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REV. 0

SITE OBSERVATIONAL WORK PLAN FOR THE UMTRA PROJECT SITE AT GRAND JUNCTION, COLORADO, MARCH 1996

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Work Performed Under DOE Contract No. DE-AC04-91AL62350

Prepared for
U.S. Department of Energy
Grand Junction Projects Office

Prepared by
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MASTER

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EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) has prepared this initial site observational work plan (SOWP) for the Uranium Mill Tailings Remedial Action (UMTRA) Project site in Grand Junction, Colorado. This SOWP is one of the first UMTRA Ground Water Project documents developed to select a compliance strategy that meets the UMTRA ground water standards (40 CFR Part 192, as amended by 60 FR 2854) for the Grand Junction site. This SOWP applies information about the Grand Junction site to the compliance strategy selection framework developed in the UMTRA Ground Water Project draft programmatic environmental impact statement (PEIS) (DOE, 1995a). This risk-based, decision-making framework identifies the decision logic for selecting compliance strategies that could be used to meet the ground water standards.

The DOE goal is to use the observational method to implement a cost-effective site strategy that complies with the ground water standards and protects human health and the environment. Based on an evaluation of the site characterization and risk assessment data available for the preparation of this SOWP, DOE proposes that the most likely compliance strategy for the Grand Junction site is no remediation based on the application of supplemental standards. This proposed strategy is based on a conceptual site model that indicates site-related contamination is confined to a limited-use aquifer as defined in the ground water standards.

The DOE developed the conceptual site model by evaluating available site-specific and regional data. There are two aquifers beneath the site: a surficial, unconfined alluvial aquifer underlain by a shale formation, which acts in part as an aquitard, and a deeper confined sandstone aquifer underlying the shale. There is an upward vertical gradient from the confined aquifer to the unconfined alluvial aquifer. The conceptual model demonstrates that the uranium processing-related contamination at the site has affected the unconfined alluvial aquifer, but not the deeper confined aquifer. The contamination in the alluvial aquifer appears to be migrating west and southwest of the site until the ground water eventually discharges to the Colorado River.

Evaluation of DOE data and studies published by others indicate that ground water in the alluvial aquifer is of limited use with widespread, ambient contamination that did not result from milling activities or residual radioactive materials and with the total dissolved solids in the alluvial aquifer most likely exceeding 10,000 milligrams per liter. There is no current known use of ground water crossgradient or downgradient of the site in the area impacted by uranium processing activities. Assessments of human health and ecological risk indicate that use of shallow background ground water could have adverse effects.

Additional data still are needed to confirm that the alluvial aquifer qualifies for supplemental standards and that supplemental standards will be protective of human health and the environment. These data will help define the regional background ground water quality, the impacts of recharge from local canals and drainage ditches on the background water quality near the site, the impacts of contaminant discharge to the Colorado River, and whether organic compounds used during uranium processing are present in the ground water.

These data then will be used to refine the conceptual site model and the potential human health and environmental risks of the proposed strategy.

The SOWP process provides stakeholders a forum for review and comment on the proposed compliance strategy. The proposed strategy that emerges in the final SOWP will be evaluated in a site-specific environmental assessment to determine environmental impacts, which will permit further stakeholder input. When the final ground water compliance strategy is accepted, it will be detailed in a compliance strategy plan or remedial action plan that will be subject to review by the state of Colorado and concurrence by the U.S. Nuclear Regulatory Commission.

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LIST OF ACRONYMS

Acronym	Definition
ac	acre
ACL	alternate concentration limit
BLRA	baseline risk assessment
cm/s	centimeter per second
DOE	U.S. Department of Energy
Eh	redox potential
EPA	U.S. Environmental Protection Agency
ft	foot
ft/s	foot per second
gal/m^3	gallons per cubic meter
ha	hectare
kg	kilogram
km	kilometer
L/day	liters per day
m	meter
mi	mile
MCL	maximum concentration limit
mg/L	milligram per liter
mS/cm	microsiemens per centimeter
MSL	mean sea level
mV	millivolt
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
PEIS	programmatic environmental impact statement
RAP	remedial action plan
SOWP	site observational work plan
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action
UMTRCA	Uranium Mill Tailings Radiation Control Act
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Ground Water Project employs the "observational method" to ensure that technically and financially sound ground water compliance strategies are selected at UMTRA Project sites. The observational method uses existing site data to develop a conceptual model of the "most probable" site conditions and appropriate strategies for achieving compliance with the U.S. Environmental Protection Agency (EPA) ground water standards (40 CFR Part 192, as amended by 60 FR 2854). This approach permits the acquisition of additional site data and the development of contingency plans to deal with deviations from anticipated conditions. The observational method links a cost-effective remedial action option with effective contingency planning that will result in full regulatory compliance and protection of human health and the environment without the burden of excessive site characterization and conservatism.

The DOE prepares site-specific site observational work plans (SOWP) to document the observational method employed at UMTRA Ground Water Project sites. The SOWPs will be used in conjunction with a variety of other programmatic and site-specific documents to select and implement the final ground water compliance strategy for each site. Due to the nature of the observational method, the development of a SOWP is an iterative process requiring one or more revisions before a final compliance strategy is selected.

1.1 PROPOSED COMPLIANCE STRATEGY

The DOE has applied the observational method at the former Climax uranium mill site in Grand Junction, Colorado (hereinafter referred to as the Grand Junction site). After evaluating currently available site-specific and regional information, the DOE proposes a ground water compliance strategy of no remediation with the application of supplemental standards based on data indicating the contamination is confined to the uppermost aquifer, which contains limited-use ground water as defined in the ground water standards.

This SOWP describes the DOE's initial use of the observational method for the Grand Junction site to propose the most likely strategy for complying with the EPA ground water standards and to recommend additional data collection efforts needed to select a final ground water compliance strategy. Section 2.0 describes the regulatory framework that governs the selection and implementation of a ground water compliance strategy for UMTRA Ground Water Project sites. Salient elements of the ground water standards that relate specifically to the proposed compliance strategy are discussed. Section 3.0 defines the current conditions at the Grand Junction site based on existing characterization data, presents potential human health and ecological risks, and presents the conceptual site model. Section 4.0 provides the decision-making framework used to arrive at the proposed ground water compliance strategy. Potential deviations from the conceptual site model, which could impact the selection of the proposed compliance strategy, are also discussed along with contingency plans for addressing deviations. Section 5.0 presents a data collection and assessment plan that identifies primary and secondary data needs, data collection and data quality objectives, and proposed field activities necessary to refine the conceptual site model and select a final compliance strategy.

1.2 RELATIONSHIP TO PROGRAMMATIC DOCUMENTS

Programmatic documents that provide guidance for the SOWP include the UMTRA Ground Water Project plan (DOE, 1993a), the draft programmatic environmental impact statement for the UMTRA Ground Water Project (PEIS) (DOE, 1995a), and the *Technical Approach to Ground Water Restoration* (DOE, 1993b). The project plan states the mission, need, and objectives for the UMTRA Ground Water Project and provides an overall technical plan and management approach for conducting the UMTRA Ground Water Project. The draft PEIS provides an objective programmatic decision-making framework for conducting the UMTRA Ground Water Project, assesses the potential programmatic impacts of conducting the Project, provides a method for determining the site-specific ground water compliance strategies, and provides data and information that can be used to analyze site-specific environmental impacts more efficiently. The technical approach document provides general technical guidance for conducting the UMTRA Ground Water Project.

1.3 RELATIONSHIP TO SITE-SPECIFIC DOCUMENTS

The Grand Junction remedial action plan (RAP) provides detailed site characterization information (DOE, 1991). The DOE has used this information along with data obtained subsequent to the preparation of the RAP to formulate the conceptual site model presented in Section 3.3. If the final ground water compliance strategy for this site requires active restoration, the DOE will prepare a ground water RAP. If remedial action is not required, the DOE will prepare a surface RAP modification.

The baseline risk assessment (BLRA) prepared for the Grand Junction site identifies potential public health and environmental risks (DOE, 1995b). This SOWP considers these potential risks and site-specific data interpreted after the BLRA was completed, ensuring the most likely compliance strategy is protective of human health and the environment.

Finally, a site-specific National Environmental Policy Act (NEPA) (42 USC §4321 *et seq.*) document (most likely an environmental assessment) will be prepared to determine any potential impacts of implementing the proposed compliance strategy.

1.4 REVISION PROCESS

At least two versions (this initial version and the final SOWP) of the Grand Junction SOWP will be prepared. This initial SOWP (Revision 0) evaluates all current information about the site, develops a conceptual site model, proposes the most likely compliance strategy based on current knowledge, and identifies additional data needs. Following stakeholder review, fieldwork will be conducted to collect additional data.

The next revision of the SOWP will evaluate the additional data collected, address any resultant changes in the conceptual site model and the proposed compliance strategy based on the new information, and summarize the results related to the data collection and quality objectives. If additional data needs are identified, further revisions of the SOWP may be required. If no additional data needs are identified and stakeholder comments are relatively minor, a final SOWP will be prepared.

The final SOWP will present the final compliance strategy and will document the results of data collection activities and applicable calculation sets. The final revision will be prepared after review by affected stakeholders and comment resolution.

2.0 REGULATORY FRAMEWORK

This SOWP recommends the strategy for the Grand Junction site that most likely will result in compliance with the EPA ground water standards applicable to DOE UMTRA Project processing sites (40 CFR Part 192, Subparts B and C). The relationship of the Uranium Mill Tailings Radiation Control Act (UMTRCA) (42 USC §7901 *et seq.*), the EPA standards, the existing DOE cooperative agreement with the state of Colorado (DOE, 1981), and the NEPA (42 USC §4321 *et seq.*) to the UMTRA Ground Water Project is described below.

2.1 URANIUM MILL TAILINGS RADIATION CONTROL ACT

The U.S. Congress passed the UMTRCA in 1978 in response to public concerns about the potential health hazards from exposure to uranium mill tailings. The UMTRCA requires the stabilization, disposal, and control of uranium mill tailings and other contaminated materials at uranium mill processing sites.

Title I of the UMTRCA

- Designates inactive uranium processing sites to undergo remediation.
- Mandates remedial action in accordance with the standards prescribed by the EPA.
- Directs the DOE to select and perform remedial action, including ground water remediation activities, with the concurrence of the U.S. Nuclear Regulatory Commission (NRC) and with participation of states and consultation with Indian tribes.
- Directs the NRC to concur that the performance of remedial actions was completed as designed and to license the disposal sites for long-term care.

The DOE has an existing cooperative agreement with the state of Colorado to perform surface remedial action at designated processing sites in Colorado, including the Grand Junction site (DOE, 1981). A new cooperative agreement will be developed to cover ground water compliance activities.

2.2 EPA GROUND WATER STANDARDS

The EPA has promulgated standards (40 CFR Part 192) for protecting human health and the environment from hazardous constituents associated with uranium processing and the resulting residual radioactive materials. These standards address two ground water contamination scenarios: 1) future ground water contamination from residual radioactive materials that may occur at the disposal site after disposal cell construction, and 2) residual contamination that occurred before disposal of the tailings piles. The UMTRA Surface Project actions address future protection of the ground water at the disposal sites with the design of disposal cells and long-term surveillance plans. The UMTRA

Ground Water Project addresses the residual contamination that occurred at the former processing sites before the surface remedial action was completed and is regulated by Subparts B and C of the EPA standards.

Subpart B requires that remedial action at processing sites is conducted to ensure the levels of contaminants in ground water meet any one of the three following specified criteria:

- Background level. Constituent concentration in the uppermost aquifer that was not affected by uranium processing activities.
- Maximum concentration limit (MCL). The maximum limit for the concentration of a listed constituent in ground water. Table 1 of 40 CFR Part 192 gives the MCLs for constituents that apply to UMTRA Project sites.
- Alternate concentration limit (ACL). Alternative limit for the concentration of a constituent that does not pose a substantial present or potential future hazard to human health or the environment, as long as the limit is not exceeded. An ACL may be applied after considering options to achieve background levels or MCLs.

The DOE, with the concurrence of the NRC, may apply supplemental standards to contaminated ground water in lieu of background levels, MCLs, or ACLs under certain conditions specified in the regulations. Supplemental standards may be applicable for the Grand Junction site if the contaminated ground water meets the criteria for limited use. Subpart B defines "limited use" as ground water that is not a current or potential source of drinking water because 1) the concentration of total dissolved solids (TDS) is in excess of 10,000 milligrams per liter (mg/L); or 2) widespread, ambient contamination, not due to activities involving residual radioactive materials from a designated processing site, exists that cannot be cleaned up using treatment methods reasonably employed in public water systems; or 3) the quantity of water reasonably available for sustained continuous use is less than 150 gallons (gal) (0.57 cubic meters [m^3]) per day.

The DOE may employ either natural flushing or active remedial procedures as a way of meeting the EPA standards. Natural flushing lets natural processes reduce the ground water contamination to background levels, MCLs, or ACLs. In addition, ground water must not be a current or projected source of drinking water during the natural flushing period. Institutional controls (measures that limit access to contamination, protect human health and the environment, and satisfy beneficial uses of ground water) must be established and maintained during the natural flushing period, which must not exceed 100 years.

Subpart C provides guidance for implementing methods and procedures, including the application of supplemental standards, that will reasonably assure the provisions of Subpart B are satisfied. Subpart C requires that a site-specific plan for meeting the applicable requirements of Subpart B be developed using information gathered from site characterization and monitoring. The plan should contain the compliance strategy, documentation of effectiveness, and a monitoring program, if required.

2.3 NATIONAL ENVIRONMENTAL POLICY ACT

The UMTRA Ground Water Project is a major federal action subject to the requirements of the NEPA (42 USC §4321 *et seq.*). The Council on Environmental Quality's regulations that implement the NEPA are codified in 40 CFR Parts 1500-1508. These regulations require each federal agency to develop its own implementing procedures. The DOE NEPA regulations are contained in 10 CFR Part 1021; further guidance is provided in DOE Order 451.1.

Pursuant to the NEPA, the DOE drafted an UMTRA Ground Water Project PEIS to analyze the potential impacts of implementing four programmatic alternatives for ground water compliance at the UMTRA Project designated processing sites (DOE, 1995a). The DOE will select the preferred alternative, which will be published in a "record of decision." All subsequent Ground Water Project activity must comply with this record of decision. The environmental impacts from implementing the proposed compliance strategy presented in the final Grand Junction SOWP will be addressed in a site-specific document that will meet NEPA requirements.

3.0 SITE CONDITIONS

This section provides background information on the Grand Junction site, presents the conceptual site model, and summarizes current site characterization knowledge with respect to geology, hydrology, geochemistry, and potential human health and ecological risks used to develop the conceptual model.

3.1 SITE BACKGROUND

The Grand Junction site is in Mesa County, in west-central Colorado near the Colorado-Utah border. The site is adjacent to the north side of the Colorado River in an industrial area of the city of Grand Junction (Figure 3.1).

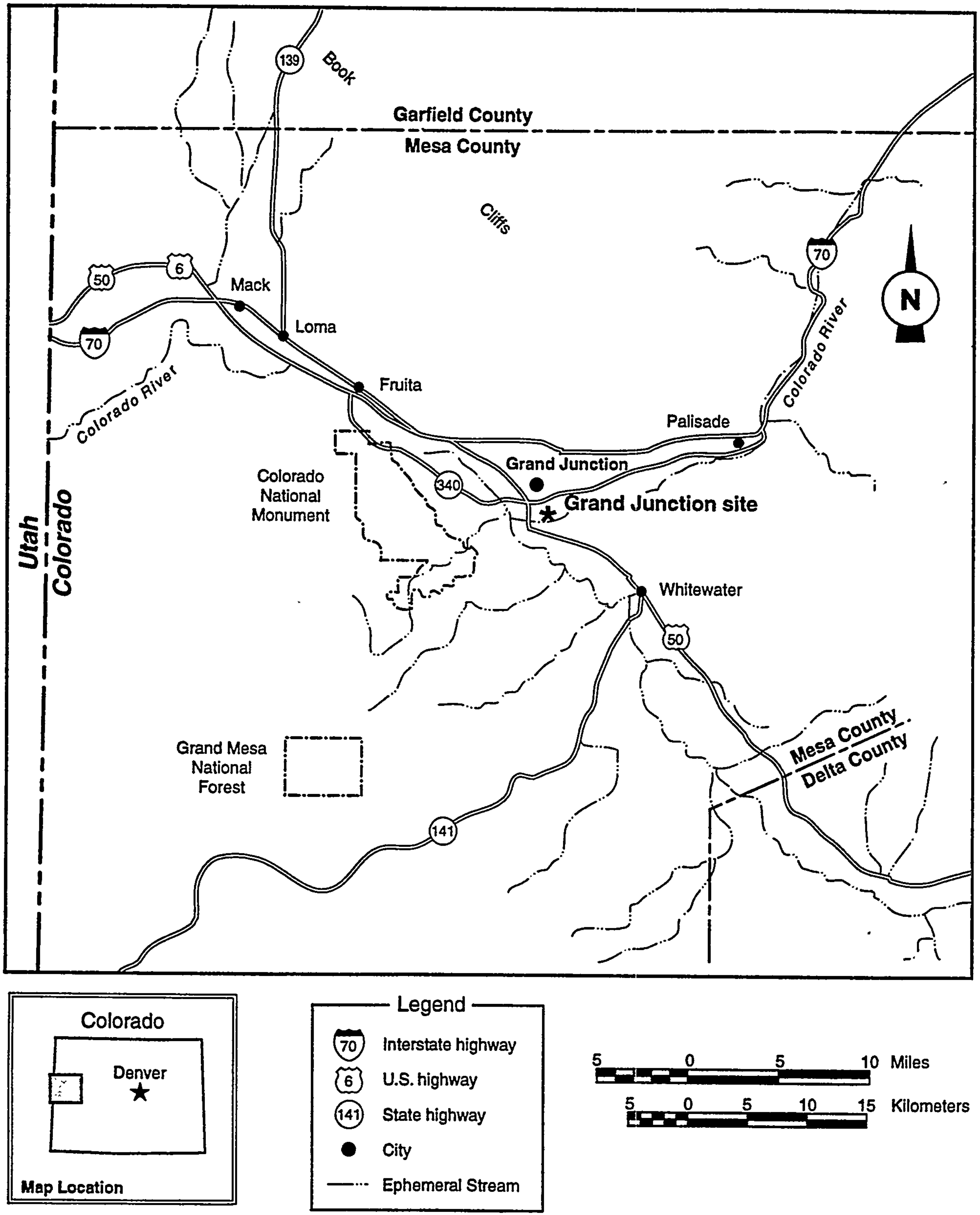
The Climax Uranium Company, which was incorporated into American Metals Climax, Inc., in 1960, processed uranium and vanadium ore at the Grand Junction site from June 1951 to March 1970. The Climax mill processed ore at the rate of 330 tons (300 metric tons) per day between 1951 and 1955. In 1955 the capacity was increased to 500 tons (450 metric tons) per day, and the mill operated at this rate until it closed in 1970. The ore processed by the Climax mill was crushed, ground, and treated to extract the product. The mill was dismantled and the tailings pile was temporarily stabilized during late 1970 to early 1971 with an interim soil cover.

Merritt (1971) indicates that the most probable water usage during ore processing was 500 gal per ton of ore (2 m^3 per metric ton). Based on 300 operating days per year, the water-use rate between 1951 and 1955 was approximately 50 million gal/year (190,000 m^3/year), and between 1955 and 1970 the water-use rate was approximately 75 million gal/year (285,000 m^3/year). Much of this process water was discharged to on-site evaporation ponds.

From 1951 to 1966, approximately 300,000 tons (272,000 metric tons) of tailings were removed from the site and used as construction material or earth fill at many locations (termed "vicinity properties") in the Grand Junction area. Residual radioactive materials subsequently remediated from these vicinity properties were returned to the site for storage pending removal for permanent disposal. The state of Colorado currently owns the former mill site.

Surface remedial action at the site was conducted in two phases. Phase I remedial action involved fencing, constructing lined retention ponds, and preparing the wastewater treatment plant foundation at the site. Phase I was completed in 1989. Phase II began in 1990 and included constructing the disposal cell and assembling the wastewater treatment plant. Residual radioactive material excavation and removal to the Cheney disposal site started in the spring of 1991. Removal of the residual radioactive material from the Grand Junction site was completed in 1994. Part of the remedial action involved constructing wetlands, including eight ponds, along the southern

Figure 3.1
Location of Grand Junction, Colorado, Site



MAC: SITE/GRJ/SOWP/REGIONALMAP

boundary of the processing site. The U.S. Army Corps of Engineers (USACE) currently is constructing a flood control levee through the site vicinity.

3.1.1 Surrounding land use

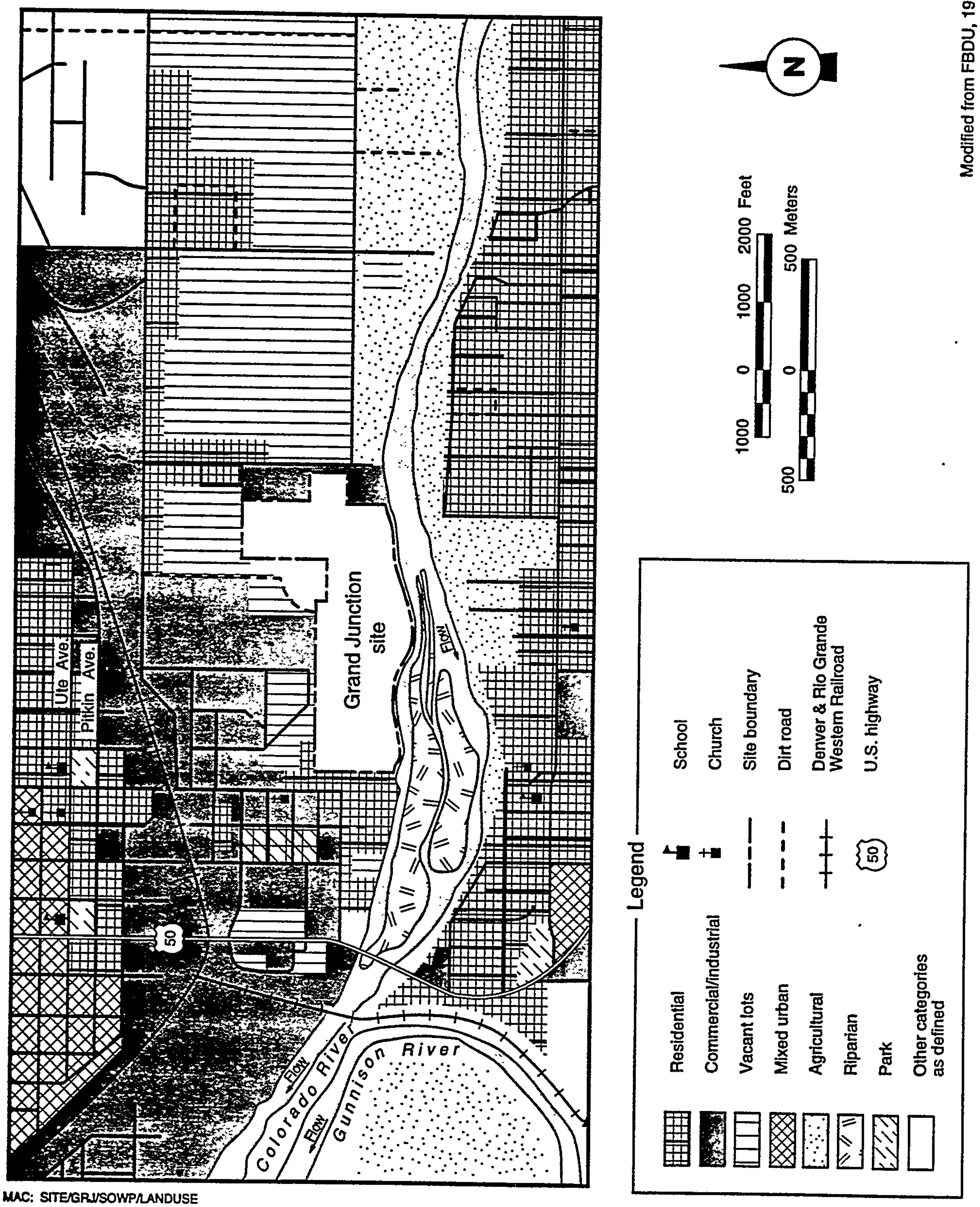
The Grand Junction site is in a primarily urbanized area, with residential, commercial, and commercial/industrial uses (Figure 3.2). Residential land use in the site vicinity is limited to areas west and northeast of the site and south of the Colorado River. The Denver and Rio Grande Western Railroad, situated approximately 0.5 mile (mi) (0.8 kilometer [km]) north of the site, is approximately the northern boundary of the industrial use area. Residential land use becomes much more prevalent about 0.25 mi (0.5 km) north of the railroad tracks. Commercial and industrial land uses occur immediately north and east of the site. Large tracts of vacant land and land used for agricultural purposes are further east of the site. The Grand Valley By-Products Company, located near the southeastern boundary of the site, is a rendering plant that has been processing animal parts and by-products for nearly 100 years.

3.1.2 Surrounding water use

The Grand Junction zoning and development code requires that all development be served by the city water treatment and distribution system. In the site vicinity and in the majority of the surrounding Grand Valley area, surface water supplies municipal and industrial needs. Most of the water for the Grand Valley originates as surface water high on the Grand Mesa. During times of drought, water may be obtained from the Gunnison River about 1 mi (1.6 km) upstream from its confluence with the Colorado River. Colorado River water from upstream of the Grand Junction site is used in irrigation canals that cross the Grand Valley upgradient from the site. No other major users of Colorado River water reside in the Grand Junction site vicinity (DOE, 1986).

Examination of current databases and intensive field reconnaissance downgradient and crossgradient from the Grand Junction site indicates that no known users of the alluvial ground water are within the area affected by contamination from the site. The Mancos Shale, which underlies the alluvium in the site vicinity, is not considered a ground water source in the Grand Junction area. The Dakota Sandstone, which underlies the Mancos Shale, is the uppermost artesian aquifer in the site vicinity. No registered wells are known to be completed in the Dakota Sandstone within the area potentially affected by contamination from the site. No future domestic use of shallow ground water in the affected hydrogeologic environment is anticipated, due to zoning and code restrictions, the availability of city water, and the poor quality of ground water in the alluvial aquifer. Also, no future use of ground water in the Dakota Sandstone is anticipated for similar reasons. Ground water quality and use are discussed in more detail in Sections 3.6 and 3.7.

Figure 3.2
Land Use Map
Grand Junction, Colorado, Site Vicinity



Modified from FBDU, 1981.

MAC: SITE/GRJ/SOWP/LANDUSE

3.1.3 Contaminant sources

The primary sources of contamination at the Grand Junction site were from uranium mill tailings and process water. During operation, the mill produced 2.2 million tons (2 million metric tons) of tailings, which were placed in a tailings pile that covered much of the western two-thirds of the site (DOE, 1986; 1991). The thickness of the former tailings pile ranged from approximately 10 to 50 feet (ft) (3 to 15 meters [m]). In addition to the main tailings pile, contaminated material resulting from vicinity property remediation was placed in or near the former evaporation ponds on the eastern portion of the site.

The evaporation ponds on the processing site covered a maximum area of 35 ac (14 ha). Based on Grand Junction's mean annual total precipitation of 8 inches (200 mm), less the average lake evaporation rate of 36 inches (910 mm) per year, the total evaporation from the ponds during the mill operation was 560 ac-ft (690,000 m^3). The total volume of water from precipitation, snowmelt, and ore processing that accumulated in the ponds from June 1951 to March 1970 was 2460 ac-ft (3,030,000 m^3). Thus, approximately 1900 ac-ft (2,300,000 m^3) of water were available to seep into the shallow alluvial aquifer while the mill was operating. A surface water mass balance for the Grand Junction processing site is presented in UMTRA Project calculation set GRJ-02-96-12-01-00.

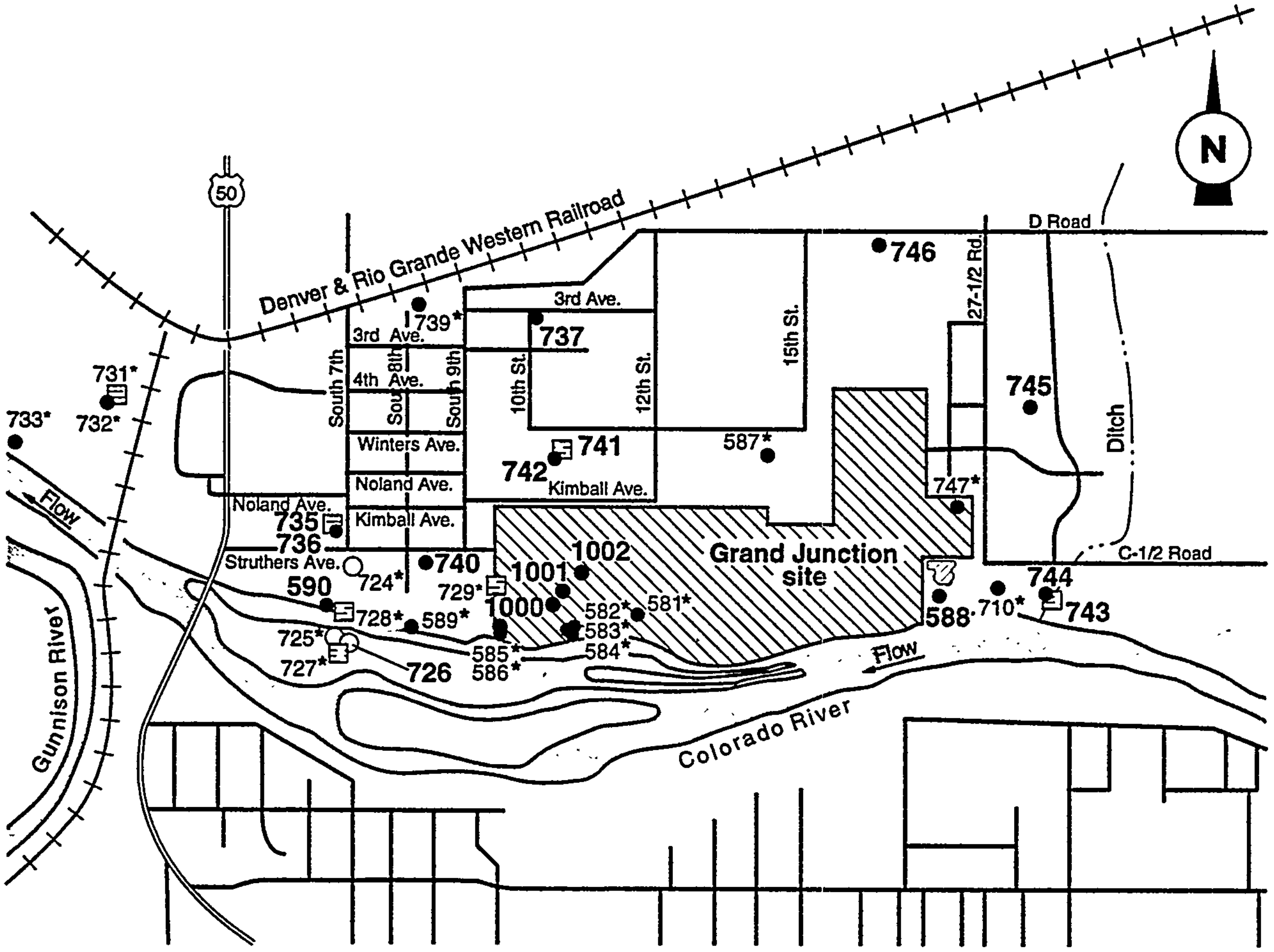
A detailed discussion of contaminant sources is in Section 3.6.

3.2 SOURCES OF EXISTING DATA

Ground water quality sampling has been performed at the Grand Junction site since the mid-1970s (DOE, 1995c; Cahn et al., 1988). The 1995 water sampling and analysis plan for the Grand Junction site (DOE, 1995c) summarizes much of these data. More detailed information on the site ground water regime is in the RAP (DOE, 1991). The BLRA (DOE, 1995b) evaluates the potential ground water contamination impacts to human health and the environment. Regional studies by the U.S. Bureau of Reclamation (USBR) and the U.S. Geological Survey (USGS) characterize ground water quality in the alluvial materials in the Grand Valley (USBR, 1978; 1986; Butler et al., 1994).

Most of the monitor wells installed historically at the site were decommissioned during surface remedial action. There are 16 monitor wells presently available for sampling in the site vicinity (Figure 3.3). These include 12 alluvial wells, 3 Mancos Shale wells, and 1 Dakota Sandstone well. This total includes 3 alluvial/Mancos Shale well clusters, which are designated: 744/743, 742/741, and 736/735. A summary of construction information and sampling history for all site wells is presented in Table 3.1. All available lithologic logs, well

Figure 3.3
Locations of Existing and Decommissioned Monitor Wells Grand Junction, Colorado, Site Vicinity

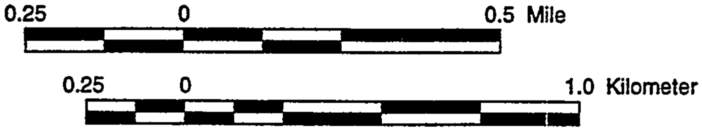


Source: DOE, 1995b.

Notes:
1. Existing monitor wells are labeled in bold type.
2. Decommissioned monitor wells are indicated by an asterisk.
3. On-site ponds are not shown.
4. Alluvial/Mancos Shale Formation well clusters:
   - 736, 735
   - 742, 741
   - 744, 743

Legend

● 740	Alluvial monitor well (12 existing)
▤ 731	Mancos Shale Formation monitor well (3 existing)
○ 724	Dakota Sandstone monitor well (1 existing)
▨	Pond
50	U.S. highway



MAC: SITE/GRJ/SOWP/MONWELLS

Table 3.1 DOE ground water monitor well completion and historical sampling data for the Grand Junction, Colorado, site

Well ID	Unit/formation screened	Location	Screened interval (ft bls)	Year sampled[a]	Decommis-sioned	Number of sampling rounds
GRJ-01-0581	Qal	On-site	27-31	89	X	1
GRJ-01-0582	MS	On-site	36-43	89	X	1
GRJ-01-0583	Qal	On-site	29-32	83, 85	X	6
GRJ-01-0584	Qal	On-site	23-26	83, 85	X	6
GRJ-01-0585	Qal	On-site	12-14	89	X	1
GRJ-01-0586	Qal	On-site	6-9	89	X	1
GRJ-01-0587	Qal	Crossgradient	8-13	83	X	3
GRJ-01-0588	Qal	Background	8-18	89, 91, 92		9
GRJ-01-0589	Qal	Downgradient	7-15	89, 91, 92	X	7
GRJ-01-0590	Qal	Downgradient	7-15	83-95	X	17
GRJ-01-0710	Qal	Background	?	89		1
GRJ-01-0724	DS	Upgradient	131-141	86-89	X	6
GRJ-01-0725	DS	Upgradient	69-99	86, 89	X	3
GRJ-01-0726	DS	Upgradient	110-140	86, 89, 90		3
GRJ-01-0727	MS	Upgradient	44-54	87	X	1
GRJ-01-0728	MS	Downgradient	12-17	85	X	3
GRJ-01-0729	MS	On-site	53-63	89	X	1
GRJ-01-0731	MS	Downgradient	26-36	85	X	3
GRJ-01-0732	Qal	Downgradient	16-21	85	X	3
GRJ-01-0733	Qal	Downgradient	16-21	86, 88, 89	X	5
GRJ-01-0735	MS	Downgradient	26-36	89		2
GRJ-01-0736A	Qal	Downgradient	10-15	85-95		14
GRJ-01-0737	Qal	Crossgradient	22-27	87, 88, 89		4
GRJ-01-0739	Qal	Crossgradient	25-30	85	X	3
GRJ-01-0740	Qal	Downgradient	12-17	85-95		13
GRJ-01-0741	MS	Crossgradient		86-89, 91-93		13
GRJ-01-0742	Qal	Crossgradient	18-23	85-95		12

Table 3.1 DOE ground water monitor well completion and historical sampling data for the Grand Junction, Colorado, site (Concluded)

Well ID	Unit/formation screened	Location	Screened interval (ft bls)	Year sampled[a]	Decommis-sioned	Number of sampling rounds
GRJ-01-0743	MS	Upgradient	25-35	86, 89, 91-93		12
GRJ-01-0744	Qal	Upgradient	10-15	89, 91, 92		10
GRJ-01-0745	Qal	Background	15-20	85-95		16
GRJ-01-0746	Qal	Background	20-25	85-95		16
GRJ-01-1000	Qal	On-site	4-9	95		2
GRJ-01-1001	Qal	On-site	6.5-11.5	95		2
GRJ-01-1002	Qal	On-site	8-13	95		2

[a] During some years, multiple sampling events occurred.

ft bls - feet below land surface.
DS - Dakota Sandstone.
MS - Mancos Shale.
Qal - Quaternary alluvium.
? - Unknown.

completion records, and well construction information for existing and decommissioned wells at the site are provided in Appendix A.

Subsets of the existing and decommissioned wells have been sampled historically. In 1988, the DOE implemented a study at 12 UMTRA sites, including Grand Junction, to screen tailings and ground water for organic constituents listed in 40 CFR Part 264, Appendix IX (Hill, 1989). Section 5.0 of this SOWP outlines the future data requirements for this site. A qualitative ecological survey that included visual observations of plants and wildlife was also conducted in the vicinity of the site in conjunction with the BLRA. No plant or animal tissue samples were collected or analyzed during this survey.

Appendix B lists available calculation sets related to the Grand Junction processing site.

3.3 CONCEPTUAL SITE MODEL SUMMARY

The DOE has reviewed available ground water characterization data identified in Section 3.2 for the site and surrounding area and developed the following conceptual site model. The conceptual model is summarized here with details and supporting information presented in Sections 3.4 through 3.8.

The near-surface geology of the Grand Junction site consists of fill materials and Quaternary alluvium. These unconsolidated deposits reach a thickness of about 20 ft (6 m) beneath the site. Ground water occurs under unconfined conditions in the alluvium and generally flows southwest, toward the Colorado River, although the ground water flows west-southwest immediately west of the site at times of peak river flow. The underlying Mancos Shale Formation, which varies in thickness from more than 100 ft (30 m) near the site to nearly absent west of the site, acts as an aquitard restricting vertical flow between the alluvium and deeper units. Based on the current understanding of the regional hydrologic regime, it is likely that there is an upward vertical hydraulic potential from deeper hydrostratigraphic units, such as the Dakota Sandstone and the Mancos Shale, to the alluvium. Thus, it is unlikely that contamination from the site could have migrated to geologic units underlying the alluvium at the site.

The alluvium, or uppermost aquifer, in the Grand Junction area consists of three recognizable units. A distinct unit exists closer to the river that includes unconsolidated sands, gravels, and cobbles; this cobble aquifer was noted by USBR (1986). This unit is overlain by and interfingers with a complex interbedding of clay, silt, and sand derived primarily from the Mancos Shale, and alluvial-derived gravel sequences (hereafter called clayey alluvium). The clayey alluvium in turn grades westward into a colluvium derived from the Mancos Shale. The cobble aquifer underlying the site is recharged by water infiltrating the clayey alluvium and colluvium upgradient of the site.

The major sources of recharge to the alluvial aquifer are from seasonal runoff, precipitation, and seepage from local irrigation canals and ditches. Areas of the site immediately adjacent to the Colorado River also receive recharge from the river during high river stage. Ground water levels in the alluvial aquifer range from approximately 20 ft (6 m) to less than 4 ft (1.3 m) below land surface in areas closest to the Colorado River, based on water level measurements from on-site monitor wells and piezometers. Ground water levels beneath the site fluctuate on the average from 2 to 5 ft (0.6 to 1.5 m) annually and are lowest during the fall and winter months. The irrigation season is from April through November, with high river stage occurring in mid- to late-June, and low river stage in September.

Throughout the Grand Valley, water quality from the unconsolidated alluvial aquifer, including the cobble aquifer, is very poor due to very high TDS. While the Mancos Shale is not considered a source of good-quality ground water in the Grand Valley, its geochemical composition and close relationship to the alluvial ground water flow system (i.e., it underlies the alluvial aquifer system in the Grand Valley) have naturally degraded the alluvial ground water quality with high dissolved salt concentrations. Moreover, the Mancos Shale has been shown to contain naturally high concentrations of several constituents, including uranium, selenium, thorium, and potassium. Based on the ground water hydrogeology and site-specific ground water geochemistry, it is evident that the Mancos Shale is the most likely source of naturally occurring high concentrations of dissolved salts and radionuclides in the shallow alluvial ground water system, including the cobble aquifer, in this area.

Because the water quality in the alluvium is poor, agriculture in the Grand Junction area has long relied on a series of irrigation canals to supply water for crops. This, in turn, has required the installation of a complex series of drainage ditches to dissipate high ground water levels caused by seepage from unlined irrigation canals. Seepage from irrigation canals has also resulted in transport of large amounts of soluble salts to the Colorado River. In an effort to mitigate this problem and improve the quality of water in the river, the USBR is currently in the process of lining major irrigation canals in the Grand Junction area.

A study by the USGS (Butler et al., 1994) indicates that water quality in the clayey alluvium upgradient of the Government Highline Canal is generally in excess of 10,000 mg/L TDS. High TDS in these ground waters is due to dissolution of salts associated with the Mancos Shale in the area. Downgradient of the Government Highline Canal, the clayey alluvium is recharged primarily by seepage from the unlined canal. This results in TDS concentrations in ground water between 3000 to 7000 mg/L directly downgradient of the canal. Further downgradient, TDS tends to increase and many samples in excess of 10,000 mg/L are observed. Lining the Government Highline Canal presumably will result in lowering the ground water table in the Grand Junction area and a return to higher TDS water (greater than 10,000 mg/L) that likely was present in the area before the beginning of irrigation.

The USGS study (Butler et al., 1994) provides regional information from a series of wells in the Grand Valley alluvium. This information indicates that many constituents of regional ground water are commonly above EPA MCLs. For example, uranium concentrations of up to 0.45 mg/L have been observed and concentrations between 0.04 and 0.07 mg/L are common. The EPA MCL for uranium is 0.044 mg/L. Selenium concentrations as high as 1.3 mg/L have been observed in the clayey alluvium. This value is 2 orders of magnitude above the EPA MCL of 0.01 mg/L.

These observations make it possible to characterize natural ground water quality in the alluvial aquifer in the Grand Junction area as poor and likely to get worse. TDS currently exceeds the 40 CFR Part 192 definition for limited-use ground water (10,000 mg/L) at many locations in the Grand Valley alluvium, and all ground water in the alluvium likely will increase in TDS after the Government Highline Canal is lined. Uranium and selenium concentrations are currently naturally high in alluvial ground water. Concentrations of these constituents also are likely to increase when the Government Highline Canal lining project is complete.

It is necessary to rely on regional background ground water quality to assess the extent of contamination at the site because upgradient ground water in the site vicinity has the potential to have been impacted by the large number of vicinity properties in the Grand Junction area. Tailings from the UMTRA Project site were once used as construction fill for projects throughout the Grand Junction area, and while most of these vicinity properties have been identified and remediated, upgradient ground water may have received some contamination when water tables in the area rose to near the ground surface. Water quality in upgradient DOE monitor wells, however, falls within the range of regional background water quality.

Tailings leachate seeped into the alluvial aquifer beneath the site and constituents subsequently migrated downgradient from the site. It is known that the extent of contamination is approximately 3000 ft (900 m) west of the site. Much of the ground water contamination from the eastern middle third of the site may have either discharged to the Colorado River or migrated west-southwest in the alluvial aquifer. Remaining contamination that migrates past the present monitor well network eventually will discharge to the Colorado River downgradient of the site. Past and current data indicate that there has been no measurable impact on the river by site-related contamination. There is currently no known use of ground water crossgradient or downgradient of the site in the area impacted by uranium processing activities.

There is currently no route for contaminated ground water to impact surface water other than the Colorado River. The DOE constructed a series of eight ponds along the southern site boundary in 1994. However, these ponds were destroyed during high river stage in early summer 1995. Construction of ponds in the riverside park downgradient (west) from the site has been proposed by developers. If constructed, these ponds should be monitored to determine any site-related impacts because of the potential for discharge of contaminated ground water to the ponds.

3.4 PHYSICAL SETTING AND GEOLOGY

The Grand Junction site is in Sections 23 and 24, Township 1 South, Range 1 West, Sixth Principal Meridian, at latitude 39°03'30" N, longitude 108°34'00" W. The site is approximately 4600 ft (1400 m) above mean sea level (MSL). The site is situated in the Grand Valley, a broad, semiarid valley cut by the Colorado River and bounded by the Book Cliffs escarpment to the north, the Grand Mesa to the east, and the Uncompahgre Plateau to the south. The Colorado River and one of its tributaries, the Gunnison River, drain the Grand Valley. The confluence of these rivers is approximately 1 mi (1.6 km) west of the site and the Colorado River continues westward and eventually southwestward around the Uncompahgre Plateau.

The generalized stratigraphy near the site comprises three hydrogeologic zones (in descending order):

- A surficial disturbed zone.
- A zone of unconsolidated alluvial sediments.
- A sequence of consolidated sedimentary formations.

The surficial disturbed zone includes a variety of soil classifications and material types deposited or altered during surface remediation. The zone varies in depth from approximately 1 ft (0.3 m) to more than 20 ft (6 m).

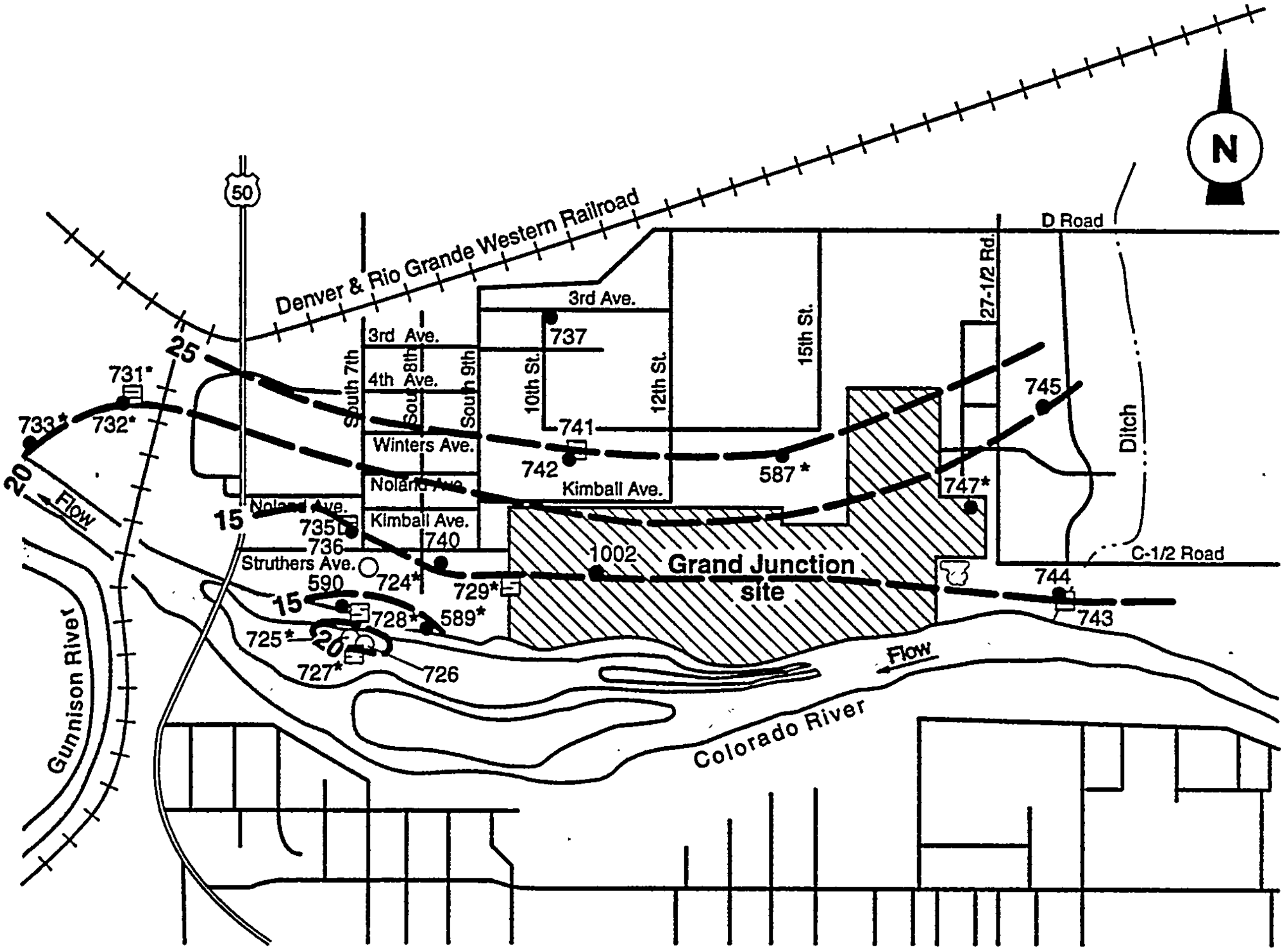
Underlying or adjacent to the surficial disturbed zone is a zone of unconsolidated alluvial sediments. In the site vicinity, this zone includes mixed gravel, sand, silt, and clay layers, ranging in thickness from 12 ft (3.7 m) to 27 ft (8.3 m). The base of the alluvium is defined by the erosional surface of the Mancos Shale Formation, which slopes gently (about 5 ft/mi [1 m/km]) to the west in the immediate vicinity of the site (USBR, n.d.). The top several feet of the Mancos Shale are heavily weathered and contain abundant gypsum and calcite in joints and bedding planes. Figure 3.4 is an isopach map showing the thickness of the combined fill and alluvium at the site and vicinity. This isopach map illustrates a general thickening of the fill/alluvium toward the north. This general trend results from the sloping erosional surface of the Mancos Shale toward the west-northwest and the slope of the topographic surface toward the south.

Underlying the unconsolidated alluvial sediments is a sequence of consolidated sedimentary formations (Figure 3.5). This SOWP will focus primarily on the uppermost formations: the Mancos Shale Formation and the Dakota Sandstone Formation. Lohman (1965) and Cahn et al., (1988) describe other deeper formations present beneath the site. This section will not discuss these deeper formations in any detail because the Dakota Sandstone Formation is the uppermost bedrock aquifer and tailings seepage will not likely impact underlying formations. Section 3.5.1 briefly discusses the deeper formations from a regional hydrologic perspective.

Structurally, a series of monoclines are present on the eastern flank of the Uncompahgre Plateau/Uplift. These monoclines are faulted locally along their anticlinal hinges (Heyman, 1983). Most of the Grand Valley north of the Colorado River is underlain by Mancos Shale. A prominent local exposure of the Mancos Shale is clearly visible on the south bank of the Colorado River, just south of the site. As a rule, however, exposed bedrock or subcropping bedrock on the south side of the Colorado River, south of Grand Junction, is composed of the Dakota Sandstone and/or the underlying Burro Canyon Formation. As stated above, all of these bedrock units dip northeastward in the Grand Valley as a result of the Uncompahgre Plateau/Uplift to the south.

The Mancos Shale Formation is a thick, relatively extensive sequence of shale that includes some sandy layers, thin sandstone beds, and thin coals. Near the Grand Junction site, the Mancos Shale varies in thickness from more than 100 ft (30 m) to nearly absent several miles west of the site (Lohman, 1965). Figure 3.6 is a structure contour map of the top of the Mancos Shale in the vicinity of the site. In general, the top of the Mancos Shale mimics that of the water table and topographic surface in the site vicinity. The Mancos Shale Formation is not considered a water source in the Grand Junction area. Although the upper portion of the Mancos Shale is weathered and capable of conducting ground water, as a whole this unit acts as an aquitard or barrier to vertical flow between the Dakota Sandstone and the alluvial aquifer due to its relatively low hydraulic conductivity. In fact, the Mancos Shale is the unit that produces confined conditions within the Dakota Sandstone beneath the Grand Valley and immediately northeast of the Grand Valley (Lohman, 1965).

Figure 3.4
Isopach Map of the Fill/Alluvium
Grand Junction, Colorado, Site Vicinity



Source: DOE, 1995b.

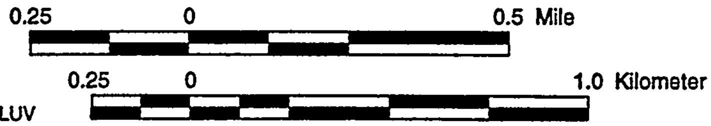
Notes:
1. Decommissioned monitor wells are indicated by an asterisk.
2. On-site ponds are not shown.
3. Thickness of fill/alluvium is based on lithologic logs provided in Appendix A.

Monitor Wells and Thicknesses (ft) of Fill/Alluvium

590	15	735	13
724	13	736	15
725	21	737	27
726	22	740	16
727	16.5	741	25
728	16	742	22.5
729	12.5	743	15
731	19	744	14.5
732	20	745	20
733	21	747	16.5

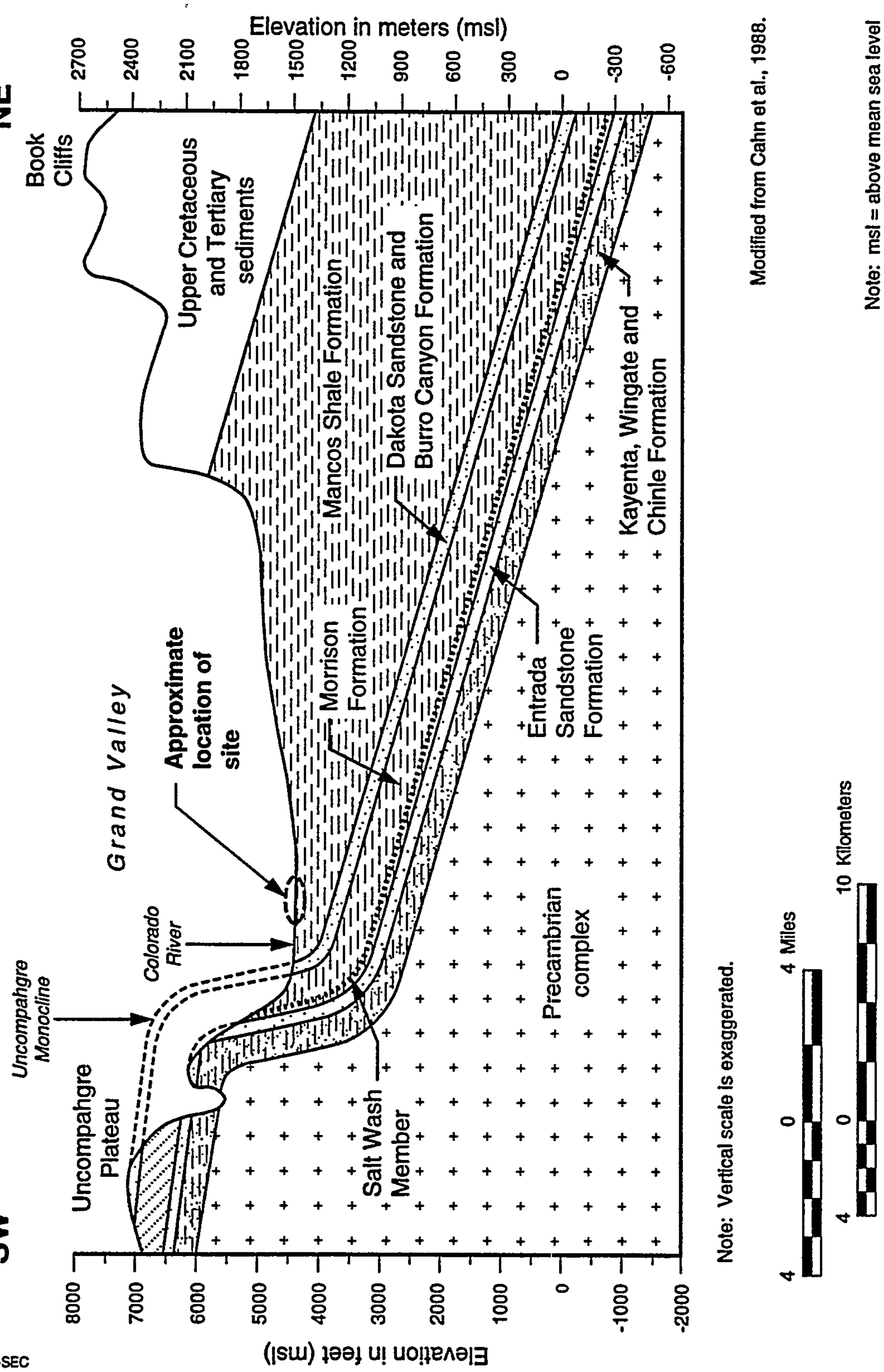
Legend

20 ▬ ▬	Inferred line of equal thickness (ft)
● 740	Alluvial monitor well
⊟ 731	Mancos Shale Formation monitor well
○ 724	Dakota Sandstone monitor well
▨	Pond
50	U.S. highway



MAC: SITE/GRJ/SOWP/FILL-ALLUV

Figure 3.5
Generalized Geologic Cross Section of the Grand Valley, Colorado



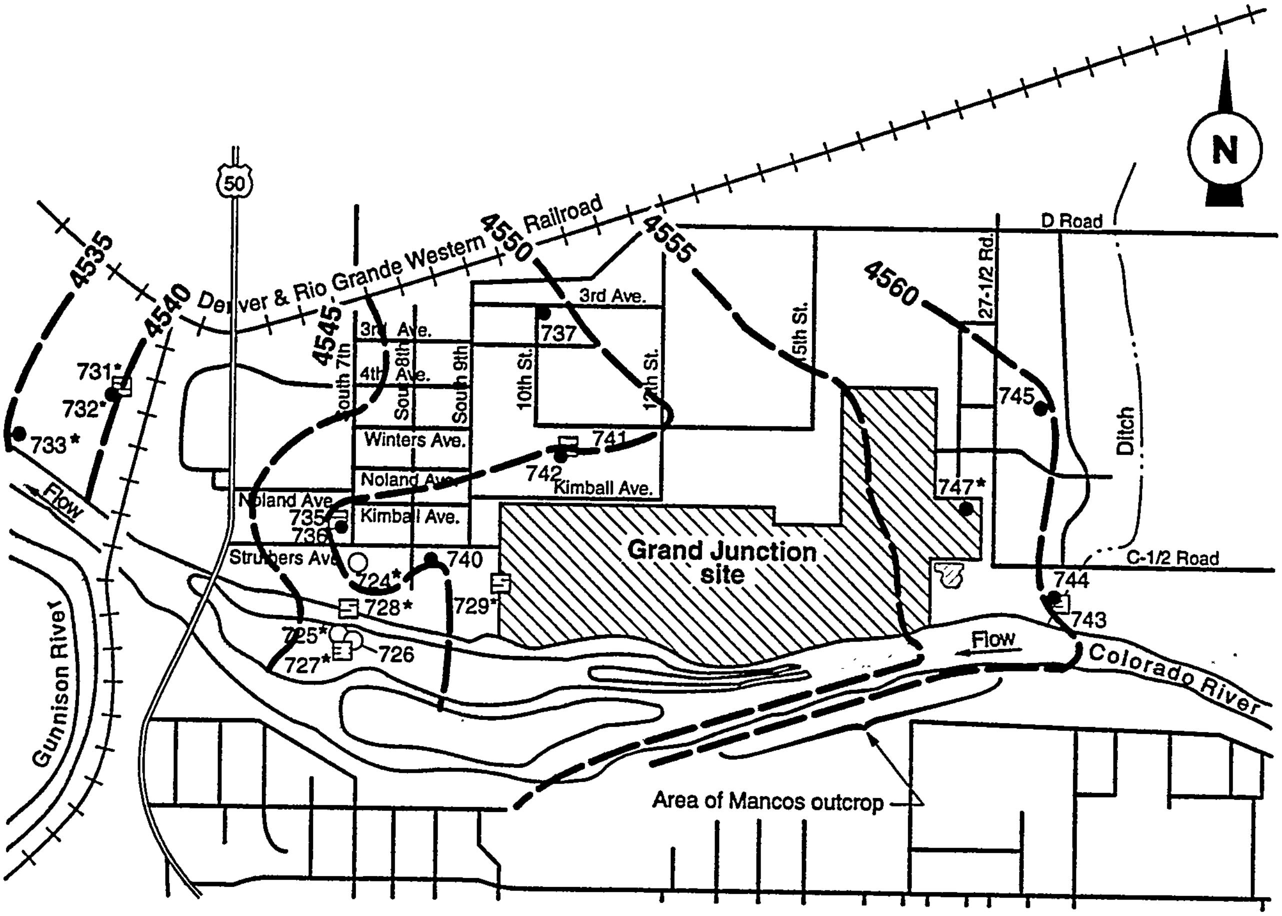
Note: Vertical scale is exaggerated.

Modified from Cahn et al., 1988.

Note: msl = above mean sea level

MAC: SITE/GRJ/SOWP/X-SEC

Figure 3.6
Structure Contour Map of the Top of the Mancos Shale Formation Grand Junction, Colorado, Site Vicinity



Source: DOE, 1995b.

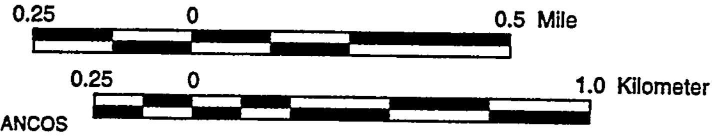
Monitor Wells and Elevations at Top of Mancos Shale Formation

724	4551.7	736	4549.7
725	4545.8	737	4548.3
726	4544.8	740	4550.1
727	4549.9	741	4547.9
728	4549.0	742	4550.2
729	4552.8	743	4560.1
731	4540.7	744	4560.3
732	4539.5	745	4559.4
733	4535.4	747	4557.8
735	4551.7		

Notes:
1. Decommissioned monitor wells are indicated by an asterisk.
2. On-site ponds are not shown.
3. Development of data based on lithologic logs provided in Appendix A and well survey data.

Legend

4545 ——	Inferred line of equal elevation of top of Mancos Shale Formation (ft above msl)
● 740	Alluvial monitor well
⊟ 731	Mancos Shale Formation monitor well
○ 724	Dakota Sandstone monitor well
♒	Pond
50	U.S. highway



MAC: SITE/GRJ/SOWP/TOPOFMANCOS

The Dakota Sandstone and Burro Canyon Formations form the uppermost bedrock aquifer that underlies the Mancos Shale. The Dakota Sandstone and Burro Canyon Formations consist of beds of sandstone, conglomeritic sandstone, shale, and coal. These units are not considered productive sources of water in the Grand Junction area (Lohman, 1965). Depth to the top of the Dakota Sandstone in the site vicinity ranges from 70 to 170 ft (20 to 50 m) below land surface. All bedrock formations beneath the processing site dip to the northeast at approximately 7 degrees (Lohman, 1965).

3.5 GROUND WATER AND SURFACE WATER HYDROLOGY

Ground water and surface water hydrology are discussed from both regional and local perspectives to allow a more complete understanding of hydrological issues affecting the site.

3.5.1 Regional ground water hydrology

The important aquitards in the Grand Valley are the Morrison Formation and the Mancos Shale, the latter of which is widespread and attains a maximum thickness of 4000 ft (1200 m) in the Grand Valley. The four confined hydrostratigraphic units in order of importance are the Entrada Sandstone, the Wingate Sandstone, the Salt Wash Member of the Morrison Formation, and the Burro Canyon Formation/Dakota Sandstone (Lohman, 1965; Cahn et al., 1988). While these units are not considered major aquifers by most standards, they are capable of producing small quantities of reasonably good-quality ground water. In contrast, the Mancos Shale produces meager amounts of highly mineralized water from the unconfined weathered zone. The USBR (1978) indicates that this zone is thin, but in many locations it has a very high hydraulic conductivity. Thus, it is believed to carry water that seeped from the local system of canals and ditches to the Colorado River. Similarly, the Dakota Sandstone produces only small quantities of generally salty water (Lohman, 1965).

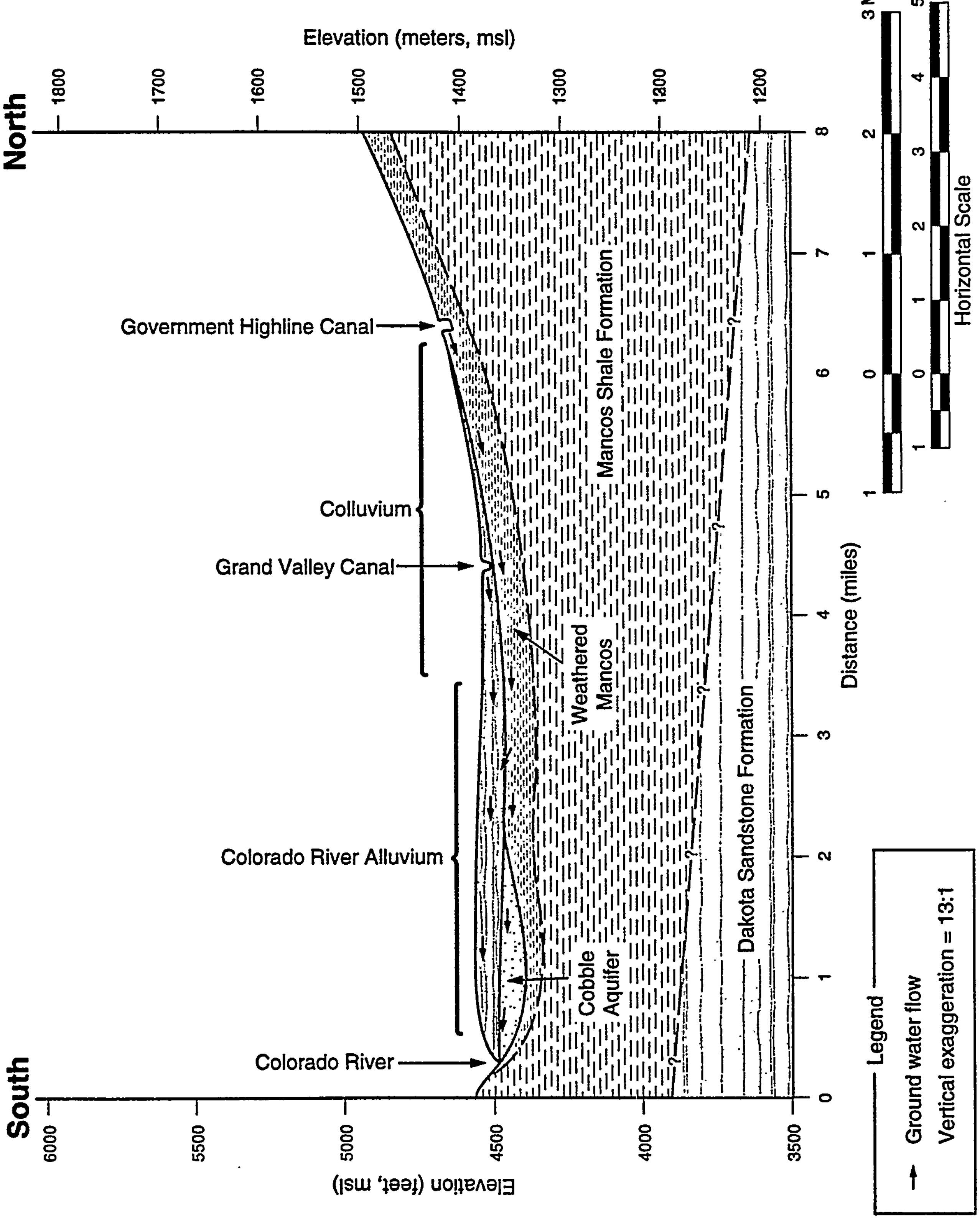
The predominant source of recharge to the bedrock aquifers in the Grand Valley is through infiltration at sandstone outcrops/subcrops and faults immediately northeast of the monocline (Lohman, 1965). These bedrock aquifers also are recharged through local precipitation. Since the ground water produced by wells completed in these bedrock hydrogeologic units is either low quantity and/or low quality, the vast majority of water used in the Grand Valley is acquired from surface water sources. The regional ground water flow direction of the confined bedrock aquifer units located within the Grand Valley is to the northeast (Lohman, 1965). This direction is consistent with the dip of these bedrock units. Ground water recharge along outcrops and faults immediately northeast of the Uncomphagre Plateau monocline moves very slowly downdip (e.g., estimated velocity of 5 ft [1.5 m] per year) in the Entrada Sandstone. The northeast dip of the Entrada Sandstone extends beyond the Grand Valley, toward the northwest-southeast trending axis of the Piceance Creek basin. Northeast of the Piceance Creek basin axis, ground water in these confined bedrock units flows southwest. Regional movement of the ground water is caused by the structural configuration of these units as well as small losses of head within these units along the flow path through upward leakage due to primary and secondary permeability (Lohman, 1965).

The regional recharge area for the Dakota Sandstone (and all deeper confined aquifer units) is located south of the Grand Junction site. Given that ground water migrates under confined conditions in these units with upward leakage, it seems reasonable to conclude that the vertical potentials from the Dakota Sandstone and deeper formations are generally upward. Since the Dakota Sandstone is believed to be confined by the Mancos Shale at the site, an upward hydraulic vertical potential likely exists between the Dakota Sandstone and the Mancos Shale.

In 1955, a test well, located about 2 mi (3 km) down river from the Grand Junction site, was completed to 61 ft (18 m) in the Dakota Sandstone (Lohman, 1965). This well flowed at 2.5 gallons (9.5 L) per minute with a static water level of plus or minus 3 ft (1 m) above ground surface. The water was salty and contained hydrogen sulfide. In 1960, the well was filled up to a depth of 29 ft (9 m). This flowing well discharges from the Dakota Sandstone to the Colorado River alluvium (1 to 5 mi [1.6 to 8 km] below the site). No recharge is possible to the west since the Dakota Sandstone is truncated. Thus, recharge must come from the southeast. As a result, ground water flow in the Dakota Sandstone is upward near the site and likely has a northeastward component of flow.

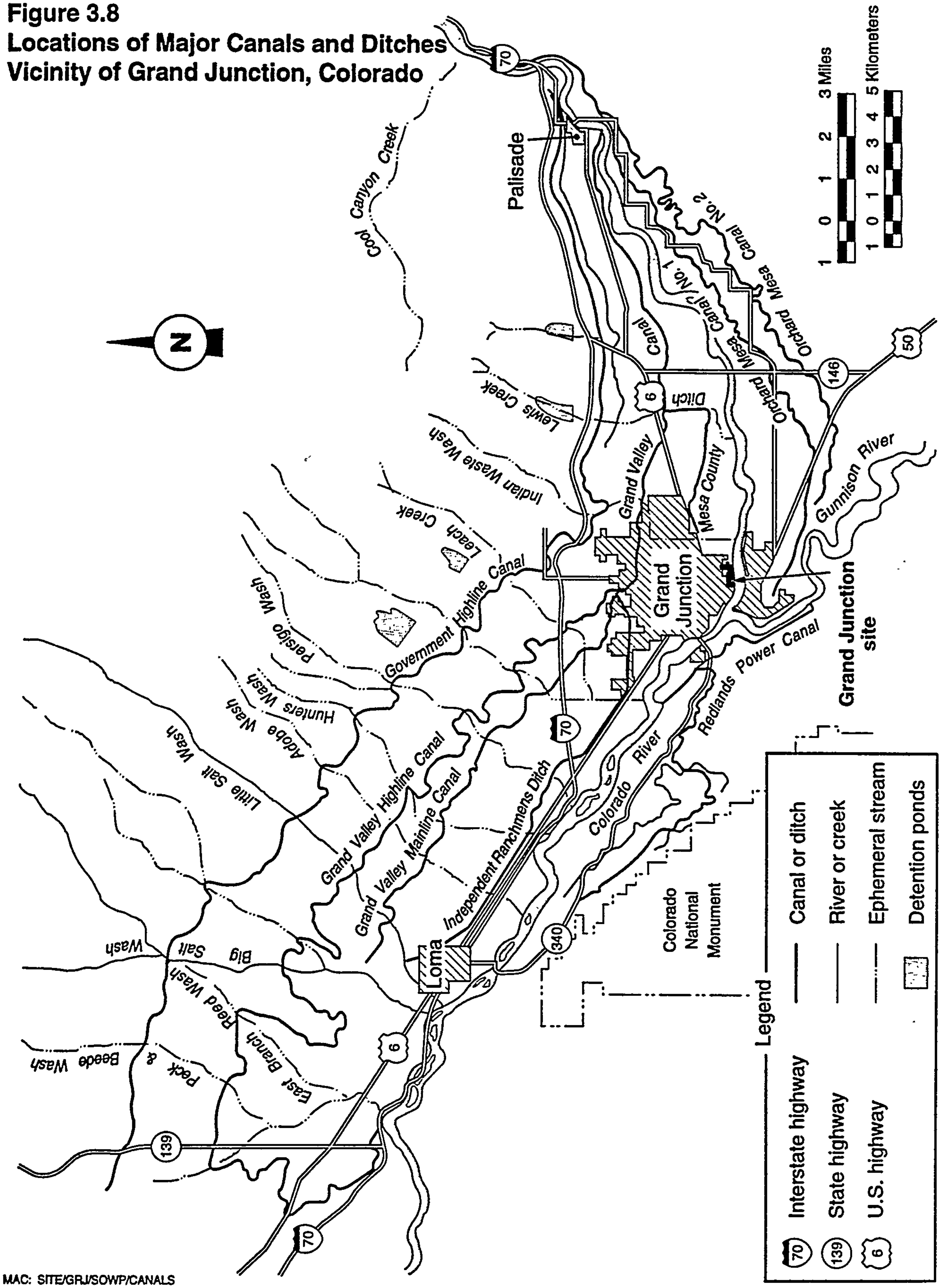
The alluvium in the Grand Junction area consists of three recognizable units. A distinct unit closer to the river consists of unconsolidated sands, gravels, and cobbles, and is locally referred to as the cobble aquifer (USBR, 1986) (Figure 3.7) The cobble aquifer is overlain by and interfingers with a complex interbedding of clay, silt, sand, and gravel derived primarily from the Mancos Shale. This clayey alluvium unit grades northward, away from the site (Figure 3.7), into a colluvium consisting of reworked Mancos Shale fragments derived from the underlying Mancos Shale as well as the Mancos Shale highlands (the Book Cliffs) to the North (Cahn et al., 1988; Evangelou et al., 1984). Along the path of the Colorado River, these unconsolidated deposits cover the Mancos shale in a 2- to 3-mi (3- to 5-km)-wide strip from Loma, Colorado, west of the Grand Junction site, to Palisade, Colorado, east of the site. To the north, the alluvium/colluvium unit thins (Figure 3.7), and eventually pinches out in the vicinity of the Government Highline Canal (Figure 3.8). Ground water recharge to the alluvial/colluvial and cobble aquifers, as well as the upper weathered Mancos Shale section, occurs as a result of precipitation, vertical upward flow from the Mancos Shale, upgradient recharge from the Mancos highlands, and seepage from the Grand Valley canal system. In the vicinity of the Grand Junction site, ground water within the alluvial and cobble aquifer discharges into the Colorado River.

Figure 3.7
Generalized Hydrogeologic Cross Section of the Uppermost Formations Within the Grand Valley, Colorado



MAC: SITE/GRJ/SOWP/GENHYDRO

Figure 3.8
Locations of Major Canals and Ditches
Vicinity of Grand Junction, Colorado



MAC: SITE/GRJ/SOWP/CANALS

Irrigation canals and ditches in the Grand Valley

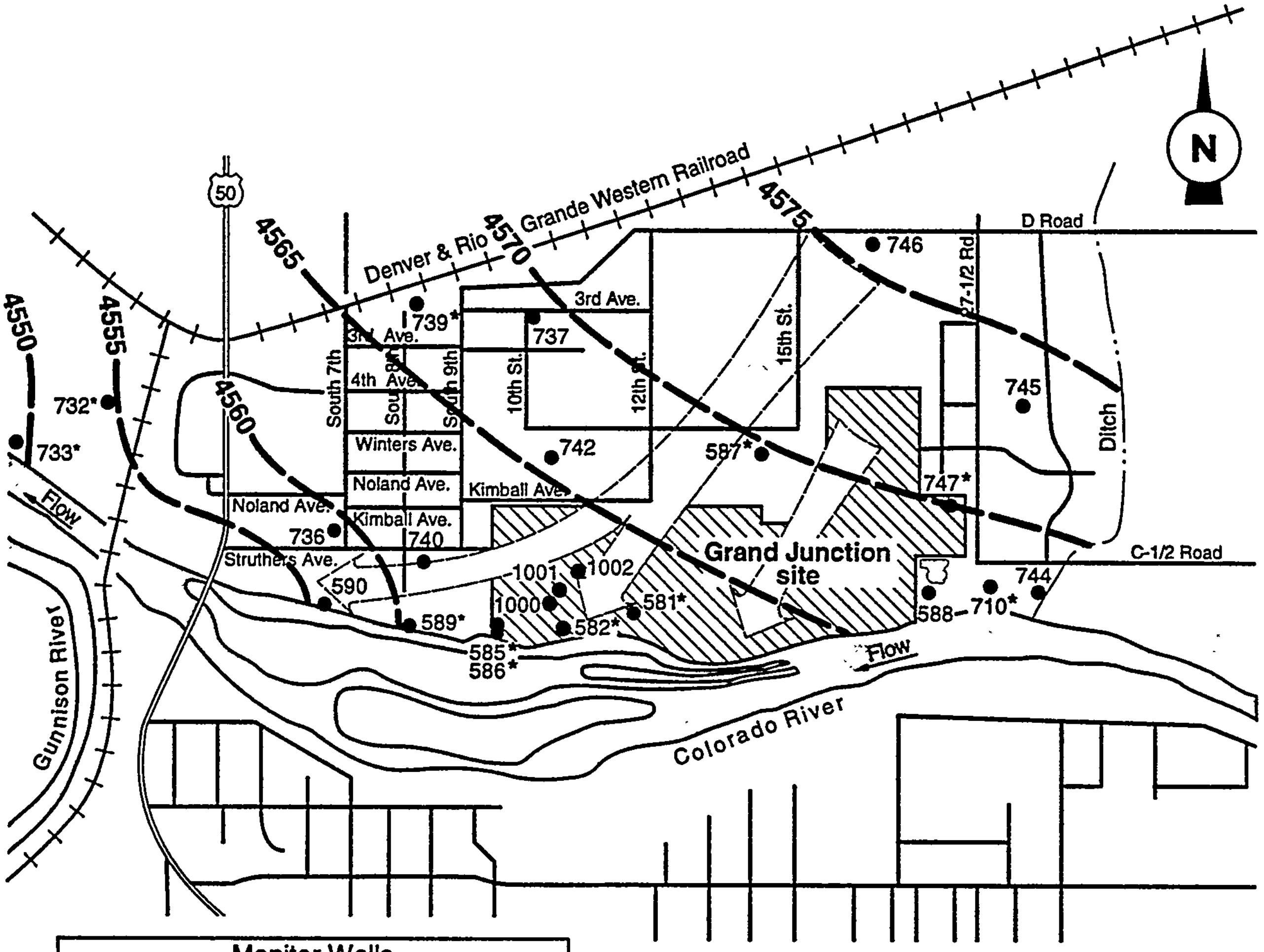
The elevation of the water table in the unconsolidated alluvium and the quality of water in this aquifer is influenced by irrigation practices in the Grand Valley. The first irrigation ditch systems were built in the early 1880s. There are currently over 180 mi (300 km) of major unlined irrigation canals built across the Grand Valley (Figure 3.8). Drainage canals and ditches were constructed by farmers in the Grand Valley to control high water tables from return flows. There are approximately 500 mi (800 km) of lateral ditches and drainage ditches, 35 outlets to the Colorado River, and 9 outlets to dry washes in the Grand Valley. Some of these ditches and portions of canals were constructed or repaired using tailings during the uranium boom in the 1950s (USBR, 1986; Cahn et al., 1988).

The irrigation canals are typically filled with Colorado River water from April through November each year. Seepage infiltrates into the alluvial and cobble aquifer and accumulates high concentrations of dissolved minerals from the weathered Mancos Shale, which is located at or near the surface of most of the Grand Valley. Poor drainage conditions, high water tables, and high evaporation rates have resulted in soil and subsoil accumulations of salt, alkali, or both, which adversely affect a portion of the available agricultural acreage in the Grand Valley (USBR, 1978). Mineralized waters from the Mancos Shale, where present, also infiltrate into the alluvial aquifer system, including the cobble aquifer (Cahn et al., 1988). The USBR has instituted a salinity control program for the Grand Valley, designed to reduce highly saline irrigation return to the Colorado River and to reduce the seepage moving through saline strata, such as the Mancos Shale (USBR, 1978; 1986). Seepage from the irrigation canals is reduced by lining the canals or placing the flow in pipes. This program is designed to reduce salt loading in the Colorado River in the Grand Valley by approximately 410,000 tons (372,000 metric tons) annually. Recent studies of ground water quality in the vicinity of the canal systems in the Grand Valley illustrate that salt loadings to the Colorado River have been reduced (Butler et al., 1994). The effect of lining the canals is to cut off the major source of recharge to the alluvial aquifer, leaving only the Mancos Shale colluvium to recharge the alluvial and cobble aquifers. This will result in locally lower water tables and a gradual degradation in water quality in this aquifer.

3.5.2 Local ground water hydrology

This section discusses ground water hydrogeologic data from the site and adjacent areas. The alluvium is the uppermost aquifer in the Grand Junction site vicinity. Based on water level measurements from on-site monitor wells and piezometers, the depth to ground water in the alluvium ranges from approximately 10 ft (3 m) in areas away from the Colorado River to less than 4 ft (1 m) in areas closest to the river. Water levels collected from the site and vicinity (Figure 3.9) document that alluvial ground water flows southwest toward the site. However, the alluvial ground water has a more pronounced westward flow direction at the western portion of the site. Figure 3.9 illustrates these two distinct ground water flow directions as a large diverging ground

Figure 3.9
Water Table Contour Map (Alluvial Aquifer), February 28 through March 7, 1989 Grand Junction, Colorado, Site Vicinity



Source: DOE, 1995b.

Monitor Wells and Water Table Elevations (ft)			
581	4564.43	737	4568.9
582	4563.32	739	NA
585	4562.43	740	4562.03
586	4562.77	742	4567.78
587	NA	744	4567.07
589	4562.09	745	4572.57
590	4555.44	746	4576.57
710	4567.65	747	NA
731	NA	1000	NA
732	NA	1001	NA
733	4549.95	1002	NA
736	4559.20		

Notes: 1. Decommissioned monitor wells are indicated by an asterisk.
2. On-site ponds are not shown.

Legend

4575 ▬	Inferred line of equal water table elevation (ft above msl)
NA	Data not available
⇙	Predominant ground water flow direction
● 740	Alluvial monitor well
▽	Pond
(50)	U.S. highway

0.25 0 0.5 Mile

0.25 0 1.0 Kilometer

MAC: SITE/GRJ/SOWP/WATRTABL

water flow direction arrow. The reason for such a divergence of alluvial ground water flow is most likely related to the stage of the Colorado River, the changing direction of the Colorado River toward the west-northwest, and perhaps the influence of the downstream confluence of the Colorado and Gunnison Rivers and discharge of ground water from the Dakota Sandstone. A smaller southwesterly-oriented alluvial ground water flow direction arrow is shown on Figure 3.9 beneath the eastern half of the site.

This ground water flow information indicates that ground water beneath the eastern two-thirds of the Grand Junction site discharges in a southwesterly direction to the Colorado River, while ground water beneath the western third of the site migrates in the alluvial aquifer in a west-southwest direction. Although data are sparse in this area, it is likely that the majority of alluvial ground water beneath the western third of the site discharges to the Colorado River before it reaches the railroad track that crosses the Colorado River on the west side of U.S. Highway 50 (U.S. 50) (Figure 3.9). Although discussed in more detail in Section 3.5, these generalizations regarding alluvial ground water flow directions are consistent with our understanding of ground water quality impacts at the site and vicinity.

Ground water levels in the alluvial aquifer beneath the site fluctuate 2 to 5 ft (0.6 to 1.5 m) annually and are lowest during fall and winter. These fluctuations occur due to changes in river stage, precipitation, local irrigation, and upgradient recharge. Presently, water level data from new on-site wells 1000, 1001, and 1002 and off-site well 746 (continuously monitored) are downloaded and assessed quarterly.

Regionally, the Mancos Shale Formation is a low-permeability formation that is not water-bearing or that transmits only limited quantities of water (Cooley et al., 1969; Lohman, 1965). Although saturated beneath the Grand Junction site, as a whole, the Mancos Shale acts as an aquitard inhibiting vertical flow between the Dakota Sandstone and the alluvial aquifer due to its relatively low hydraulic conductivity. Structurally, the Mancos Shale has been deformed by the monoclines illustrated in Figure 3.5. Visual descriptions from the lithologic logs provided in Appendix A document weathered to highly weathered shale in monitor wells 594, 711, 719, 720, 721, 724, 725, 727, 729, 730, 731, 735, 741, and 742. (Note: Many of these monitor wells have been decommissioned and their locations are not provided on figures in this report.) Sandstone seams were noted in borings 725 and 727, and fractures causing losses in circulation during drilling were noted in boring 725. Fractures in the Dakota Sandstone and Mancos Shale at borings 725 and 727 are likely trending northwest, parallel to the monocline's strike. These fractures, acting as localized vertical discharge points, may be causing the apparent westerly component of flow in the alluvial aquifer. During the advancement of boring 735, "artesian flow" was observed at 40 ft (12 m) (just 25 ft [7.6 m] below the top of the Mancos Shale) and the initial "large flow reduced to trickle after 10 minutes." These observations demonstrate that secondary permeability due to fracturing may be pronounced in the Mancos Shale beneath the site. Based on understanding of the monoclinal deformation that has occurred, it can be surmised that fracturing associated with this deformation has some vertical component. However, the current continuity of these fractures is unknown due to the self-healing nature of a unit such as the Mancos Shale with its high clay and silt content. Furthermore, from a regional hydrogeologic basin perspective, it is likely that vertical heads between the sedimentary bedrock units and the unconsolidated alluvium are upward in the vicinity of the site (see Section 3.5.1). Therefore, even if the combined primary and secondary permeabilities of the Mancos Shale are capable of conducting appreciable ground water in the vertical direction, this upward vertical potential would preclude the migration of affected ground water from the alluvium to deeper units.

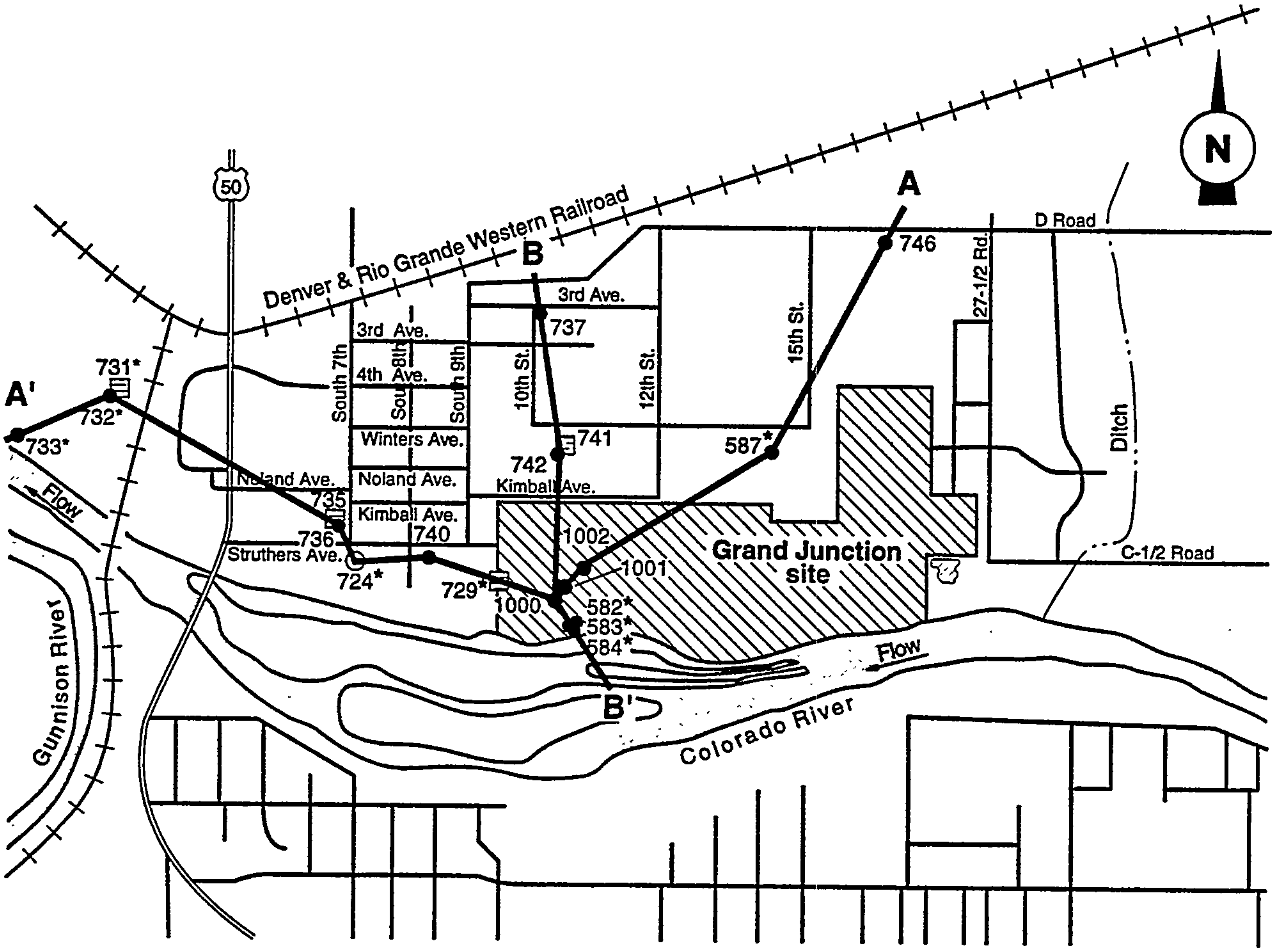
While the Mancos Shale is not considered a viable aquifer, its geochemical composition and close relationship to the alluvial ground water flow system have naturally degraded the alluvial ground water quality with high dissolved mineral salt concentrations (Evangelou et al., 1984). Moreover, the Mancos Shale has been shown to contain naturally high concentrations of uranium, thorium, and potassium (Pliler and Adams, 1962). Based on the ground water hydrogeology and site-specific ground water geochemistry (discussed in Section 3.5), it is evident that the Mancos Shale is the most likely source of naturally occurring high concentrations of dissolved salts and radionuclides in the shallow alluvial ground water system in this area.

Ground water flow directions in the Dakota Sandstone were not determined. Ground water flow in the Dakota Sandstone is very likely to the northwest. The Dakota Sandstone does have an upward potential for flow into the Mancos Shale or other overlying formations in the site vicinity (Lohman, 1965).

Figure 3.10 shows the locations of hydrogeologic cross sections A-A′ and B-B′. Cross section A-A′ (Figure 3.11) is oriented to generally coincide with the ground water flow direction along a path that crosses the western third of the site. Cross section B-B′ (Figure 3.12) is oriented roughly perpendicular to the predominant ground water flow direction and also crosses the western third of the site. These cross sections show the variability of the alluvial lithology across the site. In general, the basal alluvium consists of coarser, relatively conductive sediments such as sands and gravels compared to the near-surface materials. This pattern is consistent with fluvial reworked sediments expected next to the present channel of the Colorado River.

Cross section B-B′ shows that the alluvial materials lying below the water table become finer toward the river. The finer alluvial sediment acting in conjunction with the irregular surface of the upper Mancos Shale may retard basal ground water flow within the alluvium near the river. West and downgradient of the site (cross section A-A′, well 733), the alluvial sediments are more coarse and the Mancos Shale nearly pinches out. Both cross sections indicate that on-site fill placed during surface remediation appears to have little influence on ground water flow as the fill was generally used to replace the shallow (upper 5 ft [1.5 m]) alluvial material.

Figure 3.10
Hydrogeologic Cross Section Location Map Grand Junction, Colorado, Site Vicinity



Source: DOE, 1995b.

Notes: 1. Decommissioned monitor wells are indicated by an asterisk.
2. On-site ponds are not shown.

Legend

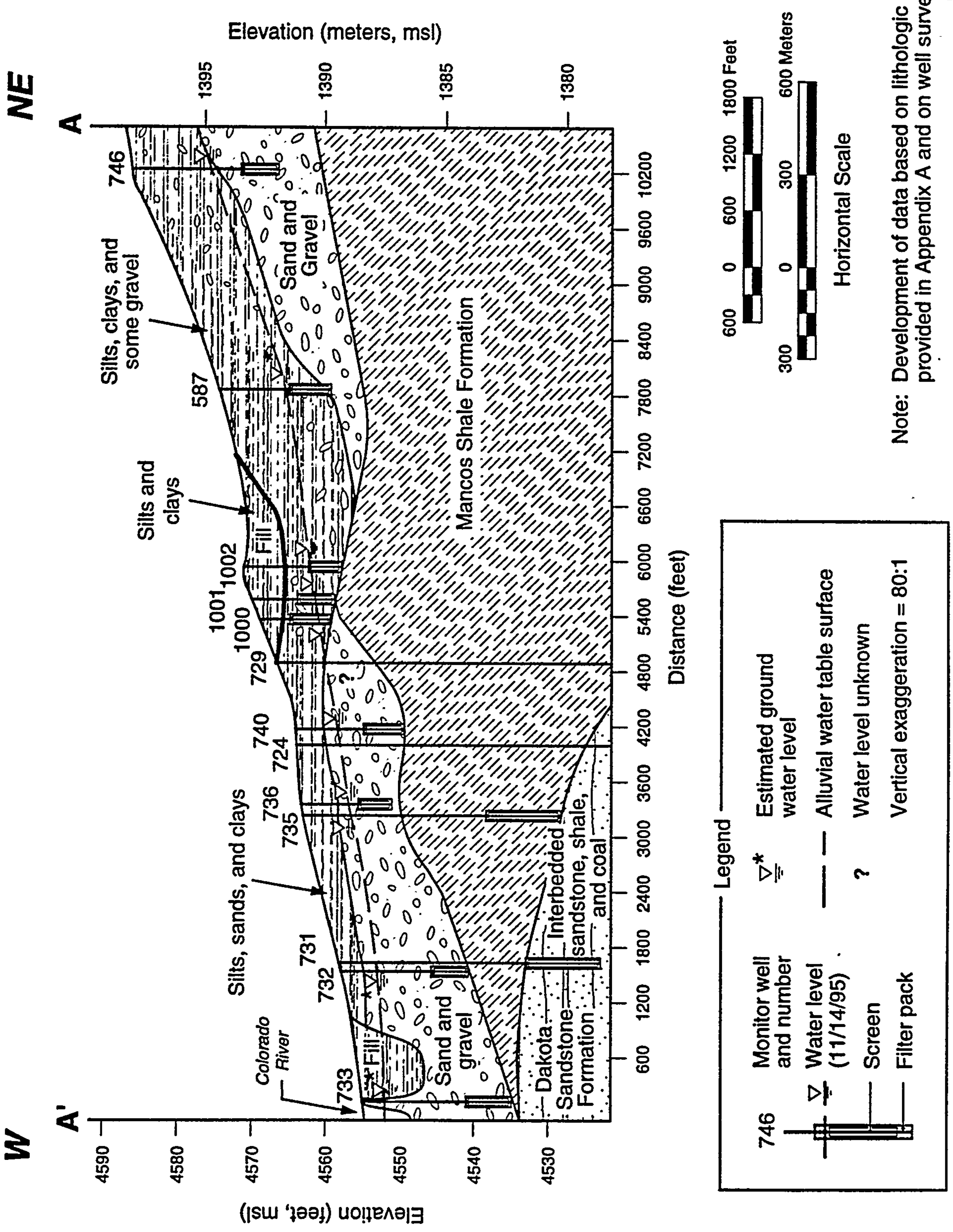
● 740	Alluvial monitor well
⊟ 731	Mancos Shale Formation monitor well
○ 724	Dakota Sandstone monitor well
▨	Pond
(50)	U.S. highway

0.25 0 0.5 Mile

0.25 0 1.0 Kilometer

MAC: SITE/GRJ/SOWP/LOCXSECS

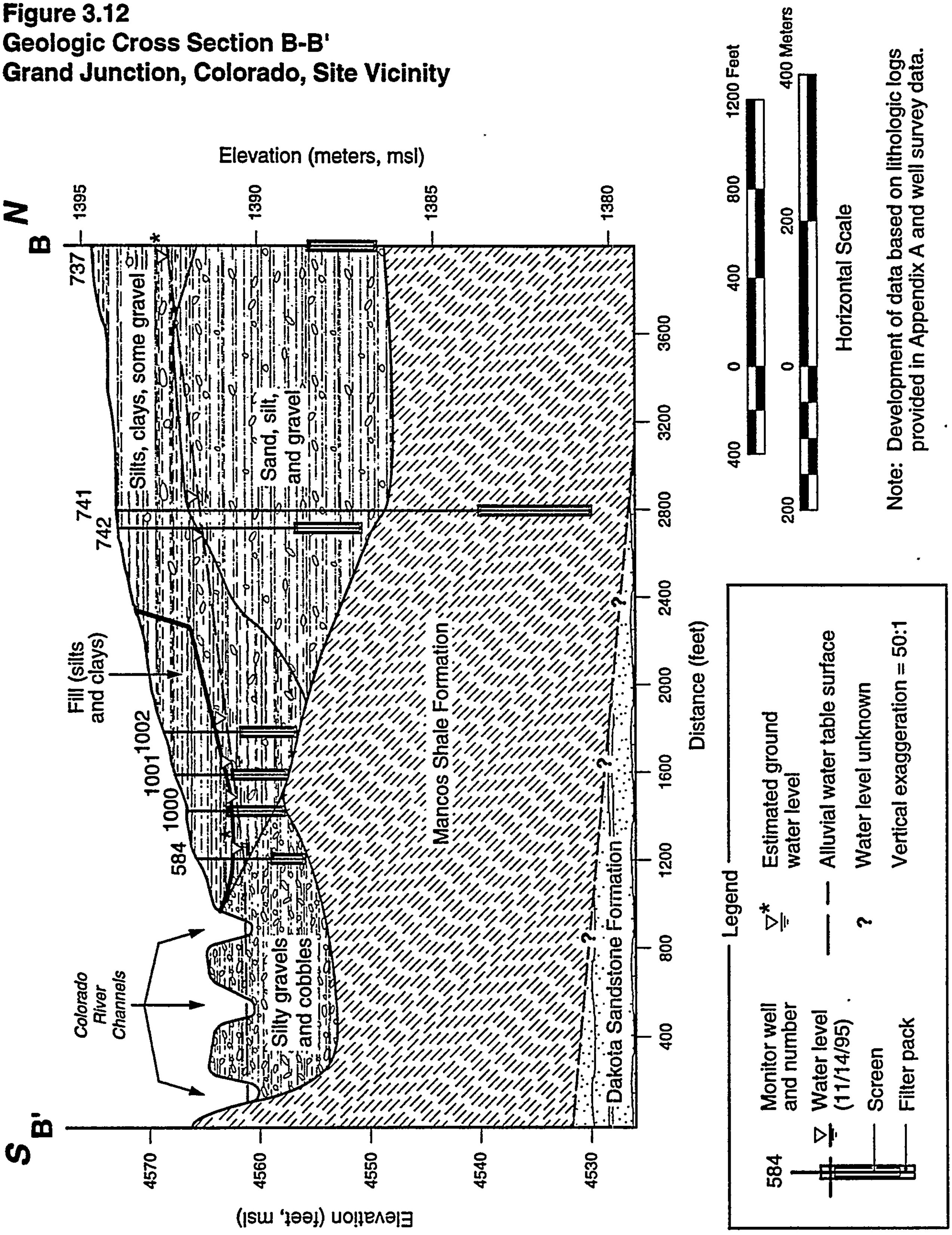
Figure 3.11
Geologic Cross Section A-A'
Grand Junction, Colorado, Site Vicinity



Note: Development of data based on lithologic logs provided in Appendix A and on well survey data.

MAC: SITE/GRJ/SOWP/XSECAA'

Figure 3.12
Geologic Cross Section B-B'
Grand Junction, Colorado, Site Vicinity



Note: Development of data based on lithologic logs provided in Appendix A and well survey data.

MAC: SITE/GRJ/SOWP/XSECBB'

Hydraulic characteristics

An average hydraulic conductivity in the alluvium, as determined from aquifer pumping tests (DOE, 1991), is approximately 1 x 10^{-3} ft per second (ft/s) (3 x 10^{2} centimeters per second [cm/s]). Linear ground water velocity in the alluvium ranges from 0.2 to 5 ft per day (0.06 to 1.5 m/day), depending on location-specific conditions (DOE, 1991).

The USBR (1978) reports a hydraulic conductivity of 6.9 x 10^{-3} ft/s (2.1 x 10^{-1} cm/s) in the weathered Mancos Shale. The DOE (1991) reports that calculated hydraulic conductivities in the unweathered Mancos Shale average 2.1 x 10^{-7} ft/s (6.4 x 10^{-6} cm/s). The horizontal hydraulic conductivity of the unweathered shale is presumed to decrease with increasing depth.

Table 3.2 summarizes hydraulic conductivity data for the Dakota Sandstone and Mancos Shale from the Grand Junction site. Depending upon the source of these data, the Mancos Shale hydraulic conductivity ranges from values similar to that of the Dakota Sandstone to roughly 1 order of magnitude lower than that of the Dakota Sandstone (Table 3.2). While this relationship makes sense, the validity of these actual values is unknown.

Table 3.3 summarizes the historic relative vertical potentials of existing ground water well clusters 742/741, 744/743, and 736/735 completed in the alluvium and Mancos Shale. These vertical-potential data, collected from 1985 through 1993, show both upward and downward relative vertical potentials. Unfortunately, the completion intervals between wells in well cluster 742/741 and well cluster 744/743 are only separated by a few feet (Appendix A). Well cluster 736/735 is a little better for evaluating vertical hydraulic potentials with a completion interval separation of approximately 10 ft (3 m). However, given that the upper weathered portion of the Mancos Shale is known to have adequate secondary permeability to conduct some ground water, these minimal completion interval separations make these data minimally useful for the purposes of developing meaningful conclusions, based on localized data, regarding the vertical potentials between these units. However, as previously discussed in the section regarding regional ground water flow systems, an upward vertical potential is most likely present under the Grand Junction site.

It has been assumed that all data in Table 3.3 represent static head. However, this is not always a reasonable assumption for wells completed in low-permeability formations such as the Mancos Shale. It is known from experience on other sites that wells completed in low-permeability shale formations may take months or even longer to recover to static levels following purging associated with sampling. This, coupled with seasonal water level fluctuations, results in the collection of water level data that may be below that of true static for the unit. Of the three well clusters presented in Table 3.3, this bias may be most likely in well cluster 736/735.

Table 3.2 Slug withdrawal test results in the alluvial aquifer, Mancos Shale and Dakota Sandstone at the Grand Junction, Colorado, site

Well ID	Hydraulic conductivity[a] by method		
(Unit of Completion)	C-B-P[b]	F-K[c]	Skibitzke[d]
GRJ-01-0585 (AL)	2.5×10^{-2}	NA	NA
GRJ-01-0586 (AL)	2.3×10^{-2}	NA	NA
GRJ-01-0587 (AL)	4.2×10^{-2}	NA	NA
GRJ-01-0588 (AL)	1.5×10^{-2}	NA	NA
GRJ-01-0589 (AL)	2.0×10^{-2}	NA	NA
GRJ-01-0590 (AL)	3.3×10^{-2}	NA	NA
GRJ-01-0724 (DS)	NA	NA	4.6×10^{-5}
GRJ-01-0725 (DS)	2.6×10^{-5}	7.9×10^{-6}	NA
	4.4×10^{-5}		
GRJ-01-0727 (MS)	5.5×10^{-6}	7.3×10^{-7}	7.7×10^{-7}
GRJ-01-0729 (MS)	NA	NA	1.9×10^{-7}
GRJ-01-0731 (MS)	NA	NA	9.4×10^{-7}
GRJ-01-0735 (MS)	NA	NA	3.9×10^{-7}
GRJ-01-0741 (MS)	5.8×10^{-5}	1.4×10^{-5}	2.4×10^{-5}
GRJ-01-0743 (MS)	4.9×10^{-4}	1.4×10^{-6}	NA

[a] Expressed as centimeters per second converted from transmissivity by assuming effective thickness of aquifer equal to saturated gravel pack.
[b] Cooper-Bredegoeft-Papadopulus (Lohman, 1972)
[c] Ferris and Knowles (1963).
[d] Skibitzke (1963).

Unit of completion: DS = Dakota Sandstone; MS = Mancos Shale; AL = alluvium.
NA = not available.

Table modified from Table 3.4 in Grand Junction RAP (DOE, 1991).

Table 3.3 Water level elevations and relative vertical potentials of ground water well clusters at the Grand Junction, Colorado, site

Well cluster	Dates sampled and water level elevations[a]												
Date	5/5/85	5/17/85	7/10/85	7/23/86	3/3/89	1/26/91	8/28/91	11/19/91	2/21/92	10/9/92	2/3/93	6/27/93	12/7/93
GRJ-01-0742[b]	4567.47	4567.45	4566.96	4567.28	4567.78	4566.78	4566.02	4566.63	4566.68	4565.96	4566.68	4566.77	4566.29
(4556.70-4551.70)[c]													
GRJ-01-0741[d]	4567.12	4567.01	4566.60	4566.95	4568.33	4567.84	4566.19	4566.84	4566.09	4565.80	4566.69	4566.75	4567.11
(4539.90-4529.90)[c]													
Vertical potential	Down	Down	Down	Down	Up	Up	Up	Up	Down	Down	Up	Down	Up

Well cluster	Dates sampled and water level elevations[a]													
Date	3/21/85	5/6/85	7/10/85	7/23/86	3/5/89	8/3/89	10/31/8	11/17/91	2/19/92	7/15/92	10/9/92	2/1/93	6/27/93	12/7/93
GRJ-01-0744[b]	4567.65	4572.02	4568.68	4568.68	4567.07	4567.13	4566.78	4567.23	4566.92	4567.08	4566.73	4567.12	4570.18	4567.2
(4566.80-4561.80)[c]														
GRJ-01-0743[d]	4567.93	4571.41	4569.12	4468.96	4566.92	4567.49	4567.29	4567.74	4567.36	4567.59	4567.32	4567.78	4570.18	4567.6
(4552.10-4542.10)[c]														
Vertical potential[d]	Up	Down	Up	Up	Down	Up	Up	Up	Up	Up	Up	Up	Equal	Up

Well cluster	Dates sampled and water level elevations[a]					
Date	5/5/85	7/10/85	7/24/86	10/29/89	6/27/93	12/7/93
GRJ-01-0736[b]	4559.05	4559.12	4558.75	4557.55	4559.12	4558.41
(4556.70-4551.70)[c]						
GRJ-01-0735[d]	4537.20	4547.15	4559.28	4533.75	4558.50	4558.44
(4538.70-4528.70)[c]						
Vertical potential	Down	Down	Up	Down	Down	Up

[a] Water level elevations in feet above MSL.
[b] Completed in Quaternary alluvium.
[c] Elevation of well screen intervals in ft above MSL.
[d] Completed in Mancos Shale.

3.5.3 Surface water-ground water interactions

The northern channel of the Colorado River forms the southern boundary of the Grand Junction site (Figure 3.3). A Mancos Shale Formation outcrop forms the southern bank of the Colorado River south of the site. Several large sandbars in the river south and southwest of the site cause the river to flow into separate channels during much of the year. The Gunnison River flows into the Colorado River about 1.5 mi (2.5 km) west of the site. As previously stated, the Colorado River is most likely the discharge point for the ground water contamination migrating from the site.

The stages of the Colorado River fluctuate seasonally, with high stage usually occurring in June and low stage occurring in February. A staff gauge installed in the Colorado River at the U.S. 50 overpass in late 1994 is used to periodically monitor river stage fluctuations. The lower curve on Figure 3.13 shows the estimated surface water hydrograph for the period October 1994 through September 1995. The hydrograph indicates that river stage at the U.S. 50 staff gauge rose more than 7 ft (2 m) during early June 1995 and returned to near low-flow stage by early September.

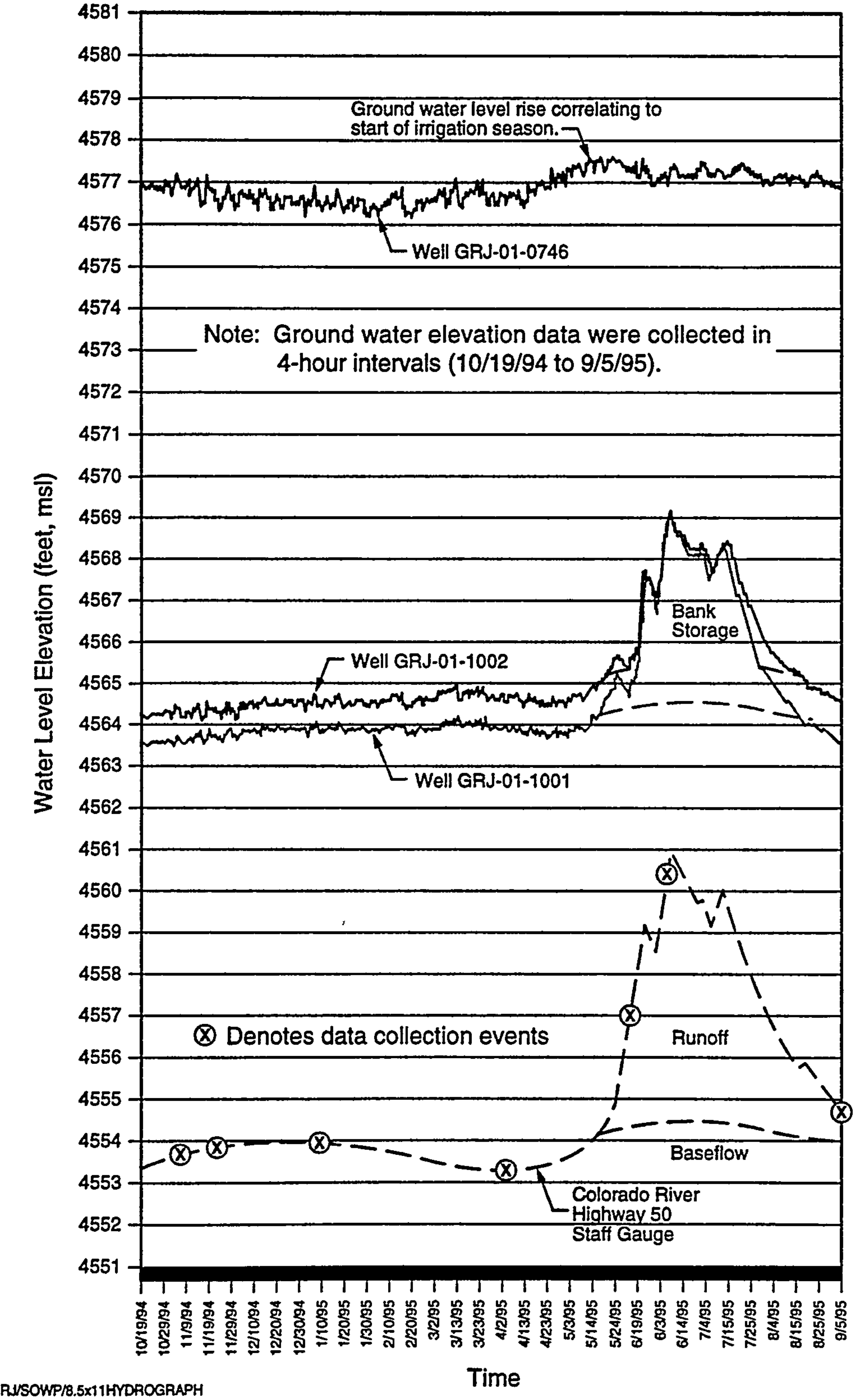
From a historical perspective, the 1995 water year was somewhat unique in that peak flow statistics from the Colorado River at the closest USGS upstream gauging station (Cameo, near DeBeque, Colorado) and the closest USGS downstream gauging station (near the Colorado-Utah state line) indicate that the 10-year high was exceeded or nearly exceeded (USGS, 1995). This makes the 1995 peak flow the highest since the initiation of systematic ground water data collection at the Grand Junction site in 1984.

Ground water levels beneath the site generally fluctuate 2 to 5 ft (0.6 to 1.5 m) annually and are lowest during fall and winter. These fluctuations occur primarily due to changes in river stage but also may occur to a lesser extent due to irrigation and upgradient recharge. Although on-site and vicinity shallow ground water levels may also be influenced slightly due to precipitation, it is expected to be a minor contributor.

Presently, continuous water level data from on-site wells 1001 and 1002 and off-site well 746 are collected and assessed quarterly. In September 1994, wells 1001, 1002, and 746 were installed and equipped with data loggers set to record ground water levels at 4-hour intervals. In assessing the relative elevations of the curves, it should be noted that well 746 is located upslope from wells 1001 and 1002, at a higher elevation.

Figure 3.13 illustrates the ground water level hydrographs for on-site wells 1001 and 1002 (middle curves) and background well 746 (top curve) for the period from October 1994 through September 1995. Wells used to gather continuous water level data were generally aligned from northeast to southwest, approximating the local ground water flow direction. Analysis of the hydrographs for wells 1001 and 1002 indicate that throughout most of the year

Figure 3.13
Ground Water and Surface Water Level Hydrographs (10/19/94-9/5/95) Grand Junction, Colorado, Site



MAC: SITE/GRJ/SOWP/8.5x11HYDROGRAPH

(during base flow conditions), on-site ground water flow is to the southwest toward the river at an approximate horizontal hydraulic gradient of 0.003. This gradient agrees closely with the determined hydraulic gradient for the entire site during low-flow conditions. The hydrographs indicate that during periods when the stage of the Colorado River is elevated (from early June through mid-July for 1995), the hydraulic gradient in the vicinity of the river is reversed for a time, depending on the distance from the river. This represents an annual phenomenon due to mountain snow melt water. During this time period, a component of flow is westward, down the axis of the Colorado River.

With the limited data available, the temporal and areal extent of the river's influence on ground water flow in the alluvium during a given year is not known. However, ground water level responses in wells 1001 and 1002 show that the alluvial aquifer at the site is influenced during high-river flow conditions. In contrast to ground water level responses observed in wells 1001 and 1002, background well 746 showed little, if any, response from fluctuation of the river stage.

In addition to the Colorado River, the canals and drainage ditches discussed in Section 3.5.1 also influence ground water in the site vicinity (Figure 3.8). These canals and ditches, which are used to irrigate and drain land in the site vicinity, have a seasonal influence on local unconfined ground water levels, and they have historically had a major influence on shallow ground water quality. The effects of these canals and ditches on local ground water quality are discussed in depth in the following section.

3.6 GEOCHEMISTRY

All available DOE water quality data from the wells shown in Figure 3.3 were used to characterize the plume geometry and the geochemical processes active at the Grand Junction site. This section will identify and discuss the following:

- Background ground water quality in the alluvial aquifer.
- Uranium processing and process solutions.
- The extent and magnitude of contamination of the alluvium by milling-related activities.
- The milling-related constituents that are of concern to human health and the environment (constituents of potential concern).
- The fate and transport characteristics of the constituents of potential concern.

3.6.1 Background ground water quality

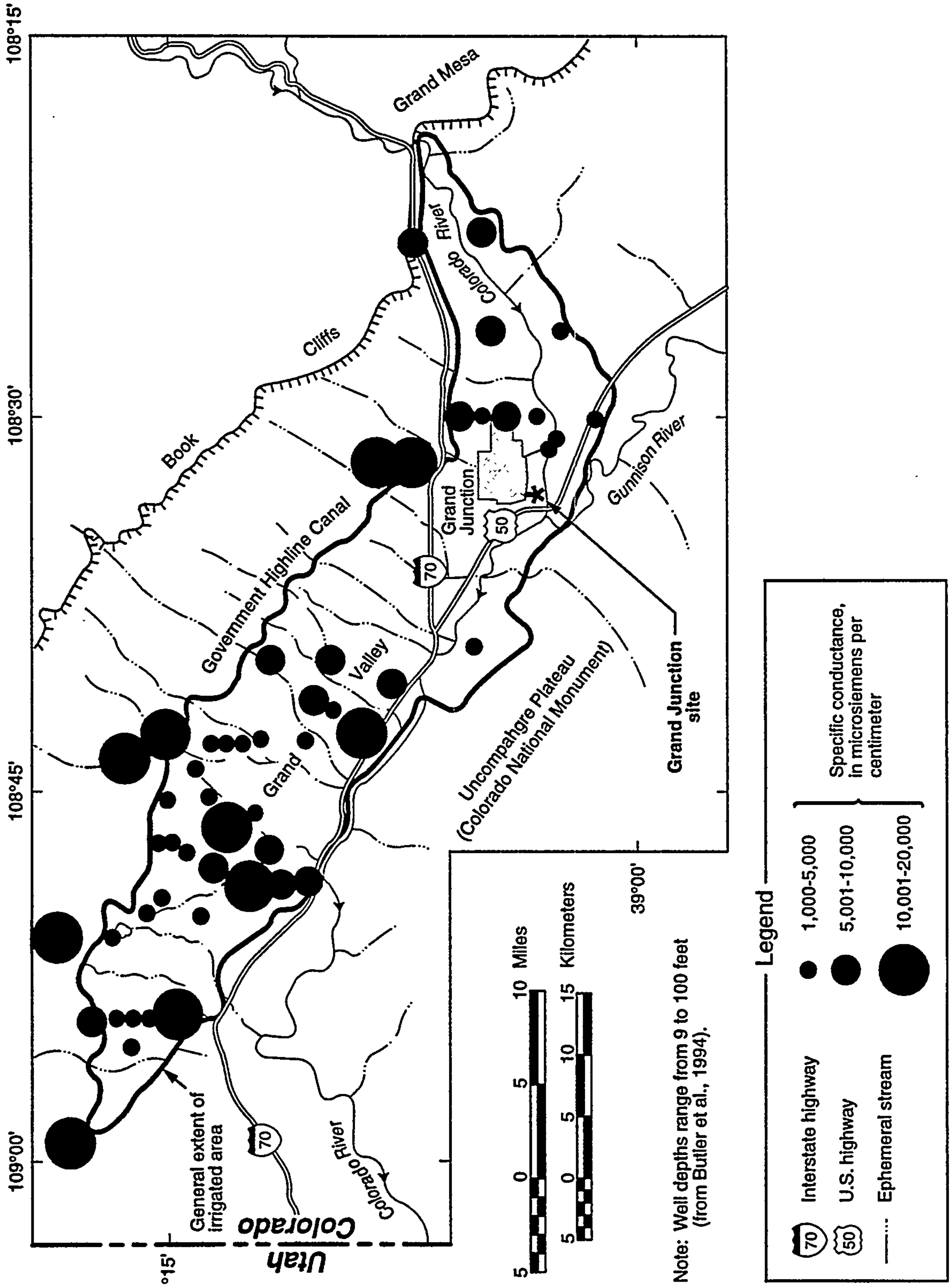
Background ground water quality is defined as the quality of ground water that would exist at the site if the milling had not taken place. Under this definition, other sources of ground water contamination (e.g., industrial or domestic sources) that have affected the water quality of the aquifers at this site would be considered part of the upgradient quality. In the past, upgradient DOE monitor wells 745 and 746 have been accepted as the monitor wells that most likely sample background ground water (Figure 3.3). However, the possibility that contaminants from tailings-contaminated vicinity properties in Grand Junction have affected the chemistry of the ground water sampled by monitor wells 745 and 746 cannot be ruled out on the basis of the currently available data. Consequently, this section contains a discussion of regional ground water quality data for certain constituents that occur at levels above the EPA MCLs (Table 1 of 40 CFR Part 192) in regional ground water in addition to a description of water quality in wells 745 and 746 as an indication of background for the Grand Junction site.

Regional ground water quality

Throughout the Grand Valley, water quality from the unconsolidated alluvial aquifer, including the cobble aquifer, is very poor due to very high TDS. As stated previously, the Mancos Shale underlies the unconfined alluvial aquifer beneath the Grand Valley. While the Mancos Shale is not considered a source of quality ground water in the Grand Valley, its geochemical composition and close relationship to the alluvial ground water flow system (i.e., it underlies the alluvial aquifer system in the Grand Valley) have naturally degraded the alluvial ground water quality with high dissolved mineral salt concentrations (Evangelou et al., 1984). Moreover, the Mancos Shale has been shown to contain naturally high concentrations of uranium, thorium, and potassium (Pliler and Adams, 1962). Based on the ground water hydrogeology and site-specific ground water geochemistry, it is evident that the Mancos Shale is the most likely source of naturally occurring high concentrations of dissolved salts and radionuclides in the shallow alluvial ground water system, including the cobble aquifer, in this area.

A study by the USGS (Butler et al., 1994) indicates that specific conductance of water in the clayey alluvium upgradient of the Government Highline Canal is generally in the range of 10,000 to 20,000 microsiemens per cm (mS/cm) (Figure 3.14). (The factor to approximately convert mS/cm conductivity to mg/L TDS is approximately 1.01 for these high-TDS, high-sulfate waters, based on 35 concurrent analyses of these parameters in ground water from the Grand Valley alluvium [Butler, et al., 1994]; thus, 10,000 mS/cm is approximately equivalent to 10,000 mg/L TDS.) High TDS in these ground waters are due to dissolution of salts associated with the Mancos Shale in the area. Calcite, gypsum and gypsum minerals (such as selenite and anhydrite), halite, and in some areas, barite, have been dissolved from unweathered Mancos Shale and redeposited in joints and bedding planes during the weathering process (USBR, 1978). Thus,

Figure 3.14
Ranges of Downhole Specific Conductance of Water From Selected Wells in Grand Valley, June-July 1991 Grand Junction, Colorado, Site Vicinity



Note: Well depths range from 9 to 100 feet (from Butler et al., 1994).

MAC: SITE/GRJ/SOWP/CONDUCT

these soluble minerals have become available to ground water in the clayey alluvium.

The result is water quality in all alluvial materials that is dominated by sodium sulfate but also contains high levels of bicarbonate, chloride, magnesium, and calcium (Butler et al., 1994).

Downgradient of the Government Highline Canal, the clayey alluvium is recharged primarily by seepage from the unlined canal. This results in TDS concentrations in ground water between 3000 to 7000 mg/L directly downgradient of the canal (Figure 3.14) (Butler et al., 1994; USBR, 1978). Further downgradient, TDS tend to increase and many samples in excess of 10,000 mg/L are observed.

The USBR is currently in the process of lining the Government Highline Canal. This action will presumably result in lowering the ground water table in the Grand Junction area and a return to higher TDS in water (more than 10,000 mg/L) that was likely present in the area before the beginning of irrigation.

The USGS study (Butler et al., 1994) also provides information from a series of wells located in the Grand Valley alluvium outside the possible influence of vicinity properties in the Grand Junction area. Most of these wells are located in the clayey alluvium, but two are located in the cobble aquifer. One of these is clearly not influenced by tailings-related contamination because there are no vicinity properties within 1 mi (1.6 km) and none upgradient of the well. Uranium concentrations in ground water from this well have been measured at 0.054 mg/L. This value exceeds the UMTRA MCL of 0.044 mg/L. Uranium concentrations of up to 0.45 mg/L have been observed, and concentrations between 0.04 and 0.07 mg/L are common in ground water in wells located in the clayey alluvium. In addition, selenium concentrations in ground water in the cobble aquifer have been reported as high as 0.17 mg/L. This value is 1 order of magnitude above the UMTRA MCL of 0.01 mg/L. Selenium concentrations as high as 1.3 mg/L have been observed in the clayey alluvium.

These observations make it possible to characterize natural ground water quality in the alluvial aquifer in the Grand Junction area as poor and likely to get worse. TDS are currently over the 40 CFR Part 192 definition for limited-use ground water (10,000 mg/L) at many locations in the Grand Valley alluvium, and all ground water in the alluvium will likely see increases in TDS after the Government Highline Canal is lined. Uranium and selenium concentrations are currently naturally high in alluvial ground water. Concentrations of these constituents also are likely to increase when the Government Highline Canal lining project is complete.

Upgradient ground water quality

Monitor wells 745 and 746 are upgradient of the Grand Junction site and are not directly affected by activities at the site. While there is a potential for upgradient wells to be impacted by contamination from vicinity properties, the fact that ground water quality in wells 745 and 746 falls within the ranges of regional background water quality suggests that there has been little, if any, impact. Table 3.4 summarizes the minimum, median, and maximum values found for chemical parameters in the ground water from these wells and from wells accessing contaminated ground water at the site. Water quality at these locations is consistent with regional water quality downgradient of the Government Highline Canal, as described by the USGS (Butler et al., 1994) and the USBR (1978).

The pH of the upgradient ground water ranges from 6.7 to 7.5. The reduction-oxidation (redox) state of the alluvial aquifer is not well known. Dissolved oxygen measurements from the limited data available suggest that the upgradient ground waters are oxygen-depleted. Slightly reducing conditions in this alluvial aquifer are consistent with the presence of significant amounts of organic carbon in the ground water from these wells (averaging over 100 mg/L in monitor well 746). Organic constituents found in ground water upgradient of the site are likely from industrial or other anthropogenic sources.

The TDS in upgradient ground water samples from monitor wells 745 and 746 range from approximately 3000 to 7200 mg/L. The upgradient alkalinity (as mg/L $CaCO_3$) ranges from 343 to 439. Despite the relatively high alkalinity of these waters, the dominant anionic species in the upgradient ground water is sulfate (median value = 2800 mg/L). The dominant cations in the upgradient ground waters are sodium, magnesium, and calcium; median concentrations in the upgradient ground water are 659 mg/L sodium, 391 mg/L magnesium, and 532 mg/L calcium. Geochemical modeling of upgradient ground water from monitor wells 745 and 746 with the numerical code PHREEQE (Parkhurst et al., 1980) indicates that the ground water is at or near saturation with respect to calcite ($CaCO_3$), magnesite ($MgCO_3$), gypsum ($CaSO_4$), and fluorite (CaF_2). Equilibration with these minerals would explain the relatively high alkalinity and relatively high concentrations of calcium, magnesium, sulfate, and fluoride (Table 3.4) in these upgradient ground waters.

Uranium, vanadium, and selenium are also present at noteworthy levels in the upgradient ground water (Table 3.4). For example, the median concentration for uranium in the upgradient ground water was 0.046 mg/L, slightly above the UMTRA MCL. Values for all these constituents, as well as TDS, are well within the observed range of concentration in alluvial ground water outside possible areas of vicinity property contamination (Butler et al., 1994).

Table 3.4 Summary of filtered ground water quality at the Grand Junction, Colorado, site

Constituent/ sample location (well GRJ-01)	Frequency of detection[a]	Observed concentration		
		Minimum	Median[b]	Maximum
	Inorganic constituents (mg/L)			
Aluminum				
Upgradient[c]	9/26	0.048	-	0.38
Plume[d]	5/23	0.004	-	0.51
Ammonium[e]				
Upgradient	23/32	<0.03	0.2	0.6
Plume	23/23	166	357	521
Antimony				
Upgradient	4/22	<0.003	-	0.012
Plume	2/23	<0.003	-	0.012
Arsenic[e]				
Upgradient	7/30	0.001	-	0.04
Plume (-0584)	6/6	0.007	0.08	0.18
Barium				
Upgradient	10/26	<0.002	-	0.02
Plume	11/21	0.002	-	0.30
Beryllium				
Upgradient	0/16	<0.001	-	<0.01
Plume	0/3	<0.005	-	<0.005
Boron				
Upgradient	16/16	0.36	0.59	0.83
Plume	15/15	0.34	0.57	0.71
Bromide				
Upgradient	4/10	0.1	-	0.6
Plume	1/1	-	-	471
Cadmium[e]				
Upgradient	7/26	<0.001	-	0.04
Plume (-0584)	4/4	0.073	0.12	0.42

Table 3.4 Summary of filtered ground water quality at the Grand Junction, Colorado, site (Continued)

Constituent/ sample location (well GRJ-01)	Frequency of detection[a]	Observed concentration		
		Minimum	Median[b]	Maximum
Calcium[e]				
Upgradient	30/30	325	445	595
Plume	33/33	360	545	654
Chloride[e]				
Upgradient	30/30	306	598	2400
Plume	33/33	490	791	970
Chromium				
Upgradient	5/26	<0.003	-	0.15
Plume	20/32	<0.001	0.01	0.03
Cobalt[e]				
Upgradient	2/22	<0.003	-	0.01
Plume (-0584)	6/6	0.05	0.14	0.66
Copper[e]				
Upgradient	10/26	0.003	-	0.03
Plume	22/33	<0.001	0.02	0.20
Cyanide				
Upgradient	0/20	<0.01	-	<0.01
Plume	0/13	<0.01	-	<0.01
Fluoride[e]				
Upgradient	26/26	0.6	1.0	1.7
Plume (-0581)	5/5	4.3	4.6	4.8
Iron[e]				
Upgradient	23/30	<0.005	0.4	2.2
Plume (-0581, -0585, -0586)	21/21	1.3	11	16
Lead				
Upgradient	2/24	<0.001	-	0.01
Plume	1/17	<0.001	-	0.01
Magnesium				
Upgradient	30/30	210	391	570
Plume	33/33	25	282	620

Table 3.4 Summary of filtered ground water quality at the Grand Junction, Colorado, site (Continued)

Constituent/ sample location (well GRJ-01)	Frequency of detection[a]	Observed concentration		
		Minimum	Median[b]	Maximum
Manganese[e]				
Upgradient	30/30	0.9	1.3	2.3
Plume (-0583, -0584, -0585, -0586)	26/26	1.8	4.1	10
Plume	3/23	<0.0001	-	0.0004
Molybdenum[e]				
Upgradient	28/28	0.01	0.11	0.23
Plume (-0583, -0584, -0585, -0586)	26/26	0.13	0.28	0.53
Nickel[e]				
Upgradient	5/26	<0.006	-	0.12
Plume (-0584)	3/3	0.28	0.32	0.38
Nitrate				
Upgradient	15/32	<0.1	-	16
Plume	11/28	<0.01	-	50
Phosphate				
Upgradient	4/14	<0.05	-	0.1
Plume	0/10	<0.1	-	<0.1
Potassium[e]				
Upgradient	30/30	4.2	8.1	12
Plume	33/33	49	96	120
Selenium				
Upgradient	16/32	<0.001	-	0.19
Plume	13/33	<0.002	-	0.24
Silica				
Upgradient	16/16	8	17	18
Plume	20/20	9	17	29
Silver				
Upgradient	1/20	<0.002	-	0.01
Plume	4/18	<0.002	-	0.004

Table 3.4 Summary of filtered ground water quality at the Grand Junction, Colorado, site (Continued)

Constituent/ sample location (well GRJ-01)	Frequency of detection[a]	Observed concentration		
		Minimum	Median[b]	Maximum
Sodium[e]				
Upgradient	30/30	345	659	910
Plume	33/33	520	950	1210
Strontium				
Upgradient	32/32	3.2	5.2	7.1
Plume	18/18	3.6	4.7	7.3
Sulfate[e]				
Upgradient	32/32	1450	2800	11,000
Plume (-0583, -0584, -0585, -0586)	26/26	3100	3945	4,900
Sulfide				
Upgradient	7/12	<0.1	0.4	40
Plume	2/5	<0.1	-	0.2
Thallium				
Upgradient	0/16	<0.005	-	<0.1
Plume	0/3	<0.1	-	<0.1
Tin				
Upgradient	4/22	<0.005	-	0.11
Plume	3/18	<0.005	-	0.008
Uranium[e]				
Upgradient	26/26	0.017	0.046	0.072
Plume (-0585, -0586)	4/4	0.29	0.30	0.45
Vanadium				
Upgradient	8/28	<0.005	-	0.11
Plume (-0584)	6/6	5.2	7.1	.14
Zinc[e]				
Upgradient	7/26	<0.002	-	1.0
Plume (-0584)	5/5	2.6	4.5	6.7

Table 3.4 Summary of filtered ground water quality at the Grand Junction, Colorado, site (Concluded)

Constituent/ sample location (well GRJ-01)	Frequency of detection[a]	Observed concentration		
		Minimum	Median[b]	Maximum
		Radionuclides (pCi/L)		
Lead-210				
Upgradient	0/4	<1.5	-	<1.5
Plume	4/10	<1.5	-	2.8
Polonium-210				
Upgradient	0/4	<1.0	-	<1.0
Plume	1/10	<1.0	-	1.1
Radium-226[e]				
Upgradient	26/32	0.0	0.1	2.3
Plume	19/22	0.0	2.1	29
Thorium-230				
Upgradient	18/22	0.0	0.1	0.6
Plume	6/17	0.2	-	5.4
Uranium-234[e]				
Upgradient	6/6	17	21	35
Plume	10/10	23	56	118
Uranium-238[e]				
Upgradient	6/6	11	15	27
Plume	10/10	23	58	116

[a] Frequency of detection = number of measurements above laboratory detection limit/total number of measurements.

[b] Calculation of the median requires that more than 50 percent of the measurements be above detection. A dash ("-") in the median column indicates that the median cannot be calculated.

[c] Upgradient concentrations are from monitor wells 745 and 746 (both sampled 1985 to 1993).

[d] Plume concentrations are from monitor wells GRJ-01-0583 and -0584 (sampled 1983 to 1985); -0581, -0585, and -0586 (sampled 1983 to 1989). Summary statistics are from all five wells unless otherwise noted.

[e] Constituent concentrations in plume wells are statistically elevated above upgradient concentrations.

pCi/L - picocuries per liter.

3.6.2 Uranium processing and process solutions

The Climax uranium mill at Grand Junction was the first American mill designed primarily for the production of uranium with vanadium as a by-product (Merritt, 1971). The milling process used at this site was somewhat more complex than that used at newer mills. The chemicals used in the milling process are listed in Table 3.5.

Table 3.5 Major chemicals used at the former Climax mill in Grand Junction, Colorado

Inorganics	Organics
Sulfuric acid	Number 2 fuel oil or kerosene
Hydrochloric acid	Di(2-ethylhexyl) phosphoric acid
Sodium chlorate	Tributyl phosphate
Ammonia	Tertiary amines
Sodium chloride	
Sodium carbonate	
Hydrogen peroxide	
Powdered iron metal	

From Merritt, 1971.

The chemicals used in the milling process and the resultant dissolution of many constituents from the raw ore (including uranium and vanadium) generated a large volume of acidic process water and waste material (see Section 3.1) that was deposited in the evaporation ponds and tailings pile at the Grand Junction site. The tailings contained significant amounts of water-soluble radiological and chemically hazardous constituents. Much of mostly acidic process water percolated through the tailings (see Section 3.1.3) and transported some of these water-soluble constituents from the tailings as leachate. Also, the Climax mill used an organic solvent extraction process to recover uranium from the pregnant solution during the milling process. However, ground water at the site was screened for the organic constituents listed in 40 CFR Part 264, Appendix IX, in 1988. Three monitor wells (GRJ-01-0583, -0736, and -0746) were sampled and no organic contamination, as represented by the Appendix IX analyte list, was found (Hill, 1989).

3.6.3 Magnitude and extent of ground water contamination

A large volume of acidic pore water from the tailings and acidic process water from the evaporation ponds has leached into and variably contaminated the alluvial ground water system below the Grand Junction site (see Section 3.1.3). The chemical interaction of the tailings leachate with the alluvial system resulted in TDS concentrations in ground water beneath the site ranging from 3000 to 10,000 mg/L.

This contaminated water is migrating along the ground water flow path shown in Figure 3.9 and ultimately discharges to the Colorado River as can be seen in the uranium isopleth map (Figure 3.15).

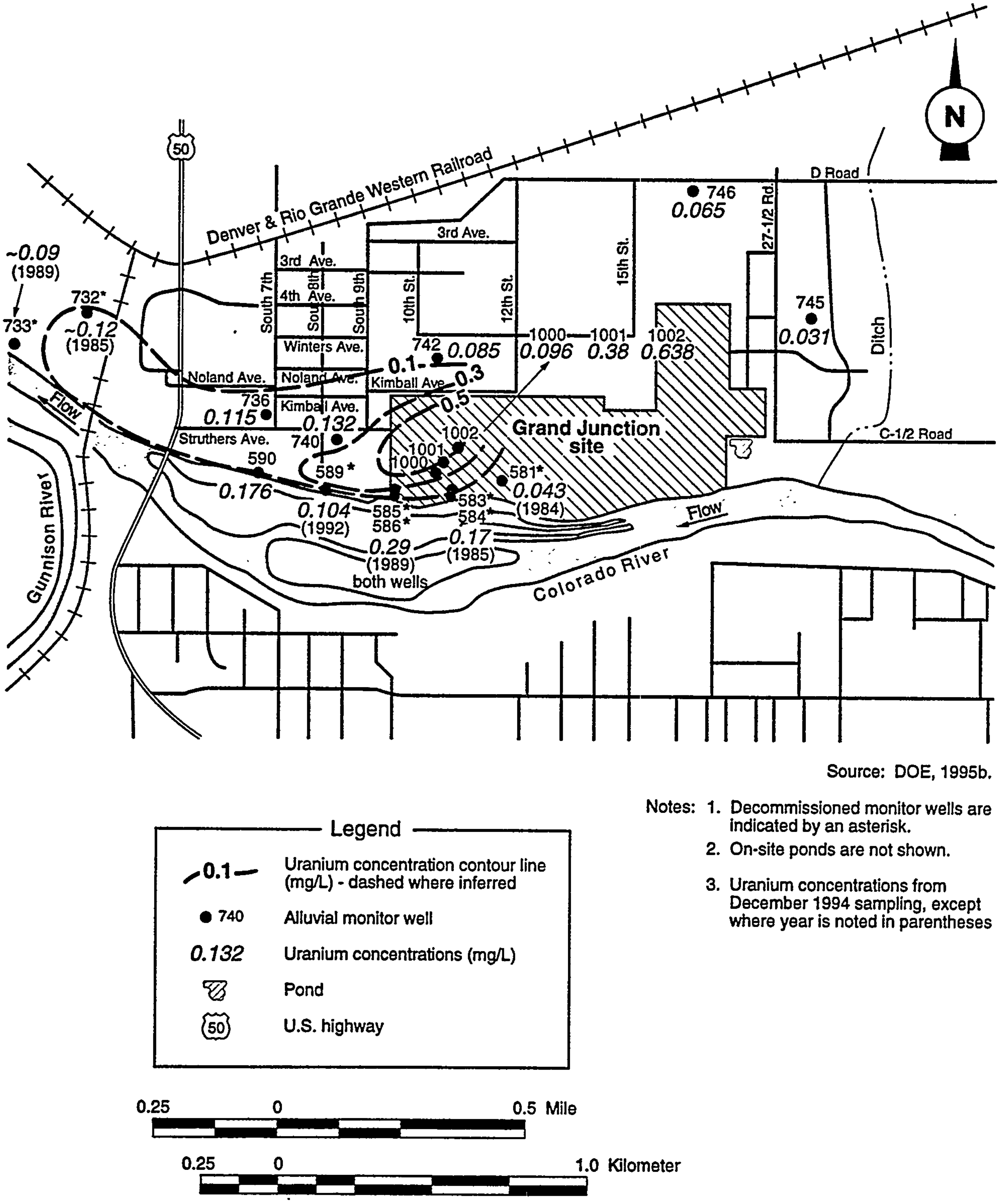
Monitor wells downgradient from the site commonly have levels of ammonium, uranium, chloride, and sulfate that are above upgradient levels. Ammonium is strongly adsorbed by clays and is not very mobile, however, and the migration of this constituent away from the site has lagged well behind the more mobile species such as sulfate, chloride, or uranium. The current downgradient extent of the contaminated ground water cannot be precisely defined because of the lack of recent chemical data from on-site and some downgradient monitor wells and the masking effects of the high upgradient levels of many of the most mobile tracer constituents (e.g., uranium, sulfate, and chloride) in the alluvium (Table 3.4).

The water quality data from monitor wells 581, 583, 584, 585, 586, 589, 740, 736, and 733 indicate that the wells farthest downgradient from the site, wells 736 and 733, show lower levels of potential site-related contamination than do the wells closer to the site. Therefore, these wells were eliminated from a determination of the magnitude of contamination.

Data from the other wells (581, 583, 584, 585, 589, 740, and 590) were analyzed to identify where the highest levels of contamination occurred before the tailings pile was removed and to quantify those levels. The analysis was complicated by the fact that the wells on the site have not been sampled recently and, in fact, no longer exist. On-site concentrations of milling-related contaminants between 1983 and 1989 were generally higher than off-site levels during the same time period, as well as higher than subsequent off-site levels measured between 1991 and 1993. Trend analyses of five constituents associated with uranium milling (chloride, sulfate, ammonium, uranium, and molybdenum) suggest that molybdenum concentrations at the site decreased by about half between 1983 and 1989. On-site sulfate concentrations may also be decreasing, but only slightly. Chloride, ammonium, and uranium concentrations were steady. These data indicate that, as expected, some constituents (molybdenum and possibly sulfate) are being attenuated by adsorption and precipitation processes at the site. Analysis of water from monitor wells 1000, 1001, and 1002 (which were installed after the tailings were removed) indicates that there have been no appreciable changes in contaminant distribution in the short time since tailings were removed.

The off-site wells located near, but downgradient from, the site (589, 590, and 740) were also studied for possible time trends in concentration levels. Between 1983 and 1995, chloride and sulfate levels in well 589 appear to have peaked and may be starting to decline. Uranium levels in this well are clearly decreasing with time. In the two other off-site wells, 590 and 740, located slightly farther from the site, chloride and sulfate concentrations appear to be increasing, but uranium is fairly steady with time. Although wells located off the site show

Figure 3.15
Distribution of Uranium in Alluvial Ground Water in the Grand Junction, Colorado, Site Vicinity



Source: DOE, 1995b.

Notes:
1. Decommissioned monitor wells are indicated by an asterisk.
2. On-site ponds are not shown.
3. Uranium concentrations from December 1994 sampling, except where year is noted in parentheses

MAC: SITE/GRJ/SOWP/URANALLUV

trends over time between 1983 and 1995, these trends do not necessarily agree in magnitude or direction. Based on these analyses, it was concluded that the highest concentrations of milling-related contaminants in the alluvial aquifer probably are still under the site itself at levels comparable to those measured in 1989. Ground water quality in on-site wells 581 and 583 through 586 from 1983 to 1989 is summarized in Table 3.4.

3.6.4 Surface water quality

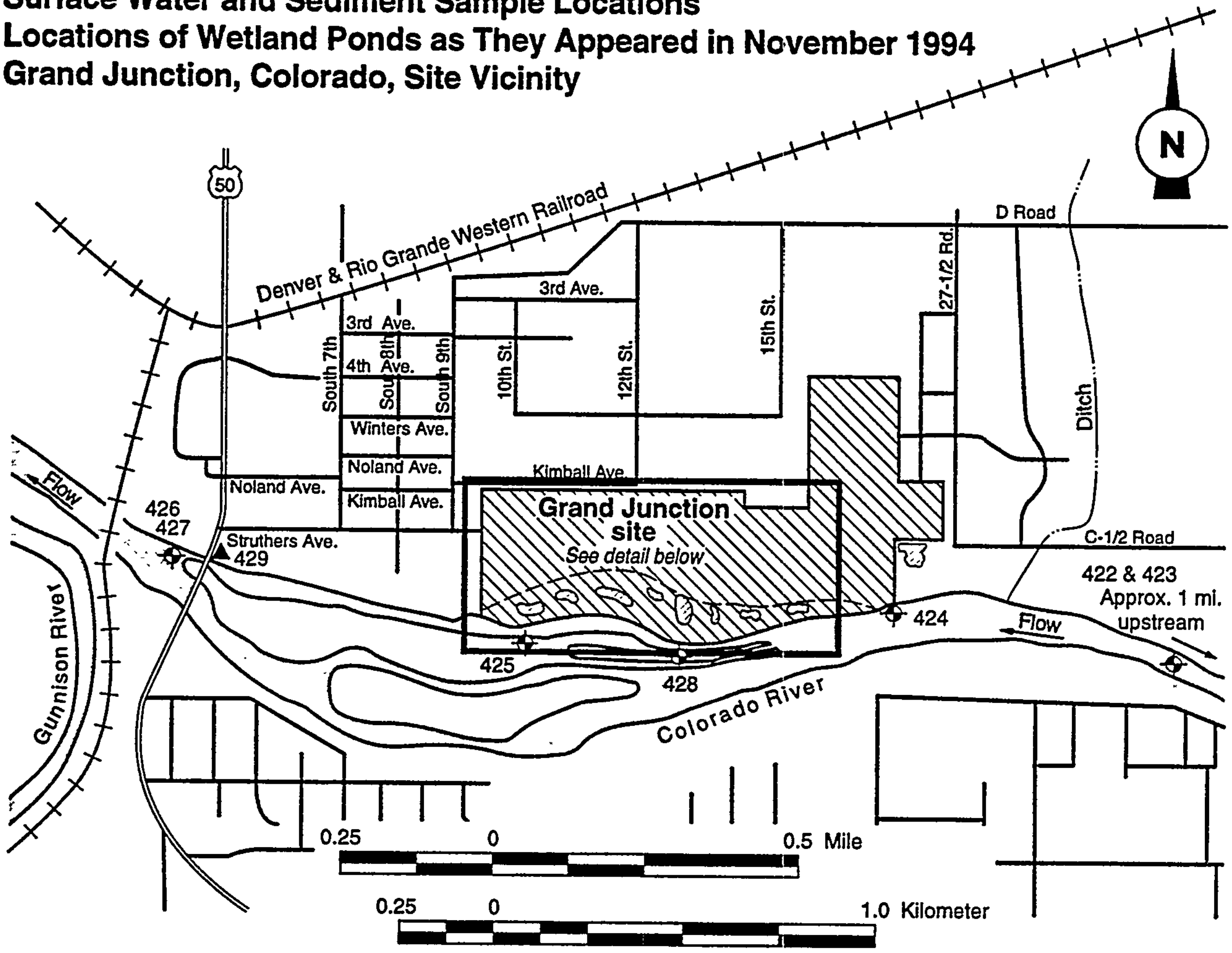
Surface water quality has been monitored for several years in the Colorado River in the vicinity of the Grand Junction site. The locations of the surface water sampling points are shown in Figure 3.16. Five locations have been sampled: one location upstream of the site, three locations adjacent to the site, and one location downstream of the site. Filtered samples were collected once, in 1991, from upstream of the site (location 423), adjacent to the site (locations 424 and 425), and downstream of the site (location 427). Between 1991 and 1993, six rounds of unfiltered samples were collected from these four locations. It should be noted that some of the sampling events occurred during low-flow conditions, which provides a conservative picture of ground water contribution to the river. At the upstream and downstream locations, the unfiltered samples were designated with location identifications of 422 and 426, respectively. One unfiltered sample was collected from location 428 in 1993. The samples collected from 1991 through 1992 were analyzed for a full suite of analytes. The samples collected in September 1993 were analyzed for a select list of analytes (molybdenum, selenium, strontium, sulfate, and uranium). Sediment samples were also collected in September 1993 from the same five surface water locations and analyzed for the same constituents.

Surface water data from the Colorado River show that most of the constituents detected at the adjacent and downstream locations were not greater than their respective upstream concentrations. From the list of ground water contaminants that are identified as exceeding upgradient ground water quality (Table 3.4), only ammonium, copper, iron, radium-226, uranium, and vanadium were detected at concentrations slightly above upstream levels at the adjacent locations adjacent to or downstream from the site. However, the differences are not statistically significant. This indicates that site-related contamination has not adversely affected the water quality of the Colorado River.

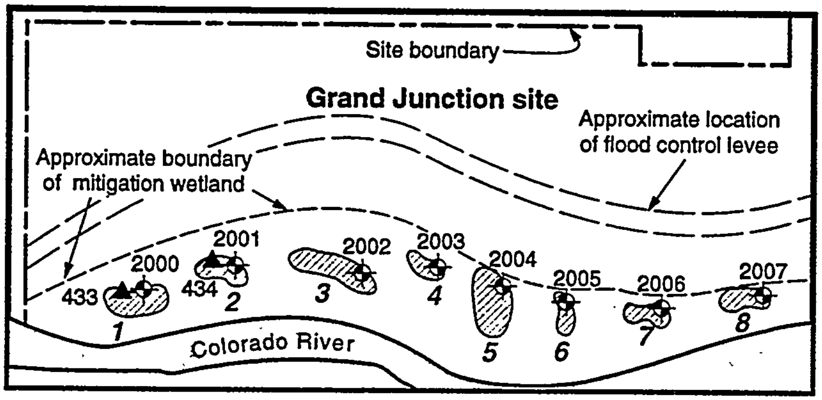
A series of eight ponds, illustrated in Figure 3.16, were constructed in a wetland along the southern boundary of the site in 1994. These ponds were sampled once in January 1995 before they were destroyed by flooding in the late spring and early summer of 1995. Observations in September 1995 indicate that ponds 1 and 2 were completely filled with silt and had no water in them. The remaining ponds held much less water then when they originally were constructed.

These ponds were fed by ground water and, thus, provide some indication of the distribution of ground water contamination at the site. For example, the most

Figure 3.16
Surface Water and Sediment Sample Locations
Locations of Wetland Ponds as They Appeared in November 1994
Grand Junction, Colorado, Site Vicinity



Source: DOE, 1995b.



Detail of surface water sampling locations

Notes:
1. Data collected January 1995.
2. Samples are filtered.
3. On-site ponds shown as they appeared in November 1994.

Legend

⌖ 2007	Surface water and sediment sampling location	▨ 7	Pond
▲ 433	Staff gauge	50	U.S. highway

MAC: SITE/GRJ/SOWP/WETPONDS

highly contaminated ponds were the two at the western edge of the site, indicating that the bulk of ground water contamination is located in the western portion of the site. However, constituent levels in these ponds probably had been increased by evaporation relative to constituent levels in nearby monitor wells. By way of illustration, the uranium concentration in ground water in monitor well 1000 is 0.096 mg/L while the surface water in pond 2000, less than 200 ft (60 m) downgradient, contained 0.473 mg/L of uranium (approximately a five-fold increase). Data from the January 1995 sampling of ponds at the Grand Junction site are given in Table 3.6.

3.6.5 Constituents of potential concern

The data summarized in Table 3.4 were used to compile a list of constituents of potential concern for the assessment of potential human health and ecological risks at the Grand Junction site (Table 3.7). A constituent was placed on the list if concentrations of the constituent in on-site wells were, on average, higher than those in the off-site upgradient wells (DOE, 1995b).

The constituents identified in the first column of Table 3.7 were screened for their impact on human health, using the criteria discussed below to develop a final list of constituents of potential concern for human health. If the maximum detected concentration of a constituent on the screening list fell into acceptable nutritional requirement levels that would not be exceeded with exposure, it was not retained as a constituent of potential concern. The constituents that fell into this category were calcium, chloride, and potassium. If the maximum detected concentration of a constituent on the screening list fell into the high end of expected dietary ranges but was of low toxicity, it was not retained as a constituent of potential concern. The constituents that fell into this category were ammonium, copper, and sodium. All remaining constituents on the list are considered constituents of potential concern because of the potential for toxic effects if people are exposed to the constituents at their maximum detected levels in ground water. These constituents were evaluated quantitatively in the BLRA (DOE, 1995b).

3.6.6 Fate and transport of constituents of potential concern

Although the aqueous speciation of a constituent in solution is one of the major determinants of its mobility in an aquifer, speciation can also influence the toxicity of some constituents. For example, trivalent arsenic species are more toxic to humans than arsenic in the pentavalent state. To determine the probable predominant species for the constituents of potential concern, the geochemical code PHREEQE (Parkhurst et al., 1980) was used to model the ground water chemistry of plume-affected alluvial ground water. Although the redox state of the ground water at Grand Junction is not well defined, the dominant solution species for the constituents of potential concern at a redox potential (Eh) of 150 millivolts (mV) are listed in Table 3.8. An Eh of 150 mV is a realistic estimate given the overall chemistry of the alluvial aquifer.

Table 3.6 Concentrations of selected constituents in water from the January 1995 sampling of ponds at the Grand Junction, Colorado, site

	Sample ID							
	Concentrations							
Constituent	2000 (pond 1)	2001 (pond 2)	2002 (pond 3)	2003 (pond 4)	2004 (pond 5)	2005 (pond 6)	2006 (pond 7)	2007 (pond 8)
Arsenic	<0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.005
Cadmium	0.003	0.004	0.04	0.001	<0.001	<0.001	0.001	<0.001
Cobalt	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride	4	3	2.2	8	2.5	2	0.8	0.6
Iron	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.27
Manganese	0.84	2.36	1.97	0.33	2.71	0.49	0.78	1.02
Molybdenum	0.18	0.09	0.02	0.07	0.05	<0.01	0.01	<0.01
Nickel	0.07	0.07	0.04	0.04	<0.04	<0.04	<0.04	<0.04
Radium-226	0.1	0.6	0.4	0.1	0.1	0.2	0.4	0.3
Sulfate	4960	3380	2690	4320	2710	2510	3180	463
Uranium	0.473	0.154	0.04	0.032	0.068	0.039	0.07	0.023
Vanadium	0.47	0.43	0.03	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.05	0.21	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Note: Refer to Figure 3.16 for pond locations.

Concentrations are reported in milligrams per liter, except for radium-226, which is reported in picocuries per liter.

Table 3.7 Constituents of potential concern for human health evaluation, Grand Junction, Colorado, site

Constituents that exceed upgradient levels	Constituents in nutritional range	Constituents of low toxicity and/or high dietary range	Constituents of potential concern
Ammonium		X	
Arsenic			X
Calcium	X		
Cadmium			X
Chloride	X		
Cobalt			X
Copper		X	
Fluoride			X
Iron			X
Manganese			X
Molybdenum			X
Nickel			X
Potassium	X		
Radium-226			X
Sodium		X	
Sulfate			X
Uranium			X
Vanadium			X
Zinc			X

Table 3.8 Aqueous species of constituents of potential concern in the alluvial aquifer at the Grand Junction, Colorado, site[a]

Constituent of potential concern	Nomenclature	Aqueous species	Valence state	Molar percent
Arsenic	Arsenate	$HAsO_4^{2-}$	As(V)	80
	Arsenate	$H_2AsO_4^-$	As(V)	20
Cadmium	Cadmium	Cd^{2+}	Cd(II)	28
	Cadmium sulfate	$CdSO_{4AQ}$	Cd(II)	24
	Cadmium chloride	$CdCl^+$	Cd(II)	21
	Cadmium bicarbonate	$CdHCO_3^+$	Cd(II)	9
	Cadmium carbonate	$CdCO_{3AQ}$	Cd(II)	8
	Cadmium disulfate	$Cd(SO_4)_2^{2-}$	Cd(II)	9
	Cadmium dichloride	$CdCl_{2AQ}$	Cd(II)	1
Cobalt[b]	Cobalt carbonate[b]	$CoCO_{3AQ}$	Co(II)	80
	Cobalt[b]	Co^{2+}	Co(II)	20
Fluoride	Fluoride	F^-	F(I)	86
	Magnesium fluoride	MgF^+	F(I)	14
	Calcium fluoride	CaF^+	F(I)	0
Iron	Ferrous iron	Fe^{2+}	Fe(II)	66
	Ferrous sulfate	$FeSO_{4AQ}$	Fe(II)	32
Manganese	Manganese	Mn^{2+}	Mn(II)	61
	Manganese sulfate	$MnSO_{4AQ}$	Mn(II)	33
	Manganese bicarbonate	$MnHCO_3^+$	Mn(II)	4
	Manganese chloride	$MnCl^+$	Mn(II)	2
Molybdenum[c]	Molybdate	MoO_4^{2-}	Mo(VI)	100
Nickel	Nickel carbonate	$NiCO_{3AQ}$	Ni(II)	79
	Nickel	Ni^{2+}	Ni(II)	10
	Nickel sulfate	$NiSO_{4AQ}$	Ni(II)	5
	Nickel bicarbonate	$NiHCO_3^+$	Ni(II)	4
	Nickel dicarbonate	$Ni(CO_3)_2^{2-}$	Ni(II)	1

Table 3.8 Aqueous species of constituents of potential concern in the alluvial aquifer at the Grand Junction, Colorado, site[a] (Concluded)

Constituent of potential concern	Nomenclature	Aqueous species	Valence state	Molar percent
Sulfate	Sulfate	SO_4^{2-}	S(VI)	95
	Calcium sulfate	$CaSO_{4AQ}$	S(VI)	1
	Magnesium sulfate	$MgSO_{4AQ}$	S(VI)	14
	Sodium sulfate	$NaSO_4^-$	S(VI)	5
	Ammonium sulfate	$NH_4SO_4^-$	S(VI)	4
Uranium	Uranyl tricarbonate	$UO_2(CO_3)_3^{4-}$	U(VI)	86
	Uranyl dicarbonate	$UO_2(CO_3)_2^{2-}$	U(VI)	13
Vanadium	Vanadium trihydroxide	$V(OH)_3^+$	V(IV)	86
	Vanadium oxide	VO^{2+}	V(IV)	8
	Vanadium oxide	$H_2V_2O_4^{2+}$	V(IV)	0
	Vanadium sulfate	$VOSO_{4AQ}$	V(IV)	5
	Vanadium fluoride	VOF^+	V(IV)	1
	Vanadate	$HV_2O_7^{3-}$	V(V)	81
	Vanadate	$H_2VO_4^-$	V(V)	16
	Vanadate	HVO_4^{2-}	V(V)	3
Zinc	Zinc	Zn^{2+}	Zn(II)	38
	Zinc sulfate	$ZnSO_{4AQ}$	Zn(II)	28
	Zinc bicarbonate	$ZnHCO_3^+$	Zn(II)	13
	Zinc carbonate	$ZnCO_{3AQ}$	Zn(II)	9
	Zinc disulfate	$Zn(SO_4)_2^{2-}$	Zn(II)	8
	Zinc dicarbonate	$Zn(CO_3)_2^{2-}$	Zn(II)	2

[a] Ground water quality analysis from well GRJ-01-0586 (1989 sampling round) and maximum concentrations of constituents of potential concern (excluding sulfate) (Table 3.4) were used as input for the model. Aqueous species were calculated using the geochemical code MINTEQA2/PRODEFA2 (Allison et al., 1991). Select speciation information was taken from Brookins (1988).

[b] Estimated from Eh-pH diagram (Brookins, 1988) and the similar behavior of nickel and cobalt in an aqueous environment.

[c] Estimated from Eh-pH diagram (Brookins, 1988).

Fate and transport of metallic constituents

The solubility and mobility of metals and metalloids (e.g., iron, chromium, arsenic, and selenium) vary dramatically as a function of water chemistry (e.g., pH, Eh, and ionic strength), aquifer matrix composition, and the chemical characteristics of the constituent. Nevertheless, some basic similarities in the aqueous chemistry of many metallic constituents allow us to group the constituents of potential concern at the Grand Junction site according to similar fate and transport characteristics.

All of the metallic and semimetallic constituents are pH-sensitive and can be solubilized and transported by ground water under acidic conditions. Some of these metals (e.g., zinc, cadmium, and nickel) are relatively insensitive to aqueous Eh conditions but form soluble cationic species under acidic ground water conditions. These constituents will generally reprecipitate (e.g., as hydroxide or carbonate compounds) or be readsorbed by the aquifer matrix once the pH and/or alkalinity of the affected water is increased to near upgradient levels by reacting with the aquifer matrix or by mixing with uncontaminated water.

Other metals and metalloids (e.g., iron, manganese, arsenic, uranium, and vanadium) are sensitive to pH and Eh conditions. Once adsorbed or precipitated, they can be remobilized by a significant change in the ambient state of either of these important ground water and aquifer parameters.

The metallic constituents of potential concern listed in Table 3.8 can be placed into the following groups based on similar fate and transport characteristics.

Iron and manganese - Iron and manganese were solubilized from the tailings and subpile aquifer matrix by the acidic tailings pore solutions that interacted with them. Tailings pore fluids were strongly oxidizing and the conditions in the shallow ground water on-site affected by tailings pore fluids are probably relatively oxidizing. Under oxidizing conditions, iron and manganese will hydrolyze and precipitate as oxyhydroxides once the pH approaches neutral values. Although this process can occur at lower values of pH (5.0 to about 6.5), the kinetics of oxidation and hydrolysis are slower. The oxidation of manganese in particular is very sensitive to pH, and this element can persist in solution as Mn^{2+} under somewhat oxidizing ground water conditions if the pH is much below about 7.5 to 8.0.

Nickel, cobalt, and zinc - The precipitation of iron and manganese as hydroxides, as acidity is neutralized by reacting with the aquifer matrix and by mixing with alkaline ground water, can be of critical importance for the fate of many other trace constituents. Iron and manganese hydroxides have a high affinity for many trace constituents, and the precipitation of these hydroxides can sweep other potentially toxic metals such as cobalt, nickel, thorium, and zinc from ground water. Under the typical pH range of 6.0 to 8.0 observed for the alkaline (alkalinity of near 400 mg/L $CaCO_3$) ground water in the alluvial aquifer, cobalt, nickel, and zinc should rapidly approach upgradient levels in downgradient ground water.

Cadmium - Cadmium will be rapidly removed by the precipitation of octavite ($CdCO_3$) and by hydrolysis reactions as the low pH of the tailings leachate is neutralized by alkaline ground water and calcite ($CaCO_3$) in the aquifer matrix. Dilution with upgradient water will produce cadmium concentrations in downgradient ground water that are typically below detection limits. Elevated levels of cadmium should be restricted to the areas underneath or immediately adjacent to the former tailings pile.

Radium - Radium solubility and mobility at the Grand Junction site should be extremely low. Radium forms a highly insoluble sulfate compound and commonly co-precipitates with barite ($BaSO_4$). Radium also has a high adsorption affinity for clays and for iron and manganese hydroxides.

Arsenic, uranium, molybdenum, and vanadium - Some other metallic constituents of potential concern such as arsenic, uranium, molybdenum, and vanadium commonly form stable anionic species under near-neutral to alkaline conditions, and they will not precipitate immediately or be completely swept by the precipitation of iron and manganese hydroxides. These constituents can be transported for significant distances under oxidizing, near-neutral to alkaline ground water conditions before they are eventually absorbed by the matrix and/or diluted to upgradient levels by mixing with uncontaminated ground water.

Fate and transport of nonmetallic constituents

As with the metallic constituents, the fate and transport of nonmetallic constituents also varies in the aquifer. Fluoride and sulfate are the only two nonmetallic constituents of potential concern identified for the Grand Junction site. The fate and transport characteristics of these constituents are discussed below.

Fluoride - Fluoride is elevated relative to upgradient levels in the tailings leachate and leachate-contaminated ground water at the Grand Junction site (Table 3.4). Geochemical modeling of upgradient ground waters, plume-affected ground water, and acidic tailings leachate indicated that all of these waters approached or slightly exceeded saturation with fluorite (CaF_2). This suggests that the upper limit on fluoride concentrations in the alkaline, plume-contaminated on-site and near-downgradient ground water will be set by the precipitation of fluorite. As the plume migrates farther downgradient, dilution with river water and adsorption of fluoride on aquifer sediments could reduce the concentration of this constituent below levels required to maintain equilibrium with fluorite.

Sulfate - Adsorption reactions are not likely to have a significant effect on the sulfate concentrations in the shallow ground water because of the relatively high concentrations involved and the gypsum-rich mineralogy of the sediments. There is some evidence that gypsum precipitation predominantly is reducing sulfate concentrations, possibly because the shallow ground water in and around the former tailings pile area is oversaturated with gypsum. Since the tailings have been removed, the ground water sulfate concentrations in these areas should decrease. Eventually, as sulfate levels drop below gypsum saturation, the gypsum that has precipitated previously will begin to redissolve. The dissolution of gypsum will buffer the sulfate concentrations at fairly high levels at the site until the gypsum supply is exhausted. At this point, sulfate concentrations at the site should equal concentrations that are observed in upgradient wells.

3.7 HUMAN HEALTH RISK SUMMARY

The BLRA for the Grand Junction site evaluated the potential for adverse human health effects to occur if people were exposed to the ground water at the site (DOE, 1995b).

3.7.1 Ground water and land use

The Grand Junction site is located in a primarily urbanized area, with commercial, industrial, and residential development nearby. To the north, northeast, and west of the site, residences have been replaced with commercial and industrial establishments. Some residences are interspersed with commercial properties west of the site. The location of the Denver and Rio Grande Western Railroad makes the area near the site desirable for industrial development. Currently, the site and the area surrounding the site are zoned industrial. Thus, the probability of the site land or the land near the site being used for residences or agricultural purposes is highly unlikely.

In the vicinity of the Grand Junction site and the majority of the Grand Valley area, municipal and industrial water needs are supplied by surface water. Most of the surface water for the Grand Valley area originates from the Grand Mesa. The Grand Junction zoning and development code requires that all development be served by the city water treatment and distribution system. The municipal water system is supplied by surface water from the Juniata and Purdy Mesa reservoirs. Ground water is not used in the Grand Junction area because of the naturally poor water quality. Water use surveys indicate there are no known current users of affected ground water in the alluvial aquifer at or near the site (DOE 1995b). Consequently, there is a low potential for shallow ground water to be used in the future. Nonetheless, the risk assessment evaluated the hypothetical future use of ground water for domestic purposes. Domestic ground water use is defined in this SOWP as ground water used for drinking, cooking, bathing, and other purposes such as irrigating gardens and watering livestock.

3.7.2 Methods

Constituents of potential concern were identified for the Grand Junction site by evaluating site-related data using the procedure discussed in Section 3.6.5.

Arsenic, cadmium, cobalt, fluoride, iron, manganese, molybdenum, nickel, radium-226, sulfate, uranium, vanadium, and zinc are evaluated quantitatively in the BLRA for the potential to adversely affect human health (DOE, 1995b).

Four potential routes of exposure were evaluated: ingestion of ground water as drinking water, dermal contact with ground water while bathing, ingestion of garden produce irrigated with ground water, and ingestion of fish that inhabit the Colorado River. Exposure doses were calculated for these exposure routes (except for the fish ingestion exposure route) by using the maximum detected concentration from the most contaminated plume wells. The concentrations in fish were calculated by using surface water quality data.

A ratio of the exposure dose from each exposure route relative to the exposure dose from ground water ingestion (as drinking water) was calculated. The results indicated that adverse toxic responses to exposure to contaminants from routes other than drinking water would not be expected. Therefore, it was determined that ingesting ground water as drinking water would be the primary contributor to total exposure, relative to all other exposure routes. Consequently, the use of ground water as drinking water was evaluated probabilistically.

Currently, no one uses the contaminated ground water. Furthermore, use of the contaminated ground water in the future is unlikely because the Grand Junction zoning and development code restrictions. In addition, natural ground water is of poor water quality and has unpleasant taste and odor. However, the BLRA (DOE, 1995b) evaluated the use of a hypothetical well for drinking water at some point in time in the future.

Probability distributions for constituent concentrations and exposure variables (that is, body weight, drinking water ingestion rates, exposure frequency, and exposure duration) were integrated to estimate the range of constituent exposure doses people could ingest from a hypothetical well constructed in the most contaminated portion of the plume. Children (1 to 10 years) were evaluated for these exposure scenarios because children consume more water on a body-weight basis than adults and consequently ingest a higher constituent dose than adults. However, when a subpopulation was identified as more sensitive to exposure to certain constituents, that population was evaluated. At the Grand Junction site, infants have been identified as the population most sensitive to sulfate. Adults were evaluated for the carcinogenic effects of arsenic, uranium, and radium-226 for an exposure duration of 70 years. The estimated range of exposure doses from constituents of potential concern a person could ingest through drinking water were compared to toxic effects these constituent levels could cause.

3.7.3 Potential impacts from contaminated ground water

As stated previously, no one currently uses the ground water contaminated by former uranium processing activities and, therefore, no human health risks have resulted from the use of the water. However, the assessment of a hypothetical well constructed in the future in the most contaminated area beneath the site would indicate that certain health risks could occur if the contaminated ground water were ingested as drinking water. It should be noted that only the people who drink all their water from the most contaminated portion of the plume could experience the adverse health effects discussed in this document. The risk assessment evaluation provides the upper limit of possible risks; therefore, this future scenario evaluation probably overestimates real risks.

The most severe noncarcinogenic health effects could occur due to the water's sulfate and manganese content and to a lesser extent fluoride, vanadium, cadmium, iron, arsenic, molybdenum, zinc, and nickel. Short-term effects from sulfate exposure would be severe diarrhea quickly leading to dehydration, especially in infants. Manganese exposure could cause memory loss, irritability, muscle rigidity, and, at higher exposures, Parkinson's-like effects.

Long-term fluoride exposure could result in dental damage (mottling) in children. Additionally, at higher doses and over a long time (10-20 years), a crippling skeletal disease could develop in adults. Vanadium exposure could cause sudden drops in cholesterol levels and cramps. A distinguishing feature of vanadium exposure is the development of a green tongue. Long-term cadmium exposure could result in an increase in proteins detected in the urine indicating kidney dysfunction. Long-term iron exposures could cause pigmentation of the skin and liver dysfunction, which could lead to cirrhosis of the liver and/or diabetes. Arsenic exposure could cause arterial thickening and skin disorders with long-term exposure. Molybdenum exposure could cause mineral imbalances with a loss of copper from the body causing anemia with long-term exposure. Zinc exposure could cause a decreased ability for copper to be absorbed resulting in a breakdown of biological processes in the body. People exposed to nickel could develop allergic dermatitis.

Carcinogenic risk estimates were calculated for the radionuclides uranium and radium-226. The increased individual excess lifetime cancer risk from exposure to uranium was estimated to be 3×10^{-4}, or three chances in 10,000 of developing cancer; for radium-226 the cancer risk was estimated to be 2×10^{-4}, or two chances in 10,000 of developing cancer. The increased individual lifetime cancer risk from exposure to arsenic was estimated to be 4×10^{-3}, or four chances in 1000 of developing cancer. The estimated risk levels for arsenic, uranium, and radium-226 exceed the EPA-recommended risk level for carcinogens of 1×10^{-4}, or one chance in 10,000 of developing cancer (40 CFR Part 300).

If exposure doses from the other exposure routes (dermal contact with ground water or eating garden produce or fish) are added to the exposure from the drinking water exposure route, the exposure concentrations would not be expected to substantially increase the potential for adverse health effects. Additionally, adverse health effects would not be expected from these exposure routes if they were the only routes of exposure.

3.7.4 Potential impacts from background ground water

Background ground water quality is discussed in Section 3.6.1. Water quality data from upgradient wells 745 and 746 were used to evaluate background ground water quality in the BLRA. As previously discussed, there is some uncertainty related to using these wells for characterizing background ground water quality. Therefore, regional ground water quality data are also used to assess background conditions in this SOWP. This section presents an evaluation of background ground water quality from a human health-based perspective to determine if background ground water would be suitable to ingest as drinking water.

Comparison to federal standards

Ground water quality data from upgradient wells 745 and 746 and USGS regional ground water data are compared to federal water quality standards in Table 3.10. As seen in this table, levels of sulfate, TDS, manganese, iron, fluoride, and chloride exceed the national secondary drinking water levels (40 CFR Part 143) in regional ground water. These levels are based on aesthetics of the water such as taste and odor. This comparison shows that upgradient and regional background ground water is considered unpalatable as drinking water. Also, since the regional ground water exhibits maximum TDS concentrations of greater than 10,000 mg/L, it may be classified as a limited-use aquifer under 40 CFR Part 192.

Selenium and uranium concentrations in background ground water exceed MCLs and the national primary drinking water level for selenium (40 CFR Part 141). Uranium concentrations have been detected in regional ground water at levels as high as at the Grand Junction site (0.45 mg/L). Selenium has been detected in regional ground water at concentrations more than five times higher than at the site.

3.7.5 Potential public health impacts from drinking background ground water

Potential public health impacts from using background ground water as drinking water are assessed by calculating point-exposure doses and comparing the exposure doses to toxic effect levels observed for the constituents of potential concern.

In the BLRA (DOE, 1995b), exposure doses are calculated for all constituents statistically detected above background at the site. Maximum concentrations of the constituents in the upgradient wells 745 or 746 and the regional background wells are used in these calculations (see Table 3.9). Selenium is also evaluated because it is detected in high concentrations in regional ground water relative to the concentrations found at the site. The potential receptors assessed were children, infants, and adults. The exposure dose calculations, which followed

Table 3.9 Comparison of concentrations of constituents in the Grand Junction, Colorado, site vicinity to federal standards

Constituent	Upgradient range[a] (min - max)	Regional range[b] (min - max)	NSDWR[c]	NPDWR[d]	UMTRA[e]
Ammonium	ND - 0.6	ND - 3	-	-	-
Arsenic	0.001 - 0.04	ND - 0.002	-	0.05	0.05
Calcium	325 - 595	98 - 610	-	-	-
Cadmium	ND - 0.04	ND - 0.002	-	0.005	0.01
Chloride	306 - 2400	140 - 2500	250	-	-
Cobalt	ND - 0.01	NA	-	-	-
Copper	0.003 - 0.03	ND - 0.016	1	-	-
Fluoride	0.6 - 1.7	0.2 - 3.1	2	4	-
Iron	ND - 2.2	ND - 0.5	0.3	-	-
Manganese	0.9 - 2.3	ND - 0.93	0.05	-	-
Molybdenum	0.01 - 0.23	ND - 0.015	-	-	0.1
Nickel	ND - 0.12	NA	-	0.1	-
Potassium	4.2 - 12	2.1 - 19	-	-	-
Radium-226	0 - 2.3	NA	-	-	5[f]
Selenium	ND - 0.19	ND - 1.3	-	0.05	0.01
Sodium	345 - 910	310 - 3200	-	-	-
Sulfate	1450 - 11,000	2000 - 9700	250	-	-
TDS	3000 - 7200	3300 - 16,100	500	-	-
Uranium	0.017 - 0.072	0.0085 - 0.74	-	-	0.044
Vanadium	ND - 0.11	0.003 - 0.17	-	-	-
Zinc	ND - 1.0	NA	5	-	-

[a] Range from upgradient background wells GRJ-01-0745 and GRJ-01-0746.
[b] Range from regional background data near the Grand Junction site (Butler et al., 1994).
[c] 40 CFR Part 143.
[d] 40 CFR Part 141.
[e] 40 CFR Part 192, as amended by 60 FR 2854.
[f] UMTRA MCL is 5 pCi/L for radium-226 and radium-228 combined.

Concentrations in milligrams per liter except for radium-226, which is picocuries per liter.
ND - not detected at the method detection limit.
NA - not analyzed.
NSDWR = national secondary drinking water regulations.
NPDWR - national primary drinking water regulations.

UMTRA Ground Water Project methodology (DOE, 1994a), used the following drinking water exposure variables:

- A 1- to 10-year-old child with an average weight of 22 kilograms (kg) and an average ingestion rate of 0.7 liters per day (L/day) of ground water for 350 days per year for 10 years.
- Since infants are more sensitive to sulfate exposure, sulfate is evaluated for an infant weighing an average of 4 kg with an average ingestion rate of 0.64 L/day of ground water for 350 days per year for 1 year.
- Arsenic is evaluated for an adult weighing 70 kg with an average ingestion rate of 2 L/day of ground water for 350 days per year for 30 years. These same parameters are used to evaluate radionuclides; however, body weight was not factored into the calculations because it is relatively insignificant when calculating exposure doses for radionuclides.

Table 3.10 presents the point-exposure dose calculation results. The doses are expressed in milligrams per kilogram of body weight per day. A graphic summary of the exposure doses where toxic effects are likely to occur are also presented in Appendix C.

The results of the assessment indicate that, if the regional ground water were ingested as drinking water, sulfate, selenium, manganese, sodium, chloride, and fluoride have the potential to cause adverse health effects. Likewise, from the upgradient wells 745 or 746, sulfate, manganese, and chloride have the potential to cause adverse health effects.

The individual excess lifetime cancer risk calculated for the upgradient background ground water, as represented by wells 745 and 746, shows that the cancer risk for arsenic (8×10^{-4}) exceeds the EPA-recommended risk level of 1×10^{-4} (40 CFR Part 300).

The conclusion of the point exposure dose evaluation and comparison to standards of upgradient and regional background ground waters substantiates that the background ground water in the Grand Junction area is poor. That is, drinking the background ground water could cause adverse health effects. In addition, the water is unpalatable due to high levels of sulfate, TDS, manganese, iron, fluoride, and chloride.

3.8 ECOLOGICAL RISK SUMMARY

This section summarizes the ecological screening evaluation performed in the BLRA for the Grand Junction site (DOE, 1995b). The methodology used to evaluate the ecological risk at the site followed EPA guidance (EPA, 1989). In late 1994, subsequent to preparation of the BLRA, eight ponds were constructed in the floodplain of the Colorado River over the Grand Junction site contaminant plume (Figure 3.16). These ponds were constructed as part of wetland

4.0 GROUND WATER COMPLIANCE STRATEGY SELECTION

This section describes the ground water compliance strategy selection process, explains the application of site-specific data to select the proposed ground water compliance strategy for the Grand Junction site, identifies data needs for the conceptual site model, and discusses handling possible deviations from the conceptual site model and the proposed strategy and contingency planning.

4.1 COMPLIANCE STRATEGY SELECTION PROCESS

The UMTRA Ground Water Project has developed the selection framework shown in Figure 4.1 to apply to individual sites to determine the appropriate strategy for achieving compliance with the ground water standards (40 CFR Part 192, as amended by 60 FR 2854). This compliance strategy selection framework is identified in the UMTRA Ground Water Project draft PEIS as the proposed action (DOE, 1995a). This risk-based, decision-making framework provides for the selection of one or more of the three ground water compliance strategies defined below.

No remediation. Application of the no remediation strategy would mean that compliance with the ground water protection standards would be met without altering the ground water or cleaning it up in any way. This could be applied at sites that have no contamination above MCLs or background levels, or at sites that have contamination above MCLs or background levels but qualify for supplemental standards or ACLs.

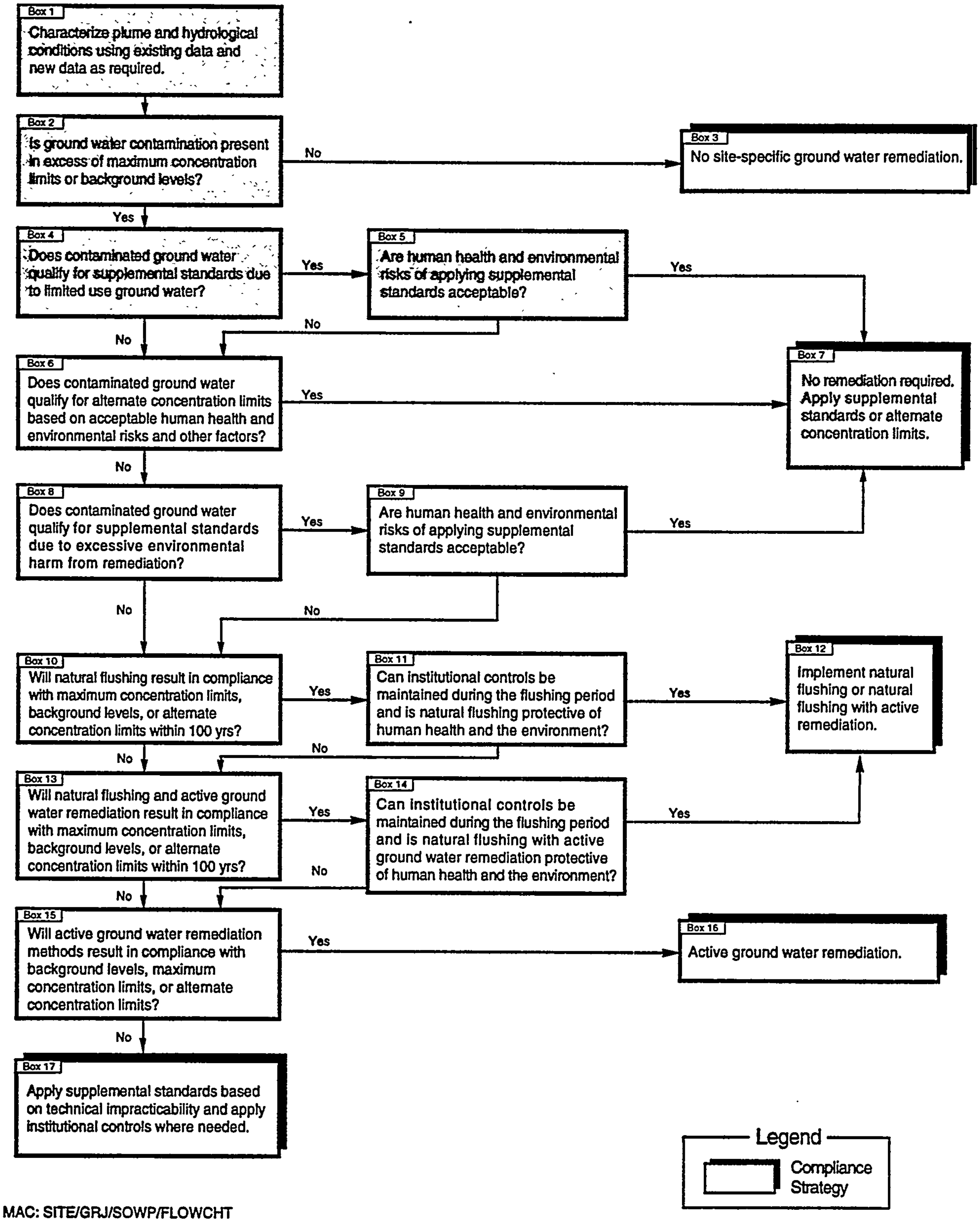
Natural flushing. Natural flushing would allow the natural ground water movement and geochemical processes to decrease the contaminant concentrations to levels within regulatory limits within a given time period. This could be applied at sites where ground water compliance would be achieved within 100 years with the application of natural flushing, where effective monitoring and institutional controls could be maintained, and the ground water is not currently and is not projected to be a drinking water source.

Active ground water remediation. Active ground water remediation would require the application of engineered ground water remediation methods such as gradient manipulation, ground water extraction and treatment, and *in situ* ground water treatment to achieve compliance with the ground water protection standards.

4.2 GRAND JUNCTION COMPLIANCE STRATEGY SELECTION

The DOE used the selection framework described above to identify the proposed ground water compliance strategy of no remediation for the Grand Junction site. The decision steps followed are highlighted in Figure 4.1 and summarized below.

Figure 4.1
Compliance Strategy Selection Process
Grand Junction, Colorado, Site



MAC: SITE/GRJ/SOWP/FLOWCHT

The first step (box 1) involved compiling and analyzing both regional and site-specific ground water characterization data. Then, site ground water quality data were compared to the ground water MCLs and background data (box 2). This comparison confirmed that the past uranium processing activities have resulted in ground water contamination that exceeds background levels or MCLs for some constituents.

The next step (box 4) evaluated whether compliance with the ground water standards could be achieved by applying supplemental standards based on the existence of limited-use ground water. The quality of the ambient ground water at the Grand Junction site indicates that the contaminated aquifer likely meets the requirements for a limited-use aquifer. DOE's review of available upgradient and regional background ground water quality data revealed that there is widespread, ambient contamination based on naturally occurring levels of molybdenum, selenium, and uranium that exceed national primary drinking water levels or UMTRA MCLs at maximum observed concentrations (see Table 3.9) and TDS is in excess of 10,000 mg/L. Based on a study of northwestern Colorado public water systems, which did not include the Grand Junction vicinity specifically (DOE, 1994b), ground water sources with these kinds and levels of contaminants are not used for municipal supply as the water cannot be cleaned up using reasonably available treatment methods. Also, it appears that the USBR canal-lining project will result in further degradation of the background ground water quality.

Then, an assessment was made to determine whether the application of supplemental standards would be protective of human health and the environment (box 5). The risk assessment summaries in Sections 3.7 and 3.8 show that natural ground water quality in the area is poor and that there is no current use of the ground water. As a result of the poor water quality and local institutional controls requiring new developments to hook up to the city water distribution system, it is unlikely that ground water contaminated by past uranium processing activities will be put to beneficial use in the foreseeable future. In addition, it is unlikely that contaminated ground water discharging into the Colorado River will present unacceptable risks to the public or the environment. Therefore, it appears that, based on current information, supplemental standards would be protective of human health and the environment.

The final step identified the proposed compliance strategy of no remediation (box 7). This SOWP proposes that the ground water standards can be met by applying supplemental standards based on the criterion of limited use and that no further remediation will be required. This compliance strategy coupled with the already completed removal of the tailings from the site, poor ambient water quality, and existing local institutional controls will be protective of human health and the environment.

4.3 DEVIATIONS AND CONTINGENCIES

The no remediation ground water compliance strategy proposed for the Grand Junction site is based on the evaluation of the existing conceptual model (Section 3.3). Additional site-specific information must be collected to confirm the conceptual model, validate the application of supplemental standards based on the limited-use ground water scenario, and confirm that there are no unacceptable human health or environmental risks from ground water entering the Colorado River. The primary focus of this effort will be on the further development of our understanding of ground water flow and solute transport in the Grand Junction area and understanding of regional background ground water quality. Before the final compliance strategy is selected, data are needed to support the limited-use classification of the alluvial aquifer and the claim that the no remediation strategy will be protective of human health and the environment. Additional data collection activities will focus on regional and site-specific hydrogeologic and geochemical conditions, impacts of lining local canals, ground water quality (including presence of organic contamination), surface water flows, impacts of ground water discharge to surface water quality, and reasonably available treatment methods for public water systems.

Within the framework of the observational method, reasonable deviations from the conceptual site model may be identified as a result of data collection and assessment. To address the potential deviations, a preliminary data needs contingency plan has been developed to deal with potential deviations and is presented in Section 5.0. This plan allows for primary data collection to support the development of the proposed compliance strategy: no remediation with supplemental standards. The contingency plan is structured so that, if in the unlikely event the aquifer does not qualify for supplemental standards or supplemental standards would not be protective of human health and the environment, primary data components of the data collection and assessment plan will still contribute useful, significant data to the most likely alternative strategy, which appears to be natural flushing based on our current understanding of the site. If at some point in the data collection and assessment process it becomes apparent to the stakeholders through evaluation of the data that an alternative compliance strategy is required, the secondary data needs component of the data collection and assessment plan will be initiated.

The hydrogeologic and geochemical data collected from the Grand Junction site and preliminary contaminant transport and ground water flow modeling indicate that natural ground water flushing appears to be an applicable alternative strategy. That is, natural ground water movement and geochemical processes will decrease the contaminant concentrations to background levels within 100 years. If further data evaluation does not support natural flushing, then active remediation would likely need to be evaluated.

Either alternative compliance strategy must be performed in conjunction with the implementation of institutional controls on ground water usage in the vicinity of the Grand Junction site. Because these strategies involve the reduction of contaminant concentrations through time, controlling ground water usage will mitigate the immediate and long-term risks to both public health and the environment. Specific institutional controls will be developed in coordination with state and local authorities wherever feasible.

5.0 DATA COLLECTION AND ASSESSMENT PLAN

Existing site conditions, as defined by regional studies and previous investigations conducted at the Grand Junction site, support the proposed ground water compliance strategy of no remediation by applying supplemental standards based on a limited-use aquifer. Additional site-specific and regional data collection activities are needed, however, to build a statistically significant database of regional background ground water quality for constituents of potential concern at the site to confirm the applicability and feasibility of this proposed compliance strategy.

As addressed in Section 4.3, proposed data collection activities may result in deviations from the conceptual site model, and the adoption of an alternative compliance strategy may be required. Therefore, the DOE has developed a data collection and assessment plan, within the framework of the observational method, that addresses the primary data needs required to support the proposed no remediation compliance strategy, as well as to support the alternative strategies of natural flushing or active remediation. The secondary data needs component of the data collection and assessment plan will only be initiated if it becomes apparent through the statistical analyses of the collected data that the aquifer will not qualify for supplemental standards or if the supplemental standards are not protective of human health and the environment.

The following sections will present a statement of primary data needs that are supportive of the no remediation strategy and those secondary data needs required to support the most likely alternative strategy of natural flushing. Also, the related data collection objectives and activities and the governing data quality objectives are briefly discussed.

Ground water monitoring, as defined in the Grand Junction water sampling and analysis plan (DOE, 1995c), will occur in conjunction with the primary and secondary data needs acquisition activities.

Data quality objectives are quantitative and qualitative statements made to ensure that data of known and appropriate quality and quantity (data sufficiency) are obtained during an investigation. To ensure that the data gathered during investigation activities are adequate to support DOE and stakeholder decisions, a clear definition of the quality objectives and the method by which decisions will be made will be established in activity-specific work plans. Substantially more detail will be provided in activity-specific work plans submitted to the stakeholders for review and comment prior to initiation of the data collection activity.

5.1 STATEMENT OF PRIMARY DATA NEEDS

The DOE has identified the following primary data required to support the proposed no remediation compliance strategy based on the conceptual site model and an evaluation of the existing data.

5.1.1 Evaluation of the Government Highline Canal

To evaluate the long-term effect of lining the Government Highline Canal on water quality in the Grand Junction area and to support the inference that water quality will become worse over time in the alluvial aquifer after the canal is lined, the DOE should locate all available regional water quality data for areas upgradient and downgradient of a lined portion of the canal and upgradient and downgradient of an unlined portion of the canal. This information will be necessary to verify the expected decline in the water table elevations and the water quality (such as higher TDS concentrations) resulting from removal of the major source of recharge to the alluvial aquifer and to help quantify the source of the remaining recharge. The data will be used to supplement the current data set, indicating that the ambient ground water quality meets the requirements for a limited-use aquifer in the vicinity of the former processing site as well as in areas throughout Grand Junction where vicinity property cleanup occurred.

A detailed work plan will be developed and submitted to the stakeholders for review and comment prior to initiating this data search activity.

5.1.2 Mass flow and dilution factors for the Colorado River

To assess the impacts of discharge of the site ground water contaminant plume to the Colorado River, calculations using Darcy's Law will be performed to 1) determine the volume of flow of the Colorado River past the site during low-flow conditions; 2) calculate the volume of ground water discharge to the Colorado River; and 3) assess the mass per unit volume of each constituent of potential concern that is added to the river by ground water discharge.

These calculations will use the highest levels of constituents of potential concern observed at the site and low-flow conditions in the Colorado River to arrive at a conservative estimate of the potential (or lack thereof) to produce measurable increases above background in constituent concentrations in the river.

5.1.3 Collection of regional data on background ground water quality

There are currently very few analyses of specific metals (e.g., uranium and vanadium) in regional background. To support a no remediation strategy based on limited-use ground water, it will be necessary to build a statistically significant database of analyses of regional background ground water for constituents of potential concern at the Grand Junction site. This effort is critical to further develop the database supporting the information on widespread, ambient contamination and could be accomplished with one year of quarterly sampling. As part of this effort, existing wells that access regional background in the alluvial system should be identified and sampled for analysis. If few such wells can be identified, consideration should be given to installation of regional background monitor wells to fill this data gap.

The well location selection process will always be accompanied by an investigation to assess that there are not any vicinity properties nearby that may affect ground water quality.

If it is determined that supportive regional background data do not exist, a detailed work plan will be developed addressing the installation and sampling of regional background monitor wells and submitted to the stakeholders for review and comment.

5.1.4 Investigation of organic contamination

An organic solvent extraction process was used by the Climax uranium processing mill. DOE performed sampling for organic compounds at the Grand Junction site and other UMTRA Project sites in 1989 (Hill, 1989). Samples of tailings and ground water were analyzed for Appendix IX (40 CFR Part 264) analytes and no organic contamination was found. Even though the Appendix IX list is comprehensive and provides coverage of EPA-regulated hazardous chemicals that can be monitored in an aqueous medium, it does not provide straightforward detection of kerosene or No. 2 fuel oil, which were process carrier chemicals used in large quantities at the Grand Junction site. The Appendix IX list also does not address many of the extracting solvents commonly used in uranium milling, notably di(2-ethylhexyl)phosphoric acid, tributyl phosphate, and tertiary amines in the case of the Grand Junction site.

No toxicological evaluation has been performed on kerosene or on the specific organic solvents and their breakdown products. Nonetheless, an initial toxicological review indicates that many of these chemicals and their derivatives are toxic. An organic screening will provide a first step in the determination of whether process-related organic compounds are present in ground water at the Grand Junction site and will serve as a starting point for the evaluation of the potential human health and ecological risks.

A detailed work plan will be developed and submitted to the stakeholders for review and comment prior to initiating this activity.

5.1.5 Evaluation of available public water supply treatment capabilities

If further investigations confirm that there is widespread, ambient contamination or poor water quality, the DOE will conduct a survey of treatment methods employed at public water systems in the Grand Junction area to determine if cost-effective treatment methods are reasonably available to clean up the naturally occurring ground water contaminants. The DOE will consult with state and local authorities to determine if such studies have already been conducted.

5.1.6 Assessment of remedial action at the processing site

In order to assess what, if any, impacts occurred to the local hydrology and geochemistry at the processing site as a result of residual radioactive material cleanup activities, the DOE will review the processing site completion report (MK-F, 1995). This review will entail assessing the excavation depths relative to the water table and the quantity and nature (both hydraulic and chemical) of the fill material used to backfill the excavations below the water table. The review will also ensure that no secondary source terms are present.

5.1.7 Evaluation of vicinity properties

The preamble to the final rule for the EPA ground water standards (60 FR 2854) states that "only a few vicinity properties contain sufficient tailings to constitute a significant threat of ground water contamination "and concluded that" the detailed assessment and monitoring, followed by identification of listed constituents and ground water standards is not required at all vicinity properties. It is necessary only at those vicinity properties with a significant potential for ground water contamination, as determined by the DOE (with concurrence of the U.S. Nuclear Regulatory Commission) using factors such as those in EPA's Resource Conservation and Recovery Act Facility Assessment Guidance Document."

The term "significant" can be defined from volume and leachable source perspectives. For tailings at a vicinity property to be determined to be significant, the volume must be large enough to potentially contribute enough chemical mass to adversely affect ground water. In addition, the leachate generation potential of the tailings must be of a magnitude to potentially adversely affect ground water.

The DOE has not made the assumption that a vicinity property with ground water contamination will qualify for supplemental standards. Rather, the DOE will address potential ground water contamination associated with vicinity properties on an as-needed basis.

The DOE acknowledges that there have been some vicinity properties with substantial volumes of tailings materials. However, the volume of tailings is just one of the criteria for determining if the vicinity property would be a source of ground water contamination and fall within the Ground Water Project. Other factors include depth to ground water, soil and bedrock geochemistry, ground water recharge and discharge, background water geochemistry, climate, and the placement of contaminated materials.

It is the intention of the DOE to screen all vicinity properties within the Grand Junction area to determine the potential for ground water contamination at each property. This screening will be done using the criteria described above. Ground water characterization will be done at the property showing the highest potential for ground water contamination.

A detailed work plan will be developed addressing the vicinity property screening process and vicinity property ground water characterization activity. This work plan will be submitted to the stakeholders for review and comment prior to initiating this activity. This activity will be done in parallel with processing site characterization work.

5.2 ASSESSMENT OF DATA AND REPORTING

Upon completion of data collection and analytical testing, data evaluation and report preparation activities will be initiated. Data evaluation activities for all data discussed above will include, but not be limited to

- Tabulation of analytical results obtained from surface water sampling, ground water sampling, and geochemical sampling.

- Calculation of risk-based analysis of contaminant data with respect to receptors.

- Synthesis of ground water level measurements, calculation of ground water elevations, and preparation of water level contour maps.

- Implementation of analytical solutions and reporting of the resultant calculation of hydraulic conductivities, ground water flow path, vertical and horizontal gradients, ground water flow velocity, contaminant fate and transport, and surface water and ground water interactions.

- The hydrogeologic data resulting from the well tests will be used along with the estimates of rate of contaminant transport, to predict the quantity and concentrations of the contaminants being discharged to the river. Calculation of a mass balance during low-flow periods to evaluate the potential environmental impact on the river water and sediments.

Upon completion of data evaluation activities, a report will be compiled and delivered that will include a discussion of all field activities, a description of the instrumentation used, the location of the surveys, copies of all field measurement data, copies of field logs, the method of interpretation, and a summary of the results relative to the data collection objective. The results and reports will be incorporated into the SOWP (Revision 1 or final). As the focus and overall objective of this report is to confirm or deny the applicability of the proposed compliance strategy, all recommendations, deviations, and contingencies will be identified, as will any additional data needs.

If the conclusion of the SOWP (Revision 1 or final) is that the proposed compliance strategy will effectively bring the site into compliance and is protective of human health and the environment, a site-specific NEPA document for the proposed compliance strategy will be prepared. This document will consider the environmental impacts of both the compliance strategy itself and the activities required to implement the strategy. If it cannot be demonstrated that the proposed compliance strategy will bring the site into compliance or that the environmental impacts of implementing the strategy are not acceptable, the revised SOWP will recommend additional steps.

5.3 STATEMENT OF SECONDARY DATA NEEDS

The following are the secondary data needs required to support a natural flushing or active remediation compliance strategy based on the conceptual site model and an evaluation of existing data. These data would need to be acquired only if the evaluation of the data addressing the primary needs did not support the adoption of the no remediation compliance strategy.

5.3.1 Investigation of the current distribution of ground water contamination

The amount and location of ground water contamination associated with the Grand Junction site is critical information if natural flushing is to be a viable strategy. There is currently no ground water quality information for most of the eastern half of the site. Figure 3.3 shows current and decommissioned monitor wells at the site. None of these wells monitored water quality on the eastern half of the site, including areas where ponds associated with uranium processing were known to exist. Part of this area contained the state-owned Colorado Tailings Repository, which stored residual radioactive materials excavated from vicinity properties. The installation of a monitor well network to fill this data gap should be considered.

If it is determined that this activity is required, a detailed work plan will be developed addressing the installation and sampling of monitor wells on the site and submitted to the stakeholders for review and comment.

5.3.2 Aquifer testing

Pending a review of existing data in the Grand Junction RAP (DOE, 1991), additional data may be needed on the variability of the hydraulic conductivity of the surficial aquifers downgradient of the site. This activity may require the installation of additional wells as either pumping and/or observation wells. Perhaps more importantly, the vertical hydraulic relationship between the alluvial aquifer and the Mancos Shale/Dakota Sandstone may require clarification/confirmation in the vicinity of the site. If needed, additional wells should be installed in well clusters (using all existing wells to their fullest potential) to evaluate and confirm that vertical hydraulic potentials are consistently upward between these units.

Also, aquifer testing will be used to evaluate the impact of canal leakage within the immediate vicinity of the site, specifically with regards to the impacts on ground water gradients and velocities.

If it is determined that additional hydraulic data should be collected through the use of various aquifer tests, a detailed work plan will be developed and submitted to the stakeholders for review and concurrence.

5.3.3 Topographic surveying

A topographic profile across the Colorado River is required to establish references for elevations, water levels, and ground water flow.

It is presumed that the Colorado River is the local base level for the ground water regime in the alluvium downgradient of the site, and that contaminated ground water from beneath the site will not cross under the river. Additional information on the water elevation in the Colorado River is needed to confirm this supposition and to aid in model development. Surveys of the elevations of all newly installed monitoring stations (e.g., monitor wells and/or surface water locations) and the topographic profile and survey of the Colorado River will all be conducted by professional surveyors licensed in the state of Colorado. The surveys will be done in accordance with second-order topographic surveying accuracy criteria.

5.3.4 Monitoring ground water quality

Additional ground water quality data are needed from existing wells to further evaluate water quality trends through time. Background water quality data in the alluvial aquifer upgradient of the site are needed to confirm naturally occurring elevated inorganic and radionuclide concentrations migrating onto the processing site. In addition, all other existing alluvial monitor wells will continue to be sampled to monitor changes in ground water quality.

5.3.5 Ground water and surface water level elevation monitoring

Continued monitoring of the ground water level elevations in the monitor well clusters should continue to further evaluate and assess the vertical gradients between aquifers. Consistent with this activity, all existing ground water and surface monitoring stations will be monitored for water levels on a single day on a quarterly basis to continue to evaluate the lateral and vertical hydrologic flow regimes.

5.3.6 Geochemical analysis of ground water and aquifer matrix

Geochemical analysis of the aquifer matrix is required to determine the interaction between the constituents in ground water and the material comprising the aquifer. These data are needed to assess contaminant migration and attenuation. These data will be used to further refine and support future solute transport modeling efforts.

Data regarding the geochemistry of both the ground water and aquifer matrix are required to determine the sorption potential of the aquifer. No such data currently exist in the Grand Junction site database, with the exception of limited pH and dissolved oxygen data from ground water samples. Additional information is probably required to quantify the interaction of solute during transport through the aquifer such as distribution and retardation coefficients, if applicable, and contaminant-specific velocities. The physical nature of the aquifer matrix will affect the dispersion and rate of migration of the plume.

If it is determined that core collection and analysis (organic compounds, inorganic compounds [mineralogy], sorption potential, isotope studies, and bulk density) should be used to collect additional geochemical data, a detailed work plan will be developed and submitted to the stakeholders for review and concurrence.

5.3.7 Toxicological literature review

An in-depth literature review to obtain toxicological data for constituents of potential concern that have no state or federal water quality or sediment quality guidelines is needed to more adequately define specific constituent impacts, if any, on drinking water resources.

5.3.8 Computer modeling of ground water flow

A quantitative evaluation of the ground water flow regime and the fate and transport of contaminants (computer modeling) is needed to complement previous evaluations and to determine and monitor the effectiveness of a natural flushing compliance strategy.

The models will integrate all the information available from the Grand Junction site and will allow quantitative evaluation of the feasibility of achieving compliance through natural flushing within 100 years.

If it is determined that models are required to support a natural flushing compliance strategy, this phase of the investigation will develop a hydrologic model that simulates the ground water flow regime at the site and predicts the transport and decay of contaminants from the site. Before initiating a full numerical computer modeling effort, a simpler analytical model will be used. This analytical model should give a reasonable estimate of the potential success of the strategy and identify major data gaps.

The analytical model will estimate the contaminant transport based on the ground water flow rate, which is calculated from an average hydraulic conductivity; the controlling gradient and cross-sectional area; and representative porosity, combined with estimated retardation factors, dispersivity, and sorption rates for the surficial aquifer.

A two-layered, three-dimensional hydrologic flow model, simulating the existing ground water flow pattern, will be developed (probably using the software package MODFLOW, according to an American Society of Testing and Materials standard currently under development). This model will incorporate the existing data on the hydrogeology and boundary conditions. It will be calibrated to emulate the existing "steady-state" conditions. The computer model will identify data gaps and uncertainties.

5.3.9 Feasibility of implementing institutional controls

The DOE needs to work with state and local authorities to identify the roles and responsibilities for implementing institutional controls at the site. In addition, it needs to be determined if existing institutional controls will be adequate to protect human health and the environment.

6.0 LIST OF CONTRIBUTORS

The following individuals contributed to the preparation of this SOWP.

Name	Contribution
W. Migdal	Document sponsor, document review
A. Vollmer	Document coordination, regulatory compliance
C. Yancey	Lead author
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J. Marshall	Risk assessment
C. Burt	Ecology
D. Erskine	Geochemistry
A. Holm, J. Gibb, R. Neri Zagal, J. Ritchey, R. Saar	Document review
J. Jones, J. Torline	Technical editing, document production coordination
L. Sanchez	Word processing
T. Bond, B. Harvey	Graphic design

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CODE OF FEDERAL REGULATIONS

10 CFR Part 1021, *Compliance with National Environmental Policy Act*, U.S. Department of Energy.

40 CFR Part 141, *National Primary Drinking Water Regulations*, U.S. Environmental Protection Agency.

40 CFR Part 143, *National Secondary Drinking Water Regulations*, U.S. Environmental Protection Agency.

40 CFR Part 192, *Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings*, U.S. Environmental Protection Agency.

40 CFR Part 264, *Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*, U.S. Environmental Protection Agency.

40 CFR Part 300, *National Oil and Hazardous Substances Pollution Contingency Plan*, U.S. Environmental Protection Agency.

40 CFR Parts 1500-1508, Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act, Council on Environmental Quality.

FEDERAL REGISTER

60 FR 2854, "Groundwater Standards for Remedial Actions at Inactive Uranium Processing Sites," final rule, 11 January 1995, U.S. Environmental Protection Agency.

U.S. CODE

42 USC §4321 *et seq., National Environmental Policy Act.*

42 USC §7901 *et seq., Uranium Mill Tailings Radiation Control Act*, as amended.

DOE ORDERS

Order 451.1, *National Environmental Policy Act Compliance Program*, 11 September 1995.

APPENDIX A

LITHOLOGIC LOGS
WELL COMPLETION RECORDS
WELL CONSTRUCTION DATA

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *581*

JOB NO. GRJ01 DATE 10/28/82

TOTAL DEPTH 35.0 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL 27.00

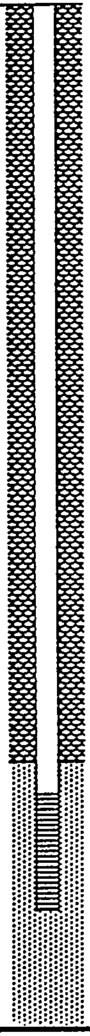
SURFACE ELEVATION 4585.20

WELL CASING TYPE 2-IN. SCHED.40 PVC

LOCATION N 59439.60 E 33674.90

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0		2-inch PVC well installed to 31 feet. Seal placed to 25.9 feet.	?		**THE MATERIAL DESCRIPTION FOR THIS WELL IS UNAVAILABLE**
5			?		
10			?		
15			?		
20			?		
25		Filter pack placed from 25.9 to 35 feet.	?		
30		Well screen placed from 27 to 31 ft.	?		
35					TD AT 35 FEET
40					
45					
50					

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 582

JOB NO. GRJ01 DATE 10/30/82

TOTAL DEPTH 42.5 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL 35.70

SURFACE ELEVATION 4585.30

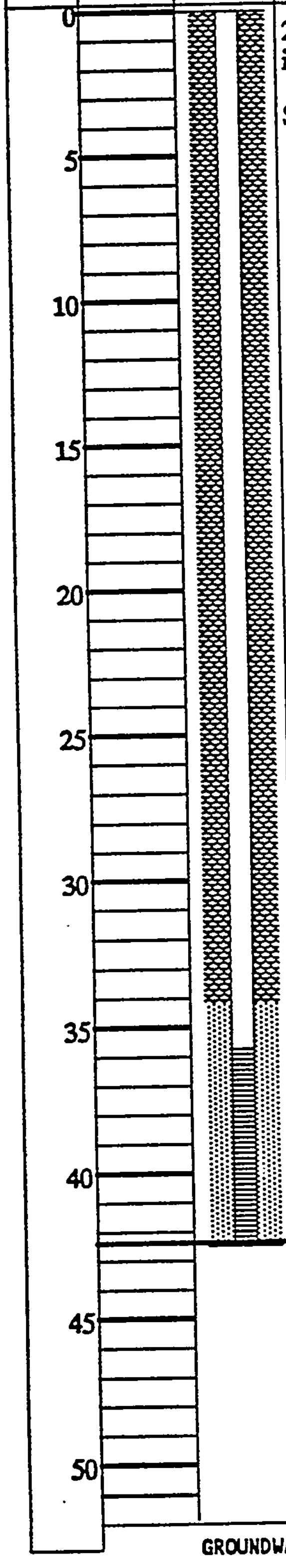
WELL CASING TYPE 2-IN. SCHED.40 PVC

LOCATION N 59310.00 E 33151.80

COMPLETION MANCOS SH. FORMATION

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification



2-inch PVC well installed to 42.5 feet.

Seal placed to 34.2 feet.

Filter pack placed from 34.2 to 42.5 feet.

Well screen placed from 35.7 to 42.5 ft.

THE MATERIAL DESCRIPTION FOR THIS WELL IS UNAVAILABLE

TD AT 42.5 FEET.

GROUNDWATER

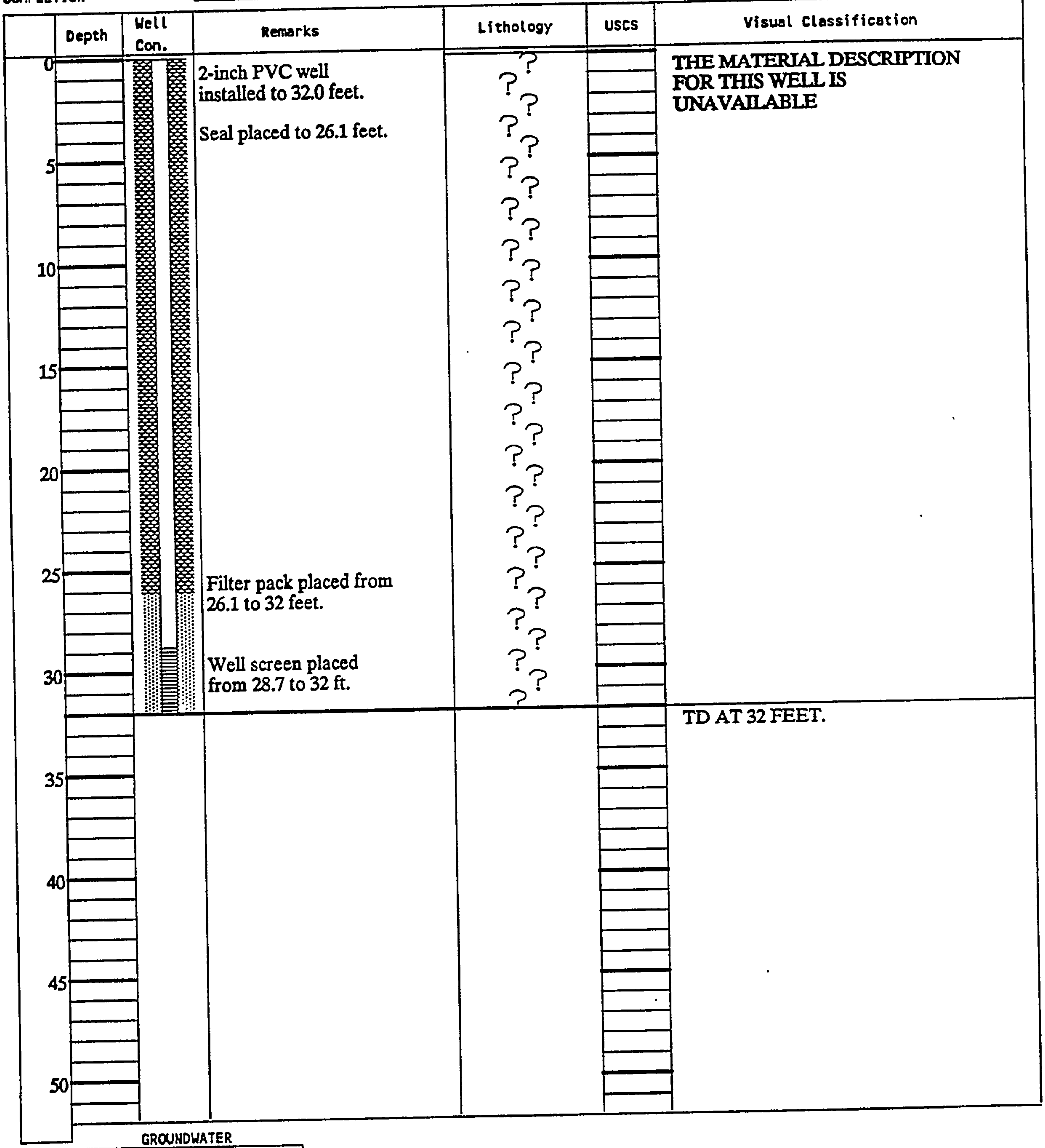
	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT

JOB NO. GRJ01 DATE 10/31/82
BORING TYPE
DEPTH OF SEAL 28.70
WELL CASING TYPE 2-IN. SCHED.40 PVC
COMPLETION ALLUVIUM

TOTAL DEPTH 32.0 feet
FIELD REP.
SURFACE ELEVATION 4585.10
LOCATION N 59316.80 E 33141.50
DATUM MSL



2-inch PVC well installed to 32.0 feet.

Seal placed to 26.1 feet.

Filter pack placed from 26.1 to 32 feet.

Well screen placed from 28.7 to 32 ft.

THE MATERIAL DESCRIPTION FOR THIS WELL IS UNAVAILABLE

TD AT 32 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *584*

JOB NO. GRJ01 DATE 10/31/82

TOTAL DEPTH 25.5 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL 24.70

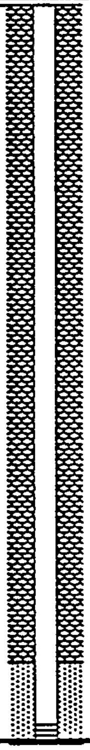
SURFACE ELEVATION 4585.00

WELL CASING TYPE 2-IN. SCHED.40 PVC

LOCATION N 59321.00 E 33153.80

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0		2-inch PVC well installed to 25.5 feet. Seal placed to 22.7 feet.	?		THE MATERIAL DESCRIPTION FOR THIS WELL IS UNAVAILABLE
5					
10					
15					
20		Filter pack placed from 22.7 to 25.5 feet.			
25		Well screen placed from 24.7 to 25.5 ft.			TD AT 25.5 FEET.
30					
35					
40					
45					
50					

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO.

JOB NO. GRJ01

DATE 11/02/82

BORING TYPE

DEPTH OF SEAL 11.90

WELL CASING TYPE 2-IN. SCHED.40 PVC

COMPLETION ALLUVIUM

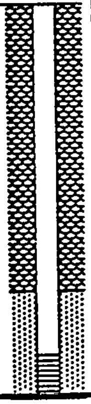
TOTAL DEPTH 13.5 feet

FIELD REP.

SURFACE ELEVATION 4566.00

LOCATION N 59179.40 E 32541.90

DATUM MSL



Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0		2-inch PVC well installed to 13.5 feet. Seal placed to 9.8 feet.	? ? ? ? ? ? ? ? ? ? ? ?		THE MATERIAL DESCRIPTION FOR THIS WELL IS UNAVAILABLE:
5					
10		Filter pack placed from 9.8 to 13.5 feet. Well screen placed from 11.9 to 13.5 ft.			
15					TD AT 13.5 FEET.
20					
25					
30					
35					
40					
45					
50					

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT **GRAND JUNCTION PROCESS SITE**

LOG OF WELL BORING NO. *586*

JOB NO. GRJ01 DATE 11/01/82

TOTAL DEPTH 8.7 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL 5.50

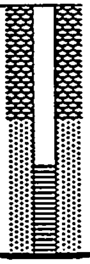
SURFACE ELEVATION 4566.20

WELL CASING TYPE 2-IN. SCHED.40 PVC

LOCATION N 59191.90 E 32539.80

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0		2-inch PVC well installed to 8.7 feet. Seal placed to 3.9 feet. Filter pack placed from 3.9 to 8.7 feet. Well screen placed from 5.5 to 8.7 ft.	? ? ? ? ? ? ? ? ? ?		**THE MATERIAL DESCRIPTION FOR THIS WELL IS UNAVAILABLE:**
5					
					TD AT 8.7 FEET
10					
15					
20					
25					
30					
35					
40					
45					
50					

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT **GRAND JUNCTION PROCESS SITE**

LOG OF WELL BORING NO. 587

JOB NO. GRJ01 DATE 12/16/82

TOTAL DEPTH 15.5 feet

FIELD REP.

BORING TYPE

SURFACE ELEVATION 4575.00

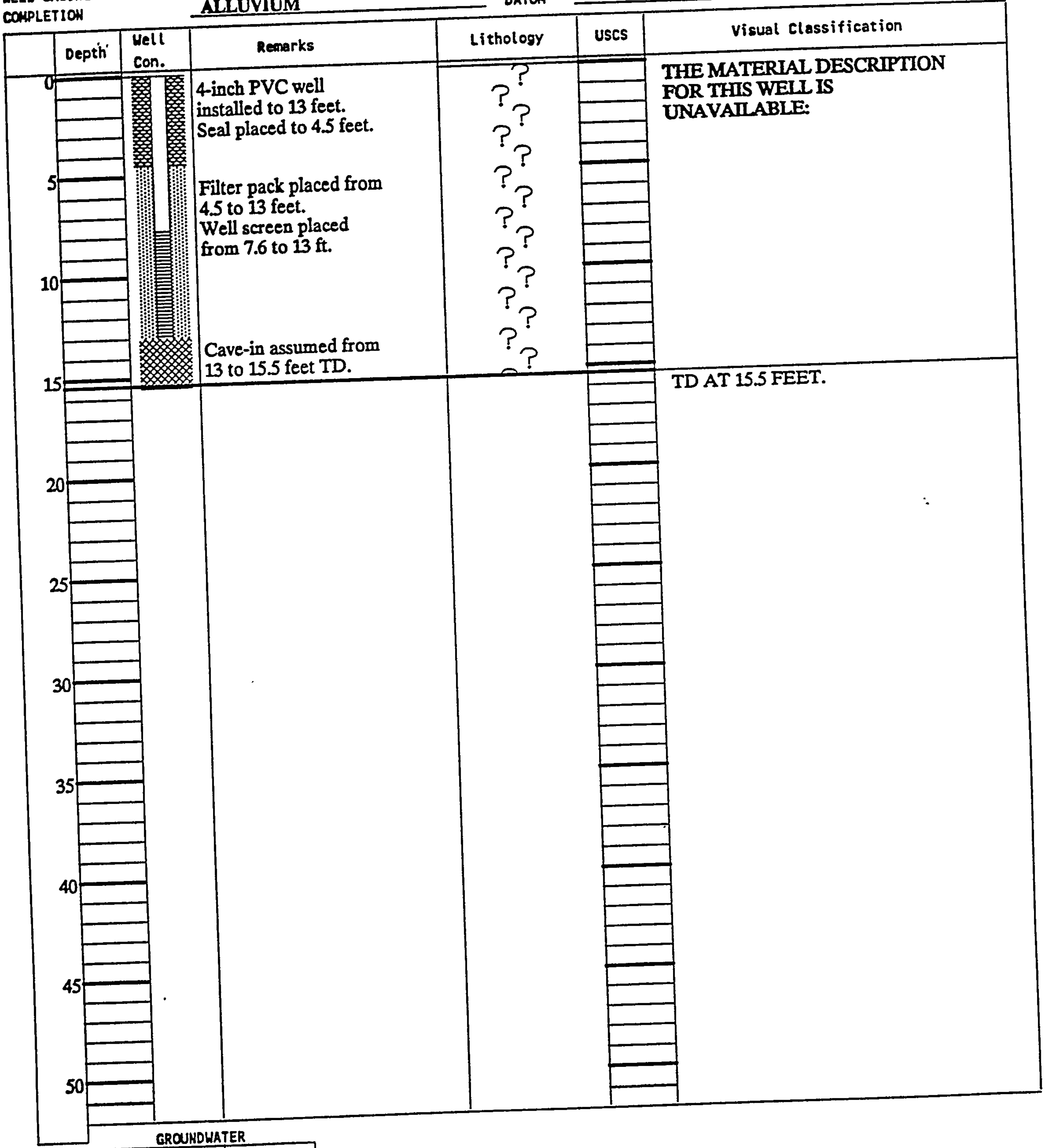
DEPTH OF SEAL 7.60

LOCATION N 60599.90 E 34829.20

WELL CASING TYPE 4-IN. SCHED.40 PVC

DATUM MSL

COMPLETION ALLUVIUM



4-inch PVC well installed to 13 feet. Seal placed to 4.5 feet.

Filter pack placed from 4.5 to 13 feet. Well screen placed from 7.6 to 13 ft.

Cave-in assumed from 13 to 15.5 feet TD.

THE MATERIAL DESCRIPTION FOR THIS WELL IS UNAVAILABLE:

TD AT 15.5 FEET.

GROUNDWATER

DEPTH	HOUR	DATE

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 588

JOB NO. GRJ01 DATE 12/12/82

BORING TYPE

DEPTH OF SEAL 7.90

WELL CASING TYPE 4-IN. SCHED.40 PVC

COMPLETION ALLUVIUM

TOTAL DEPTH 17.0 feet

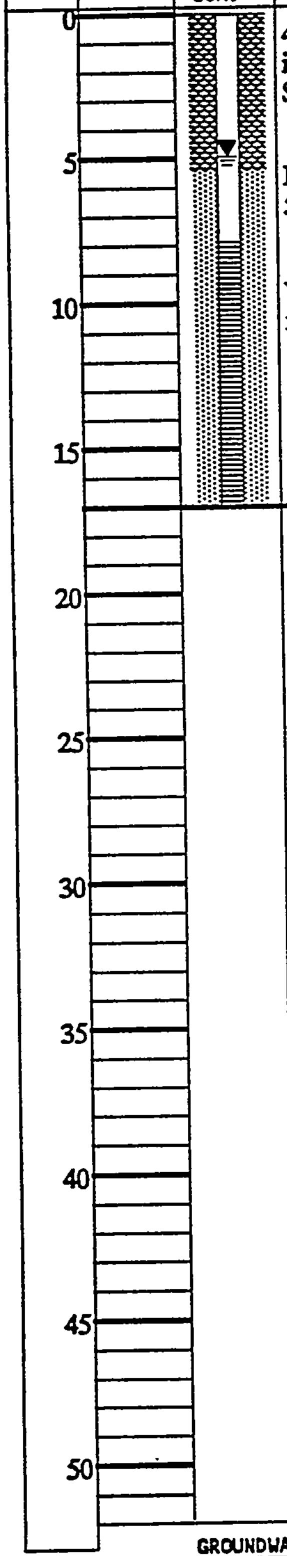
FIELD REP.

SURFACE ELEVATION 4571.50

LOCATION N 59447.60 E 35959.70

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0–17		4-inch PVC well installed to 17 feet. Seal placed to 5.4 feet. Filter pack placed from 5.4 to 17 feet. Well screen placed from 7.9 to 17 ft.	? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?		THE MATERIAL DESCRIPTION FOR THIS WELL IS UNAVAILABLE:
17					TD AT 17 FEET.



GROUNDWATER

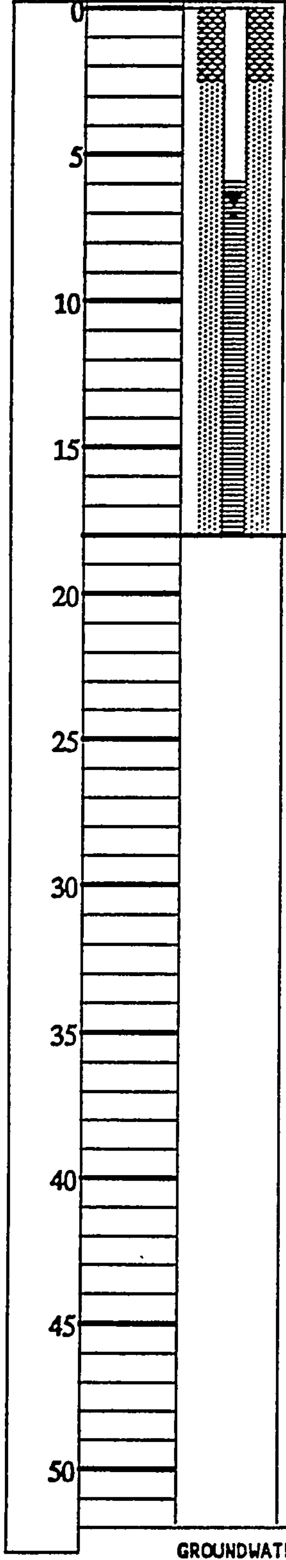
	DEPTH	HOUR	DATE
∇			
▼	4.9	16:02	7-15-92

JEG TAC TEAM

JOB NO. GRJ01 DATE 01/04/83
BORING TYPE
DEPTH OF SEAL 5.90
WELL CASING TYPE 4-IN. SCHED.40 PVC
COMPLETION ALLUVIUM

TOTAL DEPTH 18.0 feet
FIELD REP.
SURFACE ELEVATION 4566.80
LOCATION N 59399.10 E 31876.90
DATUM MSL

Depth | **Well Con.** | **Remarks** | **Lithology** | **USCS** | **Visual Classification**

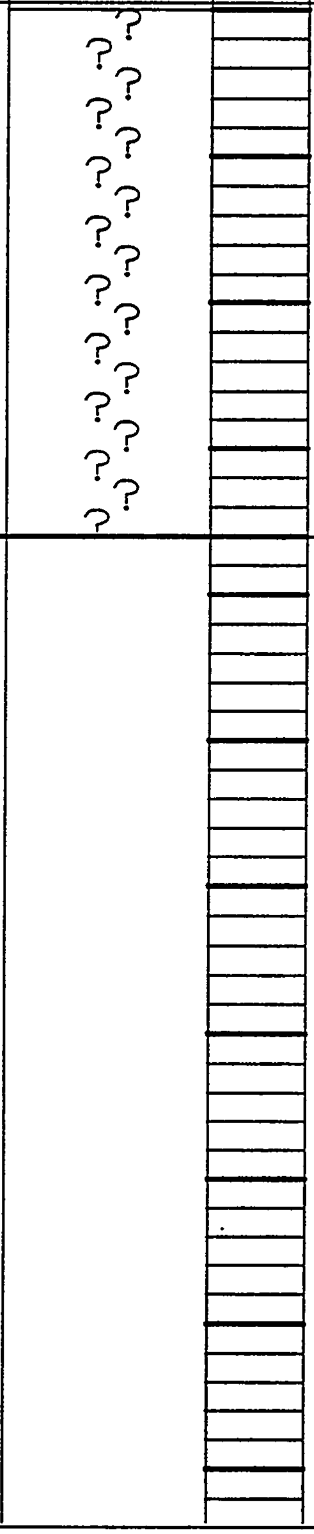


2-inch PVC well installed to 18 feet.

Seal placed to 2.5 feet.

Filter pack placed from 2.5 to 18 feet.

Well screen placed from 5.9 to 18 ft.



THE MATERIAL DESCRIPTION FOR THIS WELL IS UNAVAILABLE:

TD AT 18 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼	6.8	10:48	7-16-92

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 590

JOB NO. GRJ01 DATE 01/04/83

TOTAL DEPTH 15.5 feet

FIELD REP.

BORING TYPE

SURFACE ELEVATION 4564.70

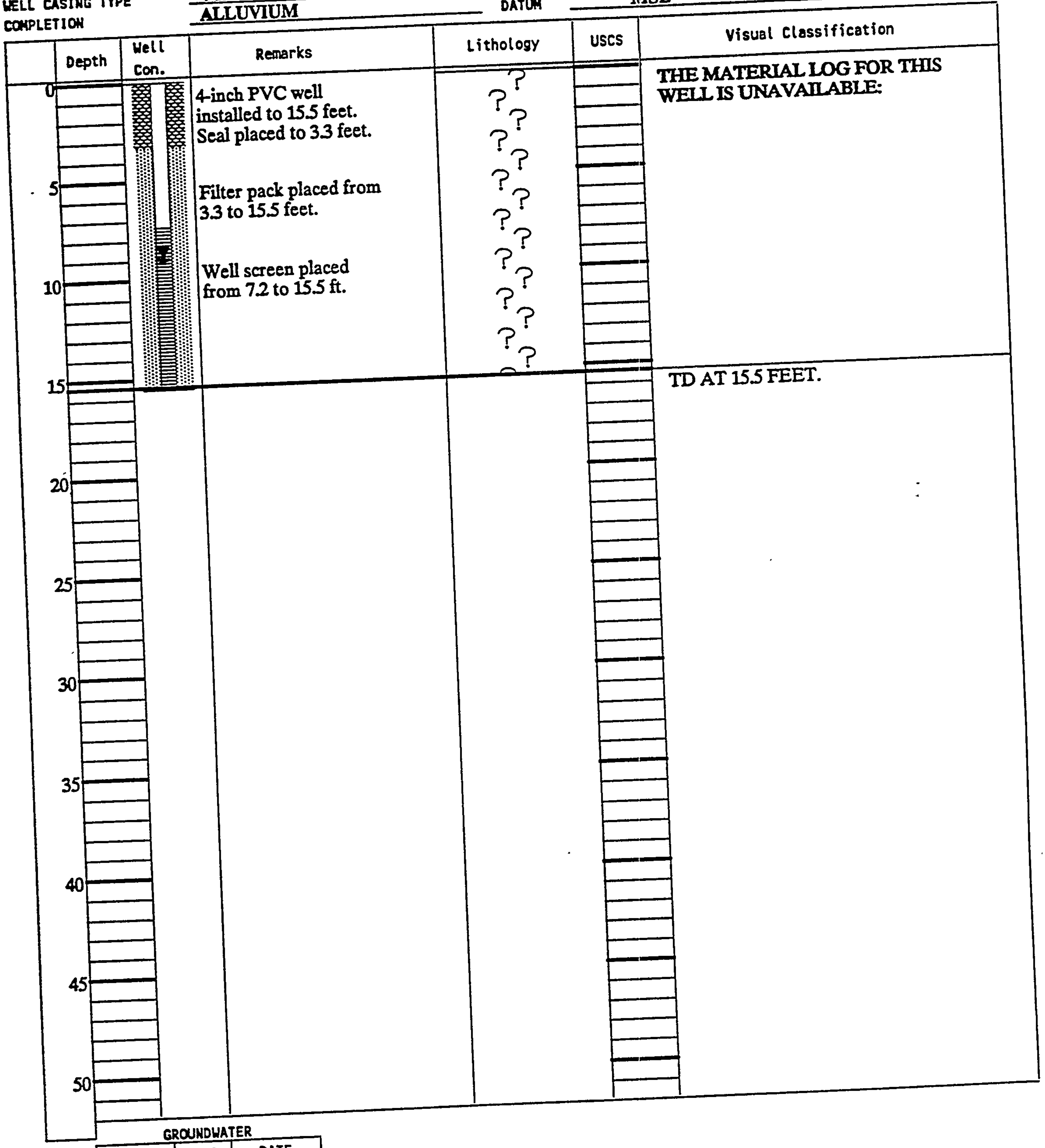
DEPTH OF SEAL 7.20

LOCATION N 59531.20 E 31295.80

WELL CASING TYPE 4-IN. SCHED.40 PVC

DATUM MSL

COMPLETION ALLUVIUM



4-inch PVC well installed to 15.5 feet. Seal placed to 3.3 feet.

Filter pack placed from 3.3 to 15.5 feet.

Well screen placed from 7.2 to 15.5 ft.

THE MATERIAL LOG FOR THIS WELL IS UNAVAILABLE:

TD AT 15.5 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼	8.9	13:20	7-16-92

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF TEST BORING NO. 591

JOB NO. GRJ01 DATE ALLUVIUM

RIG TYPE UNK
BORING TYPE UNK BOREHOLE
SURFACE ELEV
DATUM MSL

Depth In Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows/foot 140 lb. 30" free-fall drop hammer	Dry Density lbs. per cubic foot	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0										**FILL:** SAND CLAY, fine to med. grained, with shale mixed, tan.
										TAILINGS: SILTY SAND, lt. grey.
5										
10										
15										**ALLUVIUM:** SANDY SILT, fine to med. sand, brown.
										SANDY GRAVEL, very dense, BROWN.
20										TD AT 20 FEET.
25										
30										
35										
40										
45										
50										

GROUNDWATER

DEPTH	HOUR	DATE

SAMPLE TYPE

A - Auger cuttings. B - Block sample.
S - 2" O.D. 1.38" I.D. tube sample.
U - 3" O.D. 2.42" I.D. tube sample.
T - 3" O.D. thin-walled Shelby tube.

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *592*

JOB NO. GRJ01 DATE 10/21/82

TOTAL DEPTH 33.0 feet

FIELD REP. UNK

BORING TYPE

SURFACE ELEVATION 4590.90

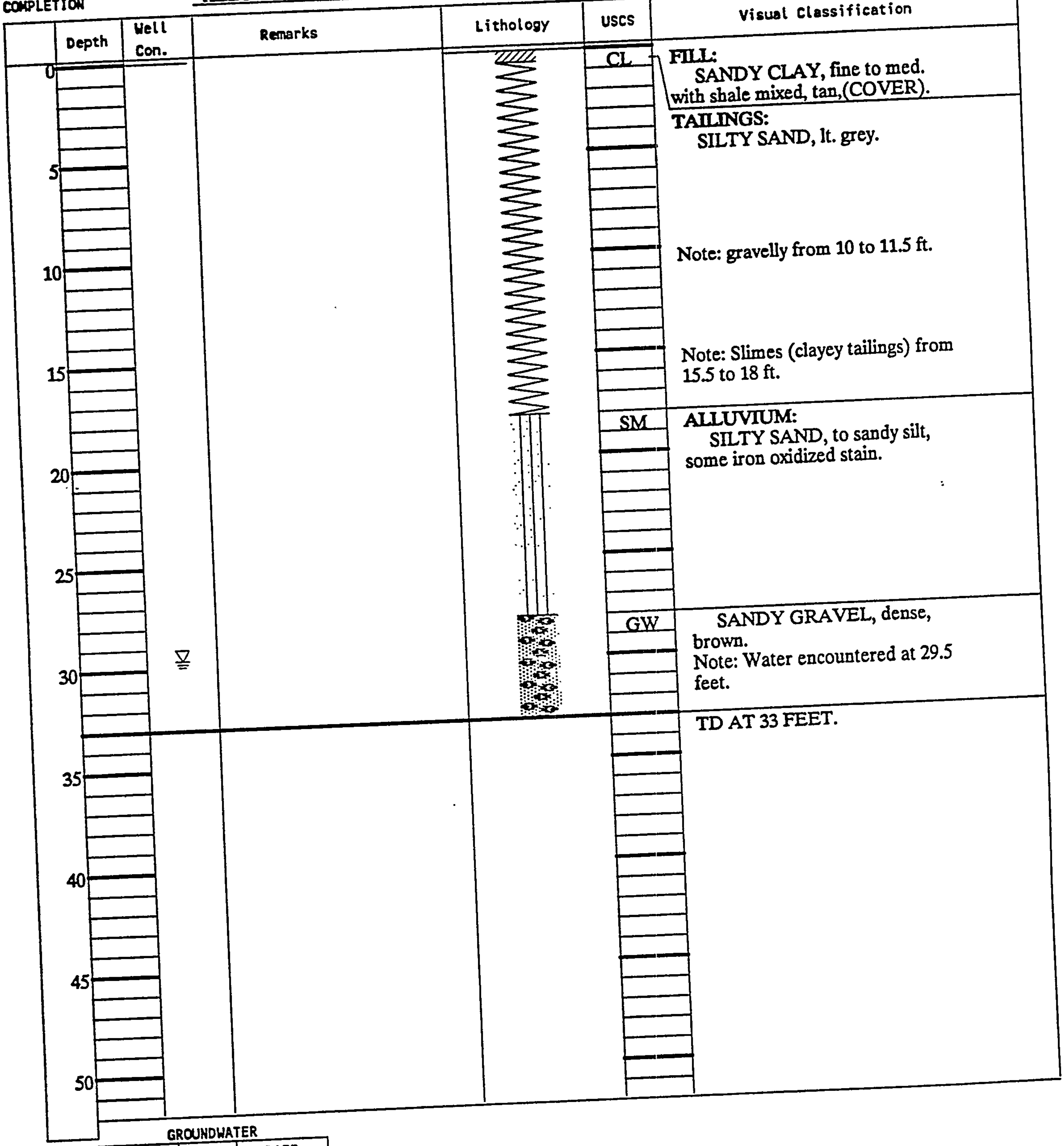
DEPTH OF SEAL 29.90

LOCATION N 59215.10 E 33788.20

WELL CASING TYPE 2-IN. SCHED.40 PVC

DATUM MSL

COMPLETION ALLUVIUM



FILL:
SANDY CLAY, fine to med. with shale mixed, tan,(COVER).

TAILINGS:
SILTY SAND, lt. grey.

Note: gravelly from 10 to 11.5 ft.

Note: Slimes (clayey tailings) from 15.5 to 18 ft.

ALLUVIUM:
SILTY SAND, to sandy silt, some iron oxidized stain.

SANDY GRAVEL, dense, brown.
Note: Water encountered at 29.5 feet.

TD AT 33 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
∇	29.6		10-21-82
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF TEST BORING NO. 593

JOB NO. GRJ01 DATE ALLUVIUM

RIG TYPE UNK

BORING TYPE UNK BOREHOLE

SURFACE ELEV

DATUM MSL

Depth In Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows/foot 140 lb. 30" free-fall drop hammer	Dry Density lbs. per cubic foot	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0										**FILL:** SANDY CLAY, cover material, with shale mixed.
										TAILINGS: SILTY SAND, fine to med., lt. grey. Note: slimes(clayey tailings) from 6.5 to 7.5 ft. Note: sandy silt to silty sand from 7.5 to 16 ft.
5										
10										
15										Note: Slimes from 16 to 17.5 feet. Note: gravelly zone from 17.5 to 20 feet.
20										Note: slimes, clayey silt from 20,5 to 23.5 ft. saturated.
										ALLUVIUM: SANDY GRAVEL, very dense, brown.
25										
										TD AT 27 FEET
30										
35										
40										
45										
50										

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

SAMPLE TYPE

A - Auger cuttings. B - Block sample.
S - 2" O.D. 1.38" I.D. tube sample.
U - 3" O.D. 2.42" I.D. tube sample.
T - 3" O.D. thin-walled Shelby tube.

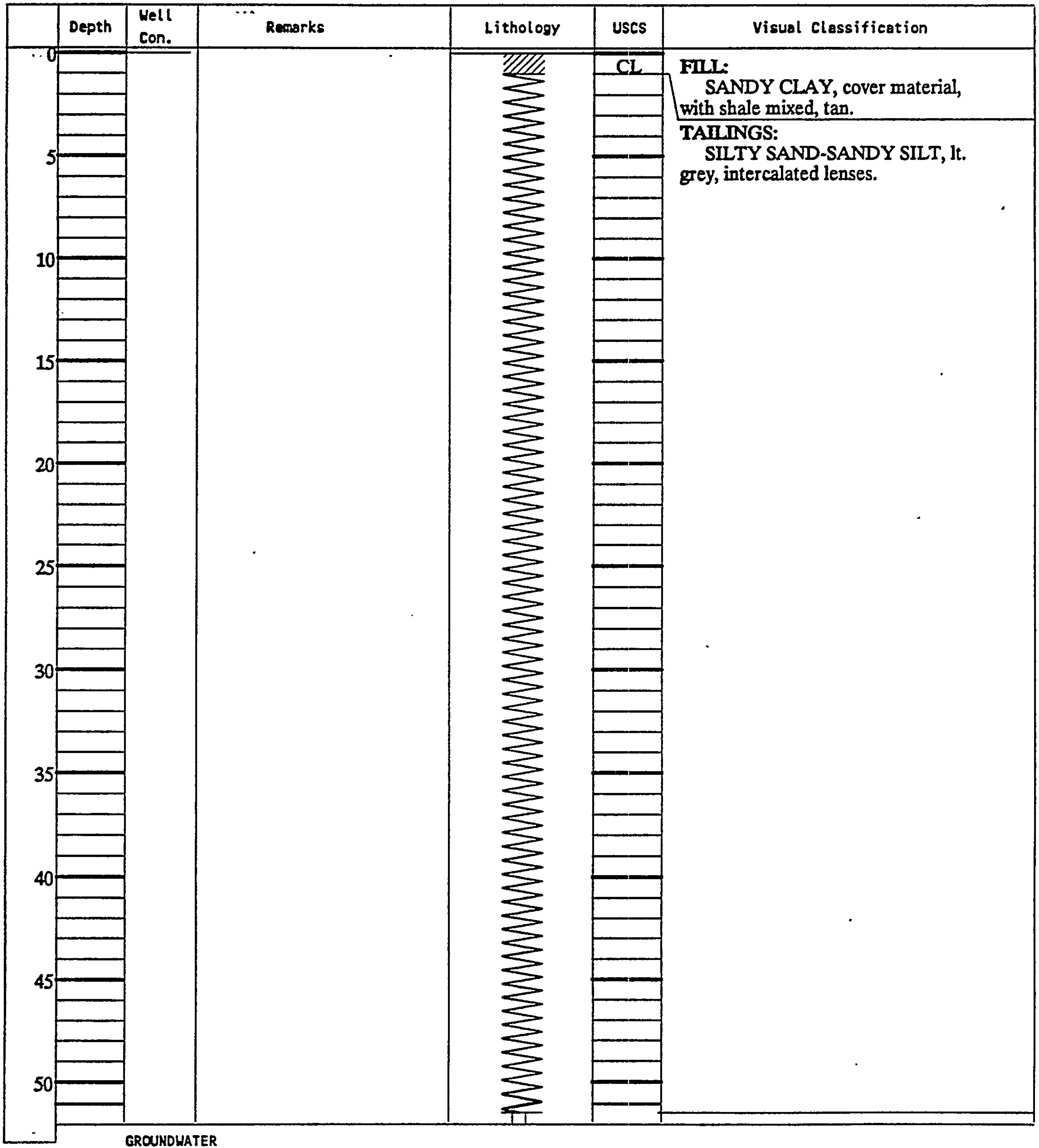
JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 594

JOB NO. GRJ01 DATE 10/22/82

BORING TYPE	UNK	TOTAL DEPTH	59.5 feet
DEPTH OF SEAL	56.40	FIELD REP.	UNK
WELL CASING TYPE	2-IN. SCHED.40 PVC	SURFACE ELEVATION	4612.40
COMPLETION	ALLUVIUM	LOCATION	N 59789.80 E 34559.60
		DATUM	MSL



FILL:
SANDY CLAY, cover material, with shale mixed, tan.

TAILINGS:
SILTY SAND-SANDY SILT, lt. grey, intercalated lenses.

GROUNDWATER

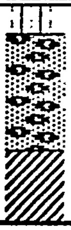
	DEPTH	HOUR	DATE
▽	55.0		10-22-82
▼			

JEG TAC TEAM

JOB NO. GRJ01 DATE 10/22/82
BORING TYPE UNK
DEPTH OF SEAL 56.40
WELL CASING TYPE 2-IN. SCHED.40 PVC
COMPLETION ALLUVIUM

TOTAL DEPTH 59.5 feet
FIELD REP. UNK
SURFACE ELEVATION 4612.40
LOCATION N 59789.80 E 34559.60
DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
				ML	**ALLUVIUM:** SANDY SILT, dk. brown.
				GW	SANDY GRAVEL, dense, brown.
55	▽				**ALLUVIUM**, continued. Note: water encountered at 55 feet.
				CH	**MANCOS SHALE FM.:** SHALE, highly weathered, soft, greyish tan.
60					TD AT 59.5
65					
70					
75					
80					
85					
90					
95					
100					



GROUNDWATER

	DEPTH	HOUR	DATE
▽	55.0		10-22-82
▼			

JEG TAC TEAM

Page 1 of 1

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *595*

JOB NO. GRJ01 DATE 10/22/82

TOTAL DEPTH 21.8 feet

BORING TYPE UNK

FIELD REP. UNK

DEPTH OF SEAL 20.30

SURFACE ELEVATION 4579.80

WELL CASING TYPE 2-IN. SCHED.40 PVC

LOCATION N 59845.70 E 33863.10

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0				CL	**FILL:** SANDY CLAY, cover mtl. with shale mixed, dk. brn.
5 10 15					**TAILINGS:** SILTY SAND TO SANDY SILT, intercalated lenses, lt. grey. Note:Mostly sandy silt from 8.5 to 12 feet. Note: gravelly lens at 14.5 feet.
20	⊽			GW	**ALLUVIUM:** SANDY GRAVEL, dense. Note: Water encountered at 21.2 feet
25 30 35 40 45 50					TD AT 21.8 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
⊽	21.2		10-22-82
▼			

JEG TAC TEAM

LOG OF WELL BORING NO. *596*

JOB NO. GRJ01 DATE 10/22/82

BORING TYPE UNK

DEPTH OF SEAL 18.40

WELL CASING TYPE 2-IN. SCHED.40 PVC

COMPLETION ALLUVIUM

TOTAL DEPTH 22.0 feet

FIELD REP. UNK

SURFACE ELEVATION 4581.60

LOCATION N 59767.30 E 32805.20

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0				CL	**FILL:** SANDY CLAY, cover mtl., with shale mixed.
5					**TAILINGS:** SILTY SAND TO SANDY SILT, intercalated lenses, lt. grey.
10					
15					Note: Black silty sand from 15 to 17 feet. Note: Slimes, clayey silt from 17 to 19.5 feet.
20				GW	**ALLUVIUM:** SANDY GRAVEL, dense.
					TD AT 22 FEET.
25					
30					
35					
40					
45					
50					

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *597*

JOB NO. GRJ01 DATE 10/22/82
BORING TYPE UNK
DEPTH OF SEAL 34.60
WELL CASING TYPE 2-IN. SCHED.40 PVC
COMPLETION ALLUVIUM
TOTAL DEPTH 38.0 feet
FIELD REP. UNK
SURFACE ELEVATION 4596.70
LOCATION N 59530.70 E 34098.00
DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0				CL	**FILL:** SANDY CLAY, cover mtl., mixed shale.
					TAILINGS: SILTY SAND TO SANDY SILT, intercalated lenses, lt. grey.
5					
10					
15					
20					
25					
30					
				GM	**ALLUVIUM:** SILTY GRAVEL AND SAND, very dense, brown to black.
35					
					TD AT 38 FEET.
40					
45					
50					

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

JEG TAC TEAM

No lith log
or Well log

Jacobs Engineering
Albuquerque NM

	DATE	TIME
At printing	SEP1495	15:20
Last update	DEC1092	09:09

PROJECT ID GRJ01
POINT ID 631

Exploration Point Definition - ADDRESS 2201

{1 DATES AND COORDINATES}

	MO	DY	YR
STARTED			
ENDED			

NORTH 60127.5200
EAST 35946.7700
ELEVATION 4611.0
TREND N00.0E PLUNGE -90.0

{2 GENERAL INFORMATION }
SUPERVISOR
DRILLER
EQUIPMENT 2-IN. SCHED.40 PVC
METHOD HOLE DIA 6.2-IN
DEPTHS: Hole 41.00 Water 1 2
STARTING PAGE #

{3 NOTES }
ALLUVIUM

ADDITIONAL NOTE

{4 POINT DESCRIPTOR CODES }
TYPE 1 LOCATION 1 40.9
TYPE 2 LOCATION 2

{5 ADDITIONAL DESCRIPTORS }
PT.DESC1 PT.DESC3
PT.DESC2 PT.DESC4

No lithlog
or Welllog

633

Jacobs Engineering
Albuquerque NM

	DATE	TIME
At printing	SEP1495	15:20
Last update	DEC1092	14:27

PROJECT ID GRJ01
POINT ID 633

Exploration Point Definition - ADDRESS 2201

{1 DATES AND COORDINATES}

	MO	DY	YR
STARTED			
ENDED			

NORTH 60117.2400
EAST 35618.3300
ELEVATION 4605.1
TREND N00.0E PLUNGE -90.0

{2 GENERAL INFORMATION }
SUPERVISOR
DRILLER
EQUIPMENT 2-IN. SCHED.40 PVC
METHOD HOLE DIA 6.2-IN
DEPTHS: Hole 34.00 Water 1 2
STARTING PAGE #

{3 NOTES }
ALLUVIUM

ADDITIONAL NOTE

{4 POINT DESCRIPTOR CODES }
TYPE 1 LOCATION 1 33.9
TYPE 2 LOCATION 2

{5 ADDITIONAL DESCRIPTORS }
PT.DESC1 PT.DESC3
PT.DESC2 PT.DESC4

634

No lith log
Or Well log

```
Jacobs Engineering
Albuquerque NM

             DATE    TIME
At printing  SEP1495 15:20
Last update  DEC1092 14:29

                                                 PROJECT ID   GRJ01
                                                 POINT ID     634_____

                  Exploration Point Definition - ADDRESS 2201

{1 DATES AND COORDINATES}
              MO  DY  YR    {2 GENERAL INFORMATION                            }
 STARTED      __  __  __     SUPERVISOR ____________________
 ENDED        __  __  __     DRILLER    ____________________
 NORTH     ___60117.3300     EQUIPMENT  2-IN. SCHED.40 PVC__
 EAST      ___35332.3000     METHOD     ____________________  HOLE DIA 6.2-IN__
 ELEVATION    4607.6___      DEPTHS: Hole ___39.00  Water  1 _______   2 _______
 TREND N00.0E  PLUNGE -90.0  STARTING PAGE # ____
{3 NOTES                                                                      }
 ALLUVIUM____________________________________________________________________
 ____________________________________________________________________________
 ____________________________________________________________________________
   ADDITIONAL NOTE _________________
{4 POINT DESCRIPTOR CODES            }  {5 ADDITIONAL DESCRIPTORS                }
 TYPE 1 ________   LOCATION 1 38.9____   PT.DESC1 ________   PT.DESC3 ________
 TYPE 2 ________   LOCATION 2 ________   PT.DESC2 ________   PT.DESC4 ________
```

635

No lith log
Or Well log

```
acobs Engineering
lbuquerque NM

                DATE     TIME
t printing     SEP1495  15:21
ast update     DEC1092  14:30

                                               PROJECT ID    GRJ01
                                               POINT ID      635____

                 Exploration Point Definition - ADDRESS 2201

1 DATES AND COORDINATES}
             MO   DY   YR     {2 GENERAL INFORMATION                                  }
STARTED      __   __   __      SUPERVISOR  ____________________
ENDED        __   __   __      DRILLER     ____________________
NORTH     ___59925.1200        EQUIPMENT   2-IN. SCHED.40 PVC__
EAST      ___35444.9000        METHOD      ____________________  HOLE DIA 6.2-IN__
ELEVATION    4615.6___         DEPTHS: Hole ___41.90  Water  1 _______  2 _______
TREND N00.0E  PLUNGE -90.0     STARTING PAGE # ____
3 NOTES                                                                           }
ALLUVIUM__________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
  ADDITIONAL NOTE ___________________
4 POINT DESCRIPTOR CODES            }  {5 ADDITIONAL DESCRIPTORS                  }
TYPE 1 ________  LOCATION 1 41.8____    PT.DESC1 ________  PT.DESC3 ________
TYPE 2 ________  LOCATION 2 ________    PT.DESC2 ________  PT.DESC4 ________
```

Page 1 of 1

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 710

JOB NO. GRJ01 DATE

TOTAL DEPTH 40.0 feet

BORING TYPE UNK

FIELD REP. UNK

DEPTH OF SEAL

SURFACE ELEVATION 4574.35

WELL CASING TYPE 72-IN.

LOCATION N 59541.50 E 36658.10

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0			?		WELL DRILLED AND INSTALLED BY OTHERS FOR WESTER MEAT PACKERS. LITHOLOGY DESCRIPTION UNKNOWN.
5			?		
10			?		
15			?		
20			?		
25			?		
30			?		
35			?		
40					TD AT 40 FEET
45					
50					

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

JEG TAC TEAM

PROJECT **GRAND JUNCTION PROCESS SITE**

LOG OF WELL BORING NO. 711

JOB NO. GRJ01 DATE 09/14/77

TOTAL DEPTH 23.5 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

SURFACE ELEVATION 4600.00

WELL CASING TYPE

LOCATION N 58650.00 E 49280.00

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0	? ?	Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?). Depth of casing is measured at 23.5 feet, with one ft. stickup.	▨	CL	ALLUVIUM: SANDY CLAY, with fine to med. gravel, reddish brown.
5 10 15	? ?		▒	GP	SANDY GRAVEL, poorly graded, subrounded, with occ, cobble, reddish brown.
20	? ?		▨	CL	MANCOS SHALE FM.: SHALE, heathered, soft, grading to mod. hard, grey.
25 30 35 40 45 50					TD AT 23.5 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 712

JOB NO. GRJ01 DATE 09/14/77

TOTAL DEPTH 34.0 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

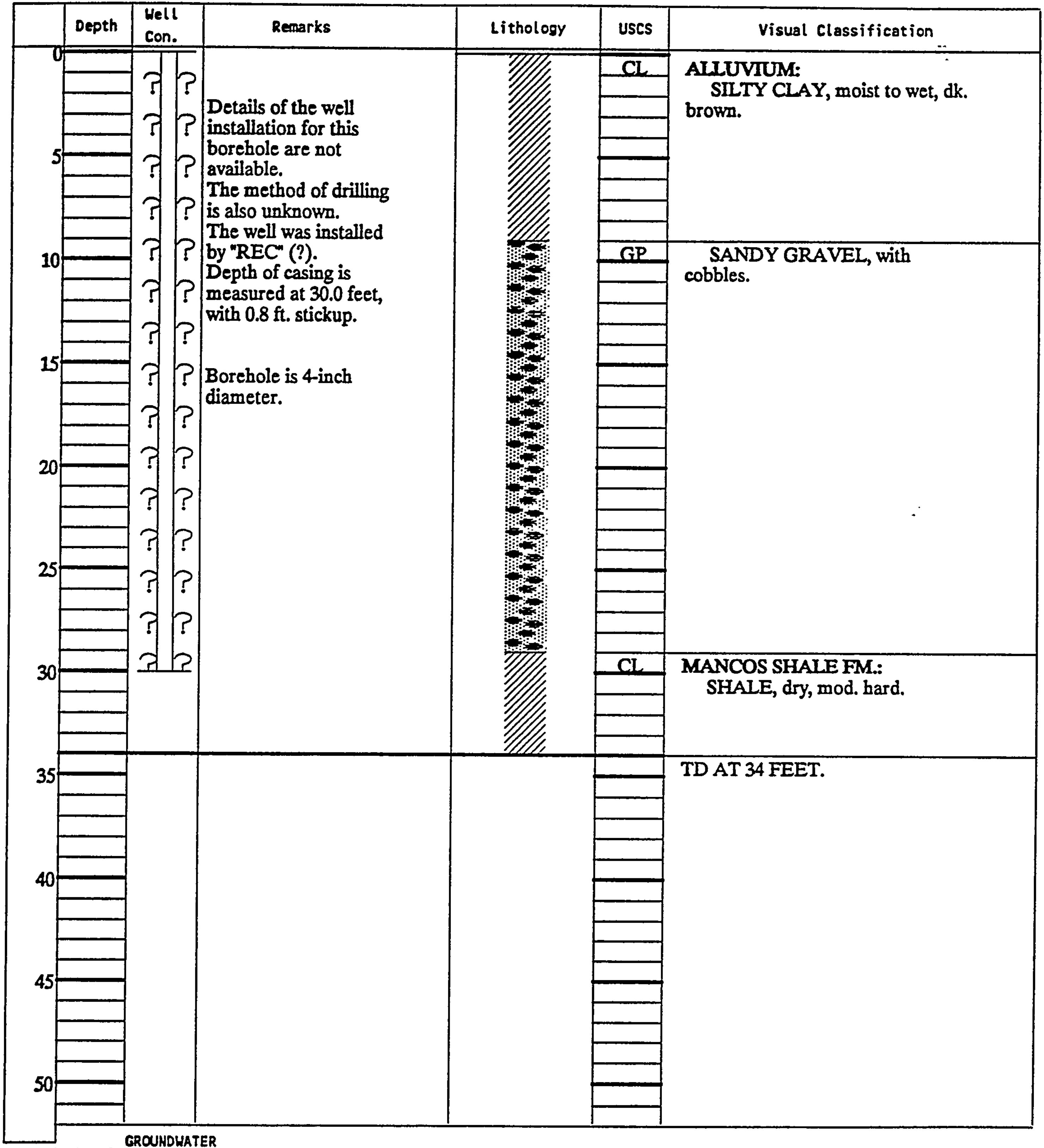
SURFACE ELEVATION 4608.00

WELL CASING TYPE

LOCATION N 60780.00 E 49410.00

COMPLETION ALLUVIUM

DATUM MSL



Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0	? ?	Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?). Depth of casing is measured at 30.0 feet, with 0.8 ft. stickup. Borehole is 4-inch diameter.	▨	CL	ALLUVIUM: SILTY CLAY, moist to wet, dk. brown.
9	? ?			GP	SANDY GRAVEL, with cobbles.
29	? ?		▨	CL	MANCOS SHALE FM.: SHALE, dry, mod. hard.
34					TD AT 34 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *713*

JOB NO. GRJ01 DATE 09/14/77

TOTAL DEPTH 39.0 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

SURFACE ELEVATION 4613.00

WELL CASING TYPE

LOCATION N 62360.00 E 49490.00

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0	? ?	Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?). Depth of casing is measured at 37.5 feet, with 1.8 ft. stickup. Borehole is 4-inch diameter.	▨	CL	ALLUVIUM: SILTY CLAY, soft, lt. brown.
10	? ?		▨		Note: moist at 10 feet.
20	? ?		●	GP	SANDY GRAVEL AND COBBLES, poorly graded.
35	? ?		▨	CL	MANCOS SHALE FM.: SHALE, dry, mod. hard.
39					TD AT 39 FEET.
40					
45					
50					

GROUNDWATER

DEPTH	HOUR	DATE

JEG TAC TEAM

Page 1 of 1

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 714

JOB NO. GRJ01 DATE 09/14/77

TOTAL DEPTH 44.0 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

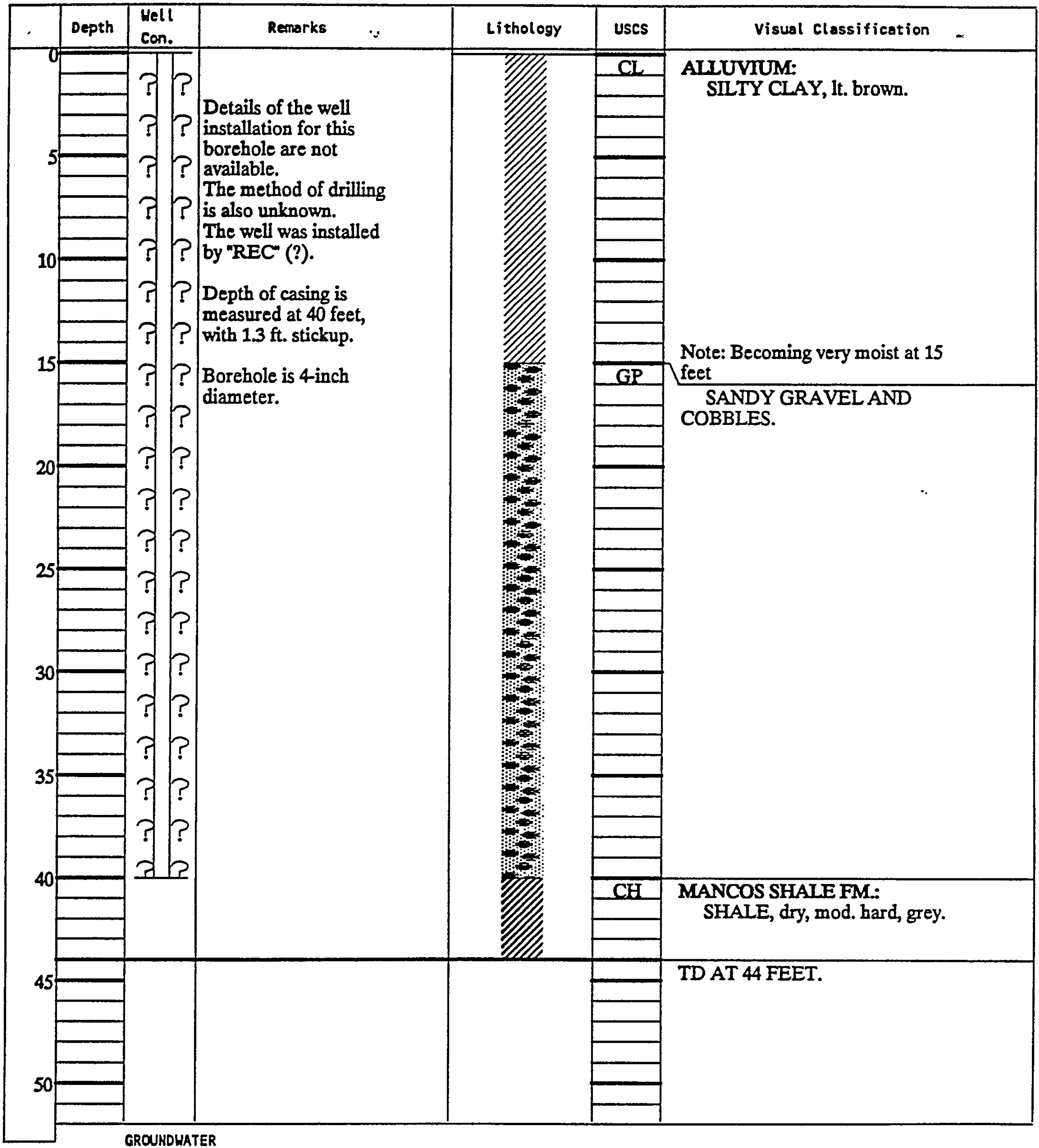
SURFACE ELEVATION 4615.00

WELL CASING TYPE

LOCATION N 62890.00 E 49500.00

COMPLETION ALLUVIUM

DATUM MSL



Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?).

Depth of casing is measured at 40 feet, with 1.3 ft. stickup.

Borehole is 4-inch diameter.

USCS	Visual Classification
CL	ALLUVIUM: SILTY CLAY, lt. brown.
	Note: Becoming very moist at 15 feet
GP	SANDY GRAVEL AND COBBLES.
CH	MANCOS SHALE FM.: SHALE, dry, mod. hard, grey.
	TD AT 44 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 715

JOB NO. GRJ01 DATE 09/14/77

TOTAL DEPTH 59.0 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

SURFACE ELEVATION 4630.00

WELL CASING TYPE

LOCATION N 64980.00 E 49580.00

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0 5 10 15 20 25	? ?	Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?). Depth of casing is measured at 59 feet, with 1.0 ft. stickup. Borehole is 4-inch diameter.	▨	CL	ALLUVIUM: SILTY CLAY, soft, brown.
30 35 40 45 50	? ?		▒	GP	SANDY GRAVEL AND COBBLES.

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 715

JOB NO. GRJ01 DATE 09/14/77

TOTAL DEPTH 59.0 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

SURFACE ELEVATION 4630.00

WELL CASING TYPE

LOCATION N 64980.00 E 49580.00

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
	? ?		▒		ALLUVIUM, Continued.
55	? ?		▒		
	? ?		▨	CH	MANCOS SHALE FM.: SHALE, dry, hard, grey.
60					TD AT 59 FEET.
65					
70					
75					
80					
85					
90					
95					
100					

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

Page 1 of 2

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 716

JOB NO. GRJ01 DATE 09/19/77

TOTAL DEPTH 74.0 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

SURFACE ELEVATION 4642.00

WELL CASING TYPE

LOCATION N 67080.00 E 49680.00

COMPLETION ALLUVIUM.

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0	? ?			GP	**FILL:** GRAVEL, road base, pit run material.
	? ?	Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?). Depth of casing is measured at 66 feet, with 0.9 ft. stickup. Borehole is 4-inch diameter.		CL	**ALLUVIUM:** SILTY CLAY, soft, brown.
5	? ?				
10	? ?				
15	? ?				
20	? ?				
25	? ?				
30	? ?				
	? ?			GP	SANDY GRAVEL, with occ. cobble, grading downward into clayey gravel.
35	? ?				
40	? ?				
45	? ?				
50	? ?				

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

Page 2 of 2

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *716*

JOB NO. GRJ01 DATE 09/19/77

TOTAL DEPTH 74.0 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

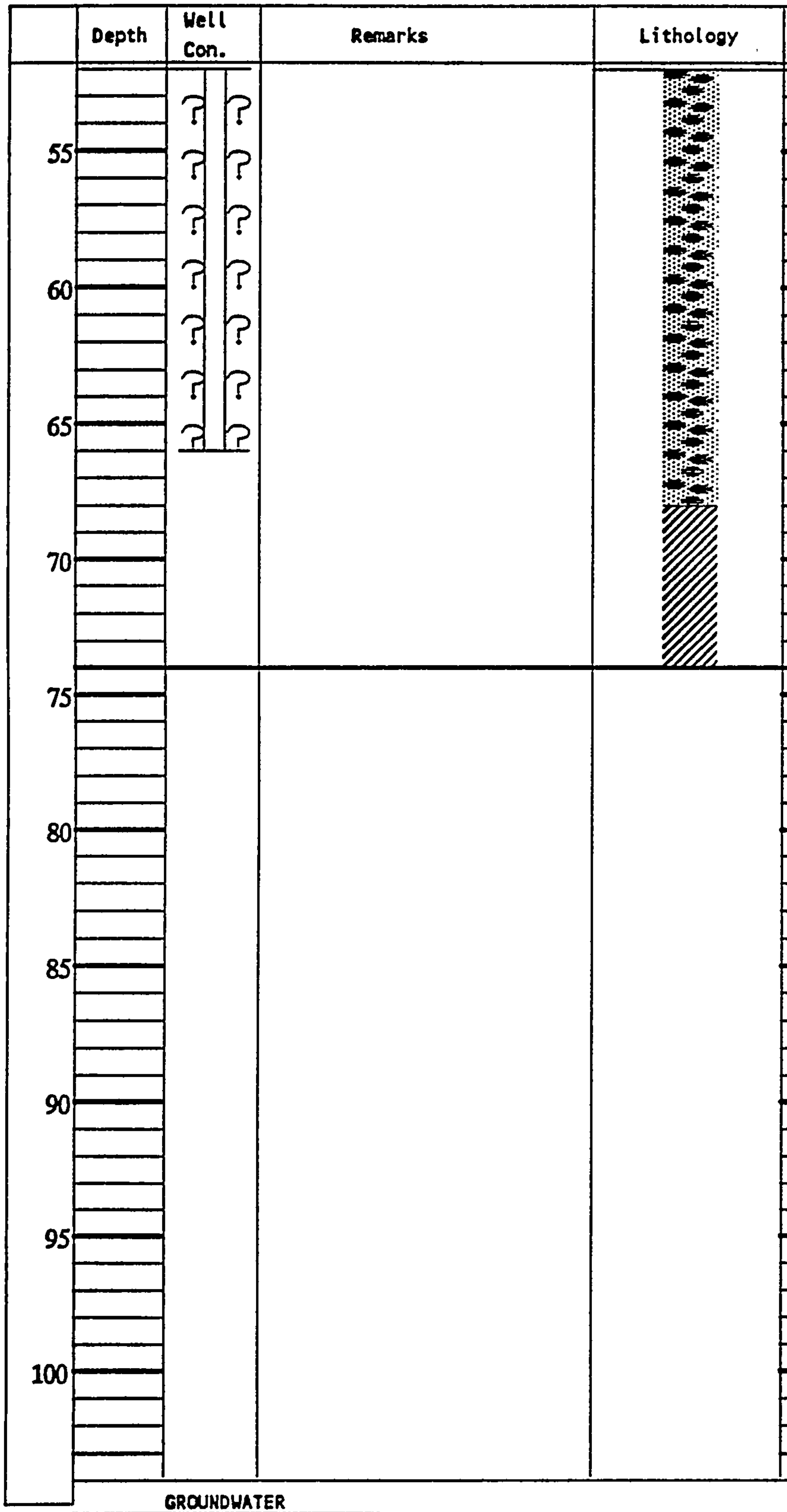
SURFACE ELEVATION 4642.00

WELL CASING TYPE

LOCATION N 67080.00 E 49680.00

COMPLETION ALLUVIUM.

DATUM MSL



USCS	Visual Classification
	ALLUVIUM, Continued.
CH	MANCOS SHALE FM.: SHALE, dry hard, grey.
	TD AT 74 FEET

GROUNDWATER

DEPTH	HOUR	DATE

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *717*

JOB NO. GRJ01 DATE 09/20/77

TOTAL DEPTH 84.0 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

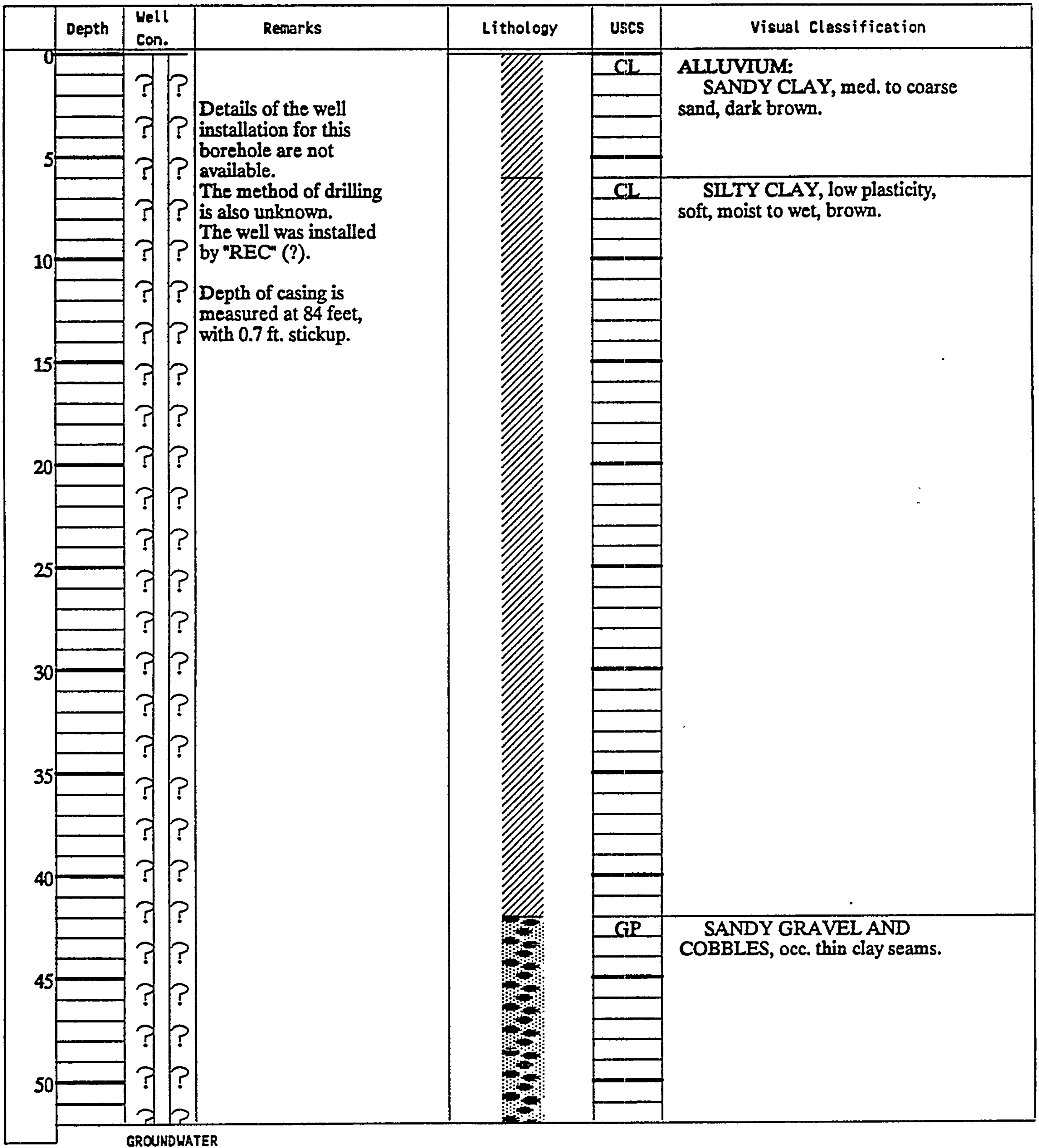
SURFACE ELEVATION 4660.00

WELL CASING TYPE

LOCATION N 68650.00 E 49700.00

COMPLETION ALLUVIUM.

DATUM MSL



Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
	? ?	Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?). Depth of casing is measured at 84 feet, with 0.7 ft. stickup.	▨	CL	ALLUVIUM: SANDY CLAY, med. to coarse sand, dark brown.
	? ?		▨	CL	SILTY CLAY, low plasticity, soft, moist to wet, brown.
	? ?			GP	SANDY GRAVEL AND COBBLES, occ. thin clay seams.

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *717*

JOB NO. GRJ01 DATE 09/20/77

TOTAL DEPTH 84.0 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

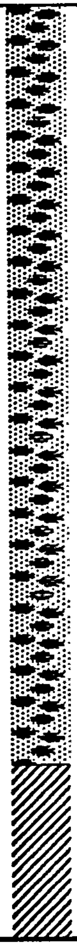
SURFACE ELEVATION 4660.00

WELL CASING TYPE

LOCATION N 68650.00 E 49700.00

COMPLETION ALLUVIUM.

DATUM MSL



Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
55	? ?				**ALLUVIUM,** Continued.
60	? ?				
65	? ?				
70	? ?				
75	? ?				
	? ?			CH	MANCOS SHALE FM.: SHALE, hard, dry.
80	? ?				
					TD AT 84 FEET.
85					
90					
95					
100					

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 718

JOB NO. GRJ01 DATE 09/20/77

TOTAL DEPTH 74.5 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

SURFACE ELEVATION 4670.00

WELL CASING TYPE

LOCATION N 70770.00 E 49750.00

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0	? ?	Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?). Depth of casing is measured at 74.5 feet, with 0.9 ft. stickup.	▨	CL	ALLUVIUM: SILTY CLAY, some fine sand, dark brown.
5	? ?		▨		
10	? ?		▨	CL	SANDY CLAY, med. to coarse grained sand, soft, wet, brown.
15	? ?		▨		
20	? ?		▨		
25	? ?		▨	CL	SILTY CLAY, some fine to med. sand, moist, lt. brown.
30	? ?		▨		
35	? ?		▨		
40	? ?		▨		
45	? ?		▨		
50	? ?		▨		

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *718*

JOB NO. GRJ01 DATE 09/20/77

TOTAL DEPTH 74.5 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

SURFACE ELEVATION 4670.00

WELL CASING TYPE

LOCATION N 70770.00 E 49750.00

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
55	? ?		▨		ALLUVIUM, Continued.
60 65 70	? ?		▨	CH	MANCOS SHALE FM.: SHALE, moist grading to dry at 65 feet, hard, grey.
75 80 85 90 95 100					TD AT 74.5 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

JEG TAC TEAM

PROJECT **GRAND JUNCTION PROCESS SITE**

LOG OF WELL BORING NO. *719*

JOB NO. GRJ01 DATE 09/14/77

TOTAL DEPTH 60.5 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

SURFACE ELEVATION 4680.00

WELL CASING TYPE

LOCATION N 72360.00 E 49800.00

COMPLETION MANCOS SHALE FM.

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0	? ?	Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?). Depth of casing is measured at 60.5 feet, with 0.8 ft. stickup. Borehole size is 4-inch.	▨	CL	ALLUVIUM: SILTY CLAY, with fine sand, moist, brown.
5	? ?		▨		
10	? ?		▨	CL	SANDY CLAY, medium to coarse sand, soft, wet, brown.
15	? ?		▨		
20	? ?		▨		
25	? ?		▨		Note: Sand content changing to mostly nedium grained.
30	? ?		▨		
35	? ?		▨		
	? ?		▨	CH	MANCOS SHALE FM.: SHALE, weathered, moist, dk. grey.
40	? ?		▨		
45	? ?		▨		
50	? ?		▨		

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

JEG TAC TEAM

Page 2 of 2

LOG OF WELL BORING NO. *719*

PROJECT GRAND JUNCTION PROCESS SITE

JOB NO. GRJ01 DATE 09/14/77

TOTAL DEPTH 60.5 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

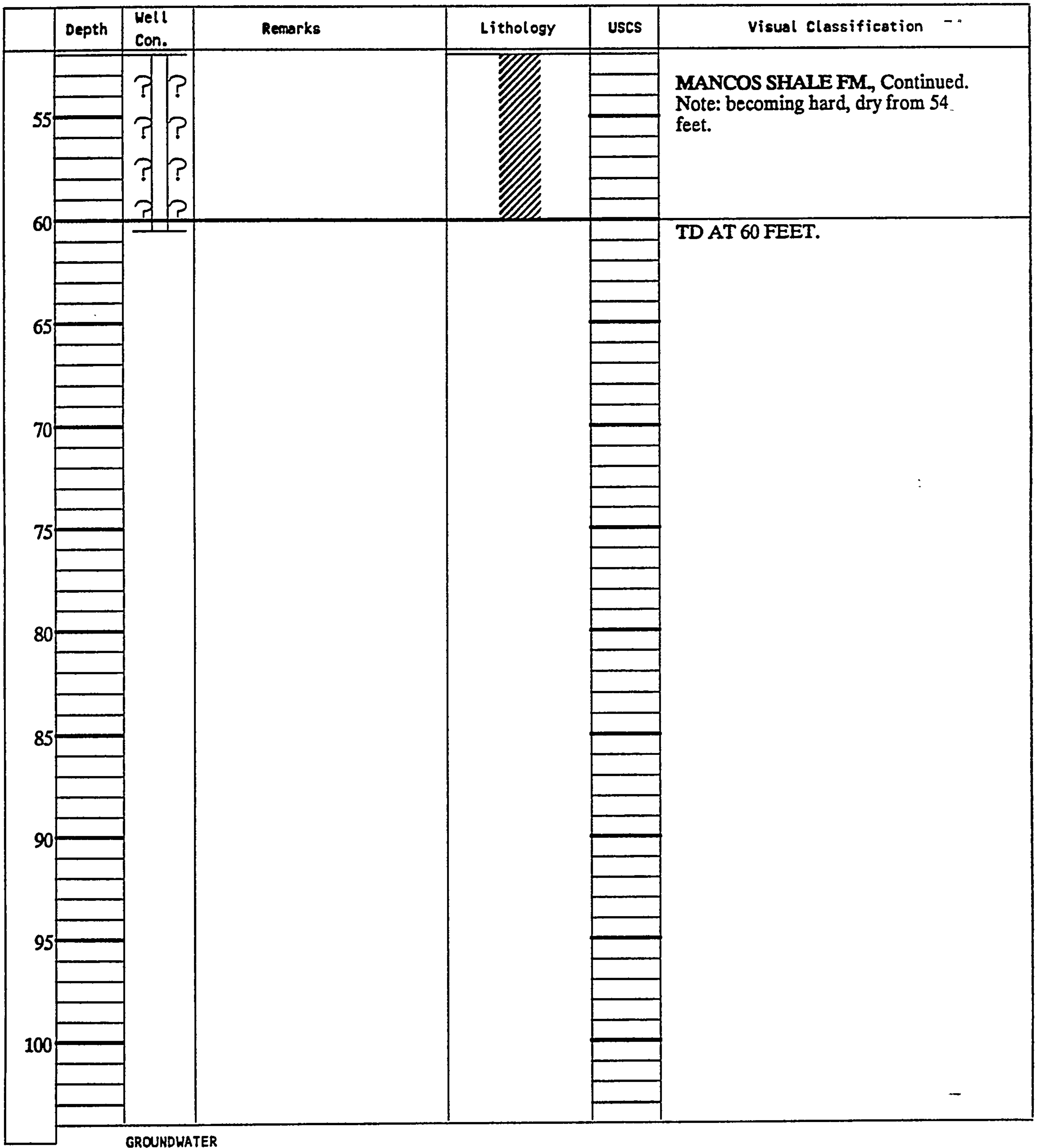
SURFACE ELEVATION 4680.00

WELL CASING TYPE

LOCATION N 72360.00 E 49800.00

COMPLETION MANCOS SHALE FM.

DATUM MSL



MANCOS SHALE FM., Continued. Note: becoming hard, dry from 54 feet.

TD AT 60 FEET.

GROUNDWATER

DEPTH	HOUR	DATE

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *720*

JOB NO. GRJ01
DATE 08/16/77
TOTAL DEPTH 54.5 feet
BORING TYPE
FIELD REP.
DEPTH OF SEAL
SURFACE ELEVATION 4734.00
WELL CASING TYPE
LOCATION N 75490.00 E 49920.00
COMPLETION MANCOS SHALE FM.
DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0	? ?		▨	CL	ALLUVIAL: SILTY CLAY, with sand, dry, dk. brown.
5	? ?	Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?).	▨	CL	SANDY CLAY, med. to coarse sand, soft, wet, brown.
10	? ?	Depth of casing is measured at 54.5 feet, with 0.9 ft. stickup.	▨		
15	? ?	Borehole size is 4-inch.	▨		
20	? ?		▨		
25	? ?		▨		Note: Sand content becomes fine to med. grained.
30	? ?		▨		
35	? ?		▨	CH	MANCOS SHALE FM.: SHALE, weathered, soft, grey.
40	? ?		▨		
45	? ?		▨		
50	? ?		▨		Note: becomes dry and hard at 48 ft.

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT

LOG OF WELL BORING NO. 720

JOB NO. GRJ01 DATE 08/16/77

TOTAL DEPTH 54.5 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

SURFACE ELEVATION 4734.00

WELL CASING TYPE

LOCATION N 75490.00 E 49920.00

COMPLETION MANCOS SHALE FM.

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
	? ?		▨		MANCOS SHALE FM., Continued.
55					TD AT 48.5 FEET.
60					
65					
70					
75					
80					
85					
90					
95					
100					

GROUNDWATER

	DEPTH	HOUR	DATE
∇			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 721

JOB NO. GRJ01 DATE 08/16/77

TOTAL DEPTH 45.5 feet

BORING TYPE

FIELD REP.

DEPTH OF SEAL

SURFACE ELEVATION 4780.00

WELL CASING TYPE

LOCATION N 76530.00 E 49970.00

COMPLETION MANCOS SHALE FM.

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0	? ?	Details of the well installation for this borehole are not available. The method of drilling is also unknown. The well was installed by "REC" (?). Depth of casing is measured at 45.5 feet, with 0.8 ft. stickup. Borehole size is 4-inch.		SM	**ALLUVIAL:** SILTY SAND, little sand, dry, brown.
5	? ?		▨	CL	SANDY CLAY, med. to coarse sand, wet, brown.
10	? ?		▨		
15	? ?		▨		
20	? ?		▨		Note: Becoming mod. hard and moist from 22 feet.
25	? ?		▨		
30	? ?		▨	CH	**MANCOS SHALE FM.:** SHALE, weathered ,soft, dry, dk. grey. Note: Becoming hard and dry from 33 feet.
35	? ?		▨		
40	? ?		▨		
45					TD AT 45 FEET.
50					

GROUNDWATER

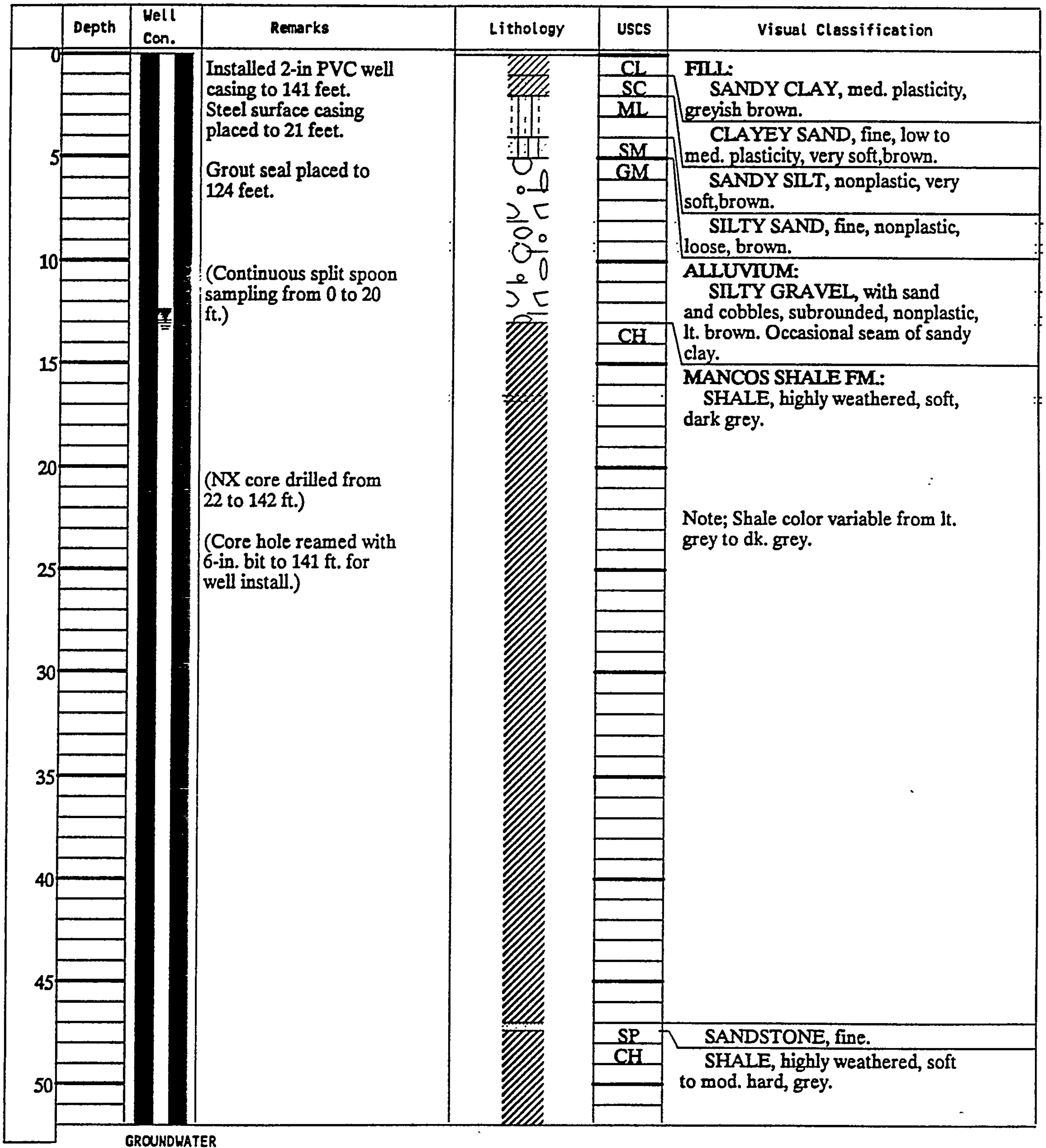
	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 724

JOB NO. GRJ01 DATE 02/28/85
TOTAL DEPTH 142.0 feet
BORING TYPE CORE/ROTARY/WATER
FIELD REP. W.WOOD
DEPTH OF SEAL 126.50
SURFACE ELEVATION 4564.70
WELL CASING TYPE 2.0-IN.SCHED.40 PVC
LOCATION N 59894.50 E 31371.50
COMPLETION DAKOTA SANDSTONE FM.
DATUM MSL



Remarks

Installed 2-in PVC well casing to 141 feet. Steel surface casing placed to 21 feet.

Grout seal placed to 124 feet.

(Continuous split spoon sampling from 0 to 20 ft.)

(NX core drilled from 22 to 142 ft.)

(Core hole reamed with 6-in. bit to 141 ft. for well install.)

Visual Classification

USCS	Visual Classification
	FILL:
CL	SANDY CLAY, med. plasticity, greyish brown.
SC	CLAYEY SAND, fine, low to med. plasticity, very soft, brown.
ML	SANDY SILT, nonplastic, very soft, brown.
SM	SILTY SAND, fine, nonplastic, loose, brown.
	ALLUVIUM:
GM	SILTY GRAVEL, with sand and cobbles, subrounded, nonplastic, lt. brown. Occasional seam of sandy clay.
	MANCOS SHALE FM.:
CH	SHALE, highly weathered, soft, dark grey. Note; Shale color variable from lt. grey to dk. grey.
SP	SANDSTONE, fine.
CH	SHALE, highly weathered, soft to mod. hard, grey.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	13.1		3-4-89
▼	12.9		8-4-89

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *724*

JOB NO. GRJ01 DATE 02/28/85

TOTAL DEPTH 142.0 feet

BORING TYPE CORE/ROTARY/WATER

FIELD REP. W.WOOD

DEPTH OF SEAL 126.50

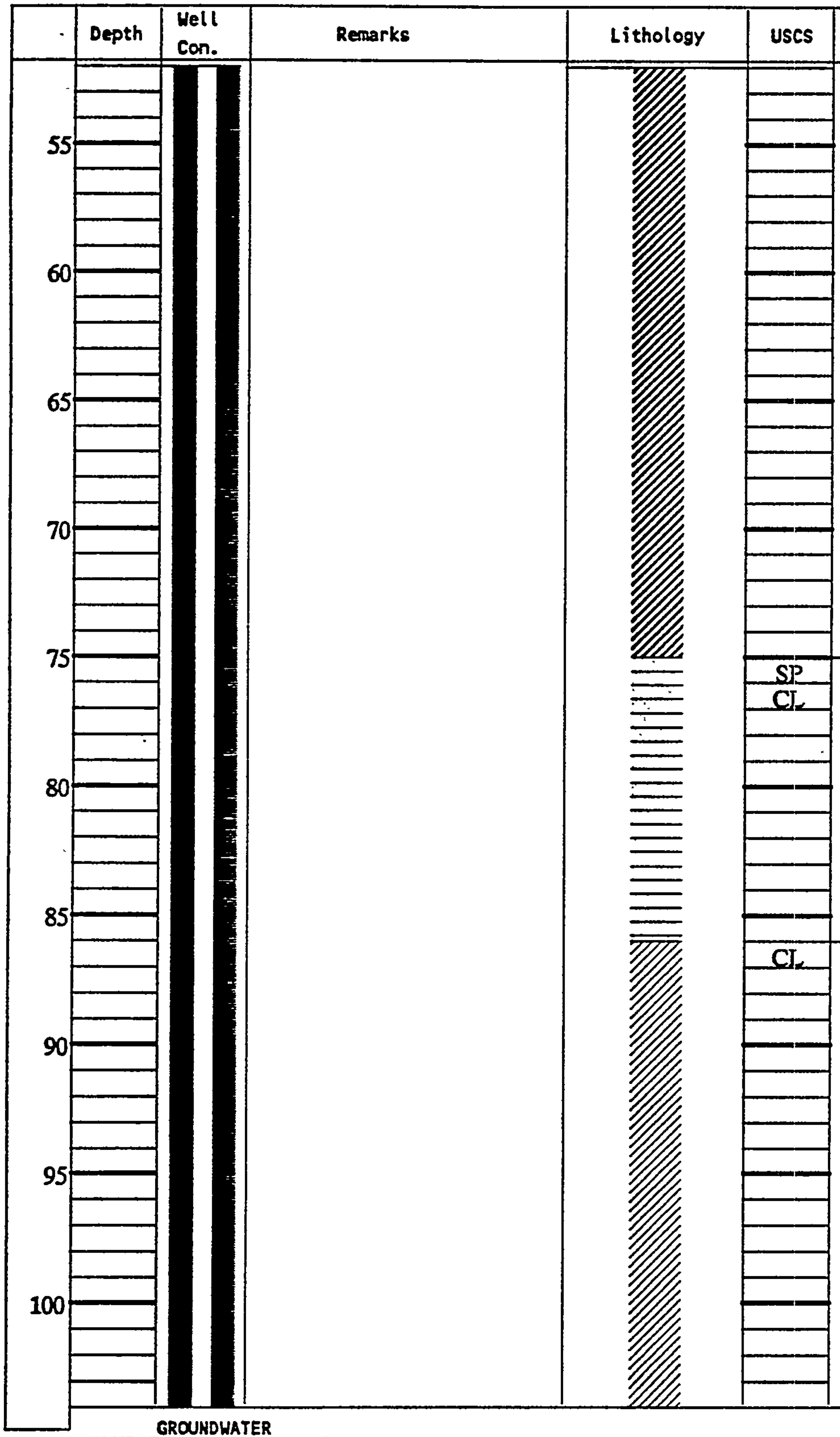
SURFACE ELEVATION 4564.70

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 59894.50 E 31371.50

COMPLETION DAKOTA SANDSTONE FM.

DATUM MSL



Visual Classification

MANCOS SHALE FM., Continued.

Note: Seam of soft, white claystone (bentonitic), at 69.5 to 70.5 ft.

DAKOTA SANDSTONE FORMATION:

SANDSTONE & SHALE, intercalated lenses, lt. grey to mottled dark grey.

SHALE, carbonaceous, black. Occasional seam of hard, lt. grey sandstone,

GROUNDWATER

	DEPTH	HOUR	DATE
▽	13.1		3-4-89
▼	12.9		8-4-89

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *724*

JOB NO. GRJ01 DATE 02/28/85

TOTAL DEPTH 142.0 feet

BORING TYPE CORE/ROTARY/WATER

FIELD REP. W.WOOD

DEPTH OF SEAL 126.50

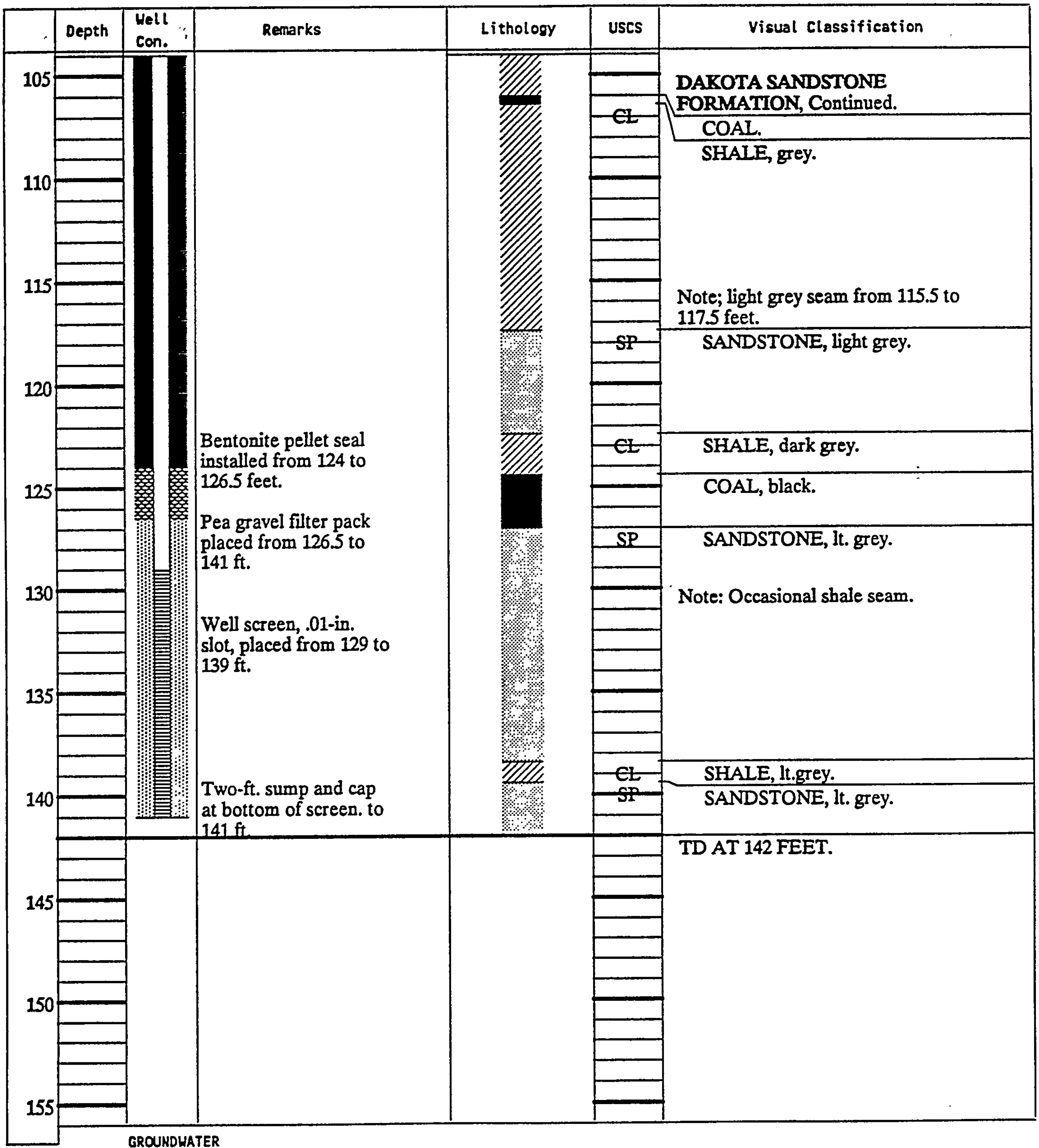
SURFACE ELEVATION 4564.70

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 59894.50 E 31371.50

COMPLETION DAKOTA SANDSTONE FM.

DATUM MSL



Bentonite pellet seal installed from 124 to 126.5 feet.

Pea gravel filter pack placed from 126.5 to 141 ft.

Well screen, .01-in. slot, placed from 129 to 139 ft.

Two-ft. sump and cap at bottom of screen. to 141 ft.

DAKOTA SANDSTONE FORMATION, Continued.

COAL.

SHALE, grey.

Note; light grey seam from 115.5 to 117.5 feet.

SANDSTONE, light grey.

SHALE, dark grey.

COAL, black.

SANDSTONE, lt. grey.

Note: Occasional shale seam.

SHALE, lt.grey.

SANDSTONE, lt. grey.

TD AT 142 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
∇	13.1		3-4-89
▼	12.9		8-4-89

JEG TAC TEAM

Page 1 of 3

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *725*

JOB NO. GRJ01 DATE 02/26/85

TOTAL DEPTH 149.0 feet

BORING TYPE CORE/ROTARY/AIR/H20

FIELD REP. W.WOOD

DEPTH OF SEAL 36.00

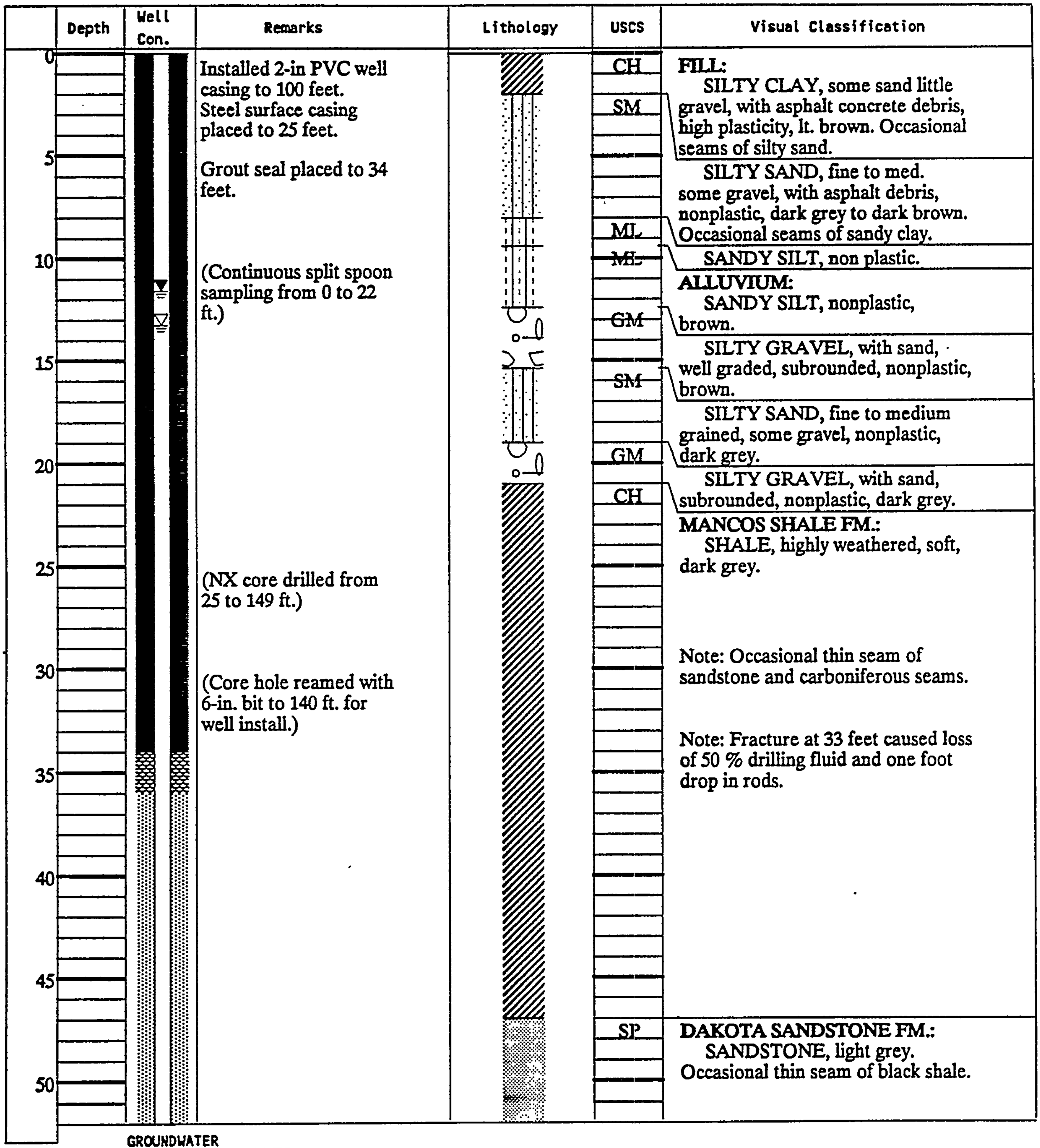
SURFACE ELEVATION 4566.80

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 59394.90 E 31268.00

COMPLETION DAKOTA SANDSTONE FM.

DATUM MSL



Remarks

Installed 2-in PVC well casing to 100 feet. Steel surface casing placed to 25 feet.

Grout seal placed to 34 feet.

(Continuous split spoon sampling from 0 to 22 ft.)

(NX core drilled from 25 to 149 ft.)

(Core hole reamed with 6-in. bit to 140 ft. for well install.)

USCS

CH
SM
ML
ML
GM
SM
GM
CH
SP

Visual Classification

FILL:

SILTY CLAY, some sand little gravel, with asphalt concrete debris, high plasticity, lt. brown. Occasional seams of silty sand.

SILTY SAND, fine to med. some gravel, with asphalt debris, nonplastic, dark grey to dark brown. Occasional seams of sandy clay.

SANDY SILT, non plastic.

ALLUVIUM:

SANDY SILT, nonplastic, brown.

SILTY GRAVEL, with sand, well graded, subrounded, nonplastic, brown.

SILTY SAND, fine to medium grained, some gravel, nonplastic, dark grey.

SILTY GRAVEL, with sand, subrounded, nonplastic, dark grey.

MANCOS SHALE FM.:

SHALE, highly weathered, soft, dark grey.

Note: Occasional thin seam of sandstone and carboniferous seams.

Note: Fracture at 33 feet caused loss of 50 % drilling fluid and one foot drop in rods.

DAKOTA SANDSTONE FM.:

SANDSTONE, light grey. Occasional thin seam of black shale.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	13.3		3-2-89
▼	11.6		8-5-89

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 725

JOB NO. GRJ01 DATE 02/26/85

BORING TYPE CORE/ROTARY/AIR/H20

DEPTH OF SEAL 36.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION DAKOTA SANDSTONE FM.

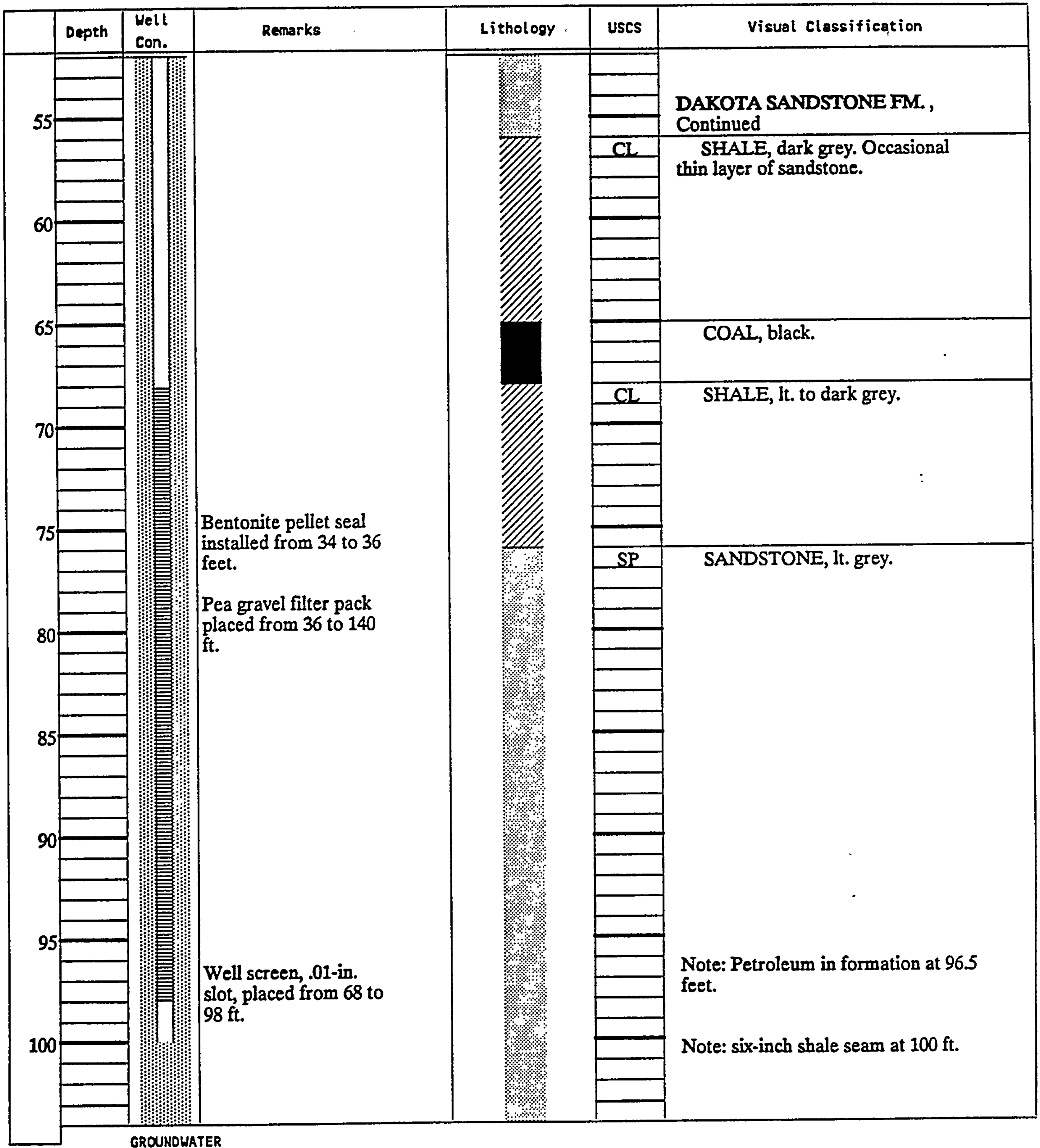
TOTAL DEPTH 149.0 feet

FIELD REP. W.WOOD

SURFACE ELEVATION 4566.80

LOCATION N 59394.90 E 31268.00

DATUM MSL



DAKOTA SANDSTONE FM., Continued

SHALE, dark grey. Occasional thin layer of sandstone.

COAL, black.

SHALE, lt. to dark grey.

SANDSTONE, lt. grey.

Bentonite pellet seal installed from 34 to 36 feet.

Pea gravel filter pack placed from 36 to 140 ft.

Note: Petroleum in formation at 96.5 feet.

Well screen, .01-in. slot, placed from 68 to 98 ft.

Note: six-inch shale seam at 100 ft.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	13.3		3-2-89
▼	11.6		8-5-89

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 725

JOB NO. GRJ01 DATE 02/26/85

BORING TYPE CORE/ROTARY/AIR/H20

DEPTH OF SEAL 36.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION DAKOTA SANDSTONE FM.

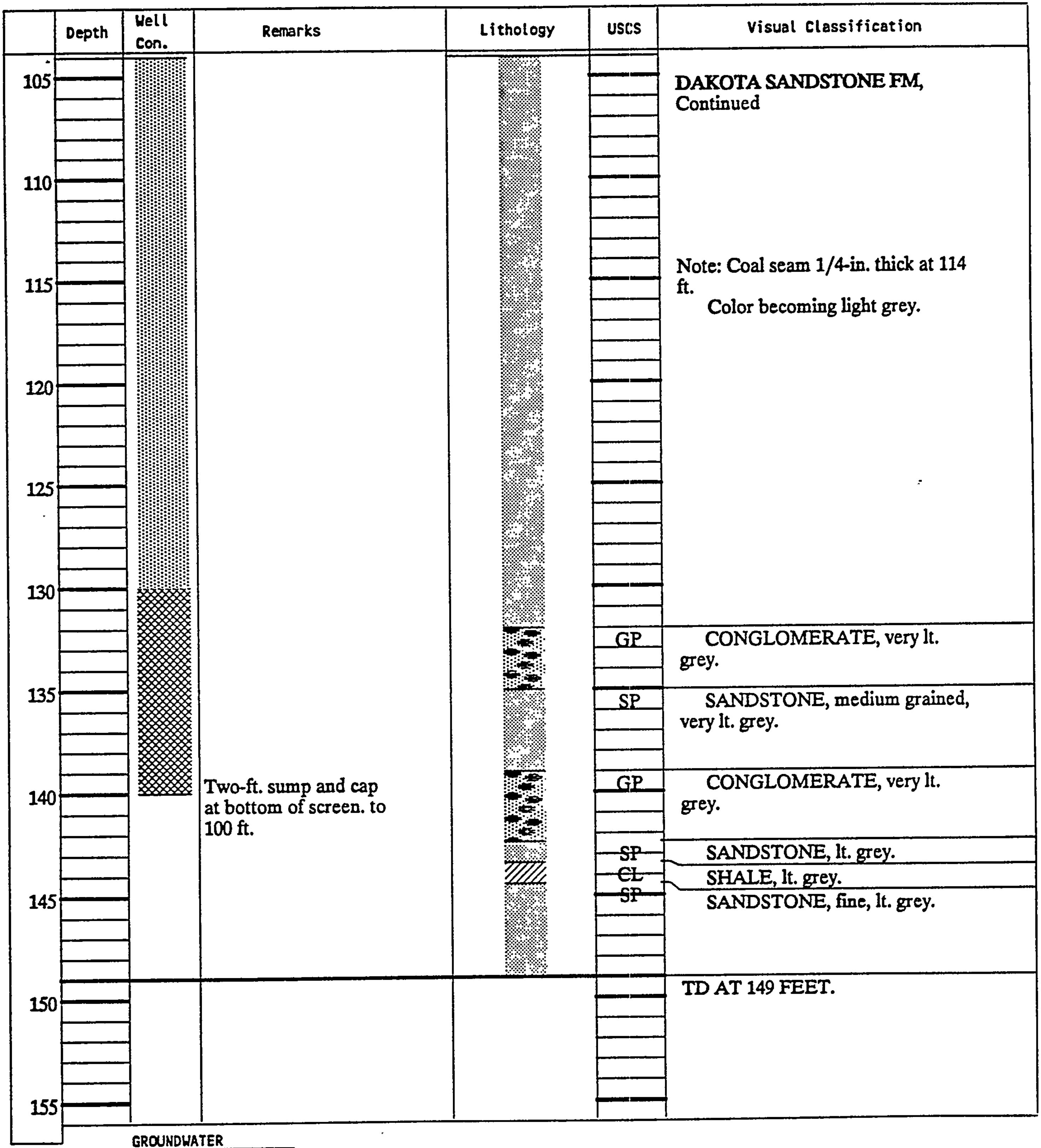
TOTAL DEPTH 149.0 feet

FIELD REP. W.WOOD

SURFACE ELEVATION 4566.80

LOCATION N 59394.90 E 31268.00

DATUM MSL



DAKOTA SANDSTONE FM, Continued

Note: Coal seam 1/4-in. thick at 114 ft.
Color becoming light grey.

CONGLOMERATE, very lt. grey.

SANDSTONE, medium grained, very lt. grey.

Two-ft. sump and cap at bottom of screen. to 100 ft.

CONGLOMERATE, very lt. grey.

SANDSTONE, lt. grey.

SHALE, lt. grey.

SANDSTONE, fine, lt. grey.

TD AT 149 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	13.3		3-2-89
▼	11.6		8-5-89

JEG TAC TEAM

Page 1 of 3

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *726*

JOB NO. GRJ01 DATE 03/10/85

TOTAL DEPTH 140.0 feet

BORING TYPE ROTARY/ WATER

FIELD REP. W.WOOD

DEPTH OF SEAL 73.00

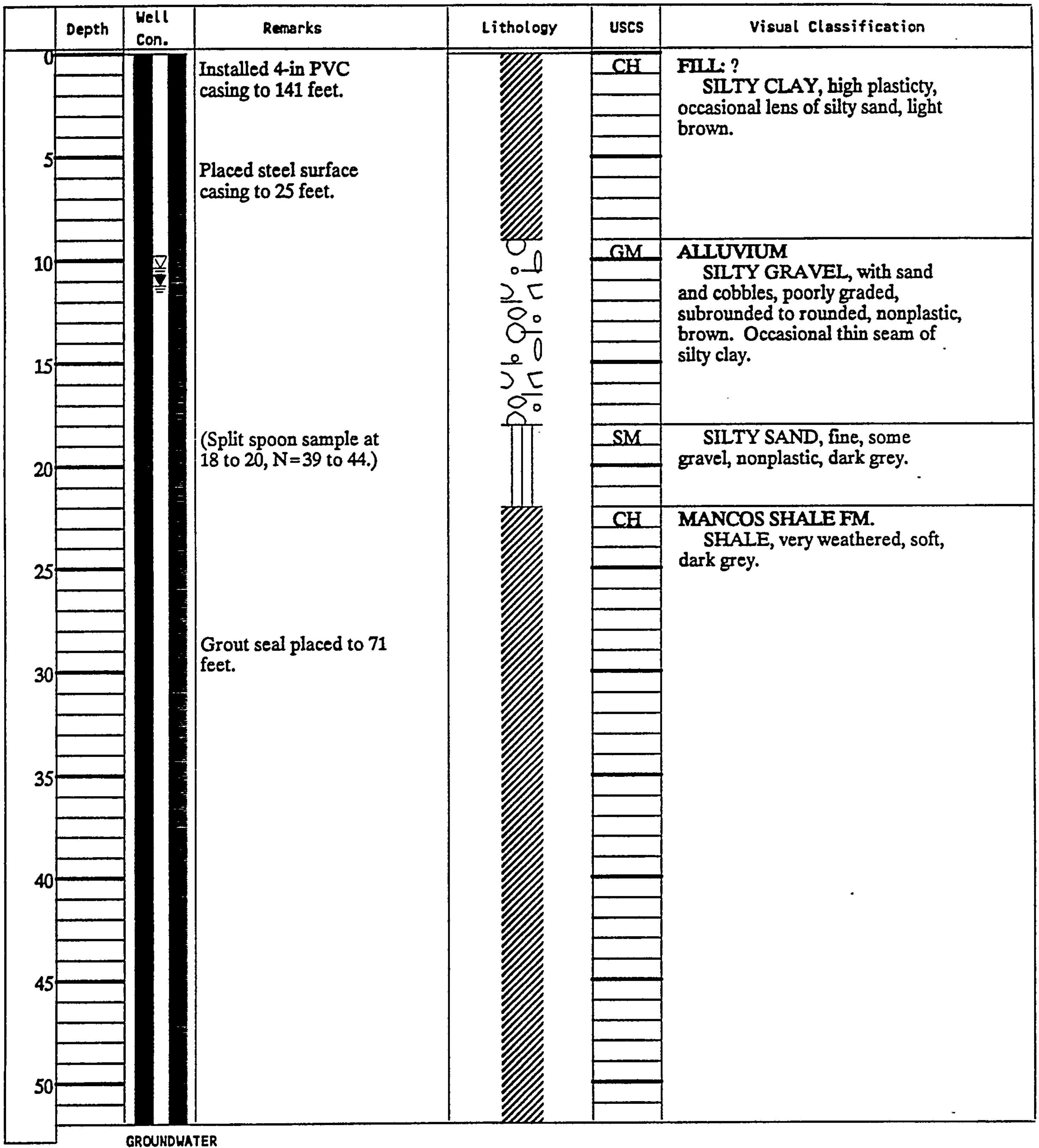
SURFACE ELEVATION 4566.80

WELL CASING TYPE 4.0-IN.SCHED.40 PVC

LOCATION N 59393.00 E 31257.30

COMPLETION DAKOTA SANDSTONE FM.

DATUM MSL



Remarks	USCS	Visual Classification
Installed 4-in PVC casing to 141 feet.	CH	**FILL: ?** SILTY CLAY, high plasticty, occasional lens of silty sand, light brown.
Placed steel surface casing to 25 feet.		
	GM	**ALLUVIUM** SILTY GRAVEL, with sand and cobbles, poorly graded, subrounded to rounded, nonplastic, brown. Occasional thin seam of silty clay.
(Split spoon sample at 18 to 20, N=39 to 44.)	SM	SILTY SAND, fine, some gravel, nonplastic, dark grey.
	CH	**MANCOS SHALE FM.** SHALE, very weathered, soft, dark grey.
Grout seal placed to 71 feet.		

GROUNDWATER

	DEPTH	HOUR	DATE
∇	10.3		3-2-89
▼	11.2		10-31-89

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *726*

JOB NO. GRJ01 DATE 03/10/85

TOTAL DEPTH 140.0 feet

BORING TYPE ROTARY/ WATER

FIELD REP. W.WOOD

DEPTH OF SEAL 73.00

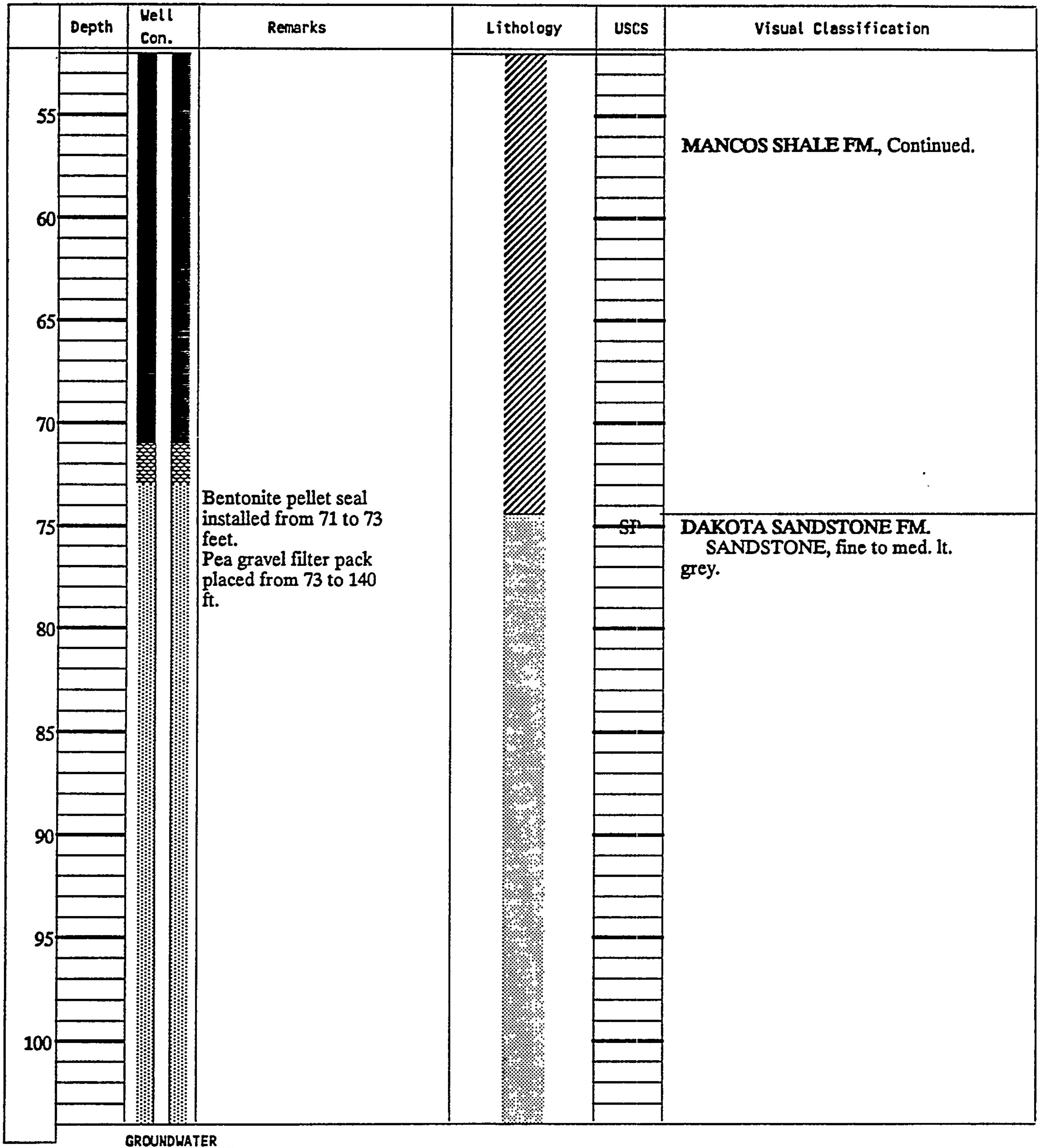
SURFACE ELEVATION 4566.80

WELL CASING TYPE 4.0-IN.SCHED.40 PVC

LOCATION N 59393.00 E 31257.30

COMPLETION DAKOTA SANDSTONE FM.

DATUM MSL



Bentonite pellet seal installed from 71 to 73 feet.
Pea gravel filter pack placed from 73 to 140 ft.

MANCOS SHALE FM., Continued.

DAKOTA SANDSTONE FM.
SANDSTONE, fine to med. lt. grey.

GROUNDWATER

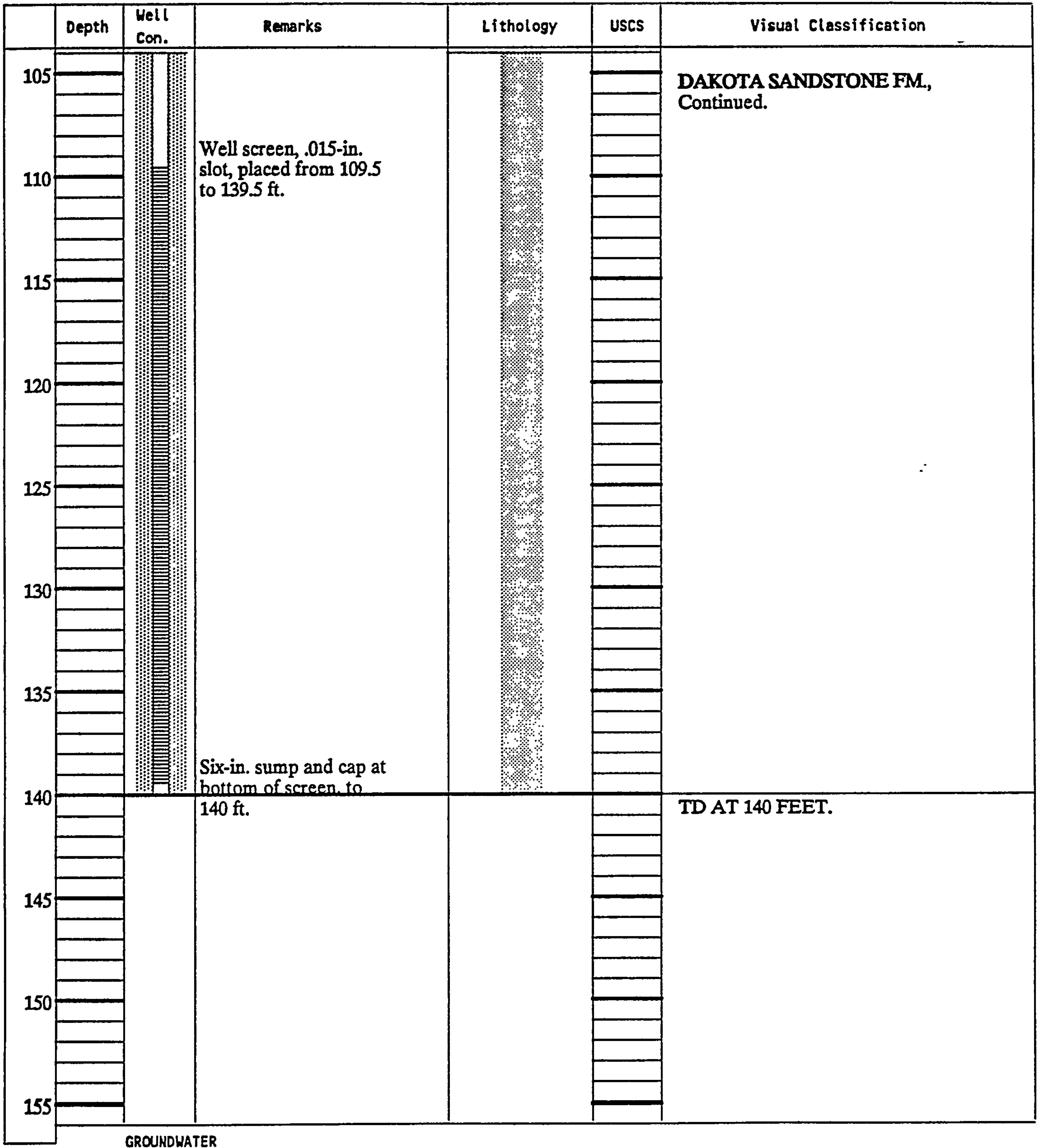
	DEPTH	HOUR	DATE
▽	10.3		3-2-89
▼	11.2		10-31-89

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 726

JOB NO. GRJ01	DATE 03/10/85	TOTAL DEPTH	140.0 feet
BORING TYPE	ROTARY/ WATER	FIELD REP.	W.WOOD
DEPTH OF SEAL	73.00	SURFACE ELEVATION	4566.80
WELL CASING TYPE	4.0-IN.SCHED.40 PVC	LOCATION	N 59393.00 E 31257.30
COMPLETION	DAKOTA SANDSTONE FM.	DATUM	MSL



Well screen, .015-in. slot, placed from 109.5 to 139.5 ft.

Six-in. sump and cap at bottom of screen, to 140 ft.

DAKOTA SANDSTONE FM., Continued.

TD AT 140 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
∇	10.3		3-2-89
▼	11.2		10-31-89

JEG TAC TEAM

Page 1 of 2

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 727

JOB NO. GRJ01 DATE 03/03/85

BORING TYPE ROTARY W/AIR/WATER

DEPTH OF SEAL 41.20

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION MANCOS SHALE FM.

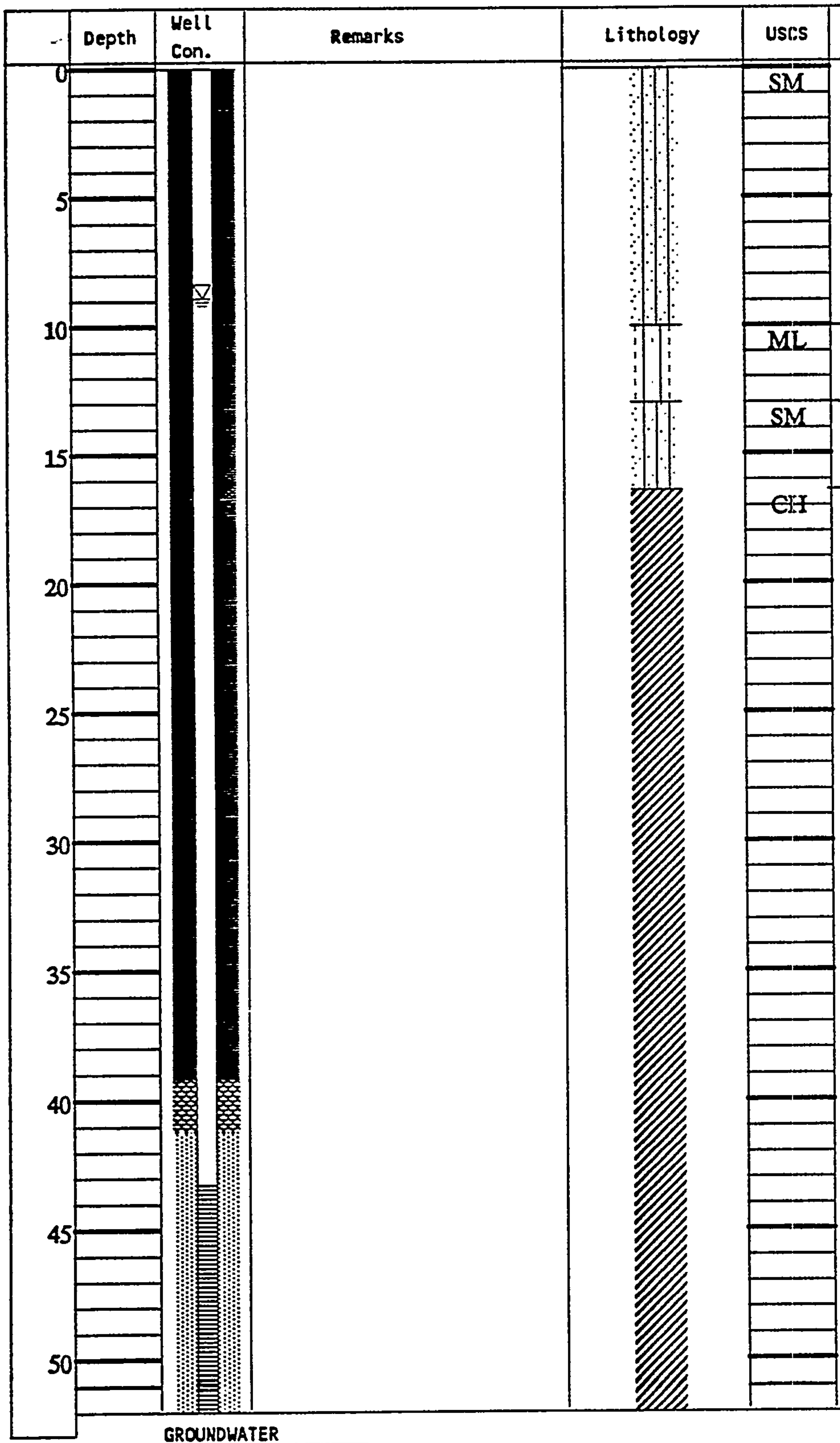
TOTAL DEPTH 55.2 feet

FIELD REP. W.WOOD

SURFACE ELEVATION 4566.40

LOCATION N 59380.30 E 31265.30

DATUM MSL



Visual Classification

FILL:
SILTY SAND, fine, some gravel, occ. asphalt and concrete chunks, nonplastic, dk. brown to dk. grey. Occ. seams of silty clay.

ALLUVIUM:
SANDY SILT, nonplastic, lt. brown.

SILTY SAND AND GRAVEL, with cobbles, poorly graded, subrounded, nonplastic, brown.

MANCOS SHALE FM:
SHALE, very weathered, soft, dk. grey.

Note: Occasional thin sandstone seam.

GROUNDWATER

	DEPTH	HOUR	DATE
∇	8.9	12:35	7-24-86
▼			

JEG TAC TEAM

Page 2 of 2

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 727

JOB NO. GRJ01 DATE 03/03/85

TOTAL DEPTH 55.2 feet

BORING TYPE ROTARY W/AIR/WATER

FIELD REP. W.WOOD

DEPTH OF SEAL 41.20

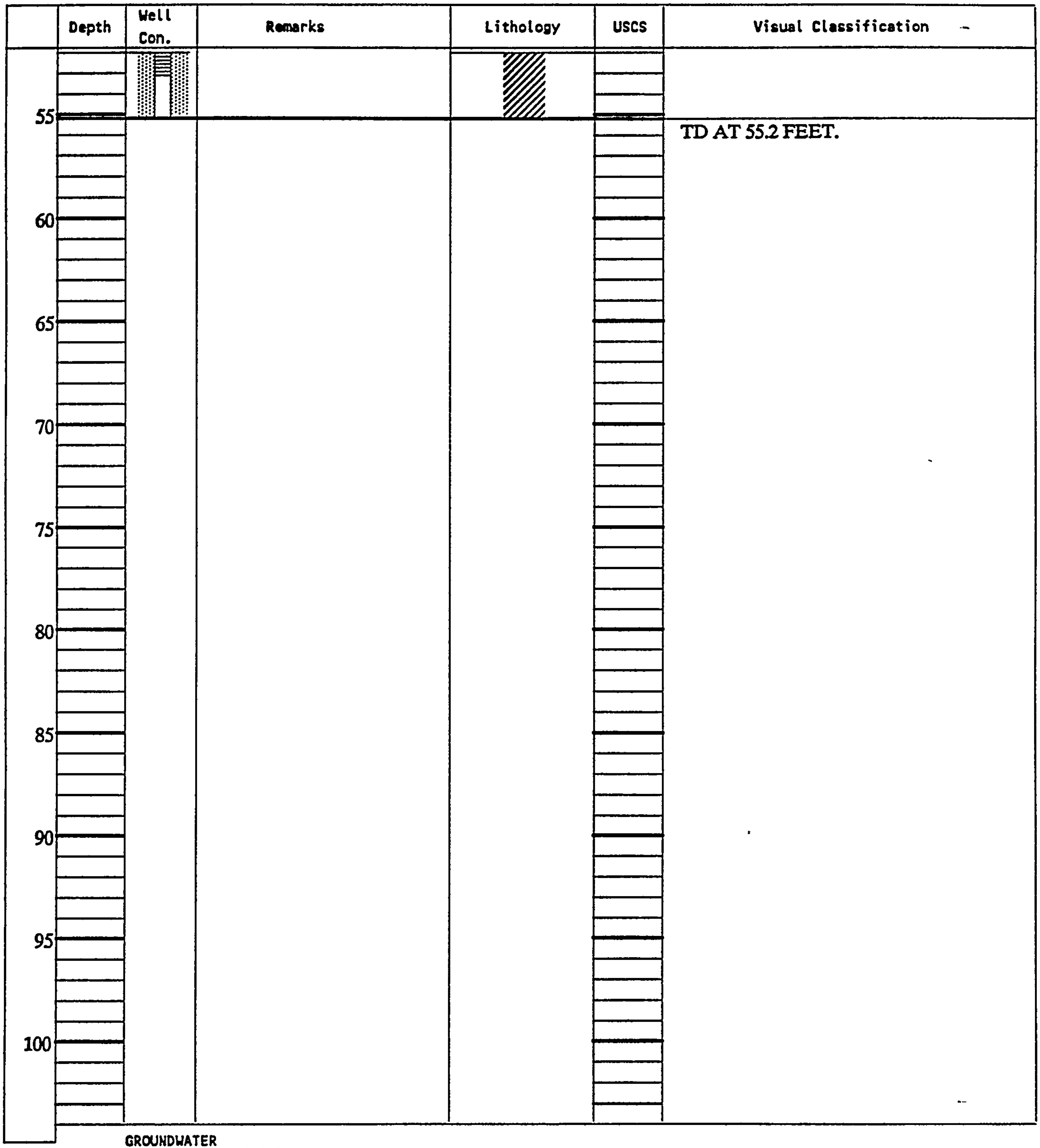
SURFACE ELEVATION 4566.40

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 59380.30 E 31265.30

COMPLETION MANCOS SHALE FM.

DATUM MSL



TD AT 55.2 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
∇	8.9	12:35	7-24-86
▼			

JEG TAC TEAM

Page 1 of 1

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *728*

JOB NO. GRJ01 DATE 02/25/85

TOTAL DEPTH 17.0 feet

BORING TYPE ROTARY W/REVERT

FIELD REP. MCKENZIE

DEPTH OF SEAL 8.00

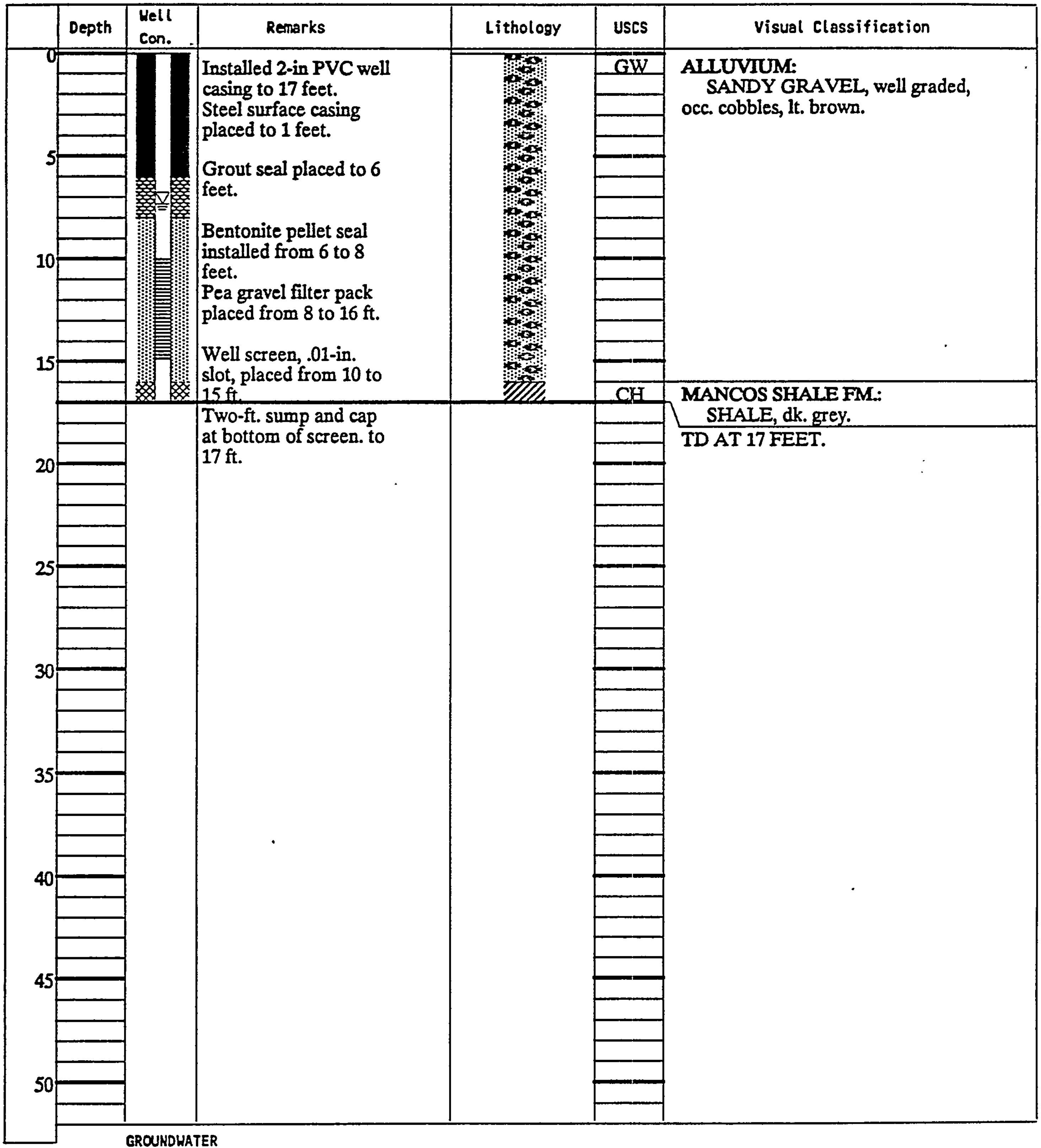
SURFACE ELEVATION 4565.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 59518.50 E 31296.10

COMPLETION MANCOS SHALE FM.

DATUM MSL



Installed 2-in PVC well casing to 17 feet. Steel surface casing placed to 1 feet.

Grout seal placed to 6 feet.

Bentonite pellet seal installed from 6 to 8 feet.

Pea gravel filter pack placed from 8 to 16 ft.

Well screen, .01-in. slot, placed from 10 to 15 ft.

Two-ft. sump and cap at bottom of screen. to 17 ft.

ALLUVIUM:
SANDY GRAVEL, well graded, occ. cobbles, lt. brown.

MANCOS SHALE FM.:
SHALE, dk. grey.

TD AT 17 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	7.3	11:10	7-24-86
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 729

JOB NO. GRJ01 DATE 03/02/85

TOTAL DEPTH 65.0 feet

BORING TYPE CORE/ROTARY/WATER

FIELD REP. W.WOOD

DEPTH OF SEAL 51.00

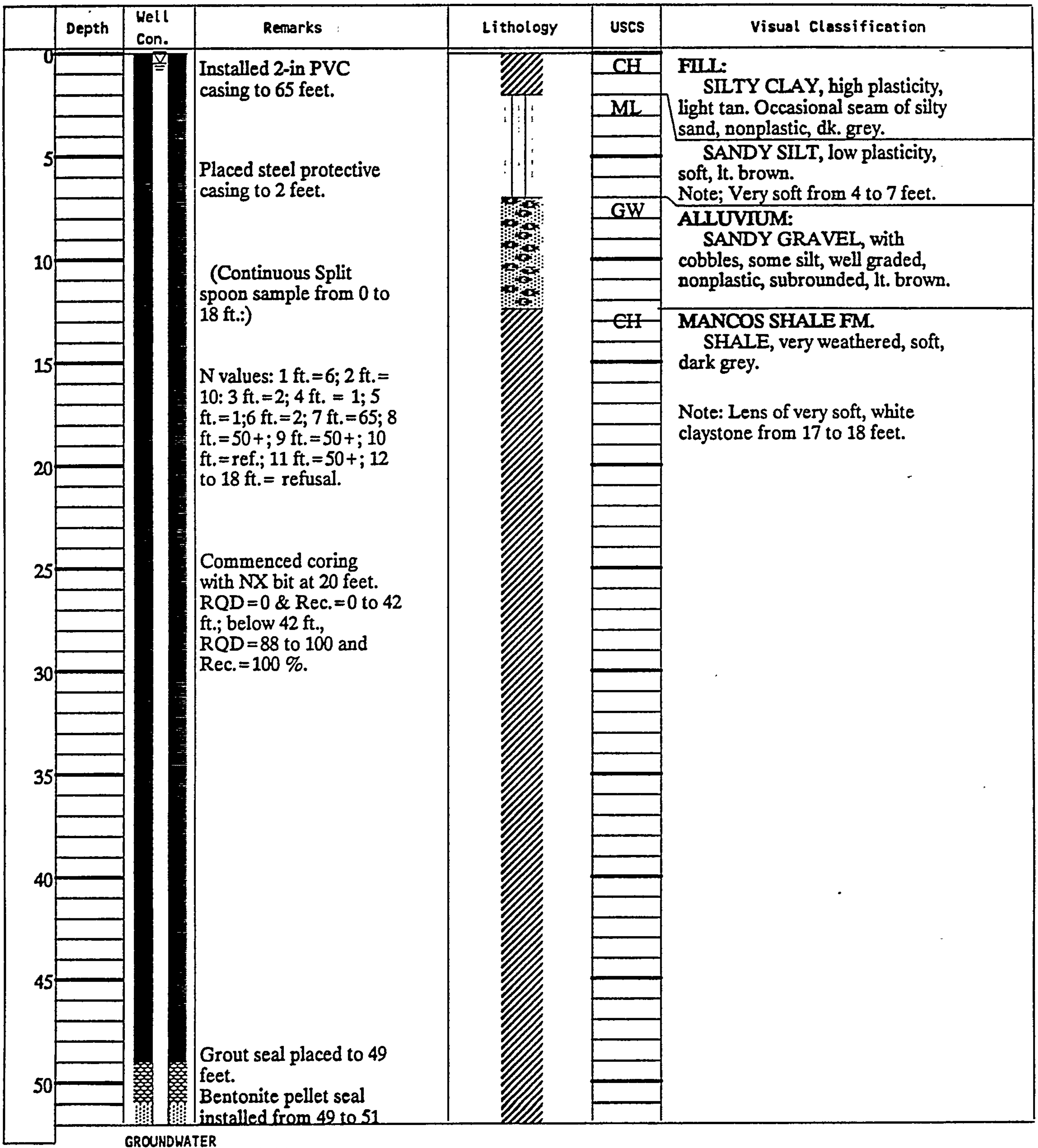
SURFACE ELEVATION 4565.30

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 59738.70 E 32572.30

COMPLETION MANCOS SHALE FM.

DATUM MSL



Installed 2-in PVC casing to 65 feet.

Placed steel protective casing to 2 feet.

(Continuous Split spoon sample from 0 to 18 ft.:)

N values: 1 ft.=6; 2 ft.=10: 3 ft.=2; 4 ft. = 1; 5 ft.=1;6 ft.=2; 7 ft.=65; 8 ft.=50+; 9 ft.=50+; 10 ft.=ref.; 11 ft.=50+; 12 to 18 ft.= refusal.

Commenced coring with NX bit at 20 feet. RQD=0 & Rec.=0 to 42 ft.; below 42 ft., RQD=88 to 100 and Rec.=100 %.

Grout seal placed to 49 feet.

Bentonite pellet seal installed from 49 to 51

FILL:

SILTY CLAY, high plasticity, light tan. Occasional seam of silty sand, nonplastic, dk. grey.

SANDY SILT, low plasticity, soft, lt. brown.

Note; Very soft from 4 to 7 feet.

ALLUVIUM:

SANDY GRAVEL, with cobbles, some silt, well graded, nonplastic, subrounded, lt. brown.

MANCOS SHALE FM.

SHALE, very weathered, soft, dark grey.

Note: Lens of very soft, white claystone from 17 to 18 feet.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	0.5	10:10	3-4-89
▼			

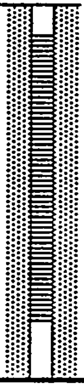
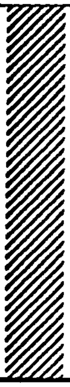
JEG TAC TEAM

AGRA
Earth & Environmental

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *729*

JOB NO. GRJ01	DATE 03/02/85	TOTAL DEPTH	65.0 feet
BORING TYPE	CORE/ROTARY/WATER	FIELD REP.	W.WOOD
DEPTH OF SEAL	51.00	SURFACE ELEVATION	4565.30
WELL CASING TYPE	2.0-IN.SCHED.40 PVC	LOCATION	N 59738.70 E 32572.30
COMPLETION	MANCOS SHALE FM.	DATUM	MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
55 60		feet. Pea gravel filter pack placed from 51 to 65 ft. Well screen, .010-in. slot, placed from 53 to 63 ft. Two-ft. sump and cap at bottom of screen, to 65 ft.			**MANCOS SHALE FM**,Continued. Note: Seam of highly weathered, soft, white shale at 57 to 58.5 feet.
65 70 75 80 85 90 95 100		NX core hole reamed with 6-in. bit for installation of well.			TD AT 65 FEET.

GROUNDWATER

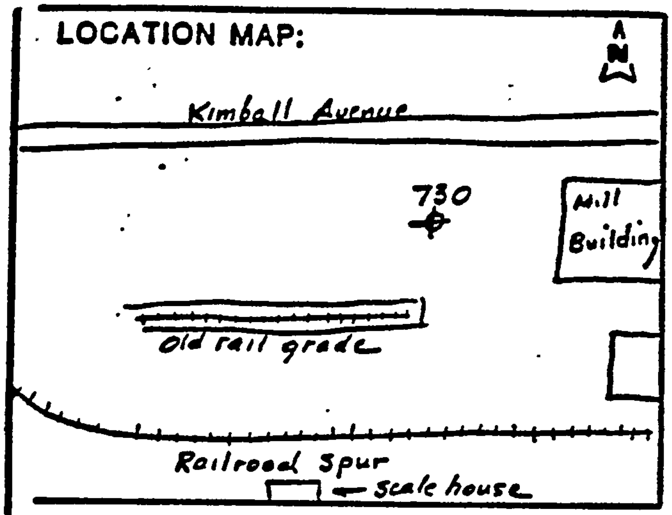
	DEPTH	HOUR	DATE
▽	0.5	10:10	3-4-89
▼			

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

BOREHOLE LOG (SOIL)

Page 1 of __

LOCATION MAP:



SITE ID: GRJ 01 LOCATION ID: 730
APPROX. SITE COORDINATES (ft.):
N 1035 E 735
GROUND ELEVATION (ft. MSL): NK
DRILLING METHOD: Continuous Sampling - NX Core
DRILLER: Marty Mendenhall
DATE STARTED: 2-12-85
DATE COMPLETED:
FIELD REP.: W R Wood

GROUNDWATER LEVELS

DATE	TIME	DEPTH (ft.)

LOCATION DESCRIPTION West side of Mill building
SITE CONDITION

DEPTH	SAMPLE INTERVAL	SAMPLE RECOVERY	SAMPLE RETAINED	TYPE	ID	BLOWS PER 6 In.	N VALUE	USCS	VISUAL CLASSIFICATION
0	☒			S	01	4-6-9 14		SC	Fill: Clayey Sand, pred. fine, some fine gravel, Low Pl, dark brown Note: Occosioial seam of Sandy Clay
	☒			S	02	13-13-50/.42			
	☒			S	03	7-5-3 7		ML	Clayey Silt, med Pl, light brown (possible fill, but no visual evidence.)
	☒			S	04	Note: No blows Sampler dropped under static weight of hammer			
10	☒			S	05	3-5-8 8		CH	Silty Clay, Hi Pl, light brown
	☒			S	06	3-5-45 37			
	☒			S	07	3-18-32 44		GM	Silty Sand & Gravel, poorly graded to 0.17', Occasional Cobble, N.P., brown Note: Occasional silt and silty clay layer.
	☒			S	08	50/.42		GW-GM	Sand, Gravel & Cobbles, well graded to 0.7', some silt, subrounded, NP brown
	☒			S	09	36-50/.42			
20	☒			S	10	50/.38			Mancos Shale, very weathered, soft, dark gray.
	☒			S	11	50/.25			

COMMENTS: Blow-out-Preventor casing set at 25feet

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JEG-AL-ENG-2S (3/84)

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *731*

JOB NO. GRJ01 DATE 03/08/85

TOTAL DEPTH 46.0 feet

BORING TYPE CORE/ROTARY/ WATER

FIELD REP. W.WOOD

DEPTH OF SEAL 21.50

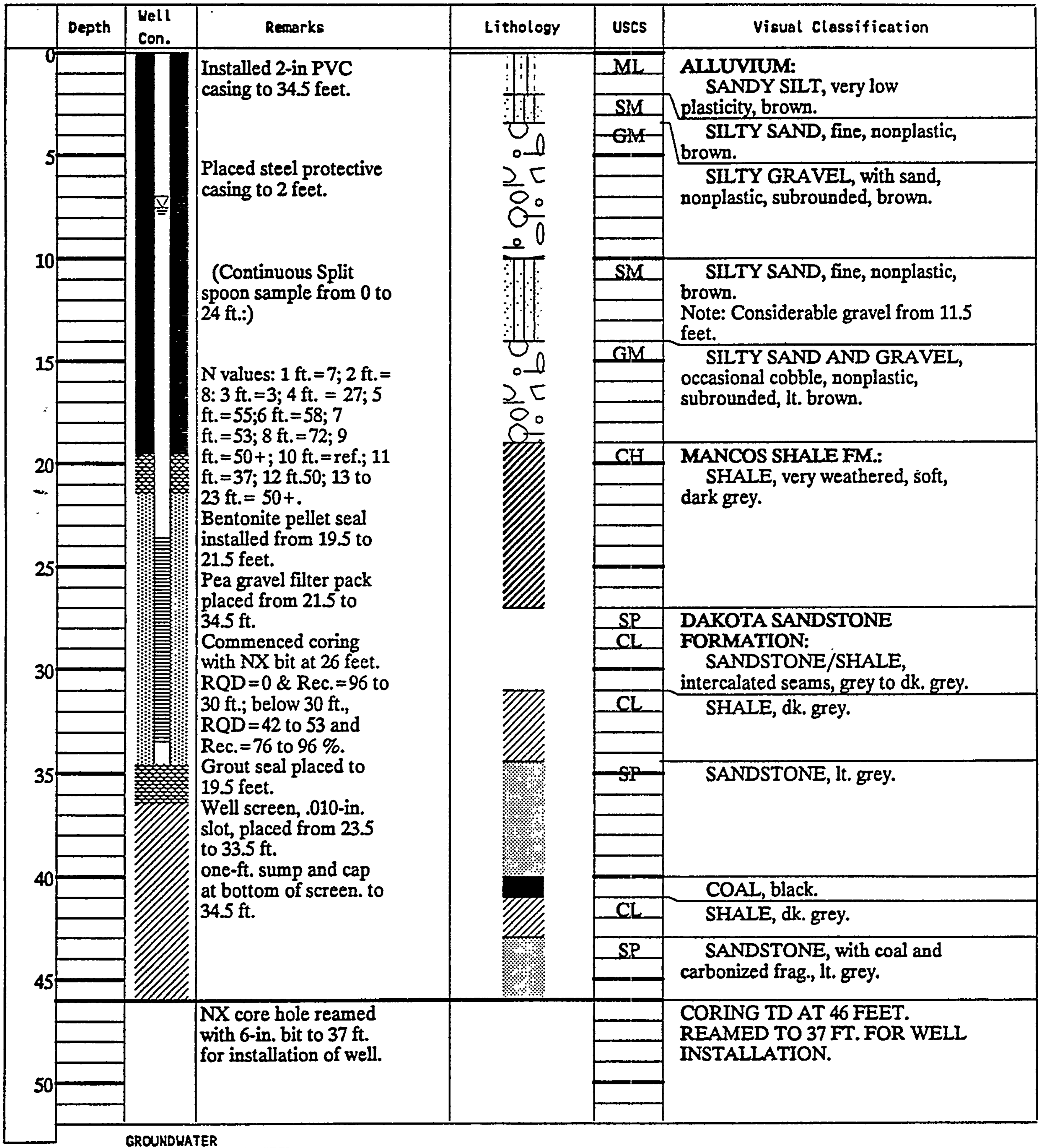
SURFACE ELEVATION 4559.70

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 60671.60 E 29820.30

COMPLETION MANCOS SHALE FM.

DATUM MSL



Installed 2-in PVC casing to 34.5 feet.

Placed steel protective casing to 2 feet.

(Continuous Split spoon sample from 0 to 24 ft.:)

N values: 1 ft.=7; 2 ft.= 8: 3 ft.=3; 4 ft. = 27; 5 ft.=55;6 ft.=58; 7 ft.=53; 8 ft.=72; 9 ft.=50+; 10 ft.=ref.; 11 ft.=37; 12 ft.50; 13 to 23 ft.= 50+.

Bentonite pellet seal installed from 19.5 to 21.5 feet.

Pea gravel filter pack placed from 21.5 to 34.5 ft.

Commenced coring with NX bit at 26 feet.

RQD=0 & Rec.=96 to 30 ft.; below 30 ft., RQD=42 to 53 and Rec.=76 to 96 %.

Grout seal placed to 19.5 feet.

Well screen, .010-in. slot, placed from 23.5 to 33.5 ft.

one-ft. sump and cap at bottom of screen. to 34.5 ft.

NX core hole reamed with 6-in. bit to 37 ft. for installation of well.

ALLUVIUM:

SANDY SILT, very low plasticity, brown.

SILTY SAND, fine, nonplastic, brown.

SILTY GRAVEL, with sand, nonplastic, subrounded, brown.

SILTY SAND, fine, nonplastic, brown. Note: Considerable gravel from 11.5 feet.

SILTY SAND AND GRAVEL, occasional cobble, nonplastic, subrounded, lt. brown.

MANCOS SHALE FM.:

SHALE, very weathered, soft, dark grey.

DAKOTA SANDSTONE FORMATION:

SANDSTONE/SHALE, intercalated seams, grey to dk. grey.

SHALE, dk. grey.

SANDSTONE, lt. grey.

COAL, black.

SHALE, dk. grey.

SANDSTONE, with coal and carbonized frag., lt. grey.

CORING TD AT 46 FEET. REAMED TO 37 FT. FOR WELL INSTALLATION.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	7.5	09:30	7-23-89
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *732*

JOB NO. GRJ01 DATE 02/25/85

BORING TYPE CORE /ROTARY/ REVERT

DEPTH OF SEAL 12.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION ALLUVIUM.

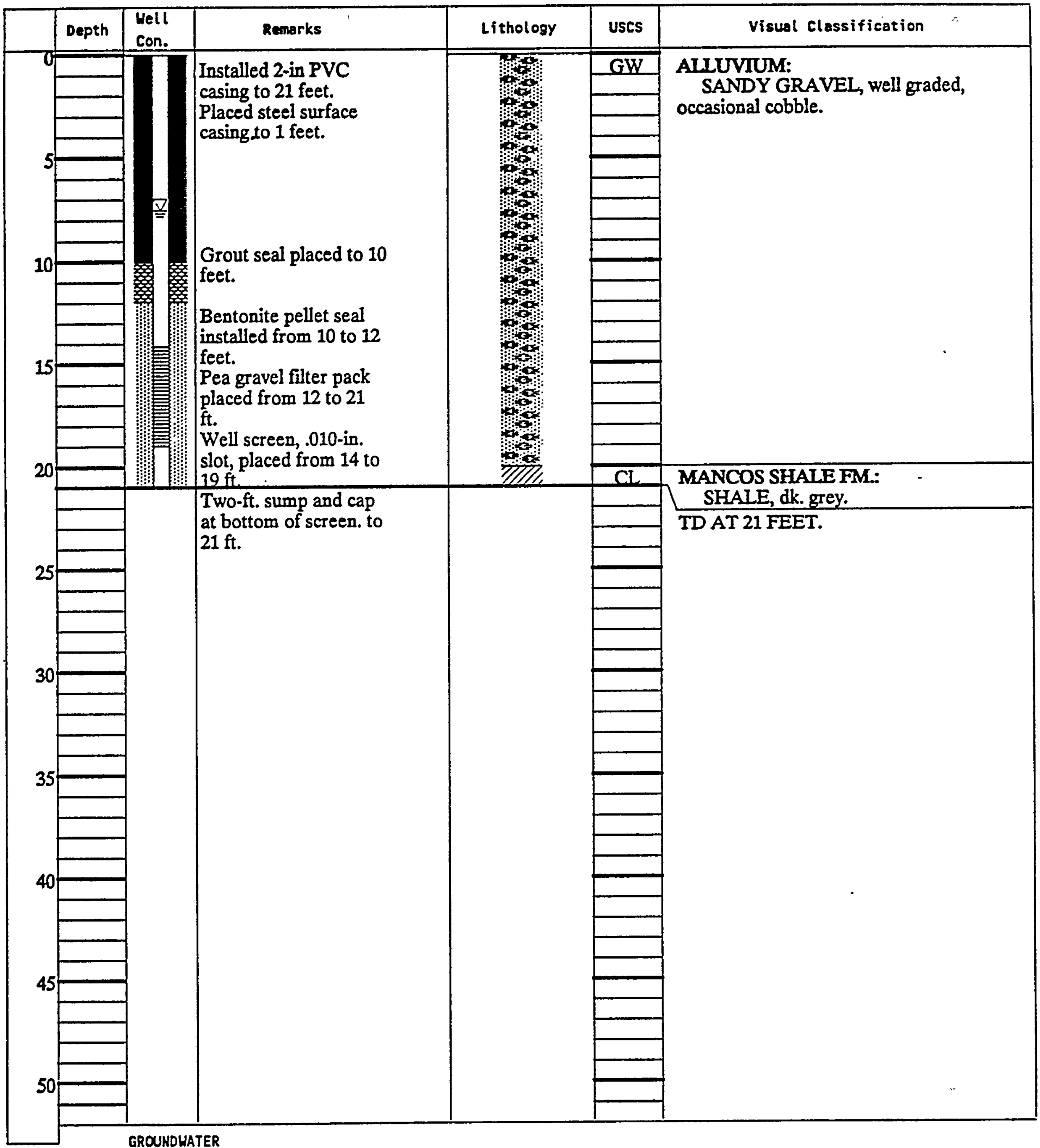
TOTAL DEPTH 21.0 feet

FIELD REP. P.MCKENZIE

SURFACE ELEVATION 4559.50

LOCATION N 60659.10 E 29817.60

DATUM MSL



Installed 2-in PVC casing to 21 feet. Placed steel surface casing to 1 feet.

Grout seal placed to 10 feet.

Bentonite pellet seal installed from 10 to 12 feet.

Pea gravel filter pack placed from 12 to 21 ft.

Well screen, .010-in. slot, placed from 14 to 19 ft.

Two-ft. sump and cap at bottom of screen. to 21 ft.

ALLUVIUM:
SANDY GRAVEL, well graded, occasional cobble.

MANCOS SHALE FM.:
SHALE, dk. grey.

TD AT 21 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	7.5	09:42	7-23-86
▼			

JEG TAC TEAM

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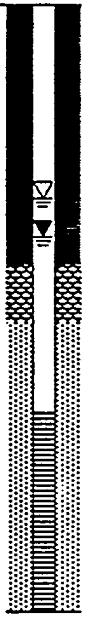
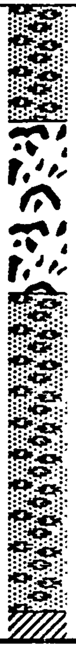
PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 733

JOB NO. GRJ01 DATE 02/26/85
BORING TYPE CORE W/ ROTARY REAM
DEPTH OF SEAL 11.00
WELL CASING TYPE 2.0-IN.SCHED.40 PVC
COMPLETION ALLUVIUM.

TOTAL DEPTH 22.0 feet
FIELD REP. P.MCKENZIE
SURFACE ELEVATION 4556.40
LOCATION N 60997.40 E 28704.70
DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0 5		Installed 2-in PVC casing to 21 feet. Steel surface casing placed to 1 feet. Grout seal placed to 9 feet.		GW	**FILL:** SANDY GRAVEL, fine to coarse, trace plasticity, little organics, very dark brown (10YR-2/2). GARBAGE, (paper, plastic etc.)
10 15		Bentonite pellet seal installed from 9 to 11 feet. Pea gravel filter pack placed from 11 to 21 ft. Well screen, .01-in. slot, placed from 14 to 19 ft.		GW	**ALLUVIUM:** SANDY GRAVEL, little silt, low cementation, trace plasticity, dk. greyish brown(10YR-4/2).
20		two-ft. sump and cap at bottom of screen. to 21 ft.		CH	**MANCOS SHALE FM.:** SHALE, friable, dk. grey (10YR-4/1).
25 30 35 40 45 50		(Continuous split spoon samples taken to 22 feet: Blow counts as follows: @ 1 ft, N= 27; @2 ft, N=50+; @3 ft., N=20; @ 4 to 7 ft.,N=1; @ 8 to 22 ft. N=50+.			TD AT 22 FEET. REAMED HOLE WITH 6-IN. BIT TO 21 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	6.7	10:06	7-23-86
▼	8.1	08:20	2-28-89

Page 1 of 1

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 735

JOB NO. GRJ01 DATE 02/28/85

TOTAL DEPTH 50.0 feet

BORING TYPE CORE/ROTARY REAM

FIELD REP. W.WOOD

DEPTH OF SEAL 24.00

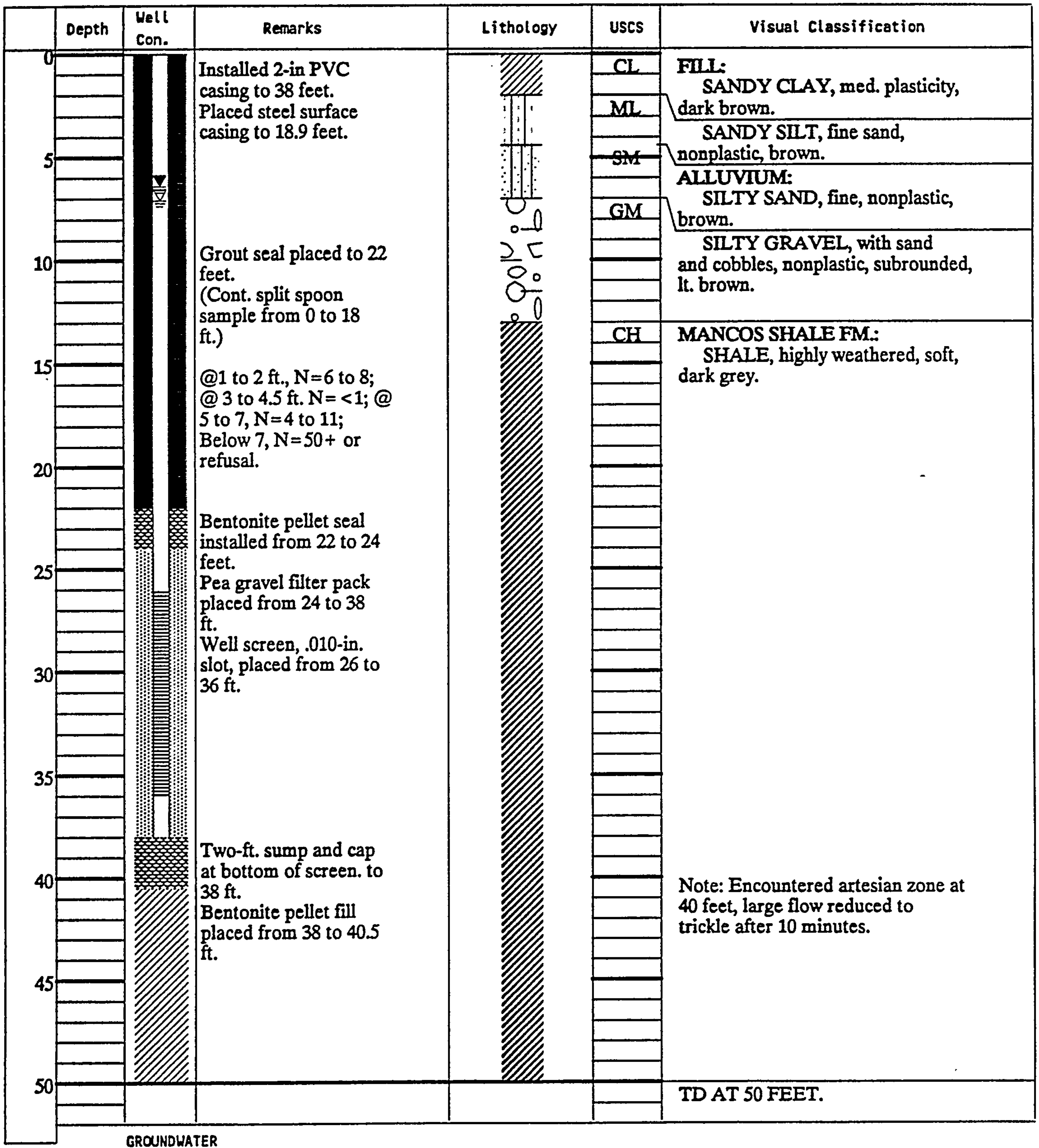
SURFACE ELEVATION 4564.70

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 60211.60 E 31261.70

COMPLETION MANCOS SHALE FM.

DATUM MSL



Installed 2-in PVC casing to 38 feet. Placed steel surface casing to 18.9 feet.

Grout seal placed to 22 feet. (Cont. split spoon sample from 0 to 18 ft.)

@1 to 2 ft., N=6 to 8; @ 3 to 4.5 ft. N= <1; @ 5 to 7, N=4 to 11; Below 7, N=50+ or refusal.

Bentonite pellet seal installed from 22 to 24 feet.

Pea gravel filter pack placed from 24 to 38 ft.

Well screen, .010-in. slot, placed from 26 to 36 ft.

Two-ft. sump and cap at bottom of screen. to 38 ft.

Bentonite pellet fill placed from 38 to 40.5 ft.

FILL:

SANDY CLAY, med. plasticity, dark brown.

SANDY SILT, fine sand, nonplastic, brown.

ALLUVIUM:

SILTY SAND, fine, nonplastic, brown.

SILTY GRAVEL, with sand and cobbles, nonplastic, subrounded, lt. brown.

MANCOS SHALE FM.:

SHALE, highly weathered, soft, dark grey.

Note: Encountered artesian zone at 40 feet, large flow reduced to trickle after 10 minutes.

TD AT 50 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	7.1	13:55	7-24-86
▼	6.4	08:45	3-3-89

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 736

JOB NO. GRJ01 DATE 02/24/85

TOTAL DEPTH 15.5 feet

BORING TYPE ROTARY W/REVERT MUD

FIELD REP. P.MCKENZIE

DEPTH OF SEAL 6.00

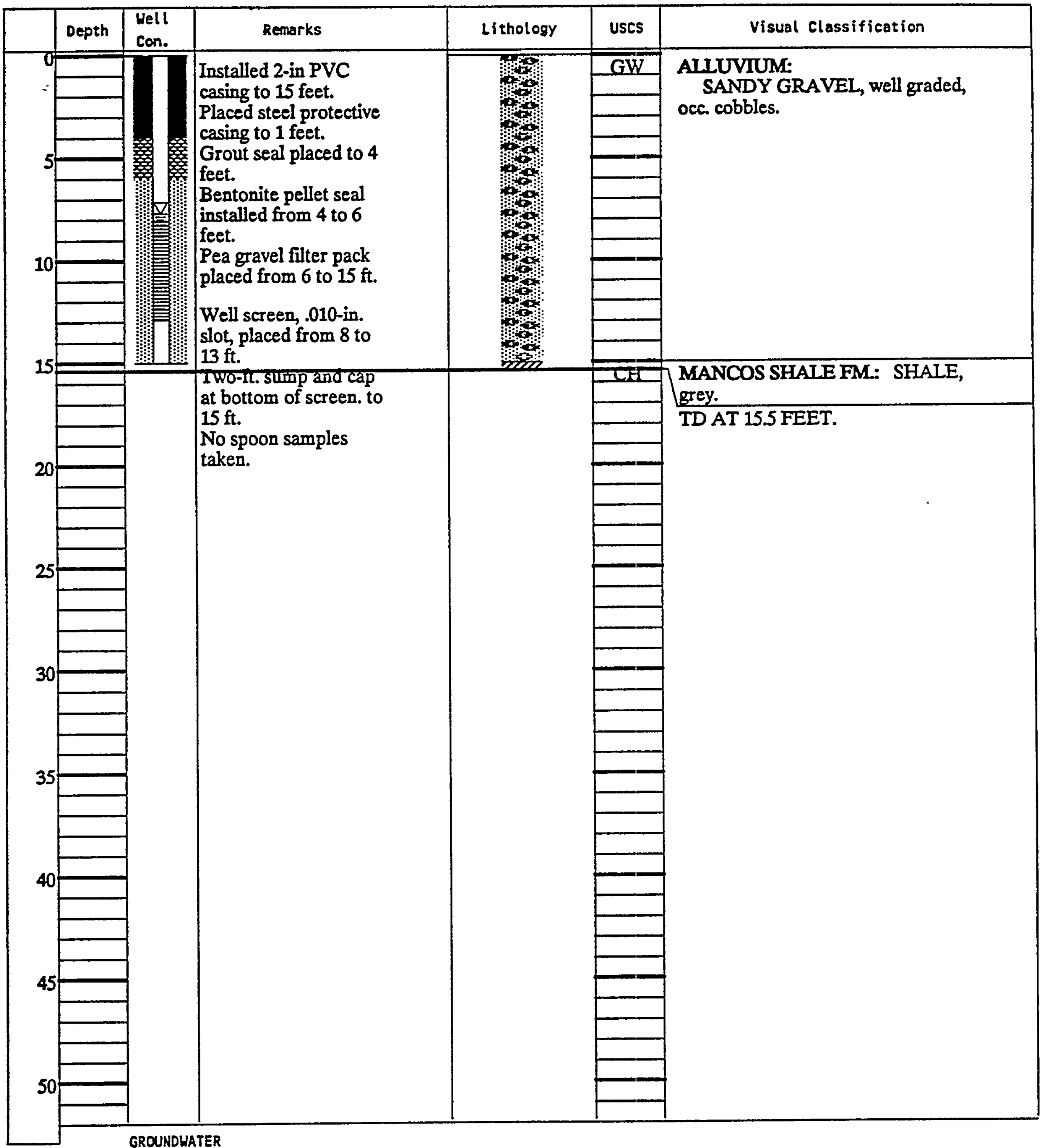
SURFACE ELEVATION 4564.70

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 60197.90 E 31270.50

COMPLETION ALLUVIUM

DATUM MSL



Remarks:

Installed 2-in PVC casing to 15 feet.
Placed steel protective casing to 1 feet.
Grout seal placed to 4 feet.
Bentonite pellet seal installed from 4 to 6 feet.
Pea gravel filter pack placed from 6 to 15 ft.

Well screen, .010-in. slot, placed from 8 to 13 ft.
Two-ft. sump and cap at bottom of screen. to 15 ft.
No spoon samples taken.

Visual Classification:

ALLUVIUM:
SANDY GRAVEL, well graded, occ. cobbles.

MANCOS SHALE FM.: SHALE, grey.

TD AT 15.5 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	7.7	13:58	7-24-86
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *737*

JOB NO. GRJ01 DATE 02/24/85

BORING TYPE ROTARY W/ REVERT MUD

DEPTH OF SEAL 18.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION ALLUVIUM

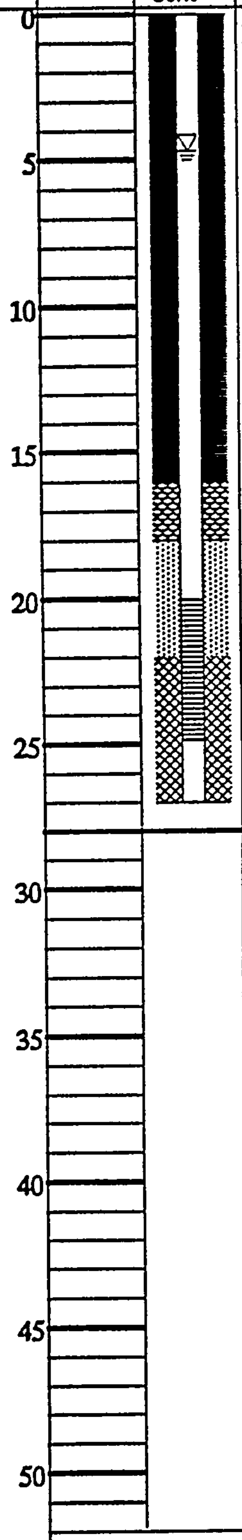
TOTAL DEPTH 28.0 feet

FIELD REP. P.MCKENZIE

SURFACE ELEVATION 4575.30

LOCATION N 61898.90 E 32967.70

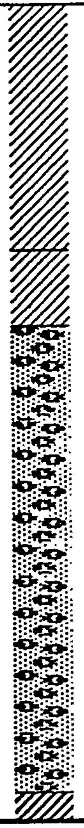
DATUM MSL



Remarks

Installed 2-in PVC casing to 27 feet. Steel surface casing placed to 1 feet. Grout seal placed to 16 feet.

Bentonite pellet seal installed from 16 to 18 feet. Pea gravel filter pack placed from 18 to 22 ft. Well screen, .01-in. slot, placed from 20 to 25 ft. Cave-in fill from 22 to 27 feet. Two-ft. sump and cap at bottom of screen. from 25 to 27 ft. SAMPLED TO 28 FEET. REAMED TO 27 FT. WITH 6-IN BIT (Continuous split spoon samples from 0 to 28 ft.: @1 to 2 ft., N=43 to 44; @3 to 6 ft., N=9 to 22; @7 to 8 ft,N=1; @9 to 10 ft. N=6 to 13; @11 to 12 ft. N=38 to 46; Below 12.5 ft. N=50+ to refusal.



USCS	Visual Classification
CL	**FILL:** GRAVELLY CLAY, (road subgrade compacted fill), lt. brownish grey. Note: Extremly loose soils at 6 to 8 feet may indicate utility trench.
~~CL~~	**ALLUVIUM:** SILTY CLAY, with some gravel, lt. brownish grey.
GW	SANDY GRAVEL, well graded, dark greyish brown (10YR-4/2).
CH	**MANCOS SHALE FM.:** SHALE, fissle, med. to high plasticity, very dark grey(7YR-3/0).
	TD AT 28.0 FT.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	4.7	16:15	7-23-86
▼			

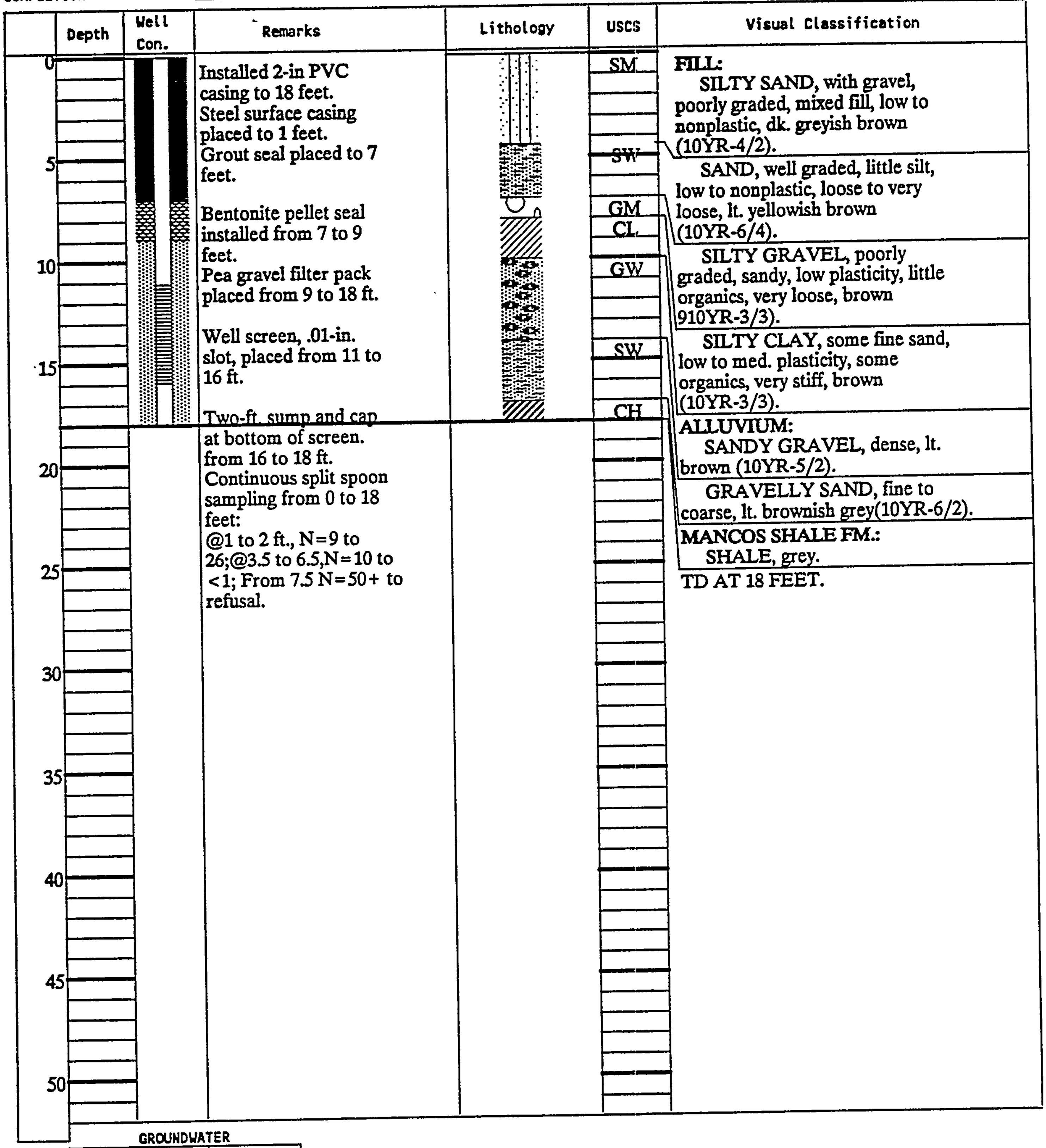
JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *738*

JOB NO. GRJ01 DATE 02/23/85
BORING TYPE ROTARY W/ REVERT
DEPTH OF SEAL 9.00
WELL CASING TYPE 2.0-IN.SCHED.40 PVC
COMPLETION ALLUVIUM

TOTAL DEPTH 18.0 feet
FIELD REP. P.MCKENZIE
SURFACE ELEVATION 4561.00
LOCATION N 60039.10 E 30049.40
DATUM MSL



Remarks

Installed 2-in PVC casing to 18 feet.
Steel surface casing placed to 1 feet.
Grout seal placed to 7 feet.

Bentonite pellet seal installed from 7 to 9 feet.
Pea gravel filter pack placed from 9 to 18 ft.

Well screen, .01-in. slot, placed from 11 to 16 ft.

Two-ft. sump and cap at bottom of screen. from 16 to 18 ft.
Continuous split spoon sampling from 0 to 18 feet:
@1 to 2 ft., N=9 to 26;@3.5 to 6.5,N=10 to <1; From 7.5 N=50+ to refusal.

Visual Classification

FILL:
SILTY SAND, with gravel, poorly graded, mixed fill, low to nonplastic, dk. greyish brown (10YR-4/2).

SAND, well graded, little silt, low to nonplastic, loose to very loose, lt. yellowish brown (10YR-6/4).

SILTY GRAVEL, poorly graded, sandy, low plasticity, little organics, very loose, brown 910YR-3/3).

SILTY CLAY, some fine sand, low to med. plasticity, some organics, very stiff, brown (10YR-3/3).

ALLUVIUM:
SANDY GRAVEL, dense, lt. brown (10YR-5/2).

GRAVELLY SAND, fine to coarse, lt. brownish grey(10YR-6/2).

MANCOS SHALE FM.:
SHALE, grey.

TD AT 18 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *739*

JOB NO. GRJ01 DATE 02/22/85

TOTAL DEPTH 30.0 feet

BORING TYPE ROTARY W/ REVERT

FIELD REP. P McKenzie

DEPTH OF SEAL 20.50

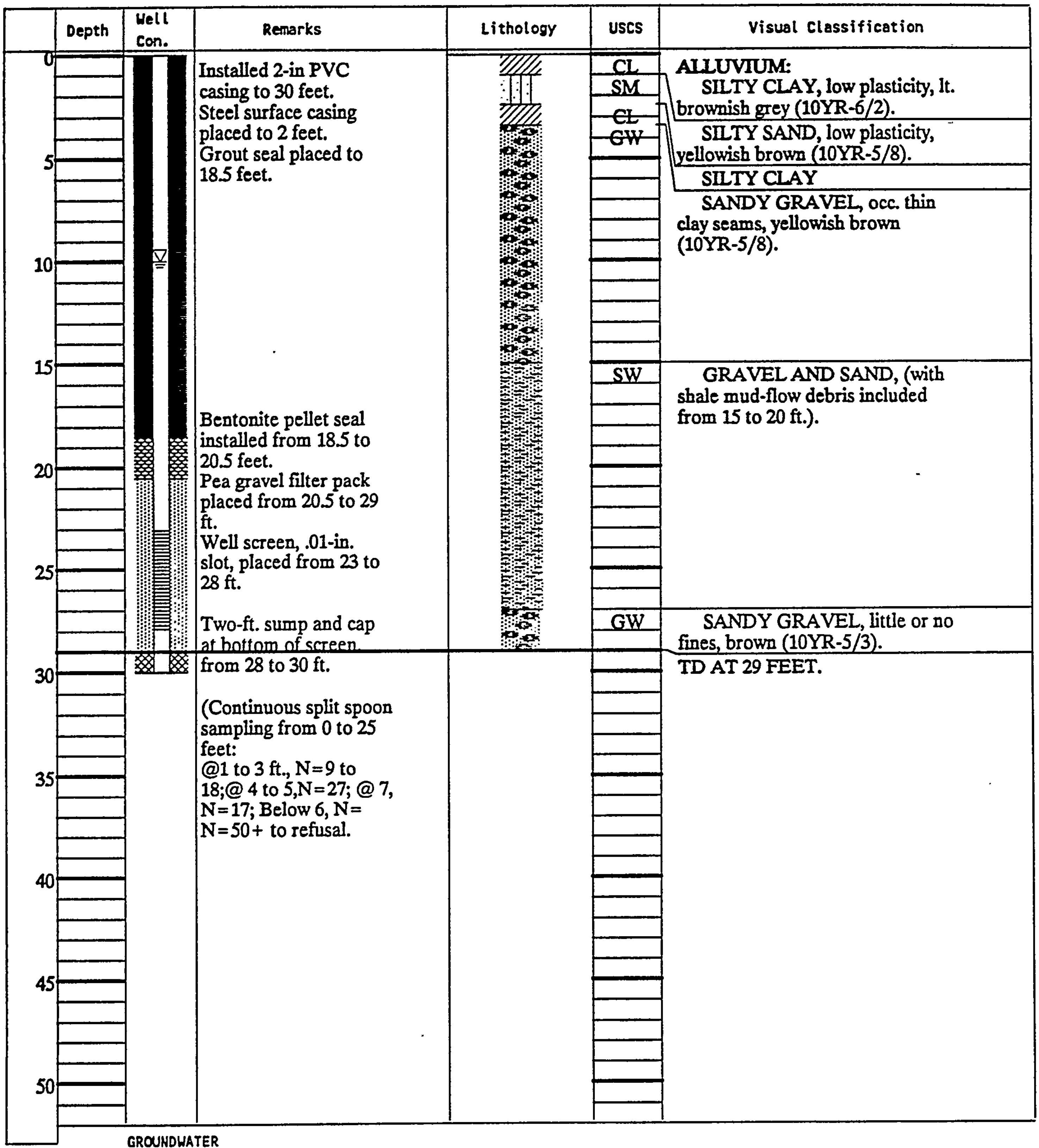
SURFACE ELEVATION 4572.90

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 60273.60 E 31970.10

COMPLETION ALLUVIUM

DATUM MSL



Installed 2-in PVC casing to 30 feet. Steel surface casing placed to 2 feet. Grout seal placed to 18.5 feet.

Bentonite pellet seal installed from 18.5 to 20.5 feet.
Pea gravel filter pack placed from 20.5 to 29 ft.
Well screen, .01-in. slot, placed from 23 to 28 ft.

Two-ft. sump and cap at bottom of screen from 28 to 30 ft.

(Continuous split spoon sampling from 0 to 25 feet:
@1 to 3 ft., N=9 to 18;@ 4 to 5,N=27; @ 7, N=17; Below 6, N= N=50+ to refusal.

ALLUVIUM:
SILTY CLAY, low plasticity, lt. brownish grey (10YR-6/2).
SILTY SAND, low plasticity, yellowish brown (10YR-5/8).
SILTY CLAY
SANDY GRAVEL, occ. thin clay seams, yellowish brown (10YR-5/8).

GRAVEL AND SAND, (with shale mud-flow debris included from 15 to 20 ft.).

SANDY GRAVEL, little or no fines, brown (10YR-5/3).

TD AT 29 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	10.0	16:08	7-23-86
▼			

JEG TAC TEAM

Page 1 of 1

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *740*

JOB NO. GRJ01 DATE 02/23/85

BORING TYPE ROTARY W/ REVERT

DEPTH OF SEAL 8.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION ALLUVIUM

TOTAL DEPTH 18.0 feet

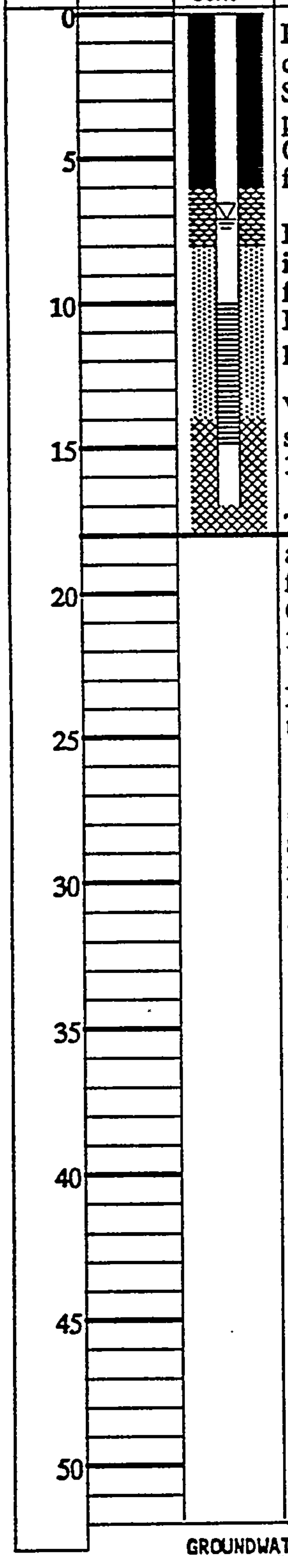
FIELD REP. P.MCKENZIE

SURFACE ELEVATION 4566.10

LOCATION N 59908.30 E 32001.10

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification



Remarks

Installed 2-in PVC casing to 17 feet. Steel surface casing placed to 1 feet. Grout seal placed to 6 feet.

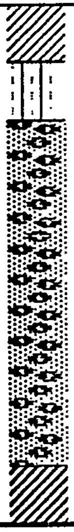
Bentonite pellet seal installed from 6 to 8 feet. Pea gravel filter pack placed from 8 to 14 ft.

Well screen, .01-in. slot, placed from 10 to 15 ft.

Two-ft. sump and cap at bottom of screen. from 15 to 17 ft. Cave-in fill from 14 to 18 ft.

Hole sampled to 18 feet then reamed to 17 feet.

(Continuous split spoon sampling from 0 to 18 feet: @1 to 3 ft., N=2 to 6; Below 4, N=50 + to refusal.



USCS	Visual Classification
CL	ALLUVIUM: SILTY CLAY, low plasticity, brown to dk. brown (10YR-4/3).
ML	CLAYEY SILT, with fine sand, low plasticity, dark yellowish brown (10YR-4/4).
GW	SAND AND GRAVEL, brown to dk. brown (10YR-4/3).
CH	MANCOS SHALE FM.: SHALE, med. to high plasticity, dark grey (7YR-3/0).
	TD AT 18 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	7.1	15:50	7-23-86
▼			

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *741*

JOB NO. GRJ01 DATE 03/01/85

BORING TYPE ROTARY W/AIR-WATER

DEPTH OF SEAL 31.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION MANCOS SHALE FM.

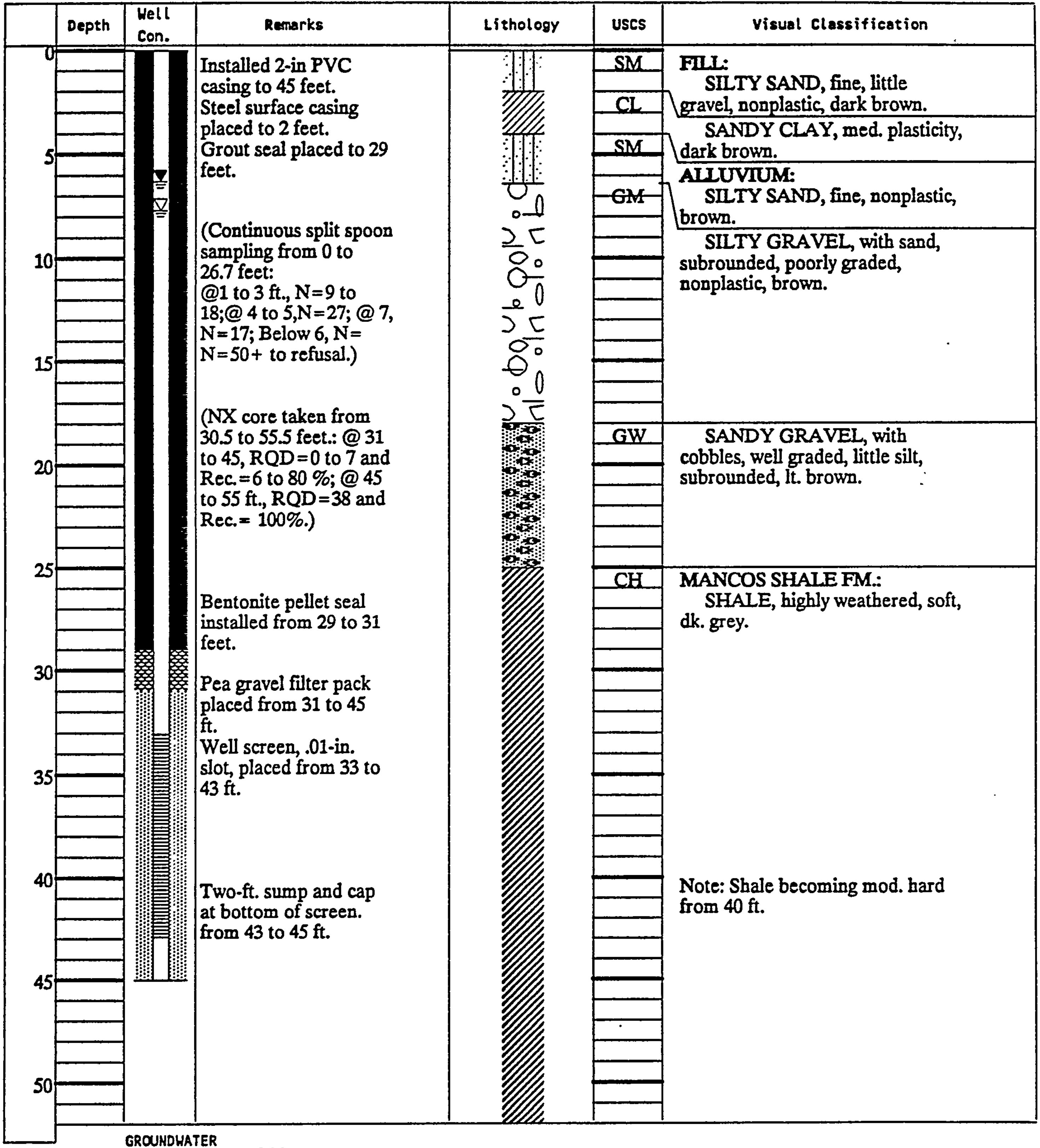
TOTAL DEPTH 55.5 feet

FIELD REP. W.WOOD

SURFACE ELEVATION 4572.90

LOCATION N 60796.00 E 33048.80

DATUM MSL



Installed 2-in PVC casing to 45 feet. Steel surface casing placed to 2 feet. Grout seal placed to 29 feet.

(Continuous split spoon sampling from 0 to 26.7 feet: @1 to 3 ft., N=9 to 18;@ 4 to 5,N=27; @ 7, N=17; Below 6, N= N=50+ to refusal.)

(NX core taken from 30.5 to 55.5 feet.: @ 31 to 45, RQD=0 to 7 and Rec.=6 to 80 %; @ 45 to 55 ft., RQD=38 and Rec.= 100%.)

Bentonite pellet seal installed from 29 to 31 feet.

Pea gravel filter pack placed from 31 to 45 ft.

Well screen, .01-in. slot, placed from 33 to 43 ft.

Two-ft. sump and cap at bottom of screen. from 43 to 45 ft.

FILL:

SILTY SAND, fine, little gravel, nonplastic, dark brown.

SANDY CLAY, med. plasticity, dark brown.

ALLUVIUM:

SILTY SAND, fine, nonplastic, brown.

SILTY GRAVEL, with sand, subrounded, poorly graded, nonplastic, brown.

SANDY GRAVEL, with cobbles, well graded, little silt, subrounded, lt. brown.

MANCOS SHALE FM.:

SHALE, highly weathered, soft, dk. grey.

Note: Shale becoming mod. hard from 40 ft.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	7.7	16:16	7-23-86
▼	6.3	12:45	3-3-89

JEG TAC TEAM

Page 2 of 2

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 741

JOB NO. GRJ01 DATE 03/01/85

BORING TYPE ROTARY W/AIR-WATER

DEPTH OF SEAL 31.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION MANCOS SHALE FM.

TOTAL DEPTH 55.5 feet

FIELD REP. W.WOOD

SURFACE ELEVATION 4572.90

LOCATION N 60796.00 E 33048.80

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
			▨		MANCOS SHALE FM.:, Continued.
55					TD OF CORE HOLE AT 55.5 FEET. REAMED TO 45 FEET FOR INSTALLATION OF WELL.
60					
65					
70					
75					
80					
85					
90					
95					
100					

GROUNDWATER

	DEPTH	HOUR	DATE
∇	7.7	16:16	7-23-86
▼	6.3	12:45	3-3-89

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *742*

JOB NO. GRJ01 DATE 02/24/85

BORING TYPE ROTARY W/REVERT

DEPTH OF SEAL 14.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION ALLUVIUM

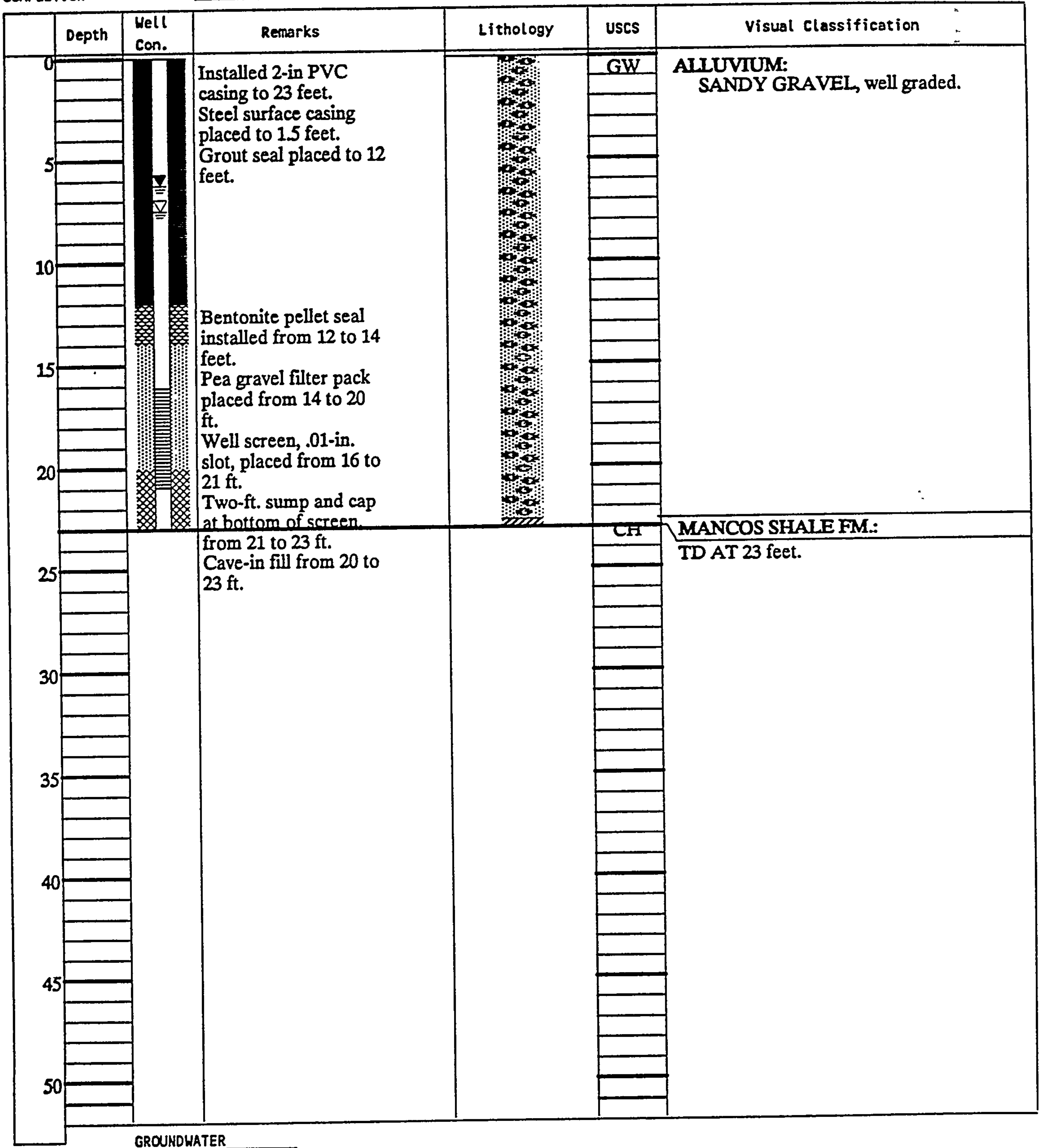
TOTAL DEPTH 23.0 feet

FIELD REP. P.MCKENZIE

SURFACE ELEVATION 4572.70

LOCATION N 60774.60 E 33047.20

DATUM MSL



Installed 2-in PVC casing to 23 feet. Steel surface casing placed to 1.5 feet. Grout seal placed to 12 feet.

Bentonite pellet seal installed from 12 to 14 feet. Pea gravel filter pack placed from 14 to 20 ft. Well screen, .01-in. slot, placed from 16 to 21 ft. Two-ft. sump and cap at bottom of screen from 21 to 23 ft. Cave-in fill from 20 to 23 ft.

ALLUVIUM:
SANDY GRAVEL, well graded.

MANCOS SHALE FM.:
TD AT 23 feet.

GROUNDWATER

	DEPTH	HOUR	DATE
∇	7.5	16:18	7-23-86
▼	6.3	18:42	7-15-92

JEG TAC TEAM

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 743

JOB NO. GRJ01 DATE 03/02/85

BORING TYPE ROTARY W/AIR

DEPTH OF SEAL 21.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION MANCOS SHALE FM.

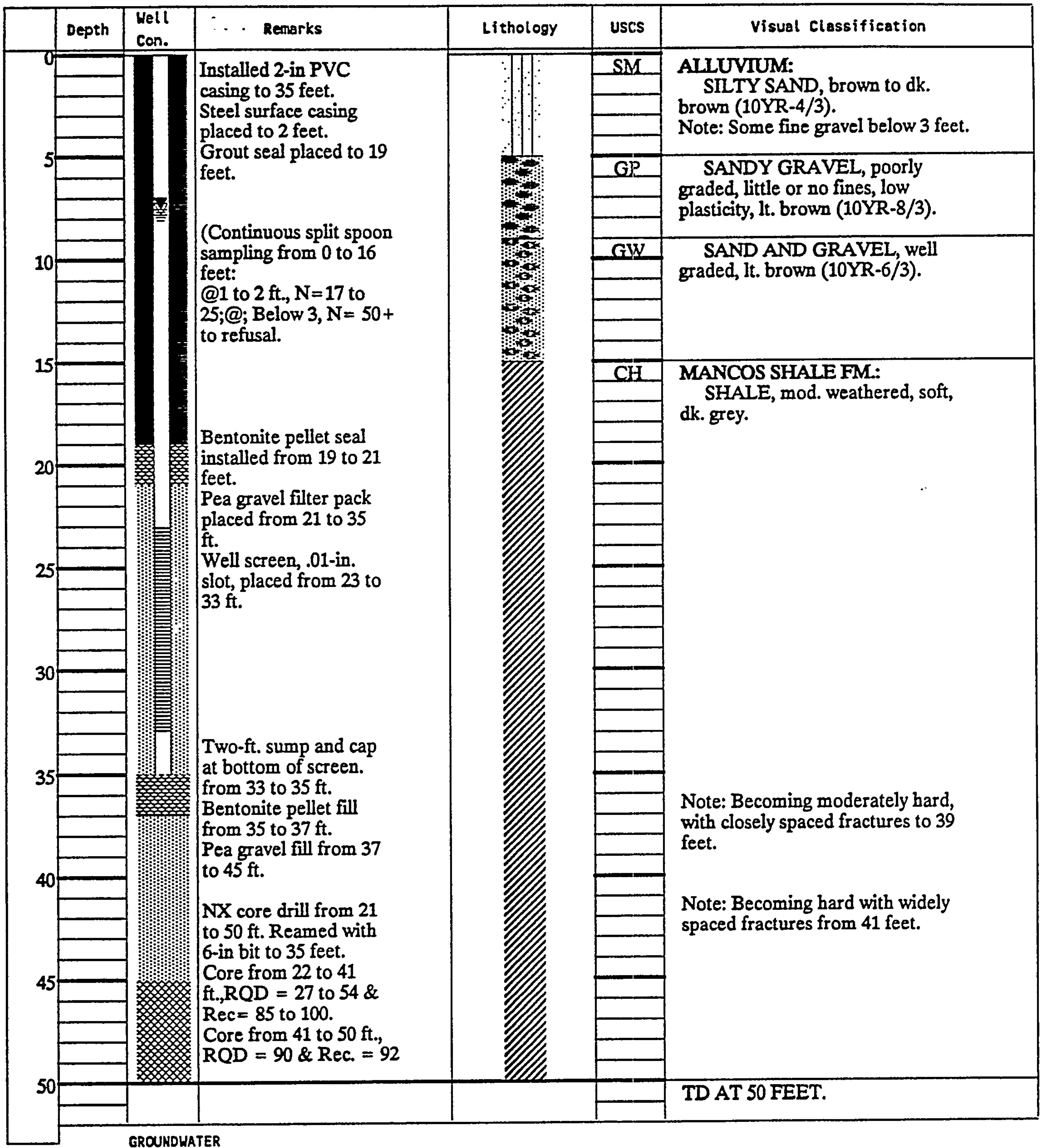
TOTAL DEPTH 50.0 feet

FIELD REP. P.MCKENZIE

SURFACE ELEVATION 4575.10

LOCATION N 59491.70 E 37069.70

DATUM MSL



Remarks

Installed 2-in PVC casing to 35 feet. Steel surface casing placed to 2 feet. Grout seal placed to 19 feet.

(Continuous split spoon sampling from 0 to 16 feet: @1 to 2 ft., N=17 to 25;@; Below 3, N= 50+ to refusal.

Bentonite pellet seal installed from 19 to 21 feet. Pea gravel filter pack placed from 21 to 35 ft. Well screen, .01-in. slot, placed from 23 to 33 ft.

Two-ft. sump and cap at bottom of screen. from 33 to 35 ft. Bentonite pellet fill from 35 to 37 ft. Pea gravel fill from 37 to 45 ft.

NX core drill from 21 to 50 ft. Reamed with 6-in bit to 35 feet. Core from 22 to 41 ft.,RQD = 27 to 54 & Rec= 85 to 100. Core from 41 to 50 ft., RQD = 90 & Rec. = 92

Visual Classification

SM — ALLUVIUM: SILTY SAND, brown to dk. brown (10YR-4/3). Note: Some fine gravel below 3 feet.

GP — SANDY GRAVEL, poorly graded, little or no fines, low plasticity, lt. brown (10YR-8/3).

GW — SAND AND GRAVEL, well graded, lt. brown (10YR-6/3).

CH — MANCOS SHALE FM.: SHALE, mod. weathered, soft, dk. grey.

Note: Becoming moderately hard, with closely spaced fractures to 39 feet.

Note: Becoming hard with widely spaced fractures from 41 feet.

TD AT 50 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	7.8	17:10	7-23-86
▼	7.5	12:00	7-15-92

JEG TAC TEAM

Page 1 of 1

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *744*

JOB NO. GRJ01 DATE 02/26/85

TOTAL DEPTH 15.0 feet

BORING TYPE ROTARY W/REVERT

FIELD REP. P.MCKENZIE

DEPTH OF SEAL 6.00

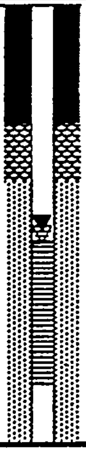
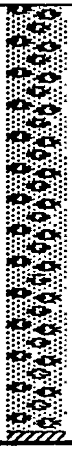
SURFACE ELEVATION 4574.80

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

LOCATION N 59492.20 E 37051.30

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0		Installed 2-in PVC casing to 15 feet. Steel surface casing placed to 1 feet. Grout seal placed to 4 feet. Bentonite pellet seal installed from 4 to 6 feet. Pea gravel filter pack placed from 6 to 15 ft. Well screen, .01-in. slot, placed from 8 to 13 ft.		GW	**ALLUVIUM:** SAND AND GRAVEL, well graded, subrounded.
5					
10					
15		Two-ft. sump and cap at bottom of screen. from 13 to 15 ft. No samples or core taken.		CH	MANCOS SHALE FM. TD AT 15 FEET.
20					
25					
30					
35					
40					
45					
50					

GROUNDWATER

	DEPTH	HOUR	DATE
▽	8.1	17:14	7-23-86
▼	7.7	10:45	7-15-92

JEG TAC TEAM

Page 1 of 1

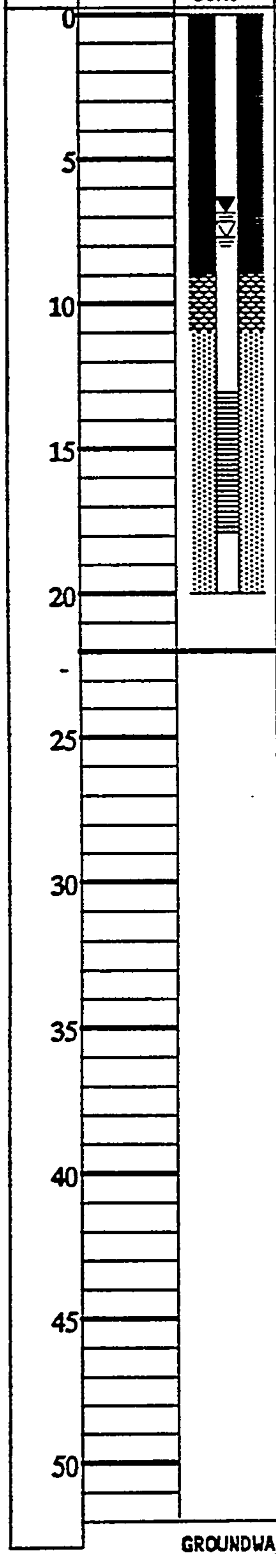
PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *745*

JOB NO. GRJ01 DATE 02/21/85
BORING TYPE ROTARY W/REVERT
DEPTH OF SEAL 11.00
WELL CASING TYPE 2.0-IN.SCHED.40 PVC
COMPLETION ALLUVIUM

TOTAL DEPTH 22.0 feet
FIELD REP. P.MCKENZIE
SURFACE ELEVATION 4579.40
LOCATION N 61040.00 E 36958.20
DATUM MSL

Depth | Well Con. | Remarks | Lithology | USCS | Visual Classification



Remarks

Installed 2-in PVC casing to 20 feet. Steel surface casing placed to 2 feet. Grout seal placed to 9 feet.

Bentonite pellet seal installed from 9 to 11 feet. Pea gravel filter pack placed from 11 to 20 ft. Well screen, .01-in. slot, placed from 13 to 18 ft.

Two-ft. sump and cap at bottom of screen. from 18 to 20 ft.

(Continuous split spoon sampling from 0 to 22 feet: @1 to 2 ft., N=10 to 16;@; @ 4 to 10 ft., N= 4 to <1; @11 to 13, N= 8 to 12; Below 13.5 ft.N= 50+ to refusal.

USCS	Visual Classification
CL	**ALLUVIUM:** SILTY CLAY, med. plasticity, lt. greyish brown (10YR-6/2). Note: rootlets in upper 2 feet.
CH	SILTY CLAY, medium to high plasticity, light brownish grey (10YR-6/2).
SW	SAND, well graded, little silt, brown (10YR-5/3).
GP	SANDY GRAVEL, poorly graded.
GW	SAND AND GRAVEL, well graded, little silt, brown (10YR-5/3).
CH	**MANCOS SHALE FM.:** SHALE, very fissle, dark grey (10YR-4/1).

TD AT 22 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	7.7	17:00	7-23-86
▼	6.9	14:25	7-15-92

JEG TAC TEAM

746

No Lithology Log
for this Well

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Jacobs Engineering
Albuquerque NM

                DATE     TIME
At printing   SEP1495  10:38
Last update   DEC1592  15:41

                                                 PROJECT ID    GRJ01
                                                 POINT ID      746_____

                   Exploration Point Definition - ADDRESS 2201

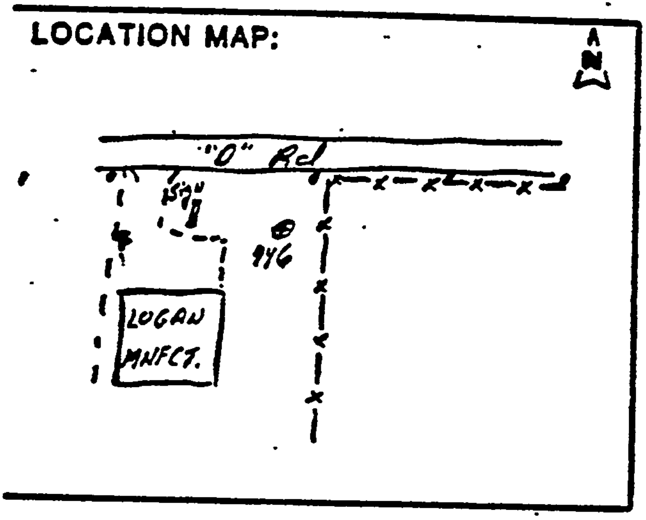
{1 DATES AND COORDINATES}
               MO  DY  YR    {2 GENERAL INFORMATION                                }
 STARTED       __  __  __      SUPERVISOR W.WOOD_____________
 ENDED         __  __  __      DRILLER    BADGER 1200_________
 NORTH     ___62365.1000       EQUIPMENT  2.0-IN.SCHED.40 PVC_
 EAST      ___35806.3000       METHOD     ROTARY W/VARIFLO MUD  HOLE DIA 6.0-in._
 ELEVATION    4586.9___        DEPTHS: Hole ___25.00  Water  1 __11.15  2 ___9.66
 TREND N00.0E  PLUNGE -90.0    STARTING PAGE # ____
{3 NOTES                                                                           }
 ALLUVIUM______________________________________________________________________
 ______________________________________________________________________________
 ______________________________________________________________________________
   ADDITIONAL NOTE ___________________
{4 POINT DESCRIPTOR CODES                }  {5 ADDITIONAL DESCRIPTORS                }
 TYPE 1 ________  LOCATION 1 8________      PT.DESC1 16:23___   PT.DESC3  15:37___
 TYPE 2 ________  LOCATION 2 _________      PT.DESC2 7-23-86_   PT.DESC4  7-15-92_
```

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

BOREHOLE LOG (SOIL)

Page 1 of __

LOCATION MAP:



SITE ID: GR-01 LOCATION ID: 746
APPROX. SITE COORDINATES (ft.):
N ______ E ______
GROUND ELEVATION (ft. MSL): ______
DRILLING METHOD: Rotary
DRILLER: S-H Drilling
DATE STARTED: 3-15-85
DATE COMPLETED: 3-15-85
FIELD REP.: [illegible]

GROUNDWATER LEVELS		
DATE	TIME	DEPTH (ft.)

LOCATION DESCRIPTION Approx 1 mile N.E of G's on "O" Rd
SITE CONDITION Flat, Natural Grasses

DEPTH	SAMPLE INTERVAL	SAMPLE RECOVERY	SAMPLE RETAINED	TYPE	ID	BLOWS PER 6 In.	N VALUE	USCS	VISUAL CLASSIFICATION
	X	NR	NR	S		17-15-10-10	20	SC	Clayey Sand, Some Gravel & Cobbles, Fine, L.P., Lt. Brn.
	X	NR	NR	S		8-4-6-7	13	CH	Clay, Red P-H.P., Brown
	X	X		S	001	2-2-3-4	7		
	X	X	X	S	002	2-1-2-5	7		
	X	NR	NR	S		2-1-1-2	3		00
	X	X	X	S	003	1-1-2-13	15		
	X	X	X	S	004	11-26-50/6"	50+	GP	Gravel, Coarse Sand, Fine-Med, Sub-Angular to Sub Rd., N.P., Grey-Black
	X	X	X	S	005	31-50/5"	50+		
	X	NR	NR	S		50/6"	50+		
	X			S	006	50/5"	50+		
	X			S	007	50/4"	50+		
	X	NR	NR	S		50/1"	50+		
	X	NR	NR	S		50/2"	50+		
									Stopped Boring @ 25.

COMMENTS: Hammer does not meet ASTM Specs

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *747*

JOB NO. GRJ01 DATE 03/13/85

BORING TYPE ROTARY W/VARIFLO MUD

DEPTH OF SEAL 8.00

WELL CASING TYPE 2.0-IN.SCHED.40 PVC

COMPLETION ALLUVIUM

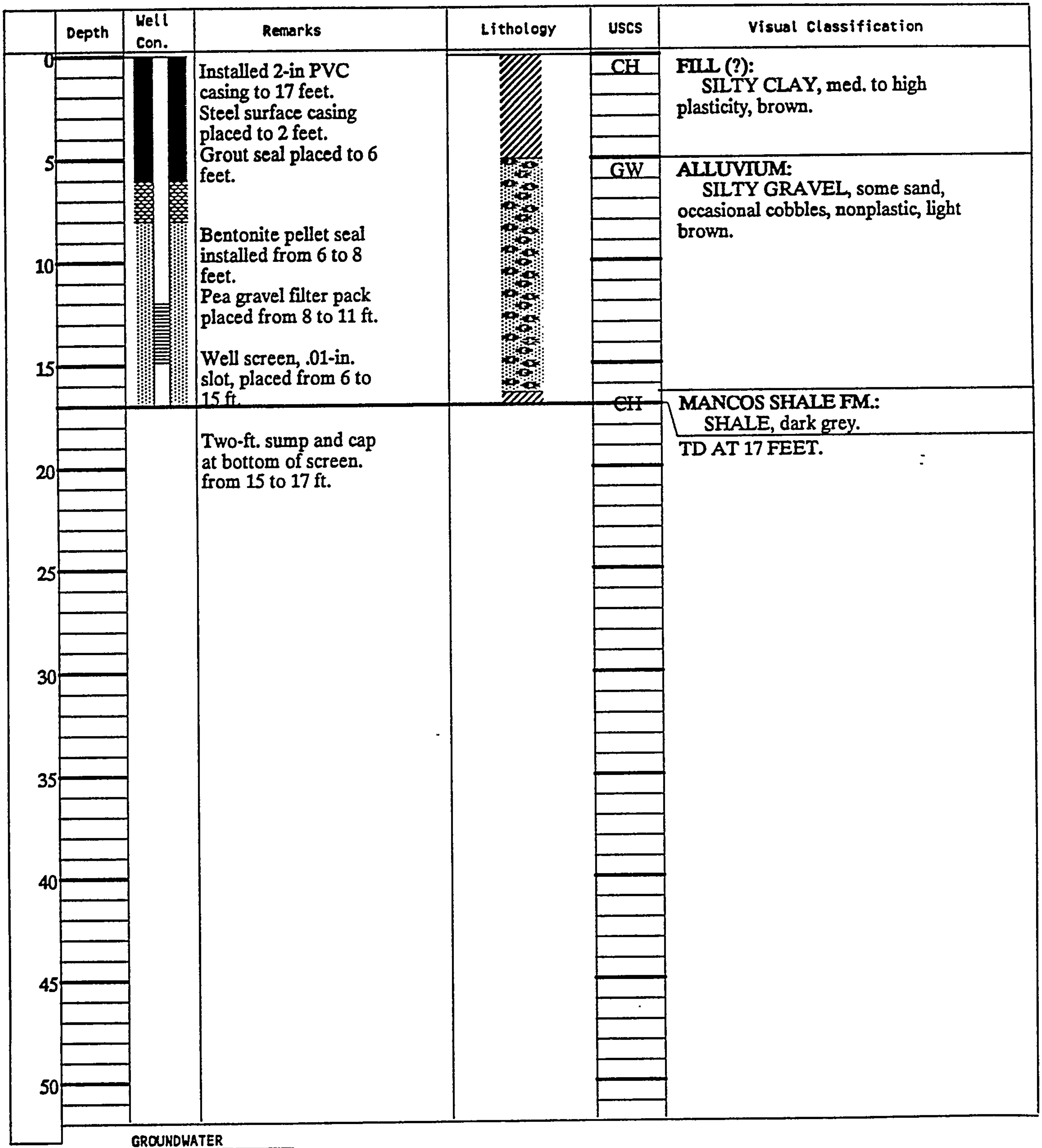
TOTAL DEPTH 17.0 feet

FIELD REP. W.WOOD

SURFACE ELEVATION 4574.30

LOCATION N 60207.80 E 36378.80

DATUM MSL



Installed 2-in PVC casing to 17 feet. Steel surface casing placed to 2 feet. Grout seal placed to 6 feet.

Bentonite pellet seal installed from 6 to 8 feet.

Pea gravel filter pack placed from 8 to 11 ft.

Well screen, .01-in. slot, placed from 6 to 15 ft.

Two-ft. sump and cap at bottom of screen. from 15 to 17 ft.

FILL (?):
SILTY CLAY, med. to high plasticity, brown.

ALLUVIUM:
SILTY GRAVEL, some sand, occasional cobbles, nonplastic, light brown.

MANCOS SHALE FM.:
SHALE, dark grey.

TD AT 17 FEET.

GROUNDWATER

	DEPTH	HOUR	DATE
▽			
▼			

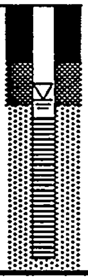
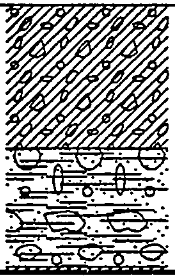
JEG TAC TEAM

Page 1 of 1

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *1000*

JOB NO. GRJ01	DATE 09/28/94	TOTAL DEPTH	9.3 feet
BORING TYPE	HOLLOW STEM AUGER	FIELD REP.	T.MONKS
DEPTH OF SEAL	3.50	SURFACE ELEVATION	4566.86 (TOC= 4568.82)
WELL CASING TYPE	4-IN.SCHED. 40 PVC	LOCATION	N 59345.13 E 32891.49
COMPLETION	ALLUVIUM	DATUM	MSL

	Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0			Placed 4-inch sched. 40 PVC to 8.8 feet. Installed steel protective casing and cement grout to 2 feet. Bentonite pellet seal placed from 2 to 3.5 feet.		GC	**ALLUVIUM:** CLAYEY GRAVEL, some silt, about 40% fine sand, 10% subrounded to angular, moderate plasticity, mod. calcareous, pale yellowish brown (10YR,6/2).
5					GM	SILTY GRAVEL AND COBBLES, subrounded to angular gravel, cobbles to 4-inch, 20% silt, slightly plastic, moderately calcareous, pale yellowish brown (10YR,6/2).
10			#20/40 sand filter pack placed from 3.5 to TD. Installed screen from 3.8 to 8.8 feet.		CH	TD AT 9.24 ON MANCOS SHALE
15						
20						
25						
30						
35						
40						
45						
50						

GROUNDWATER

	DEPTH	HOUR	DATE
▽	3.3	18:30	9/27/94
▼			

Page 1 of 1

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. 1001

JOB NO. GRJ01 DATE 09/29/94

TOTAL DEPTH 12.1 feet

BORING TYPE HOLLOW STEM AUGER

FIELD REP. T.MONKS

DEPTH OF SEAL 5.00

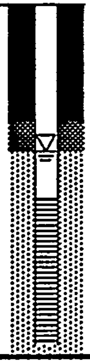
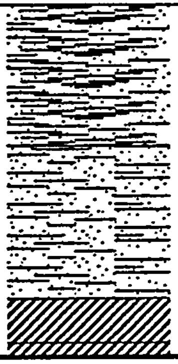
SURFACE ELEVATION 4570.41 (TOC= 4571.66)

WELL CASING TYPE 4-IN.SCHED. 40 PVC

LOCATION N 59419.40 E 32986.28

COMPLETION ALLUVIUM

DATUM MSL

Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0		Placed 4-inch sched. 40 PVC to 11.6 feet. Installed steel protective casing and cement grout to 4 feet. Bentonite pellet seal placed from 4 to 5 feet. #20/40 sand filter pack placed from 5 to TD.		ML SM	ALLUVIUM: SILT AND SAND, with gravel, 50 % silt, predominantly fine sand, subrounded to angular gravel, nonplastic, slightly calcareous, pale brown (10YR, 6/2).
5				SM	SILTY SAND, with fine gravel, 70 % predominantly fine sand, 20% silt, 10% subrounded to angular fine gravel, nonplastic, slightly calcareous, pale brown (10YR,6/2).
10				CH	SANDY CLAY, 40% fine sand, mod. calcareous, mod. plasticity, pale brown (10YR,6/2).
		Installed screen from 6.6 to 11.6 feet.		CH	MANCOS SHALE: SHALE, yellowish brown.
15					TD AT 12.13
20					
25					
30					
35					
40					
45					
50					

GROUNDWATER

	DEPTH	HOUR	DATE
▽	5.0	12:00	9/28/94
▼			

JEG TAC TEAM

Page 1 of 1

PROJECT GRAND JUNCTION PROCESS SITE

LOG OF WELL BORING NO. *1002*

JOB NO. GRJ01 DATE 09/29/94

TOTAL DEPTH 13.5 feet

BORING TYPE HOLLOW STEM AUGER

FIELD REP. T.MONKS

DEPTH OF SEAL 5.00

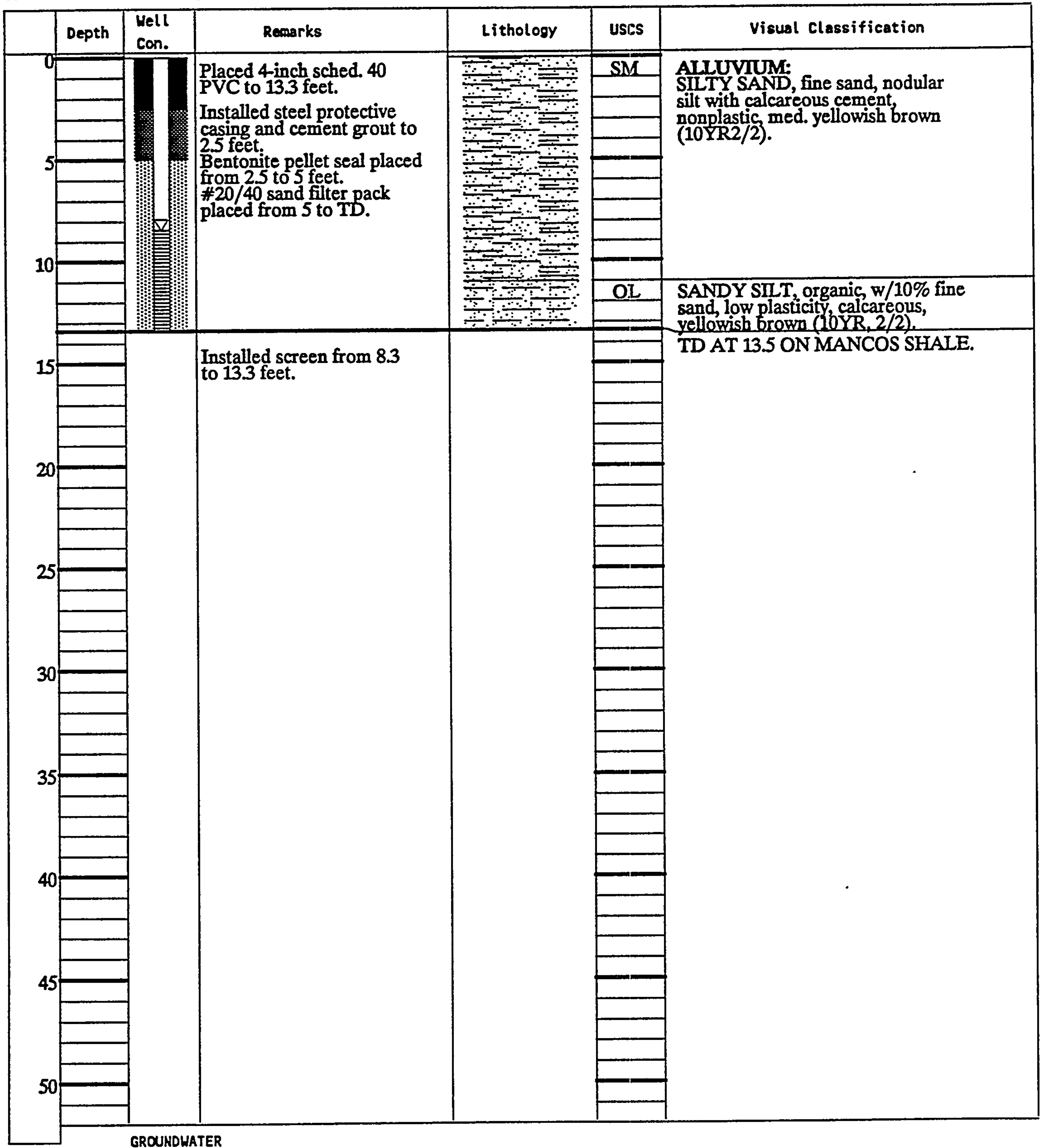
SURFACE ELEVATION 4572.78 (TOC= 4574.56)

WELL CASING TYPE 4-IN.SCHED. 40 PVC

LOCATION N 59609.20 E 33231.86

COMPLETION ALLUVIUM

DATUM MSL



Depth	Well Con.	Remarks	Lithology	USCS	Visual Classification
0		Placed 4-inch sched. 40 PVC to 13.3 feet. Installed steel protective casing and cement grout to 2.5 feet. Bentonite pellet seal placed from 2.5 to 5 feet. #20/40 sand filter pack placed from 5 to TD.		SM	ALLUVIUM: SILTY SAND, fine sand, nodular silt with calcareous cement, nonplastic, med. yellowish brown (10YR2/2).
				OL	SANDY SILT, organic, w/10% fine sand, low plasticity, calcareous, yellowish brown (10YR, 2/2).
		Installed screen from 8.3 to 13.3 feet.			TD AT 13.5 ON MANCOS SHALE.

GROUNDWATER

	DEPTH	HOUR	DATE
▽	8.5	14:20	9/28/94
▼			

JEG TAC TEAM

APPENDIX B

LIST OF AVAILABLE CALCULATION SETS

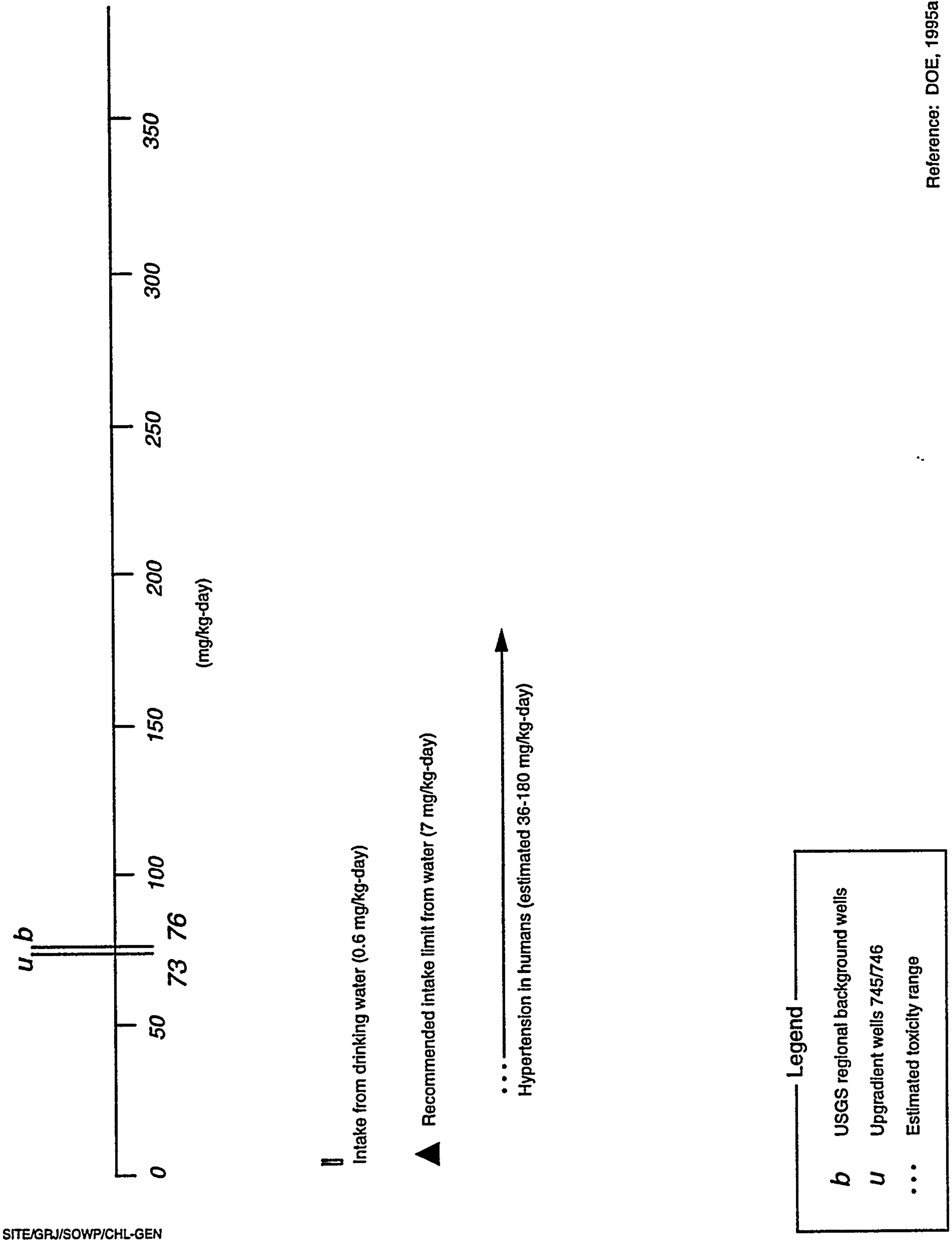
LIST OF AVAILABLE CALCULATION SETS

GRJ-08-90-14-11	Statistical Evaluation of Ground Water Contamination at the Grand Junction Processing Site.
GRJ-01-91-15-02-00	Concentration Limits at the Grand Junction Processing Site.
GRJ-02-96-12-01-00	Surface Water Mass Balance at the Grand Junction Processing Site.
GRJ-06-91-15-01-00	Hazardous Constituents in Tailings Pore-Water Compared to Background Ground Water Quality in the Alluvium at the Grand Junction Processing Site.
GRJ-07-90-15-01	Hazardous Constituents in the Tailings Pore Water Exceeding the Laboratory Method Detection Limits.
GRJ-06-91-15-01-01	Extent of Existing Contamination at the Grand Junction Processing Site.

APPENDIX C

TOXICITY RANGES

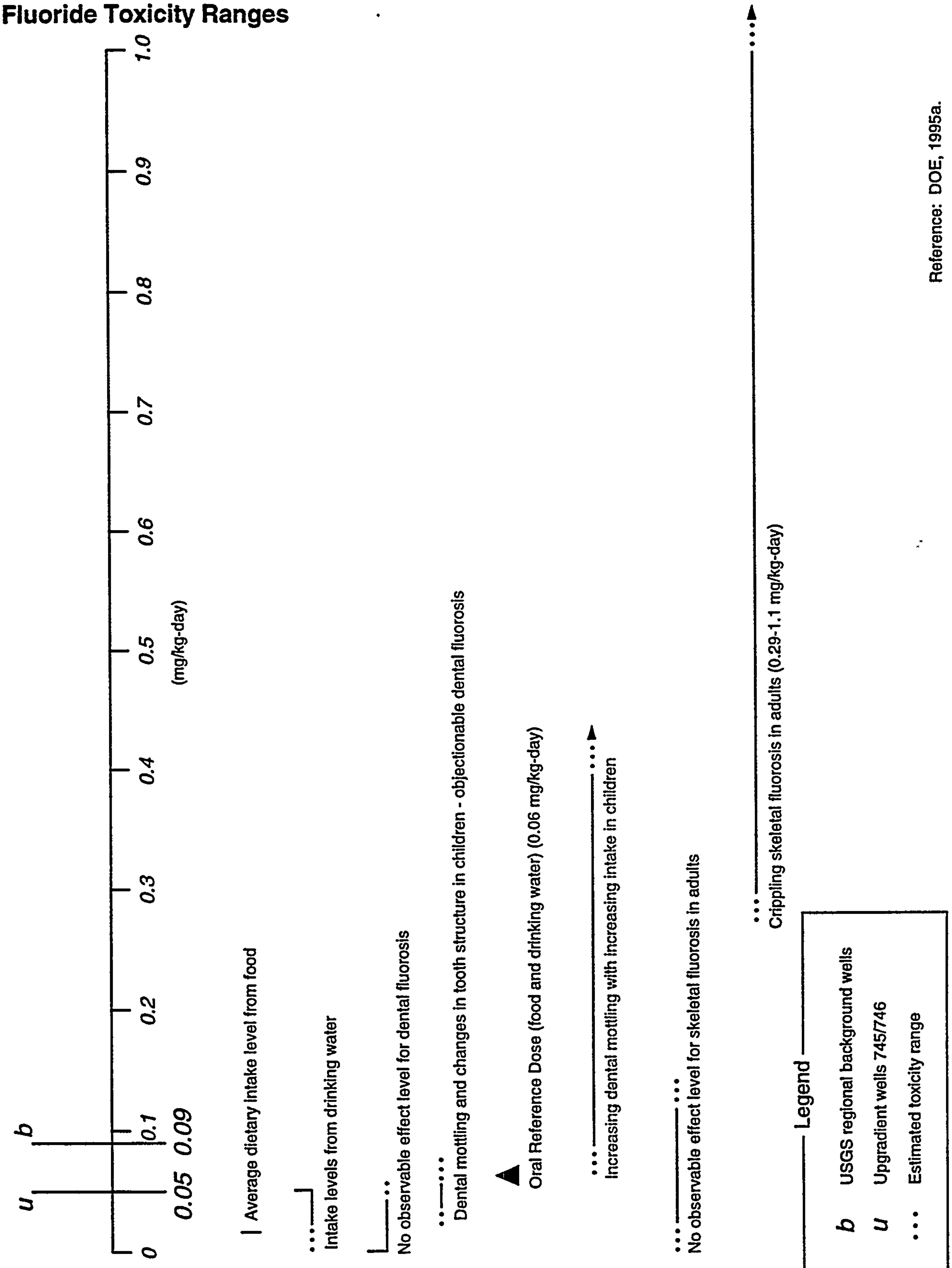
Figure C1
Chloride Toxicity Ranges



Reference: DOE, 1995a.

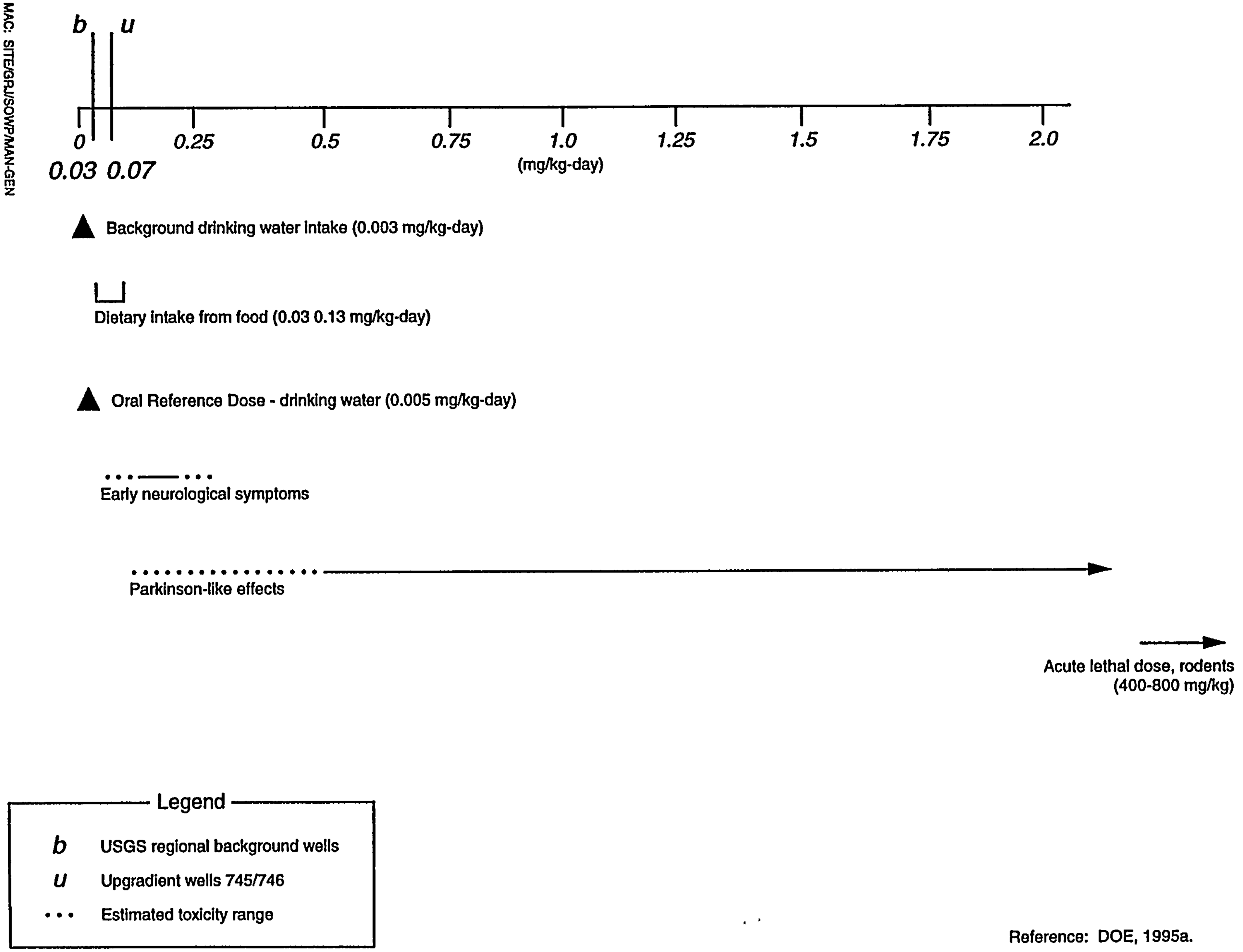
MAC: SITE/GRJ/SOWP/CHL-GEN

Figure C2
Fluoride Toxicity Ranges



MAC: SITE/GRJ/SOWP/FLR-GEN

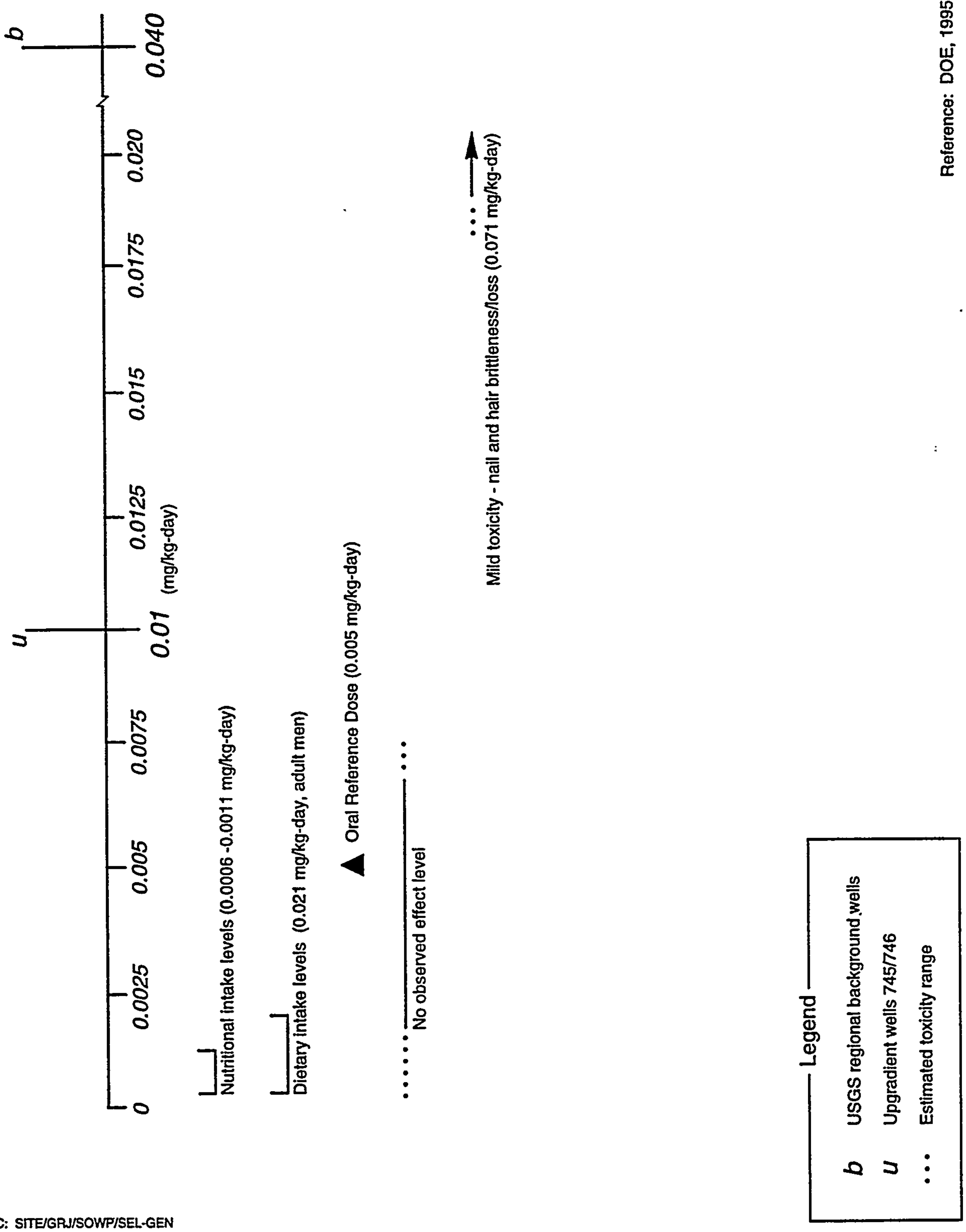
Figure C3
Manganese Toxicity Ranges



Reference: DOE, 1995a.

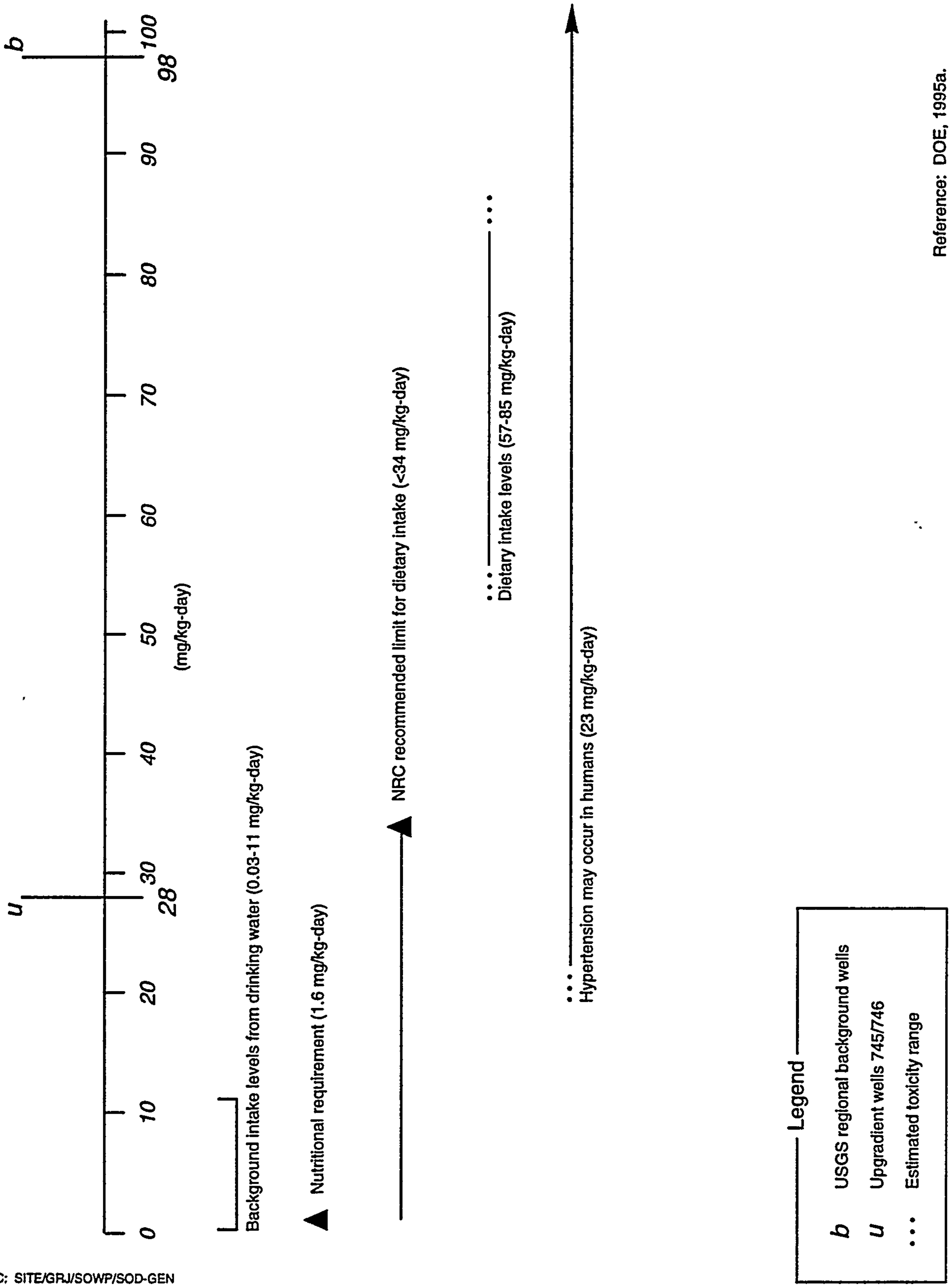
MAC: SITE/GRJ/SOWP/MAN-GEN

Figure C4
Selenium Toxicity Ranges



Reference: DOE, 1995b.

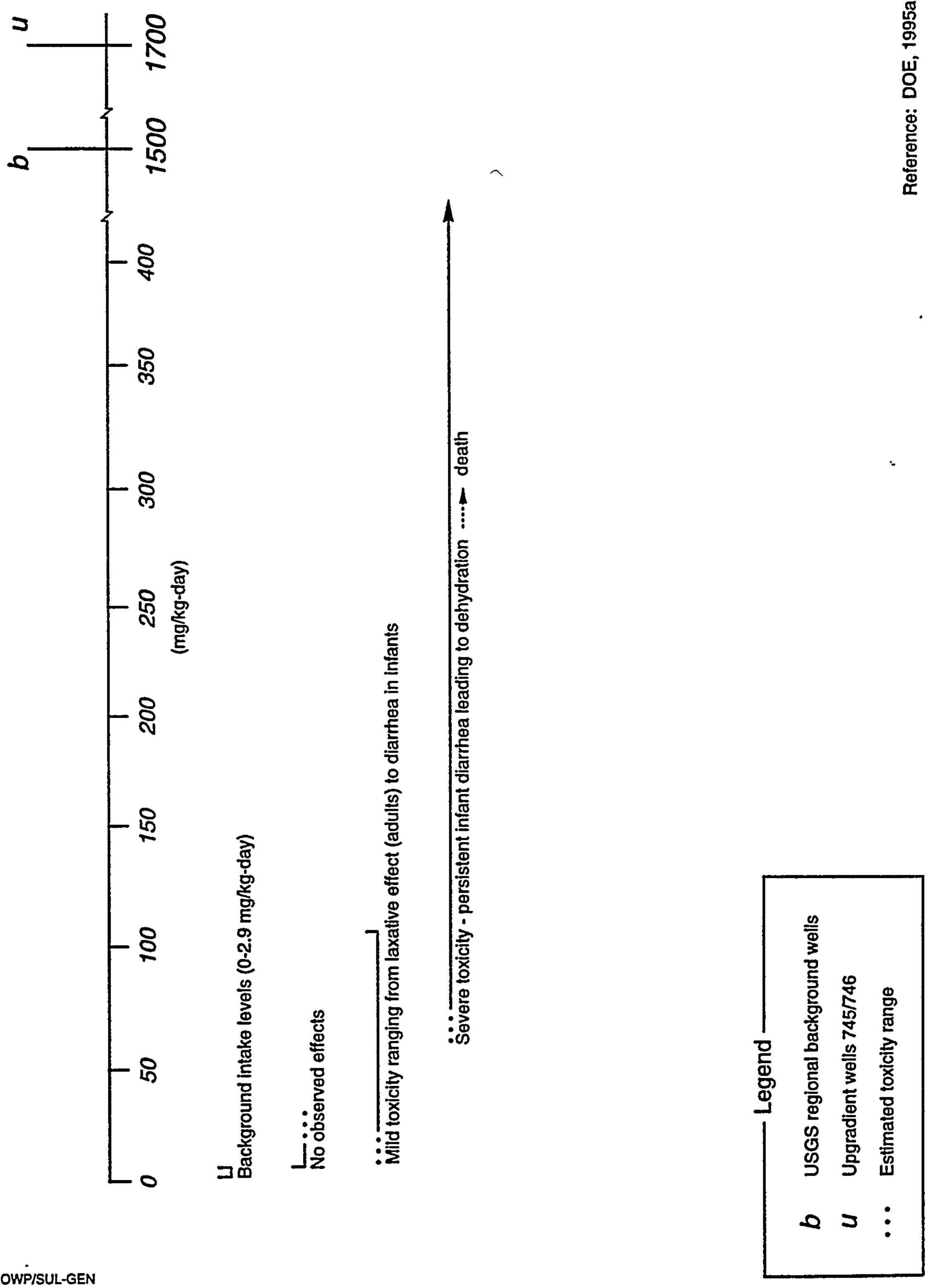
Figure C5
Sodium Toxicity Ranges



Reference: DOE, 1995a.

MAC: SITE/GRJ/SOWP/SOD-GEN

Figure C6
Sulfate Toxicity Ranges



Reference: DOE, 1995a.