provided a non-proprietary description of major components and operations that is adequate to familiarize reviewers and other interested parties with the pertinent features of the installation." NUREG-1567 § 1.1 at 1-1.

[65] Exhibit 3, pg. 4.

[66] *Id.*

ISP also contends that the extremely low permeability and presence of red bed clay precludes the possibility of groundwater contamination.[67] To the contrary, Pachlhofer cites a memo created by TCEQ titled "Uncertainty of Performance Assessment" which studied the WCS area and stated there were extensive fractures in red bed clays overlying the Santa Rosa aquifer.[68] Pachlhofer suggests that the fractures as indicated by the memo "may provide a direct pathway to the Santa Rosa aquifer."[69] The Antler Formation used to provide water to Midland, Texas overlies the Dockum Formation which contains the Santa Rosa.[70] While water from the Dockum and Santa Rosa is saline and not suitable for consumption, the water in the Antler Formation is used as potable water in Midland, TX.[71] Since fractures in red bed clay overlying the Santa Rosa provide a direct pathway to the aquifer, this pathway would have to begin in the Antler Formation, directly overlying the Dockum formation containing the Santa Rosa. Given that the Antler Formation consists of permeable sandstone and pebble conglomerates, and that these deposits are exposed in the excavation walls of the WCS llrw facility and are present within a few feet of the land surface of the WCS area,[72] ISP's analysis of subsurface permeability—or lack thereof—has overlooked the potential for groundwater contamination of the Antler and Santa Rosa Formations. This failure is contrary to the requirements of 10 C.F.R. 51.45(b)(1) and NUREG-1567 § 2.4.5.

Lastly, ISP contends that the depth of the groundwater beneath the WCS CISF precludes the possibility of groundwater contamination. However, ISP fails to consider the Ogallala

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[67] SAR at 2-21; ISP's only well borings were drilled between 2005-2009 with the shallowest well depth being 49.02 feet and the deepest well depth being 99.56 feet. *See* SAR "Boring Logs".
[68] Exhibit 3, pg. 5.
[69] *Id.*
[70] *Id.* at pg. 4.
[71] *Id.*
[72] *Id.*

Formation's presence in the subsurface along the WCS-Flying "W" Ranch at a depth of 45-105 feet and the aquifer's presence beneath the WCS site itself.[73]

For the above-mentioned reasons, ISP fails to properly provide an adequate description of the environment and the impact that the proposed action will have on the environment pursuant to 10 C.F.R. §§ 51.45(b)(1) and NUREG-1567 § 2.4.5. ISP also fails to include critical adverse information in its SAR pursuant to 10 C.F.R. §§ 51.45(e).

E. CONTENTION NO. 5:

The Applicant's Environmental Report (ER) discusses its assessment of the presence of threatened and endangered species.[74] However, the ER does not adequately characterize the threatened and endangered species in the area of the proposed CISF.

i. Basis for Contention

This contention is within the scope of this proceeding because the potential for radiological and other environmental impacts on a region must be evaluated pursuant to subpart A, part 51 of title 10.[75] As required by this section, "[an] environmental report shall contain a description of the…environment affected, and discuss…[t]he impact of the proposed action on the environment."[76] The information submitted pursuant to paragraph (b) "should not be confined to information supporting the proposed action but should also include adverse information" as well.[77] Contrary to the requirements of 10 C.F.R. § 51.45, WCS has failed to adequately evaluate the potential for the presence of threatened and endangered species and relevant conservation efforts that may be undermined by the proposed CISF.

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[73] *See* Exhibit 3, pg. 4.

[74] ER, sections 3.5.4 -3.5.8

[75] 10 C.F.R. § 72.90(e).

[76] 10 C.F.R. § 51.45(b)(1).

[77] 10 C.F.R. § 51.45(e).

ii. Facts Upon Which Petitioner Intends to Rely in Support of This Contention

Petitioners rely on the Declarations of Aaron Pachlhofer and Tommy Taylor as support for the contention. *Inter alia*, Pachelhofer finds that the Dune Sage Brush lizard is not included by Applicants a threatened species.[78] Pachlhofer and Taylor both discuss the efforts of the regional oil and gas community to protect the Lesser Prairie Chicken and that the proposed CISF is incompatible with conservation measures currently in-place. Pachlhofer discusses conservation efforts by the oil and gas community as well as the ranching community related to the Dune Sage Brush Lizard and the Lesser Prairie Chicken. Tommy Taylor addresses the Lesser Prairie Chicken efforts undertaken by the oil and gas community.[79] Applicant does not address on-going conservation efforts for either the Dune Sage Brush Lizard or Lesser Prairie Chicken or whether the proposed CISF would interfere with such efforts.

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[78] Exhibit 3, sec. G.

[79] Exhibit 1, para. 15

Based on the facts and arguments herein PBLRO and Fasken urge that the Atomic Safety and Licensing Board enter an order that confers intervenor status on Petitioners and grants the Request for Hearing.

Respectfully submitted,

/electronically signed by/
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September 28, 2018

Fasken and PBLRO’s Hearing Request and Petition to Intervene:

Exhibit List

Exhibit 1 – Declaration of Tommy Taylor

Exhibit 2 – Declaration of D.K. Boyd

Exhibit 3 – Declaration of expert Aaron Pachlhofer, P.G.

Exhibit 4 – “Geology of the WCS – Flying “W” Ranch, Andrews County, Texas” study in which expert Aaron Pachlhofer, P.G. cites in his declaration.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE COMMISSION

In the Matter of:)
)
Interim Storage Partners) Docket No. 72-1050
)
(WCS Consolidated Interim Storage Facility))
)

DECLARATION

1. My name is Tommy E. Taylor and my business address is 6101 Holiday Hill Road, Midland, Texas 79707. I reside at 4100 Timberglen Circle, Midland, Texas 79707. My position with Fasken Management, LLC is Vice President. I am authorized by the business to execute this declaration on its behalf and on behalf of the Permian Basin Land and Royalty Organization (PBLRO) of which Fasken Land and Minerals (Fasken) is a member.
2. This declaration is in support of PBLRO's and Fasken's Petition to Intervene and Request for Hearing related to the applications of Interim Storage Partners (ISP) for the construction and operation of consolidated interim spent fuel facility (CISF) proposed for Andrews County, Texas. I am authorized by PBLRO and Fasken to execute this declaration.
3. Fasken Land and Minerals, of which Fasken Management, LLC is its General Partner, (Fasken) is engaged in oil and gas extraction and production activities. Fasken owns property related to oil and gas activities located approximately 18 miles from the proposed ISP CISF site. My employment duties and personal reasons require me to travel to and spend time in the area of the proposed CISF. Generally, I use the State Highway 176 when I am in the area. At its closest point, State Highway 176 is only approximately 1 mile from the proposed CISF site. Additionally, I am personally aware of other Fasken employees who often travel for employment and personal reasons to the area and use the State Highway 176 to do so.
4. PBLRO is an association that formed in response to the CISF applications of ISP and the Holtec application to construction and operation of a CISF near Eunice, New Mexico. D.K. Boyd, a member of PBLRO and with whom I am personally familiar, owns property 4 miles from the ISP site. I am also personally familiar with the other members of PBLRO and the nature of their oil and gas business activities in the Permian Basin area. Fasken is also a member of PBLRO.
5. My understanding is that ISP proposes to establish a CISF at its site in Andrews County site to store spent nuclear fuel and so-called Greater than Class C Waste (GTCC) from commercial nuclear reactors in the United States.
6. I understand that a radiation release from the ISP facility or during transportation of spent nuclear fuel through or near the Permian Basin may contaminate the areas in which

EXHIBIT 1

Fasken and other members of PBLRO have oil and gas property interests and/or extraction and production facilities.

7. Regarding oil and gas production activities and facilities, it is my understanding that ISP's Environmental Report indicates that the area around the proposed CISF is characterized by mostly abandoned wells. (**ISP ER, Socioeconomic Assessment, p. xvii**). ISP is mistaken. In fact, there are approximately 2964 active oil wells and 334 active gas wells within the 10 mile radius of the proposed CISF. (See attached map) Hence, contrary to ISP's assertion that most oil and gas production in the area of the proposed facility has been "abandoned" the area has robust production for both oil and gas.
8. According to the Texas Railroad Commission, the Permian Basin area, that includes Andrews County, produced approximately 6.45 million cubic feet (MMcf) of natural gas per day in 2017. Through July 2018 natural gas production increased to approximately 7.26 MMcf per day.
http://www.rrc.state.tx.us/media/41515/permianbasintotalnaturalgas_perday.pdf

9. The Permian Basin According to the Texas Railroad Commission, the Permian Basin area, that includes Andrews County, produced approximately 1.859 million barrels per day (Bbl) of oil in 2017. Through July 2018 oil production increased to approximately 2.089 Bbl per day.
http://www.rrc.state.tx.us/media/41514/permianbasin_oil_perday.pdf
10. This is approximately one-third of the nation's oil production. I raise this because the proposed CISF has the potential to release radiation from the stored spent nuclear fuel and cause contamination that would interfere or preclude the continued production of oil and gas in the Permian Basin. A radiological contamination event has the potential to interrupt or foreclose further oil and gas extraction/production activities and thereby diminish or eliminate the economic value of the oil and gas assets of the Fasken and other members of PBLRO .
11. I am concerned that radiological contamination also has potential human health effects that may cause death, radiation related ailments and/or genetic defects. This potential, in addition to the impacts on human mortality and morbidity rates, also has economic costs associated with medical care and treatment of radiation related conditions that affect Fasken and other members of PBLRO.
12. Additionally, because a permanent repository for final disposition of spent nuclear fuel is neither built nor licensed, I am concerned that any so-called "interim" facility will become a permanent facility for spent nuclear fuel. The ISP facility is neither designed nor intended for permanent disposition of spent nuclear fuel. Federal law requires final disposition of spent nuclear fuel in a deep geologic repository to protect human health and the environment from unnecessary radiation exposures. However, a so-called interim facility is expected to store large volumes of waste that include long-lived radionuclides but without the long-term environmental protections afforded by a deep geologic repository.
13. Additionally, because a permanent repository for final disposition of spent nuclear fuel is neither built nor licensed, I am concerned that any so-called "interim" facility will become a *de facto* permanent facility for spent nuclear fuel. The ISP Environmental Report (ER) concedes that while the Nuclear Waste Policy Act (NWPA) required that a deep geologic repository be established by the mid-1990s, none is presently available. What the ER's cost-benefit report does not discuss is whether or how an interim facility

moves the USA closer to the establishment of a permanent repository. The reason that discussion is absent is because an interim facility will actually make establishment of a permanent facility less likely. The consistent history of failed attempts to establish a permanent repository shows no signs of reversing course. Applicant offers no objective evidence that the presence of an interim facility will alter the variables that have thus far, prevented establishment of a permanent repository.

14. The reality that an available interim facility would not further the Congressional objective of establishing a permanent repository is inherent in the NWPA's prescription that any interim facility must be predicated on the availability of a permanent repository. Congress knew well that an available interim facility would reduce or eliminate the imperative to establish a permanent repository. ISP's cost-benefit study does not discuss this aspect of the NWPA.
15. Another omission from the ER is an accurate and adequate discussion of the species in the area that are covered by the Endangered Species Act. Fasken and other members of PBLRO were instrumental in taking voluntary steps to protect the Lesser Prairie Chicken by altering oil and gas activities in certain areas. The construction and operation of a large industrial complex like the proposed CISF is not compatible with the Lesser Prairie Chicken conservation program voluntarily developed and followed by Fasken and other members of PBLRO
16. In order to assure that the licensing decision in this matter adequately protects the interests of Fasken and other PBLRO members in an environment free from radiation and other hazards associated with CISFs and to protect the economic interests of Fasken and PBLRO to which Fasken belongs, I am authorized to effect Fasken's efforts in support of PBLRO's participation in the above-captioned NRC docket.

Under penalty of perjury, the above is true and correct to the best of my knowledge and understanding.

Tommy E. Taylor
On Behalf of Fasken Land and Minerals, Ltd. & Permian Basin Land and Royalty Owners (PBLRO)
Tommy E. Taylor,
Vice President, Fasken Management, LLC

10/29/18
Date

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY OF THE COMMISSION

In the Matter of:) Docket No. 72-1050

Interim Storage Partners)

(WCS Consolidated Interim Storage Facility)

DECLARATION OF D.K. BOYD

Under penalty of perjury, I, D.K. Boyd, declare as follows:

1. My name is D.K. Boyd.

2. I am a member of Permian Basin Land and Royalty Owners (PBLRO). PBLRO is an association comprised of businesses, organizations and individuals that formed in response and opposition to the proposed consolidated interim storage facility proposals in Andrews County, Texas and Lea County, New Mexico. PBLRO members have long-term economic, social and environmental interests in the Permian Basin. Fasken Land and Minerals (Fasken) has substantial land and mineral interests in the Permian Basin and is a member of PBLRO.

3. My main address is 4200 Tanforan Avenue, Midland, Texas, 79707.

4. I own and ranch the Frying Pan Ranch, most of which I own by deed and some of which I lease from New Mexico. The Frying Pan Ranch is located on 137,599 acres in southeastern New Mexico and western Texas. The closest part of the Frying Pan Ranch to Interim Storage Partners' ("ISP") Waste Control Specialists Consolidated Interim Storage Facility (the "Facility") is only four miles away. I have attached a map identifying the location of this part of the Frying Pan Ranch and the Facility. See Attachment A.

5. I have mineral interests and working interests in oil and gas operations on the Frying Pan Ranch. I also lease some of the Frying Pan Ranch to companies conducting oil and gas operations.

6. My brother and his employees frequently and regularly spend time within 15 miles of the Facility because my brother runs cattle operations on the Frying Pan Ranch. One of my brother's employees lives on Frying Pan Ranch in New Mexico in Township 23S, Range 38E, Section 8.

EXHIBIT 2

7. I also frequently and regularly spend time on the local roads near the Facility and transportation routes for the Facility. For instance, about once a week, I drive on Highway 18 south of Eunice, New Mexico. I have to use Highway 18 to travel for business, between different parts of my ranch, and between my residences. When I am on this Highway, I have noticed rail cars traveling next to me on the Texas and New Mexico Railway because this railroad parallels Highway 18 within a couple hundred feet for almost 40 miles. It is my understanding that ISP plans to transport spent nuclear fuel to the Facility on this railroad.

8. The Texas and New Mexico Railway also runs through approximately 5.5 miles of the Frying Pan Ranch. My family and I frequently and regularly cross this railroad via car or horse to conduct our cattle operations.

9. I am concerned about the radiation risks posed by the construction and operation of the Facility to my property, my health and safety, the health and safety of my family and employees, and my environment, by living and working next to a facility housing such an enormous inventory of radioactive material, and by transportation of spent nuclear fuel to the Facility.

10. I am also concerned that an accident involving spent nuclear fuel at the Facility will harm my family and property due to radiological exposure. I am also concerned that such an accident will harm the value of my mineral and working interests in gas and oil production or make them functionally inaccessible due to radiological exposure.

11. I am also concerned about the impact the Facility will have on the value of the Frying Pan Ranch. It is my understanding that property values near a nuclear facility can be reduced as early as when it receives its license to operate due to real or perceived risks of exposure to radiation releases from the nearby facility. It is also my understanding that property values continue to decrease as the Facility is constructed and operating.

12. I am also concerned that the licensing, construction, and operation of the Facility will impact the economic prosperity of the counties where I live and own land. It is my understanding that the Permian Basin in New Mexico and Texas is the largest oil and gas producer in the United States and the second largest in the world. I am concerned that construction and operation of the Facility on top of the Permian Basin will impact the ability to continue drilling so successfully here and therefore have a negative effect on the economy. This could harm local businesses and the value of my property. I am also concerned that construction and operation of the Facility will limit the domestic production of oil and gas in the United States.

13. I am also concerned that I will not be able to avoid small doses of unwanted radiation from driving next to rail cars carrying shipments of spent nuclear fuel, which will harm my health and safety.

14. I am also concerned with the impacts to my interest and right to travel near my home posed by ISP's proposed transportation of spent nuclear fuel on the Texas and New Mexico Railway. In order to ensure myself and my family travel on the safest roads to avoid unwanted doses of radiation or potential accidents involving transportation of spent nuclear fuel, we would have to avoid highways and roads that are our primary routes to access business and everyday necessities.

15. I believe that the ISP application is inadequate and illegal as written and that my interests will not be adequately represented in this action without the opportunity of PBLRO/Fasken to intervene as a party in the proceeding on my behalf.

16. Therefore, I have authorized PBLRO/Fasken to request a hearing and intervene on my behalf in the U.S. Nuclear Regulatory Commission's licensing proceeding for the Facility.

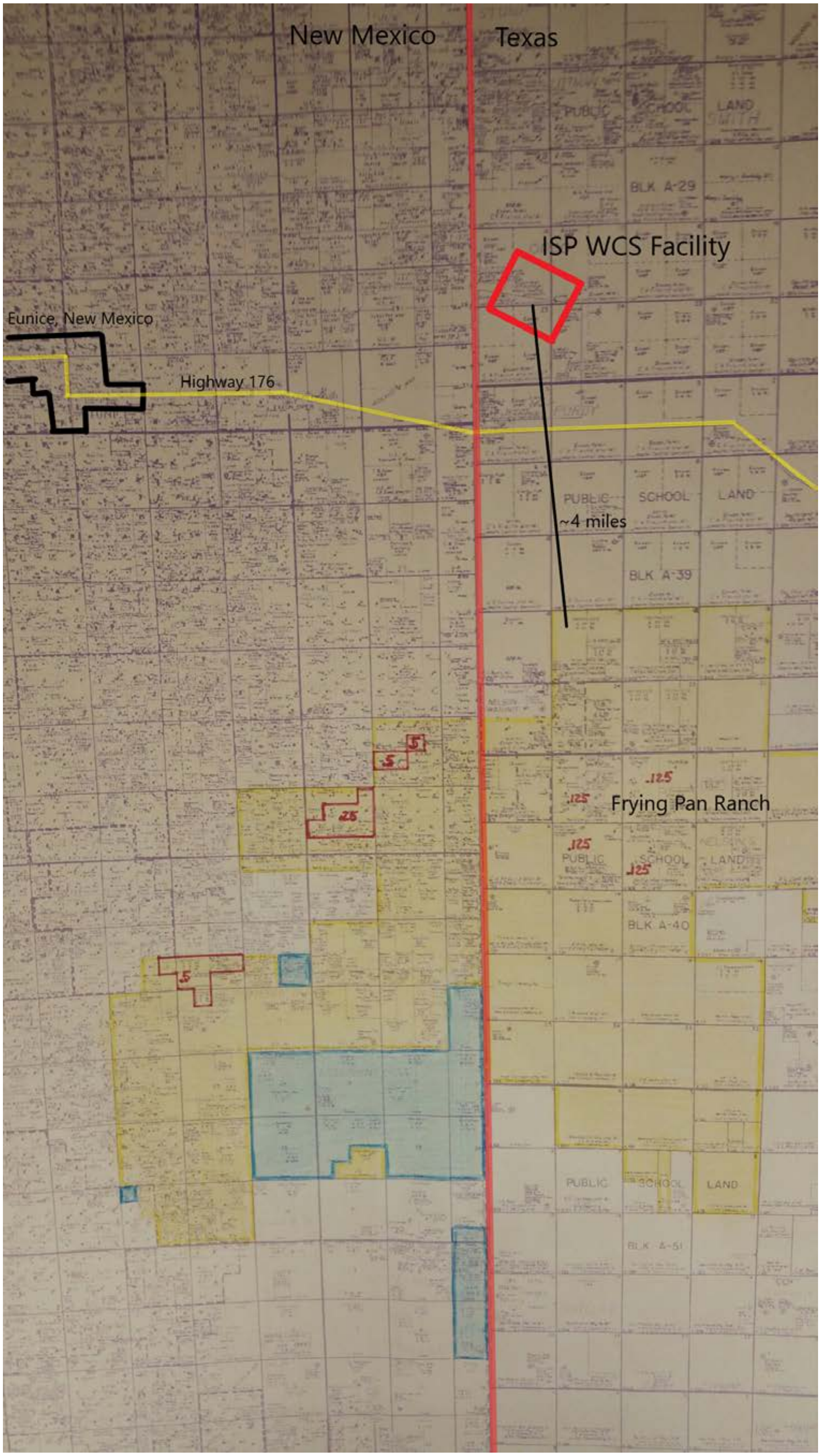
The declarant has caused this Declaration to be executed as of the date below.

Signed,

D. K. Boyd

Dated: October 29, 2018

Boyd Declaration: Attachment A



UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE COMMISSION

In the Matter of:
Interim Storage Partners)
(WCS Consolidated Interim Storage Facility))
)

Docket No. 72-1050

DECLARATION

1. My name is Aaron Pachlhofer and I am a licensed geologist and geoscientist. Since 2013 I have been employed by Fasken Oil & Ranch, Ltd. as Environmental Coordinator. In that capacity my duties include Primary management of all environmental policies, procedures, and programs for air, soil, and water concerns. My specific duties include coordination and oversight of all spill incidents, air permitting & air compliance, management of radiation issues, all regulatory interaction & notification, also management & oversight of environmental vendors. I also interpret, prepare comments for, and ensure compliance with all new and current Federal, state, and local regulations under US EPA, US BLM, Texas RRC, Texas TCEQ, NMED, and NMOCD. Additionally, I ensure compliance with any endangered species program requirements.
2. Prior to my employment with Fasken, I held a number of positions with duties related to environmental regulatory compliance, program management, emergency response, environmental assessments, groundwater monitoring, remediation and environmental data gathering and analysis.
3. I was awarded the B.S. in Geology in 1998 and the M.S. in Geology in 2004. Both degrees are from Sul Ross State University, Alpine, Texas.
4. In 2003 I received my Geologist/Geoscientist license from the State of Texas. My license has been in effect since 2003.
5. For a more complete compilation of my relevant professional experience please reference my resume that is included with my Declaration.
6. The sections below provide my analysis of the Waste Control Specialists, LLC Andrews Facility currently operating under TCEQ License #RO4100, and the concerns I have regarding their application to become a high level CISF.

I. Threats from Application to Become High Level Consolidated Interim Storage Facility of Waste Control Specialists, LLC Andrews Facility, TCEQ License #RO4100.

Waste Control Specialists, LLC (WCS) permitted a low-level nuclear disposal facility (site) on the Texas-New Mexico border in 2007 at approximately 32.441202° Latitude, -103.059348° Longitude and began accepting waste in 2009. The waste permit applications were approved by all state and federal agencies that maintain regulatory oversight of nuclear materials, including the Texas Commission on Environmental Quality (TCEQ) and the Nuclear Regulatory Commission (NRC). With the financial assistance of the City of Andrews, the facility was constructed and opened to accept hazardous and low-level nuclear waste for permanent disposal. Prior to the permitting of the site as a disposal facility, it was formerly known as the Flying 'W' Ranch.

Beginning in 2016, the WCS submitted additional permit applications for the existing low-level disposal facility to add a consolidated spent fuel interim storage facility (CISF), which is the interim storage of high-level radioactive waste from nuclear electric power plants. Due to financial difficulty, WCS has since formed a partnership with French engineering firm AREVA called Interim Waste Solutions, LLC and submitted a new permit application in 2018. The permit calls for the storage of hundreds of dry casks (a type of storage container) of spent nuclear fuel for a minimum of 40 years. The anticipated total weight

EXHIBIT 3

is 40,000 tons of radioactive material. The waste will be shipped by rail from throughout the United States to the disposal facility.

After careful review, Fasken Oil and Ranch, Ltd. (Fasken) protests the application for a consolidated interim storage facility for high level nuclear waste as it represents a permanent threat to Fasken personnel, private property, and oil & gas leases. The high-level facility also represents a permanent threat to numerous communities in Texas: Midland, Odessa, Andrews, Big Spring, Stanton, Lamesa, Seminole, Kermit, Monahans, Pecos, and more. Also threatened are communities in New Mexico: Eunice, Hobbs, Lovington, Monument, Jal, Carlsbad, and more. The site is situated in the approximate geographic center of the Permian Basin Region. The Permian Basin produces the largest volume of oil and gas in North America and recently surpassed Saudi Arabia in petroleum production. The Permian Basin region encompasses a twenty-county region in Texas and New Mexico and has a population of more than half a million people.

II. Historical Examples of Other Radiation Accidents

While Applicant asserts that its proposed CISF would be safe and that transportation of radioactive materials is also safe, there are numerous instances of serious accidents involving radioactive materials that undermine Applicant's claims of safety.[1] Applicant's confidence in the safety of the proposed CISF and the transportation of radioactive materials should be considered in light of well-recognized instances that caused unplanned release of radioactive materials and human exposures.

III. Specific Site-Related Concerns

A. Threatened Regional Population

The Permian Basin Region is comprised of the area of far west-central Texas, and eastern-central New Mexico. The following counties are included in the Permian Basin Region:

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[1] Historically there have been many accidents involving radioactive material but most have been small and contained. Few historical examples exist to provide an equivalent example of the result of an accident that could occur at the WCS site if it is licensed to become a CISF. According to the International Atomic Energy Agency, more than 100 serious nuclear-related accidents have occurred since the use of civilian nuclear reactors began in 1954. Some of the most serious civilian accidents, classified by the International Nuclear Event Scale (INES rated 0 to 7), include:
2011 - Fukushima Daichi, Japan, INES 7
1987 – Goiania Accident, Brazil, INES 5
1986 - Chernobyl accident, Ukraine, INES 7
1979 – Church Rock Uranium Spill, New Mexico, USA, no INES rating
1979 – Three Mile Island, Pennsylvania, USA, INES 5
1957 – Windscale Fire, United Kingdom, INES 5
1957 – Kyshtym disaster, USSR, INES 6
The INES scale and other nuclear accident measurement systems do not account for the contamination of liquids such as groundwater, rivers, or oceans.

In New Mexico: Chaves, Eddy, and Lea Counties. In Texas: Andrews, Borden, Crane, Dawson, Ector, Gaines, Glasscock, Howard, Loving, Martin, Midland, Pecos, Reeves, Terrell, Upton, Ward, Winkler, Yoakum Counties.

The following counties are regional boarder countries that are occasionally included in the Permian Basin Region: Brewster, Crockett, Culberson, Jeff Davis, Kent, Mitchell, Presidio, Reagan, Scurry, Sterling, and Terry Counties. These counties comprise a total population of approximately 642,000 people.

The counties in the Permian Basin considered to be imminently threatened by the site are: Andrews, Dawson, Eddy (NM), Ector, Gaines, Lea (NM), Martin, Midland, and Winkler. The imminently threatened counties have a population of approximately 434,000. The area of these counties is 13,868 square miles. In comparison, the 1,835 square mile Chernobyl Exclusion Zone would compromise 13.2% of the highest oil producing region in the Americas, the Permian Basin.

B. Direct airborne threat to Permian Basin Petroleum Region, Fasken personnel and properties, the city of Eunice, New Mexico.

Any pressurized release, dry cask rupture, explosion, or fire will release radioactive particles and fragments into the air. This is a direct threat to Fasken personnel, Fasken Private Property, and Fasken oil & gas leases. The closest Fasken oil & gas leases are 18 miles due east of the WCS site (Fasken Monterrey University and Lowe University leases). Other Fasken oil & gas leases are present in all directions from the site. Thus, any airborne release from the site would endanger Fasken personnel and property/oil & gas interests. Fasken's private property, the C-Ranch, begins 38 miles nearly due east (northwestern property line) of the site and continues south to the Midland city limits. This broad expanse of land has a high probability of receiving airborne radioactive contaminants.

Public data from the National Weather Service and the TCEQ indicates that regional winds blow to the southeast approximately 25% of the time on an annual basis. According to the permit application the average windspeed is 11.0 miles per hour. In comparison Houston, Texas winds vary from 8.3 mph to 6.7 mph, depending on the season. The Permian Basin region has higher winds than much of the rest of Texas and the United States. Any release of radioactive material might arrive in the Midland-Odessa metropolitan area (population more than 260,000) in a matter of hours with little warning. The most dominant direction of wind is from south to north, placing the town of Hobbs, New Mexico (population 38,000) which is less than 20 miles away, in direct danger of a release. Also, imminently threatened is the town of Eunice New Mexico (population 2,900), which is approximately 5 miles from the site.

The broader perspective is that the Permian Basin region's winds are highly variable and change direction frequently throughout a given day. With the site's geographically central location in the Permian Basin, any release in any direction risks contaminating large areas of the most productive oil and gas region in North America. Depending on wind direction and speed, hundreds of thousands of people could be affected. A Department of Energy Report found that an accident involving only one dry cask where only a small amount of waste was released in a rural setting would contaminate a 42-square mile area with clean-up costs exceeding 620 million dollars. A similar release in an urban setting might cost 9.5 billion (yes, billion) per square mile.

C. High Potential for Contamination of the Ogallala and Santa Rosa Aquifers

The site is a direct threat to regional groundwater usage. The Texas Water Development Board identifies four aquifers in Andrews County at or near the WCS site. These include the Dockum, Edwards-Trinity, Ogallala, and Pecos Valley Aquifers (George, et al., 2011). Texas Tech University Water Resources Center conducted a groundwater evaluation for Andrews County (Rainwater, et al. 2000) and a specific study of the WCS - Flying "W" Ranch (Lehman and Rainwater, 2000).[2] The WCS – Flying "W" Ranch study was conducted with an exploratory drilling program that included thirty-five air-rotary boreholes completed as piezometers. This program enhanced the database on subsurface geologic conditions and groundwater in the area. These reports were submitted to the Andrews Industrial Foundation and describe five geologic formations that contain groundwater at the WCS study area: the Dockum, Antler, Ogallala, Gatuña, and the "Caprock" Caliche formations (Lehman and Rainwater, 2000). According to the site map presented in Figure 2 of Lehman and Rainwater, 2000 the interim stage site lies to the north of the "Area of WCS Investigation" and mostly outside of the "WCS Permitted Boundary" that is designated on the site map. The data published for the study includes this area and shows the Ogallala aquifer to be present and a greater thickness than beneath the WCS site itself.

The Dockum Formation (also referred to as the Dockum Group) contains the Santa Rosa sandstone which is saturated with brackish water. This aquifer is interbedded above and below by red and gray shales described as "red beds" and is present in the subsurface throughout the WCS area and exposed within the excavation walls at the WCS LLRW facility. While the Dockum/Santa Rosa water is saline and not suitable for consumption or irrigation; it is widely used by the petroleum industry (including Fasken) to hydraulically fracture oil wells since it is not potable water.

The Antler Formation is part of the Edwards-Trinity Group that consists of sandstone and pebble conglomerates. These deposits are also exposed in the excavation walls of the WCS_LLRW facility and is present within a few feet of the land surface throughout the WCS area. Maximum thickness of this formation is approximately 70' and overlies the Dockum Formation. Groundwater is present in this formation. The City of Midland supplies part of its potable water from Antler formation waters.

The Ogallala Formation is present in the subsurface along the north and east sides of the WCS-Flying "W" Ranch at a depth of 45-105 ft.[3] Cross sections show the Ogallala gaining thickness to the north. Groundwater was found in 3 borings that penetrated the Ogallala according to Lehman and Rainwater, 2000. The Antler Formation and the Tertiary Ogallala formation are lithologically similar, therefore, they are often misidentified. Both formations consist of unconsolidated sand and gravel, overlap stratigraphically, and cross-formational groundwater is known to exist between these formations.

The Pecos Valley Aquifer, also referred to as the Gatuña Formation or "Cenozoic Basin Fill" in the Texas Tech study (Lehman and Rainwater, 2000), contains sandstone and conglomerates and is present in the subsurface of the WCS area and thickens to the south. Groundwater from this formation was not found in the WCS study area. Pecos Valley groundwater appears to be discharging from this formation at Baker Spring near the west side of the WCS study area. The Gatuña Formation appears to underlie the most of the WCS Study area and thickens considerably further south, according to the cross sections presented in Lehman and Rainwater, 2000. As noted above, the site is situated to the north of

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[2] Study and maps found in Attachment 1.

[3] *See Figures 2 and 4, page 22 and 24, Lehman and Rainwater, 2000*

the WCS Study area. The Gatuña Formation is likely to be found in the southwest corner beneath the interim storage site and also across the southern boundary of the site; pinching out to the east.

Overlying the Gatuña Formation is the "Caprock" Caliche,[4] known informally as the "Caprock", is a thick hard pedogenic limestone. The "Caprock" mostly lies within the unsaturated zone but locally contains groundwater.

Overlying the "Caprock" Caliche is the Blackwater Draw Formation. This formation contains mostly windblown sands and is present at or near the land surface over most of the WCS study area. This formation is not considered an aquifer but can contain perched groundwater.

With reasonable scientific certainty the Ogallala aquifer underlies the site where the interim storage facility will be constructed. During the 2007 permit approval process of the hazardous wastes and LLRW facility, the presence of the Oglala aquifer was the matter of considerable debate. In a review of aquifer maps published by the Texas Water Development board, the Ogallala aquifer is shown to exist beneath the site. As a result of a drilling program by WCS, aquifer maps were changed by the state of Texas to reflect that the Ogallala does not underlie the site. The aquifer mapping changes are still contested, as not all scientists agreed with the conclusion of the Texas Water Development board (see published maps by Texas Water Development Board). Furthermore, despite the scientific disagreement whether the Ogallala is under the WCS site, the interim storage facility site will be to the north of the WCS site where Lehman and Rainwater show the Ogallala to be present in their cross sections (Lehman and Rainwater, 2000) A 2007 memo by TCEQ titled "Uncertainty of Performance Assessment" cited extensive fractures in red bed clays overlying the Santa Rosa. The fractures are up to 3 millimeters wide. This may provide a direct pathway to the Sant Rosa aquifer.

During the permitting process of the WCS facility in 2007, TCEQ had recommended against the facility, citing fears the groundwater could intrude into the excavation for the waste disposal portion of the facility. After the TCEQ director administratively approved the application, several TCEQ employees resigned in protest.

An August 14, 2007, TCEQ internal memo titled "Groundwater intrusion into proposed LLRW facility" (Lodde, et al, 2007) states that ground water is likely to intrude into excavations at the site. Any contact between groundwater and physical material that could be released from the thin wall dry casks will migrate further into the saturated zone. As soon as this might happen, the material will be virtually impossible to recover and will continue to emit radiation until all parent/daughter half-lives are expended. The same memo concludes that groundwater is unacceptably near the boundaries of the (then) proposed disposal unit. Further, it states that predicted increases in precipitation are expected to drive groundwater into the disposal units. Finally, the memo concludes that "Intrusion of groundwater into proposed disposal units will increase mobility of radionuclides and the likelihood of public exposure to radioactivity…". The current LLRW facility at the site contains a fraction of the radioactive material that is contained in one thin wall dry cask. As noted above, the interim storage site is situated to the north of the WCS site. Groundwater present beneath the WCS site will be similar to the groundwater beneath the interim storage site; similar meaning the interim site will have a greater Ogallala formation presence beneath it, as Lehman and Rainwater show the Ogallala in north portions of their cross sections near the north boundary of the "Area of WCS Investigation".

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[4] *See Figures 2 through 7, page 22 to 27, Lehman and Rainwater, 2000*

D. Potential Subsurface Instability and Sink Hole Formation

The site location is situated over Permian aged halite formations (rock salt) and other easily dissolved evaporite mineral formations. There is extensive sinkhole formation in the Permian Basin region, including the very well known "Wink Sinks" outside of Wink, Texas, a large area of subsidence beneath the city in Carlsbad, NM, sinkholes and karst features north and east of Carlsbad, NM. There are also ground movement issues in Pecos, Crane, Monahans, Imperial, and Kermit Texas. A study published on March 16, 2018 by the Southern Methodist University Department of Earth Sciences detailed extensive ground movement across the Permian Basin Region. Unfortunately, the study area did not include the site. The importance is that the study highlights the instability of the subsurface in the Permian Basin region. The presence of groundwater could contribute to subsurface instability and sinkhole formation. The failure of applicant to identify all pertinent groundwater under site means they have not fully considered all circumstances that could contribute or cause subsurface instability or sinkholes.

E. Area Production of Oil and Gas

The application indicates that the immediate area around the site has been explored for 75 years for oil and gas and that most wells have been plugged or use enhanced recovery techniques to continue to produce hydrocarbons. In laymen's terms the application says that the petroleum production around the site is 'played out' and not economically viable. In contrast, Fasken used Petra, a commercially available petroleum industry GIS-based software to review current and former oil and gas drilling activity to determine the extent of oil and gas activities in the area of the proposed CISF.

Within a 10-mile radius of the site, there have been a total of 4,947 well bores drilled in Texas and New Mexico. Presently 3,656 of these well bores are still in production. 905 wells are shown as a dry hole. Of the total of nearly five thousand wells within ten miles of the facility, only 386 have been recorded as permanently plugged and abandoned. This clearly shows that the area around the site is still under active exploration and active production.

A complicating factor is that there is no definitive index to adequately count all well bores drilled in the area (or any area). The current API numbering system was introduced in the early 1960s and formally adopted by petroleum producing states at the beginning of 1967. Wells drilled after 1967 were assigned an API number and can be tracked with some certainty. Wells drilled prior to this date may or may not have an API number assigned to it and wells that were out of use almost certainly did not have an API number assigned. The count of nearly 5,000 individual wells made by Fasken may be low. For these older well bores, there may be little or no information to determine the subsurface construction or if the well has been properly plugged and abandoned. Records of these wells do exist, but may not be available in the respective state records. And these records may be incomplete. An example is that an old well bore was recently discovered leaking at the surface on Fasken's property. The well head was buried below ground surface and found by a rancher moving livestock through the area. After Fasken conducted an internal investigation, it was found that the well was drilled in 1962 by a company that had obtained an oil and gas lease from Fasken. The well was a noted as a dry hole and temporarily abandoned by the company that drilled it. Internal records indicate that the well has a surface casing with an open hole (no casing) below approximately 500 feet from ground surface—which was common for the period. Although this well appears on Texas Railroad Commission (RRC) public Geographic Information System mapping records, no information is available from RRC to determine the status. Only Fasken records were able to provide the historical data. Wells of this type are called orphan wells. In most cases no data are available for an orphan well due to age, or the company that drilled it may be defunct. According the RRC there are more than 10,000 orphan wells in Texas (Mittra, 2016). It is unknown how many orphan wells may exist near the site. With older orphan wells the only knowledge that the well might exist is that a permit to drill the well was obtained and these wells may or may not appear in a GIS. Finally, drilling an oil well is expensive and petroleum companies that drilled dry holes often did not permanently plug the wells due to funds expended—the well bore would be temporarily abandoned to save it in case an opportunity arose to find a use for it. There are 905 temporarily abandoned well within 10 miles of the site. The status of the surface wellheads is not known and in some cases could be open allowing anything to fall into it. A more definitive well search is needed and on-the-ground verification should be conducted.

Regardless of the current volume of oil produced within the vicinity of the site, there are hundreds of active oil and gas wells, tank batteries, gas plants, and other petroleum production facilities within reasonable vicinity of the site, each requiring regular visits from personnel for maintenance and monitoring. Some facilities, such as gas plants, are staffed 24 hours a day, seven days a week.

State Highway 176 serves as a main motor vehicle access to the site. It is also a major artery for the travel of both private citizens and oil and gas industry traffic. At the present, S.H. 176 between Andrews and Eunice is completing a widening project to accommodate the large volume of heavy oil industry traffic that utilizes this highway. The application does not include a traffic study to understand the extensive use of this roadway and the risks that might be posed to transient populations utilizing the highway during a potential release form the site.

F. Environmental Response Plan Concerns

A number of safety concerns exist within the Environmental Response Plan (ERP):

i. Andrews and Eunice Fire Departments have signed agreements to assist the site with major emergencies. Are these fire departments equipped to deal with the type of emergency that could occur at the site? Are other nearby fire departments such as Odessa and Midland equipped to deal with the risks at the site?

ii. Carlsbad Medical Center is listed as the first choice for radiological contamination treatment. The staff at the Carlsbad Hospital are trained by the WIPP personnel, which is not a high-level facility. Training should be given by personnel from a high-level facility. Hospitals in Hobbs, Odessa and Midland are closer, bigger, and better equipped. Carlsbad should not be the first choice. The distance required to get to Carlsbad could cost a person's life.

iii. For the volume of radioactive material to be stored at the site, the 6-kilometer Emergency Planning Zone is undersized. The Emergency Planning Zone includes portions of New Mexico, the Urenco National Enrichment Facility, and the outskirts of Eunice, NM.

G. Inadequate Protection for Threatened and Endangered Species

The application does not adequately address threatened or endangered species. The application for the site relies on ecological assessments completed for WCS in 2003-04 and supplemented in 2006-07. The application concludes that no threatened/endangered species present but that critical habitats are present onsite or within 3.1 miles of the site. These conclusions appear outdated and in error.

The site is entirely within the known range of the Dune Sage Brush Lizard (*Sceloporus arenicolus*). The Dune Sage Brush Lizard is listed at threatened by the US Fish and Wildlife Service (USFWS) and may be listed as endangered in the future. The application uses an incorrect common name for the species (but correct scientific name), causing confusion. On page 3-31 of the application it is noted that the Dune Sage Brush Lizard (as Sand Dune Lizard) is present at the study area for the site. However on page 3-34 and 3-35 where the species and the presence of its critical habitat is most discussed; its federal status as threatened is not listed. In table 3.5-1 on page 3-34 the Dune Sage Brush Lizard is not shown as threatened. This is an example where the application is relying on outdated information.

A portion of the site also lies within the known range of the Lesser Prairie Chicken (*Tympanuchus pallidicinctus*). It is listed as threatened by USFWS and is also under consideration for listing as an endangered species. The application also notes that no leks (mating sites) or prairie chickens were detected in 2004. More research has been devoted to the prairie chicken in the past 14 years and their range is better mapped. Recently prairie chicken number have improved according to reports from USFWS. This information is not detailed in the application showing the dated nature of the data used.

It is especially important to note that both the Dune Sage Brush Lizard and the Lesser Prairie Chicken have been the subject of extensive conservation efforts in both Texas and New Mexico by the oil & gas and ranching industries. Specifically, participation in conservation programs has prevented both species from being listed as endangered. Fasken is an active participant conservation programs for these and other species. For the Dune Sage Brush Lizard, the USFWS publicly stated that the conservation efforts undertaken directly affected the decision not to list the species as endangered. For the Lesser Prairie Chicken, litigation undertaken against the USFWS resulted in same decision: conservation efforts by industry had preserved the habitat and as a result did not warrant listing as an endangered species. The Lesser Prairie Chicken in particular is sensitive to surface disturbances such as construction activities, fences, power lines, and permanent structures.

The application relies on data that is more than 10 years old and ignores that one species is a federally listed threatened species. A complete biological re-evaluation is needed, as more threatened or endangered species may be present. Furthermore, any release of radioactive material or any amount of radiation will become a direct threat to the survivability of species noted above and the Texas Horned Lizard (*Phrynosoma cornutm*), which is protected under Texas law, and is also the state reptile.____

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Geology of the WCS – Flying "W" Ranch, Andrews County, Texas

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Submitted to

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April, 2000

EXHIBIT 4

Geology of the WCS – Flying "W" Ranch, Andrews County, Texas

by

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Geology of the WCS - Flying "W" Ranch, Andrews County, Texas

1. Introduction

The general geological setting of the WCS - Flying "W" Ranch area in western Andrews County, Texas, has been previously described in permit applications (e.g., AM Environmental, 1993) and unpublished reports (Lehman, 1996a; 1996b). These reports provide an adequate overview of the regional geological setting and a detailed description of the site-specific conditions at the WCS facility. For example, Figure 1 shows the local topography of the "red bed" surface as was determined by the thorough geotechnical investigation done during the design of the WCS facility (AME, 1993). An exploratory drilling program conducted from March through June 1999 has greatly expanded the database on subsurface geologic conditions and groundwater in this area. In this report, some pertinent general information from the earlier documents is repeated, but attention is focussed instead on new detailed information that has resulted from the recent drilling program.

Thirty-five air-rotary boreholes were completed as piezometers on the WCS - Flying "W" Ranch (Figure 2). Three of the boreholes (#22, 23, and 24) were offset and drilled to greater depth (#22B, 23B, 24B). One borehole (#4) partially collapsed and remains problematic. Detailed geologic logs for each of the 35 boreholes are included as an appendix to this report. This report provides the following:

[1] further delineation of the "Red Bed Ridge" beneath the ranch property,

[2] description of each of the geologic units penetrated in the boreholes,

[3] discussion of the relationship between the occurrence of groundwater and subsurface geologic conditions, and

[4] methods used to discriminate deposits of the Ogallala and Antlers Formations.

Several figures are included to document the subsurface geology and groundwater distribution, and are discussed where appropriate in the report. Figure 2 shows the locations of five lithologic cross-sections that are provided as Figures 3 through 7. Figures 8 through 10 map the elevation of the "red beds," the thickness of the Antlers sand, and the areal distribution of saturated thickness.

2. Nature and Origin of the Buried Triassic "Red Bed Ridge"

2.1 General Information

The WCS-Flying "W" Ranch straddles a prominent buried ridge developed on the upper surface of the Triassic Dockum Group "red beds." This feature is referred to informally as the "Red Bed Ridge." Previous reports (e.g., Lehman, 1996a) have described this feature, but the recent drilling program provides additional information on its nature and extent (Figure 8).

The crest of the buried "Red Bed Ridge" is a mile or so in width and extends for at least 100 miles from northern Lea County, New Mexico, through western Andrews County and into Winkler and Ector Counties, Texas. The modern surface topography roughly coincides with the trace of this buried ridge, but is in general more subdued. In Lea County, the buried ridge runs parallel to and less than a mile northeast or southwest of the Mescalero Escarpment (Nicholson and Clebsch, 1961; Ash, 1963; Cronin, 1969), and similarly in Winkler and Ector counties the buried ridge coincides roughly with the western escarpment of the High Plains. The ridge is at least in part a product of structural deformation, as underlying Triassic strata have subsided in response to dissolution of Permian salt beds to the south and west of the ridge, underlying the Monument Draw Trough, San Simon Swale, and Pecos River Valley (Maley and Huffington, 1953; Nicholson and Clebsch, 1961; Anderson, 1980; Baumgardner et al., 1982; Gustavson and Finley, 1985). The ridge also roughly parallels the western margin of the buried Central Basin Platform in underlying Permian strata. However, the ridge is also in part a product of post-Triassic erosion, which has removed part of the Triassic section both northeast and southwest of the ridge. Cretaceous strata are absent southwest of the ridge. To the north and east of the "Red Bed Ridge", the High Plains surface is relatively undisturbed, and underlying Cretaceous and Tertiary strata are gently inclined to the southeast. In contrast, to the south and west of the ridge, dissolution of underlying Permian salt beds has resulted in deformation of the Triassic and Tertiary strata, and the High Plains surface has been locally disrupted by subsidence.

Several authors have commented on the nature and importance of this buried ridge, but it has not received widespread attention. Hawley (1984, pp. 161-162) regarded this as the position of a major drainage divide in the sub-Ogallala topography, and that this divide separated two major fluvial systems throughout Late Cenozoic time. Deposits of the Ogallala Formation lie to the north and east of the buried ridge, while deposits of the ancestral Pecos River (variously mapped as "Cenozoic Basin Fill," Gatuña Formation, or Ogallala Formation) lie to the south and west of this ridge (Reeves, 1972; Kelley, 1980; Hawley, 1984, 1993). Hawley (1993) suggested that use of the name "Ogallala Formation" could be restricted to deposits northeast of this divide, while the name "Gatuña Formation" could be used for equivalent deposits to the southwest. Little or no sediment accumulated on the summit of the buried "Red Bed Ridge", where instead, the "Caprock" Caliche developed directly on the exposed surface of underlying Triassic or Cretaceous strata, or on a thin veneer of eolian sediment. Reeves (1972) indicated that basal Ogallala gravels are present, at least locally on the crest of the ridge, suggesting that it may not have been an effective drainage divide during the later phases of Ogallala deposition. It is apparent that the buried ridge marks the position of a persistent ancient drainage divide between the ancestral Pecos River (to the southwest) and the Brazos and Colorado Rivers (to the northeast). It also roughly coincides with the modern drainage divide.

2.2 WCS - Flying "W" Ranch

The recent drilling program defined the extent of the "Red Bed Ridge" on the ranch area in greater detail than known previously, and provided further evidence for the origin of this feature. Cretaceous strata overlie the summit of the ridge along its length. AM Environmental (1993) had previously reported over 50 boreholes and well logs within the WCS site (Figure 1), and these data points were considered in the construction of the "red bed"-related maps within Andrews County in this report. Weaver Boos & Gordon, Inc. (1997) also provided data at 11 boreholes west of the state line and west of the WCS site. The "Red Bed Ridge" enters the northwest corner of the ranch and extends to the WCS landfill area and southeastward to Windmill Hill (Figure 3). From there, the ridge branches southward to the vicinity of well #30 and eastward to the vicinity of well #26. The southern branch likely terminates south of the ranch boundary, while the eastern branch probably tracks the continuation of the ridge to the south and east. Along the length of the ridge, the "Caprock" Caliche is exposed at or near the land surface, and so generally corresponds to the mapped distribution of the Kimbrough soils or Blakeney and Conger soil association (Figure 2; Conner et al., 1974). Additional drilling is necessary to establish the continued course of the "Red Bed Ridge" to the east; however, it likely continues roughly south and east along the route of State Highway 176 where the Kimbrough and Blakeney-Conger soils are present.

The presence of the "Caprock" Caliche over the entire area, both north and south of the "Red Bed Ridge" suggests that the ridge is not the buried erosional edge of the Caprock Escarpment, one of several possible interpretations of this feature. The ridge was present prior to formation of the "Caprock" Caliche and subsequent erosional retreat of the escarpment of the High Plains. Nevertheless, the absence of Cretaceous strata southwest of the ridge indicates that at least part of the relief on this feature is a result of erosion.

On the WCS - Flying "W" Ranch, and along most of the length of the "Red Bed Ridge", the southwestern flank of the ridge is more steeply inclined than the northeastern flank. The decline in elevation of the basal sand interval of the Antlers Formation southwest of the ridge (e.g., Figure 4, well #15) suggests that some of the relief on the "Red Bed Ridge" is owing to post-Cretaceous/pre-Late Tertiary structural deformation. However, the irregular southern boundary of the ridge indicates that relief is likely not due to faulting, and may more likely reflect a gentle fold.

3. Subsurface Geology

In this following section, each of the geologic units documented in the WCS - Flying "W" Ranch drilling program is described. The formations are given in ascending order (from oldest to youngest). General information on the distribution and characteristics of each unit is provided, followed by information specific to conditions observed in the WCS - Flying "W" Ranch area.

3.1 Chinle Formation (= Cooper Canyon Formation, Dockum Group: Triassic)

3.1.2 General Information

The distribution and regional characteristics of the Triassic Dockum Group were recently reviewed by Lehman (1994a, 1994b). The Dockum Group consists of five formations; in ascending order these are the Santa Rosa, Tecovas, Trujillo, Cooper Canyon, and Redonda Formations. These strata attain their maximum total thickness in excess of 1800 ft in the subsurface of Yoakum County, and are over 1000 ft thick in western Andrews County. The uppermost unit in the Dockum Group was traditionally (but incorrectly) referred to as part of the Chinle Formation in the southern part of the High Plains region. More recently these strata have been identified as the Cooper Canyon Formation (Lehman, 1994; Lehman et al., 1992). These deposits are referred to here simply as part of the Dockum Group. The Chinle or Cooper Canyon "red beds" consist primarily of massive red or purple mudstone and siltstone. These strata underlie all of Andrews County and form a regional aquitard below the surficial permeable strata.

3.1.2 WCS - Flying "W" Ranch

The Dockum Group "red beds" are present in the subsurface beneath all of the WCS - Flying "W" Ranch area. There is a small exposure of the Dockum Group on the ranch, about 500 ft southeast of Baker Spring (Figure 8; Section 28, T.21S.). Another small exposure is mapped immediately west of the ranch (Section 29) about 0.5 mi west of Baker Spring (Geologic Atlas of Texas; Hobbs Sheet, 1976). The base of the landfill pit at the WCS facility lies within the uppermost 40 to 60 ft of the Dockum Group. The top of the Dockum Group is encountered at depths of less than 35 ft up to 120 ft below ground surface over the ranch area. At the WCS facility and elsewhere along the crest of the "Red Bed Ridge," the depth to the top of the "red beds" is very shallow, 35 ft or less; it is 100 ft or greater along the northern and southern boundaries of the area. Most borings penetrated 5 to 20 ft of the "red beds" in the upper part of the Dockum Group. These deposits consist of red (10 R 4/4 to 6/4) mudstone. Where the Dockum Group is overlain by Cretaceous strata, the uppermost 5 ft of these deposits is mottled yellowish gray (5 Y 6/2). This mottled zone is probably a weathering horizon that formed prior to deposition of the Cretaceous strata.

At the WCS landfill excavation, a 5 to 10 ft thick layer of light gray fine-grained micaceous sandstone is present within the Dockum Group, overlain and underlain by the red mudstone more typical of the formation. Similar interbedded sandstone units occur in the Chinle (= Cooper Canyon) Formation exposed in the Colorado River valley, about 80 miles east of the WCS facility. These sandstone beds are typically discontinuous, surrounded by mudstone, and not interconnected (Lehman, 1994b).

3.2 Antlers Formation (Trinity Group: Cretaceous)

3.2.1 General Information

The regional characteristics and distribution of Cretaceous strata in the Southern High Plains region were described by Brand (1953), and more recently in some detail by Fallin (1988,

1989) and Nativ and Gutierrez (1988). The entire local Cretaceous stratigraphic section consists of six formations; in ascending order these are the Antlers, Walnut, Comanche Peak, Edwards, Kiamichi, and Duck Creek Formations. In the Southern High Plains area, Cretaceous strata attain their greatest preserved thickness in the vicinity of Yoakum County where they exceed 220 ft in total thickness. Southward from Yoakum County, the Cretaceous section thins and is absent in some areas of Gaines and Andrews Counties, primarily due to erosion prior to deposition of the Ogallala Formation. In southern Andrews County, and areas further south, Cretaceous strata are thicker and widely exposed.

Only the basal Cretaceous unit, the Antlers Formation, is present in the WCS-Flying "W" Ranch area; although a small outcrop identified as Fort Terrett Formation (equivalent to the Comanche Peak Limestone) is mapped immediately west of the ranch in Section 29 T.21S. (Hobbs Sheet, 1976), and a thick bed of Cretaceous limestone is also exposed on the ranch in the floor of a gravel pit in the west-central part of Section 8 (Block A-39; see Figure 9). This material is also likely a part of the Fort Terrett (= Comanche Peak) limestone. The "basal sand" of the Cretaceous section in the High Plains region is identified as the Antlers Formation, but in older literature is also referred to as the Antlers Sandstone, Trinity Sandstone, or Paluxy Sandstone (see Fisher and Rodda, 1967). It is also referred to informally variously as the "Antlers Sand" or "Trinity Sand." This unit consists of weakly cemented fine to medium-grained quartz sandstone and chert-pebble conglomerate. The Antlers Formation varies regionally from 10 ft to 80 ft in thickness (Nativ and Gutierrez, 1988). The thick areas comprise several linear belts trending approximately southeastwardly across the High Plains, where the Antlers Formation fills erosional channels incised into the underlying "red beds" of the Dockum Group (Fallin, 1989).

3.2.2 WCS - Flying "W" Ranch

No outcrops of the Antlers Formation are found in the WCS - Flying "W" Ranch area, but these deposits are exposed in the walls of the excavation at the WCS facility, and are present within a few feet of the land surface in that vicinity. The Antlers Formation is present only in the northwest and central part of the ranch area where it forms a buried erosional remnant along the crest of the "Red Bed Ridge" (Figure 9). The top of the Antlers Formation is encountered in borings at depths between 5 and 80 ft below ground surface. The subcrop of the buried Antlers

Formation is expressed at the land surface, and corresponds roughly with the area bounded by a subtle increase in slope at a topographic elevation of about 3450 to 3485 ft.

In the WCS - Flying "W" Ranch area, the Antlers Formation attains a maximum thickness of about 70 ft and consists of three stratigraphic units; in ascending order these are [1] a lower coarse-grained gravelly sand, yellowish brown in color (10 YR 7/2 to 7/6), between 10 and 30 ft thick with distinctive multicolored chert gravel, [2] a very fine to fine-grained white (10 YR 8/2) quartzose sand, consisting of nearly pure quartzarenite, 10 to 30 ft thick, and [3] an upper interval of multicolored shale and mudstone, 5 to 45 ft thick. Where the upper shale interval is thickest, it exhibits a stratigraphic sequence with white siltstone (10 YR 8/2) at the base, grading upward to dark red or purple mudstone (10 R 4/4 or 5 YR 8/4 to 6/4), gray (5 Y 7/2) shale, and an upper layer of yellow (10 YR 7/6) calcareous shale or argillaceous limestone. The limestone layer at the top of this interval may actually be the base of the Fort Terrett (= Comanche Peak) limestone. It is exposed at the land surface in the floor of a gravel pit in Section 8 (Block A-39).

The upper shale interval (unit 3, above) is present only where the Antlers Formation exceeds 40 ft in thickness, in the northwestern corner of the WCS - Flying "W" Ranch area and in the central area surrounding Windmill Hill (see Figures 5, 7, and 9). Elsewhere in the area, the Antlers Formation has been thinned or entirely removed by post-Cretaceous erosion, and younger strata rest on the lower sandy strata of the Antlers or on the underlying Dockum Group "red beds". Only the lowermost part of the Antlers Formation (unit 1, above) is present within the WCS Facility boundaries and exposed in the walls of the excavation there.

Groundwater in the WCS - Flying "W" Ranch area is found almost exclusively in the lower sandy part of the Antlers Formation.

3.3 Ogallala Formation (Late Tertiary: Miocene)

3.3.1 General Information

The regional distribution and characteristics of the Ogallala Formation and the Ogallala aquifer are well known (Cronin, 1961; 1969), and have been documented in numerous reports (recently reviewed by Gustavson, 1990; Gustavson et al., 1991). Regionally, the Ogallala Formation thins southward across the High Plains, and so is relatively thin in Andrews County, which lies near the southwestern border of the High Plains. In the southern part of its distribution, the Ogallala Formation does not exceed 100 to 200 ft in thickness (Seni, 1980). On a local scale, the thickness of the Ogallala Formation also varies from relatively thick sections (typically exceeding 100 ft) dominated by gravel and coarse sand, to relatively thin sections (typically less than 100 ft) dominated by finer sand and silt. The thick sections represent fluvial paleo-valley fill deposits that trend southeastwardly across the High Plains. These paleo-valley deposits are marked by higher net thickness of sand and gravel, and a high percentage of sand and gravel (Seni, 1980). Such areas generally correspond to the greatest saturated thickness in the Ogallala aquifer. The broad areas where the Ogallala Formation is relatively thin or absent represent "interfluve" or upland regions between the paleo-valley axes, where fine-grained eolian sediments predominate. The Ogallala Formation is thin or absent over the top of remnant Cretaceous bedrock "highs" on interfluves (e.g., Reeves, 1972), and may never have been deposited in these areas. Where present in interfluve regions, the Ogallala has a low net sand and gravel thickness and low percentage of sand and gravel. The interfluve areas correspond to regions with lower saturated thickness in the Ogallala aquifer (e.g. Peckham and Ashworth, 1993; Nativ and Smith, 1987).

In northern Andrews County, At least 15 miles northeast of the "Red Bed Ridge," at its nearest point. the Ogallala Formation is relatively thick and consists of fluvial sand and gravel deposits filling the southernmost of the paleo-valleys, which roughly coincides with the present course of Monument Draw in northern Andrews and southern Gaines Counties. The Ogallala Formation is absent from central Andrews County and areas southward where Cretaceous strata are present at or near the land surface in most areas. The "Red Bed Ridge," including the WCS - Flying "W" Ranch area, is an interfluve region.

3.3.2 WCS - Flying "W" Ranch

The Ogallala Formation is not exposed in the WCS - Flying "W" Ranch area, but is present in the subsurface along the north and east sides of the ranch boundary at a depth of 45 to 105 ft below ground surface. In this area, the Ogallala Formation varies from 5 to 40 ft in thickness and rests on Dockum Group "red beds" or locally on the Antlers Formation (see Figures 4, 5, and 6). These deposits consist of yellowish brown (10 YR 8/4) fine to medium-grained sand with granule-pebble gravel. Where the Ogallala deposits are greater than 20 ft thick, an upper interval of very fine to fine-grained sand, slightly pink in color (5 YR 7/4) is present.

Groundwater was found in only three borings that penetrated the Ogallala Formation along the eastern border of the ranch area.

3.4 ?Gatuña Formation ("Cenozoic Basin Fill": Late Tertiary - ?Quaternary)

3.4.1 General Information

Southwest of the "Red Bed Ridge," deposits in part equivalent in age to the Ogallala Formation are present, but these have typically been identified informally as the "Cenozoic Basin Fill" (Maley and Huffington, 1953) or "Cenozoic Pecos Alluvium" (Ashworth and Flores, 1991). They are at least in part equivalent to the Gatuña Formation (Kelley, 1980). Some of these deposits have been mapped as Ogallala Formation (Nicholson and Clebsch, 1961; shown as "To" on the Geologic Atlas of Texas, Hobbs Sheet, 1976), but may more logically be included with the Gatuña Formation, as suggested by Hawley (1993). In the WCS - Flying "W" Ranch area, these deposits predate formation of the overlying "Caprock" Caliche, and therefore are equivalent in age to the Ogallala Formation. Nevertheless, they differ lithologically from sediments of the Ogallala. These deposits will be referred to here as the ?Gatuña Formation, using the question mark to indicate this uncertainty in formation assignment.

The alluvial fill of the Lower Pecos Valley (including the Gatuña Formation) is at least 13 million years old (as old as the basal sediments of the Ogallala Formation; Powers and Holt, 1993; Hawley, 1993), and so downcutting and widening of at least the lower part of the Pecos River Valley must have occurred before or during deposition of the Ogallala Formation. The youngest part of the Gatuña Formation is no older than 600,000 years.

The Pecos River Valley subsided in response to subsurface salt dissolution. A peripheral zone of subsurface (Permian) salt dissolution surrounds the High Plains, with its inner boundary generally coincident with the present escarpment of the High Plains (Gustavson and Simpkins, 1989). This peripheral belt of subsurface salt dissolution underlies the Pecos River Valley. A curvilinear belt of subsurface salt dissolution also coincides with the buried Permian Capitan Reef trend surrounding the Delaware Basin. Salt dissolution has occurred over the buried summit of the artesian reef aquifer (Anderson, 1980; Baumgardner et al., 1982; Reeves, *in* Gustavson et al., 1991). Extensive salt dissolution over the Capitan Reef trend resulted in subsidence of the Monument Draw Trough in Winkler and Ward counties, Texas and in the

Delaware Basin beneath the Pecos River Valley (Maley and Huffington, 1953). Subsidence over the reef trend resulted in a depression now filled with "Cenozoic Basin Fill," referred to locally as the Monument Draw Trough. This belt lies 15 to 20 mi west-southwest of the WCS - Flying "W" Ranch.

3.4.2 WCS - Flying "W" Ranch

The ?Gatuña Formation is exposed on the ranch only in a small area at Baker Spring (Figure 2; Section 28, T.21S.). Approximately 15 to 20 ft of coarse, red, cross-bedded gravelly sand, with scattered large boulders of sandstone and limestone, is exposed along the steep bluff on the north and east side of Baker Spring, overlain by the "Caprock" Caliche. The base of the ?Gatuña Formation is not exposed at this location, but must lie at shallow depth because the Dockum Group "red beds" crop out several hundred feet to the south. The ?Gatuña Formation is present extensively in the subsurface along the southern and southwestern boundary of the ranch area at depths from 45 to 115 ft below ground surface (see Figures 3, 4, 5, and 6). The ?Gatuña deposits are very thin in this area, from 5 to 15 ft, and consist of fine to medium-grained sand and sandstone with granule-pebble gravel. These sediments have a distinctive red coloration (10 R 6/4 to 5 YR 4/6-6/6). Deposits of the ?Gatuña Formation rest on Dockum Group "red beds" everywhere on the WCS - Flying "W" Ranch.

No groundwater was found in the boreholes in the ?Gatuña Formation, although groundwater appears to be discharging from these deposits at Baker Spring (see Figures 3 and 7).

3.5 "Caprock" Caliche (Late Tertiary - ?Quaternary)

3.5.1 General Information

Overlying all pre-Quaternary strata in the High Plains region is a thick bed of hard caliche. This dense layer of pedogenic limestone is often referred to informally as the "Caprock" Caliche in the Southern High Plains region where it overlies the Ogallala Formation. It is usually mapped as part of the Ogallala Formation. However, the term "Caprock" Caliche has not been accepted as a formally recognized stratigraphic unit, because in many areas it consists of several superimposed caliche beds that formed at different times, and includes caliche that formed earlier during deposition of the Ogallala Formation, as well as in more recent times, long after the end of Ogallala deposition (Gustavson et al., 1991). Caliche developed on the surface of older

Cretaceous rocks is mapped simply as "caliche" (shown as "Qcc" on the Geologic Atlas of Texas, Hobbs Sheet, 1976), and not as part of the Ogallala Formation although it is identical in composition and morphology to the "Caprock" Caliche and likely formed at the same time. The term "Caprock" Caliche is used here in quotation marks to reflect this informal status and uncertain correlation.

In areas such as western and southern Andrews County, where the Ogallala Formation is absent or very thin, the "Caprock" is highly brecciated, pisolitic, and silicified; and it formed directly on the eroded surface of older (Cretaceous) strata. Many of the exposures mapped as Ogallala Formation in Andrews County (shown as "To" on the Geologic Atlas of Texas, Hobbs Sheet, 1976) consist in reality only of "Caprock" Caliche developed on top of older Cretaceous strata. In many cases, no actual deposits of the Ogallala Formation are present. In southern Andrews County, and areas farther south, caliche developed on the surface of older Cretaceous rocks is mapped simply as "caliche" (shown as "Qcc" on the Geologic Atlas of Texas, Hobbs Sheet, 1976), and not as part of the Ogallala Formation.

The "Caprock" Caliche formed on the High Plains surface after deposition of the Ogallala Formation (Late Miocene) and at least in part prior to deposition of the Blanco Formation (Late Pliocene). It is likely that formation of the "Caprock" began when the High Plains surface was isolated by erosional incision of the Pecos, Canadian, Brazos, and Colorado rivers (Osterkamp and Wood, 1984).

3.5.2 WCS - Flying "W" Ranch

The "Caprock" Caliche is present over the entire ranch area, and the upper surface of the "Caprock" is exposed at the land surface in many places along crest of the "Red Bed Ridge" where erosion has removed the overlying cover of Quaternary windblown sediment (see Figure 2). Where the "Caprock" is present near the land surface, the thin Kimbrough soil, or Blakeney and Conger soil association, is developed (Conner et al., 1974). A complete section of the "Caprock" is exposed along the north and east sides of Baker Spring, and in several gravel pits (Figure 2; southeast Section 3 and west-central Section 8, Block A-39). The top of the "Caprock" typically lies at a depth of 25 to 50 ft, but is found at nearly 100 ft in the southwest corner of the ranch. The "Caprock" formed on the upper surface of the Antlers, Ogallala, and

?Gatuña Formations and engulfs materials of these formations, particularly in its lower part. It evidently formed on a land surface with substantial topographic relief (see Figures 3 through 7).

The "Caprock" Caliche consists of hard, laminated, and pisolitic caliche with included chert pebbles. It is typically 5 to 10 ft thick, but up to 20 ft thick in a few places. Where the "Caprock" is thick, it has been partially replaced with nodules and layers of opal. It has a dense brown (5 YR 6/4) laminated, pisolitic, and partly silicified upper layer that grades downward into softer lighter colored (5 YR 8/4) caliche. Where it is exposed at the land surface, the "Caprock" has degraded to form a broken rubble with fissure fillings and clasts of dark brown sand. Clasts of degraded caliche form a mantle of colluvium on slopes. In places, this degraded caliche rubble is mapped as "other Quaternary deposits" (Qao) on the Geologic Atlas of Texas Hobbs Sheet (1976).

The "Caprock" Caliche can be distinguished from younger caliche deposits in overlying Quaternary strata (e.g., Blackwater Draw Formation) which are lighter in color, softer, lower in density (owing to higher porosity), include abundant sand, and are not laminated or pisolitic.

The "Caprock" typically lies within the unsaturated zone. Groundwater was found within the "Caprock" Caliche at one location (well #2).

3.6 Blackwater Draw Formation (Quaternary: Pleistocene)

3.6.1 General Information

The regional distribution and characteristics of the Blackwater Draw Formation were reviewed by Reeves (1976) and Holliday (1989). These deposits were formerly referred to as the "windblown cover sand" and are so designated on the Geologic Atlas of Texas (shown as "Qcs" on the Hobbs Sheet, 1976).

The Blackwater Draw Formation is eolian in origin, and forms an extensive mantle over the surface of the High Plains, diminishing in grain size from predominantly sand on the southwestern side of the High Plains to clay on the northeast. Alluvial sediments of the Pecos River Valley served as the source area for windblown sediment transported to the northeast onto the High Plains surface (Holliday, 1989). Modern effective sand-transporting winds blow from the west-southwest (Machenberg, 1984, 1986); grain-size trends and orientation of Pleistocene vegetated dune ridges indicate that this has been the case for most of Quaternary time. Over the past 2 million years, most of the High Plains surface experienced periods of wind erosion and deposition, alternating with periods of stabilization of the surface by vegetation, resulting in soil formation and accumulation of the Blackwater Draw Formation (Holliday, 1989). Radiometric age determinations on ash beds, and interbedded playa deposits demonstrate that deposition of the Blackwater Draw Formation began prior to 1.4 million years ago and continued until at least 100,000 to 50,000 years ago (Gustavson et al., 1991). Interbedding of the Blackwater Draw Formation with radiocarbon-dated playa basin deposits suggests that deposition continued at least locally up to 3000 years ago (Gustavson et al., 1991; Holliday, et al., 1996).

3.6.2 WCS - Flying "W" Ranch

The Blackwater Draw Formation is present at or near the land surface over much of the ranch area, but is absent along the crest of the "Red Bed Ridge", and is buried under younger windblown sand in the northern and southern parts of the ranch (Figure 2). Where these deposits are present at the land surface, the Triomas and Wickett soil association has developed (Conner et al., 1974). A typical section of the upper part of the Blackwater Draw Formation is exposed in the gravel pit along the common southern borders of Sections 16 and 17 (Figure 2; Block A-29). Sediments of the Blackwater Draw Formation are up to 60 ft thick on the north side of area, and as much as 100 ft thick on the south, substantially thicker than previously reported (typically less than 10 ft according to the Geologic Atlas of Texas, Hobbs Sheet, 1976). The upper 5 to 15 ft of these sediments consists of reddish brown (10 R 5/6 to 5 YR 5/6 or 6/6) clayey fine to very fine sand with nodules of soft sandy caliche. Locally, the upper 5 ft is very clayey and contains a dark brown (10 YR 5/2 to 5 YR 6/6) organic surface horizon. Sand grains have iron oxide and clay coatings which give the sediment its distinctive dark red coloration. These grain coatings are a result of soil formation (Holliday, 1989). The lower part of the Blackwater Draw Formation was less affected by soil development (i.e., iron and clay illuviation), and is lighter in color (typically 5 YR 7/4 to 8/4) with many layers of soft sandy caliche. The lower 10 to 20 ft contains some coarse to very coarse sand as well as layers of granule-small pebble gravel, and may be partly alluvial rather than eolian in origin.

The Blackwater Draw Formation typically lies within the unsaturated zone. No groundwater was found in these deposits.

3.7 Playa Deposits (Quaternary: Holocene)

3.7.1 General Information

The origin and history of playa basins on the High Plains has been a subject of study and debate for nearly a century (reviewed by Reeves, in Gustavson, 1990 and Gustavson et al., 1991; Holliday et al., 1996). Playa basins range in size from 30 ft to 1.5 miles in diameter, though most are less than half a mile in diameter, and exhibit up to 30 ft of topographic relief. The basins originated 30,000 to 10,000 years ago, although some may be older, and have partially or completely filled with up to 3 to 30 ft of sediment since that time (Holliday et al., 1996). The basins formed within the eolian "cover sands" of the High Plains (Blackwater Draw Formation) primarily by wind erosion, and hence are larger and more numerous where the "cover sands" are thicker (Holliday et al., 1996). The basins typically hold water temporarily only after extended periods of rainfall, and focussed infiltration of water through the floors of the playas may cause dissolution of shallow soil caliche layers beneath the basin, resulting in subsidence and gradual enlargement of the basins over time (Osterkamp and Wood, 1987; Wood and Osterkamp, 1987). However, Holliday et al. (1996) argued that dissolution-induced subsidence is not generally responsible for the origin of playa basins. Formerly, buffalo (and more recently, cattle) may also have played a role in enlarging the original depressions by transporting mud or dust out of the basins on their hooves and hides. Playa basins are apparently a surficial phenomenon, and do not reflect deep-seated subsidence or salt dissolution.

3.7.2 WCS - Flying "W" Ranch

Playa deposits are found only in one area, south of the WCS facility boundary (Figure 2; vicinity of borehole #19). The deposits consist of 10 ft of dark brown clayey fine sand, underlain by 5 ft of color mottled yellow and brown ("gleyed") clayey fine sand. The deposits occupy a subcircular depression in the land surface, approximately 2000 ft in diameter. This playa basin is not active, since it is not known to accumulate surface runoff, and the deposits appear to be undergoing erosion. An arcuate dune deposit (shown as "Qsd" on the Geologic Atlas, Hobbs Sheet; 1976) bounds the northeastern margin of the depression (see Figures 2 and 4). There are no mapped occurrences of Lipan clay soils (as are typically developed in the bottoms of modern playas in this region) on the ranch area (Conner et al., 1974).

No groundwater was found in playa deposits on the WCS - Flying "W" Ranch.

3.8 Windblown Sand (Quaternary: Holocene)

3.8.1 General Information

Recent deposits of eolian dunes, now mostly stabilized by vegetation, are mapped as "windblown sand sheets, dunes, and dune ridges undivided" (Qsu) on the Geologic Atlas of Texas (Hobbs Sheet, 1976). These are probably equivalent in part to those referred to as the Monahans Formation to the southwest in the Pecos River valley (Green, 1961; Machenberg, 1984). These surficial eolian deposits are younger than the Blackwater Draw Formation that they overlie in many areas, and are typically 5 to 10 ft in thickness. In places these deposits are undergoing active transport as modern dunes, but in most areas they are at least partially stabilized by vegetation.

3.8.2 WCS - Flying "W" Ranch

Windblown sand deposits are present extensively in the north, northeast, and southwest part of the area. Their distribution generally corresponds with the Jalmar and Penwell soil association (Conner et al., 1974). Windblown sand deposits are up to 35 ft thick, and consist of light yellowish brown (5 YR 5/4 to 7.5 YR 6/4) clean, very well sorted sand. In most areas, they form a thin irregular veneer, 5 to 15 ft thick, over the land surface, with the thickest accumulations in northwest-southeast trending vegetated linear dune ridges. These deposits are distinguished from similar sands in the Blackwater Draw Formation by their pale coloration (locally very pale; e.g. 10 YR 8/4), absence of iron oxide grain coatings, and absence of caliche nodules.

Deposits of windblown sand typically lie within the unsaturated zone. No groundwater was found in these deposits on the WCS - Flying "W" Ranch.

4. Geological Control on Groundwater Hydrology

4.1 General Information

Three regional aquifers converge in central Andrews County. The "Ogallala aquifer" extends southward across the Southern High Plains into the northern part of Andrews County (e.g., Cronin, 1969). The "Edwards-Trinity (Plateau) aquifer" extends northward from the Edwards Plateau into southeastern Andrews County (e.g., Ashworth et al., 1991). The "Cenozoic Pecos Alluvium aquifer" extends northward from the Pecos River Valley into southwestern Andrews County (e.g., Ashworth and Flores, 1991). The boundaries between these aquifers are as yet poorly defined in Andrews County. Cretaceous strata on the High Plains, such as documented here on the WCS - Flying "W" Ranch area, are thought to be in hydraulic continuity with the Ogallala Formation; and they are included together as part of the "High Plains aquifer" in many studies (e.g., Knowles et al., 1984; Peckham and Ashworth, 1993) although the nature of cross-formational flow between these units is not well established. In such regional studies, the WCS - Flying "W" Ranch area has been generally included within the distribution of the Ogallala (High Plains) aquifer.

However, the WCS - Flying "W" Ranch area straddles the "Red Bed Ridge," which exerts control on local and regional groundwater flow. The "Red Bed Ridge" probably acts as a regional groundwater divide, separating the Ogallala (High Plains) aquifer to the northeast from the "Cenozoic Basin Fill" aquifer (or the "Cenozoic Pecos Alluvium" aquifer of Ashworth and Flores, 1991) to the southwest. Groundwater flow in the Cenozoic Basin Fill aquifer is to the south-southwest, while flow in the High Plains aquifer is to the east-southeast (Nicholson and Clebsch, 1961). The Triassic bedrock "high" beneath the overlying Cenozoic deposits interrupts the groundwater table in many areas along its length. In northern Lea County, the crest of the "Red Bed Ridge" lies above the water table in the Ogallala Formation to the northeast (Ash, 1963; see his sheet 1, cross-section A-A'). Similarly, in central Lea County, Nicholson and Clebsch (1961, their Plate 2) illustrated several areas where the water table in Cenozoic deposits is interrupted by bedrock highs on the Triassic "Red Bed Ridge". In western Andrews County, the crest of the "Red Bed Ridge" coincides with the belt of 0 to less than 20' saturated thickness in the High Plains aquifer (Knowles et al., 1984).

4.2 WCS - Flying "W" Ranch

Groundwater is not present continuously beneath the WCS - Flying "W" Ranch, but was encountered in 17 of 35 boreholes completed (see Figure 10). Over 60 previous boreholes and well logs, all of which located the "red bed" surface contact without finding water, were reported by AM Environmental (1993) on the WCS site and Weaver Boos & Gordon, Inc. (1997) to the west of the state line, and these data points were also considered in construction of Figure 10. Groundwater occurs in two discrete areas, one in the northwestern corner of the ranch, and the other in the central area surrounding Windmill Hill. In both cases the groundwater occurs almost exclusively (14 of 17 wells) within the basal sand unit of the Antlers Formation, and the limits of observed groundwater (Figure 10) clearly correspond with the subcrop of the Antlers Formation (Figure 9). The two groundwater-bearing areas are not connected, although the complete lateral extent of both areas is yet to be established. The saturated thickness is typically less than 10 ft in each area. The maximum saturated thickness observed is 25 ft in the northwestern area (Figure 10). Both areas are overlain by the upper shale interval of the Antlers Formation (unit 3, above) which could conceivably act as a confining layer (see Figures 3 and 5). However, in most wells the sand interval in the Antlers Formation is not entirely saturated. Water table elevations suggest that groundwater here likely reflects local recharge and not regional lateral flow within the "High Plains aquifer." The many closed surface depressions along the crest of the "Red Bed Ridge" could act as local recharge points (Figure 5). These depressions are not playa basins, but have formed where the "Caprock" Caliche is at or near the land surface (e.g., see areas mapped as Kimbrough soils; Conner et al., 1974) and are known to hold surface runoff after extended periods of rainfall. One artificially deepened depression southeast of Windmill Hill (southeast Section 4, Block A-39) retains a significant amount of surface runoff. High water table elevations beneath the central area suggest that recharge may occur in the area southeast of Windmill Hill (Figure 5, see Figure 10; sections 3 and 8, Block A-39).

These local "pockets" of groundwater do not appear to contribute groundwater southward to the "Cenozoic Pecos Alluvium" (=Gatuña) Aquifer. No groundwater was encountered along the southern border of the WCS - Flying "W" Ranch. The Gatuña Formation was fully penetrated in at least ten borings and no groundwater was found, although water appears to discharge from the Gatuña Formation at Baker Spring. Similarly, in light of the declining water table elevation and declining saturated thickness along the north and east boundaries of the ranch area, the local groundwater "pockets" may also not contribute groundwater northward or eastward to the Ogallala Aquifer.

The absence of groundwater at lower elevations to the south, steep decline in the water table elevation, and low saturated thickness to the north and east together suggest that some barrier to lateral flow of groundwater may exist. The nature of such a barrier is unknown. Alternatively, it is possible that local groundwater flows laterally to the southeast beneath Windmill Hill and discharges at the land surface where the elevation falls below the level of the local water table at incised drainages immediately east of Sections 2 and 9 (Block A-39; see Figure 10, Figures 6 and 7). The incised drainage in the southeast corner of Section 2 flows intermittently eastward to an unnamed saline lake basin about 1 mile east of the WCS - Flying "W" Ranch. Saline lake basins are known to be sites of groundwater discharge on the High Plains (e.g., Wood et al., 1992). However, the incised surface drainage here is not known to be an area of spring discharge, but is dammed at points along its length, where it retains surface runoff. Further exploratory drilling to the north and east of the WCS - Flying "W" Ranch is necessary to firmly establish the limits of groundwater in these areas.

Similarly, it is not clear why the two areas where local groundwater occurs are not connected. The basal sand interval of the Antlers Formation is present continuously between the two areas (Figure 9), and elevations on the land surface, water table, and "red bed" surface suggest that lateral southeastward flow of groundwater could occur between the two areas (Figure 7). No barrier to lateral flow is apparent. Groundwater flowing southeastward from the northwestern area may be intercepted in the subsurface by a southwesterly-directed drainage (Section 16, Block A-29) to discharge at the land surface at Baker Spring (Figure 3). The lack of groundwater in boreholes both north and south of Baker Spring drilled by Weaver Boos & Gordon, Inc. (1997) in Lea County indicate it is also possible that groundwater may flow to Baker Spring from the west or northwest. This uncertainty might be resolved by installation of an additional borehole between well location #16 and the WCS facility (i.e., in the northwest corner of section 25, Block A-29) or west of Baker Spring in Lea County.

5. Discrimination of Ogallala and Antlers Deposits

5.1 General Information

Because of uncertainties regarding the nature of cross-formational flow of groundwater between Cretaceous strata and the Ogallala Formation, it is useful to discriminate these deposits in the subsurface where possible. In recent reports, Cretaceous strata are often not separated from the Ogallala Formation, and these are collectively included in the "High Plains aquifer" (e.g., Knowles et al., 1984; Ashworth et al., 1991; Peckham and Ashworth, 1993). Nevertheless, it may be important to distinguish these strata for regulatory considerations (e.g., Dutton, 1999).

Determining exactly where the Ogallala Formation pinches out in Andrews County is problematic. Existing compilations of water well driller's logs in the area are not very useful in discriminating whether or not the Ogallala Formation is actually present, because in well cuttings the hard caliche layers (such as the "Caprock" Caliche) are difficult for water well drillers to distinguish from Cretaceous limestone beds (such as in the Comanche Peak and Edwards Limestone), and the sand and gravel in the Ogallala Formation is difficult to distinguish from that in the Antlers Formation. The top of the underlying Dockum Group "red beds" is often readily identified in cuttings by water well drillers, and so this interface is often reliably picked on logs.

In well cuttings it is often difficult to distinguish the Antlers Formation from the Ogallala Formation, because both units consist predominantly of poorly cemented sand and gravel. Sands in the Antlers Formation are fine to medium-grained, white to yellow, and highly quartzose, with brightly colored chert pebble gravel, dominantly comprised of pink, red, and black chert, and white quartzite. Sand in the Ogallala Formation is fine to medium-grained and sublithic, with pebble gravel containing clasts of igneous and metamorphic rocks (quartzite, granite, rhyolite, and gneiss), sedimentary rocks (limestone and sandstone), and abraded Cretaceous *Gryphaea* shells (e.g., reviewed by Reeves, 1984).

5.2 WCS - Flying "W" Ranch

The excellent exposure in the walls of the excavation at the WCS facility leaves little doubt that this unit is the Antlers Formation, and not the Ogallala Formation. It is identical in composition to the same unit exposed to the east at Shafter and Whalen Lakes. Similarly, in the surrounding subsurface where the upper shale interval (unit 3, described above) is present at the top of the Antlers Formation, these deposits are readily identified because similar strata are not known to occur in the Ogallala Formation. Nevertheless, in many areas it remains difficult to discriminate the Antlers and Ogallala solely on the basis of well cuttings.

In an effort to systematically discriminate deposits of the Ogallala and Antlers Formations, samples of each unit were obtained from locations where their identification was certain. Two samples of gravel from the base of the Antlers Formation were obtained from definitively mapped exposures (SHA-5 from the western side of Shafter Lake in central Andrews County; FLU-1 from a roadcut on FM 1269 north of Fluvanna in Scurry County). Two samples of gravel were obtained from water wells drilled to the base of the Ogallala Formation (AND-1 and AND-2 from two wells in the Monument Draw paleo-valley adjacent to US Hwy 385 in northcentral Andrews County). These were compared with a sample of gravel (WCS-1) collected from the landfill excavation at the WCS facility. Approximately 1 kg samples were washed, disaggregated, and sieved to separate all pebbles larger than 8 mm (U.S. Standard #4 mesh sieve) for identification. All pebbles were identified as to lithology and counted (n = 247 to 2691) to determine their relative abundance in each sample. The results of this analysis are given in Figure 11.

Samples of the Antlers gravel are distinctive in consisting entirely of clasts of multicolored chert, hydrothermal "vein" quartz, and a few highly indurated dark brown sandstone (possibly quartzite) clasts (pebble types 1 - 8 in Figure 11). Samples of Ogallala gravel also contain these clast types, though in lower relative abundance, because the Ogallala gravel is derived in part from erosion and reworking of the Antlers deposits. Importantly however, samples of Ogallala gravel also contain high percentages of limestone clasts, reworked Cretaceous mollusc shells (e.g., *Gryphaea*), friable yellow, pink, and black sandstone clasts, and porphyritic igneous rock clasts (pebble types 9 - 12 on Figure 11). These are entirely absent in samples of gravel from the Antlers Formation.

Careful inspection of washed cuttings from borings will reveal at least a few of these distinctive clast types if present, and so it is not necessary to sieve, count, and identify all pebbles to obtain an accurate stratigraphic determination. Ogallala sand also typically has a high percentage of lithic grains compared to Antlers sand, which is virtually pure quartzarenite. These criteria were used to distinguish the two deposits over the WCS - Flying "W" Ranch area.

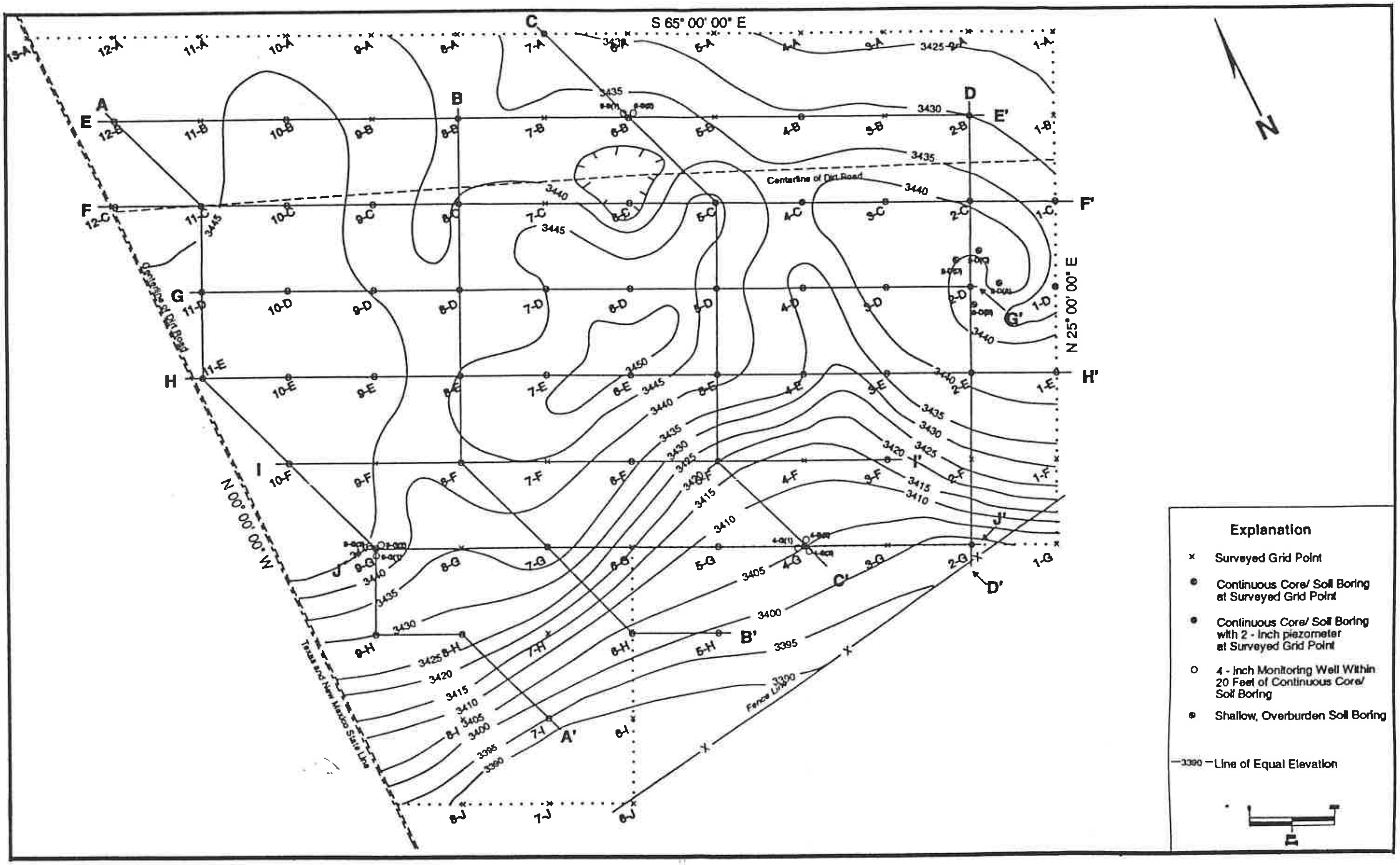

Figure 1. Contour Map of the Dockum ("red beds") Group Surface Beneath the WCS Site [Source: AME (1993)]

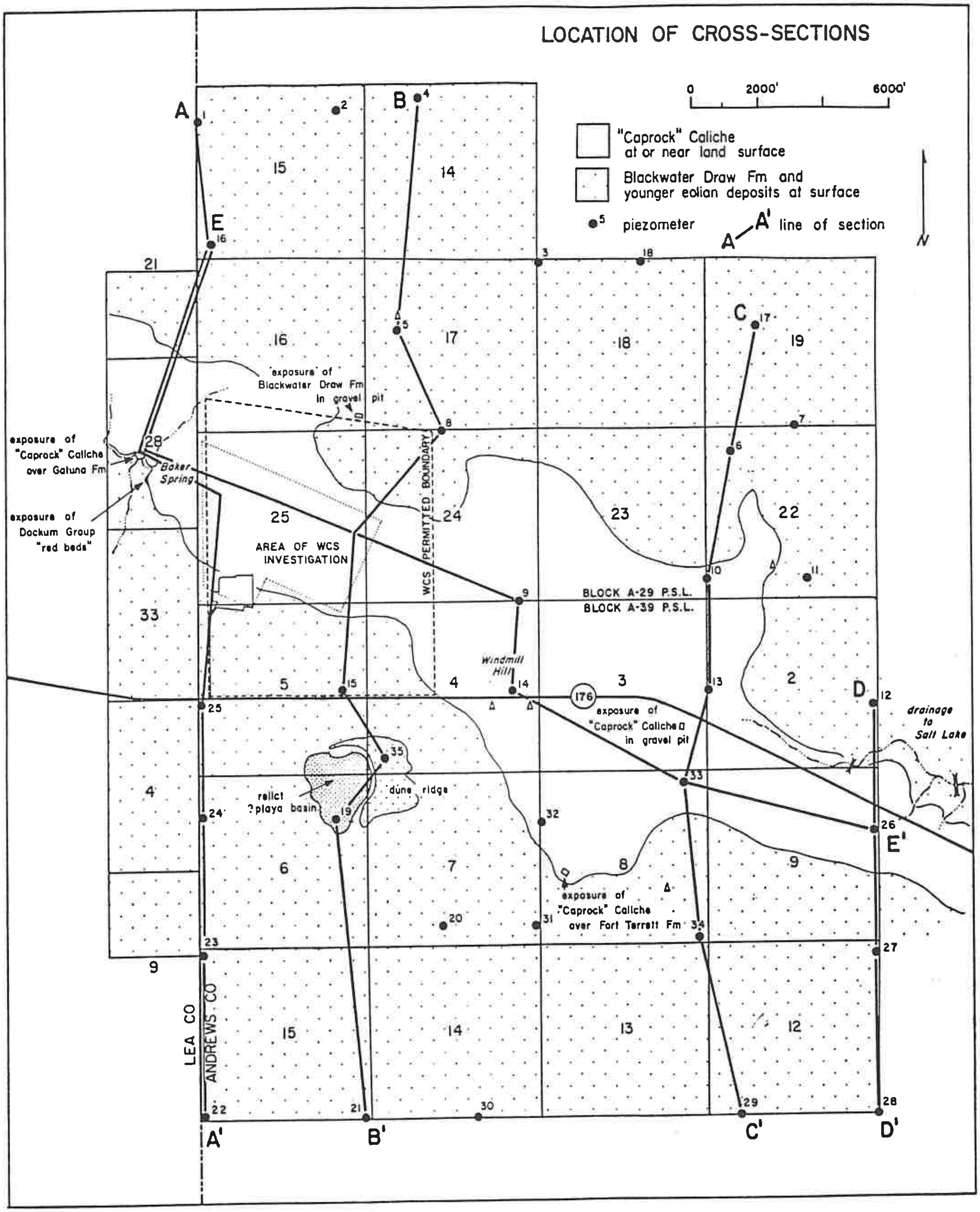

Figure 2. WCS – Flying "W" Diamond Ranch Site Map

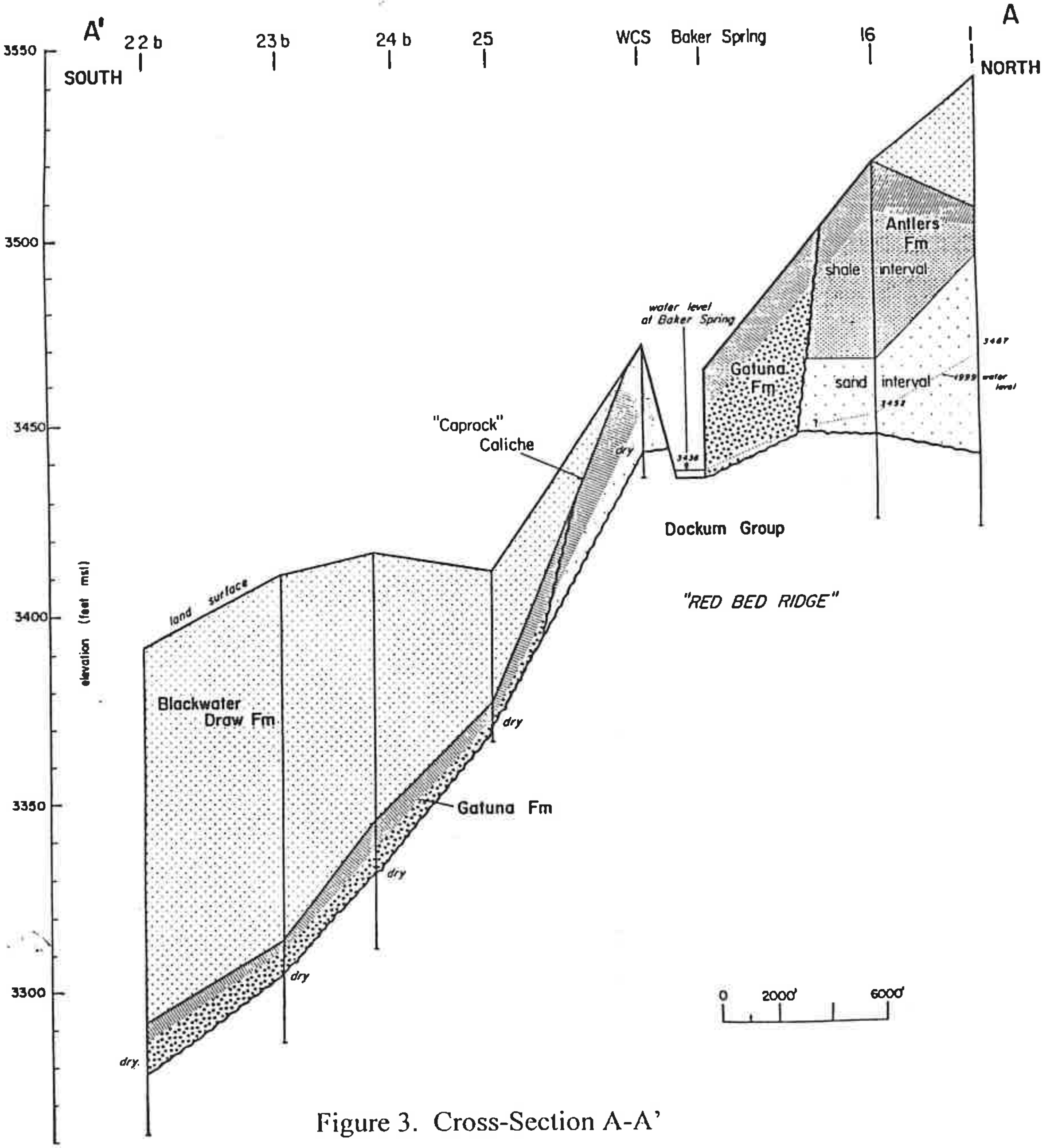

Figure 3. Cross-Section A-A'

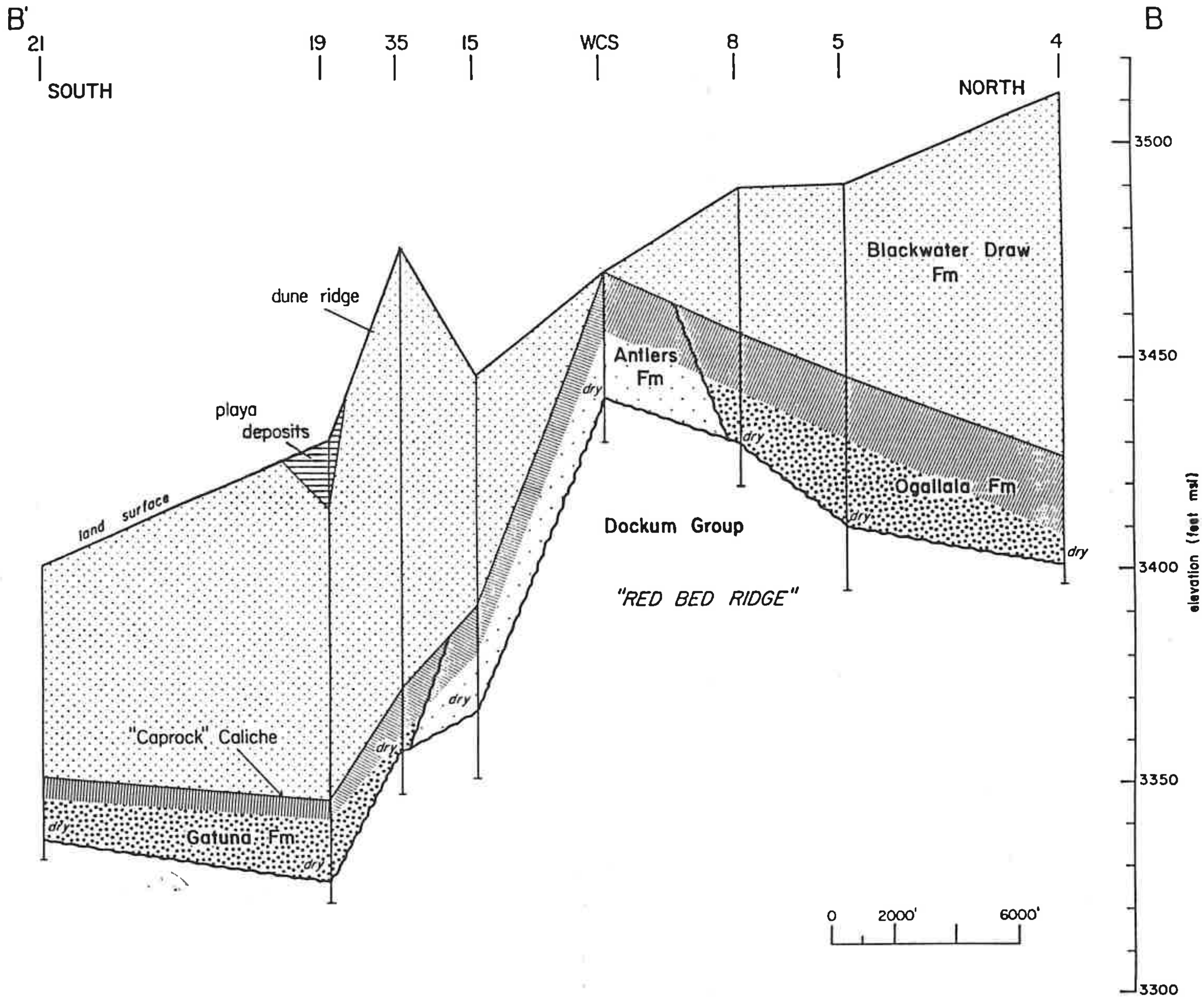

Figure 4. Cross-Section B-B'

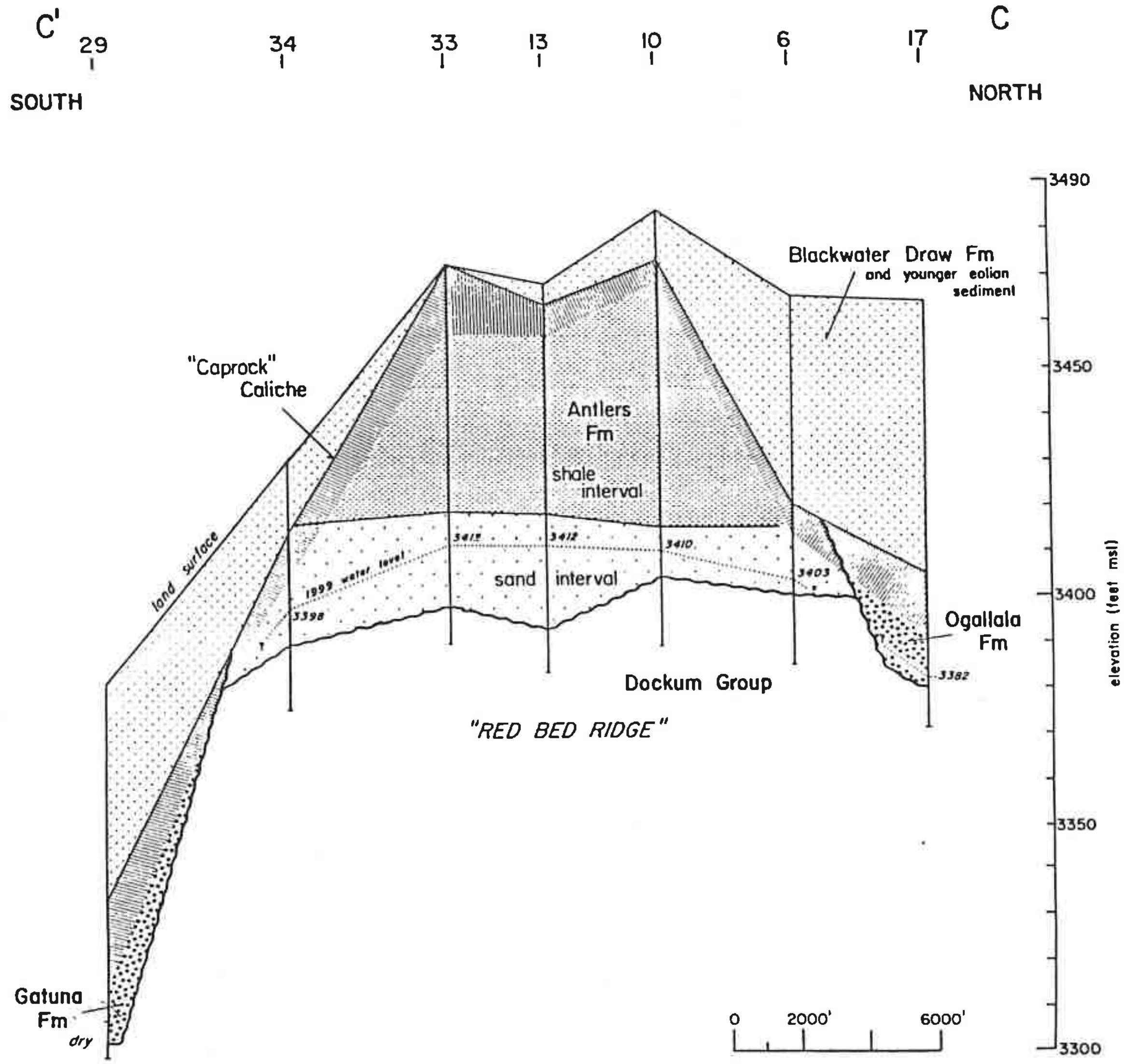

Figure 5. Cross-Section C-C'

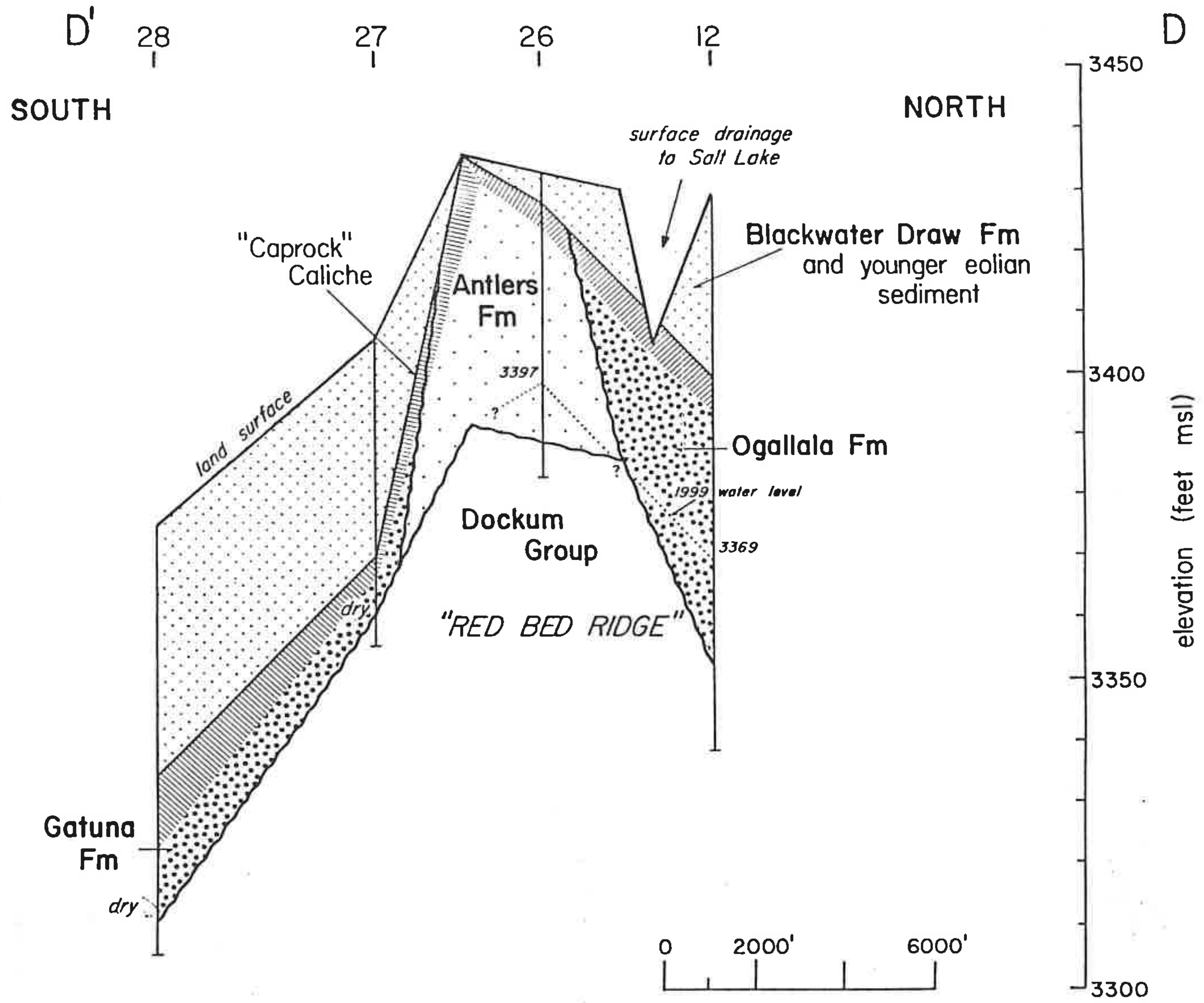

Figure 6. Cross-Section D-D'

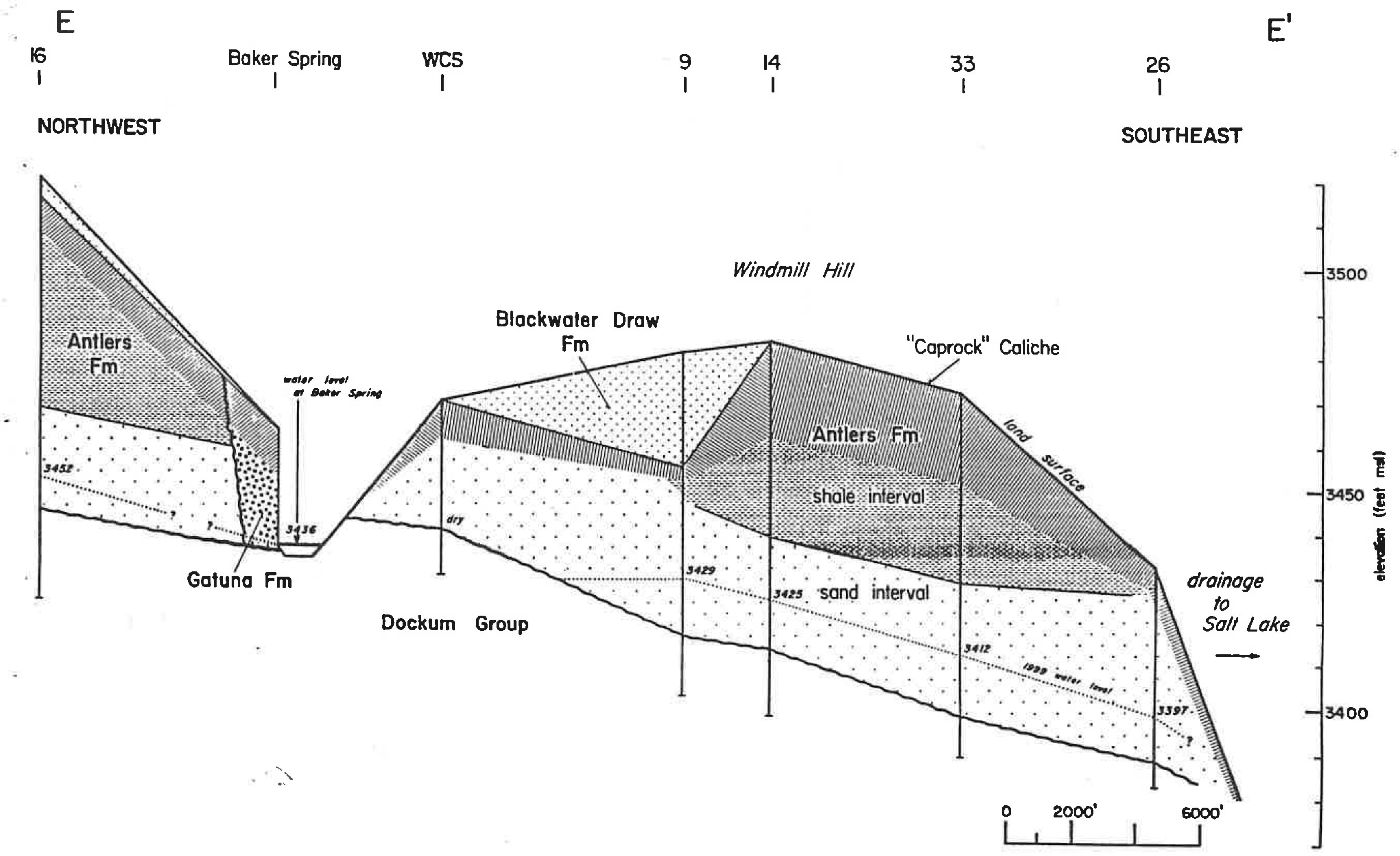

Figure 7. Cross-Section E-E'

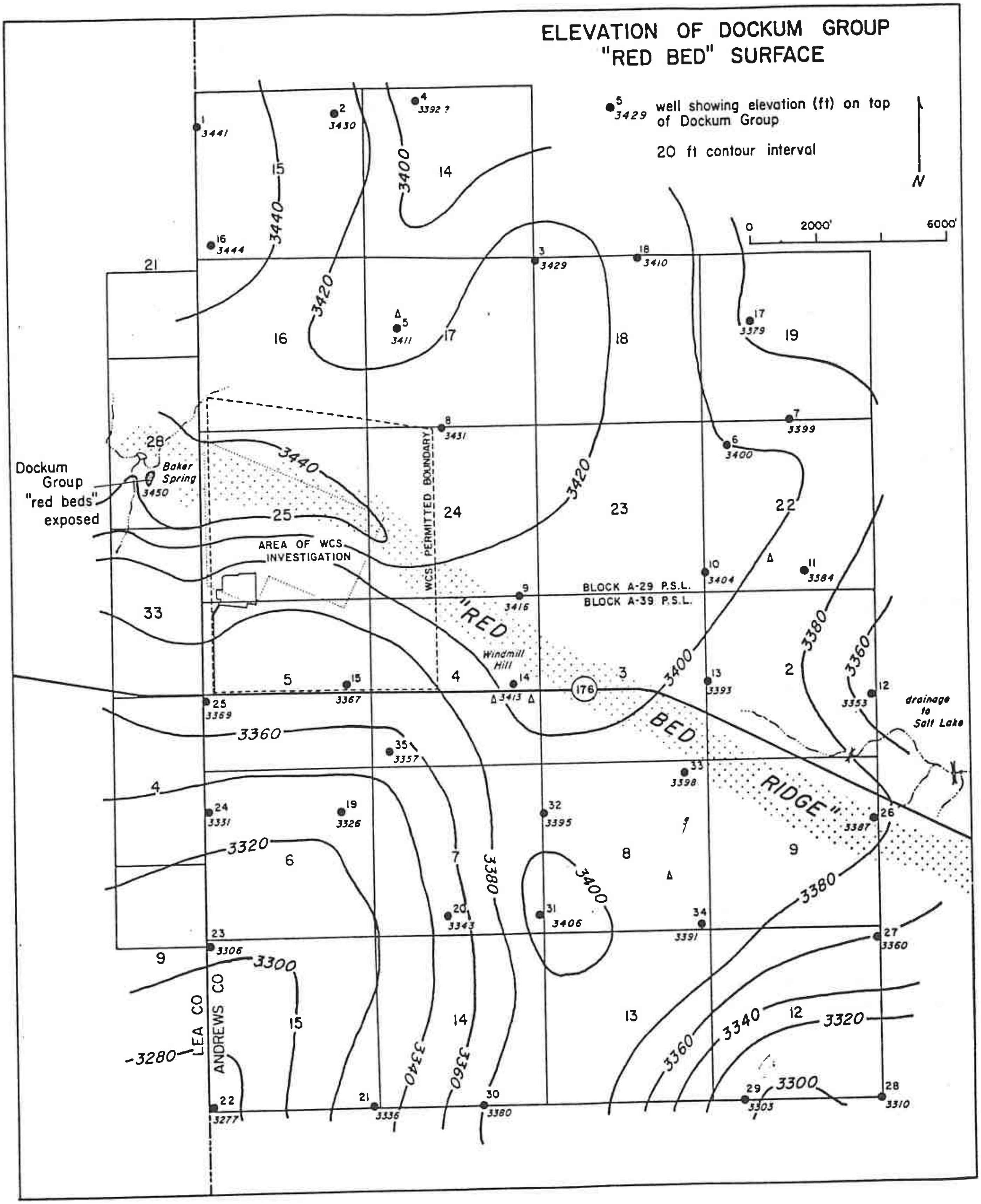

Figure 8. Elevation of Dockum Group "Red Bed" Surface

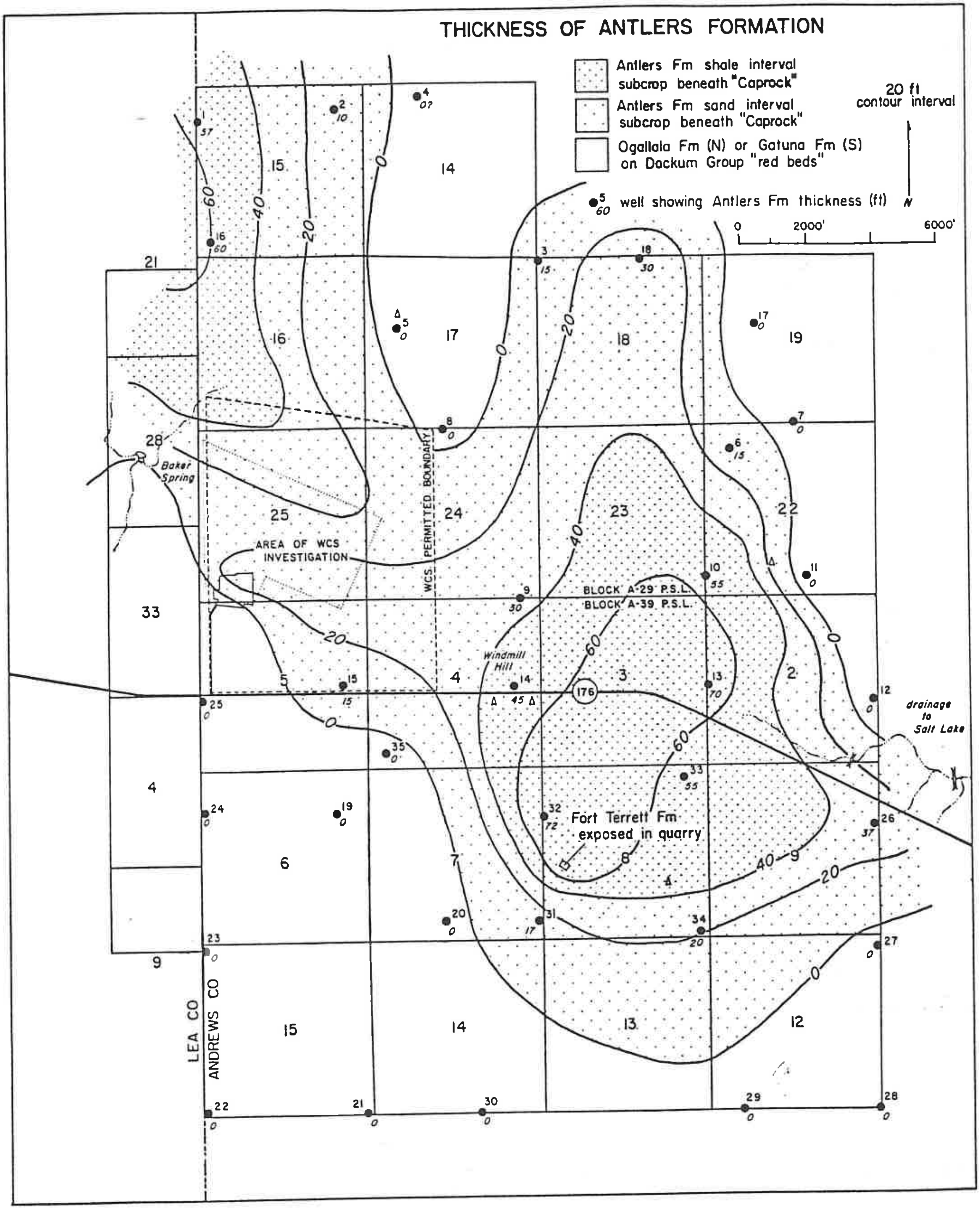

Figure 9. Thickness of Antlers Formation

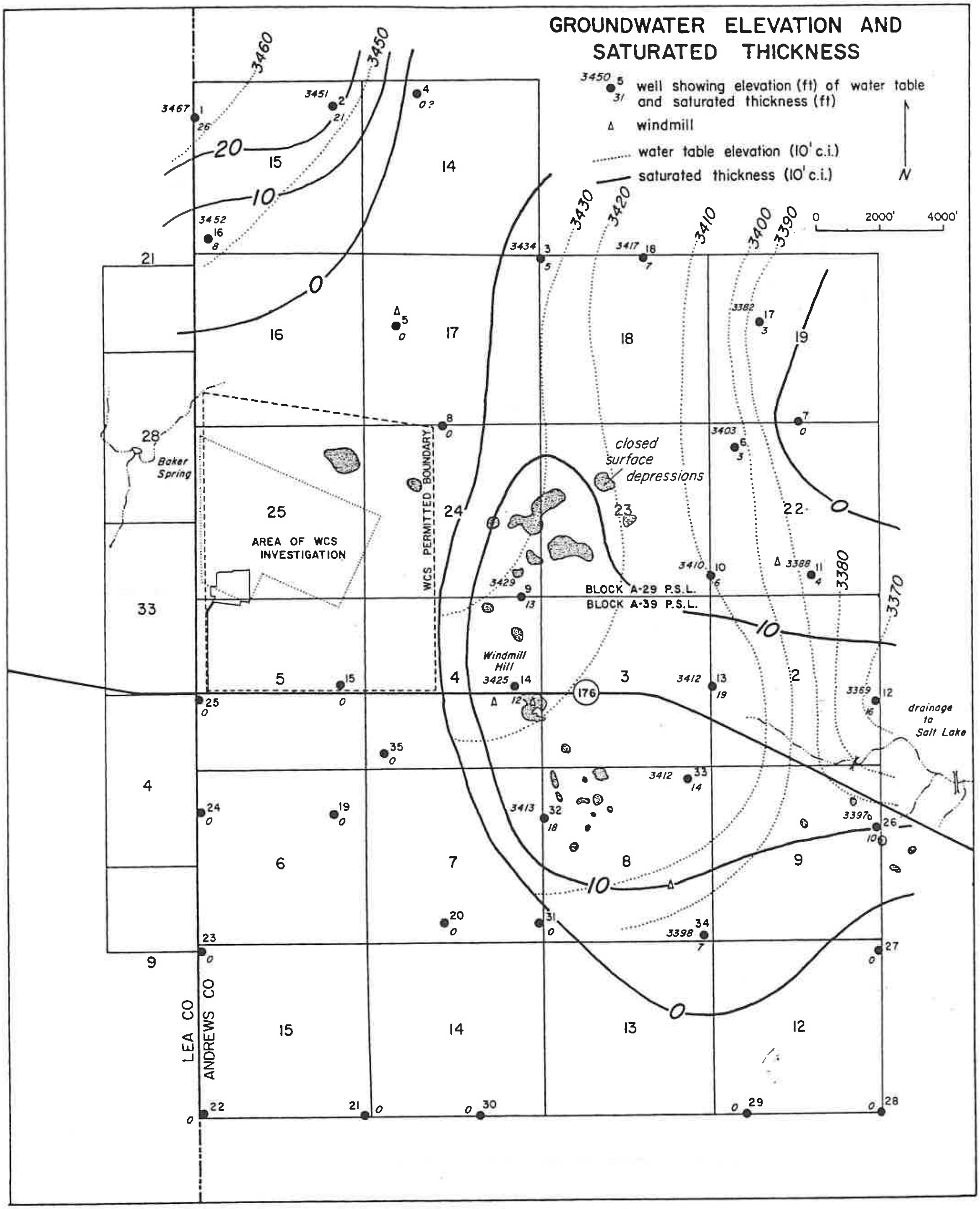

Figure 10. Groundwater Elevation and Saturated Thickness

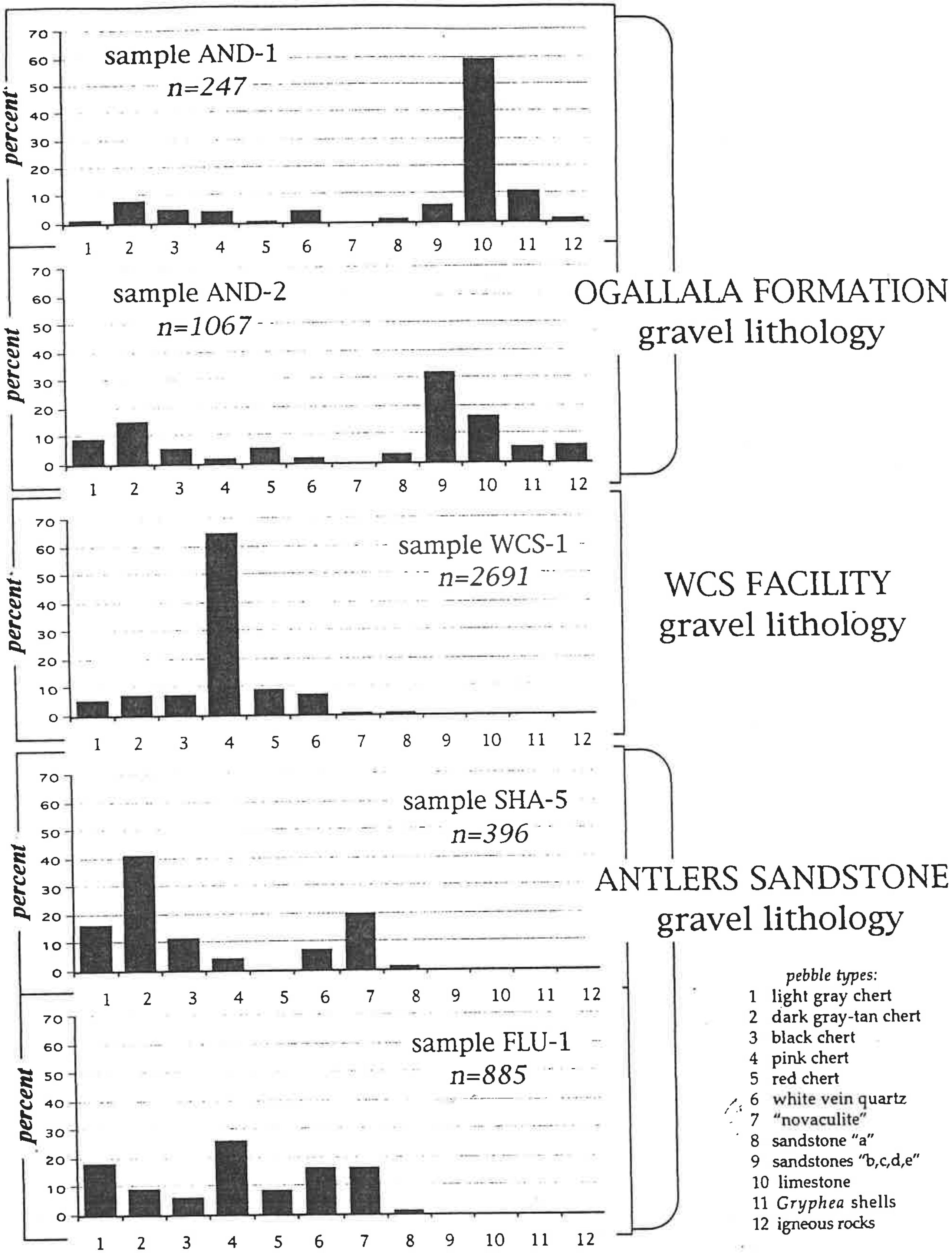

Figure 11. Comparison of Gravel Characteristics in Ogallala and Antlers Formations

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APPENDIX

Geologic Logs

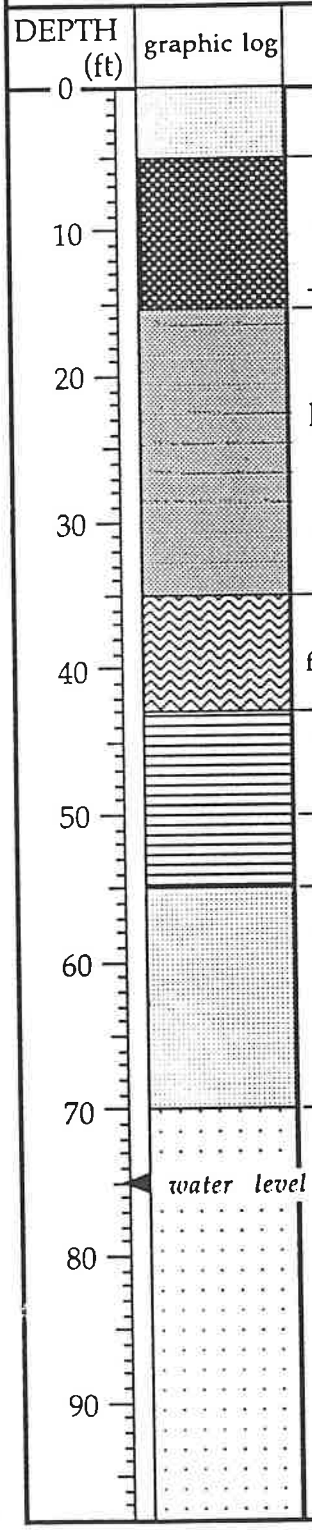
DRILLING LOG	**HOLE No. 1**	*project* WCS - FLYING "W" RANCH	*sheet 1 of 2*

location: NW section 15, Block A-29

drilling agency/driller: Scarborough Drilling, Inc. (Lane)

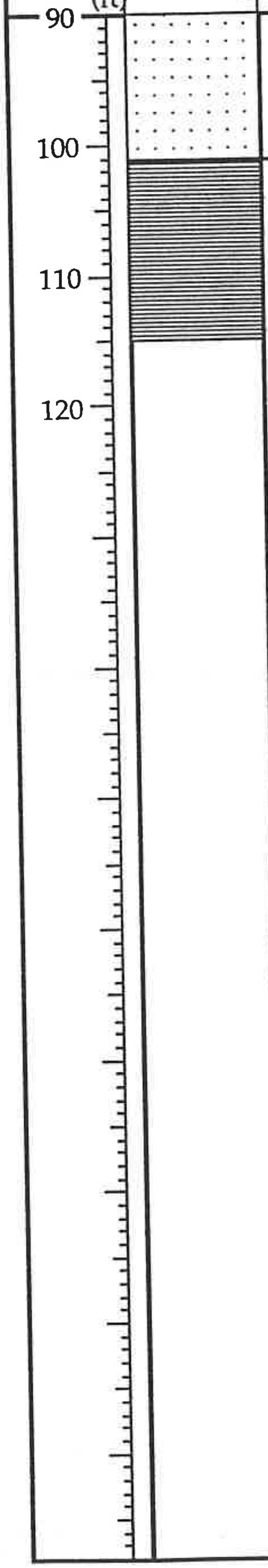
total depth of hole: 120 ft
elevation top of hole: 3542 ft (MSL)
elevation ground-water: 3467 ft

date hole drilled: 3/22/99
sampling interval: 5 ft (Dean Muirhead)
geologist: Thomas M. Lehman 3/25/99



lithologic description	stratigraphic unit & remarks
light brown very well sorted clean fine sand *5 YR 5/4*	WINDBLOWN SAND
reddish brown clayey fine sand weakly cemented/iron oxide grain coatings *10 R 5/6* - nodules of soft sandy caliche	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 5/4 to 6/4*	
hard laminated/pisolitic caliche f sand matrix w/chert grains (vc sand - granule)	"CAPROCK" CALICHE
- fragments of hematite-cemented sandstone light gray mudstone/shale	ANTLERS FORMATION
red/yellow/purple color-mottled mudstone/siltstone	
- spots of hematite cement clean, very well sorted vf-fine sand/sandstone (quartzarenite) *10 YR 7/2*	
fine-medium sand/sandstone (sublitharenite) with vc-granule chert gravel *10 YR 7/2 to 7/4* - grades downward into medium-coarse sand with granule-small pebble gravel	

DRILLING LOG - continuation sheet	**HOLE No. 1**	*project* WCS RANCH	*sheet* 2 *of* 2



DEPTH (ft)	lithologic description	stratigraphic unit & remarks
90	medium-coarse sand/sandstone with granule-pebble chert gravel	ANTLERS FORMATION -continued
101	*top of "red beds" at 101' (elev. 3441')*	
	red mudstone *10 R 4/4*	DOCKUM GROUP
115	*t.d. 115 ft*	

DRILLING LOG | **HOLE No. 2** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 2*

location: NE section 15, Block A-29

drilling agency/driller: Scarborough Drilling, Inc. (Lane)

total depth of hole: 110 ft

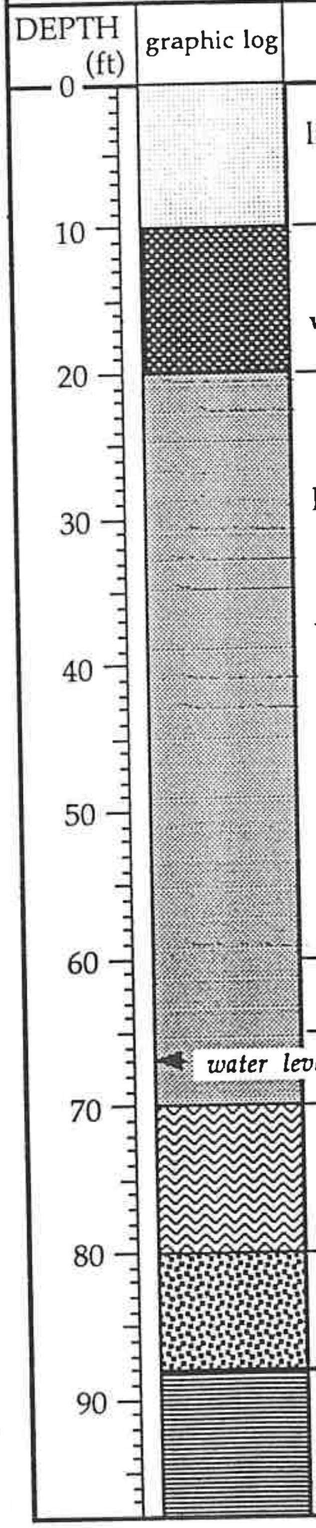
elevation top of hole: 3518 ft (MSL)

elevation ground-water: 3451 ft

date hole drilled: 3/22/99

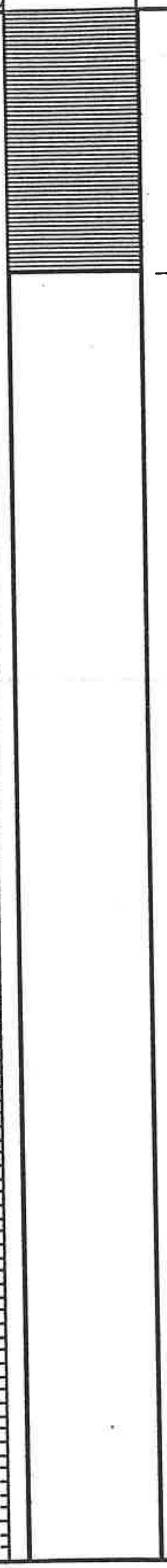
sampling interval: 5 ft (Dean Muirhead)

geologist: Thomas M. Lehman 3/26/99



lithologic description	stratigraphic unit & remarks
light yellowish brown very well sorted clean fine sand *7.5 YR 6/4*	WINDBLOWN SAND
reddish brown clayey fine sand *10 R 5/6* weakly cemented/iron oxide grain coatings and nodules of soft sandy caliche	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 6/4* - grades downward into fine-medium sand - layer of hard caliche	
hard laminated/pisolitic caliche f sand matrix w/chert grains (granule-small pebbles) - opalized	"CAPROCK" CALICHE
granule-small pebble chert gravel in clean very fine-medium sand and sandstone (quartzarenite)	ANTLERS FORMATION *top of "red beds" at 88' (elev. 3430')*
red mudstone	DOCKUM GROUP

DRILLING LOG - continuation sheet	HOLE No. 2	*project* WCS RANCH	*sheet 2 of 2*

DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks
90 100 110 120		red mudstone *10 R 4/4* —— *t.d. 110 ft*	DOCKUM GROUP

DRILLING LOG | **HOLE No. 3** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location: NW section 18, Block A-29

drilling agency/driller: Scarborough Drilling, Inc. (Lane)

total depth of hole: 80 ft

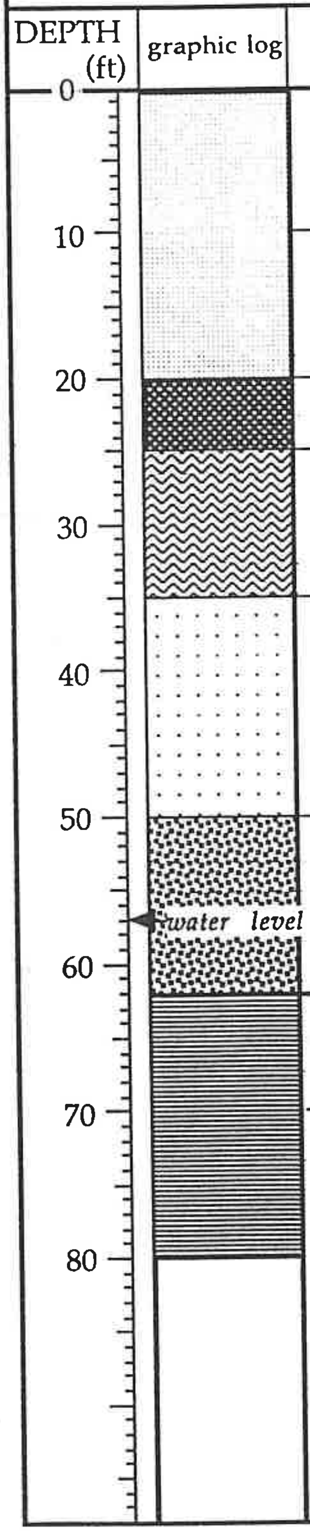
elevation top of hole: 3491 ft (MSL)

elevation ground-water: 3434 ft

date hole drilled: 3/23/99

sampling interval: 5 ft (Justin Brown)

geologist: Thomas M. Lehman 3/30/99



lithologic description	stratigraphic unit & remarks
light brown clean, well sorted fine sand *5 YR 7/4* no caliche very pale *10 YR 8/4* no caliche	WINDBLOWN SAND
reddish brown clayey fine sand - soft sandy caliche *5 YR 6/6*	BLACKWATER DRAW FORMATION
hard laminated/pisolitic caliche in fine sand/chert granule matrix	"CAPROCK" CALICHE
fine/medium sand and granule gravel *10 YR 8/4* - red and gray shale clasts	OGALLALA FORMATION
light yellowish brown vf-fine sand/sandstone *10 YR 7/6* - grades downward to f-med sand with granule-small pebble gravel	ANTLERS FORMATION
	top of "red beds" at 62 ft (elev. 3429')
yellow mudstone red mudstone *10 R 6/4* ------ *t.d. 80 ft*	DOCKUM GROUP

DRILLING LOG	HOLE No. 4	*project* WCS - FLYING "W" RANCH	*sheet 1 of 2*

location:
NW section 14, Block A-29

drilling agency / driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 115 ft
elevation top of hole: 3512 ft (MSL)
elevation ground-water: ?

date hole drilled: 4/6/99
sampling interval: 5 ft (Jeff Stovall)
geologist: Thomas M. Lehman 4/12/99

DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks
0 10 20	░	yellow ~~very well~~ sorted clean fine sand (sublitharenite) *yellow 10 YR 7/4 to 7/6* *yellow/orange 7.5 YR 6/4 to 6/6* *orange/red 5 YR 6/4 to 6/6* no caliche throughout	WINDBLOWN SAND
30 40	▓	reddish brown clayey fine sand weakly cemented / iron oxide grain coatings *5 YR 5/4 to 6/4* - nodules of soft sandy caliche	BLACKWATER DRAW FORMATION
50 60 70 80	▒	pale fine sand with soft sandy caliche *5 YR 8/2* - a few chert grains (vc sand - granule)	
90	≋	hard laminated / pisolitic caliche f sand matrix with a few chert grains (vc sand - granule)	"CAPROCK" CALICHE

DRILLING LOG - continuation sheet	**HOLE No. 4**	*project* WCS RANCH	*sheet* 2 *of* 2

DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks
90	▨	hard laminated/pisolitic caliche	"CAPROCK" CALICHE
100	░	fine/medium sand (sublitharenite) with scattered chert grains (vc sand)	OGALLALA FORMATION
110	░	*5 YR 7/4* ------- *t.d. 115 ft*	
120			

DRILLING LOG | **HOLE No. 5** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

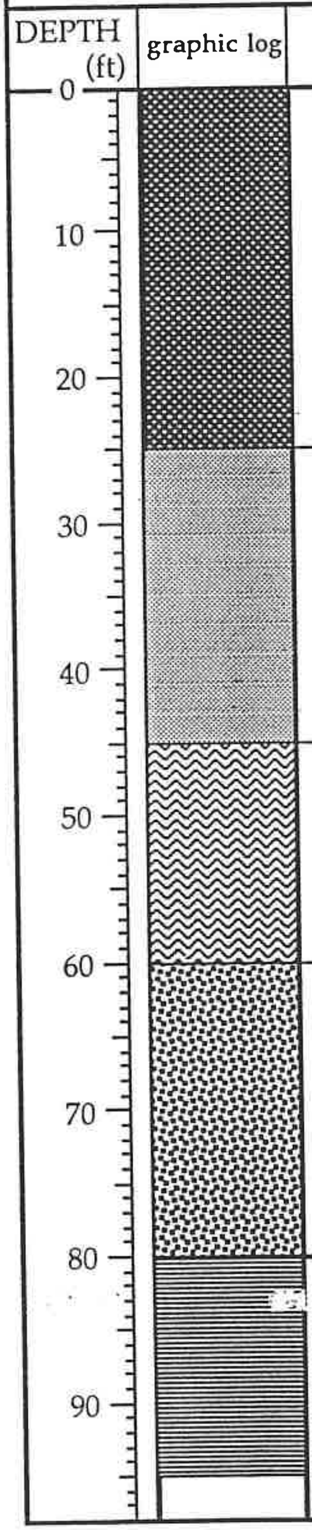
location:
NW section 17, Block A-29

drilling agency/driller:
Scarborough Drilling, Inc. (Lane)

total depth of hole: 95 ft
elevation top of hole: 3491 ft (MSL)
elevation ground-water: dry

date hole drilled: 3/23/99
sampling interval: 5 ft (Justin Brown)
geologist: Thomas M. Lehman 3/29/99

DEPTH (ft) | graphic log



lithologic description	stratigraphic unit & remarks
reddish brown clayey fine sand *5 YR 6/6* no caliche	BLACKWATER DRAW FORMATION
fine sand with soft sandy caliche	
hard laminated caliche - opalized - opalized - with fine sand/chert granule matrix	"CAPROCK" CALICHE
fine/medium sand and granule/small pebble gravel - limestone pebbles	OGALLALA FORMATION
top of "red beds" at 80 ft (elev. 3411')	
red mudstone ------- *t.d. 95 ft*	DOCKUM GROUP

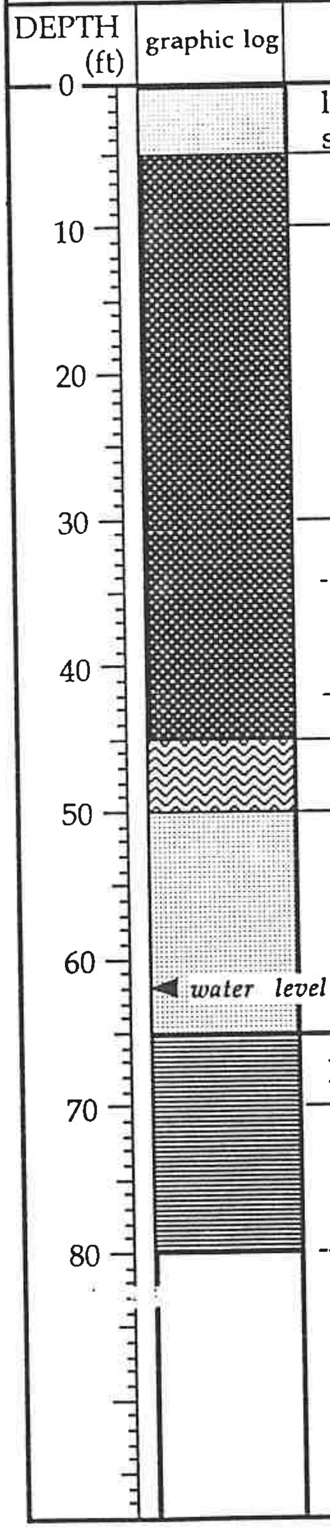
DRILLING LOG | **HOLE No. 6** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location:
NW section 22, Block A-29

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 80 ft
elevation top of hole: 3465 ft (MSL)
elevation ground-water: 3403 ft

date hole drilled: 3/24/99
sampling interval: 5 ft (Justin Brown)
geologist: Thomas M. Lehman 3/29/99



lithologic description	stratigraphic unit & remarks
light brown clean, well sorted fine sand *5 YR 5/4*	WINDBLOWN SAND
- very clayey, no caliche reddish brown clayey fine sand *5 YR 5/6* - w/soft sandy caliche *5 YR 7/4 to 8/2* - a few chert granules/small pebbles	BLACKWATER DRAW FORMATION
hard laminated/pisolitic caliche in fine sand/chert granule matrix	"CAPROCK" CALICHE
light yellowish brown vf-fine sand/sandstone (quartzarenite) *10 YR 7/6* - grades downward to f-med sand - a few granule-small pebble chert clasts	ANTLERS FORMATION
top of "red beds" at 65 ft (elev. 3400')	
yellow mudstone red mudstone *10 R 6/4* ------- *t.d. 80 ft*	DOCKUM GROUP

DRILLING LOG	**HOLE No. 7**	*project* WCS - FLYING "W" RANCH	*sheet 1 of 1*

location: SE section 19, Block A-29

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 70 ft

elevation top of hole: 3454 ft (MSL)

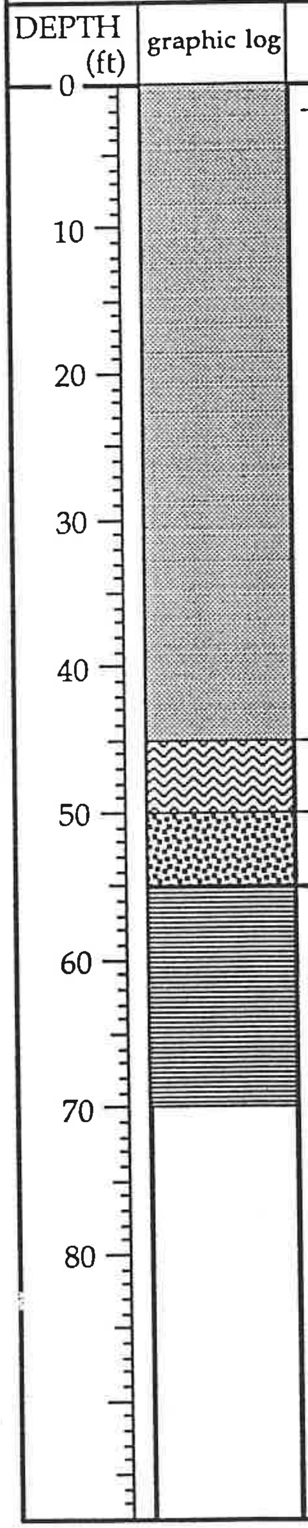
elevation ground-water: dry

date hole drilled: 3/25/99

sampling interval: 5 ft (Justin Brown)

geologist: Thomas M. Lehman 3/31/99

DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks



- fragments of reddish-brown clayey sandstone

pale fine sand with soft sandy caliche

5 YR 7/4 to 8/2

BLACKWATER DRAW FORMATION

hard laminated caliche
in fine sand matrix

"CAPROCK" CALICHE

fine/medium sand (sublitharenite)

OGALLALA FORMATION

top of "red beds" at 55 ft (elev. 3399')

red mudstone

DOCKUM GROUP

------- *t.d. 70 ft*

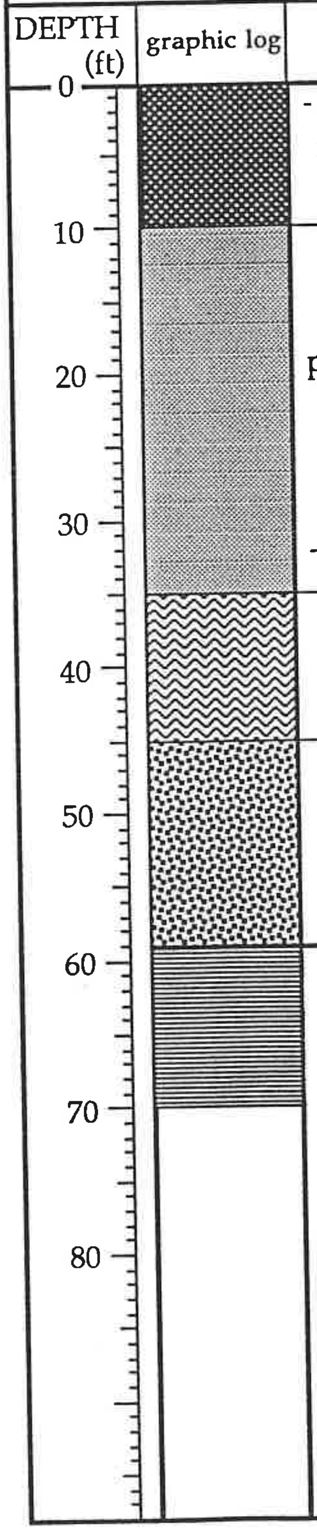
DRILLING LOG | **HOLE No. 8** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location: NW section 24, Block A-29

drilling agency/driller: Scarborough Drilling, Inc. (Lane)

total depth of hole: 70 ft
elevation top of hole: 3490 ft (MSL)
elevation ground-water: dry

date hole drilled: 3/23/99
sampling interval: 5 ft (Justin Brown)
geologist: Thomas M. Lehman 3/30/99



lithologic description	stratigraphic unit & remarks
- surface eroded reddish brown clayey fine sand with sandy caliche 5 YR 6/6	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche 5 YR 8/2 - a few chert grains (vc sand)	
hard laminated caliche in fine sand/chert granule matrix	"CAPROCK" CALICHE
fine/medium sand (sublitharenite) - a few chert grains (vc sand-granule)	OGALLALA FORMATION
top of "red beds" at 59 ft (elev. 3431')	
red mudstone ------- *t.d. 70 ft*	DOCKUM GROUP

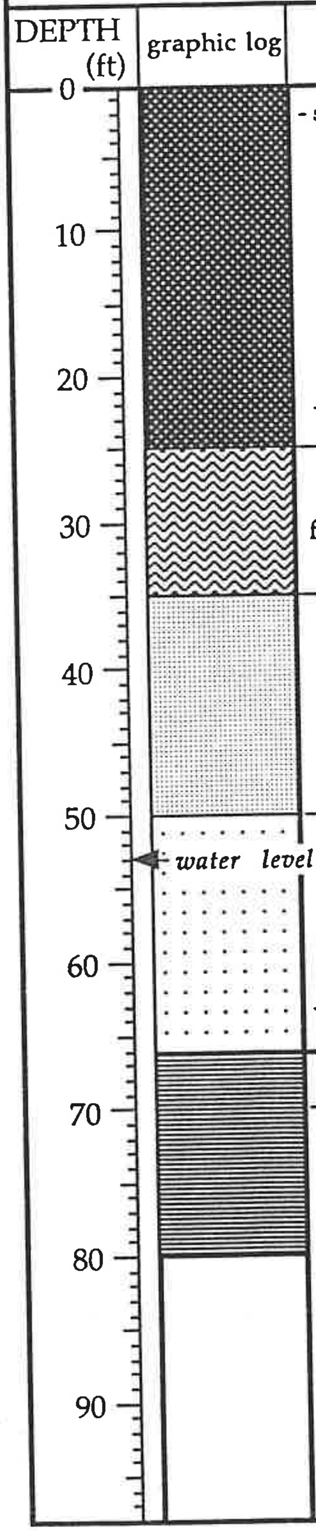
DRILLING LOG | **HOLE No. 9** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location:
SE section 24, Block A-29

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 80 ft
elevation top of hole: 3482 ft (MSL)
elevation ground-water: 3429 ft

date hole drilled: 3/24/99
sampling interval: 5 ft (Justin Brown)
geologist: Thomas M. Lehman 3/29/99



lithologic description	stratigraphic unit & remarks
- surface residue of sandy caliche/dark brown sand clasts reddish brown clayey fine sand weakly cemented/iron oxide grain coatings *5 YR 7/2 to 6/4* - nodules of soft sandy caliche	BLACKWATER DRAW FORMATION
hard laminated/pisolitic caliche f sand matrix w/chert grains (vc sand - granule)	"CAPROCK" CALICHE
clean, very well sorted vf-fine sand/sandstone (quartzarenite) *10 YR 8/2* fine-medium sand/sandstone (sublitharenite) with sparse vc-granule chert gravel *10 YR 7/2 to 7/4* - coarser medium sand with granule chert gravel	ANTLERS FORMATION
yellow mudstone red mudstone ------- *t.d. 80 ft*	*top of "red beds" at 66 ft (elev. 3416')* DOCKUM GROUP

DRILLING LOG | **HOLE No. 10** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location: SE section 23, Block A-29

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 95 ft

elevation top of hole: 3484 ft (MSL)

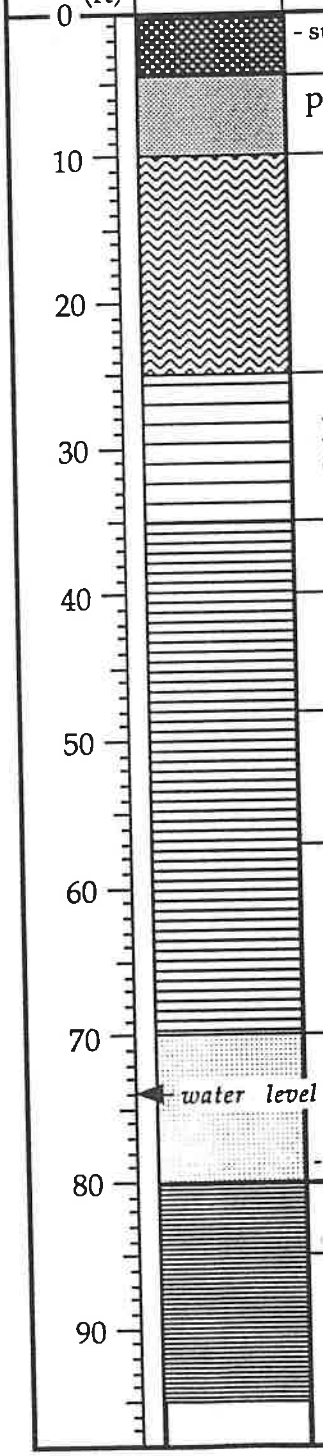
elevation ground-water: 3410 ft

date hole drilled: 3/24/99

sampling interval: 5 ft (Justin Brown)

geologist: Thomas M. Lehman 3/30/99

DEPTH (ft) | graphic log



lithologic description	stratigraphic unit & remarks
- surface rubble of dark brown sand with caliche fragments	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 5/4 to 6/4*	
hard laminated/pisolitic caliche in fine sand matrix	"CAPROCK" CALICHE
yellow silty limestone (fossiliferous) and siltstone-vf sandstone *10 YR 7/6*	ANTLERS FORMATION
yellow mudstone/shale	
gray mudstone/shale *5 Y 7/2*	
red mudstone/siltstone *5 YR 8/4 to 6/4*	
white mudstone/siltstone *10 YR 8/2*	
clean, very well sorted vf-fine sand/sandstone (quartzarenite) *10 YR 7/2 to 7/4* - grades to med sand granule-pebble chert gravel	*top of "red beds" at 80 ft (elev. 3404')*
yellow mudstone	DOCKUM GROUP
red mudstone *------ t.d. 95 ft*	

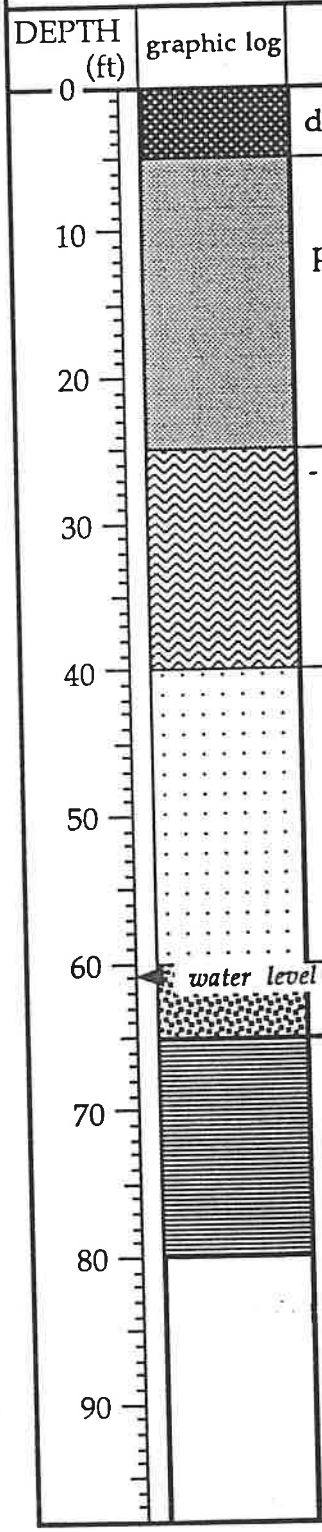
DRILLING LOG	HOLE No. 11	*project* WCS - FLYING "W" RANCH	*sheet 1 of 1*

location:
SE section 22, Block A-29

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 80 ft
elevation top of hole: 3449 ft (MSL)
elevation ground-water: 3388 ft

date hole drilled: 3/24/99
sampling interval: 5 ft (Justin Brown)
geologist: Thomas M. Lehman 3/31/99



lithologic description	stratigraphic unit & remarks
dark reddish brown fine sand *10 R 5/6*	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 8/2*	
- a few chert grains (vc sand-granule) hard laminated/pisolitic caliche in fine sand matrix	"CAPROCK" CALICHE
pink fine sand (sublitharenite)	OGALLALA FORMATION
gray - yellow fine sand/sandstone	
top of "red beds" at 65 ft (elev. 3384')	
red mudstone ------- *t.d. 80 ft*	DOCKUM GROUP

DRILLING LOG
HOLE No. 12
project WCS - FLYING "W" RANCH
sheet 1 of 1

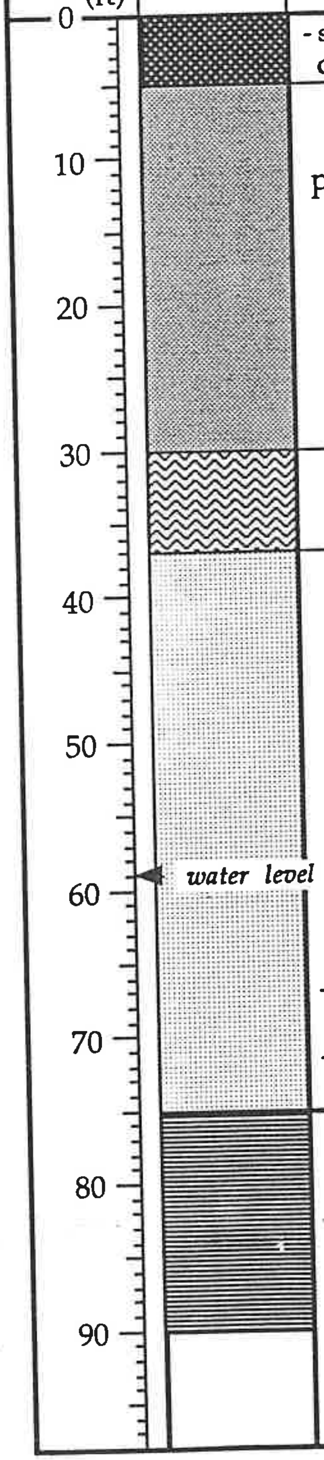
location: SE section 2, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 90 ft
elevation top of hole: 3428 ft (MSL)
elevation ground-water: 3369 ft

date hole drilled: 3/25/99
sampling interval: 5 ft (Justin Brown)
geologist: Thomas M. Lehman 3/31/99

DEPTH (ft) | graphic log



lithologic description	stratigraphic unit & remarks
- surface eroded with caliche rubble dark brown clayey fine sand 5 YR 6/6	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche 5 YR 8/2	
hard laminated/pisolitic caliche in fine sand matrix	"CAPROCK" CALICHE
pink fine sand (sublitharenite) weakly calcite cemented 5 YR 7/4 - a few chert grains (vc sand-granule) - a few chert grains (vc sand-granule)	OGALLALA FORMATION
top of "red beds" at 75 ft (elev. 3353')	
- red mudstone ------- *t.d. 90 ft*	DOCKUM GROUP

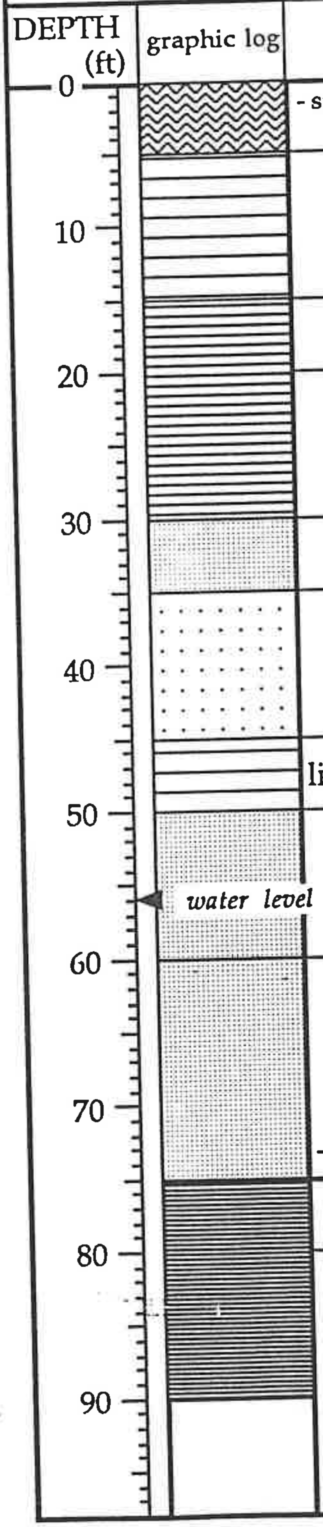
DRILLING LOG	HOLE No. 13	project WCS - FLYING "W" RANCH	sheet 1 of 1

location:
SW section 2, Block A-39

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 90 ft
elevation top of hole: 3468 ft (MSL)
elevation ground-water: 3412 ft

date hole drilled: 3/25/99
sampling interval: 5 ft (Justin Brown)
geologist: Thomas M. Lehman 3/30/99



lithologic description	stratigraphic unit & remarks
- surface rubble of dark brown sand with fragments of hard pisolitic caliche	"CAPROCK" CALICHE
yellow siltstone *10 YR 7/6*	ANTLERS FORMATION
gray mudstone/shale *5 Y 7/2*	
gray - red - yellow mottled mudstone/siltstone	
white very well sorted vf-fine sand/sandstone (quartzarenite) *10 YR 7/2 to 7/4*	
dark red fine-medium sand/sandstone	
light gray - pink siltstone/vf sandstone	
white very well sorted vf-fine sand/sandstone (quartzarenite) *10 YR 8/2*	
fine-medium sand with sparse granule chert gravel - grades to med sand granule-pebble chert gravel	
	top of "red beds" at 75 ft (elev. 3393')
yellow mudstone	DOCKUM GROUP
red mudstone	
------ *t.d. 90 ft*	

DRILLING LOG | **HOLE No. 14** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

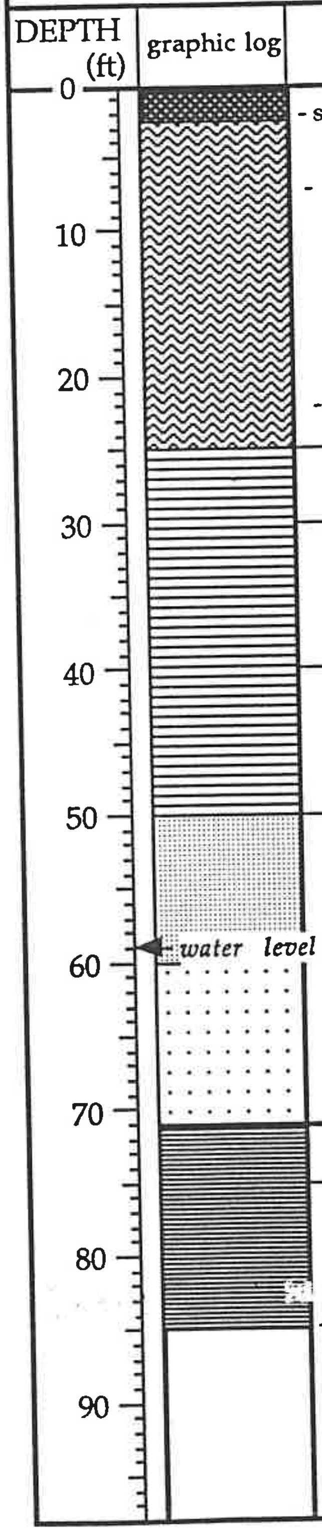
location: SE section 4, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 85 ft
elevation top of hole: 3484 ft (MSL)
elevation ground-water: 3425 ft

date hole drilled: 3/25/99
sampling interval: 5 ft (Justin Brown)
geologist: Thomas M. Lehman 3/29/99

DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks



- surface rubble of dark brown sand with caliche fragments
- opalized

hard laminated/pisolitic caliche

- gray shale fragments

"CAPROCK" CALICHE

gray mudstone/shale *5 Y 7/2*

red and purple mottled mudstone and siltstone *5 YR 8/4 to 6/4*

white siltstone *10 YR 8/2*

clean, very well sorted vf-fine sand/sandstone (quartzarenite) *10 YR 7/2 to 7/4*

fine-medium sand/sandstone (sublitharenite) with sparse granule-pebble chert gravel

ANTLERS FORMATION

top of "red beds" at 71 ft (elev. 3413')

yellow mudstone

red mudstone

------- t.d. 85 ft

DOCKUM GROUP

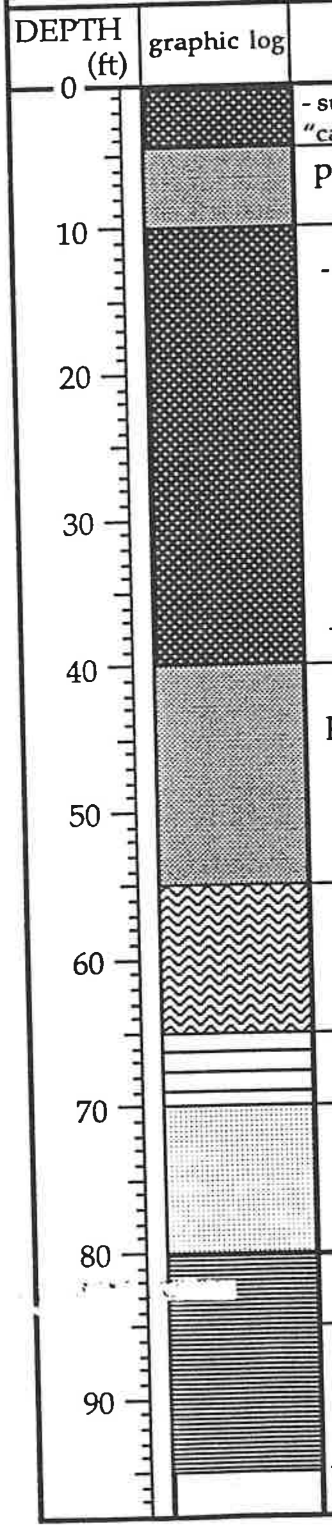
DRILLING LOG	**HOLE No. 15**	*project* WCS - FLYING "W" RANCH	*sheet 1 of 1*

location:
SE section 5, Block A-39

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 95 ft
elevation top of hole: 3447 ft (MSL)
elevation ground-water: dry

date hole drilled: 3/26/99
sampling interval: 5 ft (Dean Muirhead)
geologist: Thomas M. Lehman 4/9/99



lithologic description	stratigraphic unit & remarks
- surface rubble of dark brown sand with caliche "caprock" fragments, red shale, chert pebbles	- colluvium
pale fine sand with soft sandy caliche *5 YR 5/4*	BLACKWATER DRAW FORMATION
- fragments of hard laminated caliche reddish brown fine sand with soft sandy caliche - a few chert grains (vc sand)	
pale fine sand with soft sandy caliche *5 YR 5/4 to 6/4* - a few chert grains (vc sand - granule)	
hard laminated/pisolitic caliche in fine sandy chert gravel matrix (granule-large pebble)	"CAPROCK" CALICHE
red - yellow mottled siltstone/vf ss	ANTLERS FORMATION
white, very well sorted vf-fine sand/sandstone (quartzarenite) *10 YR 7/2 to 7/4*	
yellow/gray mudstone	*top of "red beds" at 80 ft (elev. 3367')* DOCKUM GROUP
red mudstone ------- *t.d. 95 ft*	

DRILLING LOG | **HOLE No. 16** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location: SW section 15, Block A-29

drilling agency/driller: Scarborough Drilling, Inc. (Lane)

total depth of hole: 96 ft

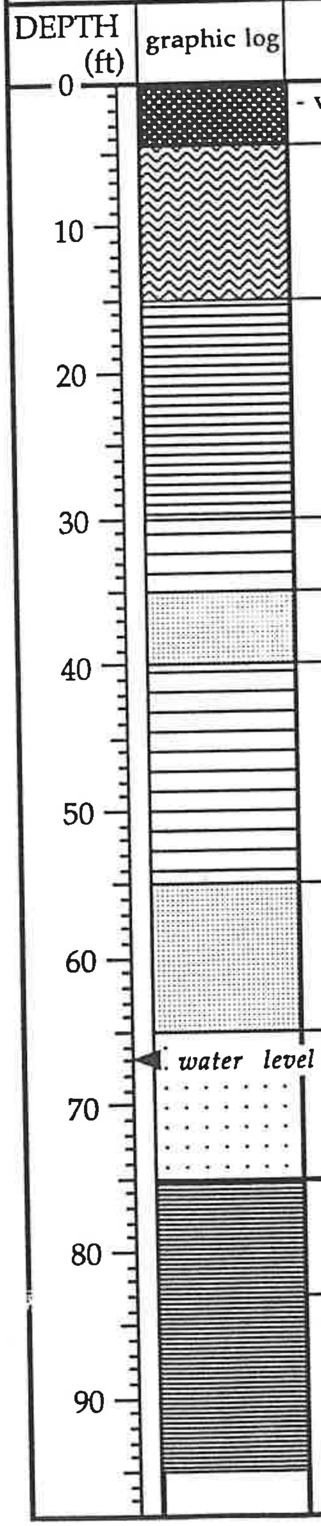
elevation top of hole: 3519 ft (MSL)

elevation ground-water: 3452 ft

date hole drilled: 3/23/99

sampling interval: 5 ft (Dean Muirhead)

geologist: Thomas M. Lehman 3/26/99



lithologic description	stratigraphic unit & remarks
- vf-f clayey light brown sand with caliche *5 YR 5/4*	BLACKWATER DRAW FORMATION
hard laminated/pisolitic caliche	"CAPROCK" CALICHE
purple - red - yellow mottled mudstone/shale	ANTLERS FORMATION
purple siltstone	
white very well sorted vf-fine sand/sandstone (quartzarenite) *10 YR 8/2*	
purple siltstone/vf sandstone	
white well sorted fine sand/sandstone (sublitharenite)	
yellow fine-medium sand/sandstone (sublitharenite) with granule-pebble chert gravel	
top of "red beds" at 75 ft (elev. 3444')	
yellow siltstone	DOCKUM GROUP
red mudstone	
------- *t.d. 96 ft*	

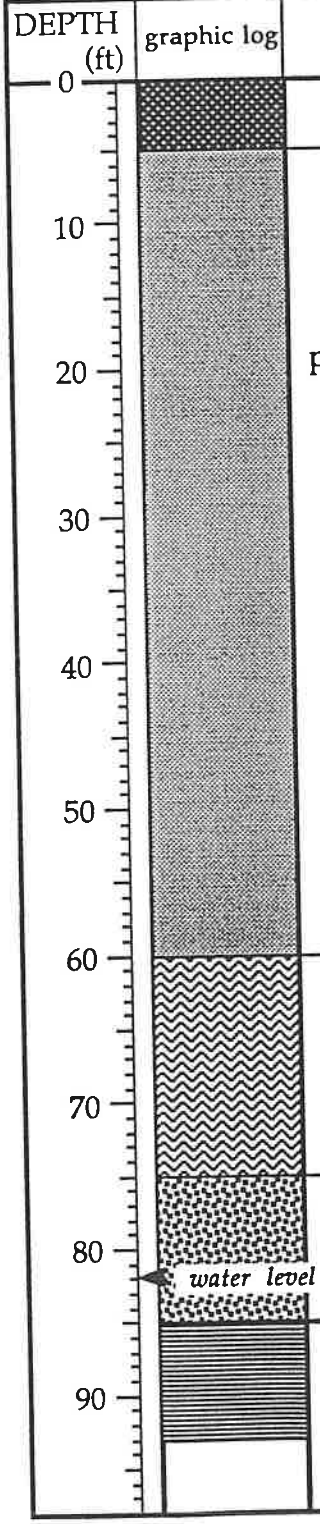
DRILLING LOG | **HOLE No. 17u** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location:
NW section 19, Block A-29

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 93 ft
elevation top of hole: 3464 ft (MSL)
elevation ground-water: 3382 ft

date hole drilled: 4/7/99
sampling interval: 5 ft (Dean Muirhead)
geologist: Thomas M. Lehman 4/12/99



lithologic description	stratigraphic unit & remarks
dark brown fine sand *10 YR 5/2* "mollic" horizon? - no caliche	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 8/2*	
hard laminated/pisolitic caliche in fine sand matrix	"CAPROCK" CALICHE
fine sand with scattered vc sand - granule chert grains	OGALLALA FORMATION
top of "red beds" at 85 ft (elev. 3379')	
yellow mudstone ------- *t.d. 93 ft*	DOCKUM GROUP

DRILLING LOG | **HOLE No. 18u** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location: NE section 18, Block A-29

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 75 ft

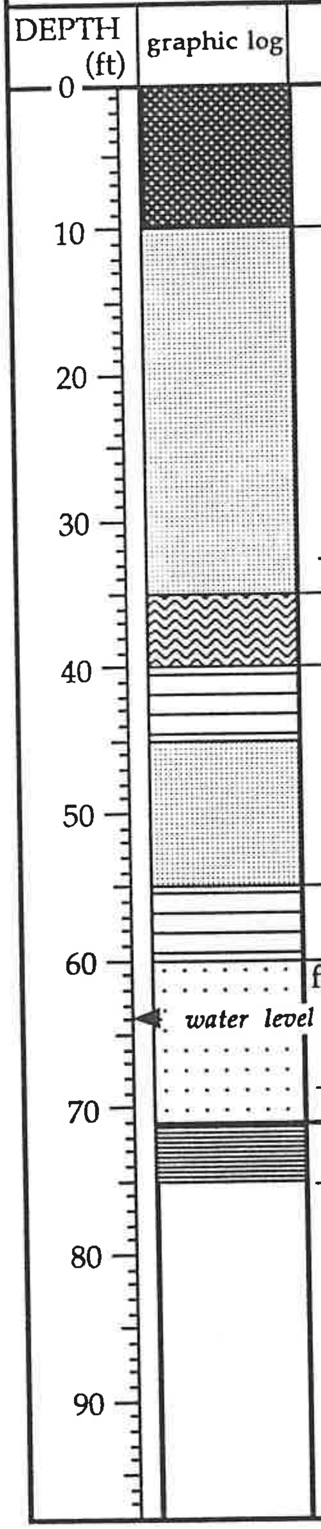
elevation top of hole: 3481 ft (MSL)

elevation ground-water: 3417 ft

date hole drilled: 4/7/99

sampling interval: 5 ft (Dean Muirhead)

geologist: Thomas M. Lehman 4/20/99



lithologic description	stratigraphic unit & remarks
reddish brown clayey fine sand weakly cemented/iron oxide grain coatings *5 YR 7/2 to 6/4*	BLACKWATER DRAW FORMATION
pale fine sand with soft white sandy caliche *5 YR 5/4 to 6/4* - slightly redder in color	
hard laminated/pisolitic caliche no gravel	"CAPROCK" CALICHE
clean, white siltstone - grades downward to vf-fine sandstone (quartzarenite) *10 YR 8/2*	ANTLERS FORMATION
red/gray mudstone	
fine-med sand/sandstone (sublitharenite) with granule chert gravel *10 YR 7/2 to 7/4* - coarser medium sand with pebble chert gravel	*top of "red beds" at 71 ft (elev. 3410')*
yellow/red mudstone ------ *t.d. 75 ft*	DOCKUM GROUP

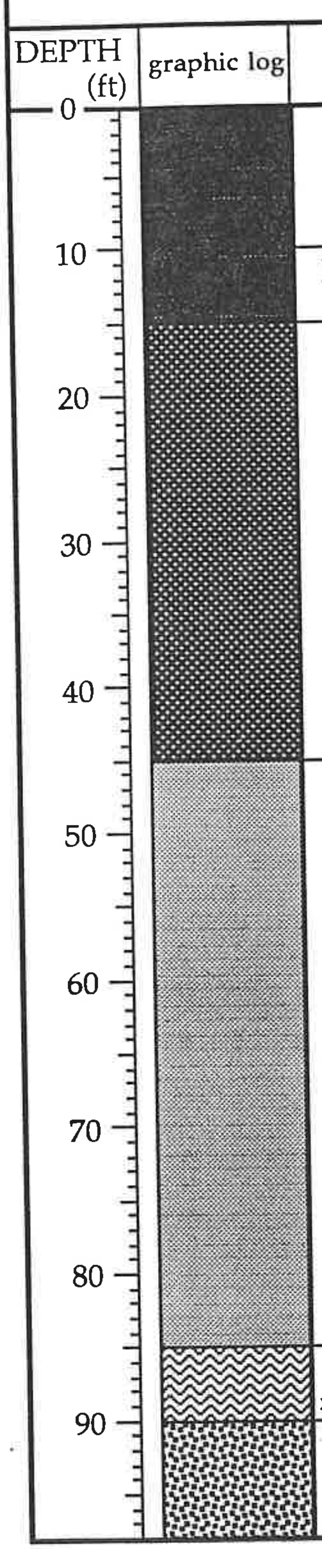
DRILLING LOG | **HOLE No. 19u** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 2*

location:
NE section 6, Block A-39

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

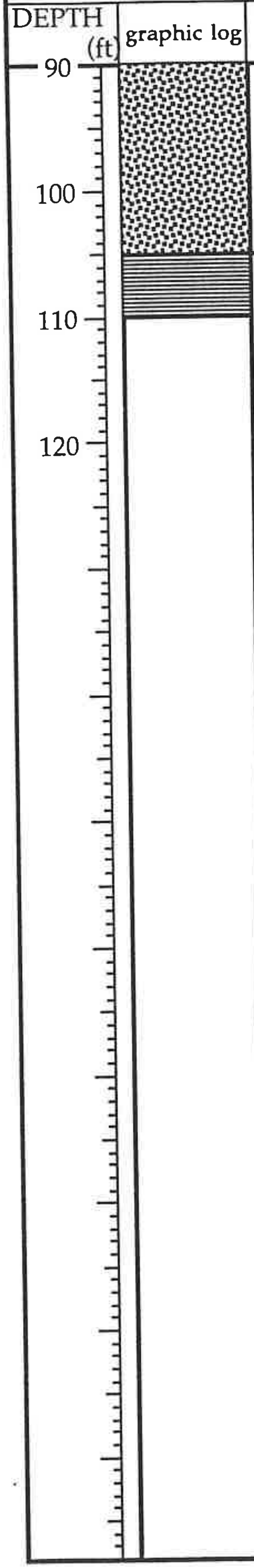
total depth of hole: 110 ft
elevation top of hole: 3431 ft (MSL)
elevation ground-water: dry

date hole drilled: 4/15/99
sampling interval: 5 ft (Dean Muirhead)
geologist: Thomas M. Lehman 4/20/99



lithologic description	stratigraphic unit & remarks
dark brown clayey fine sand *5 YR 4/2 to 4/4* no caliche yellow-brown gleyed clayey fine sand *10 YR 6/2*	PLAYA DEPOSITS
reddish brown fine sand/sandstone *5 YR 5/6 to 6/6*	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 8/4 to 7/4* grades downward from fine to fine/medium sand - a few chert grains (vc sand - granule)	
hard laminated/pisolitic caliche red f-med sand matrix with granule chert gravel	"CAPROCK" CALICHE
red fine-med sand/sandstone with chert granule-pebble gravel *5 YR 4/6 to 5/6*	? GATUNA FORMATION

DRILLING LOG - continuation sheet | **HOLE No. 19u** | *project* WCS RANCH | *sheet 2 of 2*



lithologic description	stratigraphic unit & remarks
red fine-medium sand/sandstone with chert granule-pebble gravel *5 YR 4/6 to 6/6*	? GATUNA FORMATION
top of "red beds" at 105 ft (elev. 3326')	
red mudstone ------- *t.d. 110 ft*	DOCKUM GROUP

DRILLING LOG

HOLE No. 20u

project WCS - FLYING "W" RANCH

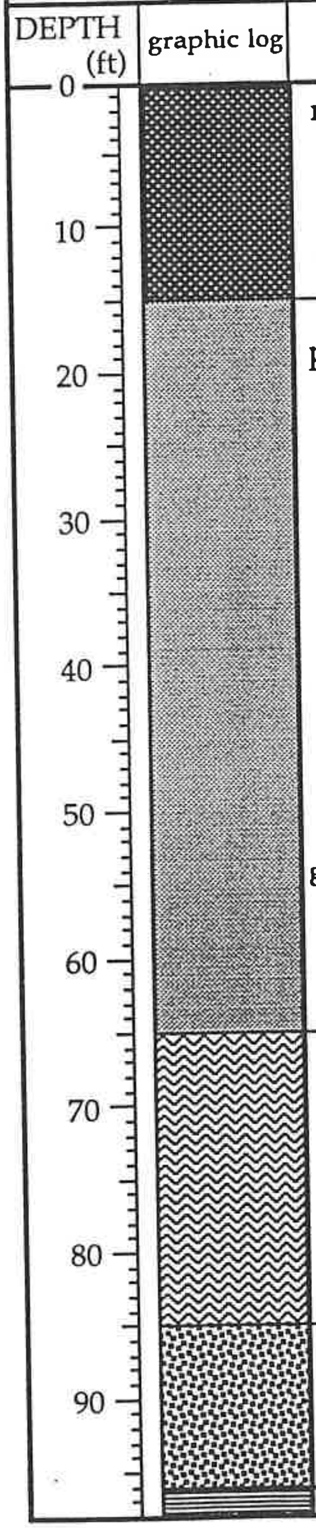
sheet 1 of 2

location:
SW section 7, Block A-39

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

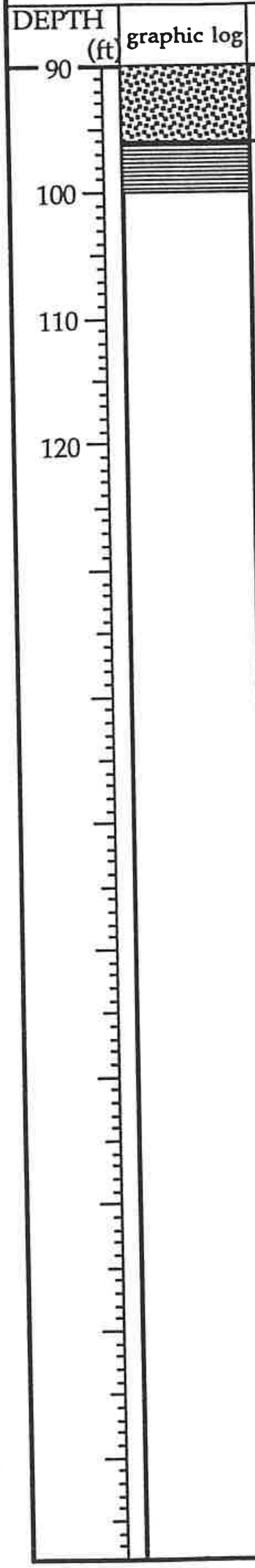
total depth of hole: 100 ft
elevation top of hole: 3439 ft (MSL)
elevation ground-water: dry

date hole drilled: 4/5/99
sampling interval: 5 ft (Dean Muirhead)
geologist: Thomas M. Lehman 4/21/99



lithologic description	stratigraphic unit & remarks
reddish brown fine sand/sandstone with weak Fe-oxide cement, no caliche *5 YR 5/6 to 6/6* - sparse sandy caliche	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 8/4 to 7/4* grades downward from fine to fine/medium sand	
nodules of hard laminated/pisolitic caliche in fine-med sand with chert gravel (granule-small pebble)	"CAPROCK" CALICHE poorly developed - appears to be discontinuous
red fine-med sand/sandstone with chert granule-pebble gravel *5 YR 4/6 to 5/6*	? GATUNA FORMATION
red mudstone	DOCKUM GROUP

DRILLING LOG - continuation sheet	**HOLE No. 20u**	*project* WCS RANCH	*sheet* 2 *of* 2



lithologic description	stratigraphic unit & remarks
red fine-medium sand/sandstone with chert granule-pebble gravel	? GATUNA FORMATION
	top of "red beds" at 96 ft (elev. 3343')
red mudstone	DOCKUM GROUP
t.d. 100 ft	

DRILLING LOG | **HOLE No. 21** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location: SE section 15, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 70 ft

elevation top of hole: 3401 ft (MSL)

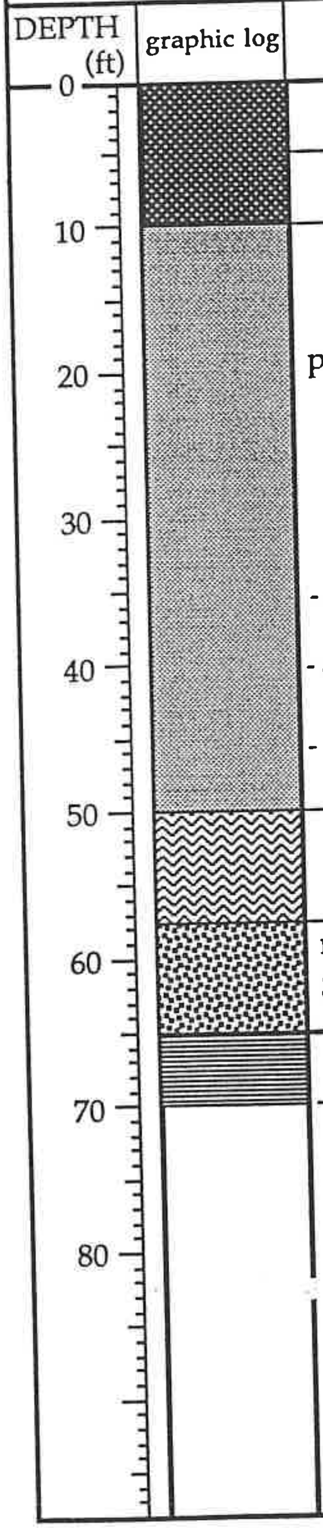
elevation ground-water: dry

date hole drilled: 3/30/99

sampling interval: 5 ft (Dean Muirhead)

geologist: Thomas M. Lehman 4/8/99

DEPTH (ft) | graphic log | lithologic description | stratigraphic unit & remarks



dark brown fine sand *10 YR 5/2*

reddish brown clayey fine sand
no caliche *5 YR 6/6*

pale fine sand with soft sandy caliche

5 YR 8/2

- a few chert grains (vc sand)
- a few chert grains (vc sand)
- a few chert grains (vc sand)

hard laminated caliche
in fine red sand/chert granule matrix

red fine/medium sand and granule/small pebble gravel *10 R 6/4*

red mudstone

------- *t.d. 70 ft*

BLACKWATER DRAW FORMATION

"CAPROCK" CALICHE

? GATUNA FORMATION

top of "red beds" at 65 ft (elev. 3336')

DOCKUM GROUP

DRILLING LOG	HOLE No. 22	*project* WCS - FLYING "W" RANCH	*sheet 1 of 2*

location: SW section 15, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 110 ft

elevation top of hole: 3392 ft (MSL)

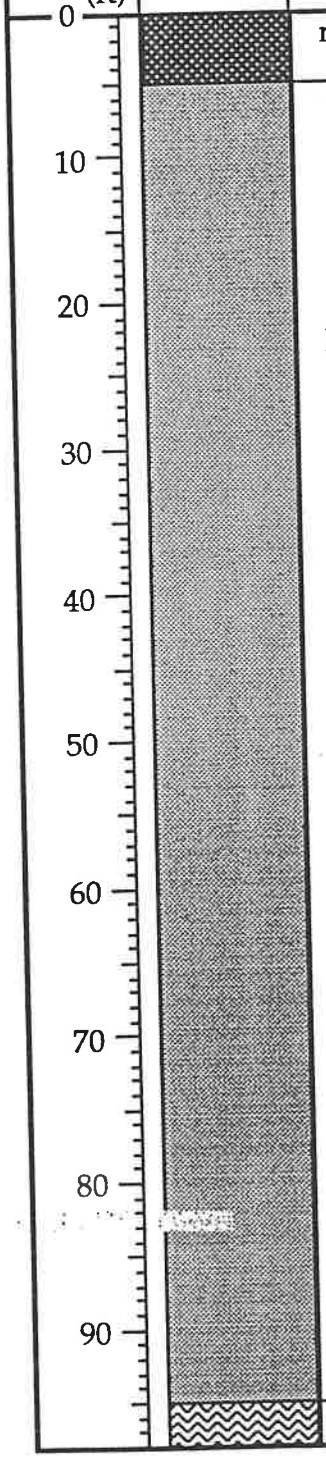
elevation ground-water: dry

date hole drilled: 4/1/99

sampling interval: 5 ft (Jeff Stovall)

geologist: Thomas M. Lehman 4/7/99

DEPTH (ft) | graphic log



lithologic description	stratigraphic unit & remarks
reddish brown clayey fine sand *10 YR 5/2* - some sandy caliche	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 7/4* grades downward from fine to fine/medium sand	
clasts (?) of hard laminated caliche	"CAPROCK". CALICHE

DRILLING LOG - continuation sheet	HOLE No. 22	*project* WCS RANCH	*sheet* 2 *of* 2

DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks
90		pale fine/medium sand with scattered sandy caliche	
		hard laminated/pisolitic caliche (poorly developed -clasts in fine/med sand)	"CAPROCK" CALICHE
100		red fine/medium sand/sandstone (sublitharenite) with granule chert gravel *10 R 6/4*	? GATUNA FORMATION
110		—— *t.d. 110 ft*	
120			

DRILLING LOG | **HOLE No. 22B** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 2*

location: SW section 15, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 125 ft

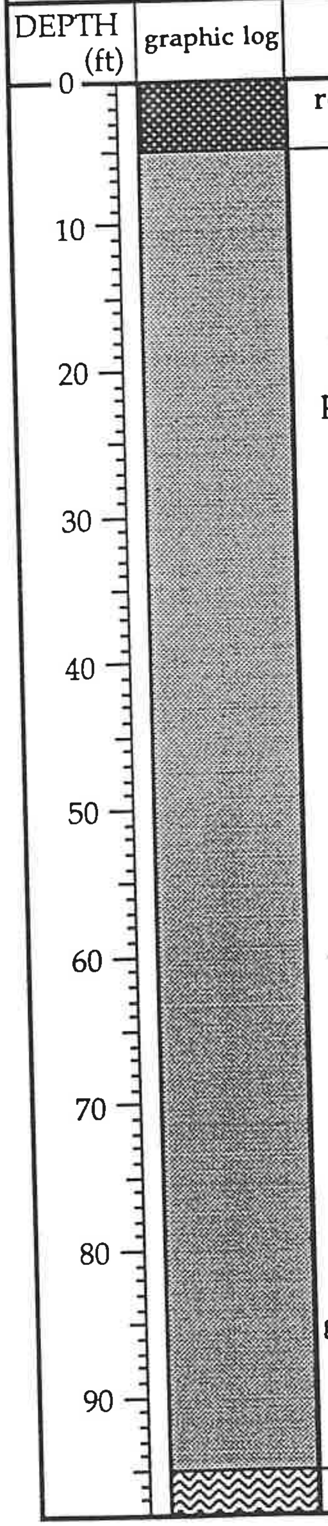
elevation top of hole: 3392 ft (MSL)

elevation ground-water: dry

date hole drilled:

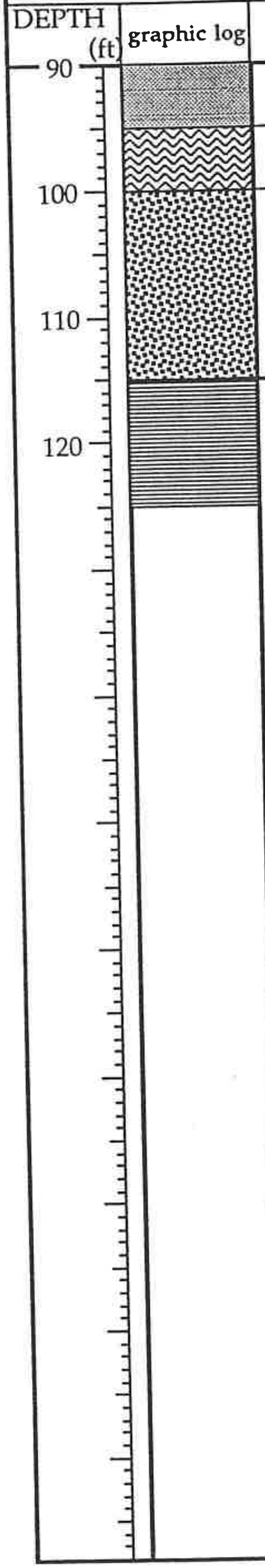
sampling interval: 5 ft

geologist: Thomas M. Lehman 6/25/99



lithologic description	stratigraphic unit & remarks
reddish brown clayey fine sand 10 YR 5/2	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche 5 YR 7/4 grades downward from fine to fine/medium sand	
hard laminated caliche	"CAPROCK" CALICHE

DRILLING LOG - continuation sheet | **HOLE No. 22B** | *project* WCS RANCH | *sheet 2 of 2*



lithologic description	stratigraphic unit & remarks
pale fine/medium sand with scattered sandy caliche	
hard laminated/pisolitic caliche	"CAPROCK" CALICHE - poorly developed, nodular and discontinuous
red fine/medium sand/sandstone (sublitharenite) with granule - small pebble chert gravel *10 R 6/4*	? GATUNA FORMATION
top of "red beds" at 115 ft (elev. 3277')	
red mudstone *10 R 4/4* ------- *t.d. 125 ft*	DOCKUM GROUP

DRILLING LOG	HOLE No. 24	project WCS - FLYING "W" RANCH	sheet 1 of 1

location: NW section 6, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 80 ft

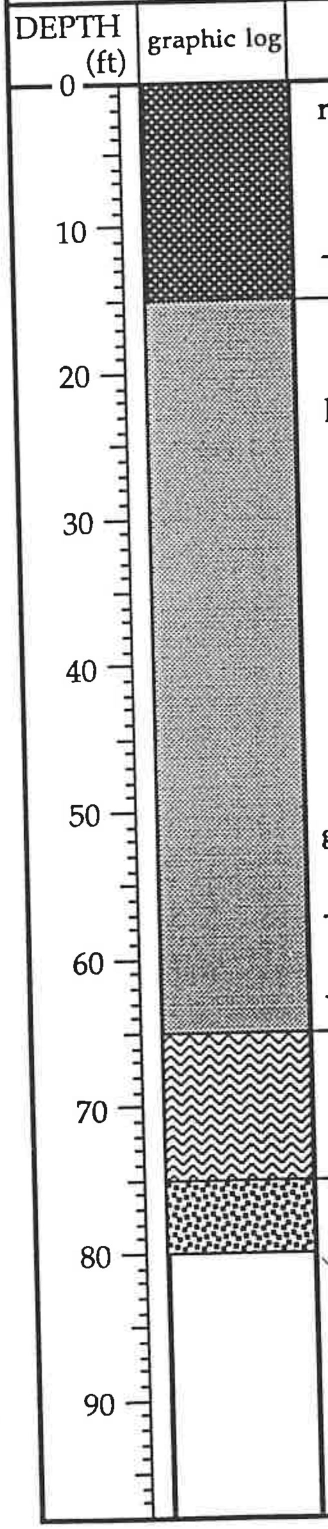
elevation top of hole: 3416 ft (MSL)

elevation ground-water: dry

date hole drilled: 4/1/99

sampling interval: 5 ft (Jeff Stovall)

geologist: Thomas M. Lehman 4/7/99



lithologic description	stratigraphic unit & remarks
reddish brown clayey fine sand *10 YR 5/2* no caliche - a few chert grains (vc sand)	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 7/4* grades downward from fine to fine/medium sand - a few chert grains (vc sand - granule) - a few chert grains (vc sand - granule)	
hard laminated/pisolitic caliche f-med sand matrix with granule-small pebble chert gravel	"CAPROCK" CALICHE
red fine/medium sandy granule-pebble gravel *10 R 6/4* *t.d. 80 ft*	? GATUNA FORMATION

DRILLING LOG	HOLE No. 24B	*project* WCS - FLYING "W" RANCH	*sheet 1 of 2*

location: NW section 6, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 100 ft

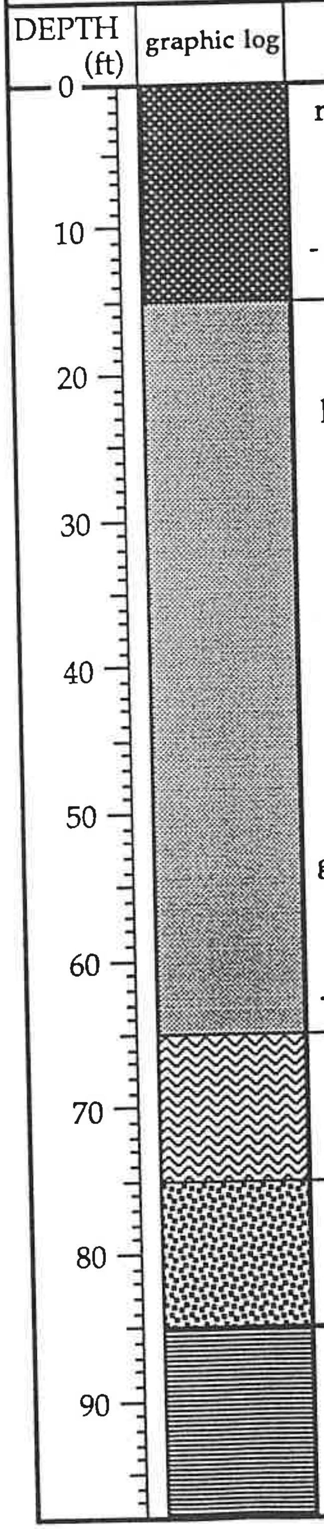
elevation top of hole: 3416 ft (MSL)

elevation ground-water: dry

date hole drilled:

sampling interval: 5 ft

geologist: Thomas M. Lehman 6/25/99



lithologic description	stratigraphic unit & remarks
reddish brown clayey fine sand *10 YR 5/2* no caliche - a few chert grains (vc sand)	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 7/4* grades downward from fine to fine/medium sand - a few chert grains (vc sand - granule)	
hard laminated/pisolitic caliche f-med sand matrix with granule-small pebble chert gravel	"CAPROCK" CALICHE - poorly developed, appears to be nodular and discontinuous
red fine/medium sandy granule-pebble gravel *10 R 6/4*	? GATUNA FORMATION
	top of "red beds" at 85 ft (elev. 3331`)
red mudstone *10 R 4/4*	DOCKUM GROUP

DRILLING LOG - continuation sheet	**HOLE No. 24B**	*project* WCS RANCH	*sheet 2 of 2*

DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks
90	▤	red mudstone *10 R 4/4*	DOCKUM GROUP
100		------ *t.d. 100 ft*	
110			
120			

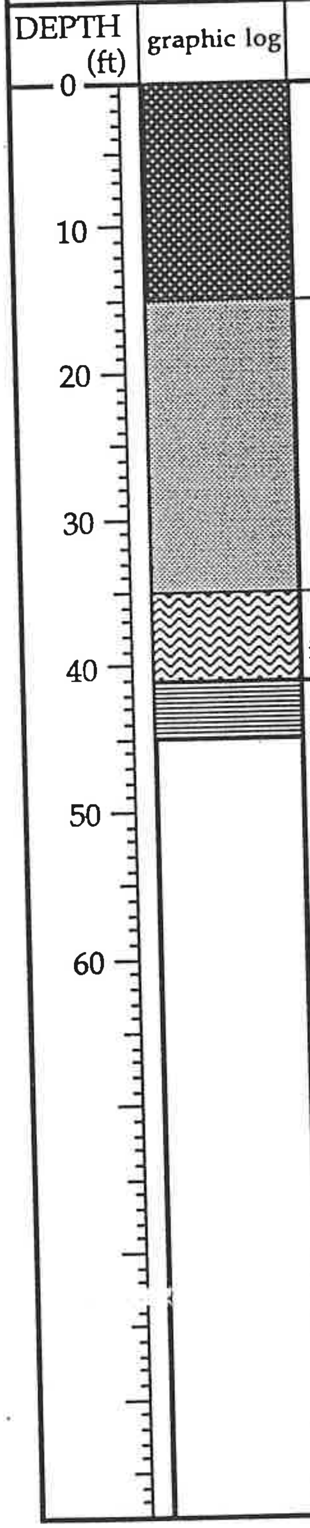
DRILLING LOG | **HOLE No. 25** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location: SW section 5, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 45 ft
elevation top of hole: 3410 ft (MSL)
elevation ground-water: dry

date hole drilled: 3/31/99
sampling interval: 5 ft (Dean Muirhead)
geologist: Thomas M. Lehman 4/9/99

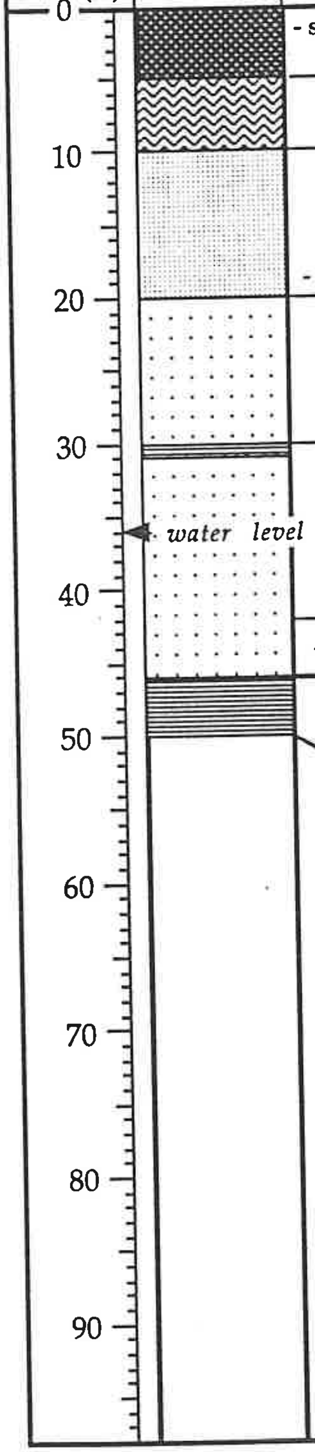


lithologic description	stratigraphic unit & remarks
reddish brown clayey fine sand *5 YR 5/6 to 6/6* - with sandy caliche - with sandy caliche and a few chert granules	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 8/2* - a few chert grains (vc sand - granule) - a few chert grains (vc sand - granule)	
hard laminated caliche in fine red sand matrix with a few chert granules	"CAPROCK" CALICHE *top of "red beds" at 41 ft (elev. 3369')*
red mudstone ------- *t.d. 45 ft*	DOCKUM GROUP

DRILLING LOG	**HOLE No. 26**	*project* WCS - FLYING "W" RANCH	*sheet 1 of 1*

location: NE section 9, Block A-39	drilling agency/driller: Scarborough Drilling, Inc. (Scott)
total depth of hole: 50 ft elevation top of hole: 3433 ft (MSL) elevation ground-water: 3397 ft	date hole drilled: 3/30/99 sampling interval: 5 ft (Dean Muirhead) geologist: Thomas M. Lehman 4/22/99

DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks



- surface rubble of dark brown sand with caliche fragments

hard laminated/pisolitic caliche

"CAPROCK" CALICHE

clean, white, well sorted vf-fine sand/sandstone (quartzarenite)
10 YR 7/2 to 7/4

- spots of yellow limonite cement

clean, white, well sorted fine-med sand/sandstone (quartzarenite)

- gray mudstone layer

yellow fine-medium sand/sandstone (quartzarenite) with sparse granule-small pebble chert gravel
10 YR 7/6

- large chert pebble gravel

ANTLERS FORMATION

top of "red beds" at 46 ft (elev. 3387')

yellow mudstone

t.d. 50 ft

DOCKUM GROUP

DRILLING LOG	HOLE No. 27	*project* WCS - FLYING "W" RANCH	*sheet 1 of 1*

location: NE section 12, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 50 ft

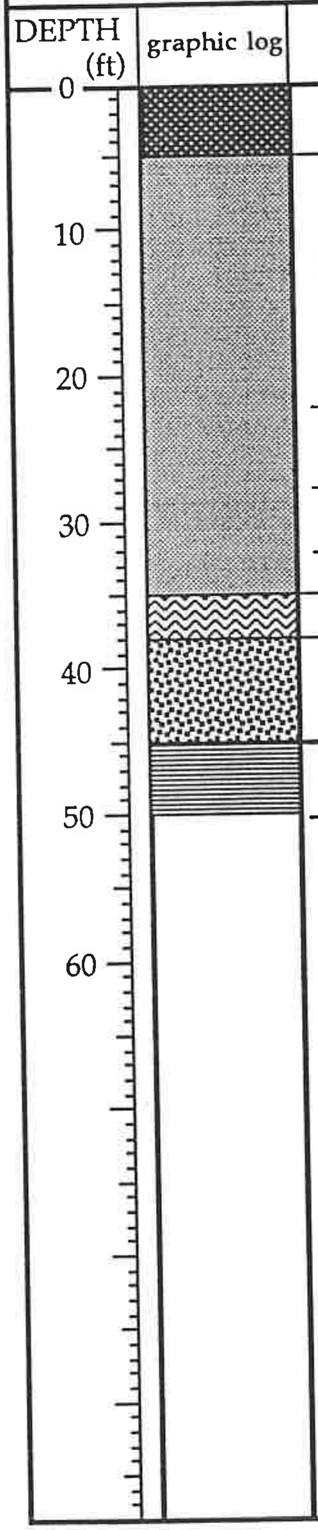
elevation top of hole: 3405 ft (MSL)

elevation ground-water: dry

date hole drilled: 3/30/99

sampling interval: 5 ft (Dean Muirhead)

geologist: Thomas M. Lehman 4/7/99



lithologic description	stratigraphic unit & remarks
dark brown fine sand *10 YR 5/2* fragments of hard (?'caprock') caliche and a few chert pebbles throughout	BLACKWATER DRAW FORMATION degraded and with surface colluvium
pale fine sand with soft sandy caliche *5 YR 8/2* - a few chert grains (vc sand - granule) - a few chert grains (vc sand - granule) - abundant chert grains (granule - small pebble)	
hard laminated caliche	"CAPROCK" CALICHE poorly developed
red fine sandy granule-pebble gravel *10 R 6/4*	? GATUNA FORMATION
top of "red beds" at 45 ft (elev. 3360')	
red mudstone ------- *t.d. 50 ft*	DOCKUM GROUP

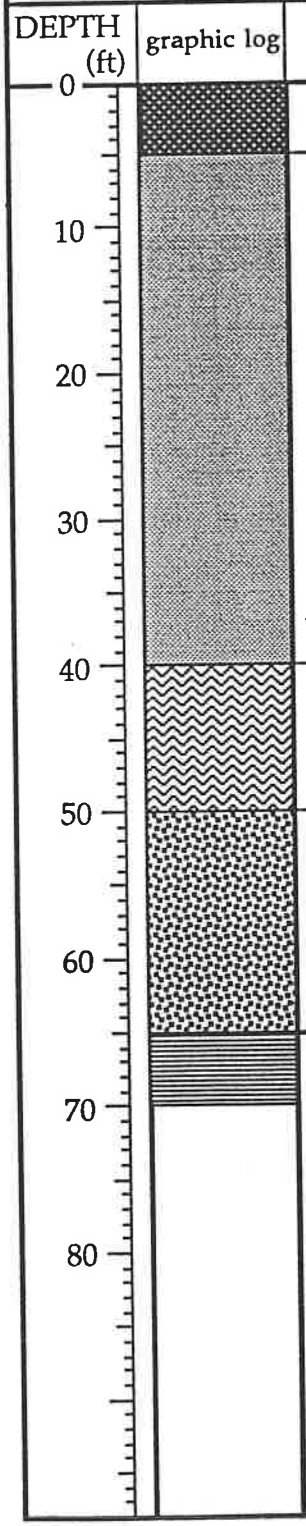
DRILLING LOG	HOLE No. 28	*project* WCS - FLYING "W" RANCH	*sheet 1 of 1*

location:
SE section 12, Block A-39

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 70 ft
elevation top of hole: 3375 ft (MSL)
elevation ground-water: dry

date hole drilled: 3/31/99
sampling interval: 5 ft (Dean Muirhead)
geologist: Thomas M. Lehman 4/12/99



lithologic description	stratigraphic unit & remarks
reddish brown clayey fine sand no caliche *5 YR 6/6*	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 8/2* - a few chert grains (vc sand) - a few chert grains (vc sand) - a few chert grains (vc sand)	
hard laminated/pisolitic caliche in fine red sand/chert granule matrix	"CAPROCK" CALICHE
fine/medium sand and granule/small pebble chert gravel	? GATUNA FORMATION
top of "red beds" at 65 ft (elev. 3310')	
red mudstone ------- *t.d. 70 ft*	DOCKUM GROUP

DRILLING LOG | **HOLE No. 29u** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

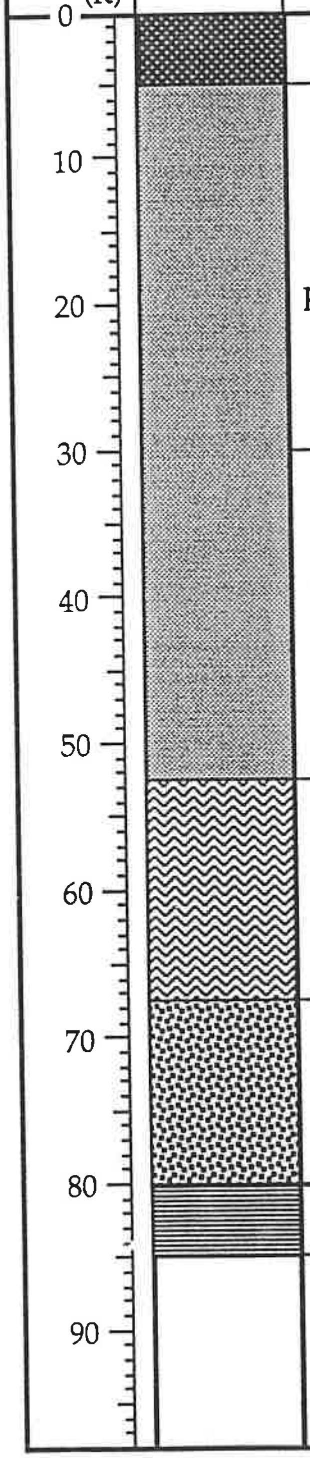
location:
SW section 12, Block A-39

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 85 ft
elevation top of hole: 3383 ft (MSL)
elevation ground-water: dry

date hole drilled: 3/31/99
sampling interval: 5 ft (Dean Muirhead)
geologist: Thomas M. Lehman 4/20/99

DEPTH (ft) | graphic log



lithologic description	stratigraphic unit & remarks
reddish brown clayey fine sand no caliche *5 YR 6/6*	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 8/2* - with chert gravel (granule) - with chert gravel (granule-small pebble)	
hard laminated/pisolitic caliche in fine red sand/chert granule-pebble matrix	"CAPROCK" CALICHE
red fine/medium sand and granule/small pebble gravel *10 R 6/4* - nodules of "caprock" caliche throughout	? GATUNA FORMATION
red mudstone *t.d. 85 ft*	*top of "red beds" at 80 ft (elev. 3303')* DOCKUM GROUP

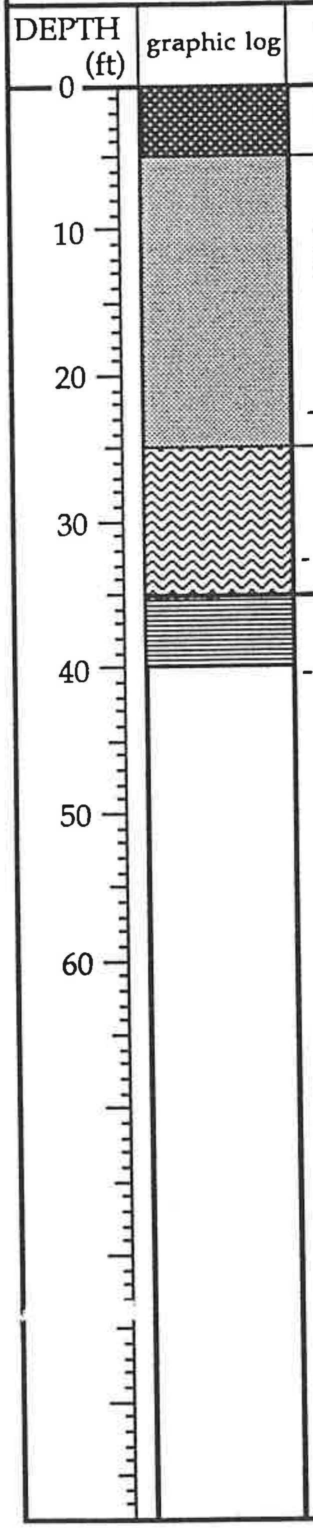
DRILLING LOG	HOLE No. 30u	*project* WCS - FLYING "W" RANCH	*sheet 1 of 1*

location: SE section 14, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 40 ft
elevation top of hole: 3415 ft (MSL)
elevation ground-water: dry

date hole drilled: 4/5/99
sampling interval: 5 ft (Dean Muirhead)
geologist: Thomas M. Lehman 4/19/99



lithologic description	stratigraphic unit & remarks
reddish brown fine sand *5 YR 6/6*	BLACKWATER DRAW FORMATION
pale fine sand/weakly-cemented sandstone with soft sandy caliche *5 YR 8/2* - a few chert grains (vc sand - granule)	
hard laminated/pisolitic caliche red f-med sand/granule-pebble chert matrix - a few clasts of yellow/red sandstone	"CAPROCK" CALICHE residue of ? GATUNA FORMATION
red mudstone ------- *t.d. 40 ft*	DOCKUM GROUP

top of "red beds" at 35 ft (elev. 3380')

DRILLING LOG	HOLE No. 31	*project* WCS - FLYING "W" RANCH	*sheet 1 of 1*

location: SE section 7, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 60 ft

elevation top of hole: 3460 ft (MSL)

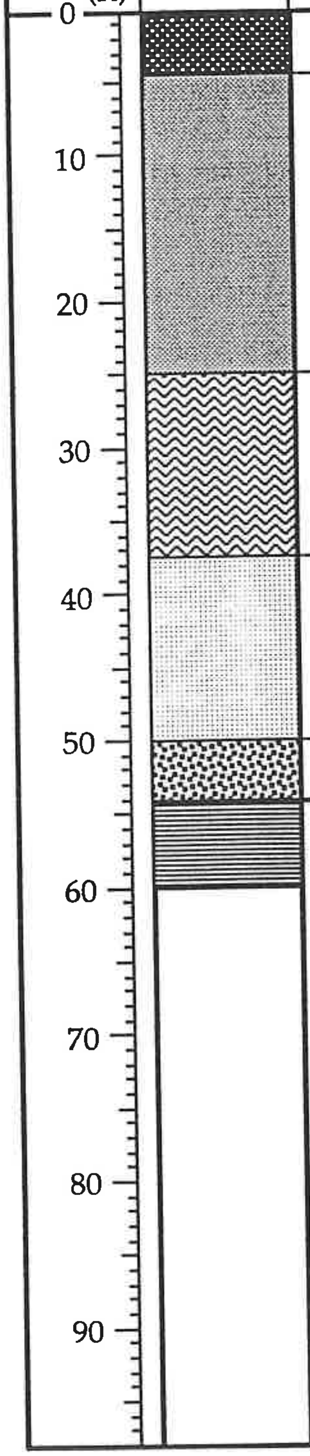
elevation ground-water: dry

date hole drilled: 3/29/99

sampling interval: 5 ft (Dean Muirhead)

geologist: Thomas M. Lehman 4/19/99

DEPTH (ft) | graphic log



lithologic description	stratigraphic unit & remarks
dark reddish brown fine sand with soft sandy caliche	BLACKWATER DRAW FORMATION
pale fine sand with soft sandy caliche *5 YR 5/4 to 6/4*	
hard laminated/pisolitic caliche in fine sandy chert gravel matrix (granule-large pebble) - clasts of gray, red, purple mudstone	"CAPROCK" CALICHE
pale yellow fine-medium sand/sandstone (sublitharenite) with chert gravel (vc sand-granule) *10 YR 8/4*	ANTLERS FORMATION
sandy chert gravel (granule-pebble)	
	top of "red beds" at 54 ft (elev. 3406')
yellow/red mudstone *------ t.d. 60 ft*	DOCKUM GROUP

DRILLING LOG | **HOLE No. 32** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 2*

location: NW section 8, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 100 ft

elevation top of hole: 3483 ft (MSL)

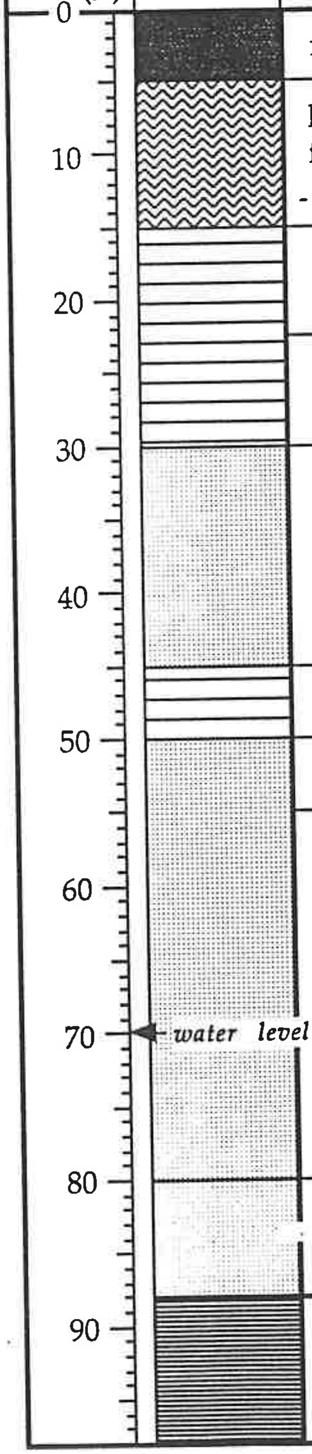
elevation ground-water: 3413 ft

date hole drilled: 3/29/99

sampling interval: 5 ft (Dean Muirhead)

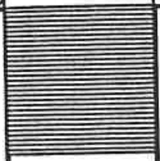
geologist: Thomas M. Lehman 4/20/99

DEPTH (ft) | graphic log



lithologic description	stratigraphic unit & remarks
reddish brown fine sand/no caliche	BLACKWATER DRAW FORMATION
hard laminated/pisolitic caliche in fine sandy matrix - with purple siltstone clasts	"CAPROCK" CALICHE
purple siltstone *5 RP 7/2* with yellow *5 Y 8/4* mottles	ANTLERS FORMATION
pale yellow-gray mudstone/siltstone *10 Y 9/2*	
white well sorted fine-med sand/sandstone (quartzarenite) *5 YR 8/2*	
red mudstone *5 YR 5/4* with laminae of yellow *10 YR 7/4*	
white fine-med sand/sandstone (sublitharenite) *5 YR 8/2*	
medium-coarse sand/sandstone (sublitharenite) with sparse granule chert gravel *10 YR 8/2 to 7/2*	
yellow fine-med sand/sandstone (sublitharenite) *10 YR 7/4*	
top of "red beds" at 88 ft (elev. 3395')	
red mudstone	DOCKUM GROUP

DRILLING LOG - continuation sheet	HOLE No. 32	*project* WCS RANCH	*sheet 2 of 2*

DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks
90		red mudstone	DOCKUM GROUP
100		------ *t.d. 100 ft*	
110			
120			

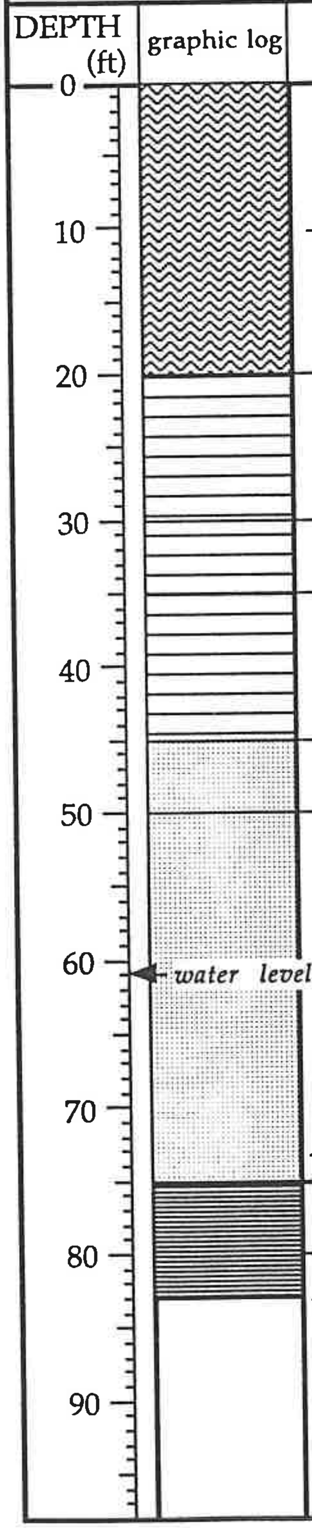
DRILLING LOG | **HOLE No. 33** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location:
NE section 8, Block A-39

drilling agency/driller:
Scarborough Drilling, Inc. (Scott)

total depth of hole: 83 ft
elevation top of hole: 3473 ft (MSL)
elevation ground-water: 3412 ft

date hole drilled: 3/29/99
sampling interval: 5 ft (Dean Muirhead)
geologist: Thomas M. Lehman 4/19/99



lithologic description	stratigraphic unit & remarks
hard laminated/pisolitic caliche in fine sandy matrix with dark brown sand clasts - partly opalized	"CAPROCK" CALICHE
pale yellow-gray mudstone/siltstone 10 Y 9/2 white mudstone/siltstone with purple/yellow mottling 5 Y 9/2 dark red mudstone with laminae of white and purple 10 R 4/4 white very well sorted very fine sand/sandstone (quartzarenite) yellow fine-medium sand/sandstone with sparse granule chert gravel 10 YR 8/4 - grades to med sand granule-pebble chert gravel	ANTLERS FORMATION
yellow/red mudstone red mudstone ------- *t.d. 83 ft*	*top of "red beds" at 75 ft (elev. 3398')* DOCKUM GROUP

DRILLING LOG | **HOLE No. 34** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 1*

location: SE section 8, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 55 ft

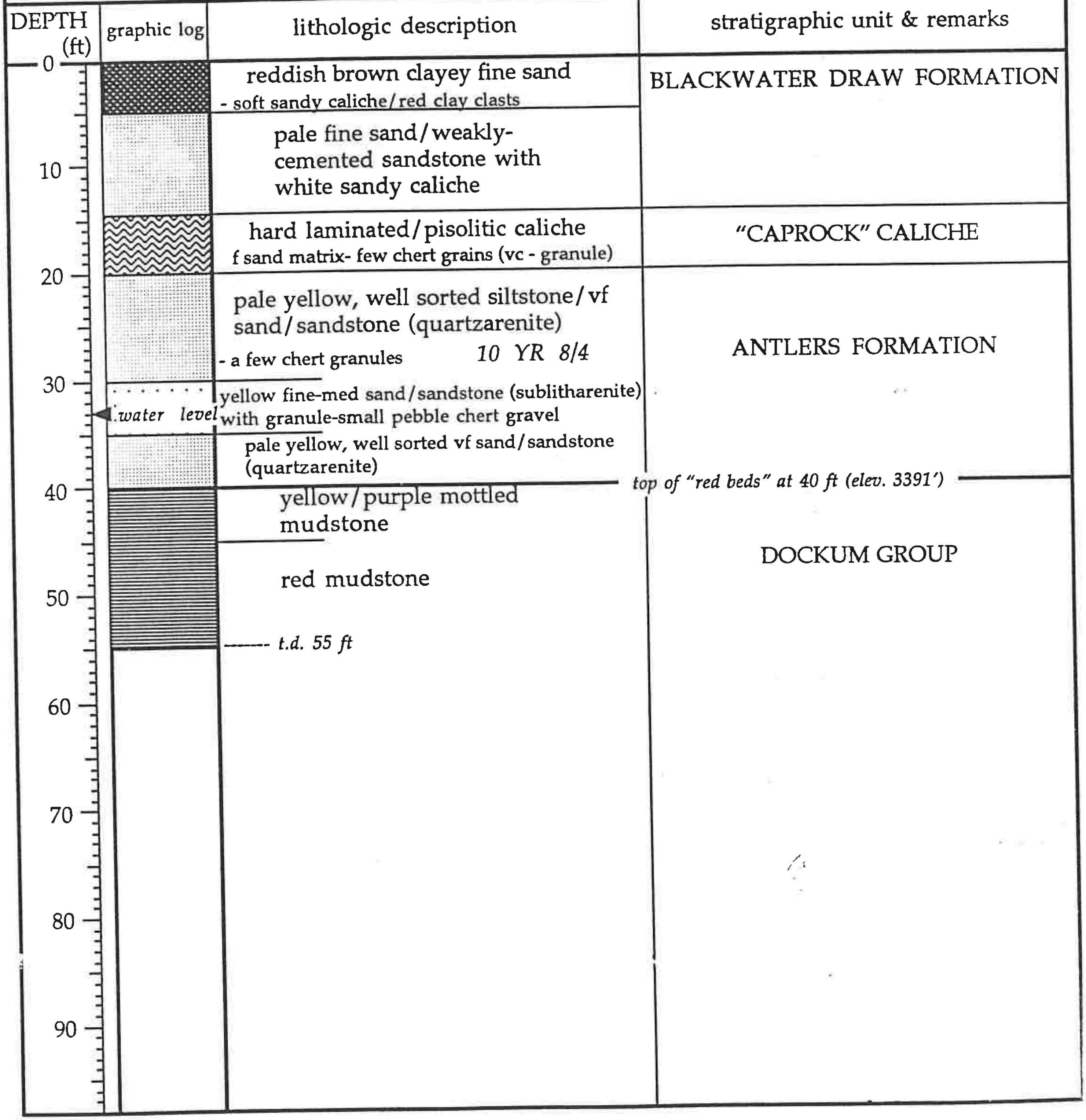
elevation top of hole: 3431 ft (MSL)

elevation ground-water: 3398 ft

date hole drilled: 3/29/99

sampling interval: 5 ft (Dean Muirhead)

geologist: Thomas M. Lehman 4/19/99



reddish brown clayey fine sand
- soft sandy caliche/red clay clasts

pale fine sand/weakly-cemented sandstone with white sandy caliche

hard laminated/pisolitic caliche
f sand matrix- few chert grains (vc - granule)

pale yellow, well sorted siltstone/vf sand/sandstone (quartzarenite)
- a few chert granules 10 YR 8/4

yellow fine-med sand/sandstone (sublitharenite) with granule-small pebble chert gravel

pale yellow, well sorted vf sand/sandstone (quartzarenite)

yellow/purple mottled mudstone

red mudstone

t.d. 55 ft

BLACKWATER DRAW FORMATION

"CAPROCK" CALICHE

ANTLERS FORMATION

top of "red beds" at 40 ft (elev. 3391')

DOCKUM GROUP

DRILLING LOG | **HOLE No. 35** | *project* WCS - FLYING "W" RANCH | *sheet 1 of 2*

location: SW section 4, Block A-39

drilling agency/driller: Scarborough Drilling, Inc. (Scott)

total depth of hole: 130 ft

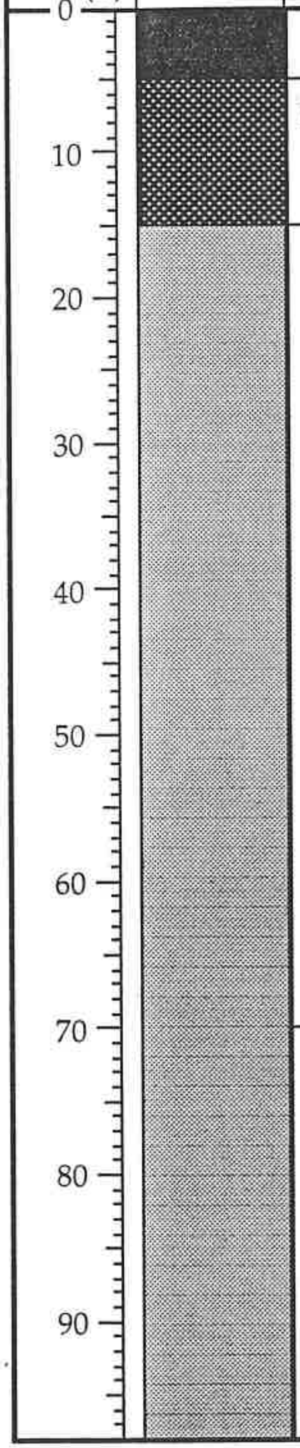
elevation top of hole: 3477 ft (MSL)

elevation ground-water: dry

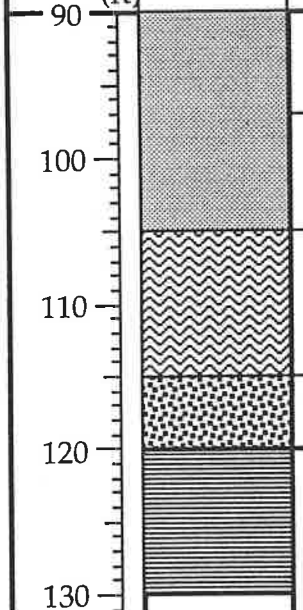
date hole drilled: 4/6/99

sampling interval: 5 ft (Jeff Stovall)

geologist: Thomas M. Lehman 4/22/99

DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks
		dark brown fine sand with large clasts of caliche rubble	- colluvium
		reddish brown fine sand/sandstone with weak Fe-oxide cement, no caliche *5 YR 5/6 to 6/6*	BLACKWATER DRAW FORMATION
		pale fine sand with soft white sandy caliche *5 YR 7/4*	"
		grades downward from fine to fine/medium sand slightly lighter in color *5 YR 8/4*	

DRILLING LOG - continuation sheet	HOLE No. 35	*project* WCS RANCH	*sheet 2 of 2*



DEPTH (ft)	graphic log	lithologic description	stratigraphic unit & remarks
90		pale fine-medium sand with soft white sandy caliche	
100		- contains sparse chert gravel (vc sand - granule) and nodules of hard pisolitic caliche	
110		nodules of hard pisolitic caliche in fine-medium sand with chert granule gravel	"CAPROCK" CALICHE - poorly developed, appears to be nodular and discontinuous
		red fine-medium sandstone with chert granule gravel	? GATUNA FORMATION
120		*top of "red beds" at 120 ft (elev. 3357')*	
		red mudstone	DOCKUM GROUP
130		------- *t.d. 130 ft*	