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AUG 23 2002

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U.S. Nuclear Regulatory Commission
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Rockville, MD 20852-2747

Subject: Transmittal of Revised *Long-Term Surveillance Plan for the U.S. Department of Energy Lakeview Uranium Mill Tailings Disposal Site, Lakeview, Oregon*

Dear Mr. Gillen:

Enclosed are four copies of the subject plan for your agency's review and approval.

The DOE revised the plan to incorporate a recalculated critical diameter for rock armor on the west side slope. Other revisions were made to the plan to make it consistent with a format that has evolved over the past 15 years and that has been accepted by the NRC.

The quality of the riprap on the Lakeview cell cover has been an issue since construction of the facility. The DOE has observed a gradual decrease in median diameter of the rock. The original design calculations of required median diameter were conservative, and the riprap is now at the lower end of the range of sizes calculated to be able to withstand the erosive force of a probable maximum precipitation event.

The DOE has reevaluated the critical rock size for this application, in consultation with NRC. The current design guidance allows use of one-half of a probable maximum precipitation event as the impulse. Also, the reevaluation accounts for loss of erosive energy from surface rugosity and loss of run-off volume from infiltration, whereas the original calculation considered the surface to be smooth and impermeable. The revised critical median diameter is 1.8 inches, as contrasted to the previous median diameter requirement of 2.7 inches.

If you have any questions, please call me at (970) 248-6037 with questions, or e-mail me at akleinrath@gjo.doe.gov.

Sincerely,

Art Kleinrath

Art Kleinrath
Program Manager

Enclosure

cc w/enclosure:
D. Stewart-Smith, State of Oregon
File: LLKV 1.1 (Garcia)

cc w/o enclosure:
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awk/dg-nmss.doc

GJO-2002-353-TAC
GJO-LLKV 1.1

Long-Term Surveillance and Maintenance Program

Long-Term Surveillance Plan for the U.S. Department of Energy Lakeview Uranium Mill Tailings Disposal Site, Lakeview, Oregon

DRAFT

August 2002

U.S. Department of Energy

GRAND JUNCTION OFFICE

Work Performed Under DOE Contract No DE-AC13-02GJ79491 for the U S. Department of Energy
Approved for public release, distribution is unlimited

GJO–2002–353-TAC
GJO-LLKV 1.1

Long-Term Surveillance and Maintenance Program

Long-Term Surveillance Plan

for the

U.S. Department of Energy
Lakeview Uranium Mill Tailings Disposal Site
Lakeview, Oregon

DRAFT

Revised August 2002

This document supersedes document number
UMTRA-DOE/AL/62350-19F, Rev. 3. August 1994

Prepared by
U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado

Work Performed Under DOE Contract Number DE-AC13-02GJ79491
for the U.S. Department of Energy

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Recalculation of D_{50}, Minimum Median Diameter of Riprap for the Side Slope of the Lakeview, Oregon, Disposal Cell

Acronyms

BM	boundary monument
CFR	*Code of Federal Regulations*
cm/s	centimeters per second
D_{50}	median diameter
DOE	U.S. Department of Energy
EDA	energy dissipation area
EPA	U.S. Environmental Protection Agency
GJO	Grand Junction Office
LTP	Long-Term Performance [Project]
LTSM	Long-Term Surveillance and Maintenance [Program]
LTSP	Long-Term Surveillance Plan
MCL	maximum concentration limit
mg/L	milligrams per liter
MW	monitor well
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration
PMP	probable maximum precipitation
QA	Quality Assurance
SM	survey monument
SMK	site marker
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action [Project]
UMTRCA	Uranium Mill Tailings Radiation Control Act (88 USC 7901, *et seq.*)

1.0 Introduction

1.1 Purpose

This Long-Term Surveillance Plan (LTSP) explains how the U.S. Department of Energy (DOE), as the long-term custodian, will meet requirements of the general license for the Lakeview uranium mill tailings disposal site, Lakeview, Oregon. (**Note:** Some references cited in Section 4.0 of this revised LTSP refer to the Lakeview disposal site as the Collins Ranch site, an informal designation no longer used.)

1.2 Legal and Regulatory Requirements

The Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978, as amended, provides for the remediation and regulation of uranium mill tailings at two categories of uranium mill sites, Title I and Title II. Title I sites, such as Lakeview, are former uranium mill sites unlicensed and essentially abandoned as of January 1, 1978. Title II sites are uranium mill sites under specific license on January 1, 1978. In both cases, the licensing agency is the U.S. Nuclear Regulatory Commission (NRC), or in the case of certain Title II sites, an Agreement State.

Federal regulations at Title 10 *Code of Federal Regulations* (CFR) Part 40.27 provide for the licensing, custody, and long-term care of uranium mill tailings disposal sites remediated under Title I of UMTRCA.

A general license is issued by the NRC for the long-term custody and care of such sites. Long-term care includes institutional control, inspection, monitoring, maintenance, and other measures to ensure that the sites continue to protect public health, safety, and the environment after remediation is completed.

The general license becomes effective when a site-specific LTSP receives NRC concurrence. The original LTSP for the Lakeview site (DOE 1994) received NRC concurrence on September 15, 1995 (Appendix F).

Requirements at 10 CFR 40.27 for the LTSP and for the long-term surveillance and maintenance of the Lakeview site are listed in Table 1–1 in this revised LTSP.

Table 1–1. Requirements for the Long-Term Surveillance Plan and the Long-Term Surveillance and Maintenance of the Lakeview Disposal Site

Requirements for the LTSP		
No	*Requirement*	*This LTSP*
1	Final site conditions	Section 2 0
2	Legal description of the site	Appendix B
3	Long-term surveillance program	Section 3 0
4.	Follow-up inspections	Section 3 4
5.	Maintenance and other actions	Section 3 5, Appendix D
Requirements for Long-Term Surveillance and Maintenance		
No	*Requirement*	*This LTSP*
1.	Changes to the LTSP	Section 3 1
2	Permanent NRC right-of-entry	Section 3.1
3	Notification of significant problems or actions	Section 3.6

The plans, procedures, and specifications in this revised LTSP are based on the guidance document, *Guidance for Implementing the Long-Term Surveillance Program for UMTRCA Title I and Title II Disposal Sites* (DOE 2000). Rationale and procedures in the guidance document are considered part of this revised LTSP.

1.3 Role of the U.S. Department of Energy

In 1988, the DOE designated the Grand Junction Office (GJO) to be the program office for the long-term surveillance and maintenance of all DOE remedial action project disposal sites, as well as other sites as assigned, and to be the common office for the surveillance, monitoring, maintenance, and institutional control of these sites. The DOE established the Long-Term Surveillance and Maintenance (LTSM) Program at GJO to carry out this responsibility.

The LTSM Program is responsible for the implementation and revision of the LTSP (Section 3.1).

2.0 Final Site Conditions

2.1 Site History

The Lakeview disposal site is a relocated site in that tailings and other contaminated materials were moved (relocated) from the former millsite area to a remote disposal site that met remedial action objectives for long-term safety and isolation (DOE 1989a). The former millsite was approximately 1 mile north of the town of Lakeview. The disposal site is 11.1 miles by road northwest of Lakeview. Millsite history is described below. The disposal site is described in Sections 2.2 and 2.3.

The Lakeview uranium processing mill was built by the Lakeview Mining Company in 1958 and began operating that year. Uranium ore came from the White King and Lucky Lass mines, both approximately 16 road miles northwest of Lakeview, Oregon.

The owners of the Lakeview mill also owned the Gunnison Mining Company, which operated the uranium mill at Gunnison, Colorado. Both mills were acquired in 1961 by Kerr-McGee Oil Industries through its subsidiary Kermac Nuclear Fuels Corporation. Between 1960 and 1968, the mill had five owners.

From 1958 to 1961, there were 130,000 tons of ore processed at the Lakeview Mill. The rated capacity of the mill was 210 tons per day. Uranium ore was processed by a sodium chlorate and sulfuric acid leach process.

In 1968, the Lakeview mill was acquired at Atlantic Richfield Company. In 1974, Atlantic Richfield began a cleanup operation at the mill under a plan approved by the Oregon State Health Division. The cleanup was completed in 1977 to meet state requirements for control of radiation. Both mill buildings and immediate surroundings were involved in the cleanup and decontamination.

In 1978, Atlantic Richfield sold the property by the Precision Pine Lumber Company, which used the site and buildings as a lumber mill. The property was sold to Goose Lake Lumber Company in 1987, although Precision Pine Lumber continued to own title to the uranium mill tailings on site. (The tailings pile and evaporation ponds were approximately 2000 feet west of the former mill buildings.)

The Lakeview mill site was designated for cleanup under UMTRCA in 1978. Remedial action began in 1986 and was completed three years later in 1989. During this remedial action, 926,000 cubic yards (736,000 dry tons) of contaminated material from the tailings pile, evaporation ponds, buildings, and wind- and water-borne deposits were removed from the mill site and carried by truck to the Lakeview disposal site on the Collins Ranch northwest of the Lakeview, Oregon. Windblown materials on property adjacent to the former mill site were included in this removal.

Further information on millsite history is in Ford, Bacon, and Davis 1977; DOE 1985; and DOE 1992; and in additional references cited in these documents.

2.2 Area Description

The Lakeview disposal site is in Lake County, Oregon, approximately 7 miles northwest of the town of Lakeview (Figure 2–1).

The site is within the northwestern part of the basin and range province, a large physiographic region characterized by north and northwest-trending normal faults. The site is on the western edge of the Goose Lake graben, a down-dropped fault block.

The area immediately surrounding the site is ranch land (Collins Ranch) at an elevation of 4,900 to 5,000 feet. Mountains to the north and west are in the Fremont National Forest where summits reach elevations of more than 8,000 feet. Immediately north of the site, Augur Hill rises to an elevation of 5,029 feet.

Vegetation at the site comprises sagebrush, other brushy plants, and grasses. The meadow below the site to the west is grassy. At elevations just a few hundred feed above the site, vegetation consists of a ponderosa pine community.

The site is in the eastern Oregon high desert in the rain shadow of the Cascade Mountains. The climate is semiarid with 16 inches of annual precipitation including 61 inches of snow. Most precipitation falls in the nine months of fall, winter, and spring. Summers are relatively dry.

Based on information from the Lakeview airport, the nearest weather station, mean temperature extremes range from a daily low of 20°F in January to a daily maximum of 83°F in July (DOE 1985a). Average wind speed is 7.5 miles per hour, predominantly out of the south. Topography and elevation are understood to affect the local climate at the site. The site probably receives more wind and is both colder in winter and perhaps slightly cooler in summer than at the Lakeview airport weather station.

2.3 Site Description

2.3.1 Legal Description

Pursuant to Section 104 of UMTRCA, the State of Oregon acquired the site from a private interest through civil action suit. This acquisition provided a 40-acre site and perpetual access to the site across the Collins Ranch from County Road 2-16B. The legal description of the site and a brief history of the acquisition are in Appendix B. The site boundary is shown on Figure 2–2.

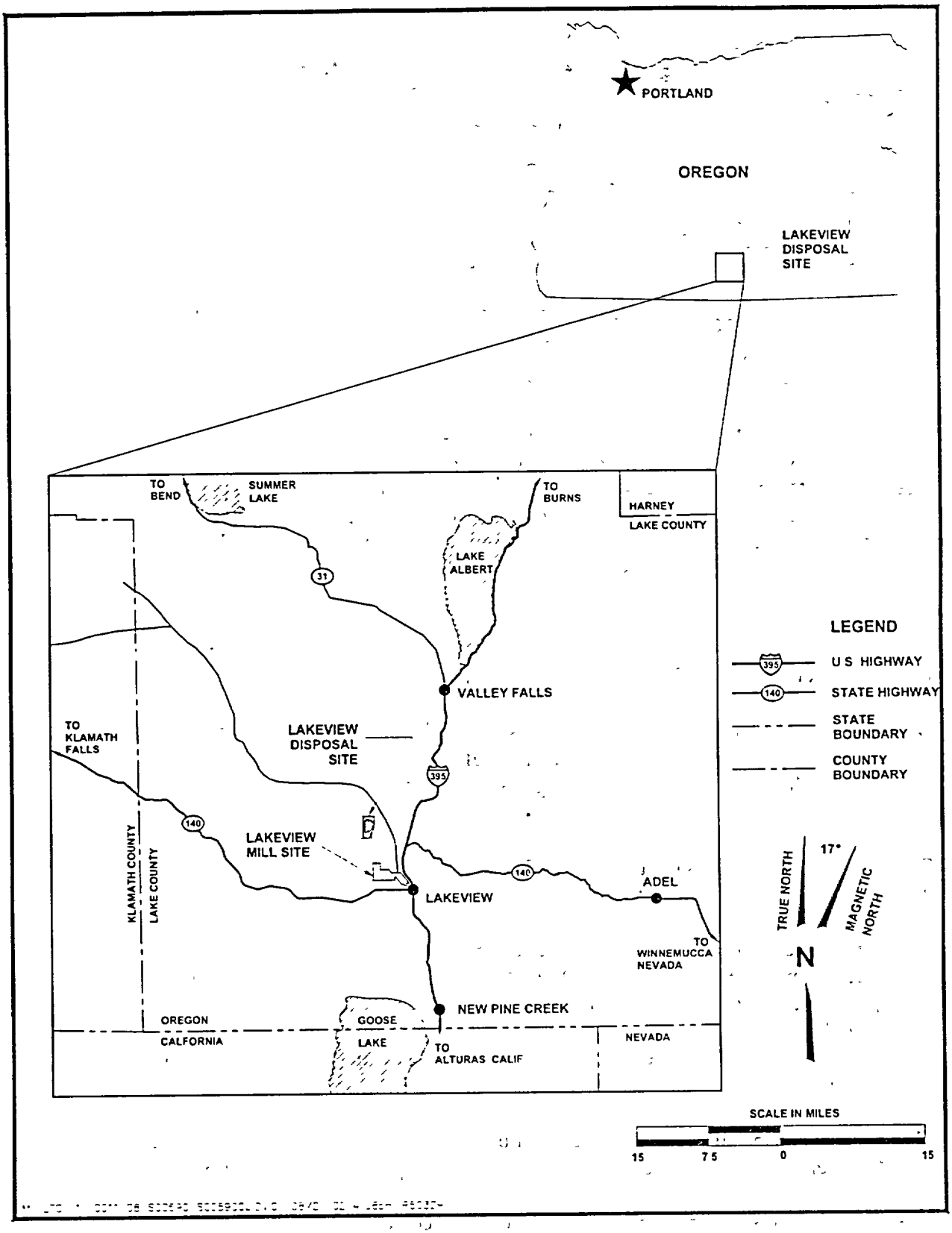


Figure 2–1 Location of Lakeview, Oregon, Disposal Site

2.3.2 Location and Access

Directions to the site follow. See also Figure 2–1.

Mileage	Route
0 0	Junction of U.S. Highway 395 and State Highway 140 north of the Lakeview commercial district
4 5	Junction with Highway 140 East Continue north
6 3	Turn left (west) on County Road 2-16
7.1	Goose Lake County landfill on the right
9 0	Cross Cox Creek
9 55	Turn right (north) on County Road 2-16B
10 0	Turn left (west) on site access road
10.2	Cattle guard and cable across road Open cable gate continue west (By arrangement with Collins Ranch, DOE has a lock on the cable gate.)
10.9	Turn right (north)
11.1	Entrance gate in southeast fence line

Although DOE has permanent and unrestricted access to the site (DOE 1994), an access protocol is established with the owner of Collins Ranch. DOE will have its own lock on the cable gate (see mileage table above) and will advise the ranch by telephone or mail prior to each site visit. The point of contact, address, and telephone number will appear in the inspection checklist (Appendix C). (Land ownership and contact information are ephemeral. Should ownership or contact information change, this will be noted in the checklist.)

2.3.3 Site Description

Features described in this LTSP are shown on Figure 2–2.

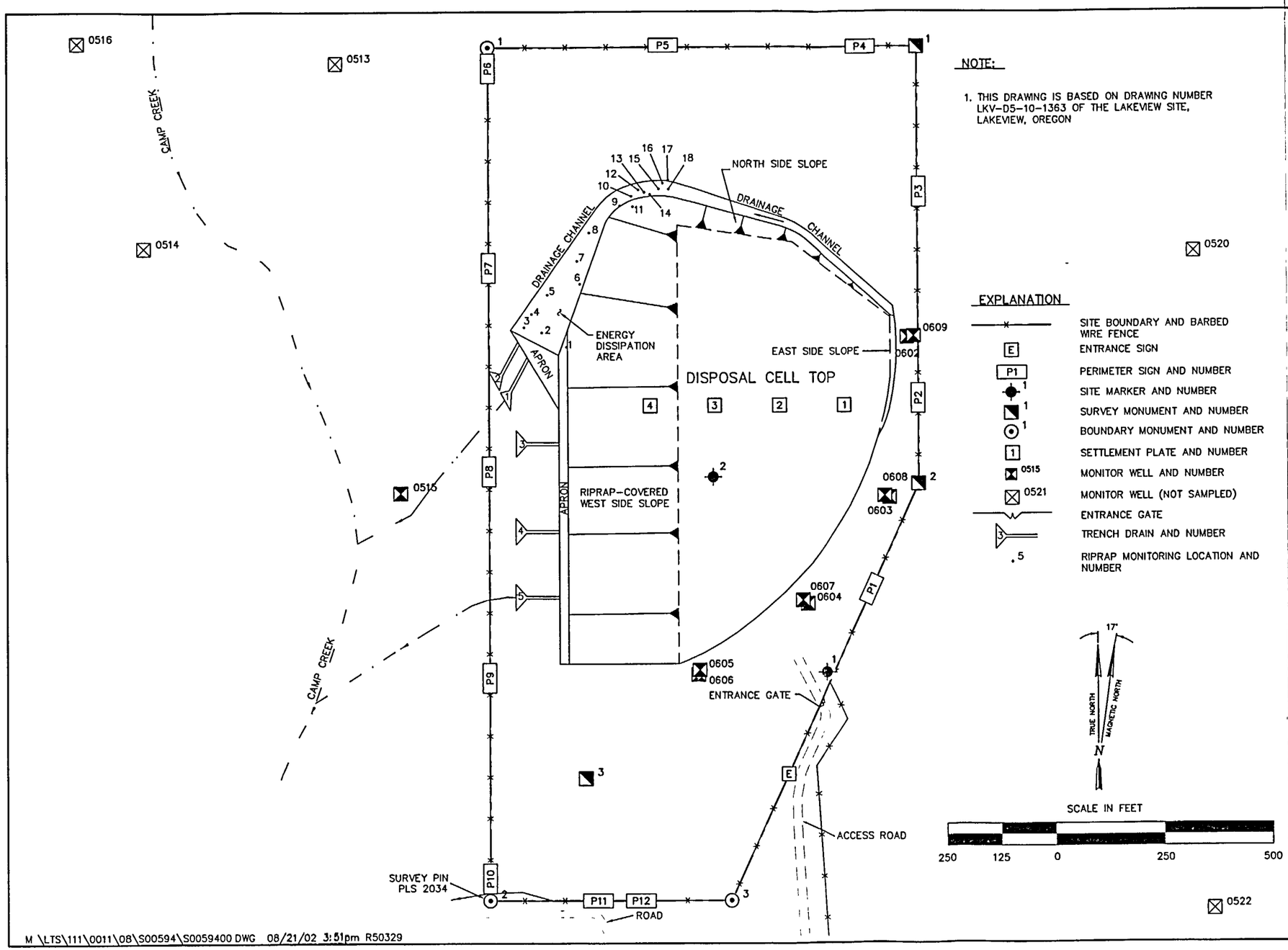
Disposal Site. The site comprises 39.6 acres on a hill slope that faces west. The disposal cell itself is in the approximate center of the disposal site. Land around the disposal cell is covered with sagebrush, other bushy plants, and grass. Some of the vegetation is natural (although modified by grazing), and some was planted during final stages of remedial action.

Disposal Cell. The disposal site contains 736,000 dry tons of mill tailings Radioactivity within the disposal cell is 42 curies of radium-226.

The disposal cell comprises 16.05 acres and is roughly rectangular in outline. It extends 1,100 feet from north to south and 800 feet from east to west. The east side of the cell begins at the top of a drainage divide and slopes downward toward Camp Creek valley on the west. The top of the disposal cell is at an elevation of 4,967 feet; the bottom is at an elevation of approximately 4,900 feet. The "footprint" of the disposal cell, as discussed below, is at an elevation of 4,880 feet.

The top of the disposal cell is relatively flat but designed to shed runoff to the west at a 2-to-4-percent grade. The side slope on the west is steeper with a grade of 5:1.

The disposal cell is a surface impoundment but it is constructed partly below grade, as indicated in Figure 2–3.



NOTE:

1. THIS DRAWING IS BASED ON DRAWING NUMBER LKV-D5-10-1363 OF THE LAKEVIEW SITE, LAKEVIEW, OREGON

EXPLANATION

- SITE BOUNDARY AND BARBED WIRE FENCE
- E — ENTRANCE SIGN
- P1 — PERIMETER SIGN AND NUMBER
- 1 — SITE MARKER AND NUMBER
- 1 — SURVEY MONUMENT AND NUMBER
- 1 — BOUNDARY MONUMENT AND NUMBER
- 1 — SETTLEMENT PLATE AND NUMBER
- 0515 — MONITOR WELL AND NUMBER
- 0521 — MONITOR WELL (NOT SAMPLED)
- ENTRANCE GATE
- 3 — TRENCH DRAIN AND NUMBER
- .5 — RIPRAP MONITORING LOCATION AND NUMBER

LOCATIONS OF MONUMENTS, MARKERS, AND WELLS		
TYPE	COORDINATES	
	STATE PLANE EAST	STATE PLANE NORTH
BOUNDARY MONUMENT		
1	2017778.00	226667.00
2	2017778 00	224723 00
3	2018335.00	224723 00
SURVEY MONUMENT		
1	2018772.00	226667 00
2	2018772 00	225670 00
3	2018000 00	225000 00
SITE MARKER		
1	2018557.49	225240.45
2	2018296.12	225686 67
WELLS		
0513	2017425 20	226631.50
0514	2016981.30	226211.00
0515	2017575 00	225650 60
0516	2016829.70	226676 80
0520	2019410 56	226200 65
0521	2019640 73	225449.67
0522	2019449 69	224700 57
0523	2020147.73	225172 97
0602	2018747.11	226005 07
0603	2018704.53	225639 30
0604	2018513 60	225397.45
0605	2018263.20	225246 85
0606	2018260 19	225236.64
0607	2018502.27	225405 67
0608	2018693 88	225643 35
0609	2018762 21	226007 66

U.S. DEPARTMENT OF ENERGY GRAND JUNCTION OFFICE GRAND JUNCTION, COLORADO	Work Performed by S. M. Stoller Corporation Under DOE Contract No DE-AC13-02GJ79491
LAKEVIEW, OREGON DISPOSAL SITE	
DATE PREPARED AUGUST 21, 2002	FILENAME S0059400

Figure 2–2. Lakeview, Oregon, Disposal Site

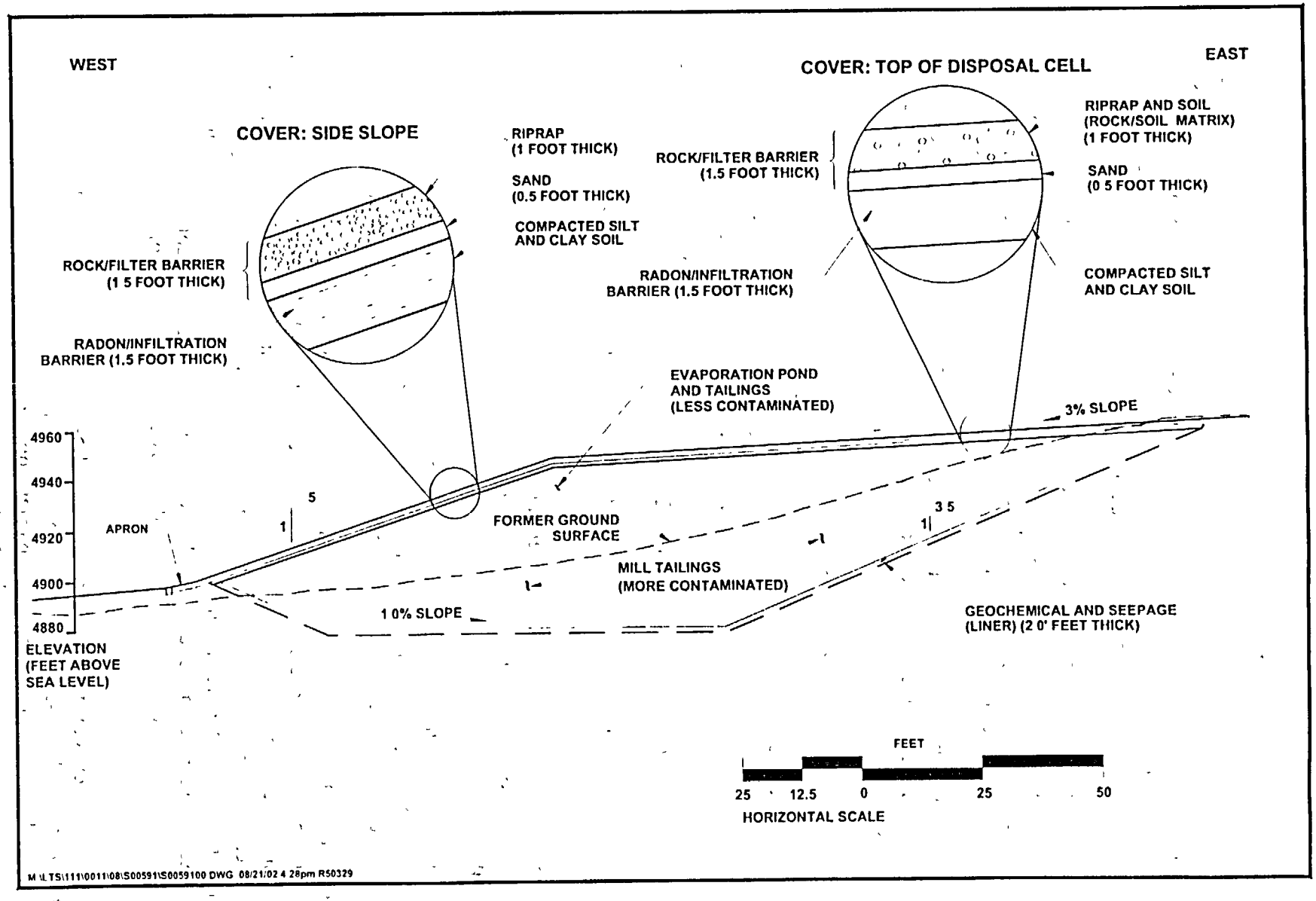


Figure 2–3. Cross Section through the Lakeview, Oregon, Disposal Cell

Two drainage features are incorporated in the design of the disposal cell. The first is a large drainage channel that wraps around the disposal cell on the north and northwest. This channel diverts run-on from Augur Hill, and some of the run-off from the northern part of the disposal cell, into the natural drainage (Camp Creek) west of the site. At the lower end of this drainage channel, the channel widens and flattens into a basin-like feature lined with very large diameter rock. This is an energy dissipation area (EDA).

The second drainage feature is a series of five trench drains. Two of these drains are at the mouth of the EDA, and three are along the apron at the base of the side slope of the disposal cell. The trench drains are essentially rock-filled ditches that collect run-off, divert it away from the disposal cell, and disperse it across the low-lying meadow west of the disposal cell.

As stated above, the disposal cell is partly below grade (Figure 2–3). During construction, a footprint as much as 40 feet deep was excavated in the side of the hill to increase the capacity of the disposal cell and to reduce the above-grade profile of the cell.

The footprint was lined with a highly compacted layer of natural silt and clay soil obtained from the disposal site excavation (DOE 1992). This liner is 2-feet thick. On construction drawings it is referred to as a geochemical and seepage flow barrier. The liner has high neutralization, adsorption, and ion exchange capacity to restrict and attenuate downward movement of contaminants through the bottom of the disposal cell. The liner was compacted to achieve a hydraulic conductivity value of 1×10^{-7} centimeters per second (cm/s) to prevent seepage into the underlying unsaturated sediments (Section 2.4.1).

Tailings were placed on top of this liner. The tailings were covered with another engineered barrier, the cover.

The cover consists of two layers: a lower radon-and-infiltration barrier and upper rock-and-filter layer. The rock-and-filter layer is composed of two sub-layers, sand at the bottom and riprap at the top.

The lowest layer in the cover is a highly compacted radon-and-infiltration barrier (radon barrier). It rests directly on the underlying tailings. The radon barrier is approximately 1.5-feet thick and constructed of the same natural silt and clay soils used for the footprint liner.

Like the liner, the radon barrier was compacted to achieve a hydraulic conductivity of less than 1×10^{-7} cm/s. The purpose of this very low permeability is (1) to prevent release of high levels of radon to the atmosphere (radon flux); and (2) to prevent infiltration of precipitation through the cover. The tight compaction also helps to keep the radon barrier from drying out. Moisture in the radon barrier further retards the movement of radon through the cover. (Within the disposal cell, less contaminated materials from the evaporation ponds and windblown deposits were placed over the more contaminated mill tailings as an additional control on upward movement of radon.)

The radon barrier is overlain and protected by a 1.5-foot-thick rock-and-filter layer. At the bottom of the rock-and-filter layer is a sub-layer of sand 0.5-foot thick (filter layer). This highly permeable layer is to protect the radon barrier from erosion and to provide a means of shedding runoff rapidly from the disposal cell with minimal infiltration.

Above the sandy filter layer is a 1-foot-thick layer of coarse riprap. The riprap prevents erosion from large or severe storms. The median diameter (D_{50}) of the riprap, as installed, was 2.7 inches (range: 2.7 to 3.9 inches). (D_{50} is a measure such that 50 percent of the rock by weight is a certain size or larger.) Rock of this size was calculated to be sufficient to prevent erosion in the event of a flood from a Probable Maximum Precipitation (PMP) event. (PMP is a theoretically "worst possible" storm. As a theoretically worst possible storm, the probability of occurrence is extremely small.) Since the disposal cell was completed in 1989, surficial weathering has caused some of the riprap to break. For response to this issue, see Sections 3.3.2 and 3.5.

On the relatively flat top of the disposal cell, the riprap was covered with a thin layer of soil, perhaps 4-to-6-inches deep. The cover on top of the disposal cell is therefore referred to in remedial action documents as a rock-soil matrix. Subsequent small excavations in the rock-soil matrix, performed as part of cover performance studies by the Long-Term Performance (LTP) Project, showed that at some places the soil has settled into the interstices of the underlying riprap. At other places, the soil still partially covers the riprap. The addition of a soil on top of the disposal cell was not part of the original design.

Purpose of the rock-soil matrix was apparently twofold: first, to protect against erosion by reducing runoff; and second, to improve the aesthetics of the site. Reducing runoff to the side slope of the disposal cell would preclude channelized or concentrated runoff at locations along the top of the side slope where there may have been low spots in the cover. This precaution against concentrated runoff apparently allowed smaller diameter riprap to be placed on the side slope of the disposal cell (DOE 1989b). The rock-soil matrix appears to be working in this respect.

The second objective of the rock-soil matrix was to support various range grasses to make the disposal cell appear more natural. The effort to establish grass on the rock-soil matrix, for the most part, failed. Only a sparse cover of grass was achieved. The soil placed over the riprap was too thin to hold sufficient moisture to support the grass. Since then sagebrush, rabbitbrush, bitterbrush, and similar deep-rooted bushes have begun to establish on top of the disposal cell. Grass remains sparse.

2.3.4 Institutional Control

Institutional controls at the disposal site consist of (1) federal ownership (withdrawal) of the land and permanent access to the site; (2) warning signs; and (3) a barbed-wire stock fence. The site is remote, surrounded by private land, and generally inaccessible to the general public. The site is not visible from public roads.

2.3.5 Specific Site Surveillance Features

Specifications for construction of the features described in this section are in the initial LTSP (DOE 1994) and guidance document (DOE 2000b). Coordinates on Plate 1 for boundary monuments, survey monuments, and site markers were confirmed by a global positioning system in 1999.

Fence. A stock fence encloses the site. The fence is, from place to place, either a standard 4-strand barbed-wire fence or a combination of woven and barbed wire. The entrance gate is a

tubular metal, double-swing gate at the end of the access road. This gate is near the middle of the southeastern fence line.

Boundary Monuments. There are three permanent boundary monuments. They are at the northwest corner of the site (BM-1), southwest corner (BM-2), and south-southeast corner (BM-3) of the site. Boundary monuments are Berntsen Model A-1 federal aluminum survey monuments. Ceramic magnets in the top and bottom of each Model A-1 monument allow the monuments to be located by metal detector if they ever become buried. The bottom of boundary monuments is at a depth of 3 feet to prevent displacement from frost heaving.

Survey Monuments. There are three permanent survey monuments. Two of the three, SM-1 and SM-2, are at the northeast and east-southeast corners of the site, respectively. The third survey monument, SM-3, is well inside the site boundary south of the disposal cell. Survey monuments are Berntsen RT-1 markers set in concrete. The bottom of the concrete is at a depth of 3 feet, sufficient to prevent displacement from frost heaving. Four steel reinforcing bars (rebar) in the concrete will allow the monuments to be located by metal detector if they ever become buried. The survey monuments are referenced to the U.S. Coast and Geodetic Survey triangulation station on the top of Augur Hill immediately north of the site.

Boundary monuments and the two survey monuments along the boundary are not at exact corners, but are set just inside the boundary at each corner.

Site Markers. Site markers are unpolished granite monuments. SMK-1 is just north of the entrance gate. SMK-2 is on top of the disposal cell near the center. The markers are inscribed with a diagram to show the site boundary and location of the disposal cell inside the site boundary, the date of closure (June 29, 1988), the quantity of tailings (736,000 dry tons), and the level of radioactivity (42 curies of radium-226).

Signs. Twelve perimeter (warning) signs and an entrance sign are mounted on steel posts along the site boundary. The signs are metal placards, similar in size to highway signs. The sign posts are set in concrete.

Perimeter signs state that the site is a uranium mill tailings repository, U.S. government property, and no trespassing allowed. The international symbol for radioactive materials (trefoil) on the signs warns of the potential hazard, although there is no hazard as long as the engineered cover over the tailings remains intact.

An entrance sign is posted at the entrance gate. This sign provides the same information as the perimeter signs but has, in addition, a 24-hour telephone number for the public to use in case of emergencies or inquiry (970-248-6070).

Settlement Plates. There are four settlement plates in a line from east to west across the middle of the disposal cell. They were installed to monitor settlement immediately following construction of the disposal cell. Settlement, as measured, was 0.3 inch or less and was considered insignificant. Monitoring was terminated before the site was licensed. The settlement plates are artifacts of construction and no longer monitored or maintained.

Monitor Wells. See Section 3.7.1.

2.4 Ground Water and Surface Water

2.4.1 Geology

The Lakeview site is underlain by as much as 1,000 feet of unconsolidated-to-consolidated Quaternary sediments. Depth to bedrock is unknown but believed to be greater than 1,000 feet based on information from the eastern edge of the Goose Lake Basin (DOE 1994).

Stratigraphy beneath the site is described in general terms in the various remedial action documents (e.g., DOE 1985b, 1992, and 1994). The eastern portion of the site is said to rest on a series of interbedded sands, silts, and fat or highly plastic lacustrine clays that together may be more than 1,000-feet thick. Finer grained materials predominate in the upper 150 feet of this sequence with coarser sediments beneath. It is suggested that the eastern part of the site may rest on a pediment surface.

Sand and gravelly deposits underlie the western part of the site. These coarser, gravelly sediments may represent a remnant stream terrace or alluvial fan deposit. The location and nature of the contact between the finer-grained deposits that underlie the site on the east and the more gravelly deposits that underlie the site on the west is not defined.

The different sedimentary facies are interpreted to be fluvial and lacustrine in origin. The clays are described as lacustrine. Attempts during site characterization to correlate specific lithologic units between boreholes were unsuccessful due to the complexity of the stratigraphy beneath the site.

2.4.2 Hydrology

During site characterization, 16 boreholes were drilled to depths of 22 to 125 feet (DOE 1994). Nine of these boreholes were completed as monitor wells.

Information from these 16 boreholes was used to define ground water conditions at the site. The series of gravels, sands, silts, and clays, described above, constitute the uppermost aquifer. This aquifer is referred to in the original LTSP (DOE 1994) as the "lacustrine aquifer," based on the interpretation that the sediments were deposited in or around a large lake, the remnant of which would be the present-day Goose Lake.

During site characterization, depth to the water table ranged from 10 feet along Camp Creek valley west of the site to as much as 75 feet at the southern edge of the site. Silt, silty sand, and clay-rich sediments beneath the disposal cell were unsaturated to a depth of at least 40 feet. More recent measurements suggest that depth to the water table may vary from place to place and be as shallow as 20 feet. This zone of unsaturated sediments provides a natural barrier between the disposal cell and regional ground water.

Ground water flows from northwest to southeast under unconfined to semi-confined conditions (Figure 2–4). Ground water recharge is primarily regional with little or no recharge through soils or unsaturated sediments near the site, although Camp Creek undoubtedly loses some water that may reach the unconfined aquifer. Recharge occurs along silty or sandy layers on or between clay-rich layers.

Discharge is to surface drainages southeast of the site and ultimately to Goose Lake. Ground water may be discharged to irrigation wells downgradient from the site.

2.4.3 Surface Water

Camp Creek flows in the small valley about 3,000 feet west of the site and at an elevation about 50 feet lower. It is a small stream with a catchment above the site of only about 13 square miles. Because of the difference in elevation and small size of the catchment basin, flooding along this creek is not a credible risk to the site.

2.4.4 Water Quality

Water quality at the Lakeview disposal site is described in the site characterization report (DOE 1985b) and in the original LTSP (DOE 1994). Ground water was uncontaminated before the disposal cell was built and it remains uncontaminated.

The LTSM Program monitors ground water on an every-fifth-year basis (Section 3.7). Results of monitoring are in annual reports to NRC on the same every-fifth-year basis (Section 3.3.5). The LTSM Program began monitoring in 1999, five years after the disposal site was licensed. The first report to include results of ground water monitoring was the 1999 annual report (DOE 2000a).

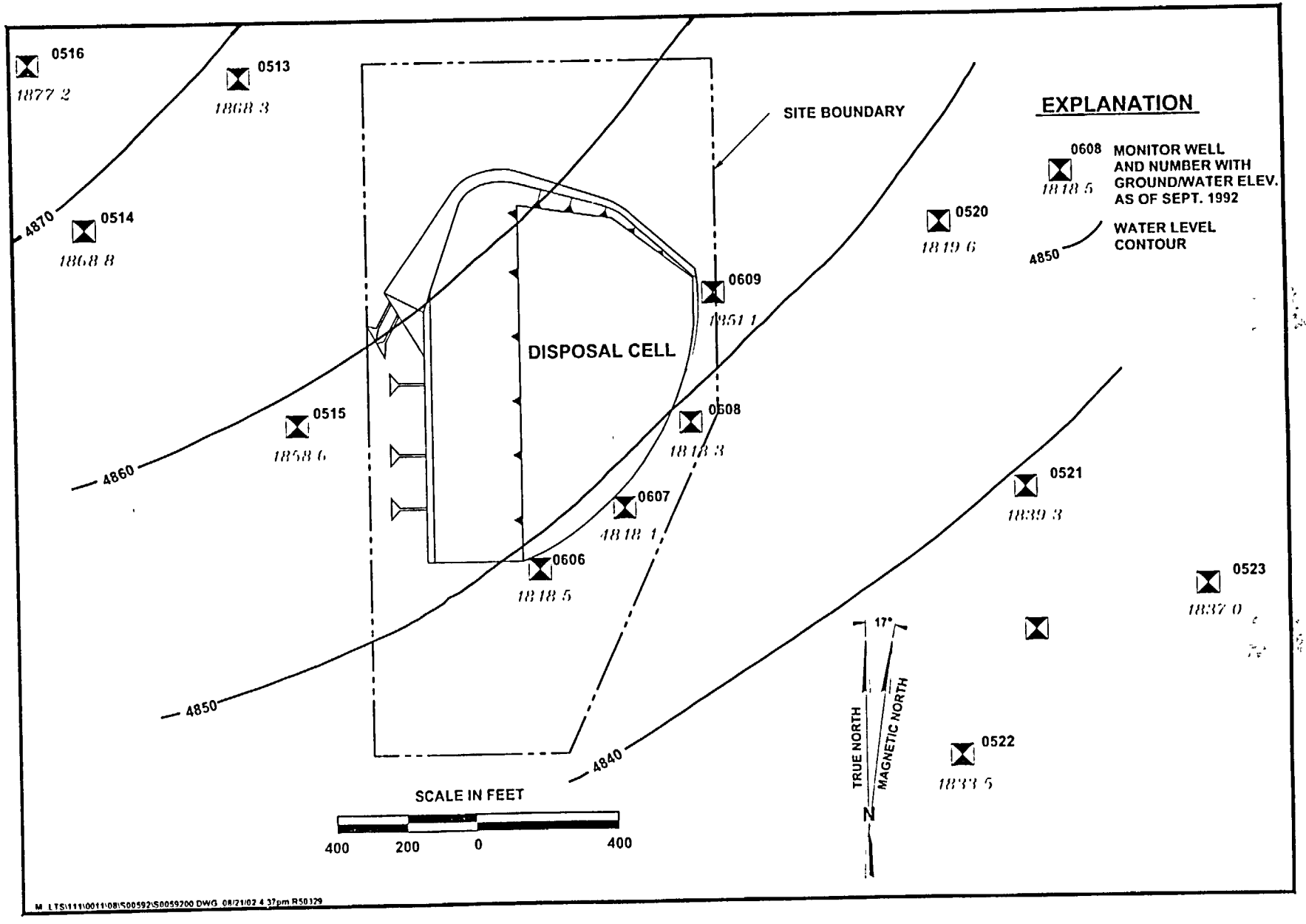


Figure 2-4. Potentiometric Surface and Monitor Wells, Lakeview, Oregon, Disposal Site, September 1992

End of current text

3.0 Long-Term Surveillance Program

3.1 General License for Long-Term Custody

With NRC concurrence in the original LTSP (DOE 1994 and Appendix F), the site was included under the general license for long-term custody [10 CFR 40.27(b)].

Although sites remediated under UMTRCA are designed and constructed to last "for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years" [40 CFR 192, Subpart A, 192.02(a)], there is no termination of the general license for DOE's long-term custody of these sites [10 CFR 40.27(b)].

When DOE determines that revision of the LTSP is necessary, DOE will notify NRC. Changes to the LTSP may not conflict with the requirements of the general license (Section 3.2).

Additionally, DOE must guarantee NRC permanent right-of-entry to the site so that NRC may conduct site inspections. Access to the Lakeview site is described in Section 2.3.2.

3.2 Requirements of the General License

Requirements of the general license are at 10 CFR 40.27 and 10 CFR 40, Appendix A, Criterion 12. The requirements of the general license and the sections in this LTSP where each is addressed are listed in Table 3–1.

Table 3–1. Requirements of the General License and DOE Response

Requirement	Response, This LTSP
1 Annual site inspection	Section 3 3
2. Annual inspection report	Section 3 3 5
3. Follow-up inspections and follow-up inspection reports, as necessary	Section 3 4
4 Site maintenance, as necessary	Section 3.5
5 Emergency measures in the event of catastrophe	Section 3 6
6 Environmental monitoring, if required.	Section 3 7

3.3 Annual Site Inspection

3.3.1 Frequency of Inspection

At a minimum, sites must be inspected annually to confirm the integrity of visible features at the site and to determine the need, if any, for maintenance, additional inspections, or monitoring (10 CFR 40, Appendix A, Criterion 12).

To meet the inspection requirement, DOE will inspect the site once each calendar year. The date of the inspection may vary from year to year, but DOE will endeavor to inspect the site once every 12 months unless circumstances warrant variance. The variance will be explained in the inspection report. DOE will notify NRC of the annual inspection at least 30 days in advance.

3.3.2 Inspection Procedure

To ensure a thorough and uniform inspection, the site is divided into areas called transects. Transects for the inspection of the Lakeview site are listed in Table 3–2 and shown in Figure 3–1.

Table 3–2. Transects Used During Inspection of the Lakeview Disposal Site

Transect	Description
Top of disposal cell	Relatively flat area on top of the disposal cell covered by the rock-soil matrix
Side slope of disposal cell and associated drainage structures	Includes: 1 Rip-rap covered side slope of the disposal cell. 2 Gradation tests on side slope riprap (Appendix D). 3. North drainage channel and EDA. 4. Re-photography of selected large diameter rocks in the EDA. 5. Trench drains along the west side of the disposal cell.
Area between disposal cell and site boundary including stock fence	Remainder of the site. Includes: 1. Site boundary, fence, and perimeter signs. 2. On-site areas disturbed during remedial action and subsequently regraded and vegetated. 3. On-site areas undisturbed and naturally vegetated
Outlying area	Area within 0.25 mile of the site boundary

Each transect inside the site is visually inspected during a walk-over. Within each transect, inspectors examine specific site surveillance features, such as survey and boundary monuments, signs, site markers, and other features listed in Sections 2.3.5 and 3.3.3 and in the Checklist (Appendix C). Inspectors also examine each transect for maintenance requirements, success of previous maintenance, and for erosion, settling, slumping, plant or animal encroachment, human intrusion or vandalism, and other activity or phenomenon that might affect the safety, integrity, long-term performance, or institutional control of the site.

Inspectors will note changes within 0.25 mile of the site. Changes that might be significant include new development, changes in land use, and erosion or instability of slopes around the site.

Inspectors will use photographs, as necessary, to support or supplement written observations.

The tendency of some of the rock in the riprap on the side slope to break was first noted by inspectors during a pre-licensing site inspection in 1995. The breakage is due to natural weathering processes. Subsequently, a procedure was developed to measure changes in the median or D_{50} size of the riprap over time (Appendix D). This procedure (gradation testing) was implemented in 1997 and is repeated annually, usually during the annual site inspection. Results of gradation testing will be in the annual report to NRC (Section 3.3.5).

3.3.3 Inspection Checklist

Inspectors are briefed, and the inspection checklist is reviewed before the annual inspection. A sample checklist is provided in Appendix C. The checklist includes:

- Specific site surveillance features to be inspected
- Routine observations to be made
- Special issues or problems to be observed and evaluated

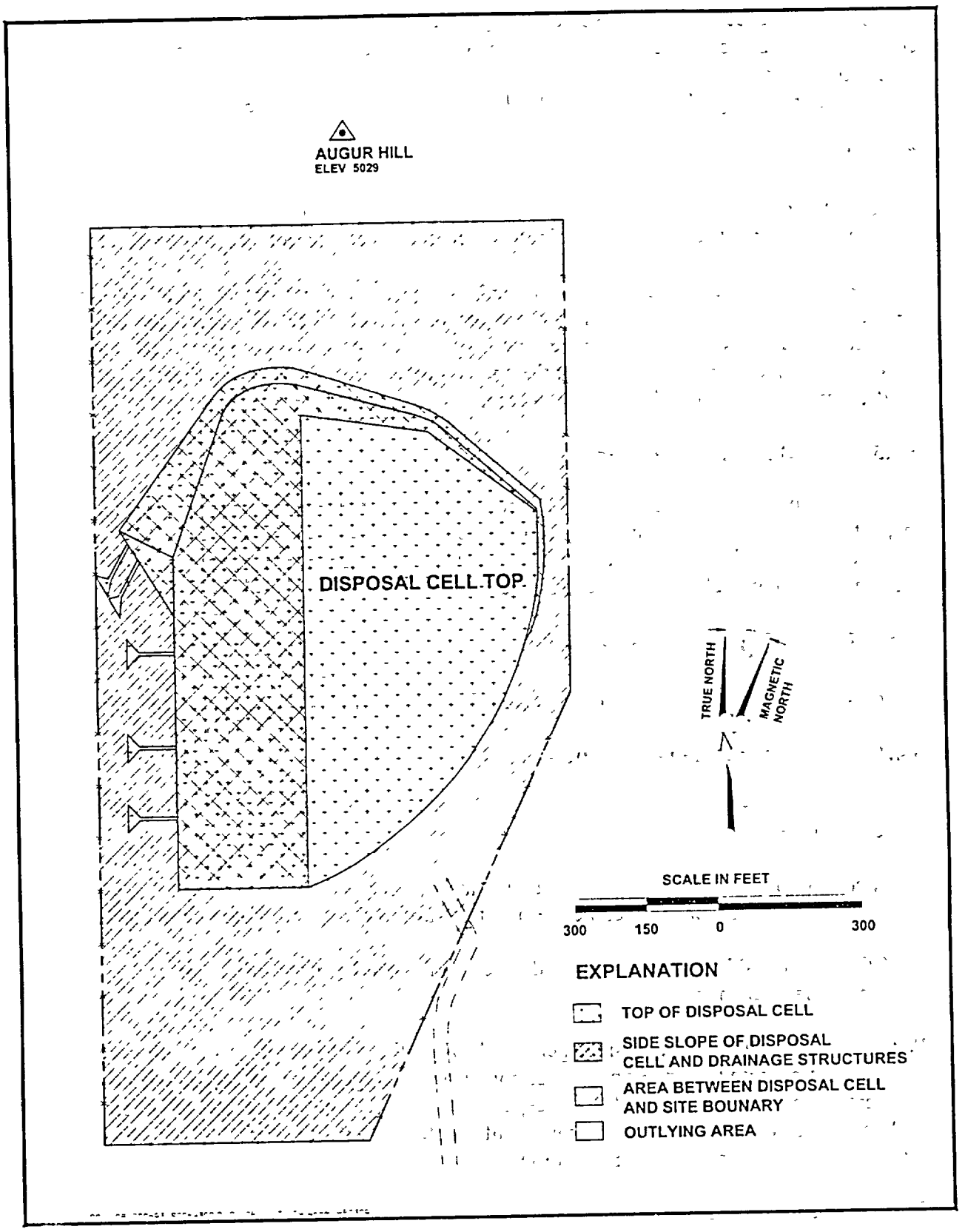


Figure 3–1. Transects Used During Inspection of the Lakeview, Oregon, Disposal Site

The inspection checklist is reviewed annually and, if necessary, revised to reflect changes or new conditions at the site. The checklist is accompanied by a copy of the Project Safety Plan (DOE 2001). This plan includes general and site-specific health and safety requirements for the inspection, including a list of local medical and emergency services (Section 3.10).

3.3.4 Personnel

A team of two or more inspectors performs annual inspections. Inspectors are trained and experienced scientists and engineers. Training includes participation in previous site inspections.

Engineers will typically be civil, geotechnical, or geological engineers. Scientists will typically be geologists, hydrologists, biologists, or environmental scientists. The inspection team will be selected on the basis of skills and experience appropriate to the issues or concerns at the site. If serious or unique problems develop at the site, additional inspectors, specialized in specific fields, may be assigned to the inspection team.

3.3.5 Annual Inspection Report

Results of the annual inspection will be reported to NRC within 90 days of the last Title I site inspection in the calendar year (10 CFR 40, Appendix A, Criterion 12). In the event that the report cannot be submitted in accordance with 10 CFR 40, DOE will notify NRC. Annual reports are available to the public and other agencies.

3.4 Follow-Up Inspections

Follow-up inspections are in response to significantly new or changed conditions at the site.

3.4.1 Criteria for Follow-Up Inspections

Criteria for follow-up inspections are at 10 CFR 40.27(b)(4). DOE will conduct a follow-up inspection when:

1. A condition is identified during the annual inspection (or other site visit) that requires personnel, perhaps with special expertise, to return to the site to evaluate the condition.

2. DOE is notified by a citizen or outside agency that conditions at the site are substantially changed.

With respect to citizens and outside agencies, DOE will establish and maintain lines of communication with Collins Ranch, local police, and emergency response agencies to facilitate notification in the event of significant trespass, vandalism, or natural disaster. These agencies will be requested to notify DOE or provide information should a significant event occur that might affect the security or integrity of the site.

DOE may request the assistance of local agencies to confirm the seriousness of a condition before conducting a follow-up inspection or emergency response.

The public may use the 24-hour DOE telephone number posted prominently on the entrance sign to request information or to report a problem at the site (Section 2.3.5).

Once a new or changed condition is identified, DOE will evaluate the information and determine whether a follow-up inspection is warranted. Conditions that may require a routine follow-up inspection include changes in vegetation, erosion, storm damage, low-impact human intrusion, minor vandalism, or the need to evaluate, design, or perform maintenance projects.

Conditions that threaten the safety of the site or the integrity of the disposal cell may require a more urgent follow-up inspection. Slope failure, disastrous storm, major seismic event, and deliberate human intrusion are among these conditions.

DOE will use a graded approach with respect to follow-up inspections. Urgency will be proportional to the potential seriousness of the condition. For example, a follow-up inspection to investigate vegetation may be postponed until a particular time during the growing season. A follow-up inspection to evaluate erosion may be scheduled to avoid snow cover.

In the event of "unusual damage or disruption" (10 CFR 40, Appendix A, Criterion 12), damage that may compromise or threaten the safety, security, or integrity of the site, DOE will

- Notify NRC pursuant to 10 CFR 40, Appendix A, Criterion 12, or 10 CFR 40.60, whichever is determined to apply;
- Begin DOE's internal occurrence notification process (DOE Order 232.1A);
- Respond with an immediate follow-up inspection or emergency response team;
- Implement emergency measures, as necessary, to prevent or contain exposure or excursion of radioactive materials (Section 3.6).

3.4.2 Personnel

DOE will assign inspectors to follow-up inspections on the same basis as the annual site inspection (see Section 3.4).

3.4.3 Reports

Results of routine follow-up inspections will be included in the annual inspection report to NRC (Section 3.3.5). Separate reports will not be issued unless DOE determines that is it advisable to notify NRC and other agencies of a potentially serious problem at the site.

If follow-up inspections are required for more urgent reasons, DOE will submit a preliminary report of the follow-up inspection to NRC within the 60-day period required by 10 CFR 40, Appendix A, Criterion 12.

3.5 Site Maintenance

Sites remediated under UMTRCA are designed and constructed so that "ongoing active maintenance is not necessary to preserve isolation" of radioactive material (10 CFR 40, Appendix A, Criterion 12). No recurrent "active" maintenance is required at the Lakeview site, although minor repairs are needed from time to time.

Minor maintenance required in the past and likely to be required in the future includes repair of broken wires in the fence and replacement of perimeter signs. In 2000, small gullies downslope from the trench drains were filled with rock to prevent further erosion. Should continued gradation tests (Section 3.2.2 and Appendix D) and subsequent risk assessment indicate that the riprap on the side slope no longer meets design objectives, a large-scale repair may be required.

Routine maintenance completed during the previous 12 months will be summarized in the annual inspection report (Section 3.3.5).

3.6 Emergency Response

Emergency response is action DOE will take in response to "unusual damage or disruption" that threatens or compromises site safety, security, or integrity (10 CFR 40, Appendix A, Criterion 12).

3.6.1 Criteria for Emergency Response

Conceptually, there is a continuum in the progression from small-scale, minor, routine maintenance (Section 3.4) to large-scale intervention that might include reconstruction of the disposal cell following an unlikely disaster. Although required by 10 CFR 40.27(b)(5), criteria for initiating specific responses to progressively more serious problems are not easily established because the spectrum and scale of all potential problems is unforeseeable. The information in Table 3–3 is a guide to the actions DOE may make in response to increasingly serious problems.

Table 3–3. Criteria for Emergency Response

Priority	Event	Example	DOE Response
1 Urgent	Breach of containment with excursion of contaminated materials	Side slope of disposal cell fails, radioactive materials are dispersed	1. Notify NRC 2. Conduct immediate follow-up inspection by DOE emergency response team 3 Recover radioactive materials. 4 Repair side slope
2	Breach of containment without excursion of contaminated materials.	Side slope of disposal cell fails, or failure is imminent. Radioactive materials are not dispersed	1 Notify NRC 2 Conduct immediate follow-up inspection by DOE emergency response team. 3 Repair side slope.
3	Cover materials no longer meet design specifications.	Riprap on side slope continues to weather and no longer meets design objectives.	1. Perform risk assessment 2. If risk unacceptable, design for repair. 3. Complete repair
4[a]	Breach of site security with or without excavation or removal of materials.	Willful human intrusion or significant vandalism	Restore security Harden security as necessary
5 Routine	Minor problems, small-scale changes.	Minor vandalism, fence repairs, undesirable changes in vegetation.	Routine maintenance

[a]Priority is highly dependent upon scale and on-site evaluation

The table shows that the difference between routine maintenance and various emergency responses is primarily one of risk or urgency. Priorities are listed in the table in inverse order relative to the probability of occurrence of the problem. The highest priority responses are the least likely to be required.

3.6.2 Notification

In accordance with 10 CFR 40.60, DOE will notify:

Uranium Recovery and Low-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission

within 4 hours of discovery of a Priority 1 or 2 event in Table 3–3. The telephone number for the NRC Operations Center is: 301-816-5100.

3.6.3 Procedure for Emergency Response

In the event of a Priority 1 or 2 event, an emergency response team will assess the damage and decide whether evaluation of the problem is required or if immediate intervention (additional remedial action) is essential. This decision will be based on the emergency team's evaluation of the adequacy of the damaged feature to perform its intended function.

To make this decision, the emergency response team will assess and evaluate the following. The evaluation may include risk analysis.

1. Adequacy of the design specification(s) for the damaged feature to control or accommodate the observed problem(s).
2. Extent of the damage, degradation, or departure from the design (or as-built condition) of the damaged feature.
3. Ability of the feature, in its damaged condition, to withstand a design-basis event.

DOE will provide NRC with a clear, technical explanation for its decision to study and evaluate or intervene with additional remedial action (DOE 2000b).

3.7 Environmental Monitoring

Ground water monitoring is the only monitoring required at the Lakeview site.

3.7.1 Ground Water Monitoring

As a best management practice, DOE will monitor ground water at the Lakeview site for a period of time to demonstrate that the initial performance of the disposal cell meets design requirements.

Monitoring, as established by the initial LTSP (DOE 1994), will be every 5 years at 1 upgradient and 8 downgradient monitor wells (Table 3–4 and Figure 2–3). The downgradient wells are approximately 50 feet downgradient from the edge of the disposal cell to provide early detection should the disposal cell no longer perform as an effective containment system. The downgradient wells are in four pairs. In each pair, one well is screened at shallow depth (approximately 100 feet) and one deeper (approximately 150 feet). The upgradient well, MW–0515, is screened at approximately 100 feet, and is used as a reference and to detect changes in regional (upgradient) ground water chemistry.

Table 3–4. Ground Water Sampling Locations at the Lakeview, Oregon, Disposal Site

Well	Location	Screened Depth, feet
MW–0602	Downgradient	100
MW–0609	Downgradient	150
MW–0603	Downgradient	100
MW–0608	Downgradient	150
MW–0604	Downgradient	100
MW–0607	Downgradient	150
MW–0605	Downgradient	100
MW–0606	Downgradient	150

When the wells are sampled, water levels will be measured to detect changes that may occur as a result of long-term weather patterns.

Samples will be analyzed for standard water quality indicators, field parameters, and three specific analytes: arsenic, cadmium, and uranium.

After every 5-year monitoring event, results will be evaluated and the frequency of monitoring may be modified. When DOE determines that further monitoring is no longer required, this LTSP will be revised (Section 3.1) and all wells will be decommissioned in accordance with state ground water protection requirements.

Ground water was extensively studied during site characterization. Data from site characterization is summarized in the initial LTSP (DOE 1994). Ground water in the uppermost aquifer is characterized as calcium-bicarbonate type. Total dissolved solids (TDS) range from 92 to 252 milligrams per liter (mg/L), pH from 5.83 to 8.24, and the Eh is generally oxidizing.

In 1995, the Environmental Protection Agency (EPA) established ground water standards for potential contaminants associated with uranium mill tailings. These standards, or maximum concentration limits (MCLs), are at 40 CFR 192.04.

Results from site characterization showed that background ground water at the Lakeview disposal site is uncontaminated with respect to contaminants with MCLs, although arsenic and selenium did barely exceed their respective MCL on at least one occasion (DOE 1994). In all

other instances, the concentration of potential contaminants with MCLs is below the MCL value, and in most cases below laboratory detection limits, in background ground water samples.

Pore fluids from the mill tailings also were characterized during remedial action. Pore fluids represent a possible worst-case leachate that might escape from the disposal cell. Of the 13 constituents measured in the pore fluids, each with an MCL, mean values for three exceeded their respective MCL: arsenic, cadmium, and uranium. These three constituents are therefore target analytes for evaluating the initial performance of the disposal cell. Results of monitoring for these three constituents since the disposal cell was closed in 1989 are presented in Table 3–5.

Table 3–5. Results of Monitoring for Target Analytes, Lakeview, Oregon, Disposal Site, 1989–1999

Well	Location	Arsenic MCL = 0.05[a]	Cadmium MCL = 0.01[a]	Uranium MCL = 0.044[a]
MW–0515	Upgradient	0 01 U[2] – 0.011	0.001 U[b] – 0 001	0 001U[b] – 0 001
MW–0602	Downgradient, shallow	Dry well, no results	Dry well, no results	Dry well, no results
MW–0603	Downgradient, shallow	Dry well, no results	Dry well, no results	Dry well, no results
MW–0604	Downgradient, shallow	Dry well, no results	Dry well, no results	Dry well, no results
MW–0605	Downgradient, shallow	Dry well, no results	Dry well, no results	Dry well, no results
MW–0606	Downgradient, deep	0 0143 – 0 02	0 001 U	0.001 U – 0 003
MW–0607	Downgradient, deep	0 0072 – 0.014	0.001 U	0.001 U – 0 003
MW–0608	Downgradient, deep	0 01 U – 0 007	0 001 U	0 001 U – 0 003
MW–0609	Downgradient, deep	0.01 U – 0.001	0.001 U	0.001 U – 0.001

[a]All results in milligrams per liter, mg/L
[b]U = Below laboratory detection limit

Results over the 10-year period since closure of the disposal cell, 1989–1999, show no significant differences between upgradient and downgradient wells. All results are near or below laboratory detection limits.

3.7.2 Reports of Ground Water Monitoring

Results of future ground water monitoring will be in the annual report to NRC (Section 3.3.5). Results of each 5-year evaluation of the monitoring will be in the annual report or reported separately.

3.8 Records

The LTSM Program maintains select site records at the GJO facility. These records have been chosen because they contain critical information needed to ensure the continued management and the follow-on actions and controls (including property management) required to protect public health and the environment and to demonstrate compliance with applicable legal requirements. This stewardship record collection does not include information pertaining to employee and/or public health and safety considerations with respect to former site operations. (Note: The DOE Albuquerque Operations Office is responsible for personnel inquiries for staff working on the DOE remediation of the site.)

The stewardship collection is indexed and integrated into the LTSM Program files and databases. The records and select site-specific references at the GJO are managed using the GJO records system, and geographical and environmental data is managed using a separate electronic database. Refer to the LTSM Working File Index for guidance on management of the collection.

Access and Retrieval—The records at the GJO are available to the LTSM site steward as well as all stakeholders. Key site documents (e.g., closure reports, environmental assessments, fact sheets, records of decision, inspections, and long-term surveillance plans) and site mapping/environmental data (e.g., boundaries, structures, and wells) are viewable from the LTSM website.

Pre-Stewardship Record Collection—The pre-stewardship collection created during site remediation (known as the AL UMTRA Surface Collection) was created and managed by the DOE Albuquerque Operations Office. Select portions of the AL UMTRA Surface Collection were transferred to the GJO for continued use by the LTSM site steward, and the remainder of the collection was transferred to the Rocky Mountain region of the national archives and federal records center in Denver, Colorado.

The Rocky Mountain region of national archives and federal records center in Denver, Colorado, is currently the designated archive facility for the Lakeview site records created during remediation and long-term stewardship of the site. To facilitate retrieval of records after site operations cease and because the greatest repository of site knowledge rests with the site steward, the LTSM Program will obtain copies of the of box and file indices (as available) and Records Transmittal and Receipt forms (SF 135) for the site. These indices and the SF 135s will be retained with the site stewardship collection.

Currently permission to access those site documents which reside in the federal records center must be obtained from the DOE Albuquerque Operations Office. The LTSM Program will work with the DOE Albuquerque Operations Office to ensure that the LTSM site steward is included in the concurrence for the destruction of any temporary records.

Regulatory Requirements—LTSM Program records are maintained in full compliance with DOE requirements:

1. DOE Order 200.1, Information Management Program
2. 36 CFR Parts 1220-1236, National Archives and Records Administration

3.9 Quality Assurance

The long-term care of the Lakeview site and all activities related to the annual surveillance, monitoring, and maintenance of the site comply with DOE Order 414.1A, Quality Assurance (QA) and ANSI/ASQC E4-1994, *Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs* (American Society for Quality Control 1994).

QA requirements are transmitted to subcontractors through procurement documents if and when appropriate.

3.10 Health and Safety

LTSM activities are conducted in accordance with health and safety procedures established for the LTSM Program and are consistent with DOE orders, regulations, codes, and standards.

Health and safety concerns specific to work at the Lakeview site are in the *Long-Term Surveillance and Maintenance Program Project Safety Plan* (DOE 2001). This plan contains a list of emergency telephone numbers and addresses for local fire, hospital, ambulance, and police or sheriff agencies, as well as a map to the nearest emergency medical facility. Personnel are briefed on health and safety requirements during a pre-inspection meeting.

Maintenance subcontractors are advised of health and safety requirements through appropriate procurement documents. Subcontractors must develop health and safety plans for all activities subject to Occupational Safety and Health Administration (OSHA) requirements. Subcontractor health and safety plans are reviewed and approved before contracts are awarded.

End of current text

4.0 References

10 *Code of Federal Regulations* (CFR) 40. Appendix A, Criterion 12. "Long-Term Site Surveillance."

10 CFR 40 Section 27. "General License for Custody and Long-Term Care of Residual Radioactive Material Disposal Sites."

40 CFR 192.02(a). "Standards."

40 CFR 192.04. "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, Corrective Action: Maximum Concentration of Constituents for Groundwater Protection."

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———, 2001. *Long-Term Surveillance and Maintenance Program Project Safety Plan*, GJO-2001-213-TAR, MAC-LEHS 2.1, prepared by the U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado, April.

Appendix A

Real Estate Documentation for Disposal Site and Access Corridor

Acquisition

The Lakeview disposal site, near Lakeview, Oregon, was acquired by the state of Oregon through a civil action suit, Lake County Circuit Case No. L-86-060-CV, File No. 330-050-TL001-86, state of Oregon, by and through the Energy Facility Siting Counsel v. John Collins, et al. The U.S. Army Corps of Engineers worked with the state of Oregon to transfer the disposal site and access easement to the Federal government, thus completing the real estate transactions. Final disposition of the case provided a 40-acre parcel with perpetual access leading west from County Road 2-16B across the Collins Ranch to the disposal site, as well as unlimited access to all off-site ground water monitoring wells.

Legal Description

Disposal site. The Lakeview disposal site is located on a 40-acre parcel of land in Sections 11 and 12, Township 38 South (T38S), Range 19 East (R19E), Willamette Meridian, Lake County, Oregon, and is more particularly described as,

> Beginning at a point on the east line of Section 11, T38S, R19E, said point of beginning bears north 00° 17'25" east 816.36 feet (ft) from the southeast corner of Section 11; thence west 211.02 ft; thence north 1950.00 ft; thence east 220.90 ft to the east line of Section 11, T38S, R19E; thence continuing in Section 12, T38S, R19E, east 779.10 ft; thence south 1000.00 ft; thence south 24° 42' 18" west 1045.71 ft; thence west 351.93 ft to the point of beginning.

Access road. A strip of land 60-feet wide, located in Section 12, T38S, R19E, Willamette Meridian, Lake County Oregon, provides perpetual easement to the site. The centerline of this easement is more particularly described as,

> Beginning at a point on the west right-of-way line of County Road 2-16B, said point of beginning bears north 00°10'19" east 30.00 ft; thence north 89°37'12" west 30.00 feet from the southeast section corner of Section 12; thence north 89°37'34" west 2638.25 ft to a point that bears north 00°22' 26" east 30.00 feet from the south 1/4 corner of Section 12; thence north 89°3'06" west 1449.65 feet; thence north 86°29'18" west 379.15 ft; thence along a 250.00-foot-radius curve to the right 330.71 ft; thence north 10°41'45" west 359.83 ft; thence north 3°20'24" west 380.92 ft; thence north 00°45'38" east 55.27 ft; thence north 8°40'28" east 40.01 ft; thence north 18°16'10" east 82.69 ft; thence north 11°18'58" east 41.38 ft; thence north 1°03'53" west 24.99 ft to the east boundary of the Lakeview disposal site, said point bears north 23°57'25" east 1356.57 ft from the southwest corner of said Section 12.

The basis of bearings for the foregoing descriptions is the Oregon state plane coordinate system, south zone.

Repository

The deed transferring the Lakeview disposal site to the Federal government was recorded on July 12, 1995, in Lake County, Oregon, in File Book 229, page 642 (DOE 1994).

Documentation and correspondence related to property acquisition are on file at the U.S. Department of Energy, Grand Junction Office, 2597 B ¾ Road, Grand Junction, Colorado 81503.

Appendix B

Sample Field Photograph Log

Field Photograph Log

Site:_____ Roll No __ (of __)

Date:_____ Purpose of Visit_____

Frame	Azimuth	PL-Number	Subject/Description
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			

Remarks:

Inspector/Photographer: _____

End of current text

Appendix C

Inspection Checklist

Inspection Checklist: Lakeview

Date of This Revision: _____
Last Annual Inspection: _____
Inspectors: _____ and _____

Next Annual Inspection (Planned): _____

N.B.: Action items 4 and 5 may require extended time on site.

No.	Item	Issue	Action
1	Access	Contact Collins Ranch by phone (or mail) before the inspection.	Current contact: John Collins P.O Box 127 Trail, Oregon 97541 Telephone: 541-878-7327
2	Specific site surveillance features	See attached list	Inspect Identify maintenance requirements. Stock fence often requires repair (broken wire, etc.)
3	Monitor wells	There are 9 monitor wells in the LTSM monitoring network. There are an additional 7 unused wells earmarked for decommissioning.	Inspect the 9 LTSM monitor wells each year. Also inspect the seven additional wells that are no longer monitored until they are decommissioned
4	Vegetation	The Long-Term Performance (LTP) Project is investigating the long-term effect of deep-rooted plants on top of the disposal cell	Inspectors may be asked to make observations during the inspection to support the LTP Project. In future, measures to control vegetation may be required.
5	Rock Durability	LTSP requires annual gradation tests to determine D_{50} of the riprap on the side slope Eighteen (18) numbered boulders in the north drainage channel and EDA are monitored by rephotography	Repeat gradation test Use procedure in Appendix D Repeat rephotography
6	Erosion Below Trench Drains	Gullies downslope from the trench drains were filled with rock in 2000 to prevent further erosion	Evaluate success of the repair.

Checklist of Site Specific Surveillance Features: Lakeview

Feature	Comment
Access Road	DOE lock on cable gate
Entrance Gate	
Entrance Sign	
Perimeter Signs	Total: 12
Perimeter Fence	Barbed-wire stock fence
Survey Monuments	Total: 3. SM-3 is inside site boundary south of disposal cell
Boundary Monuments	Total: 3
Site Markers	Total: 2
Monitor Wells	Upgradient (background) MW-0515: On Collins property, west of P-8 Downgradient wells, in pairs, along east side of disposal cell, from north to south MW–0602 and –0609 MW–0603 and –0608 MW–0604 and –0607 MW–0605 and –0606 Wells no longer monitored. MW–0513 Northwest of disposal site MW–0514 Northwest of disposal site MW–0516 Northwest of disposal site MW–0520 East of disposal site MW–0521 East of disposal site MW–0522 East of disposal site MW–0523

Appendix D

Gradation Testing Procedure

Lakeview Riprap Gradation Testing Procedure

Equipment needed:

- 8-inch diameter sieve stack including: 4-inch opening, 3-inch opening, 2½-inch opening, and 1½-inch opening.
- 2-foot by 2-foot wire mesh with 25 equally spaced intersections at 4-inch centers.
- white paint with ¼-inch wide brush.

1) Determine 10 random locations systematically distributed across the west face. All distances are measured in feet from the top of the side slope on the south end of the disposal cell.
   - determine 10 pairs of random numbers between 0.0 and 1.0.
   - the first number of the pair is the longitudinal number (x), the second is the transverse number (y); enter numbers into the following table and perform the computations indicated. For example; to determine the location of sample number (3), multiply the first random number, (x) by 100 and add 200 to the product, and multiply the second random number, (y) by 270. Enter these results in the table columns on the far right.

Sample Locations for Stone Dimension Determination

Sample Number	Random Number Pairs (x,y)		Multiplier		Sample Locations	
	Longitudinal (x)	Transverse (y)	Longitudinal (ft)	Transverse (ft)	Longitudinal Distance From South End (ft)	Transverse Distance From Top Slope (ft)
1			100x	270y		
2			100x + 100	270y		
3			100x + 200	270y		
4			100x + 300	270y		
5			100x + 400	270y		
6			100x + 500	270y		
7			100x + 600	270y		
8			100x + 700	255y		
9			100x + 800	215y		
10			100x + 900	130y		

2) Locate each sample location on the side slope with a wire flag.

3) Place the wire mesh at the sample location. Orient the mesh perpendicular to the slope with the southwest corner adjacent to the wire flag.

4) Paint a white dot on each stone lying directly beneath a wire intersection.

5) Remove the mesh, and pass each marked stone through the sieve stack until the stone is retained on a sieve.

6) Record the number of stones retained on each sieve on a copy of the attached form, verify that the total number of stones equals 25.

7) Replace sampled stones within the 2-foot by 2-foot sample location.

Data reduction procedure

At each sample location determine the stone size corresponding to the sample point D_{50} according to the following procedure:

1) Determine the percent retained on each of the three sieves using equation (1):

$$R_i = \frac{N_i}{A} \times 100$$

where: R_i = percent retained on sieve i,
N_i = number of stones retained on sieve i,
A = total number of stones sampled (25),
i = sieve size, i.e. 4-inch, 2½-inch, and 1½-inch.

For example, when 5 stones are retained in the 4-inch sieve:

$$R_{4\text{-}inch} = \frac{5}{25} \times 100 = 20\%$$

2) Determine the percent passing each sieve size by subtracting the sum of percentages retained from 100 as shown in equation (2):

$$P_i = (100 - \Sigma R_i)$$

where: P_i = percent passing sieve i.

For example:

when $R_{4\text{-}inch} = 30\%$ and $R_{3\text{-}inch} = 35\%$:

$$P_{3\text{-}inch} = 100 - (30 + 35) = 35\%$$

3) Determine D_{50} as the size where 50 percent of the stones are smaller. Compute D_{50} by linear interpolation (proportioning). The following equation illustrates this process:

$$D_{50} = S_{i+} - \frac{(P_{i+} - 50) x (S_{i+} - S_{i-})}{(P_{i+} - P_{i-})}$$

where: D_{50} (inch) = size for which 50 percent of the stones are smaller.
S_{i+} (inch)= sieve size that more than 50 percent passes,
S_{i-} (inch) = sieve size that less than 50 percent passes,
P_{i+} = percentage passing greater than 50,
P_{i-} = percentage passing less than 50.

For example:

when $P_{3\text{-}inch}$ = 70%, $P_{2\frac{1}{2}\text{-}inch}$ = 35%, S_{i+} = 3-inch, and S_{i-} = 2½-inch;

$$D_{50}(inch) = 3 - inch - \frac{(70-50)x(3 - inch - 21/2 - inch)}{(70-35)} = 2.7\,inch$$

4) Determine and report the mean ($\bar{x}$) of the in situ slope D_{50} using data collected from all ten sample locations using equation (4):

$$\bar{x} = \frac{\sum_{j=1}^{10} x_j}{10}$$

where: $\bar{x}$ = mean in situ slope D_{50},
x = computed sample location D_{50},
j = sample location counter from 1 to 10.

Lakeview, Oregon
Type-B Riprap Gradation Monitoring

Sample Location Number	Number of Stones Retained			
	4-inch	22-inch	12-inch	Total
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Appendix E

Agency Notification Agreements

Department of Energy
Albuquerque Field Office
P.O. Box 5400
Albuquerque, New Mexico 87185-5400

Albert R. Chernoff
UMTRA Project Manager
U.S. Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, NM 87185-5400

Dear Mr. Chernoff:

This letter is in response to the U.S. Department of Energy (DOE) request for notification as set forth in the DOE's letter. This office will contact the DOE Grand Junction Projects Office at (303) 248-6070 if flash flood or tornado warnings are issued for Lake County, Oregon.

Sincerely,

Mr. Mike Brooks
National Weather Service Office

MIS/UMT/0892-0044

Albert R. Chernoff

UMTRA Project Manager

U.S. Department of Energy

Uranium Mill Tailings Remedial Action

Project Office

5301 Central Avenue, N.E., Suite 1720

Albuquerque, New Mexico 87108

Attention. Steve Hamp

Dear Mr. Chernoff.

This letter is to concur with U.S. Department of Energy (DOE) request for notification as set forth in the DOE's letter of 8-13, 1992. As requested in your letter, this office will contact the DOE's Grand Junction Projects Office at (303) 248-6070 if any unusual event or anomaly is observed or reported at the Lakeview disposal site.

Sincerely,

Name

Sheriff

Title

Lake County Sheriff's Department

513 Center Street

Lake County Courthouse

Lakeview, OR 97630

Enclosures

cc: CJones, GJPO

JVirgona, GJPO

SHamp, UMTRA

FBosiljevac

MDay, TAC

MBLeaf, TAC

MIS.|UMT|OU94|0023

no USGS letter head
undated, but logged in 6/15/94

Clinton C. Smythe
Engineering and Construction Group Leader
Uranium Mill Tailings Remedial Action
Project Office
2155 Louisiana NE, Suite 4,000
Albuquerque, NM 87110

Dear Mr. Smythe:

This letter is to confirm that the DOE Grand Junction Projects Office (24-hour phone line, (303) 248-6070 has been added to our notification list for the occurrence of earthquakes near the following locations:

Disposal Site	Latitude	Longitude
COLORADO		
Durango (Bodo Canyon)	N37.15	W107.90
Grand Junction	N38.91	W108.32
Gunnison (Landfill)	N38.51	W106.85
Maybell	N40.55	W107.99
Naturita (Dry Flats)	N38.21	W108.60
Rifle (Estes Gulch)	N39.60	W107.82
Slick Rock (Burro Canyon)	N38.05	W108.87
IDAHO		
Lowman	N44.16	W115.61
NEW MEXICO		
Ambrosia Lake	N35.41	W107.80
NORTH DAKOTA		
Bowman	N46.23	W103.55
OREGON		
Lakeview (Collins Ranch)	N42.2	W120.3
PENNSYLVANIA		
Canonsburg	N40.26	W80.25
Burrell VP	N40.62	W79.65
TEXAS		
Falls City	N28.91	W98.13
UTAH		
Mexican Hat	N37.10	W109.85
Salt Lake City (Clive)	N40.69	W113.11

We have entered the following selection criteria into our notification program:

1. Any earthquake of magnitude 3.0 or greater, within 0.3 degrees (about 20 miles) of any site shown above, or

2. Any earthquake of magnitude 5.0 or greater, within 1.0 degrees (about 70 miles) of any site shown above.

Sincerely,

Bruce W. Presgrave

Bruce Presgrave
U.S. Geological Survey
National Earthquake Information Center
P.O. Box 25046
Mail Stop 967
Denver Federal Center
Denver, Colorado 80225

Please address future correspondence to Stuart Koyanagi at the above address. I have moved to a different project.

Thank you + best regards,

Bruce Presgrave

Appendix F

Certification and Concurrence Documents

NRC/UMT/0993-0044

UNITED STATES

NUCLEAR REGULATORY COMMISSION

REGION IV

URANIUM RECOVERY FIELD OFFICE
BOX 25325
DENVER, COLORADO 80225

SEP 01 1993

LTSM000740

Docket No. WM-64

LLRV 21.3.5

U.S. Department of Energy
Albuquerque Operations Office
ATTN: Albert R. Chernoff
Project Manager
P.O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. Chernoff:

We have completed our review of the certification data for the uranium mill tailings site at Lakeview, Oregon. The data reviewed were the Final Completion Report, the Final Audit Report, and all other associated documentation pertinent to the completed remedial action at Lakeview. The results of our review are documented in the enclosed Final Completion Review Report.

Based on our review of the certification data and on observations and record checks made during periodic site visits, we concur that, with the exception of ground-water restoration, the Department of Energy (DOE) has completed the remedial action in accordance with the approved plans and specifications, and that this action complies with the Environmental Protection Agency's standards in 40 CFR 192, Subparts A-C. I have therefore signed the enclosed signature pages signifying NRC's concurrence in the completion of remedial action at Lakeview, Oregon.

Ground-water cleanup at the processing site will be addressed by DOE as part of a separate ground-water restoration program once the proposed EPA ground-water standards have been finalized. This will require that DOE maintain control of the processing site in a manner consistent with DOE's April 9, 1993, policy letter.

If you have any questions, please contact the NRC Lakeview project manager, Ray Gonzales, at FTS (303) 231-5808.

Sincerely,

Edward F. Hawkins
for Ramon E. Hall
Director

Enclosures:
As stated

cc:
S. Hamp, DOE
F. Miera, Oregon
D. Stewart-Smith, Oregon

U.S. DEPARTMENT OF ENERGY
CERTIFICATION SUMMARY
for the
Lakeview, Oregon, Disposal Site

The Uranium Mill Tailings Remedial Action Project Manager and the Contracting Officer for the U.S. Department of Energy certify that the Lakeview, Oregon, remedial action is complete. The processing and disposal sites have been remediated and meet all design criteria and technical specifications contained in the approved Remedial Action Plan, as required under Public Law 95-604. This certification applies only to the earth surface remediation. The groundwater restoration activities at the Lakeview mill site will be completed separately. The undersigned request that the U.S. Nuclear Regulatory Commission concur in this certification.

Melanie J. Thomas
Contracting Officer
Programs and R&D Branch
Contracts and Procurement Division

DATE: April 1, 1992

Albert R. Chernoff
Project Manager
Uranium Mill Tailings Remedial
Action Project Office

DATE: 3/19/92

The Director, Uranium Recovery Field Office, Region IV, U.S. Nuclear Regulatory Commission hereby concurs with the U.S. Department of Energy's completion of surface remedial action at the Lakeview, Oregon processing and disposal site.

for Edward F. Hawkins
Mr. Ramon E. Hall, Director
Uranium Recovery Field Office
Region IV, DFSS
U.S. Nuclear Regulatory Commission

DATE: September 1, 1993

LTSM007352

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 15, 1995

Mr. Richard F. Sena, Acting Director
Environmental Restoration Division
Uranium Mill Tailings Remedial Action Project
U.S. Department of Energy
2155 Louisiana NE, Suite 4000
Albuquerque, New Mexico 87110

SUBJECT: ACCEPTANCE OF LONG-TERM SURVEILLANCE PLAN (LTSP), LAKEVIEW, OREGON URANIUM MILL TAILINGS REMEDIATION PROJECT

Dear Mr. Sena:

The U.S. Nuclear Regulatory Commission staff hereby accepts the U.S. Department of Energy's (DOE's) final LTSP for the Lakeview, Oregon, Uranium Mill Tailings Remedial Action Project site. This action establishes the Lakeview site under the general license in Title 10 Code of Federal Regulations (10 CFR) Part 40.27.

The acceptance of the Lakeview LTSP is based on the staff's determination that all open issues have been adequately addressed in the page changes to the August 1994 final LTSP, which were submitted by cover letter dated August 15, 1995, and DOE's ability to perform inspections and long-term site surveillance in accordance with Criterion 12 of 10 CFR 40, Appendix A. The LTSP for the Lakeview site satisfies the requirements set forth in the Uranium Mill Tailings Radiation Control Act of 1978, as amended, for the long-term surveillance of a disposal site, and all requirements in 10 CFR 40.27.

As we have previously discussed with Mr. Michael Abrams, the DOE Project Manager, two areas of concern relating to rock durability and seepage from the disposal cell have been identified by NRC staff during the LTSP review. These concerns do not directly impact the acceptance of the Lakeview LTSP and licensing of the site, but may ultimately impact the long-term monitoring strategy and long-term surveillance of the Lakeview site. A brief description of these concerns are presented below.

Rock durability was recognized as a potential concern by DOE during the remedial construction at the site. DOE subsequently proposed to over-design the thickness of the rock cover by 100 percent. NRC was informed of the potential concern and concurred in the proposed remedy. NRC also concurred in the Completion Report for the remedial action on September 1, 1993. Since completion of the disposal cell construction, some of the rock in the cover has deteriorated significantly at a rate that appears more rapid than anticipated.

In an effort to address the rock durability concern, DOE transmitted by cover letter dated July 10, 1995, the results of a petrographic evaluation performed

on the rip-rap covering the disposal cell. Based on this evaluation, DOE recommended that no additional action be taken to improve the rock cover on the side slopes of the cell or modify the inspection approach. However, the NRC staff concludes that the petrographic analysis cannot provide the empirical information needed to evaluate the rip-rap performance through repeated freeze-thaw cycles of a 200-year design life. Consequently, the NRC staff plans to conduct an independent evaluation of the rip-rap durability through freeze-thaw testing. Rock samples have recently been collected from the side-slope and provided to an NRC contractor for testing. The findings from this testing and any recommendations for revising the LTSP, if needed, will be forwarded to DOE.

The seepage concern centers on the documented application of dust-control water in excess of specifications during tailings placement, and the potential for seepage to cause instability of the disposal cell slope. This concern could not be resolved during the site visits conducted for the LTSP review, because of the unusually high rainfall experienced earlier this year. Future conversations with the DOE personnel performing the inspections and a review of post-closure inspection documents may resolve this concern.

Although rock durability and potential seepage are areas-of-concern, the NRC staff concludes that these concerns do not presently require corrective action. In accordance with 10 CFR 40.27(b), this letter accepting the LTSP constitutes the action bringing the Lakeview disposal site under NRC general license. In the event that any future testing, or inspections indicate that any of the disposal cell's components have failed or will likely fail, DOE will be required to implement corrective action measures as described in Chapter 9 of the LTSP, under provisions of the general license.

As described in DOE's guidance document for long-term surveillance, any further interactions between the NRC and the DOE pertaining to the Lakeview site will be conducted with the DOE's Grand Junction Projects Office. If you have any questions regarding this letter, please contact the NRC Project Manager, Michael Layton, at (301) 415-6676.

Sincerely,

Joseph J. Holonich, Chief
High-Level Waste and Uranium
Recovery Projects Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

cc: S. Hamp, DOE Alb
M. Abrams, DOE Alb
D. Bierley, TAC Alb
J. Virgona, DOE GJPO

Attachment

Recalculation of D_{50}, the Minimum Median Diameter of Riprap for the Side Slope of the Lakeview Disposal Cell

1.0 Summary

The Lakeview disposal cell was designed and constructed to prevent erosion that might result from a hypothetical Probable Maximum Precipitation (PMP) storm.

> ...The design criteria for the stability of the UMTRA Project tailings piles due to erosive forces resulting from rainfall across the top and down the sides of the stabilized embankment [disposal cell] are based on runoff from the localized PMP...The PMP is the most severe possible event that could occur as a result of combination of the most severe meteorological conditions occurring over a watershed at the same time...It is felt by most hydrologists that the recurrence interval [for a PMP] is on the order of 100,000 years...If the cost of designing for the PMF is excessive, a storm of lesser intensity may be used..." (DOE 1989).

The PMP is a conservative, worst possible case. The likelihood of a PMP event during the 200-to-1,000-year lifetime of the disposal cell is extremely small. Nevertheless, the PMP was used during remedial action as the basis to determine the minimum median diameter (D_{50}) of the riprap to be placed on the side slope of the Lakeview disposal cell. Using the PMP, Rational Method formula, and the Stephenson formula for calculation, the D_{50} for the riprap was determined to be 2.7 inches (in.) (range: 2.7 to 3.9 in.) (DOE 1989; DOE 1994.)

The disposal cell was completed in 1988. LTSM inspectors began reporting breakage of the riprap in annual inspection reports beginning in 1995. (Breakage of the riprap is due to physical and chemical weathering of the rock, although alteration of the rock before quarrying and stresses induced during quarrying are likely contributing factors.)

In consultation with NRC, LTSM began a series of annual gradation tests in 1997. The purpose of these tests was to determine the size distribution of the riprap and to record progressive changes, if any, in the size of the rock in the years that followed. Since the first measurements in 1997, the $D_{50}$of the riprap has decreased as shown in Figure 1. This raises the question whether the smaller riprap still provides adequate erosion protection for the disposal cell.

This Technical Task (Calculation No. S00631) addresses this question by recalculating D_{50}. The PMP is again used for the calculation, but a new U.S. Army Corps of Engineers model, Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS), is used in place of the more general and overly conservative Rational Method to calculate D_{50}. HEC-HMS is a refined model that is considered more realistic with respect to natural, expectable conditions, and is approved by NRC for use at disposal sites. The new D_{50} is calculated to be 1.8 in.

DOE will continue annual gradation tests at the Lakeview disposal site in accordance with the Long-Term Surveillance Plan, Revision 4, to which this Technical Task is attached. Results of these tests will be in the annual inspection report (Section 3.3.5).

If it becomes apparent that the riprap is continuing to break, and that the measured D_{50} will eventually fall below 1.8 in., DOE, in consultation with NRC, will evaluate alternatives and intervene, as necessary, to maintain erosion protection on the side slope of the disposal cell.

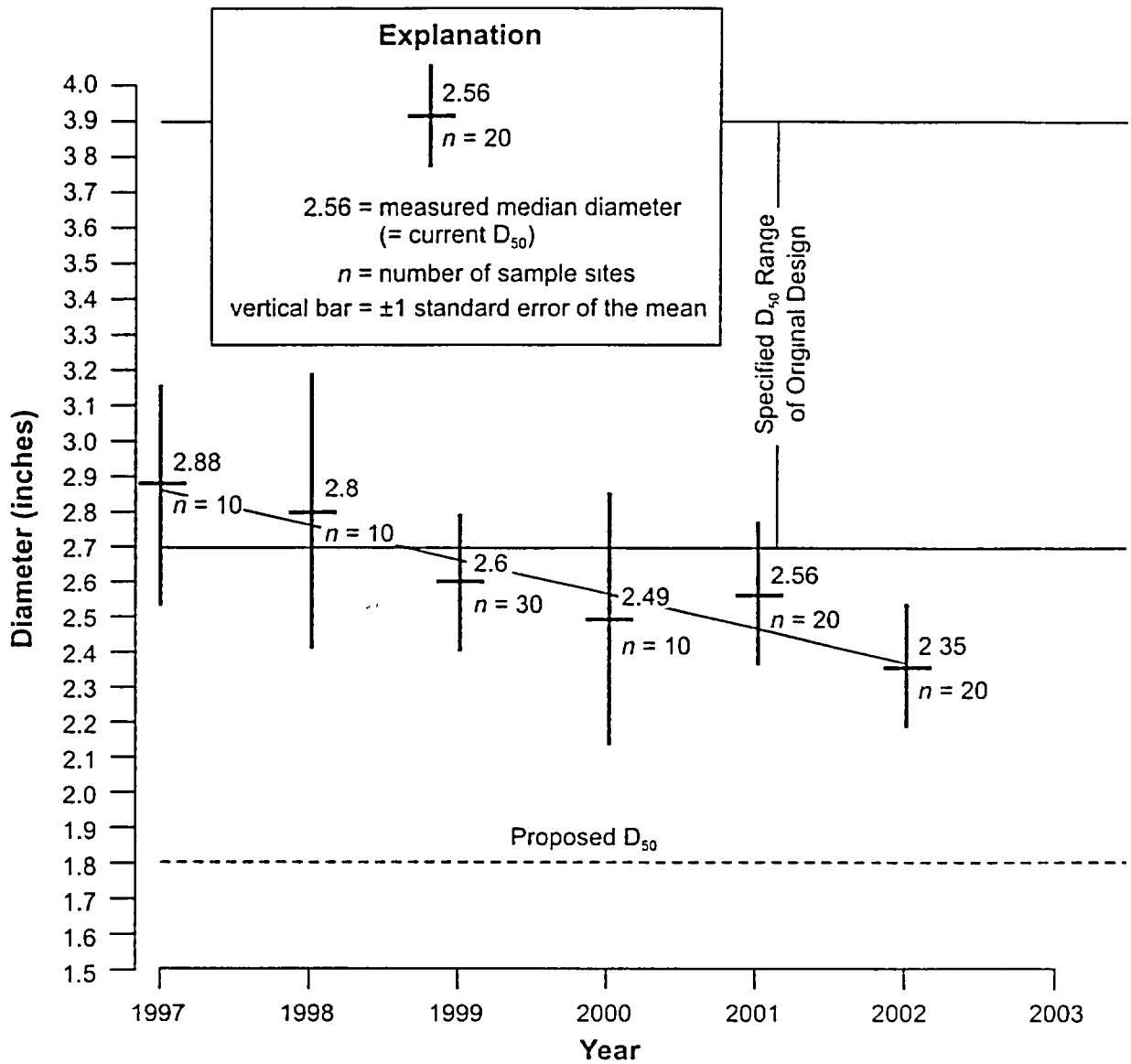

Figure 1. Results of Annual Gradation Tests, Lakeview, Oregon, Disposal Site, 1997–2002

2.0 Statement of Problem

During design of the disposal cell, conservative hydrological models, assumptions, and estimates were used to determine D_{50} of the riprap on the side slope of the disposal cell.

Specifically, estimates for the volume and intensity of rainfall during a PMP storm were used in the calculations. A PMP is a hypothetical storm with very small probability of occurrence, probably less than 1 chance in a 1,000 of occurring in any given year. A design that anticipates a PMP is therefore conservative. The PMP is retained and used in this Technical Task to preserve this conservatism.

However, DOE notes that the minimum or smallest severe storm that a disposal cell must survive is specified in a recent NRC publication, NUREG 1623, as the Standard Project Flood (SPF) (NRC 1999). The SPF is defined as 40 to 60 percent, or approximately half of the PMP (SPF = ½ PMP).

Additionally, for the original design, initial-runoff estimates were calculated with the Rational Formula, $Q = CiA$, where C is a coefficient, i is rainfall intensity (inches per hour [in./hr]), and A is the area of runoff (acres). Design guidance in effect during the remedial action project specified a coefficient of $C = 1$ to maximize surface runoff in the calculations (DOE 1989).

A coefficient of $C = 1$ is appropriate for a perfectly smooth, impervious surface, that is, a surface that permits no infiltration and no resistance to surface runoff. The side slope of the disposal cell, however, is neither smooth nor impervious. It is armored with rough, jagged riprap that contains significant void space to accommodate infiltration. Both roughness and infiltration retard runoff. A coefficient of $C = 1$ is not, therefore, truly representative of a riprap-armored side slope. Use of $C = 1$ is, however, a conservative design parameter, albeit unrepresentative.

For the recalculation of D_{50} in this Technical Task, runoff is recomputed using the U.S. Army Corps of Engineers HEC-HMS model that incorporates measured infiltration rates and estimates of surface roughness.

The new minimum median rock size, D_{50}, required to protect the side slope from erosion is recalculated in this Technical Task using design procedures developed by Abt et al., (1998) and in accordance with NRC guidance. The proposed new value for D_{50} is 1.8 in.

3.0 Method of Solution

Step 1. Obtain original data, assumptions, and calculations used by the remedial action project to determine the D_{50} of the riprap. This will include the estimate for runoff, expressed as a unit discharge, determined by the Rational Method.

Step 2. Determine values for PMP and SPF, where SPF = ½ PMP. Use these values to estimate runoff using the HEC-HMS method (software). Match runoff estimates from the original Rational Method formula with the estimates from HEC-HMS.

Step 3. Calculate soil hydraulic conductivity from field infiltration tests. Use hydraulic conductivity data to calculate runoff from the top and side slopes of the disposal cell.

Step 4. Use the calibrated PMP from Step 3 and the HEC-HMS program to model runoff. Take into account infiltration and surface roughness. Use the Green-Apt infiltration option in HEC-HMS to account for infiltration losses. Use kinematic wave analysis to model surface runoff.

Step 5. Use calibrated PMP to estimate side slope runoff. Superimpose top slope and side slope runoff, as unit discharge, to recalculate D_{50} of side slope riprap.

Step 6. Calculate D_{50} for a PMP storm. Use the simplified formula of Abt in accordance with latest NRC guidance. Repeat the calculation for the required minimum storm, SPF, where SPF = ½ PMP. Compare results.

4.0 Assumptions

1. Results of infiltration tests on the top slope of the disposal cell are representative of the actual infiltration characteristics of the top slope.

2. Values for runoff and intensity of rainfall, computed with the HEC-HMS model, are realistic and representative of possible extreme conditions at the site.

5.0 References

Abt, S.R., T.L. Johnson, C.I. Thorton, and S.C. Trabant, 1998. "Riprap sizing at the toe of embankment slopes", *J. of Hydr. Engrg.*, ASCE, 124(7):672-677.

Ang, A. H-S, and W.H. Tang, 1975. *Probability Concepts in Engineering Planning and Design Volume I Basic Principles*, John Wiley and Sons, New York.

Daily Climate Summary, Lakeview 2 NNW, http://www.wrcc.dri.edu/cgi-bin/cliRECt.pl?orlake

Decagon Devices, Inc. 1998. *Measuring Soil Hydraulic Conductivity with a Disk Infiltrometer*, Application Note, Pullman, Washington.

Lambe, T.W., and R.V. Whitman, 1969. *Soil Mechanics*, Massachusetts Institute of Technology, John Wiley and Sons, Inc., New York.

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MK-ES Document 4005-LKV-C-01-00330-01, 1986. Calculation No. 13-728-01-01, "Hydrology Parameters, Site Drainage."

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Zhang, R. 1997. "Determination of soil sorptivity and hydraulic conductivity from the disk infiltrometer." *Soil Sci. Soc. Am. J.*, 61:1024-1030.

6.0 Computer Sources

Microsoft Excel 2000

Hydrologic Modeling System HEC-HMS, version 2.1, January 2001
US Army Corps of Engineers
Hydrologic Engineering Center
609 Second Street Davis, CA 95616-4687 USA

7.0 Calculation

Step 1. Obtain Data Used to Calculate the Original D_{50}

The hydrologic and D_{50} calculations performed by the remedial action project were recovered from site record files to obtain the original values for the amount and intensity of rainfall, runoff, and geometric parameters (slope length, basin area, slope angle) used to calculate the original D_{50}.

The original calculations followed design guidance in the Technical Assistance Document (TAD) (DOE 1989). This guidance specified that the PMP and the Rational Method formula were to be used to calculate runoff, expressed as a unit discharge. The Rational Method formula is conservative. It overstates runoff in comparison to runoff observed during actual storms. It overstates runoff by assuming that the slope is a smooth, impervious surface (no roughness to impede runoff and zero infiltration).

The magnitude of the PMP assumed in the original calculation of unit discharge will be used later in this task as input to a more realistic, less conservative computation of unit discharge.

The unit discharge calculated by the Rational Method formula for the original design will be matched with unit discharge calculated using the HEC-HMS model to ensure that the same rainfall intensity is used in the recalculation of D_{50} as was used in the original calculation. In the recalculation, the top and side slopes will again be assumed to be a smooth surfaces with zero infiltration and zero roughness. Precipitation will be varied until identical unit discharges are obtained.

MK-ES Calculation No. 13-728-01-01, used in the original design, provided the following:

PMP rainfall intensity was computed using equation 1.

$$i = 10^{1.64-0.27(\log t)^2} \qquad (1)$$

where, i = rainfall intensity in in./hr
t = time of concentration in minutes (min).

A time of concentration, t =2.5 min, was used by the remedial action project in the original calculation.

From equation 1, the PMP rainfall intensity, i, was calculated to be 39.6 in./hr.

This value for the PMP rainfall intensity was used to compute unit discharge values for both the top and side slopes of the disposal cell using the Rational Method procedures outlined in the TAD. The runoff (unit discharge) values, in cubic feet per second per foot (cfs/ft), were computed to be:

Top slope of the disposal cell: 0.39 cfs/ft
Side slope: 0.53 cfs/ft.

(The unit discharge value for the side slope includes the runoff component from the top slope.)

The D_{50} of riprap required to armor the top and side slopes of the disposal cell was computed using the Safety Factors Method for the top slope and the Stephenson Method for the side slope (DOE 1989). The two respective values were determined to be:

Top slope: 0.37 ± in.
Side slope: 2.70 in.

Step 2. Recalculate Runoff Using the HEC-HMS Model

The PMP for the Lakeview disposal site was recomputed using National Weather Service Hydrometerological Report No. 58 (HMR 58, no date). The PMP was recomputed so that the D_{50} recalculated in this Technical Task would be based on more realistic assumptions than the original PMP, a hypothetically worst possible storm, and as such, a storm of very low probability. The recomputed PMP is used to compute a new unit discharge value. (HMR 58 may not have been available when the original D_{50} was calculated. HMR 58 is currently available on line.)

New draft guidance from NRC, NUREG 1623, allows the use of the SPF, which is approximately one-half the PMP, in certain applications (NRC 1999). For the recalculation of D_{50} in this Technical Task, the PMP is retained although results using the SPF are included for comparison.

Runoff from the Lakeview disposal cell is modeled with the U.S. Army Corps of Engineers, Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS) computer program (version 2.1, January 2001). This is the method of hydrological analysis currently accepted by the NRC. It replaces the over-simplified Rational Method and a previous version of the Corps of Engineers program, HEC-1.

To obtain equal results for runoff from the Rational Method formula and from HEC-HMS, precipitation values are adjusted until the unit discharges computed by both methods are equal. This is done for both the top and side slopes of the disposal cell.

The original, remedial action project used the Rational Method formula to compute unit discharges in accordance with the TAD. The Rational Method formula is expressed as

$$q = CiLw \tag{2}$$

where, q = the unit discharge in cfs/ft
C = the runoff coefficient equal to 1
i = the rainfall intensity in inches per hour (in./hr)
L = maximum distance in feet (ft)
w = unit width equal to 1 ft

The runoff coefficient, $C = 1$, is conservative. As explained above, such value for C is appropriate for a perfectly smooth, impervious surface, with no infiltration and no roughness or surface resistance to runoff – not a rock-covered surface with considerable roughness and significant interstitial (void) space. However, to calibrate precipitation with unit discharges, an impervious, smooth surface will also be used in the HEC-HMS calculations. This ensures that both Rational Method and HEC-HMS calculations are equally conservative in this respect.

The Lakeview disposal site is slightly north of the California border. PMP information for California is provided by the National Weather Service (HMR 58). The National Weather Service report gives estimates of general-storm PMP for drainages in California and bordering areas. (There is no similar report for the State of Oregon, so the California information is used.)

From HMR 58, the 1-hour general-storm PMP for the Lakeview area is 8.5 in./hr. The SPF precipitation, at ½ the PMP, is 4.25 in./hr. The PMP computation is provided in Appendix A of this Technical Task.

The HEC-HMS program allows a user to produce a site-specific hyetograph. (A site-specific hyetograph shows the maximum rainfall intensity expected per unit of time for a given site.) Figure 2 shows maximum rainfall intensity in 15-minute intervals for both a PMP and PMP + 80 percent storms at the Lakeview site.

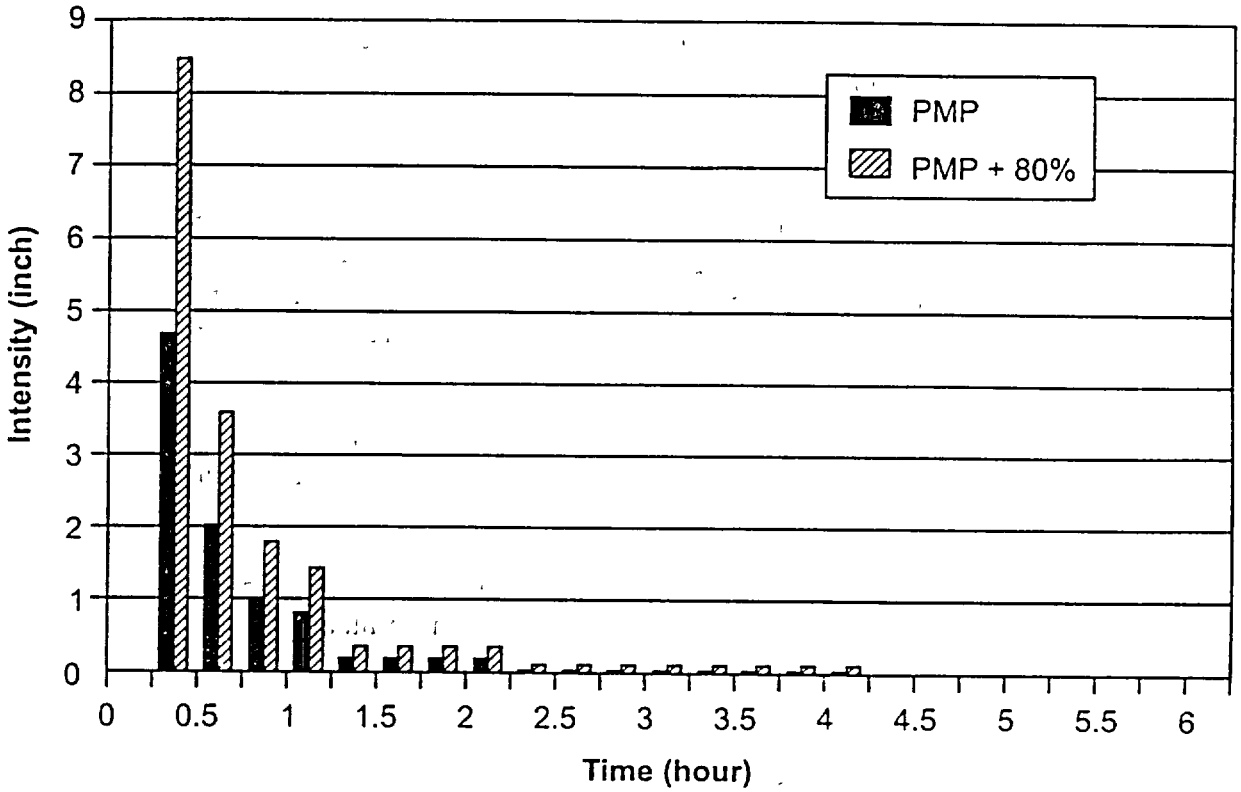


Figure 2. Hyetograph for Lakeview, Oregon, Disposal Site

Temporal distribution for the PMP and PMP + 80 percent storms, in 15-minute intervals, is shown in Table 1. In this table, progressively greater rainfall depths, used to create the HEC-HMS hyetograph in Figure 2, are listed in column 2. Different precipitation amounts (PMP + 10 percent and PMP + 80 percent) are used to achieve calibration with the original MK-ES runoff calculations (Columns 4 and 5, Table 1).

Geometric parameters of the Lakeview disposal cell are in Table 2. These parameters and the PMP rainfall depths in Table 1 are used with the HEC-HMS program to calculate peak discharge (cfs) and unit discharge (cfs/ft). Results of HEC-HMS runs for the top slope are in Table 3, and copies of HEC-HMS outputs are in Appendix B of this Technical Task. (Side slope runoff is calculated in Step 3.)

Table 1. Temporal Distribution of Rainfall Depths for PMP, PMP + 10 Percent, and PMP + 80 Percent Storms

Time (hour)	Depth (inches)	Delta, PMP (inches)	Delta, PMP + 10% (inches)	Delta, PMP+ 80% (inches)
0.0	0 00	-	-	-
0.25	4 70	4.70	5 17	8 47
0.50	6.70	2.00	2.20	3 60
0.75	7.70	1.00	1.10	1 80
1.00	8 50	0 80	0.88	1 44
1.25	8.70	0.20	0.22	0 36
1.50	8 90	0 20	0.22	0 36
1.75	9 10	0.20	0.22	0.36
2.00	9 30	0.20	0.22	0.36
2.25	9 35	0.05	0 055	0 09
2.50	9 40	0.05	0 055	0.09
2 75	9 45	0.05	0.055	0 09
3 00	9.50	0.05	0 055	0 09
3 25	9.55	0 05	0 055	0 09
3.50	9.60	0 05	0 055	0 09
3 75	9.65	0 05	0 055	0 09
4 00	9.69	0 05	0 055	0.09
4.25	9.70	0 01	0.011	0 018
4 50	9 71	0.01	0.011	0.018
4 75	9 72	0 01	0.011	0 018
5.00	9.73	0 01	0 011	0 018
5.25	9.74	0.01	0.011	0 018
5 50	9 75	0 01	0.011	0 018
5.75	9 76	0.01	0.011	0 018
6.00	9 78	0 01	0.011	0 018
	total 6-hr rainfall	9.78	10.76	17.60

Table 2. Geometric Parameters of Lakeview, Oregon, Disposal Cell

Description	Value
top slope area (ft^2/mi^2)	290,350 / 0 0104
top slope length (ft)	500
top slope grade (%)	-3 0
side slope area (ft^2/mi^2)	270,000 / 0 0097
side slope length (ft)	270
side slope grade (%)	-20 0

Table 3. HEC-HMS Top Slope Calibration Runs

Run #	Description [ ][a]	Peak Discharge (cfs)	Unit Discharge (cfs/ft)
3	impervious, PMP [3], w =557.6 ft	121	0 22
5	impervious, PMP [4], w =557 6 ft	133	0 24
6	impervious, PMP [5], w =557 6 ft	218	0.39

[a]value in brackets denotes column in Table 1

Table 3 shows that if the PMP from HMR 58 is increased by 80 percent, the calculated runoff, a unit discharge of 0.39 cfs/ft, is equivalent to the original MK-ES calculation. The PMP + 80 percent figure, referred to as the calibrated PMP, is used in this Technical Task to determine the effect of infiltration and surface roughness on the top slope.

If new design guidance is implemented by NRC, the smallest severe flood or storm (minimum design storm) the disposal cell must survive could become the SPF, as explained above. Before the SPF could be accepted as the minimum design storm, weather records must be checked to verify that higher precipitation events, those greater than the SPF, have not occurred.

Maximum daily rainfall records for the period January 1, 1928, through July 31, 2000, are in Appendix C (Daily Climate Summary, no date). During this 72-year period, the maximum daily rainfall (maximum rainfall in a 24-hour period) was approximately 56 percent of the SPF and 28 percent of the 1-hour PMP. The SPF, therefore, could reasonably be advanced as the new minimum design storm, the most extreme storm realistically expectable at the disposal site.

Step 3. Calculate Soil Hydraulic Conductivity and Runoff form Top and Side Slopes of the Disposal Cell

Infiltration tests were performed on the top slope of the disposal cell by DOE in 2000 and 2001. Data from these tests were used to calculate saturated hydraulic conductivity of the soil-rock matrix on the top slope (Appendix E). Saturated hydraulic conductivity is used with the HEC-HMS model to calculate surface runoff; and surface runoff is used in turn to compute a new unit discharge value.

Figure 3 shows the top slope of the disposal cell, in plan, with a superimposed 100-ft grid. The grid was used to locate 32 sampling stations for the infiltration tests. Data from the infiltration tests is used to estimate soil hydraulic conductivity.

Decagon (brand name) minidisk infiltrometers were used for infiltration tests according to the method proposed by Zhang to simulate water movement (soil hydraulic conductivity) in unsaturated soils (Zhang 1997). The method follows procedures in an application note from Decagon (see Appendix D). Cumulative infiltration is measured with respect to time, and the results fitted to the following equation:

$$I = \left(C_1 t + C_2 \sqrt{t}\right) \tag{3}$$

where, C_1 and C_2 are coefficients from the curve fit
t = time in seconds (sec)

Results of infiltration tests at the 32 test locations are in Appendix E.

Results of the curve fitting exercise are in Table 4.

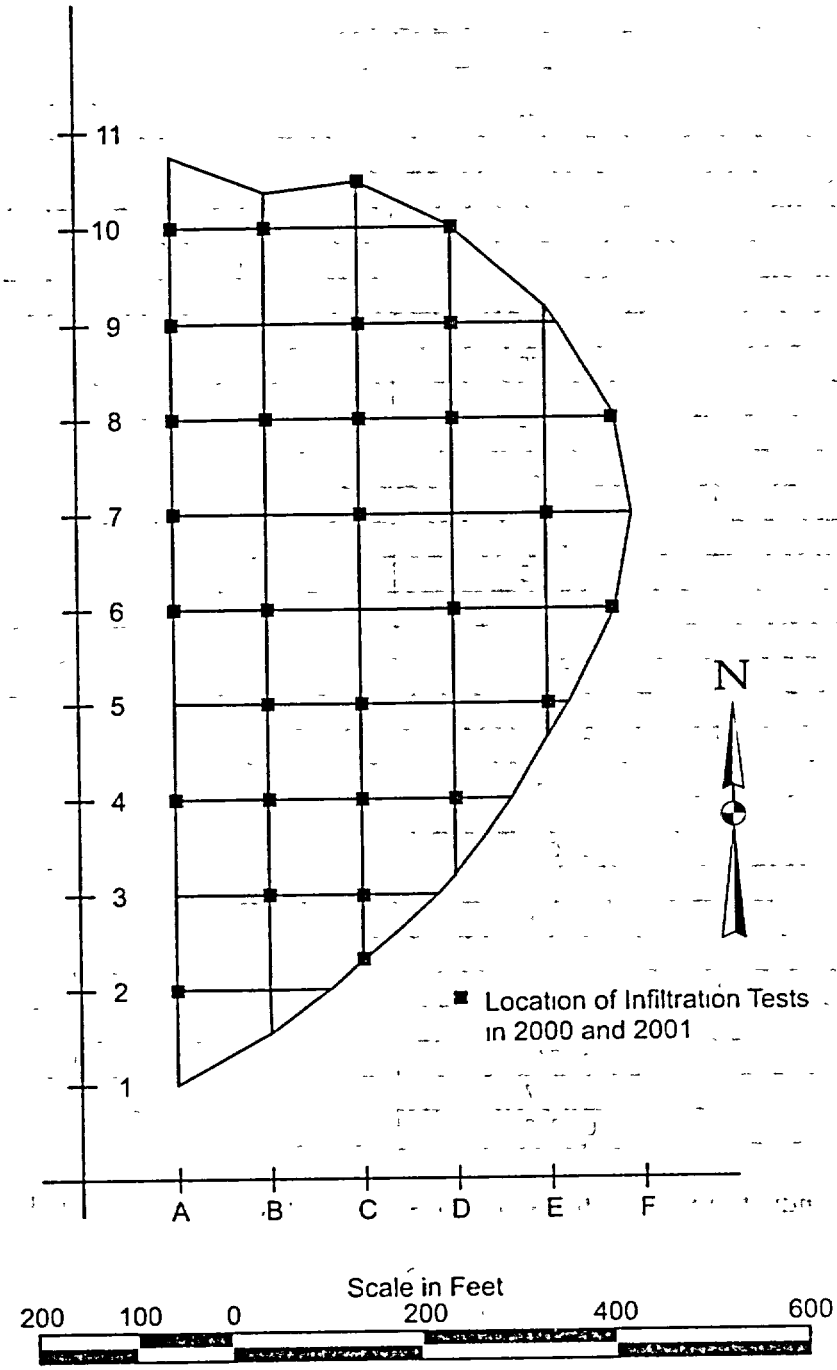


Figure 3. 100-foot Sampling Grid Superimposed on Plan Drawing of Top Slope, Lakeview, Oregon, Disposal Cell

Table 4. Infiltration Curve-Fitting Results

Location	C_1	C_2	r^2
A2	0.0014	0 0183	0 9956
A4	0 0021	0.0126	0 9992
A6	0.0001	0 0046	0 9962
A6 RETEST	0 0016	-0 0075	0 9718
A7	0.0040	0.0536	0 9963
A7	0 0049	-0 0893	0.9863
A8	0.0034	0 0501	0 9998
A9	0.00003	0 0539	0 9874
A10	0.0079	0 0340	0 9998
B3	0 0025	0 0341	0 9982
B4	0 0025	0.0060	0 9984
B5	0 0025	0 0456	0 9986
B6	0.0042	0.0962	0 9994
B10	0 0056	0 0671	0 9995
C2	0.0015	0 0079	0.9272
C3	0 0022	0.0303	0.9985
C4	0 0026	0.518	0 9998
C5	0.0037	0 0077	0.9947
C7	0 0045	0 0166	0 9992
C8	0 0025	0.0265	0.9995
C9	0 0048	0 0523	0 9994
C11	0 0004	0 0217	0 9923
D4	0 0010	0 0162	0 9980
D6	0.0037	0.0400	0.9992
D8	0 0020	-0 0194	0 9664
D9	0 0020	0 0417	0 9989
D10	0.0048	0.0210	0 9987
E5	0.0034	0.0202	0 9994
E7	0 0041	-0.0095	0 9996
F6	0 0057	0 0551	0.9994
F8	0.0013	0 0703	0.9994

The hydraulic conductivity of the top slope soil-rock matrix is then computed as

$$k_{h_o} = \frac{C_1}{A}, \tag{4}$$

where, k_{ho} = hydraulic conductivity of the soil measured at the suction valve on the minidisk surface

A = a nondimensional coefficient that relates soil retention parameters, infiltrometer parameters, and initial water content as defined by van Genuchten:

$$A = \frac{11\ 65\left(n^{0\ 1} - 1\right)e^{\left[2\ 92(n-1\ 9)\alpha h_o\right]}}{(\alpha r_o)^{0\ 91}} \qquad n \geq 1.9 \tag{5}$$

$$A = \frac{11.65\left(n^{0.1} - 1\right)e^{\left[7.5(n-1.9)\alpha h_o\right]}}{(\alpha r_o)^{0.91}} \qquad n < 1.9 \tag{6}$$

where, n and α = van Genuchten soil parameters
h = suction pressure at the minidisk surface in centimeters (cm)
r_o = radius of the minidisk in cm

Radius of the minidisk used in the tests was 1.59 cm.

The suction rate was -0.5 cm. Because of the surface tension, water will only flow into pores with a diameter small enough to create positive capillary pressure, that is, water pressures in the pore must exceed the air pressure in the pore. Using a water tension of –0.5 cm, the largest pore that water will flow into is approximately 6 millimeters (mm) in diameter (McWorter and Sunada 1981). Pores larger than 6 mm are macropores that will initially transmit larger volumes of water than the surrounding soil matrix, but will soon close upon wetting. Thus, the low suction rate of –0.5 cm, applied by the minidisk infiltrometer, did not impede flow to the soil and essentially represents saturated flow.

Van Genuchten soil parameter values for 12 U.S. Department of Agriculture (USDA) soil textural classes specified by Carsel and Parrish (1988) are provided by Decagon in its Application Note. This note is in Table 1 of Appendix D.

Soil samples were taken across the top slope of the disposal cell during hydraulic infiltration tests. Samples were combined for particle-size analysis and classification purposes. Results of particle-size analyses are in Appendix F. These results indicate that soil on the top slope of the disposal cell is a sandy loam according to USDA soil classification.

Referring to Table 1 in the Decagon Application Note, the appropriate value for coefficient A is 5.3. This value may also be computed using equation 4 or equation 5 above. Hydraulic conductivity values for each infiltration test are computed with equation 3, using A = 5.3 and fitted values of C_I. Results are in Table 5.

In order to determine a representative value for soil hydraulic conductivity, and the confidence limits on that value, the distribution of computed conductivity values are compared against a normal distribution. To determine if the values are normally distributed, they can be plotted on normal probability paper. If the fit is linear (a more or less straight line), the data are normally distributed. In lieu of plotting on normal probability paper, the standard normal variate of each value can be computed and plotted on arithmetic paper. Methods outlined by Ang and Tang are followed to produce Table 6 (Ang and Tang 1975). Data from Table 6 are plotted on Figure 4.

Table 5. Computed Soil Hydraulic Conductivities

Location	Soil Hydraulic Conductivity (cm/s)
A2	2.64×10^{-4}
A4	3.96×10^{-4}
A6	1.89×10^{-5}
RETEST A6	3.02×10^{-4}
A7	7.55×10^{-4}
A7	9.25×10^{-4}
A8	6.42×10^{-4}
A9	5.66×10^{-4}
A10	1.46×10^{-3}
B3	4.72×10^{-4}
B4	4.72×10^{-4}
B5	4.72×10^{-4}
B6	7.92×10^{-4}
B8	1.26×10^{-4}
B10	1.06×10^{-3}
C2	2.83×10^{-4}
C3	4.05×10^{-4}
C4	4.91×10^{-4}
C5	6.98×10^{-4}
C7	8.49×10^{-4}
C8	4.72×10^{-4}
C9	9.06×10^{-4}
C11	7.55×10^{-4}
D4	1.89×10^{-4}
D6	6.98×10^{-4}
D8	3.77×10^{-4}
D9	3.77×10^{-4}
D10	9.06×10^{-4}
E5	6.42×10^{-4}
E7	7.74×10^{-4}
F6	1.08×10^{-3}
F8	2.45×10^{-4}

Table 6 Standard Normal Variate of Computed Soil Hydraulic Conductivity Estimates

Rank, *m*	*k*	Plotting Position, *m/(n+1)*	Standard Normal variate
1	5.66E-06	0 0303	-1.38146
2	1.89E-05	0 0606	-1.29234
3	7.55E-05	0 0909	-1.20321
4	1 26E-04	0 1212	-1 11408
5	1 89E-04	0 1515	-1.02496
6	2.45E-04	0.1818	-0 93583
7	2 64E-04	0.2121	-0 8467
8	2 83E-04	0 2424	-0 75758
9	3 02E-04	0 2727	-0.66845
10	3.77E-04	0.3030	-0.57932
11	3.77E-04	0 3333	-0 4902
12	3 96E-04	0.3636	-0 40107
13	4 15E-04	0 3939	-0 31194
14	4 72E-04	0 4242	-0.22282
15	4 72E-04	0 4545	-0.13369
16	4.72E-04	0.4848	-0.04456
17	4 72E-04	0.5152	0 044563
18	4 91E-04	0 5455	0 13369
19	6 42E-04	0 5758	0.222816
20	6 42E-04	0 6061	0 311943
21	6.98E-04	0 6364	0.40107
22	6 98E-04	0.6667	0 490196
23	7 55E-04	0 6970	0.579323
24	7.74E-04	0 7273	0 668449
25	7.92E-04	0 7576	0 757576
26	8.49E-04	0 7879	0 846702
27	9 06E-04	0.8182	0 935829
28	9 06E-04	0 8485	1.024955
29	9.25E-04	0 8788	1.114082
30	1.06E-03	0 9091	1 203209
31	1.08E-03	0.9394	1.292335
32	1 49E-03	0 9697	1.381462

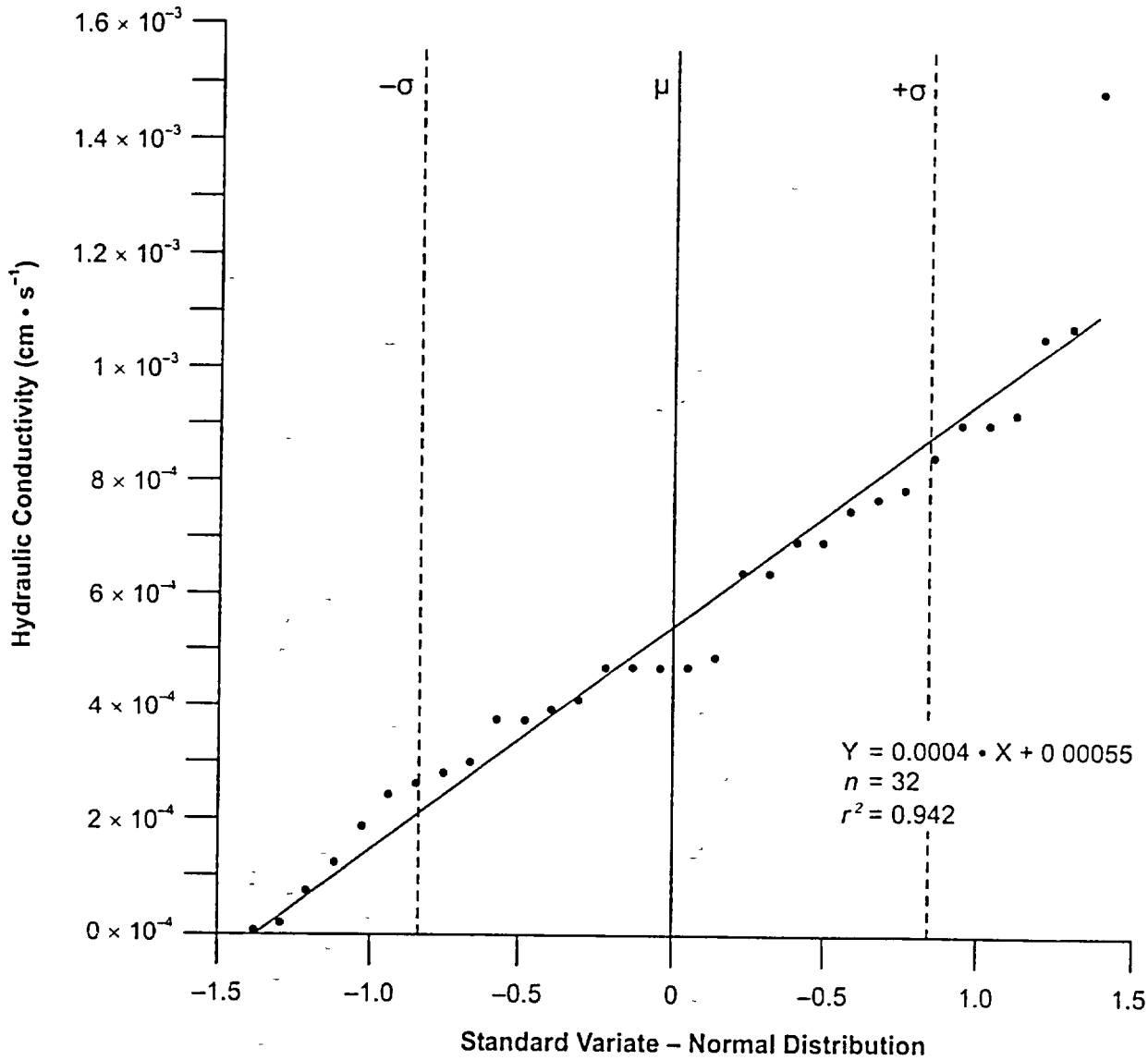


Figure 4. Results of Hydraulic Conductivity Tests on the Top Slope of the Lakeview, Oregon, Disposal Site, 2000 and 2001

Inspection of Figure 3 indicates that the data reasonably follow a linear fit, that is, $r^2 = 0.942$, which is near $r^2 = 1.0$ for a straight line relationship among normally distributed data. The data are therefore considered normally distributed.

The mean and standard error of the mean for the soil hydraulic conductivity data are computed to be:

mean, $\mu = 5.5 \times 10^{-4}$ cm/sec
standard error, s.e. = 6.1×10^{-5} cm/sec.

The mean values for soil hydraulic conductivity, plus or minus 1 standard error (s.e.) at 95 percent confidence, are:

Description	Soil Hydraulic Conductivity (cm/s)
$\mu - 1$ s.e. @ 95% confidence	4.3×10^{-4}
μ	5.5×10^{-4}
$\mu + 1$ s.e. @ 95% confidence	6.7×10^{-4}

Top Slope Runoff

Infiltration into the top slope cover is modeled in HEC-HMS with the Green-Ampt infiltration model. Using this approach, the amount of precipitation that filters through the soil profile and the infiltration capacity of the soil are governed by Richard's equation that is derived by combining an unsaturated-flow form of Darcy's Law with conservation of mass. Input required for the Green-Apt model in HEC-HMS are,

initial loss = quantity of moisture initially in the soil, analogous to the initial abstraction used in the SCS Runoff Curve Number Method
k = soil hydraulic conductivity (cm)
ξ = wetting-front suction (cm)
$\phi - \theta$ = porosity minus volumetric moisture content = moisture volume deficit in cubic centimeters or inches (cm^3 or $in.^3$)

Initial loss is a function of the soil moisture present at the beginning of the precipitation event, and is assumed to be 10 percent of mean annual precipitation, or 1.6 in. (4.06 cm) for the Lakeview site.

Soil hydraulic conductivity is computed as explained above in Step 2 of this task. Wetting front suction, 8.74 in. (22.2 cm), is estimated for the sandy loam soil from values provided by Rawls (Rawls et al. 1982). Volumetric moisture deficit is determined from measured vales of porosity, ϕ, and volumetric moisture content, θ, obtained during the infiltration tests. Porosity and volumetric moisture content test results are provided in Appendix G. Average porosity and volumetric moisture content yield volume moisture deficits ranging between 0.320 and 0.482 cm^3.

Surface roughness is modeled in HEC-HMS using a kinematic-wave model. Using the kinematic-wave model, slope, length, and surface roughness are used in a Manning's equation formulation that incorporates physically measured and estimated characteristics of the overland flow basin, which in this case is the top slope of the disposal cell. This approach creates a more realistic model for the top surface of the disposal cell than the Rational Method used in the original calculation. Values used for the kinematic-wave, overland-flow model used for the top slope are:

length = 500 ft
slope = 0.03 ft/ft
roughness = 0.15

These values apply to the entire area of the top slope of the disposal cell.

The estimated roughness value for the top slope is from the HEC-HMS user's manual. Table 6–1 in the user's manual is for short grass prairie and applicable to the Lakeview site. Results are in Table 8, runs 7, 8, and 9.

Side Slope Runoff

The side slope of the disposal cell is covered with a layer of riprap 12- in. thick. The riprap rests on an underlying layer of sand (sand-bedding layer) 6- in. thick. The riprap and sand-bedding layers are naturally porous. They overlie a relatively impermeable radon barrier 18- in. thick.

For the riprap layer, the horizontal hydraulic conductivity is taken to be equal to the vertical hydraulic conductivity. Saturated hydraulic conductivity values are used in a simplified HEC-HMS runoff computation (the initial-loss module) to compute side-slope runoff.

Rock cover materials are assumed to be infinite with respect to hydraulic conductivity compared to the underlying sand-bedding layer. The sand-bedding layer is assumed to have a saturated hydraulic conductivity of 10^{-2} cm/sec (Lambe and Whitman 1969).

Air-entry permeameter tests were performed in the upper and lower halves of the 18-in. thick radon barrier in 1997 and 1998. These tests indicate that the mean saturated hydraulic conductivity, a measure of permeability, is approximately four times greater in the upper half than in the lower half of the radon barrier (Table 7; and Waugh, in progress).

Table 7. Saturated Hydraulic Conductivities, Side Slope Radon Barrier, Lakeview, Oregon, Disposal Site[a]

condition tested	mean saturated hydraulic conductivity (cm/s)
upper radon barrier	3.2×10^{-5}
lower radon barrier	8.1×10^{-6}

[a]Waugh (in progress)

A harmonic mean of the saturated hydraulic conductivities is computed by assuming that the upper and lower portions of the 18-in. thick radon barrier are each 9 in. in thickness, or

$$k_{sat} = 18'' / (9''/3.2 \times 10^{-5} + 9''/8.1 \times 10^{-6}) = 1.3 \times 10^{-5} \text{ cm/s}$$

These conductivities and the calibrated PMP values from HEC-HMS are used to compute the side slope component of runoff. Results are in Step 5.

Step 4. Model Surface Runoff for PMP and SPF

The mean and range of saturated hydraulic conductivity values were used with the calibrated precipitation intensity and duration (from Steps 2 and 3) as input to HEC-HMS.

Infiltration and surface runoff from the top slope are processes that reduce the amount and intensity of surface runoff. The Green-Ampt infiltration option was used with kinematic wave analysis to model infiltration and surface runoff. By accounting for infiltration and surface runoff, a more realistic value for surface runoff, expressed as a unit discharge, can be used to compute a new D_{50}.

Top slope infiltration values calculated in Step 3 are used to run the HEC-HMS model with the calibrated PMP, or PMP + 80 percent, as listed in Table 1, Column 5. Results from HEC-HMS modeling of runoff on a vegetated, soil-covered slope, in this case the top slope of the disposal cell, are in Table 8, runs 7, 8, and 9. Side slope infiltration values, calculated in Step 3, are also used to run the HEC-HMS model along with the calibrated PMP to produce runoff estimates for the side-slope of the disposal cell. Results for the side slope is also in Table 8.

Table 8. HEC-HMS Vegetated Top Slope and Side Slope Runs, Calibrated PMP Precipitation

Run #	Description	Peak Discharge (cfs)	Unit Discharge (cfs/ft)
7	Green-Ampt infiltration, mean *k*	174	0 312
8	Green-Ampt infiltration, mean *k* – 1 S E.	173	0.311
9	Green-Ampt infiltration, mean *k* + 1 S E	175	0.314
10	side slope	210	0.210

Runoff calculations were also performed for the SPF (minimum design storm) using HEC-HMS. Identical infiltration conditions were assumed. Since, for the original design, runoff from a smaller, 200-year, SPF storm event was not calculated, runoff from such a storm event is also calculated here, again assuming an impervious, smooth surface, as a most conservative case. Results are in Table 8.

Step 5. Determine Total Side Slope Runoff

Calibrated PMP (PMP + 80 percent) is used to compute runoff from the side slope. Most of the runoff comes from the top slope as side-slope run-on (Table 9). A lessor component of side-slope runoff is from precipitation that falls directly on the side slope. Runoff from the top slope, expressed as unit discharge, is added to runoff from the side slope to calculate total runoff on the side slope.

Table 9. Unit Discharge for Top Slope (Vegetated) and Side Slope, Calculated for SPF Using HEC-HMS Model

Run #	Description	Peak Discharge (cfs)	Unit Discharge (cfs/ft)
20	top slope, Green-Ampt infiltration, mean *k*	108.55	0 190
NA	side slope, measured and assumed conductivity	104 79	0 105

Step 6. Compute D_{50} for Side Slope Riprap for PMP and SPF Events. Use the Simplified Method (HEC-HMS model and Apt formula)

The newly computed total unit discharge (top slope runoff plus side slope runoff) is used to calculate D_{50} with the Apt formula in accordance with latest NRC guidance, "Design of Erosion Protection for Long-Term Stabilization, NUREG 1623" (Abt et al. 1998; Johnson 1999). The result is compared to the initial calculation that used the Stephenson method (DOE 1989).

Minimum D_{50} values are computed for side slope erosion protection using both the simplified formula in NUREG 1623 and the Stephenson method in the TAD. Unit discharges presented in Tables 8 and 9 are added together for D_{50} computations in Table 10.

Table 10. Minimum D_{50} for Side Slope Riprap Calculated for Calibrated PMP and SPF by Simplified and Stephenson Methods

Condition	Unit Discharge, q (cfs/ft)	D_{50} (inches)	
		Simplified	Stephenson
Calibrated PMP			
impervious surface	0.530	1 83	2 59
mean *k*	0 522	1.82	2 57
mean *k* – 1 S.E	0.521	1.82	2.57
mean *k* + 1 S E	0 524	1 82	2 58
SPF			
mean *k*	0 295	1 32	1 76

Table 9 shows D_{50} results for both the calibrated PMP and SPF storm events. D_{50} is calculated for both storms using the original Stephenson Method specified in the TAD and the newer HEC-HMS method in recent NRC guidance (DOE 1989; NRC 1999).

The original design, using Stephenson, determined D_{50} to be 2.6 in. (approximately). (A D_{50} of 2.7 in. was eventually adopted.) This Technical Task, using the more recent HEC-HMS model, recalculates D_{50} to be 1.8 in. If NRC's draft guidance is eventually adopted, the D_{50} recalculated for the SPF would be 1.3 in. Pending implementation of the new guidance, DOE will adopt 1.8 in. as the appropriate standard for continuing annual gradation tests.

8.0 Discussion

The PMP computed by the remedial action project (MK-ES Calculation No., 13-728-01-01) used the method suggested by the NRC (DOE 1989; NRC 1986). With this method, the general one-hour PMP storm is computed for the Lakeview area. The time of concentration, *t*, which is the time for a water particle to travel across the top and down the side slope of the disposal cell (longest flow path), was computed with the Kirpich method (NRC 1986). PMP intensity was adjusted, that is, increased, to account for the time of concentration by the method outlined by Nelson (NRC 1986). This rainfall intensity is generally conservative in that it represents the peak

rainfall intensity of the design storm. Because of the inherent conservatism in the Kirpich method, the reanalyzed PMP had to be increased by 80 percent to achieve an identical runoff in the HEC-HMS computation.

Estimates for infiltration and surface roughness, as variables, did not have any practical effect on D_{50} compared to an impervious, smooth surface. This is because of the intensity of extreme design storms. Water from such storms falls so fast that infiltration does not occur to the extent that might be expected and surface roughness is not effective in slowing the runoff.

Using the Simplified Method (HEC-HMS and Apt formula), the unit discharge is lower and the calculated D_{50} smaller. The decrease in D_{50}, from 2.7 in. to 1.8 in., results from the computation method used to determine D_{50}. The Simplified Method, used here, was derived from flume studies, in which failure was defined as the point at which a rock particle was moved out of place. While in the original Stephenson method, failure was defined on theoretical incipient motion. Thus, for a given flow rate a smaller rock size will result for the Simplified Method computation. The Simplified Method is more representative of natural storm conditions that can be realistically expected at the site.

9.0 Conclusion

Based on this re-evaluation of runoff from the top slope of the Lakeview disposal cell and using the Simplified Method to compute D_{50}, the minimum median rock diameter necessary to protect the disposal cell during a PMP event 1.8 in. The minimum D_{50} to protect the disposal cell from a SPF – if adopted as the design storm – would be 1.3 in.

End of current text

Appendix A
Lakeview PMP Determination

Local PMP Calculation

Determine the average depth PMP for 6 hr duration w/o areal distribution, step A from HMR 58: 2.4 Local Procedures

Step 1. one hour 1-mi² local storm,

from Fig 2.21 use 8.5 inches

Step 2. adjustment for mean drainage elev.

elevation is <6000 ∴ no adjustment

Step 3. Adjustment for duration, multiplier A

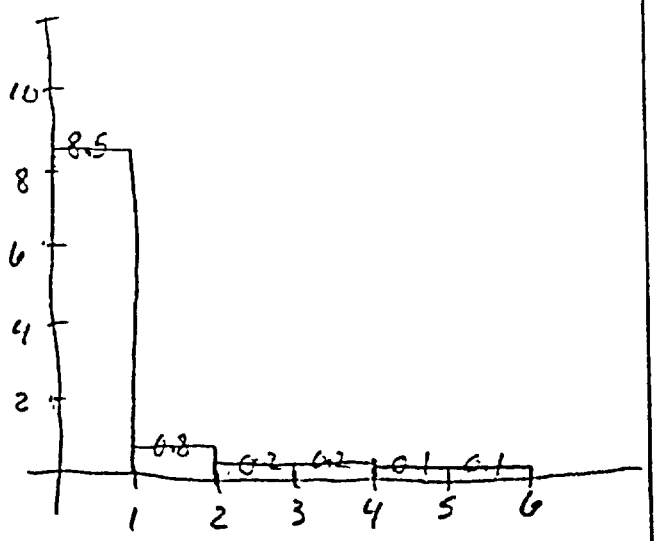
Duration (hr)	multiplier (%)	depth
0	0	—
0.25	55	4.7
0.50	79	6.7
0.75	91	7.7
1.00	100	8.5
2.00	109.5	9.3
3.00	112	9.5
4.00	114	9.7
5.00	114.5	9.7
6.00	115	9.8

Step 4. adjustment for basin area

area is to small, no adjustment possible

Step 5 Temporal distribution

hourly increments	depth	Δ
6	9.8	
5	9.7	0.1
4	9.6	0.1
3	9.5	0.2
2	9.3	0.2
1	8.5	0.8
		8.5



2.4 Local-Storm Procedures

Two options are available for obtaining the local-storm PMP values. They are :

A. Obtain the average depth of PMP for a drainage without specifying its areal distribution, or

B. Specify the areal distribution of the precipitation from a PMP storm within a drainage.

Option A requires Steps 1-5 below; Option B requires that Steps 1 and 2 are used followed by Step 6. If Option B is selected, a drainage average depth of the isohyetal precipitation pattern for various PMP storm placements must be chosen. There will be as many average depths for the drainage as there are placements for the PMP storm. The average depths of precipitation in a drainage obtained from Option B will be less than the average depth of PMP from Option A unless the drainage has the exact boundary shape shown in Figure 2.20.

Local-Storm Calculations

Step

1. One-hour, 1-mi^2 local storm

   Locate the basin on Figure 2.21 and determine the basin-average, 1-hour, 1-mi^2, local-storm index value of PMP. Use linear interpolation.

2. Adjustment for Mean Drainage Elevation

   Determine the mean elevation of the drainage. No adjustment is necessary for elevations of 6,000 feet or less. If the mean elevation is greater than 6,000 feet, reduce the PMP from Step 1 by 9 percent for every 1,000 feet above the 6,000-foot level. Figure 2.22 can be used to graphically determine this value.

   As an example of the elevation adjustment let us assume we have a basin with a mean elevation of 8,700 feet (2,700 feet above 6,000 feet). The reduction factor would be 24.3 percent (2.7 times .09), giving an elevation-adjusted PMP of 76 percent (rounded) of 1-hour, 10-mi^2 PMP. Had Figure 2.22 been used, a value of about 76 percent is read off the line labeled pseudo-adiabat for an elevation of 8,700 feet.

3. Adjustment for Duration

   The 1-mi^2 local-storm PMP estimates for durations less than 1 hour are obtained from Figure 2.23, as a percentage of the 1-hour amount from Step 2. For durations greater than 1 hour, determine the location of the basin on Figure 2.24, which provides a 6-hour to 1-hour ratio of the local-storm PMP. Multiply this ratio by the 1-hour local-storm PMP to obtain the 6-hour local-storm PMP. The four multipliers on Figure 2.24 are defined as A (1.15), B (1.2), C (1.3), and D (1.4) and correspond to the A, B, C, and D of Figure 2.23. Local-storm PMP amounts for durations of 1 to 6 hours can be obtained from Figure 2.23 or Table 2.10 for specific durations.

4. Adjustment for Basin Area

   Figures 2.25, 2.26, 2.27 and 2.28 give the area reductions to 500 mi^2 depending on the 6-hour depth-duration ratio used in Step 3. The reductions obtained for the selected durations and area of the basin then are multiplied respectively by the results from Step 3, and a smooth curve is drawn on graph paper for the plotted values to get estimates for durations not specified.

5. Temporal Distribution

Review of local-storm temporal distributions for this region show that most local storms have durations less than 6 hours and that the greatest 1-hour amount occurs in the first hour. The recommended sequence of hourly increments is as follows: arrange the hourly increments from largest to smallest as obtained directly by successive subtraction of values read from the smoothed depth-duration curve. The most intense 1-hour of precipitation occurs in the first hour of the storm, the second most intense hour in the second hour, and so forth.

6. Areal Distribution for Local-Storm PMP

The elliptical pattern in Figure 2.20 and the tabulated percentages in Tables 2.11, 2.12, 2.13 and 2.14, are used to describe the areal distribution of precipitation of a local PMP storm. The 2:1 ratio of the major to minor axis of Figure 2.20 should be used or "placed" only on a map at a 1:500,000 scale. The average index value from Step 2 (or Step 1 if no elevation adjustment is made) is multiplied by each of the percentages from the appropriate table (Tables 2.11, 2.12, 2.13 or 2.14) to obtain the value for each lettered isohyet (A - J). Once the labels have been determined for each application, the pattern can be moved to different placements on the basin. In most instances, the greatest volume of precipitation will be obtained when the pattern is centered in the drainage. However, peak flows may actually occur with placements closer to the drainage outlet. The basin-averaged depth of precipitation is obtained for chosen local PMP storm placements.

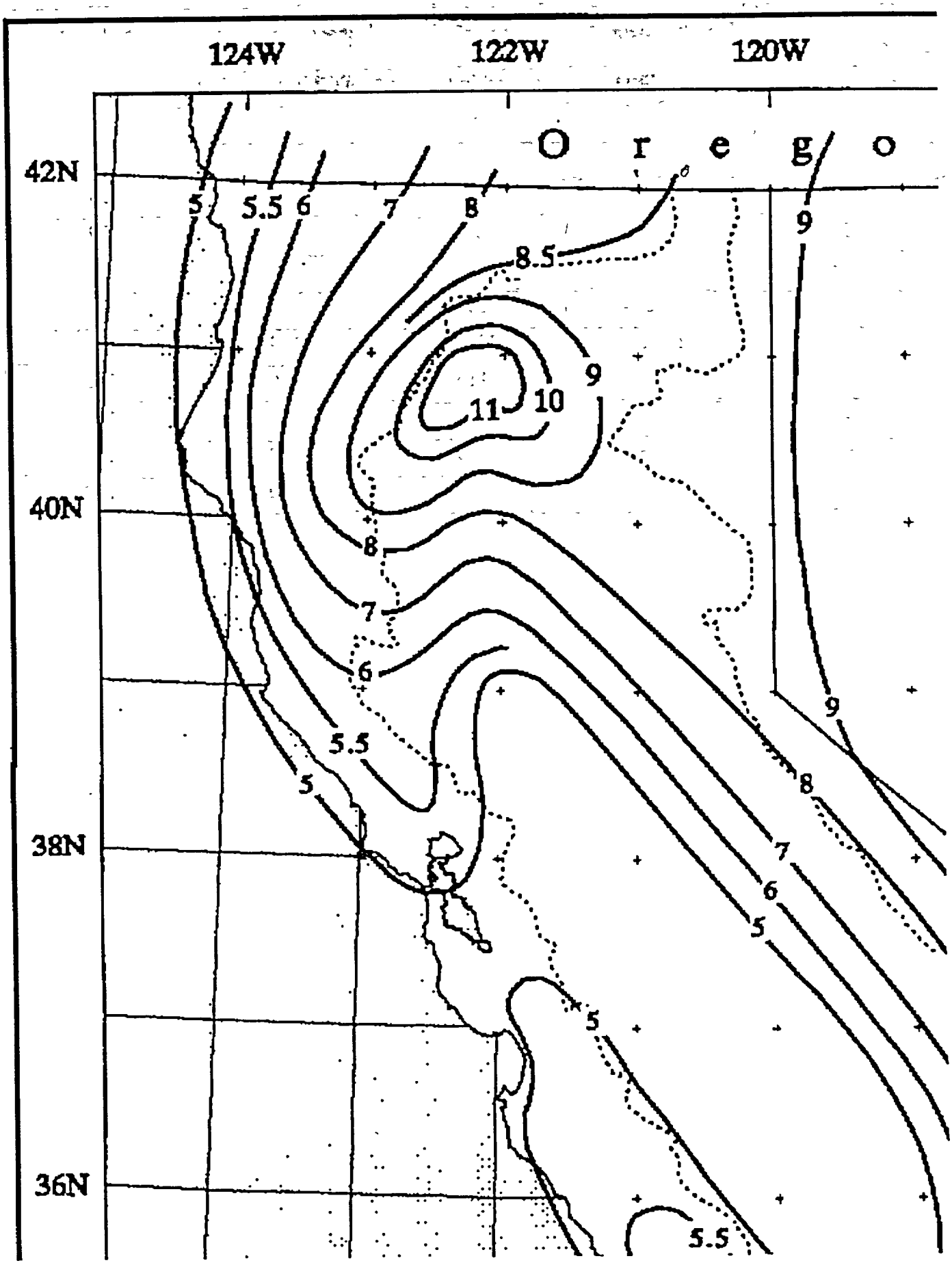

124W
122W
120W
42N
40N
38N
36N
O r e g o
5
5.5
6
7
8
8.5
9
10
11
5.5

Table 2.10. Depth-duration relations (percent of 1-hour amount) for 1-mi^2 PMP for California local storms.

Duration (hours)	Relationship Designator (see Figure 2.23)			
	A	B	C	D
0	0	0	0	0
0.25	55	55	55	55
0.50	79	79	79	79
0.75	91	91	91	91
1	100	100	100	100
2	109.5	110.5	114	117
3	112	116	120	126
4	114	118	125	132
5	114.5	119	128	137
6	115	120	130	140

Appendix B
HEC-HMS runs

HMS * Summary of Results

Project : LKV infiltration Run Name : Run 1

Start of Run : 01Apr01 0800 Basin Model : LKV topslope
End of Run : 01Apr01 1400 Met. Model : 6-hr PMP
Execution Time : 12Sep01 1056 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
topslope	76.868	01 Apr 01 0815	3.8148	0.010
runoff	67.854	01 Apr 01 0815	3.8849	0.010

HMR 56 PMP
Green-Ampt infiltration
entire topslope, flow length = 475'

Width = 0.010 mi² $\left(\frac{5280\text{ft}}{1\text{mi}}\right)^2 \frac{1}{475'}$ = 278,784/475 = 586.9 ~ 587'

$\frac{76.868\text{ cfs}}{587'}$ = 0.13 cfs/ft

HMS * Summary of Results

Project : LKV infiltration Run Name : Run 2

Start of Run : 01Apr01 0800 Basin Model : LKV top slope #2

End of Run : 01Apr01 1400 Met. Model : 6-hr PMP

Execution Time : 12Sep01 1357 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
topslope#2	121.18	01 Apr 01 0815	5.2519	0.010
runoff	108.54	01 Apr 01 0815	5.3528	0.010

impervious

HMR-56 PMP

entire topslope, flow length = 475'

width = 587'

121.2 cfs/587' = 0.21 cfs/ft - need to be

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 3

Start of Run : 01Apr01 0800 Basin Model : top slope #3
End of Run : 01Apr01 1400 Met. Model : 6-hr PMP
Execution Time : 12Sep01 1523 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
top slope #3	121.02	01 Apr 01 0815	5.2236	0.010
runoff	108.39	01 Apr 01 0815	5.3249	0.010

Impervious
HMR-56 PMF
[illegible] slope, flow length = 500'
area = 0.010
width = 0.010(5280')²/500 = 557.6'
121.02/557.6 = 0.22 cfs/ft = q
need higher pump to make MK q of 0.39 cfs/ft

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 4

Start of Run : 01Apr01 0800 Basin Model : top slope #3
End of Run : 01Apr01 1400 Met. Model : 6-hr PMP
Execution Time : 12Sep01 1551 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
top slope #3	121.02	01 Apr 01 0815	6.3137	0.010
runoff	108.39	01 Apr 01 0815	6.4653	0.010

Impervious
Hmr 58 PMP @ 5 min?

A=0.010
L = 500'
W = 5576'

121.02/5576 = 0.22 cfs/ft up precip. by 10%
(see run 5)

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 5

Start of Run : 01Apr01 0800 Basin Model : top slope #3
End of Run : 01Apr01 1400 Met. Model : 6-hr PMP, HMR 58+
Execution Time : 12Sep01 1610 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
top slope #3	133.04	01 Apr 01 0815	5.7427	0.010
runoff	119.49	01 Apr 01 0815	5.8519	0.010

$A = 0.010\ mi^2$

$L = 500'$

$W = 557.6'$

$133.04 / 557.6 = 0.239\ cfs/ft$

MK-ES $q = 0.39\ cfs/ft$ $0.39 \times 557.6 = 217.46$

if HMR 58 1 hr precip = 8.5
HMR 58+ 1 hr precip = 9.35

$$\frac{8.5 - 9.35}{121.02 - 133.04} = \frac{8.5 - x}{121.02 - 217.46}$$

$$\frac{-0.85}{-12.02} = \frac{8.5 - x}{-96.44}$$

$$81.97 = -102.17 + 12.02x$$

$$15.32 = x$$

$\frac{15.32}{8.5} = 1.8 \Rightarrow$ 80% increase - try

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 6

Start of Run : 01Apr01 0800 Basin Model : top slope #3
End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++
Execution Time : 12Sep01 1627 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
top slope #3	218.22	01 Apr 01 0815	9.3913	0.010
runoff	198.64	01 Apr 01 0815	9.5550	0.010

Area = 0.010

L = 500'

W = 557.6'

218.22/557.6 = 0.39 cfs/ft

HMS * Summary of Results for top slope #3

Project : LKV top slope #3 Run Name : Run 6

Start of Run	: 01Apr01 0800	Basin Model	: top slope #3
End of Run	: 01Apr01 1400	Met. Model	: 6 hr PMP, HMR 58 ++
Execution Time	: 12Sep01 1645	Control Specs	: 6-hour

Computed Results

Peak Discharge	: 218.22 (cfs)	Date/Time of Peak Discharge	: 01 Apr 01 0815
Total Precipitation	: 17.61 (in)	Total Direct Runoff	: 17.61 (in)
Total Loss	: 0.00 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 17.61 (in)	Total Discharge	: 17.61 (in)

HMS * Summary of Results for top slope #3

Project : LKV top slope #3 Run Name : Run 6

Start of Run : 01Apr01 0800 Basin Model : top slope #3

End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++

Execution Time : 12Sep01 1645 Control Specs : 6-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Apr 01	0800				0.00	0.00	0.00
01 Apr 01	0815	8.47	0.00	8.47	218.22	0.00	218.22
01 Apr 01	0830	3.60	0.00	3.60	92.73	0.00	92.73
01 Apr 01	0845	1.80	0.00	1.80	46.42	0.00	46.42
01 Apr 01	0900	1.44	0.00	1.44	37.02	0.00	37.02
01 Apr 01	0915	0.36	0.00	0.36	9.36	0.00	9.36
01 Apr 01	0930	0.36	0.00	0.36	9.29	0.00	9.29
01 Apr 01	0945	0.36	0.00	0.36	9.29	0.00	9.29
01 Apr 01	1000	0.36	0.00	0.36	9.26	0.00	9.26
01 Apr 01	1015	0.09	0.00	0.09	2.70	0.00	2.70
01 Apr 01	1030	0.09	0.00	0.09	2.33	0.00	2.33
01 Apr 01	1045	0.09	0.00	0.09	2.32	0.00	2.32
01 Apr 01	1100	0.09	0.00	0.09	2.32	0.00	2.32
01 Apr 01	1115	0.09	0.00	0.09	2.32	0.00	2.32
01 Apr 01	1130	0.09	0.00	0.09	2.32	0.00	2.32
01 Apr 01	1145	0.09	0.00	0.09	2.32	0.00	2.32
01 Apr 01	1200	0.09	0.00	0.09	2.31	0.00	2.31
01 Apr 01	1215	0.02	0.00	0.02	0.92	0.00	0.92
01 Apr 01	1230	0.02	0.00	0.02	0.52	0.00	0.52
01 Apr 01	1245	0.02	0.00	0.02	0.47	0.00	0.47
01 Apr 01	1300	0.02	0.00	0.02	0.46	0.00	0.46
01 Apr 01	1315	0.02	0.00	0.02	0.46	0.00	0.46
01 Apr 01	1330	0.02	0.00	0.02	0.46	0.00	0.46
01 Apr 01	1345	0.02	0.00	0.02	0.46	0.00	0.46
01 Apr 01	1400	0.02	0.00	0.02	0.46	0.00	0.46
		17.63					

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 7

Start of Run : 01Apr01 0800 Basin Model : LKV topslope
End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++
Execution Time : 17Sep01 1335 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
topslope	174.07	01 Apr 01 0815	7.9401	0.010
runoff	157.52	01 Apr 01 0815	8.0776	0.010

Area = 0.010
L = 500'
∴ W = 557.6'

174.07/557.6 = 0.312 cfs/ft

HMS * Summary of Results for topslope

Project : LKV top slope #3 Run Name : Run 7

Start of Run	: 01Apr01 0800	Basin Model	: LKV topslope
End of Run	: 01Apr01 1400	Met. Model	: 6 hr PMP, HMR 58 ++
Execution Time	: 17Sep01 1335	Control Specs	: 6-hour

Computed Results

Peak Discharge	: 174.07 (cfs)	Date/Time of Peak Discharge	: 01 Apr 01 0815
Total Precipitation	: 17.61 (in)	Total Direct Runoff	: 14.89 (in)
Total Loss	: 2.82 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 14.80 (in)	Total Discharge	: 14.89 (in)

HMS * Summary of Results for topslope

Project : LKV top slope #3 Run Name : Run 7

Start of Run : 01Apr01 0800 Basin Model : LKV topslope

End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++

Execution Time : 17Sep01 1335 Control Specs : 6-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Apr 01	0800				0.00	0.00	0.00
01 Apr 01	0815	8.47	1.72	6.75	174.07	0.00	174.07
01 Apr 01	0830	3.60	0.12	3.48	89.65	0.00	89.65
01 Apr 01	0845	1.80	0.10	1.70	43.96	0.00	43.96
01 Apr 01	0900	1.44	0.08	1.36	35.00	0.00	35.00
01 Apr 01	0915	0.36	0.07	0.29	7.87	0.00	7.87
01 Apr 01	0930	0.36	0.07	0.29	7.53	0.00	7.53
01 Apr 01	0945	0.36	0.06	0.30	7.65	0.00	7.65
01 Apr 01	1000	0.36	0.06	0.30	7.74	0.00	7.74
01 Apr 01	1015	0.09	0.06	0.03	2.15	0.00	2.15
01 Apr 01	1030	0.09	0.05	0.04	0.99	0.00	0.99
01 Apr 01	1045	0.09	0.05	0.04	0.95	0.00	0.95
01 Apr 01	1100	0.09	0.05	0.04	1.00	0.00	1.00
01 Apr 01	1115	0.09	0.05	0.04	1.05	0.00	1.05
01 Apr 01	1130	0.09	0.05	0.04	1.09	0.00	1.09
01 Apr 01	1145	0.09	0.05	0.04	1.12	0.00	1.12
01 Apr 01	1200	0.09	0.04	0.05	1.15	0.00	1.15
01 Apr 01	1215	0.02	0.02	0.00	0.67	0.00	0.67
01 Apr 01	1230	0.02	0.02	0.00	0.25	0.00	0.25
01 Apr 01	1245	0.02	0.02	0.00	0.12	0.00	0.12
01 Apr 01	1300	0.02	0.02	0.00	0.08	0.00	0.08
01 Apr 01	1315	0.02	0.02	0.00	0.06	0.00	0.06
01 Apr 01	1330	0.02	0.02	0.00	0.05	0.00	0.05
01 Apr 01	1345	0.02	0.02	0.00	0.05	0.00	0.05
01 Apr 01	1400	0.02	0.02	0.00	0.05	0.00	0.05

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 8

Start of Run : 01Apr01 0800 Basin Model : LKV topslope +
End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++
Execution Time : 17Sep01 1349 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
topslope	173.32	01 Apr 01 0815	7.8626	0.010
runoff	156.83	01 Apr 01 0815	7.9999	0.010

Area = 0.010
L = 500'
∴ W = 5576'

173.32/5576 = 0.311 cfs/ft

HMS * Summary of Results for topslope

Project : LKV top slope #3 Run Name : Run 8

Start of Run	: 01Apr01 0800	Basin Model	: LKV topslope +
End of Run	: 01Apr01 1400	Met. Model	: 6 hr PMP, HMR 58 ++
Execution Time	: 17Sep01 1349	Control Specs	: 6-hour

Computed Results

Peak Discharge	: 173.32 (cfs)	Date/Time of Peak Discharge	: 01 Apr 01 0815
Total Precipitation	: 17.61 (in)	Total Direct Runoff	: 14.74 (in)
Total Loss 16.8	: 2.96 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 14.65 (in)	Total Discharge	: 14.74 (in)

HMS * Summary of Results for topslope

Project : LKV top slope #3 Run Name : Run 8

Start of Run : 01Apr01 0800 Basin Model : LKV topslope +

End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++

Execution Time : 17Sep01 1349 Control Specs : 6-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Apr 01	0800				0.00	0.00	0.00
01 Apr 01	0815	8.47	1.75	6.72	173.32	0.00	173.32
01 Apr 01	0830	3.60	0.14	3.46	89.30	0.00	89.30
01 Apr 01	0845	1.80	0.11	1.69	43.69	0.00	43.69
01 Apr 01	0900	1.44	0.09	1.35	34.75	0.00	34.75
01 Apr 01	0915	0.36	0.08	0.28	7.67	0.00	7.67
01 Apr 01	0930	0.36	0.08	0.28	7.32	0.00	7.32
01 Apr 01	0945	0.36	0.07	0.29	7.46	0.00	7.46
01 Apr 01	1000	0.36	0.07	0.29	7.55	0.00	7.55
01 Apr 01	1015	0.09	0.06	0.03	2.03	0.00	2.03
01 Apr 01	1030	0.09	0.06	0.03	0.84	0.00	0.84
01 Apr 01	1045	0.09	0.06	0.03	0.78	0.00	0.78
01 Apr 01	1100	0.09	0.06	0.03	0.83	0.00	0.83
01 Apr 01	1115	0.09	0.05	0.04	0.88	0.00	0.88
01 Apr 01	1130	0.09	0.05	0.04	0.93	0.00	0.93
01 Apr 01	1145	0.09	0.05	0.04	0.97	0.00	0.97
01 Apr 01	1200	0.09	0.05	0.04	1.00	0.00	1.00
01 Apr 01	1215	0.02	0.02	0.00	0.61	0.00	0.61
01 Apr 01	1230	0.02	0.02	0.00	0.24	0.00	0.24
01 Apr 01	1245	0.02	0.02	0.00	0.12	0.00	0.12
01 Apr 01	1300	0.02	0.02	0.00	0.08	0.00	0.08
01 Apr 01	1315	0.02	0.02	0.00	0.06	0.00	0.06
01 Apr 01	1330	0.02	0.02	0.00	0.05	0.00	0.05
01 Apr 01	1345	0.02	0.02	0.00	0.05	0.00	0.05
01 Apr 01	1400	0.02	0.02	0.00	0.05	0.00	0.05

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 9

Start of Run : 01Apr01 0800 Basin Model : LKV topslope -
End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++
Execution Time : 17Sep01 1354 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
topslope	174.89	01 Apr 01 0815	8.0234	0.010
runoff	158.29	01 Apr 01 0815	8.1613	0.010

Area 0.010
L = 500'
∴ W = 5576'

174.89/5576 = 0.3140 cfs/ft

HMS * Summary of Results for topslope

Project : LKV top slope #3 Run Name : Run 9

Start of Run	: 01Apr01 0800	Basin Model	: LKV topslope -
End of Run	: 01Apr01 1400	Met. Model	: 6 hr PMP, HMR 58 ++
Execution Time	: 17Sep01 1354	Control Specs	: 6-hour

Computed Results

Peak Discharge	: 174.89 (cfs)	Date/Time of Peak Discharge	: 01 Apr 01 0815
Total Precipitation	: 17.61 (in)	Total Direct Runoff	: 15.04 (in)
Total Loss	: 2.66 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 14.96 (in)	Total Discharge	: 15.04 (in)

HMS * Summary of Results for topslope

Project : LKV top slope #3 Run Name : Run 9

Start of Run : 01Apr01 0800 Basin Model : LKV-topslope

End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++

Execution Time : 17Sep01 1354 Control Specs : 6-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Apr 01	0800				0.00	0.00	0.00
01 Apr 01	0815	8.47	1.69	6.78	174.89	0.00	174.89
01 Apr 01	0830	3.60	0.11	3.49	90.05	0.00	90.05
01 Apr 01	0845	1.80	0.08	1.72	44.27	0.00	44.27
01 Apr 01	0900	1.44	0.07	1.37	35.25	0.00	35.25
01 Apr 01	0915	0.36	0.06	0.30	8.09	0.00	8.09
01 Apr 01	0930	0.36	0.06	0.30	7.76	0.00	7.76
01 Apr 01	0945	0.36	0.06	0.30	7.87	0.00	7.87
01 Apr 01	1000	0.36	0.05	0.31	7.94	0.00	7.94
01 Apr 01	1015	0.09	0.05	0.04	2.27	0.00	2.27
01 Apr 01	1030	0.09	0.05	0.04	1.16	0.00	1.16
01 Apr 01	1045	0.09	0.05	0.04	1.14	0.00	1.14
01 Apr 01	1100	0.09	0.04	0.05	1.18	0.00	1.18
01 Apr 01	1115	0.09	0.04	0.05	1.22	0.00	1.22
01 Apr 01	1130	0.09	0.04	0.05	1.26	0.00	1.26
01 Apr 01	1145	0.09	0.04	0.05	1.29	0.00	1.29
01 Apr 01	1200	0.09	0.04	0.05	1.31	0.00	1.31
01 Apr 01	1215	0.02	0.02	0.00	0.73	0.00	0.73
01 Apr 01	1230	0.02	0.02	0.00	0.26	0.00	0.26
01 Apr 01	1245	0.02	0.02	0.00	0.13	0.00	0.13
01 Apr 01	1300	0.02	0.02	0.00	0.08	0.00	0.08
01 Apr 01	1315	0.02	0.02	0.00	0.06	0.00	0.06
01 Apr 01	1330	0.02	0.02	0.00	0.05	0.00	0.05
01 Apr 01	1345	0.02	0.02	0.00	0.05	0.00	0.05
01 Apr 01	1400	0.02	0.02	0.00	0.05	0.00	0.05
			2.69				

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 10

Start of Run : 01Apr01 0800 Basin Model : LKV side slope
End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++
Execution Time : 17Sep01 1456 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
side slope	209.57	01 Apr 01 0815	9.4657	0.010
runoff	190.57	01 Apr 01 0815	9.6171	0.010

w = 1000'

q = 209.57 cfs/1000' = 0.21 cfs/ft

HMS * Summary of Results for side slope

Project : LKV top slope #3 Run Name : Run 10

Start of Run	: 01Apr01 0800	Basin Model	: LKV side slope
End of Run	: 01Apr01 1400	Met. Model	: 6 hr PMP, HMR 58 ++
Execution Time	: 17Sep01 1456	Control Specs	: 6-hour

Computed Results

Peak Discharge	: 209.57 (cfs)	Date/Time of Peak Discharge	: 01 Apr 01 0815
Total Precipitation	: 17.61 (in)	Total Direct Runoff	: 18.30 (in)
Total Loss	: 0.04 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 17.58 (in)	Total Discharge	: 18.30 (in)

Project : LKV top slope #3 Run Name : Run 10

Start of Run : 01Apr01 0800 Basin Model : LKV side slope

End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++

Execution Time : 17Sep01 1456 Control Specs : 6-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Apr 01	0800				0.00	0.00	0.00
01 Apr 01	0815	8.47	0.02	8.45	209.57	0.00	209.57
01 Apr 01	0830	3.60	0.00	3.60	91.81	0.00	91.81
01 Apr 01	0845	1.80	0.00	1.80	47.70	0.00	47.70
01 Apr 01	0900	1.44	0.00	1.44	36.98	0.00	36.98
01 Apr 01	0915	0.36	0.00	0.36	15.34	0.00	15.34
01 Apr 01	0930	0.36	0.00	0.36	9.83	0.00	9.83
01 Apr 01	0945	0.36	0.00	0.36	9.08	0.00	9.08
01 Apr 01	1000	0.36	0.00	0.36	8.86	0.00	8.86
01 Apr 01	1015	0.09	0.00	0.09	5.51	0.00	5.51
01 Apr 01	1030	0.09	0.00	0.09	3.36	0.00	3.36
01 Apr 01	1045	0.09	0.00	0.09	2.60	0.00	2.60
01 Apr 01	1100	0.09	0.00	0.09	2.34	0.00	2.34
01 Apr 01	1115	0.09	0.00	0.09	2.27	0.00	2.27
01 Apr 01	1130	0.09	0.00	0.09	2.25	0.00	2.25
01 Apr 01	1145	0.09	0.00	0.09	2.24	0.00	2.24
01 Apr 01	1200	0.09	0.00	0.09	2.23	0.00	2.23
01 Apr 01	1215	0.02	0.00	0.02	1.70	0.00	1.70
01 Apr 01	1230	0.02	0.00	0.02	1.20	0.00	1.20
01 Apr 01	1245	0.02	0.00	0.02	0.84	0.00	0.84
01 Apr 01	1300	0.02	0.00	0.02	0.67	0.00	0.67
01 Apr 01	1315	0.02	0.00	0.02	0.56	0.00	0.56
01 Apr 01	1330	0.02	0.00	0.02	0.50	0.00	0.50
01 Apr 01	1345	0.02	0.00	0.02	0.47	0.00	0.47
01 Apr 01	1400	0.02	0.00	0.02	0.46	0.00	0.46

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 11

Start of Run : 01Jun99 0800 Basin Model : LKV topslope
End of Run : 02Jun99 0800 Met. Model : SCS 200 yr
Execution Time : 17Sep01 1519 Control Specs : 24-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
topslope	0.88710	01 Jun 99 2000	0.16784	0.010
runoff	0.81801	01 Jun 99 2000	0.16932	0.010

W = 557.6

q = 0.8871/557.6 = 0.0016 cfs/ft

HMS * Summary of Results for topslope

Project : LKV top slope #3 Run Name : Run 11

Start of Run	: 01Jun99 0800	Basin Model	: LKV topslope
End of Run	: 02Jun99 0800	Met. Model	: SCS 200 yr
Execution Time	: 17Sep01 1519	Control Specs	: 24-hour

Computed Results

Peak Discharge	: 0.88710 (cfs)	Date/Time of Peak Discharge	: 01 Jun 99 2000
Total Precipitation	: 3.15 (in)	Total Direct Runoff	: 0.31 (in)
Total Loss	: 2.83 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 0.32 (in)	Total Discharge	: 0.31 (in)

HMS * Summary of Results for topslope

Project : LKV top slope #3 Run Name : Run 11

Start of Run : 01Jun99 0800 Basin Model : LKV topslope

End of Run : 02Jun99 0800 Met. Model : SCS 200 yr

Execution Time : 17Sep01 1519 Control Specs : 24-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Jun 99	0800				0.00000	0.00000	0.00000
01 Jun 99	0900	0.03	0.03	0.00	0.00264	0.00000	0.00264
01 Jun 99	1000	0.04	0.03	0.00	0.01957	0.00000	0.01957
01 Jun 99	1100	0.04	0.04	0.00	0.02453	0.00000	0.02453
01 Jun 99	1200	0.04	0.04	0.00	0.02664	0.00000	0.02664
01 Jun 99	1300	0.05	0.04	0.00	0.02940	0.00000	0.02940
01 Jun 99	1400	0.05	0.05	0.01	0.03322	0.00000	0.03322
01 Jun 99	1500	0.06	0.05	0.01	0.03741	0.00000	0.03741
01 Jun 99	1600	0.07	0.06	0.01	0.04164	0.00000	0.04164
01 Jun 99	1700	0.09	0.08	0.01	0.05227	0.00000	0.05227
01 Jun 99	1800	0.11	0.10	0.01	0.06693	0.00000	0.06693
01 Jun 99	1900	0.17	0.15	0.02	0.10842	0.00000	0.10842
01 Jun 99	2000	1.35	1.21	0.14	0.88710	0.00000	0.88710
01 Jun 99	2100	0.34	0.31	0.03	0.22755	0.00000	0.22755
01 Jun 99	2200	0.15	0.14	0.02	0.10403	0.00000	0.10403
01 Jun 99	2300	0.11	0.09	0.01	0.07166	0.00000	0.07166
01 Jun 99	2400	0.08	0.08	0.01	0.05638	0.00000	0.05638
02 Jun 99	0100	0.07	0.06	0.01	0.04645	0.00000	0.04645
02 Jun 99	0200	0.06	0.05	0.01	0.04042	0.00000	0.04042
02 Jun 99	0300	0.05	0.05	0.01	0.03547	0.00000	0.03547
02 Jun 99	0400	0.05	0.04	0.00	0.03071	0.00000	0.03071
02 Jun 99	0500	0.04	0.04	0.00	0.02707	0.00000	0.02707
02 Jun 99	0600	0.04	0.03	0.00	0.02539	0.00000	0.02539
02 Jun 99	0700	0.04	0.03	0.00	0.02428	0.00000	0.02428
02 Jun 99	0800	0.04	0.03	0.00	0.02334	0.00000	0.02334

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 12

Start of Run : 01Jun99 0800 Basin Model : LKV side slope
End of Run : 02Jun99 0800 Met. Model : SCS 200 yr
Execution Time : 17Sep01 1523 Control Specs : 24-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
side slope	8.2753	01 Jun 99 2000	1.5770	0.010
runoff	7.9154	01 Jun 99 2000	1.5859	0.010

Area = 0.010 mi²

L = 870'

W = 1000'

q = 8.2753 cfs / 1000 = 0.0083 cfs/ft

HMS * Summary of Results for side slope

Project : LKV top slope #3 Run Name : Run 12

Start of Run	: 01Jun99 0800	Basin Model	: LKV side slope
End of Run	: 02Jun99 0800	Met. Model	: SCS 200 yr
Execution Time	: 17Sep01 1523	Control Specs	: 24-hour

Computed Results

Peak Discharge	: 8.2753 (cfs)	Date/Time of Peak Discharge	: 01 Jun 99 2000
Total Precipitation	: 3.15 (in)	Total Direct Runoff	: 3.05 (in)
Total Loss	: 0.07 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 3.08 (in)	Total Discharge	: 3.05 (in)

HMS * Summary of Results for side slope

Project : LKV top slope #3 Run Name : Run 12

Start of Run : 01Jun99 0800 Basin Model : LKV side slope

End of Run : 02Jun99 0800 Met. Model : SCS 200 yr

Execution Time : 17Sep01 1523 Control Specs : 24-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Jun 99	0800				0.0000	0.0000	0.0000
01 Jun 99	0900	0.03	0.02	0.01	0.0041	0.0000	0.0041
01 Jun 99	1000	0.04	0.00	0.03	0.0599	0.0000	0.0599
01 Jun 99	1100	0.04	0.00	0.04	0.1841	0.0000	0.1841
01 Jun 99	1200	0.04	0.00	0.04	0.2434	0.0000	0.2434
01 Jun 99	1300	0.05	0.00	0.05	0.2709	0.0000	0.2709
01 Jun 99	1400	0.05	0.00	0.05	0.3077	0.0000	0.3077
01 Jun 99	1500	0.06	0.00	0.06	0.3478	0.0000	0.3478
01 Jun 99	1600	0.07	0.00	0.06	0.3899	0.0000	0.3899
01 Jun 99	1700	0.09	0.00	0.08	0.4854	0.0000	0.4854
01 Jun 99	1800	0.11	0.00	0.11	0.6383	0.0000	0.6383
01 Jun 99	1900	0.17	0.00	0.17	1.1165	0.0000	1.1165
01 Jun 99	2000	1.35	0.00	1.35	8.2753	0.0000	8.2753
01 Jun 99	2100	0.34	0.00	0.34	2.2082	0.0000	2.2082
01 Jun 99	2200	0.15	0.00	0.15	1.0354	0.0000	1.0354
01 Jun 99	2300	0.11	0.00	0.10	0.6954	0.0000	0.6954
01 Jun 99	2400	0.08	0.00	0.08	0.5446	0.0000	0.5446
02 Jun 99	0100	0.07	0.00	0.07	0.4457	0.0000	0.4457
02 Jun 99	0200	0.06	0.00	0.06	0.3823	0.0000	0.3823
02 Jun 99	0300	0.05	0.00	0.05	0.3362	0.0000	0.3362
02 Jun 99	0400	0.05	0.00	0.04	0.2890	0.0000	0.2890
02 Jun 99	0500	0.04	0.00	0.04	0.2538	0.0000	0.2538
02 Jun 99	0600	0.04	0.00	0.04	0.2362	0.0000	0.2362
02 Jun 99	0700	0.04	0.00	0.03	0.2238	0.0000	0.2238
02 Jun 99	0800	0.04	0.00	0.03	0.2151	0.0000	0.2151

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 13

Start of Run : 01Jun99 0800 Basin Model : top slope #3

End of Run : 02Jun99 0800 Met. Model : SCS 200 yr

Execution Time : 25Sep01 1320 Control Specs : 24-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
top slope #3	8.6741	01 Jun 99 2000	1.6710	0.010
runoff	8.2996	01 Jun 99 2000	1.6809	0.010

Area = 0.010 mi²

L = 500'

∴ ft² = 5280'

8.6741 / 5280 = 0.02 cfs/ft

HMS * Summary of Results for top slope #3

Project : LKV top slope #3 Run Name : Run 13

Start of Run	: 01Jun99 0800	Basin Model	: top slope #3
End of Run	: 02Jun99 0800	Met. Model	: SCS 200 yr
Execution Time	: 25Sep01 1320	Control Specs	: 24-hour

Computed Results

Peak Discharge	: 8.6741 (cfs)	Date/Time of Peak Discharge	: 01 Jun 99 2000
Total Precipitation	: 3.15 (in)	Total Direct Runoff	: 3.13 (in)
Total Loss	: 0.00 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 3.15 (in)	Total Discharge	: 3.13 (in)

HMS * Summary of Results for top slope #3

Project : LKV top slope #3 Run Name : Run 13

Start of Run : 01Jun99 0800 Basin Model : top slope #3

End of Run : 02Jun99 0800 Met. Model : SCS 200 yr

Execution Time : 25Sep01 1320 Control Specs : 24-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Jun 99	0800				0.0000	0.0000	0.0000
01 Jun 99	0900	0.03	0.00	0.03	0.2118	0.0000	0.2118
01 Jun 99	1000	0.04	0.00	0.04	0.2339	0.0000	0.2339
01 Jun 99	1100	0.04	0.00	0.04	0.2542	0.0000	0.2542
01 Jun 99	1200	0.04	0.00	0.04	0.2747	0.0000	0.2747
01 Jun 99	1300	0.05	0.00	0.05	0.3051	0.0000	0.3051
01 Jun 99	1400	0.05	0.00	0.05	0.3458	0.0000	0.3458
01 Jun 99	1500	0.06	0.00	0.06	0.3865	0.0000	0.3865
01 Jun 99	1600	0.07	0.00	0.07	0.4281	0.0000	0.4281
01 Jun 99	1700	0.09	0.00	0.09	0.5502	0.0000	0.5502
01 Jun 99	1800	0.11	0.00	0.11	0.6946	0.0000	0.6946
01 Jun 99	1900	0.17	0.00	0.17	1.1368	0.0000	1.1368
01 Jun 99	2000	1.35	0.00	1.35	8.6741	0.0000	8.6741
01 Jun 99	2100	0.34	0.00	0.34	2.2100	0.0000	2.2100
01 Jun 99	2200	0.15	0.00	0.15	0.9731	0.0000	0.9731
01 Jun 99	2300	0.11	0.00	0.11	0.6796	0.0000	0.6796
01 Jun 99	2400	0.08	0.00	0.08	0.5378	0.0000	0.5378
02 Jun 99	0100	0.07	0.00	0.07	0.4428	0.0000	0.4428
02 Jun 99	0200	0.06	0.00	0.06	0.3899	0.0000	0.3899
02 Jun 99	0300	0.05	0.00	0.05	0.3393	0.0000	0.3393
02 Jun 99	0400	0.05	0.00	0.05	0.2904	0.0000	0.2904
02 Jun 99	0500	0.04	0.00	0.04	0.2582	0.0000	0.2582
02 Jun 99	0600	0.04	0.00	0.04	0.2500	0.0000	0.2500
02 Jun 99	0700	0.04	0.00	0.04	0.2378	0.0000	0.2378
02 Jun 99	0800	0.04	0.00	0.04	0.2297	0.0000	0.2297

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 14

Start of Run : 01Apr01 0800 Basin Model : LKV side slope
End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++
Execution Time : 01Oct01 1330 Control Specs : 6-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
side slope	210.05	01 Apr 01 0815	9.2604	0.010
runoff	191.02	01 Apr 01 0815	9.4149	0.010

unit discharge

210.05 cfs / 1000' = 0.21 cfs/ft

HMS * Summary of Results for side slope

Project : LKV top slope #3 Run Name : Run 14

Start of Run	: 01Apr01 0800	Basin Model	: LKV side slope
End of Run	: 01Apr01 1400	Met. Model	: 6 hr PMP, HMR 58 ++
Execution Time	: 01Oct01 1330	Control Specs	: 6-hour

Computed Results

Peak Discharge	: 210.05 (cfs)	Date/Time of Peak Discharge	: 01 Apr 01 0815
Total Precipitation	: 17.61 (in)	Total Direct Runoff	: 17.90 (in)
Total Loss	: 0.04 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 17.58 (in)	Total Discharge	: 17.90 (in)

HMS * Summary of Results for side slope

Project : LKV top slope #3 Run Name : Run 14

Start of Run : 01Apr01 0800 Basin Model : LKV side slope

End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++

Execution Time : 01Oct01 1330 Control Specs : 6-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Apr 01	0800				0.00	0.00	0.00
01 Apr 01	0815	8.47	0.02	8.45	210.05	0.00	210.05
01 Apr 01	0830	3.60	0.00	3.60	89.96	0.00	89.96
01 Apr 01	0845	1.80	0.00	1.80	45.78	0.00	45.78
01 Apr 01	0900	1.44	0.00	1.44	36.05	0.00	36.05
01 Apr 01	0915	0.36	0.00	0.36	12.75	0.00	12.75
01 Apr 01	0930	0.36	0.00	0.36	9.21	0.00	9.21
01 Apr 01	0945	0.36	0.00	0.36	9.01	0.00	9.01
01 Apr 01	1000	0.36	0.00	0.36	8.90	0.00	8.90
01 Apr 01	1015	0.09	0.00	0.09	4.75	0.00	4.75
01 Apr 01	1030	0.09	0.00	0.09	2.82	0.00	2.82
01 Apr 01	1045	0.09	0.00	0.09	2.36	0.00	2.36
01 Apr 01	1100	0.09	0.00	0.09	2.26	0.00	2.26
01 Apr 01	1115	0.09	0.00	0.09	2.24	0.00	2.24
01 Apr 01	1130	0.09	0.00	0.09	2.24	0.00	2.24
01 Apr 01	1145	0.09	0.00	0.09	2.24	0.00	2.24
01 Apr 01	1200	0.09	0.00	0.09	2.23	0.00	2.23
01 Apr 01	1215	0.02	0.00	0.02	1.54	0.00	1.54
01 Apr 01	1230	0.02	0.00	0.02	0.98	0.00	0.98
01 Apr 01	1245	0.02	0.00	0.02	0.68	0.00	0.68
01 Apr 01	1300	0.02	0.00	0.02	0.54	0.00	0.54
01 Apr 01	1315	0.02	0.00	0.02	0.48	0.00	0.48
01 Apr 01	1330	0.02	0.00	0.02	0.46	0.00	0.46
01 Apr 01	1345	0.02	0.00	0.02	0.45	0.00	0.45
01 Apr 01	1400	0.02	0.00	0.02	0.44	0.00	0.44

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 15

Start of Run : 01Jun99 0800 Basin Model : LKV side slope
End of Run : 02Jun99 0800 Met. Model : SCS 200 yr
Execution Time : 01Oct01 1332 Control Specs : 24-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
side slope	8.3465	01 Jun 99 2000	1.5752	0.010
runoff	7.9839	01 Jun 99 2000	1.5844	0.010

unit discharge

[illegible] cfs/1000' = [illegible]

HMS * Summary of Results for side slope

Project : LKV top slope #3 Run Name : Run 15

Start of Run	: 01Jun99 0800	Basin Model	: LKV side slope
End of Run	: 02Jun99 0800	Met. Model	: SCS 200 yr
Execution Time	: 01Oct01 1332	Control Specs	: 24-hour

Computed Results

Peak Discharge	: 8.3465 (cfs)	Date/Time of Peak Discharge	: 01 Jun 99 2000
Total Precipitation	: 3.15 (in)	Total Direct Runoff	: 3.04 (in)
Total Loss	: 0.07 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 3.08 (in)	Total Discharge	: 3.04 (in)

HMS * Summary of Results for side slope

Project : LKV top slope #3 Run Name : Run 15

Start of Run : 01Jun99 0800 Basin Model : LKV side slope

End of Run : 02Jun99 0800 Met. Model : SCS 200 yr

Execution Time : 01Oct01 1332 Control Specs : 24-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Jun 99	0800				0.0000	0.0000	0.0000
01 Jun 99	0900	0.03	0.02	0.01	0.0073	0.0000	0.0073
01 Jun 99	1000	0.04	0.00	0.03	0.0931	0.0000	0.0931
01 Jun 99	1100	0.04	0.00	0.04	0.2233	0.0000	0.2233
01 Jun 99	1200	0.04	0.00	0.04	0.2487	0.0000	0.2487
01 Jun 99	1300	0.05	0.00	0.05	0.2764	0.0000	0.2764
01 Jun 99	1400	0.05	0.00	0.05	0.3138	0.0000	0.3138
01 Jun 99	1500	0.06	0.00	0.06	0.3541	0.0000	0.3541
01 Jun 99	1600	0.07	0.00	0.06	0.3954	0.0000	0.3954
01 Jun 99	1700	0.09	0.00	0.08	0.5076	0.0000	0.5076
01 Jun 99	1800	0.11	0.00	0.11	0.6536	0.0000	0.6536
01 Jun 99	1900	0.17	0.00	0.17	1.1166	0.0000	1.1166
01 Jun 99	2000	1.35	0.00	1.35	8.3465	0.0000	8.3465
01 Jun 99	2100	0.34	0.00	0.34	2.1489	0.0000	2.1489
01 Jun 99	2200	0.15	0.00	0.15	0.9648	0.0000	0.9648
01 Jun 99	2300	0.11	0.00	0.10	0.6665	0.0000	0.6665
01 Jun 99	2400	0.08	0.00	0.08	0.5247	0.0000	0.5247
02 Jun 99	0100	0.07	0.00	0.07	0.4297	0.0000	0.4297
02 Jun 99	0200	0.06	0.00	0.06	0.3741	0.0000	0.3741
02 Jun 99	0300	0.05	0.00	0.05	0.3259	0.0000	0.3259
02 Jun 99	0400	0.05	0.00	0.04	0.2807	0.0000	0.2807
02 Jun 99	0500	0.04	0.00	0.04	0.2472	0.0000	0.2472
02 Jun 99	0600	0.04	0.00	0.04	0.2328	0.0000	0.2328
02 Jun 99	0700	0.04	0.00	0.03	0.2218	0.0000	0.2218
02 Jun 99	0800	0.04	0.00	0.03	0.2130	0.0000	0.2130

HMS * Summary of Results

Project : LKV top slope #3 Run Name : Run 16

Start of Run : 01Jun99 0800 Basin Model : LKV side slope imp.
End of Run : 02Jun99 0800 Met. Model : SCS 200 yr
Execution Time : 02Oct01 1230 Control Specs : 24-hour

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
side slope - imp	8.3416	01 Jun 99 2000	1.6140	0.010
runoff	7.9780	01 Jun 99 2000	1.6235	0.010

$q = \frac{8.3416\ cfs}{1000} = 0.00834\ cfs/ac$

HMS * Summary of Results for side slope - imp

Project : LKV top slope #3 Run Name : Run 16

Start of Run	: 01Jun99 0800	Basin Model	: LKV side slope imp.
End of Run	: 02Jun99 0800	Met. Model	: SCS 200 yr
Execution Time	: 02Oct01 1230	Control Specs	: 24-hour

Computed Results

Peak Discharge	: 8.3416 (cfs)	Date/Time of Peak Discharge	: 01 Jun 99 2000
Total Precipitation	: 3.15 (in)	Total Direct Runoff	: 3.12 (in)
Total Loss	: 0.00 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 3.15 (in)	Total Discharge	: 3.12 (in)

HMS * Summary of Results for side slope - imp

Project : LKV top slope #3 Run Name : Run 16

Start of Run : 01Jun99 0800 Basin Model : LKV side slope imp.

End of Run : 02Jun99 0800 Met. Model : SCS 200 yr

Execution Time : 02Oct01 1230 Control Specs : 24-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Jun 99	0800				0.0000	0.0000	0.0000
01 Jun 99	0900	0.03	0.00	0.03	0.2074	0.0000	0.2074
01 Jun 99	1000	0.04	0.00	0.04	0.2271	0.0000	0.2271
01 Jun 99	1100	0.04	0.00	0.04	0.2466	0.0000	0.2466
01 Jun 99	1200	0.04	0.00	0.04	0.2666	0.0000	0.2666
01 Jun 99	1300	0.05	0.00	0.05	0.2966	0.0000	0.2966
01 Jun 99	1400	0.05	0.00	0.05	0.3353	0.0000	0.3353
01 Jun 99	1500	0.06	0.00	0.06	0.3753	0.0000	0.3753
01 Jun 99	1600	0.07	0.00	0.07	0.4161	0.0000	0.4161
01 Jun 99	1700	0.09	0.00	0.09	0.5329	0.0000	0.5329
01 Jun 99	1800	0.11	0.00	0.11	0.6748	0.0000	0.6748
01 Jun 99	1900	0.17	0.00	0.17	1.0924	0.0000	1.0924
01 Jun 99	2000	1.35	0.00	1.35	8.3416	0.0000	8.3416
01 Jun 99	2100	0.34	0.00	0.34	2.1402	0.0000	2.1402
01 Jun 99	2200	0.15	0.00	0.15	0.9424	0.0000	0.9424
01 Jun 99	2300	0.11	0.00	0.11	0.6601	0.0000	0.6601
01 Jun 99	2400	0.08	0.00	0.08	0.5208	0.0000	0.5208
02 Jun 99	0100	0.07	0.00	0.07	0.4292	0.0000	0.4292
02 Jun 99	0200	0.06	0.00	0.06	0.3777	0.0000	0.3777
02 Jun 99	0300	0.05	0.00	0.05	0.3292	0.0000	0.3292
02 Jun 99	0400	0.05	0.00	0.05	0.2817	0.0000	0.2817
02 Jun 99	0500	0.04	0.00	0.04	0.2504	0.0000	0.2504
02 Jun 99	0600	0.04	0.00	0.04	0.2424	0.0000	0.2424
02 Jun 99	0700	0.04	0.00	0.04	0.2307	0.0000	0.2307
02 Jun 99	0800	0.04	0.00	0.04	0.2228	0.0000	0.2228

HMS * Summary of Results for top slope #3

Project : LKV top slope #3 Run Name : Run 19

Start of Run	: 01Apr01 0800	Basin Model	: top slope #3
End of Run	: 01Apr01 1400	Met. Model	: NRC 1/2
Execution Time	: 16Apr02 1307	Control Specs	: 6-hour

Computed Results

Peak Discharge	: 108.55 (cfs)	Date/Time of Peak Discharge	: 01 Apr 01 0815
Total Precipitation	: 4.24 (in)	Total Direct Runoff	: 4.30 (in)
Total Loss	: 0.00 (in)	Total Baseflow	: 0.00 (in)
Total Excess	: 4.24 (in)	Total Discharge	: 4.30 (in)

HMS * Summary of Results for top slope #3

Project : LKV top slope #3 Run Name : Run 19

Start of Run : 01Apr01 0800 Basin Model : top slope #3

End of Run : 01Apr01 1400 Met. Model : NRC 1/2

Execution Time : 16Apr02 1307 Control Specs : 6-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Apr 01	0800				0.00	0.00	0.00
01 Apr 01	0815	4.24	0.00	4.24	108.55	0.00	108.55
01 Apr 01	0830	0.00	0.00	0.00	1.75	0.00	1.75
01 Apr 01	0845	0.00	0.00	0.00	0.31	0.00	0.31
01 Apr 01	0900	0.00	0.00	0.00	0.11	0.00	0.11
01 Apr 01	0915	0.00	0.00	0.00	0.05	0.00	0.05
01 Apr 01	0930	0.00	0.00	0.00	0.03	0.00	0.03
01 Apr 01	0945	0.00	0.00	0.00	0.02	0.00	0.02
01 Apr 01	1000	0.00	0.00	0.00	0.01	0.00	0.01
01 Apr 01	1015	0.00	0.00	0.00	0.01	0.00	0.01
01 Apr 01	1030	0.00	0.00	0.00	0.01	0.00	0.01
01 Apr 01	1045	0.00	0.00	0.00	0.01	0.00	0.01
01 Apr 01	1100	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1115	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1130	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1145	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1200	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1215	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1230	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1245	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1300	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1315	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1330	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1345	0.00	0.00	0.00	0.00	0.00	0.00
01 Apr 01	1400	0.00	0.00	0.00	0.00	0.00	0.00

HMS * Summary of Results for side slope

Project : LKV top slope #3 Run Name : ~~Run-10~~ Run 20 modified by G. Smith 4/16/02

Start of Run : 01Apr01 0800 Basin Model : LKV side slope

End of Run : 01Apr01 1400 Met. Model : 6 hr PMP, HMR 58 ++

Execution Time : 17Sep01 1456 Control Specs : 6-hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
01 Apr 01	0800				0.00	0.00	0.00
01 Apr 01	0815	8.47	0.02	8.45	209.57 104.79	0.00	209.57
01 Apr 01	0830	3.60	0.00	3.60	91.81 45.91	0.00	91.81
01 Apr 01	0845	1.80	0.00	1.80	47.70 23.85	0.00	47.70
01 Apr 01	0900	1.44	0.00	1.44	36.98	0.00	36.98
01 Apr 01	0915	0.36	0.00	0.36	15.34	0.00	15.34
01 Apr 01	0930	0.36	0.00	0.36	9.83	0.00	9.83
01 Apr 01	0945	0.36	0.00	0.36	9.08	0.00	9.08
01 Apr 01	1000	0.36	0.00	0.36	8.86	0.00	8.86
01 Apr 01	1015	0.09	0.00	0.09	5.51	0.00	5.51
01 Apr 01	1030	0.09	0.00	0.09	3.36	0.00	3.36
01 Apr 01	1045	0.09	0.00	0.09	2.60	0.00	2.60
01 Apr 01	1100	0.09	0.00	0.09	2.34	0.00	2.34
01 Apr 01	1115	0.09	0.00	0.09	2.27	0.00	2.27
01 Apr 01	1130	0.09	0.00	0.09	2.25	0.00	2.25
01 Apr 01	1145	0.09	0.00	0.09	2.24	0.00	2.24
01 Apr 01	1200	0.09	0.00	0.09	2.23	0.00	2.23
01 Apr 01	1215	0.02	0.00	0.02	1.70	0.00	1.70
01 Apr 01	1230	0.02	0.00	0.02	1.20	0.00	1.20
01 Apr 01	1245	0.02	0.00	0.02	0.84	0.00	0.84
01 Apr 01	1300	0.02	0.00	0.02	0.67	0.00	0.67
01 Apr 01	1315	0.02	0.00	0.02	0.56	0.00	0.56
01 Apr 01	1330	0.02	0.00	0.02	0.50	0.00	0.50
01 Apr 01	1345	0.02	0.00	0.02	0.47	0.00	0.47
01 Apr 01	1400	0.02	0.00	0.02	0.46	0.00	0.46

Appendix C
Lakeview 2 NNW Maximum Daily Precipitation Records

LKV Precipitation
Maximum Recorded Values
Jan. 1, 1928 to Jul. 31, 2000

		rainfall amount (in)	1.4	1 8	2.0	2 4	2 6	2 8	3 2	8 5
		recurrance interval	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	PMP
day of year	record rainfall amount						percent			
1	0 98		70	54	49	41	38	35	31	12
2	0 67		48	37	34	28	26	24	21	8
3	0 36		26	20	18	15	14	13	11	4
4	1.19		85	66	60	50	46	43	37	14
5	0 63		45	35	32	26	24	23	20	7
6	0 62		44	34	31	26	24	22	19	7
7	0.71		51	39	36	30	27	25	22	8
8	0 62		44	34	31	26	24	22	19	7
9	0.53		38	29	27	22	20	19	17	6
10	1.13		81	63	57	47	43	40	35	13
11	1.02		73	57	51	43	39	36	32	12
12	0 88		63	49	44	37	34	31	28	10
13	0 59		42	33	30	25	23	21	18	7
14	0.99		71	55	50	41	38	35	31	12
15	0.86		61	48	43	36	33	31	27	10
16	0 81		58	45	41	34	31	29	25	10
17	0 62		44	34	31	26	24	22	19	7
18	0 51		36	28	26	21	20	18	16	6
19	1 34		96	74	67	56	52	48	42	16
20	1.78		127	99	89	74	68	64	56	21
21	1.09		78	61	55	45	42	39	34	13
22	0 79		56	44	40	33	30	28	25	9
23	0 96		69	53	48	40	37	34	30	11
24	0 77		55	43	39	32	30	28	24	9
25	0.78		56	43	39	33	30	28	24	9
26	0 61		44	34	31	25	23	22	19	7
27	0.74		53	41	37	31	28	26	23	9
28	0 56		40	31	28	23	22	20	18	7
29	0 38		27	21	19	16	15	14	12	4
30	0.77		55	43	39	32	30	28	24	9
31	0.77		55	43	39	32	30	28	24	9
32	0.37		26	21	19	15	14	13	12	4
33	0.53		38	29	27	22	20	19	17	6
34	0.60		43	33	30	25	23	21	19	7
35	0 73		52	41	37	30	28	26	23	9
36	1.03		74	57	52	43	40	37	32	12
37	0 65		46	36	33	27	25	23	20	8
38	1.01		72	56	51	42	39	36	32	12
39	0 70		50	39	35	29	27	25	22	8
40	1.53		109	85	77	64	59	55	48	18
41	1.13		81	63	57	47	43	40	35	13
42	0 45		32	25	23	19	17	16	14	5
43	0 57		41	32	29	24	22	20	18	7
44	0 55		39	31	28	23	21	20	17	6
45	0 51		36	28	26	21	20	18	16	6
46	0 64		46	36	32	27	25	23	20	8
47	0 43		31	24	22	18	17	15	13	5
48	0 43		31	24	22	18	17	15	13	5
49	0 59		42	33	30	25	23	21	18	7
50	0 95		68	53	48	40	37	34	30	11
51	0 68		49	38	34	28	26	24	21	8
52	0 49		35	27	25	20	19	18	15	6
53	0 95		68	53	48	40	37	34	30	11
54	0.34		24	19	17	14	13	12	11	4

LKV Precipitation
Maximum Recorded Values
Jan. 1, 1928 to Jul. 31, 2000

		rainfall amount (in)	1.4	1.8	2 0	2 4	2 6	2.8	3 2	8 5
		recurrance interval	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	PMP
day of year	record rainfall amount						percent			
55	0 92		66	51	46	38	35	33	29	11
56	0 35		25	19	18	15	13	13	11	4
57	0 78		56	43	39	33	30	28	24	9
58	0 62		44	34	31	26	24	22	19	7
59	0.88		63	49	44	37	34	31	28	10
60	0.95		68	53	48	40	37	34	30	11
61	0 58		41	32	29	24	22	21	18	7
62	0 61		44	34	31	25	23	22	19	7
63	0 70		50	39	35	29	27	25	22	8
64	0.81		58	45	41	34	31	29	25	10
65	0 46		33	26	23	19	18	16	14	5
66	0 84		60	47	42	35	32	30	26	10
67	0 85		61	47	43	35	33	30	27	10
68	0.97		69	54	49	40	37	35	30	11
69	0.61		44	34	31	25	23	22	19	7
70	0.51		36	28	26	21	20	18	16	6
71	0 69		49	38	35	29	27	25	22	8
72	1 22		87	68	61	51	47	44	38	14
73	0 40		29	22	20	17	15	14	13	5
74	0 67		48	37	34	28	26	24	21	8
75	0.70		50	39	35	29	27	25	22	8
76	0 44		31	24	22	18	17	16	14	5
77	0 42		30	23	21	18	16	15	13	5
78	0.57		41	32	29	24	22	20	18	7
79	0.64		46	36	32	27	25	23	20	8
80	0.55		39	31	28	23	21	20	17	6
81	0 61		44	34	31	25	23	22	19	7
82	0 48		34	27	24	20	18	17	15	6
83	0 89		64	49	45	37	34	32	28	10
84	0 69		49	38	35	29	27	25	22	8
85	0 87		62	48	44	36	33	31	27	10
86	0 72		51	40	36	30	28	26	23	8
87	0 49		35	27	25	20	19	18	15	6
88	0 43		31	24	22	18	17	15	13	5
89	0 54		39	30	27	23	21	19	17	6
90	0 61		44	34	31	25	23	22	19	7
91	0.30		21	17	15	13	12	11	9	4
92	1 04		74	58	52	43	40	37	33	12
93	0 37		26	21	19	15	14	13	12	4
94	0 62		44	34	31	26	24	22	19	7
95	0.38		27	21	19	16	15	14	12	4
96	0.42		30	23	21	18	16	15	13	5
97	0 63		45	35	32	26	24	23	20	7
98	0 55		39	31	28	23	21	20	17	6
99	0 42		30	23	21	18	16	15	13	5
100	0.33		24	18	17	14	13	12	10	4
101	1.10		79	61	55	46	42	39	34	13
102	0.33		24	18	17	14	13	12	10	4
103	0 30		21	17	15	13	12	11	9	4
104	0.50		36	28	25	21	19	18	16	6
105	1.15		82	64	58	48	44	41	36	14
106	0 48		34	27	24	20	18	17	15	6
107	0 31		22	17	16	13	12	11	10	4
108	0 63		45	35	32	26	24	23	20	7

LKV Precipitation
Maximum Recorded Values
Jan. 1, 1928 to Jul. 31, 2000

		rainfall amount (in)	1.4	1.8	2.0	2.4	2.6	2.8	3.2	8.5
		recurrance interval	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	PMP
day of year	record rainfall amount						percent			
109	0.70		50	39	35	29	27	25	22	8
110	0.37		26	21	19	15	14	13	12	4
111	0.67		48	37	34	28	26	24	21	8
112	0.39		28	22	20	16	15	14	12	5
113	0.51		36	28	26	21	20	18	16	6
114	0.56		40	31	28	23	22	20	18	7
115	0.38		27	21	19	16	15	14	12	4
116	0.90		64	50	45	38	35	32	28	11
117	0.41		29	23	21	17	16	15	13	5
118	0.52		37	29	26	22	20	19	16	6
119	0.60		43	33	30	25	23	21	19	7
120	0.71		51	39	36	30	27	25	22	8
121	1.01		72	56	51	42	39	36	32	12
122	0.74		53	41	37	31	28	26	23	9
123	0.39		28	22	20	16	15	14	12	5
124	1.10		79	61	55	46	42	39	34	13
125	0.48		34	27	24	20	18	17	15	6
126	0.46		33	26	23	19	18	16	14	5
127	1.35		96	75	68	56	52	48	42	16
128	0.83		59	46	42	35	32	30	26	10
129	0.71		51	39	36	30	27	25	22	8
130	0.57		41	32	29	24	22	20	18	7
131	0.57		41	32	29	24	22	20	18	7
132	0.87		62	48	44	36	33	31	27	10
133	0.32		23	18	16	13	12	11	10	4
134	0.64		46	36	32	27	25	23	20	8
135	0.83		59	46	42	35	32	30	26	10
136	0.42		30	23	21	18	16	15	13	5
137	0.76		54	42	38	32	29	27	24	9
138	0.85		61	47	43	35	33	30	27	10
139	0.57		41	32	29	24	22	20	18	7
140	0.83		59	46	42	35	32	30	26	10
141	0.34		24	19	17	14	13	12	11	4
142	0.45		32	25	23	19	17	16	14	5
143	0.32		23	18	16	13	12	11	10	4
144	0.91		65	51	46	38	35	33	28	11
145	0.53		38	29	27	22	20	19	17	6
146	0.44		31	24	22	18	17	16	14	5
147	0.64		46	36	32	27	25	23	20	8
148	0.61		44	34	31	25	23	22	19	7
149	0.57		41	32	29	24	22	20	18	7
150	0.69		49	38	35	29	27	25	22	8
151	1.12		80	62	56	47	43	40	35	13
152	0.77		55	43	39	32	30	28	24	9
153	0.52		37	29	26	22	20	19	16	6
154	0.76		54	42	38	32	29	27	24	9
155	0.59		42	33	30	25	23	21	18	7
156	1.24		89	69	62	52	48	44	39	15
157	0.93		66	52	47	39	36	33	29	11
158	1.82		130	101	91	76	70	65	57	21
159	1.02		73	57	51	43	39	36	32	12
160	1.23		88	68	62	51	47	44	38	14
161	1.25		89	69	63	52	48	45	39	15
162	0.89		64	49	45	37	34	32	28	10

LKV Precipitation
Maximum Recorded Values
Jan. 1, 1928 to Jul. 31, 2000

		rainfall amount (in)	1 4	1.8	2.0	2 4	2 6	2 8	3 2	8 5
		recurrance interval	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	PMP
day of year	record rainfall amount						percent			
163	0 63		45	35	32	26	24	23	20	7
164	0 40		29	22	20	17	15	14	13	5
165	0 40		29	22	20	17	15	14	13	5
166	0 80		57	44	40	33	31	29	25	9
167	0 55		39	31	28	23	21	20	17	6
168	1.19		85	66	60	50	46	43	37	14
169	0 83		59	46	42	35	32	30	26	10
170	0 59		42	33	30	25	23	21	18	7
171	0 86		61	48	43	36	33	31	27	10
172	0 45		32	25	23	19	17	16	14	5
173	0 36		26	20	18	15	14	13	11	4
174	0 39		28	22	20	16	15	14	12	5
175	0 59		42	33	30	25	23	21	18	7
176	0.70		50	39	35	29	27	25	22	8
177	0 52		37	29	26	22	20	19	16	6
178	0 56		40	31	28	23	22	20	18	7
179	0 60		43	33	30	25	23	21	19	7
180	0 57		41	32	29	24	22	20	18	7
181	0 67		48	37	34	28	26	24	21	8
182	0 65		46	36	33	27	25	23	20	8
183	0 29		21	16	15	12	11	10	9	3
184	0 34		24	19	17	14	13	12	11	4
185	0.58		41	32	29	24	22	21	18	7
186	0.17		12	9	9	7	7	6	5	2
187	0 39		28	22	20	16	15	14	12	5
188	0.16		11	9	8	7	6	6	5	2
189	0 15		11	8	8	6	6	5	5	2
190	0 45		32	25	23	19	17	16	14	5
191	0.14		10	8	7	6	5	5	4	2
192	0 21		15	12	11	9	8	8	7	2
193	0 34		24	19	17	14	13	12	11	4
194	0 37		26	21	19	15	14	13	12	4
195	0 03		2	2	2	1	1	1	1	0
196	0 05		4	3	3	2	2	2	2	1
197	0 54		39	30	27	23	21	19	17	6
198	0 09		6	5	5	4	3	3	3	1
199	0 63		45	35	32	26	24	23	20	7
200	0 79		56	44	40	33	30	28	25	9
201	0 28		20	16	14	12	11	10	9	3
202	0.16		11	9	8	7	6	6	5	2
203	0 54		39	30	27	23	21	19	17	6
204	0 55		39	31	28	23	21	20	17	6
205	0.56		40	31	28	23	22	20	18	7
206	0 00		0	0	0	0	0	0	0	0
207	0.32		23	18	16	13	12	11	10	4
208	0 25		18	14	13	10	10	9	8	3
209	0 44		31	24	22	18	17	16	14	5
210	0.31		22	17	16	13	12	11	10	4
211	0 27		19	15	14	11	10	10	8	3
212	0 22		16	12	11	9	8	8	7	3
213	0 17		12	9	9	7	7	6	5	2
214	0 23		16	13	12	10	9	8	7	3
215	0.32		23	18	16	13	12	11	10	4
216	0.18		13	10	9	8	7	6	6	2

LKV Precipitation
Maximum Recorded Values
Jan. 1, 1928 to Jul. 31, 2000

		rainfall amount (in)	1 4	1.8	2.0	2 4	2 6	2 8	3 2	8 5
		recurrance interval	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	PMP
day of year	record rainfall amount						percent			
217	0 09		6	5	5	4	3	3	3	1
218	0.17		12	9	9	7	7	6	5	2
219	0 51		36	28	26	21	20	18	16	6
220	0 08		6	4	4	3	3	3	3	1
221	0 09		6	5	5	4	3	3	3	1
222	0 17		12	9	9	7	7	6	5	2
223	0 42		30	23	21	18	16	15	13	5
224	0.73		52	41	37	30	28	26	23	9
225	0.46		33	26	23	19	18	16	14	5
226	0.58		41	32	29	24	22	21	18	7
227	0 21		15	12	11	9	8	8	7	2
228	0 75		54	42	38	31	29	27	23	9
229	0 13		9	7	7	5	5	5	4	2
230	0 25		18	14	13	10	10	9	8	3
231	0 40		29	22	20	17	15	14	13	5
232	0.48		34	27	24	20	18	17	15	6
233	0 65		46	36	33	27	25	23	20	8
234	0.05		4	3	3	2	2	2	2	1
235	0 36		26	20	18	15	14	13	11	4
236	0 22		16	12	11	9	8	8	7	3
237	0 26		19	14	13	11	10	9	8	3
238	0 50		36	28	25	21	19	18	16	6
239	0 34		24	19	17	14	13	12	11	4
240	0 07		5	4	4	3	3	3	2	1
241	0 63		45	35	32	26	24	23	20	7
242	0 37		26	21	19	15	14	13	12	4
243	1 00		71	56	50	42	38	36	31	12
244	0 34		24	19	17	14	13	12	11	4
245	0 39		28	22	20	16	15	14	12	5
246	0.12		9	7	6	5	5	4	4	1
247	1.20		86	67	60	50	46	43	38	14
248	0.17		12	9	9	7	7	6	5	2
249	0 06		4	3	3	3	2	2	2	1
250	0.09		6	5	5	4	3	3	3	1
251	0 25		18	14	13	10	10	9	8	3
252	1.17		84	65	59	49	45	42	37	14
253	0.77		55	43	39	32	30	28	24	9
254	0.15		11	8	8	6	6	5	5	2
255	0.34		24	19	17	14	13	12	11	4
256	0.57		41	32	29	24	22	20	18	7
257	0.25		18	14	13	10	10	9	8	3
258	0.63		45	35	32	26	24	23	20	7
259	0.57		41	32	29	24	22	20	18	7
260	0.51		36	28	26	21	20	18	16	6
261	0.50		36	28	25	21	19	18	16	6
262	0 76		54	42	38	32	29	27	24	9
263	0.81		58	45	41	34	31	29	25	10
264	0.30		21	17	15	13	12	11	9	4
265	0 65		46	36	33	27	25	23	20	8
266	0 59		42	33	30	25	23	21	18	7
267	0 45		32	25	23	19	17	16	14	5
268	0 27		19	15	14	11	10	10	8	3
269	0.33		24	18	17	14	13	12	10	4
270	0 89		64	49	45	37	34	32	28	10

LKV Precipitation
Maximum Recorded Values
Jan. 1, 1928 to Jul. 31, 2000

		rainfall amount (in)	1 4	1.8	2 0	2 4	2 6	2 8	3 2	8 5
		recurrance interval	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	PMP
day of year	record rainfall amount						percent			
271	0 46		33	26	23	19	18	16	14	5
272	0 43		31	24	22	18	17	15	13	5
273	0 59		42	33	30	25	23	21	18	7
274	0 35		25	19	18	15	13	13	11	4
275	0 52		37	29	26	22	20	19	16	6
276	0 97		69	54	49	40	37	35	30	11
277	0 31		22	17	16	13	12	11	10	4
278	0 32		23	18	16	13	12	11	10	4
279	0 39		28	22	20	16	15	14	12	5
280	0 23		16	13	12	10	9	8	7	3
281	0 43		31	24	22	18	17	15	13	5
282	0 46		33	26	23	19	18	16	14	5
283	1 15		82	64	58	48	44	41	36	14
284	2 10		150	117	105	88	81	75	66	25
285	0 81		58	45	41	34	31	29	25	10
286	1 41		101	78	71	59	54	50	44	17
287	0 82		59	46	41	34	32	29	26	10
288	0 49		35	27	25	20	19	18	15	6
289	0.71		51	39	36	30	27	25	22	8
290	0 57		41	32	29	24	22	20	18	7
291	0 33		24	18	17	14	13	12	10	4
292	0 36		26	20	18	15	14	13	11	4
293	0 24		17	13	12	10	9	9	8	3
294	0 49		35	27	25	20	19	18	15	6
295	0 29		21	16	15	12	11	10	9	3
296	0 85		61	47	43	35	33	30	27	10
297	0 47		34	26	24	20	18	17	15	6
298	0 69		49	38	35	29	27	25	22	8
299	0.60		43	33	30	25	23	21	19	7
300	0.68		49	38	34	28	26	24	21	8
301	1.03		74	57	52	43	40	37	32	12
302	0.57		41	32	29	24	22	20	18	7
303	0.58		41	32	29	24	22	21	18	7
304	0.98		70	54	49	41	38	35	31	12
305	0 29		21	16	15	12	11	10	9	3
306	1 05		75	58	53	44	40	38	33	12
307	0.74		53	41	37	31	28	26	23	9
308	0.69		49	38	35	29	27	25	22	8
309	0 84		60	47	42	35	32	30	26	10
310	0.73		52	41	37	30	28	26	23	9
311	0 69		49	38	35	29	27	25	22	8
312	0.70		50	39	35	29	27	25	22	8
313	0.47		34	26	24	20	18	17	15	6
314	0 69		49	38	35	29	27	25	22	8
315	0 56		40	31	28	23	22	20	18	7
316	0.45		32	25	23	19	17	16	14	5
317	1 06		76	59	53	44	41	38	33	12
318	0.77		55	43	39	32	30	28	24	9
319	0 40		29	22	20	17	15	14	13	5
320	1.27		91	71	64	53	49	45	40	15
321	0 68		49	38	34	28	26	24	21	8
322	0 57		41	32	29	24	22	20	18	7
323	0 57		41	32	29	24	22	20	18	7
324	1.02		73	57	51	43	39	36	32	12

LKV Precipitation
Maximum Recorded Values
Jan. 1, 1928 to Jul. 31, 2000

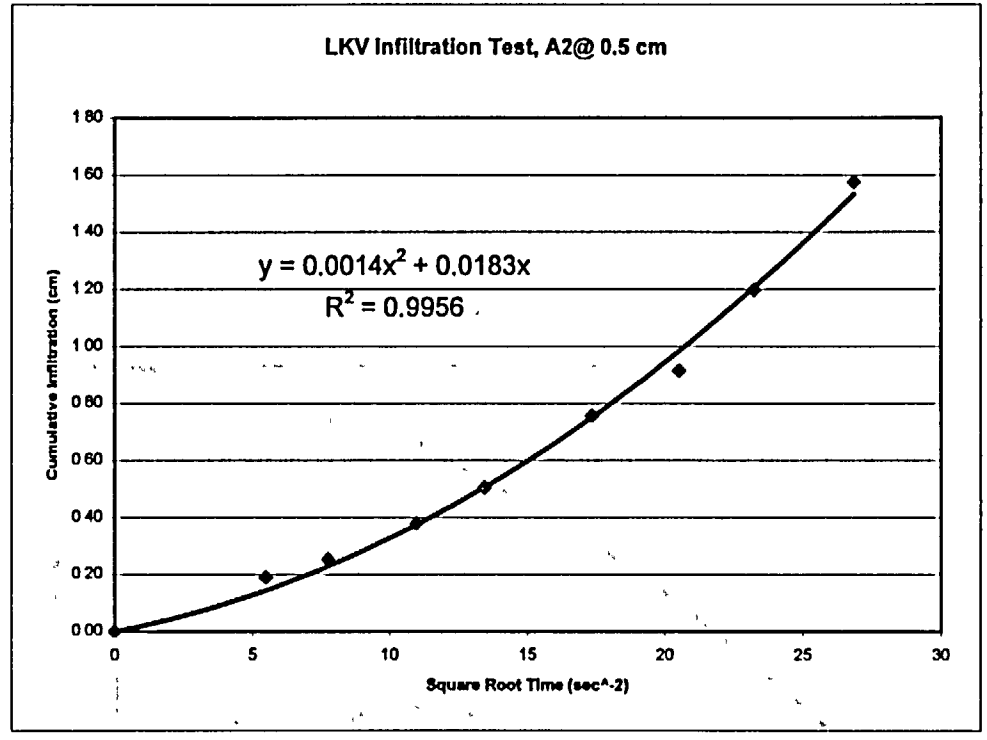
		rainfall amount (in)	1 4	1 8	2 0	2 4	2 6	2 8	3 2	8 5
		recurrance interval	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	PMP
day of year	record rainfall amount						percent			
325	1.14		81	63	57	48	44	41	36	13
326	1.10		79	61	55	46	42	39	34	13
327	0.79		56	44	40	33	30	28	25	9
328	0.81		58	45	41	34	31	29	25	10
329	0.72		51	40	36	30	28	26	23	8
330	1.16		83	64	58	48	45	41	36	14
331	0.90		64	50	45	38	35	32	28	11
332	0 45		32	25	23	19	17	16	14	5
333	2 02		144	112	101	84	78	72	63	24
334	0.43		31	24	22	18	17	15	13	5
335	0 31		22	17	16	13	12	11	10	4
336	0.87		62	48	44	36	33	31	27	10
337	0.62		44	34	31	26	24	22	19	7
338	1.11		79	62	56	46	43	40	35	13
339	0 56		40	31	28	23	22	20	18	7
340	0.61		44	34	31	25	23	22	19	7
341	0 46		33	26	23	19	18	16	14	5
342	0.42		30	23	21	18	16	15	13	5
343	0 54		39	30	27	23	21	19	17	6
344	0 74		53	41	37	31	28	26	23	9
345	2.39		171	133	120	100	92	85	75	28
346	0 61		44	34	31	25	23	22	19	7
347	1.10		79	61	55	46	42	39	34	13
348	0 65		46	36	33	27	25	23	20	8
349	0 78		56	43	39	33	30	28	24	9
350	1.02		73	57	51	43	39	36	32	12
351	0 36		26	20	18	15	14	13	11	4
352	1.02		73	57	51	43	39	36	32	12
353	0 65		46	36	33	27	25	23	20	8
354	1.66		119	92	83	69	64	59	52	20
355	0 62		44	34	31	26	24	22	19	7
356	0.83		59	46	42	35	32	30	26	10
357	2.27		162	126	114	95	87	81	71	27
358	0.88		63	49	44	37	34	31	28	10
359	0 63		45	35	32	26	24	23	20	7
360	0 70		50	39	35	29	27	25	22	8
361	0.76		54	42	38	32	29	27	24	9
362	0 80		57	44	40	33	31	29	25	9
363	0 58		41	32	29	24	22	21	18	7
364	0 93		66	52	47	39	36	33	29	11
365	0 75		54	42	38	31	29	27	23	9
366	0 63		45	35	32	26	24	23	20	7
	2.39	maximum	171	133	120	100	92	85	75	28

Appendix E
Disk Infiltrometer Data and Hydraulic Conductivity Determination Plots

Site A2 bare soil

h = 0.5 cm

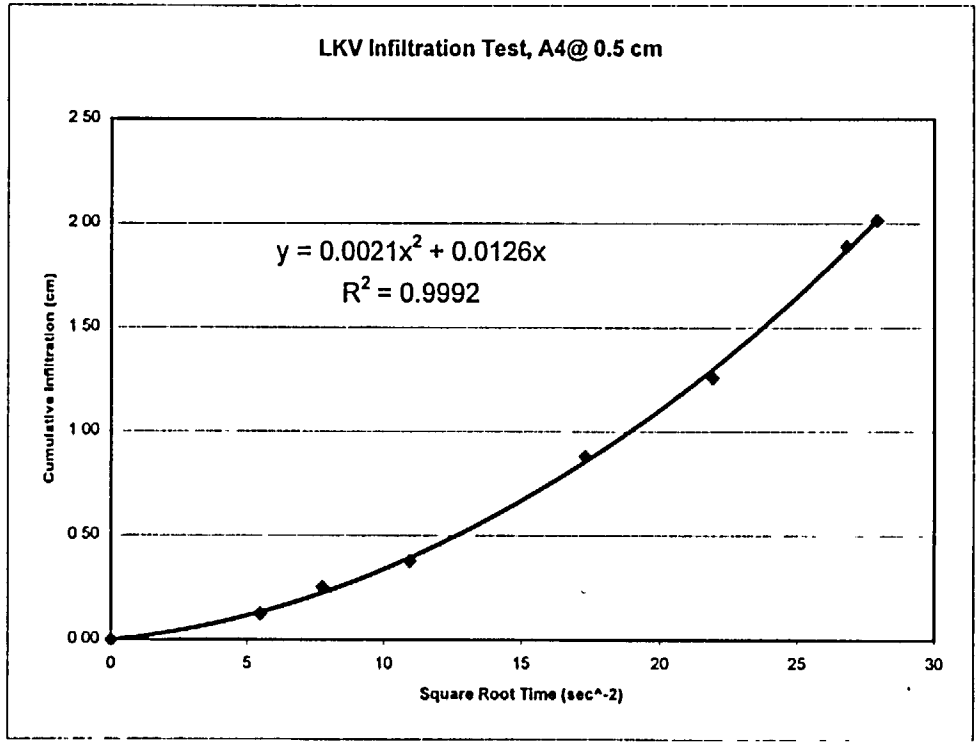
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
30	1.5	5.477	0.189
60	2.0	7.746	0.252
120	3.0	10.954	0.378
180	4.0	13.416	0.504
300	6.0	17.321	0.756
420	7.3	20.494	0.913
540	9.5	23.238	1.196
720	12.5	26.833	1.574



Site A4 **bare soil, rocky edge, trc fi grvl, desiccation cracking, wet soil due to tipping infiltrometer & restarting test**

h = 0.5 cm

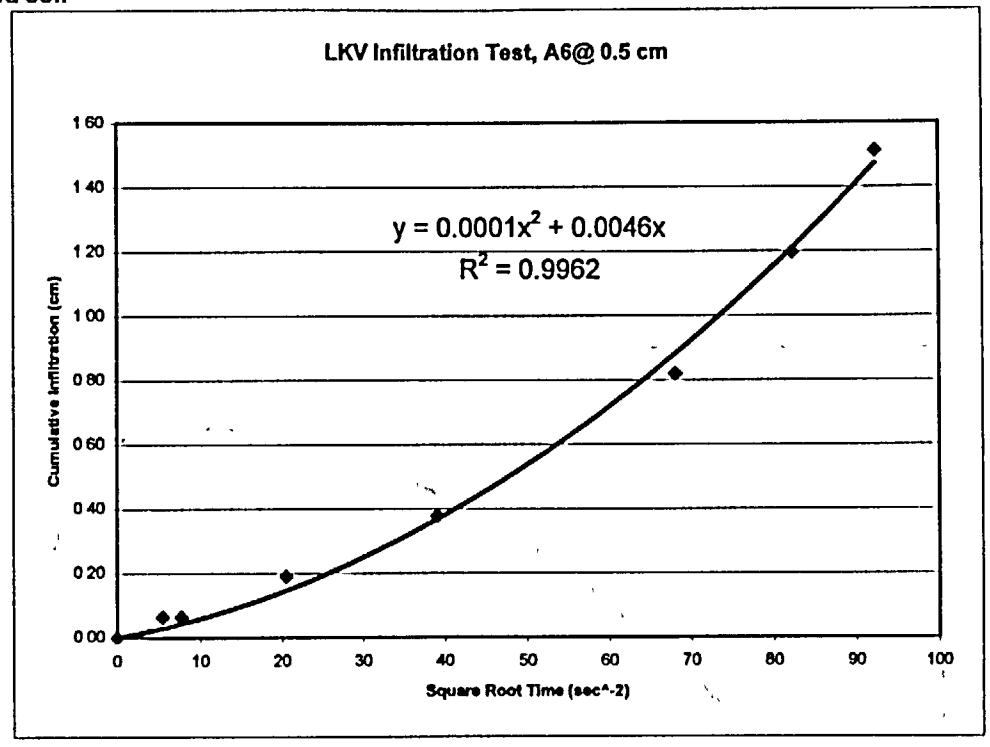
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	13.0	0.000	0.000
30	14.0	5.477	0.126
60	15.0	7.746	0.252
120	16.0	10.954	0.378
300	20.0	17.321	0.882
480	23.0	21.909	1.259
720	28.0	26.833	1.889
780	29.0	27.928	2.015



Site A6 **bare soil with some fine gravel, nearly saturated soil**

h = 0.5 cm

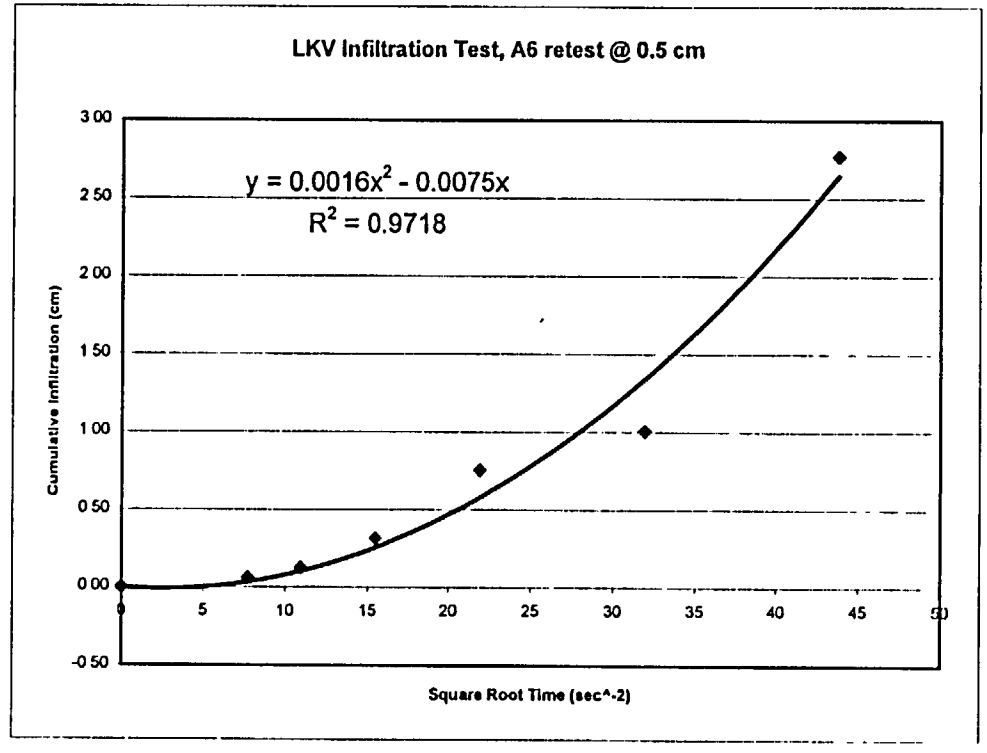
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
30	0.5	5.477	0.063
60	0.5	7.746	0.063
420	1.5	20.494	0.189
1530	3.0	39.115	0.378
4620	6.5	67.971	0.819
6750	9.5	82.158	1.196
8520	12.0	92.304	1.511



Site A6 **retest from Sep. 2000, bare soil, in grasses, some med-fi grvl, dry soil, micropores to 1 mm dia.**

h = 0.5 cm

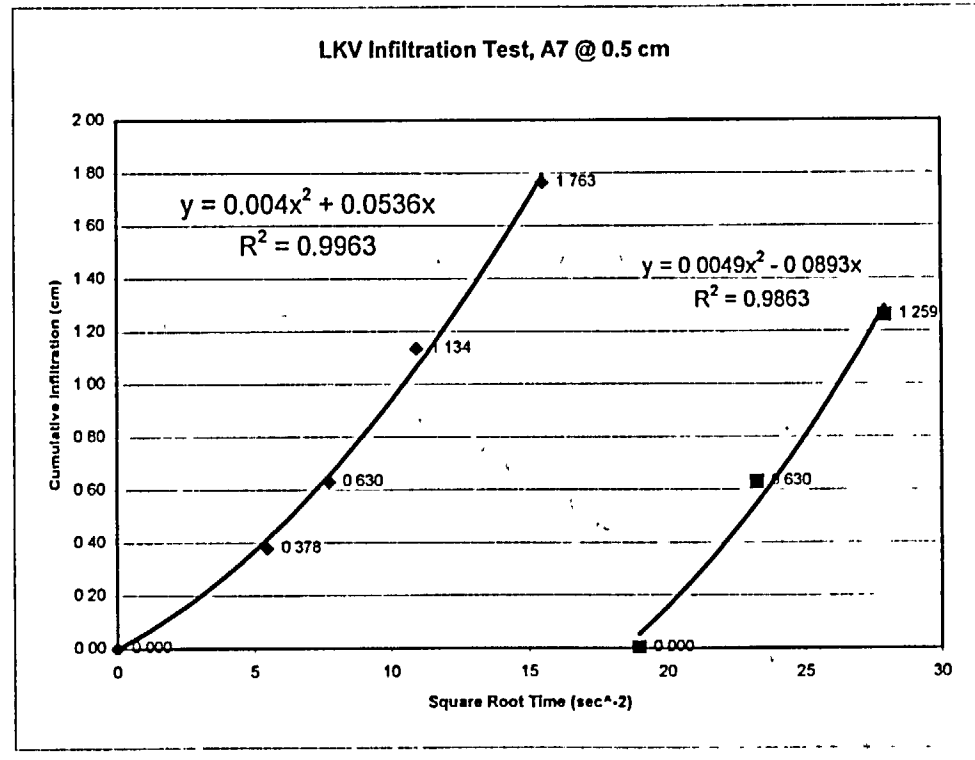
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	4.0	0.000	0.000
60	4.5	7.746	0.063
120	5.0	10.954	0.126
240	6.5	15.492	0.315
480	10.0	21.909	0.756
1020	12.0	31.937	1.008
1920	26.0	43.818	2.771



Site A7 **top slope crest, wheat grass stand, cleared, dry soil, fi to med sand, desiccation cracking**

h = 0.5 cm

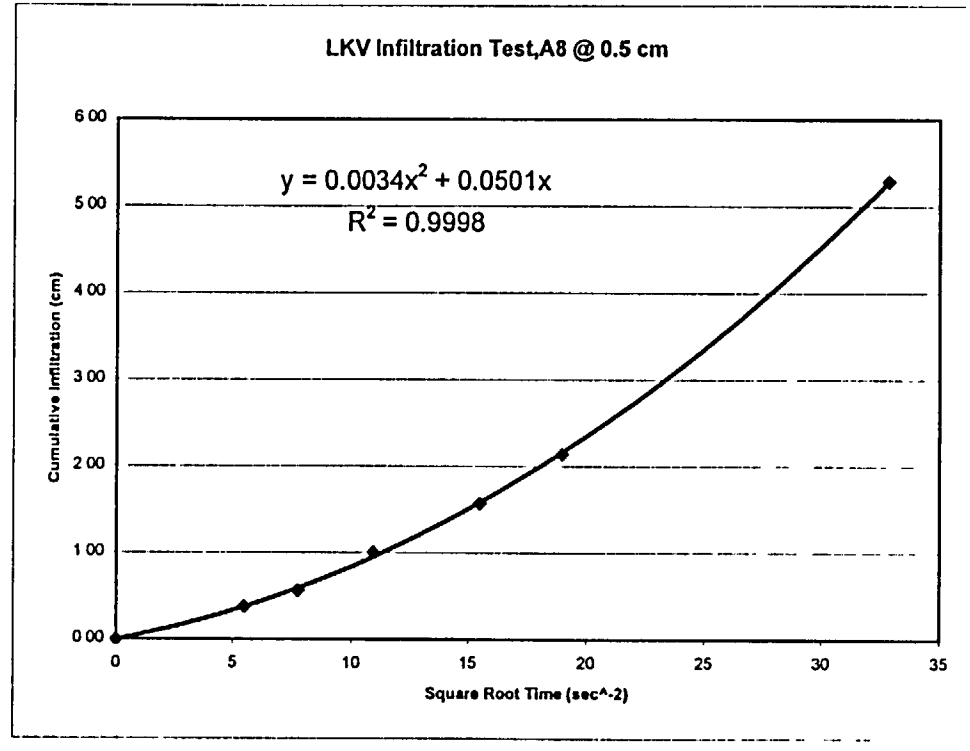
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)	
0	2.0	0.000	0 000	
30	5.0	5.477	0.378	
60	7.0	7.746	0.630	
120	11.0	10.954	1.134	
240	16.0	15.492	1.763	tipped
360	21.0	18.974	0.000	
540	26.0	23 238	0 630	
780	31.0	27.928	1.259	



Site A8 **top slope crest, wheat grass stand, cleared, dry soil, coarse to med sand, fi macropores, desiccation cracking, in rabbitbrush**

h = 0.5 cm

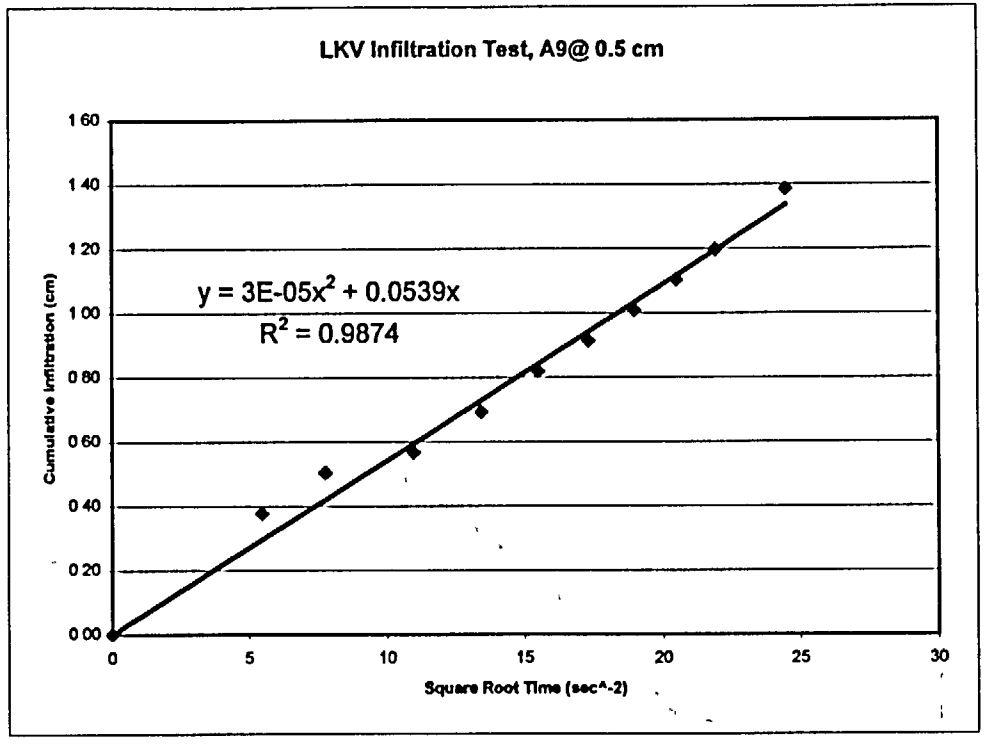
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	14.0	0.000	0.000
30	17.0	5.477	0.378
60	18.5	7.746	0.567
120	22.0	10.954	1.008
240	26.5	15.492	1.574
360	31.0	18.974	2.141
1080	56.0	32.863	5.290



Site A9 **bare soil in grass stand, nearly saturated soil**

h = 0.5 cm

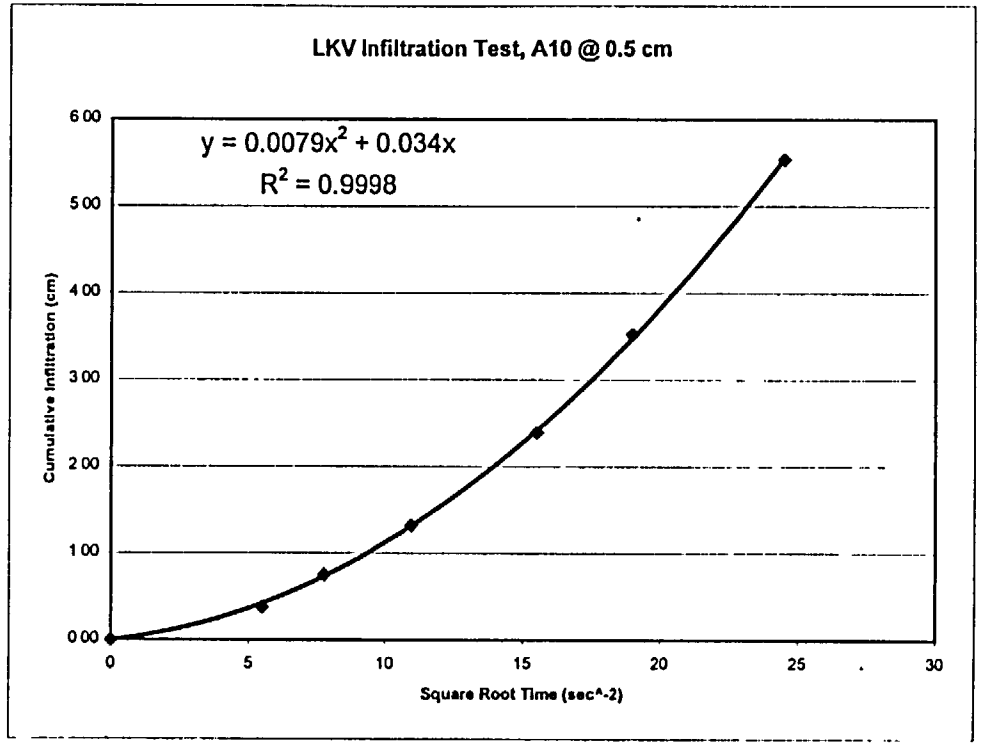
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
30	3.0	5.477	0.378
60	4.0	7.746	0.504
120	4.5	10.954	0.567
180	5.5	13.416	0.693
240	6.5	15.492	0.819
300	7.3	17.321	0.913
360	8.0	18.974	1.008
420	8.8	20.494	1.102
480	9.5	21.909	1.196
600	11.0	24.495	1.385



Site A10 **bare soil in wheat grass stand, litter, on plant stem, occ. Coarse sand, med macropores, wet soil**

h = 0.5 cm

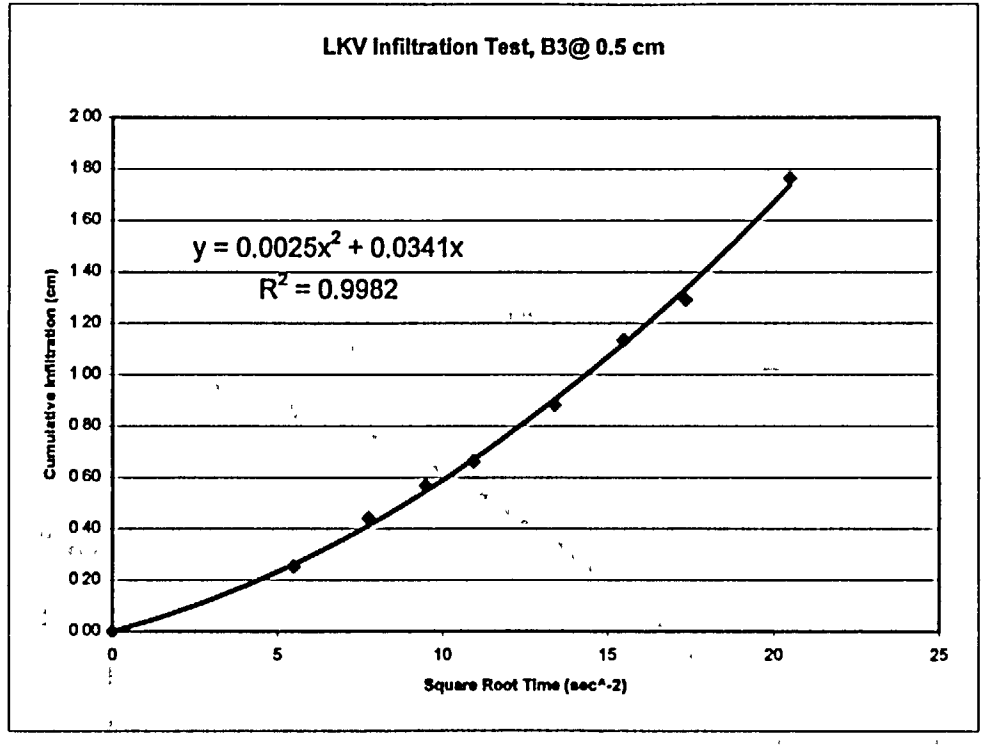
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	1.0	0.000	0.000
30	4.0	5.477	0.378
60	7.0	7.746	0.756
120	11.5	10.954	1.322
240	20.0	15.492	2.393
360	29.0	18.974	3.526
600	45.0	24.495	5.542



Site B3 bare soil, grass stand

h = 0.5 cm

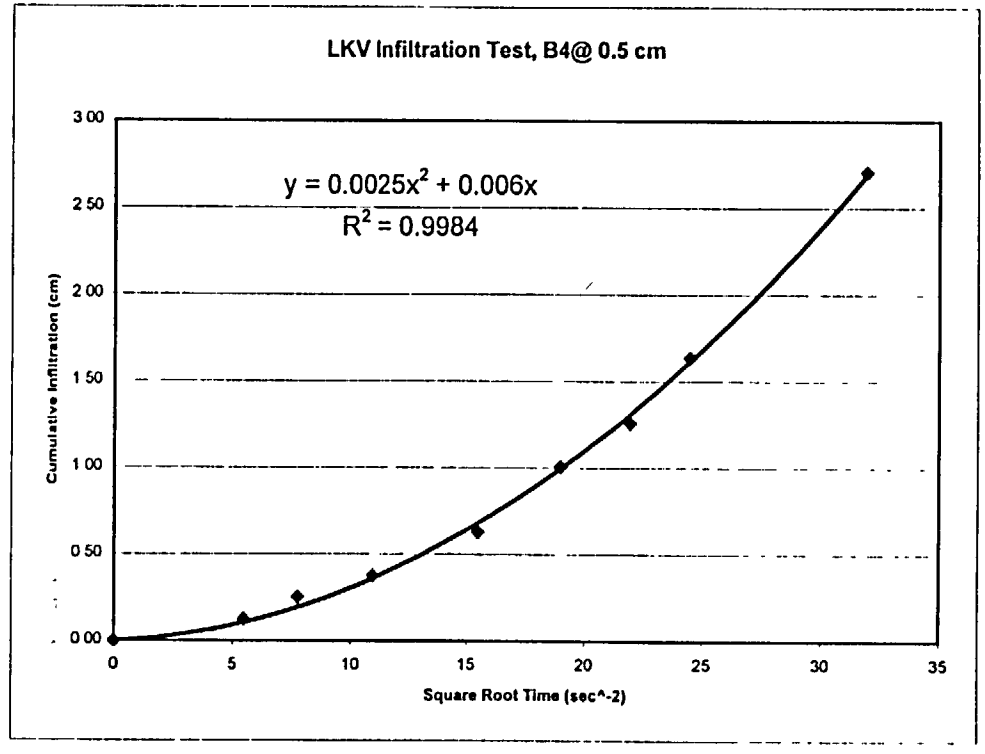
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
30	2.0	5.477	0.252
60	3.5	7.746	0.441
90	4.5	9.487	0.567
120	5.3	10.954	0.661
180	7.0	13.416	0.882
240	9.0	15.492	1.134
300	10.3	17.321	1.291
420	14.0	20.494	1.763



Site B4 **cheat grass stand, micro terranes, hummocky (frost heave?), desiccation cracks, bare soil, trc fi grvl, wet soil (due to restarting test)**

h = 0.5 cm

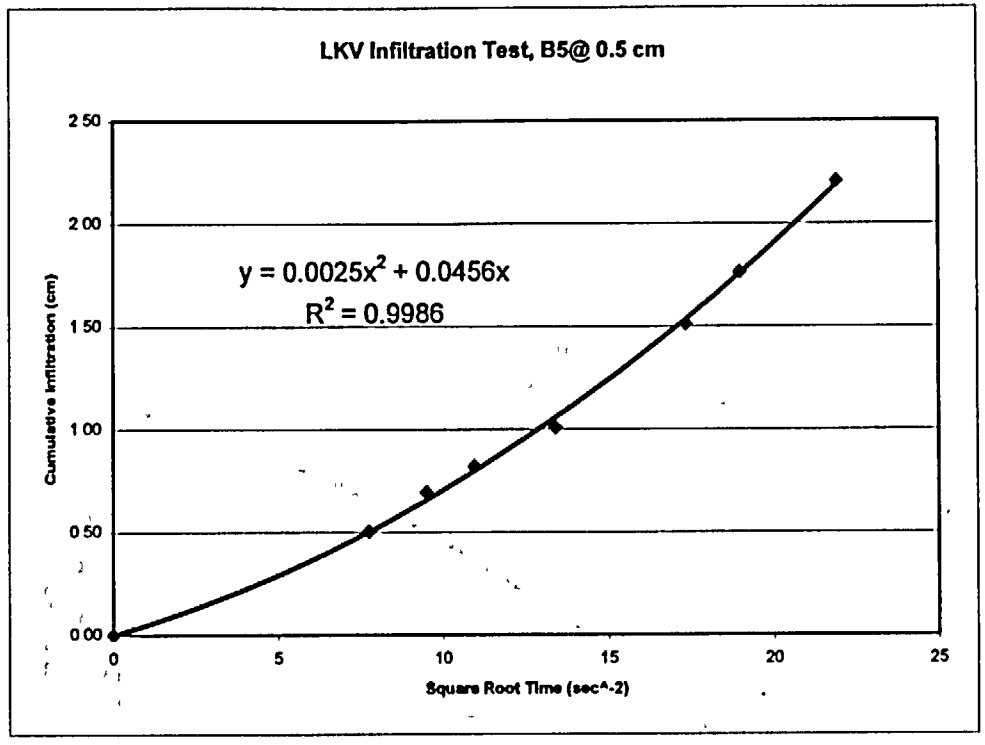
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	2.0	0.000	0.000
30	3.0	5.477	0.126
60	4.0	7.746	0.252
120	5.0	10.954	0.378
240	7.0	15.492	0.630
360	10.0	18.974	1.008
480	12.0	21.909	1.259
600	15.0	24.495	1.637
1020	23.5	31.937	2.708



Site B5 soil with small plants, nearly saturated soil

h = 0.5 cm

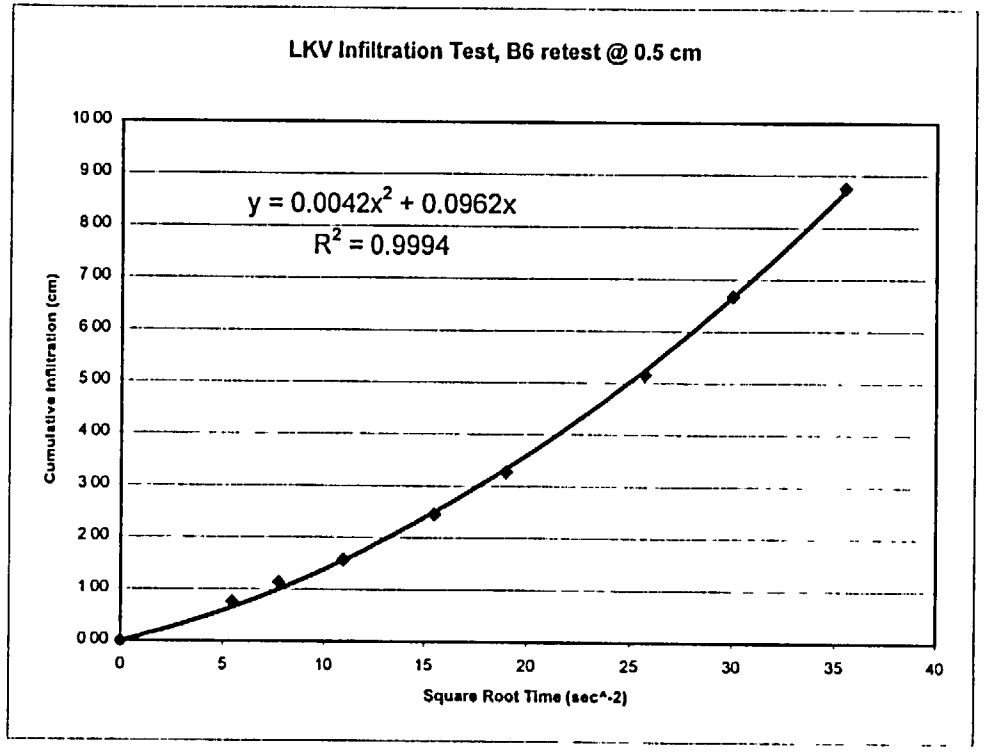
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
60	4.0	7.746	0.504
90	5.5	9.487	0.693
120	6.5	10.954	0.819
180	8.0	13.416	1.008
300	12.0	17.321	1.511
360	14.0	18.974	1.763
480	17.5	21.909	2.204



Site B6 **small veg., cheat grass stand, test over plant stem, dry soil, trc fi grvl, desiccation cracks**

h = 0.5 cm

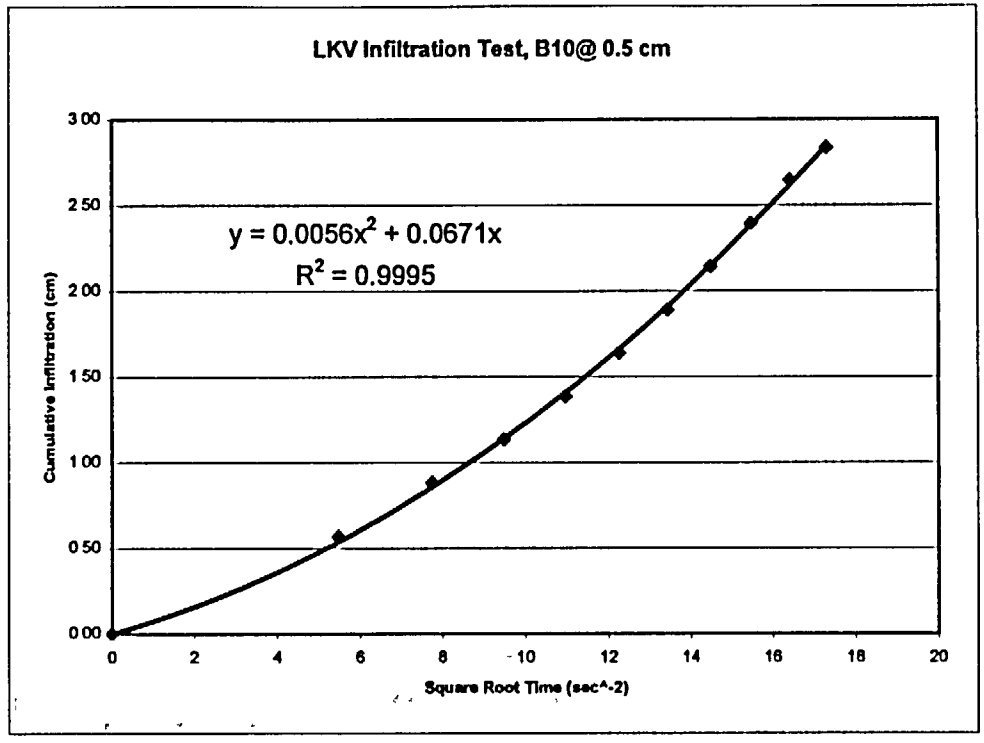
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	3.0	0.000	0.000
30	9.0	5.477	0.756
60	12.0	7.746	1.134
120	15.5	10.954	1.574
240	22.5	15.492	2 456
360	29.0	18.974	3.275
660	44.0	25.690	5.164
900	56.0	30.000	6.675
1260	72.5	35.496	8.753



Site B10 soil with small plants, nearly saturated soil

h = 0.5 cm

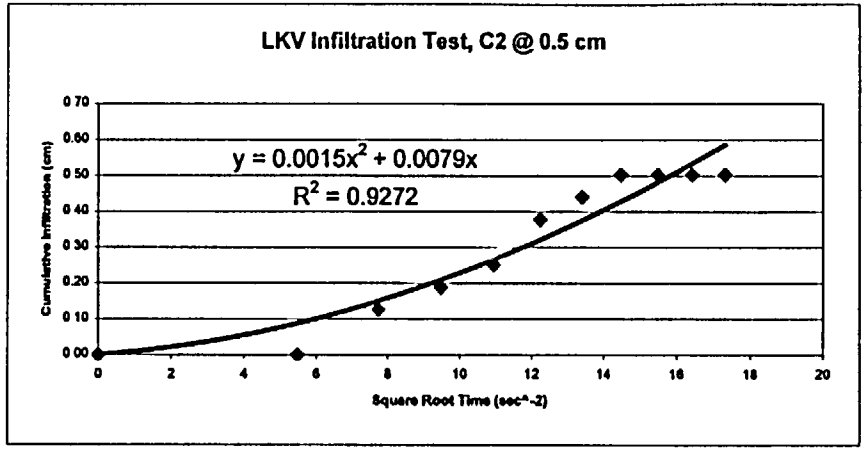
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	1.0	0.000	0.000
30	5.5	5.477	0.567
60	8.0	7.746	0.882
90	10.0	9.487	1.134
120	12.0	10.954	1.385
150	14.0	12.247	1.637
180	16.0	13.416	1.889
210	18.0	14.491	2.141
240	20.0	15.492	2.393
270	22.0	16.432	2.645
300	23.5	17.321	2.834



Site C2 **In bare area, some small gravel, nearly saturated soil**

h = 0.5 cm

time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	2.0	0.000	0.000
30	2.0	5.477	0.000
60	3.0	7.746	0.126
90	3.5	9.487	0.189
120	4.0	10.954	0.252
150	5.0	12.247	0.378
180	5.5	13.416	0.441
210	6.0	14.491	0.504
240	6.0	15.492	0.504
270	6.0	16.432	0.504
300	6.0	17.321	0.504



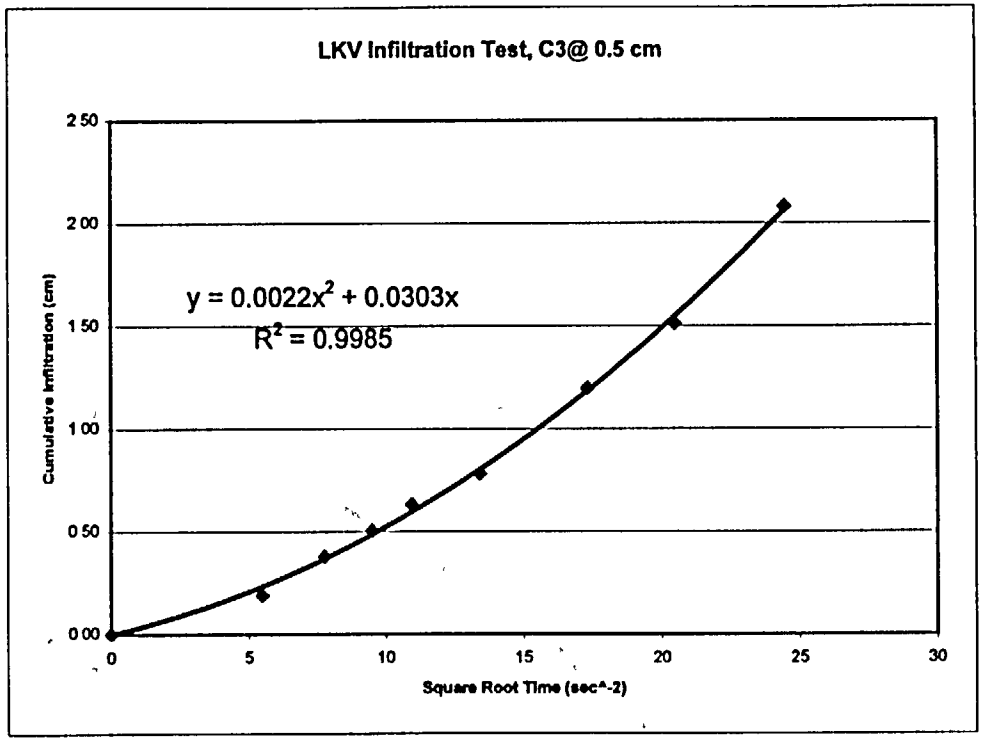
h = 2.0 cm

time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	5.0	2.236	0.000
30	5.0	2.236	0.378
60	5.0	2.236	0.378
90	5.0	2.236	0.378
120	5.0	2.236	0.378
150	5.0	2.236	0.378
180	5.0	2.236	0.378
210	5.0	2.236	0.378
240	5.0	2.236	0.378
270	5.0	2.236	0.378
300	5.0	2.236	0.378

Site C3 **bare soil, trace gravel, trace litter, nearly saturated soil**

h = 0.5 cm

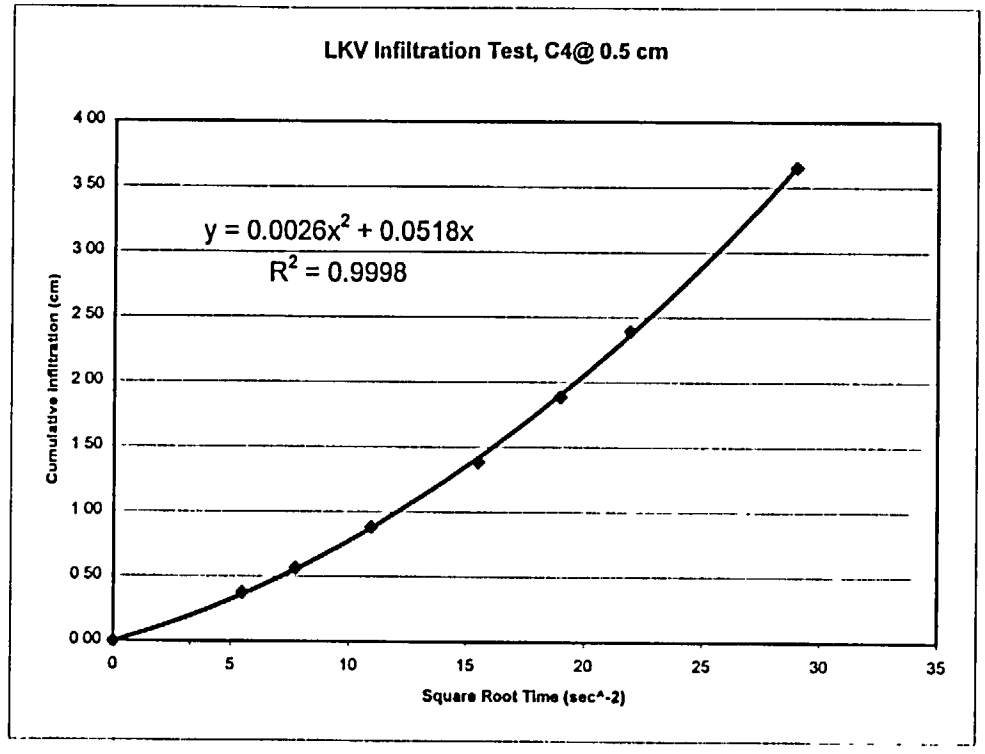
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
30	1.5	5.477	0.189
60	3.0	7.746	0.378
90	4.0	9.487	0.504
120	5.0	10.954	0.630
180	6.2	13.416	0.781
300	9.5	17.321	1.196
420	12.0	20.494	1.511
600	16.5	24.495	2.078



Site C4 **wheat grass stand, organic litter, some to trc fi grvl, dry soil**

h = 0.5 cm

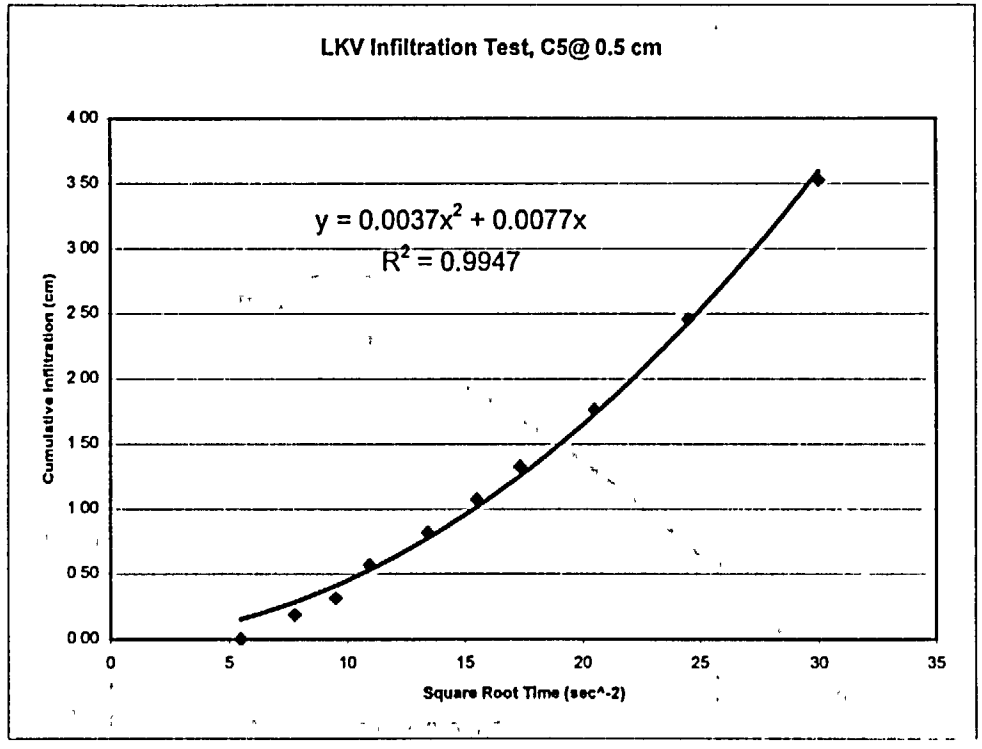
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	1.0	0 000	0.000
30	4.0	5.477	0.378
60	5.5	7.746	0.567
120	8 0	10.954	0.882
240	12.0	15 492	1.385
360	16.0	18.974	1.889
480	20.0	21.909	2.393
840	30.0	28.983	3.652



Site C5 **cheat grass stand, micro terranes (frost heave?), desiccation cracks, bare soil, trc fi grvl, dry soil**

h = 0 5 cm

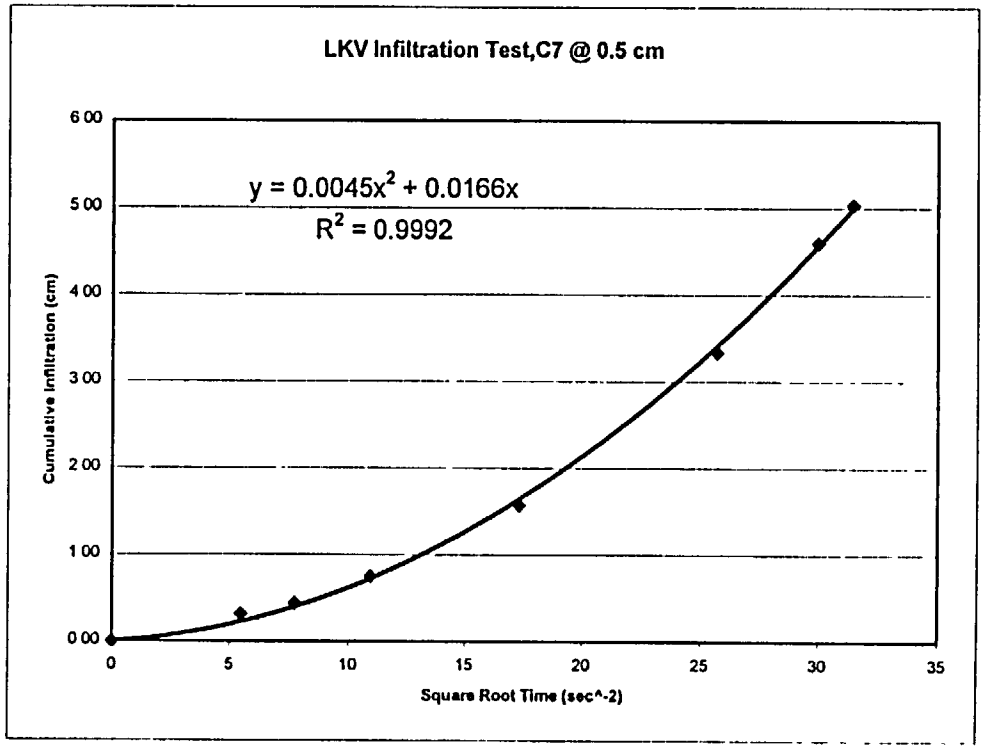
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
30	9.5	5.477	0.000
60	11.0	7.746	0.189
90	12.0	9 487	0.315
120	14.0	10.954	0.567
180	16.0	13.416	0.819
240	18.0	15.492	1.071
300	20.0	17.321	1.322
420	23.5	20.494	1.763
600	29.0	24.495	2.456
900	37.5	30.000	3 526



Site C7 **wheat grass stand, cleared litter from surface, fi macropores,dry soil, no grvl**

h = 0.5 cm

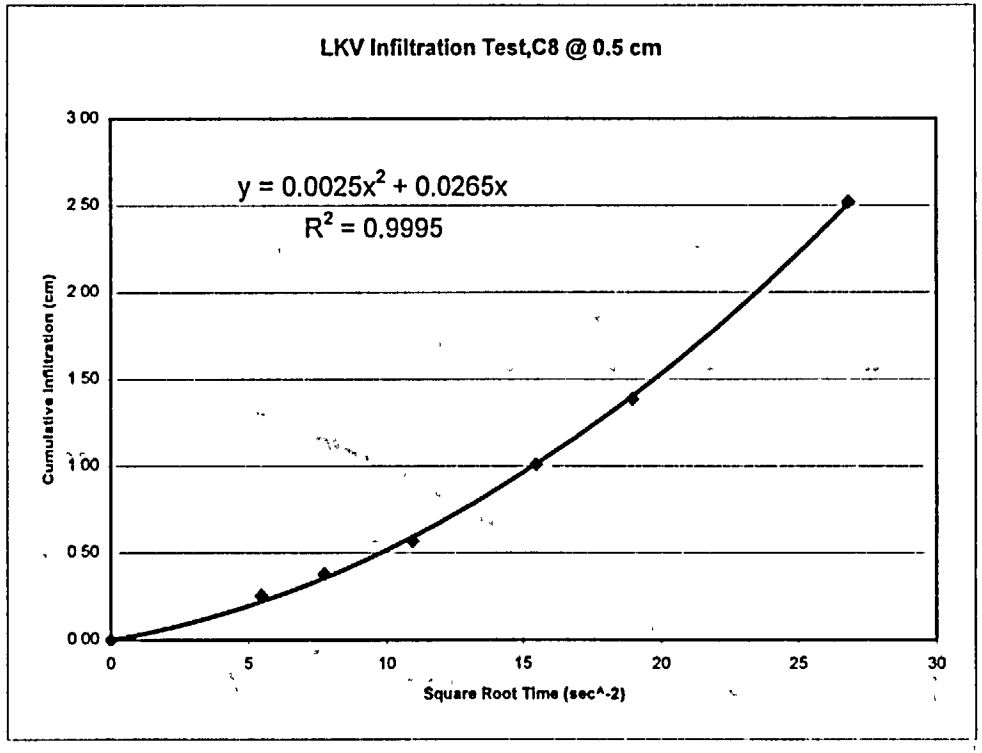
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	1.0	0.000	0.000
30	3 5	5.477	0.315
60	4.5	7.746	0.441
120	7.0	10.954	0.756
300	13.5	17.321	1.574
660	27.5	25.690	3.338
900	37.5	30.000	4.597
990	41.0	31.464	5.038



Site C8 **rocky area, thin soil, desiccation cracking, fi grvl, occ small plant, cheatgrass, fi macropores**

h = 0.5 cm

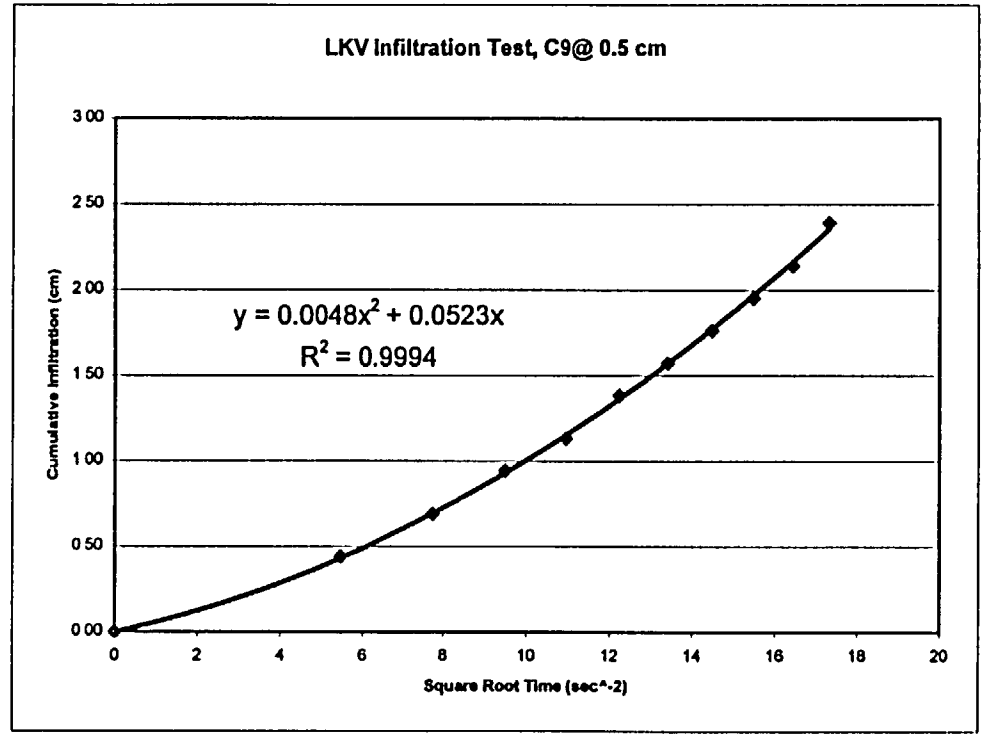
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	11.0	0.000	0 000
30	13.0	5.477	0.252
60	14.0	7.746	0 378
120	15.5	10.954	0.567
240	19.0	15.492	1.008
360	22.0	18.974	1.385
720	31.0	26 833	2.519



Site C9 **soil with small plants, some litter, nearly saturated soil**

h = 0.5 cm

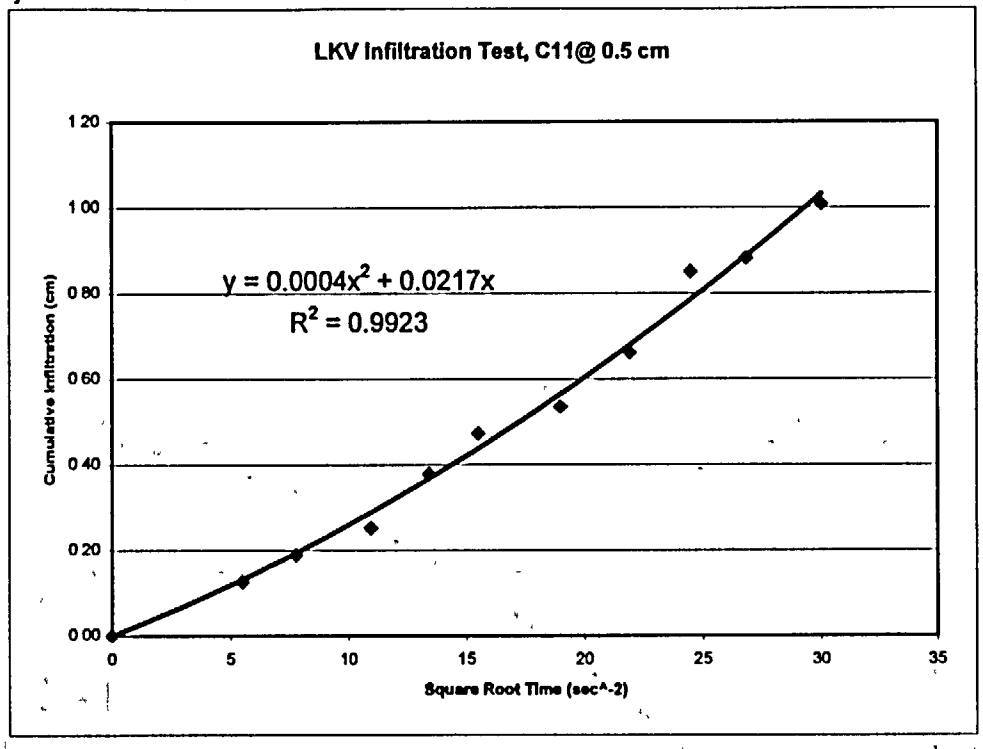
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
30	3.5	5.477	0.441
60	5.5	7.746	0.693
90	7.5	9.487	0.945
120	9.0	10.954	1.134
150	11.0	12.247	1.385
180	12.5	13.416	1.574
210	14.0	14.491	1.763
240	15.5	15.492	1.952
270	17.0	16.432	2.141
300	19.0	17.321	2.393



Site C11 bare soil with trace fine gravel, some litter, nearly saturated soil

h = 0.5 cm

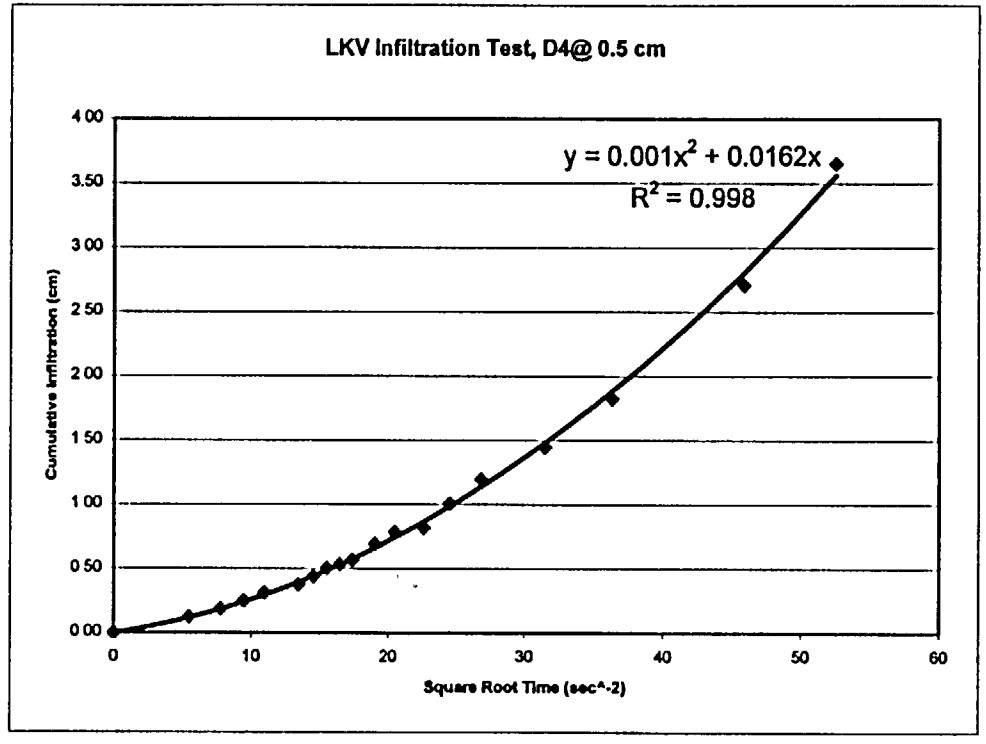
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
30	1.0	5.477	0.126
60	1.5	7.746	0.189
120	2.0	10.954	0.252
180	3.0	13.416	0.378
240	3.8	15.492	0.472
360	4.3	18.974	0.535
480	5.3	21.909	0.661
600	6.8	24.495	0.850
720	7.0	26.833	0.882
900	8.0	30.000	1.008



Site D4 **in bare area , fine gravel, nearly saturated soil**

h = 0.5 cm

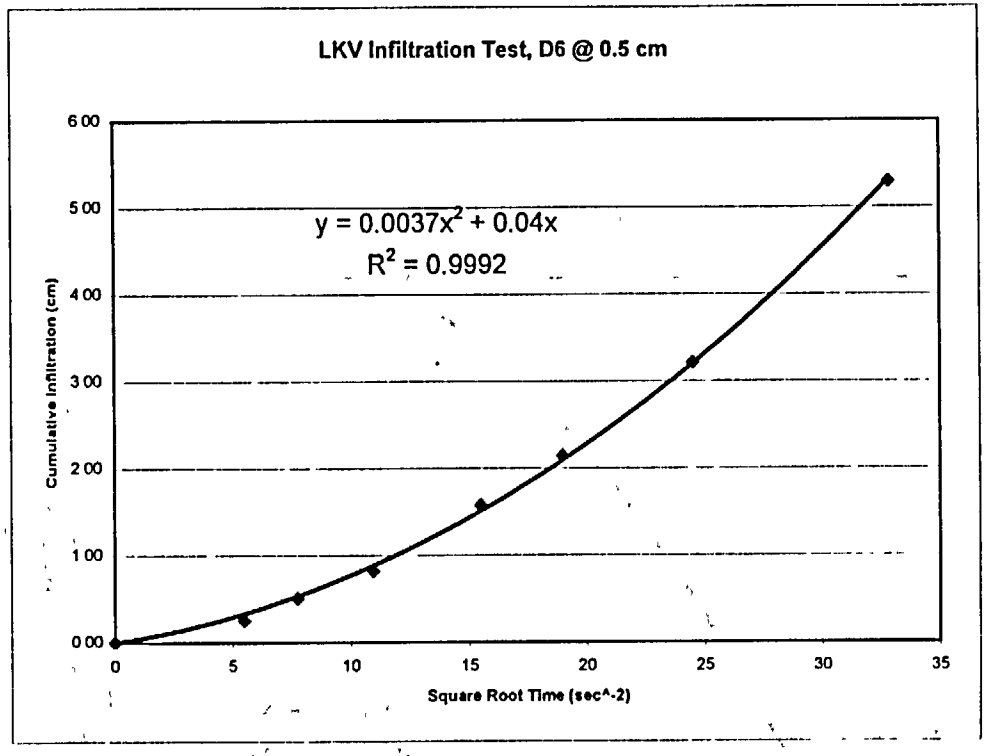
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
30	1.0	5.477	0.126
60	1.5	7.746	0.189
90	2.0	9.487	0.252
120	2.5	10.954	0.315
180	3.0	13.416	0.378
210	3.5	14.491	0.441
240	4.0	15.492	0.504
270	4.3	16.432	0.535
300	4.5	17.321	0.567
360	5.5	18.974	0.693
420	6.3	20.494	0.787
510	6.5	22.583	0.819
600	8.0	24.495	1.008
720	9.5	26.833	1.196
990	11.5	31.464	1.448
1320	14.5	36.332	1.826
2100	21.5	45.826	2.708
2760	29.0	52.536	3.652



Site D6 wheat grass stand, bare soil area, dry soil, 6+ macropores 1mm ϕ, desiccated soil

h = 0.5 cm

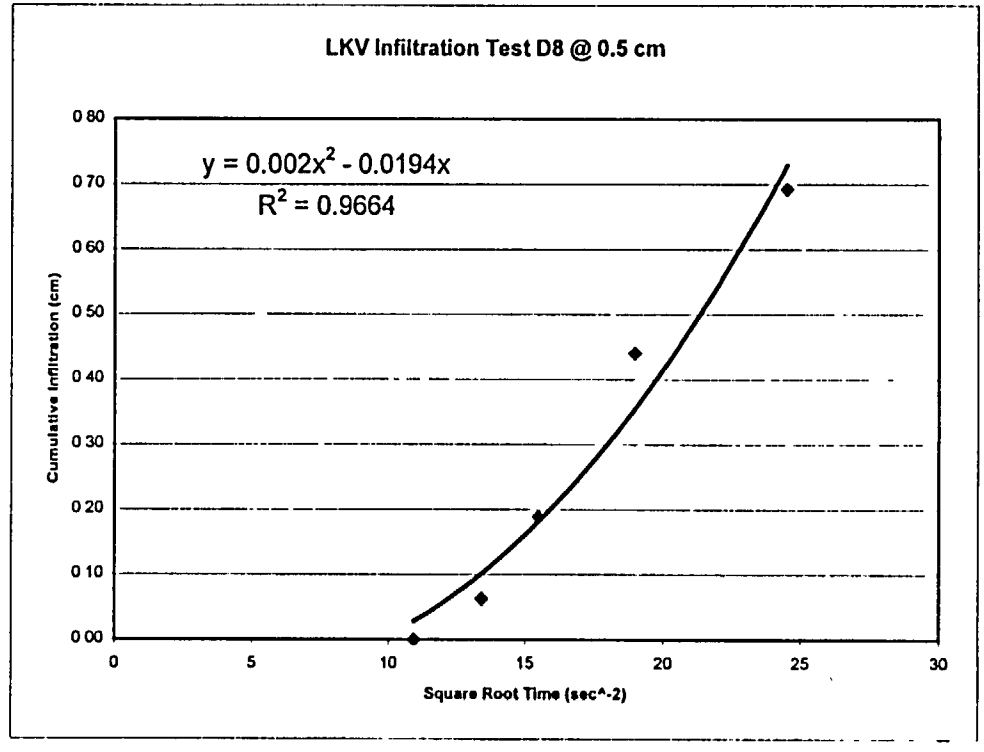
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	4.0	0.000	0.000
30	6 0	5.477	0.252
60	8.0	7.746	0.504
120	10 5	10.954	0.819
240	16.5	15.492	1.574
360	21.0	18.974	2.141
600	29.5	24.495	3.212
1080	46.0	32.863	5.290



Site D8 **cheat grass stand, fi macropores, juxtaposed desiccation crack, dry soil**

h = 0.5 cm

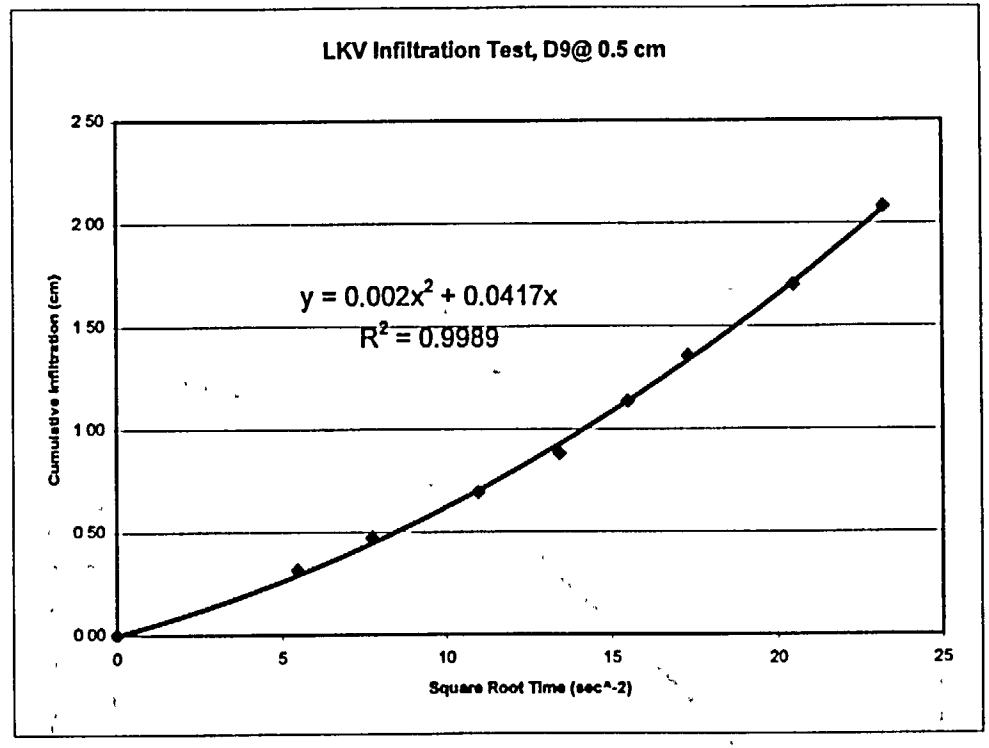
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	12.0	0.000	0.000
30	14.0	5.477	0.252
120	17.5	10.954	0.000
180	18.0	13.416	0.063
240	19.0	15.492	0.189
360	21.0	18.974	0.441
600	23.0	24.495	0.693



Site D9 **bare soil with trace litter, nearly saturated soil**

h = 0.5 cm

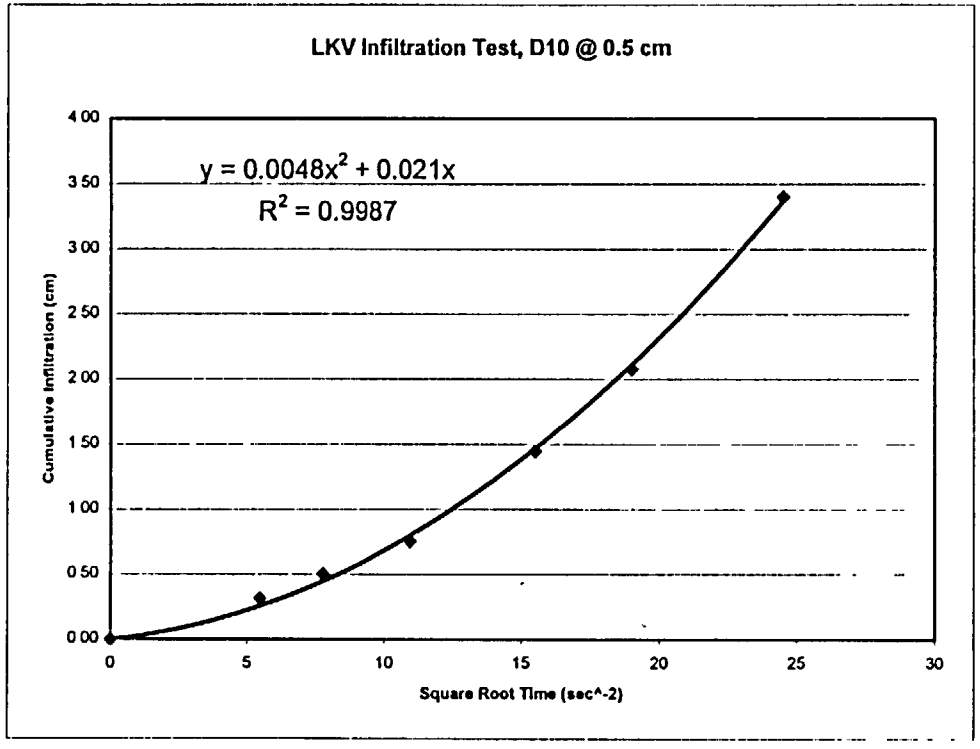
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
30	2.5	5.477	0.315
60	3.8	7.746	0.472
120	5.5	10.954	0.693
180	7.0	13.416	0.882
240	9.0	15.492	1.134
300	10.8	17.321	1.354
420	13.5	20.494	1.700
540	16.5	23.238	2.078



Site D10 bare soil in wheat grass stand, fi grvl, desiccation cracks, fi macropores

h = 0.5 cm

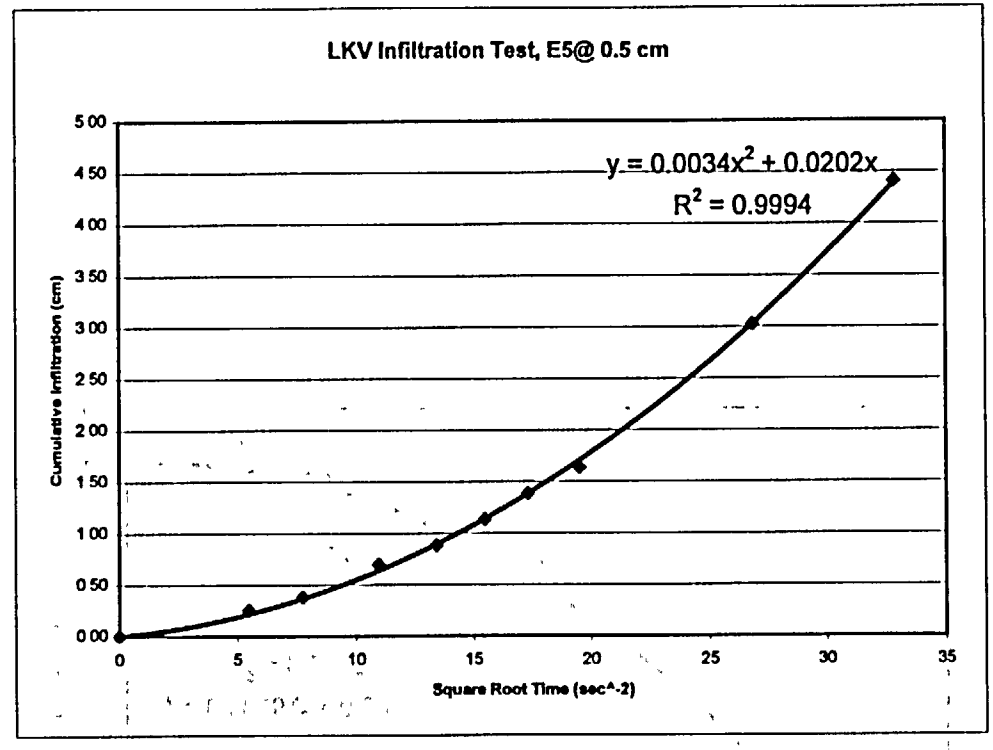
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	4.0	0.000	0.000
30	6.5	5.477	0 315
60	8.0	7.746	0.504
120	10.0	10.954	0.756
240	15.5	15.492	1.448
360	20.5	18.974	2.078
600	31.0	24.495	3.401



Site E5 grass stand, litter, nearly saturated soil

h = 0.5 cm

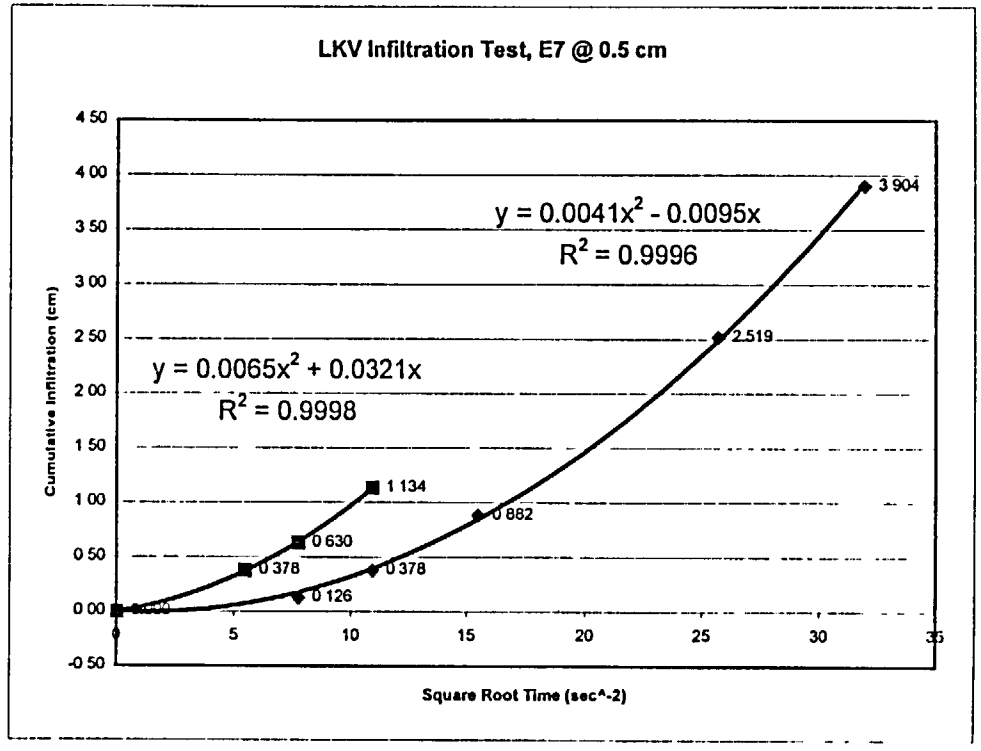
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	0.0	0.000	0.000
30	2.0	5.477	0.252
60	3.0	7.746	0.378
120	5.5	10.954	0.693
180	7.0	13.416	0.882
240	9.0	15.492	1.134
300	11.0	17.321	1.385
380	13.0	19.494	1.637
720	24.0	26.833	3.023
1080	35.0	32.863	4.408



Site E7 cheat grass stand, med. macropores, dry & wet soil

h = 0.5 cm

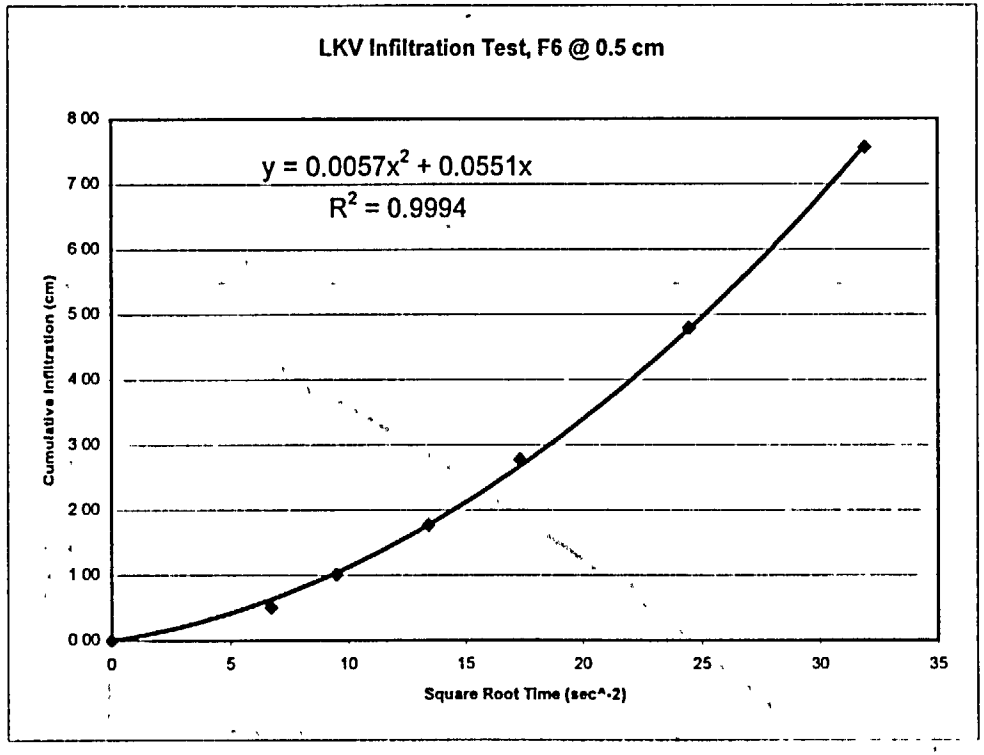
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)	
0	20.0	0.000	0.000	
60	21.0	7.746	0.126	
120	23.0	10.954	0.378	wet
240	27.0	15.492	0.882	
660	40.0	25.690	2.519	
1020	51.0	31.937	3.904	
0	8.0	0.000	0.000	
30	11.0	5.477	0.378	dry
60	13.0	7.746	0.630	
120	17.0	10.954	1.134	



Site F6 wheat grass stand, cleared litter from surface, dry soil, no grvl, fi macropores

h = 0 5 cm

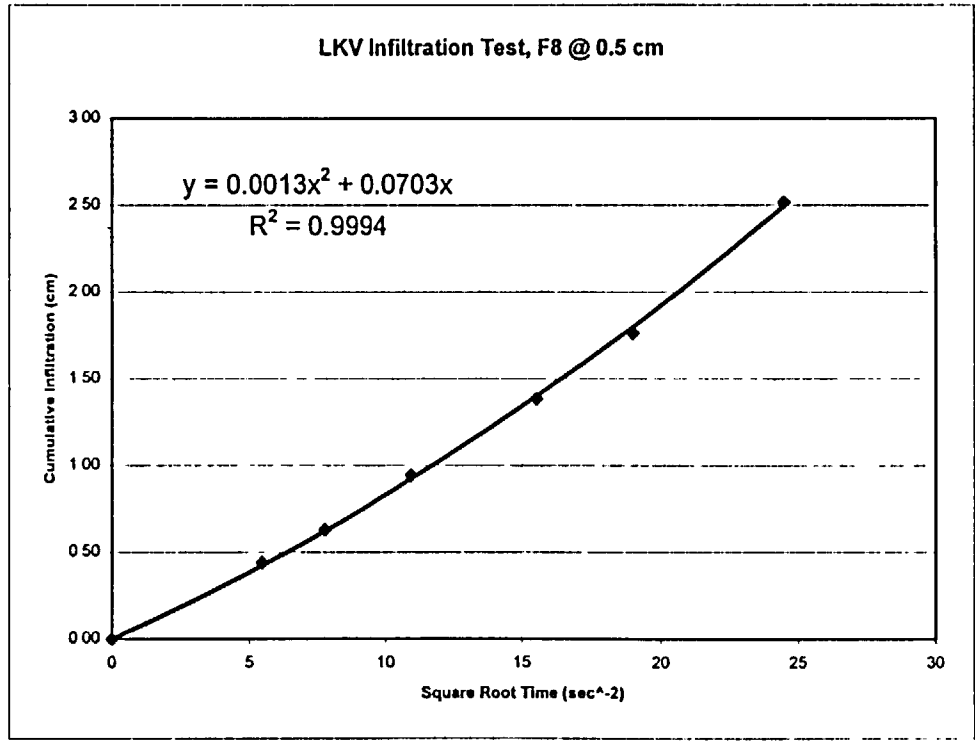
time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	3 0	0.000	0.000
45	7.0	6.708	0.504
90	11.0	9.487	1.008
180	17.0	13.416	1.763
300	25.0	17.321	2.771
600	41.0	24.495	4.786
1020	63.0	31.937	7.557



Site F8 **wheat grass - rabbitbrush, med - coarse macropores, fi grvl, dry soil**

h = 0.5 cm

time (sec)	volume (ml)	square root time	Cumulative Infiltration (cm)
0	7.0	0.000	0.000
30	10.5	5.477	0.441
60	12.0	7.746	0.630
120	14.5	10.954	0.945
240	18.0	15.492	1.385
360	21.0	18.974	1.763
600	27.0	24.495	2.519



Appendix D
Decagon Devices Application Note

Measuring Soil Hydraulic Conductivity with a Disk Infiltrometer

A number of methods are available for measuring soil hydraulic conductivity with a disk infiltrometer. We suggest using the method proposed by Zhang (1997). The method requires measuring cumulative infiltration vs. time and fitting the results with the function

$$I = (C_1 t + C_2 \sqrt{t}) \tag{1}$$

The hydraulic conductivity of the soil is then computed from

$$k = \frac{C_1}{A} \tag{2}$$

A is computed from:

$$A = \frac{11.65(n^{0.1} - 1)\, e^{[2.92(n-1.9)\alpha h_o]}}{(\alpha r_o)^{0.91}} \qquad n \geq 1.9$$

$$A = \frac{11.65(n^{0.1} - 1)\, e^{[7.5(n-1.9)\alpha h_o]}}{(\alpha r_o)^{0.91}} \qquad n < 1.9 \tag{3}$$

where n and α are the van Genuchten parameters for the soil, r_o is the disk radius, and h_o is the suction at the disk surface. The van Genuchten parameters for the 12 texture classes of soil were obtained from Carsel and Parrish (1988). The minidisk infiltrometer has a radius of 1.59 cm and three different suction rates 0.5, 2.0, and 6.0 cm. Values of A computed for the minidisk infiltrometers are given in Table 1.

Table 1. van Genuchten Parameters for 12 Soil Texture Classes

Texture	α (cm^{-1})	n	A h_o = 0.5cm	A h_o = 2.0cm	A h_o = 6.0cm
sand	0.145	2.68	5.4	8.9	33.3
loamy sand	0.124	2.28	4.7	5.8	10.0
sandy loam	0.075	1.89	5.3	5.2	5.1
loam	0.036	1.56	6.8	6.0	4.1
silt	0.016	1.37	10.2	9.3	7.2
silt loam	0.020	1.41	9.1	8.1	6.0
sandy clay loam	0.059	1.48	3.7	2.8	1.3
clay loam	0.019	1.31	7.4	6.5	4.7
silty clay loam	0.010	1.23	10.3	9.5	7.8
sandy clay	0.027	1.23	4.0	3.3	1.9
silty clay	0.005	1.09	8.1	7.7	6.8
clay	0.008	1.09	5.2	4.9	4.0

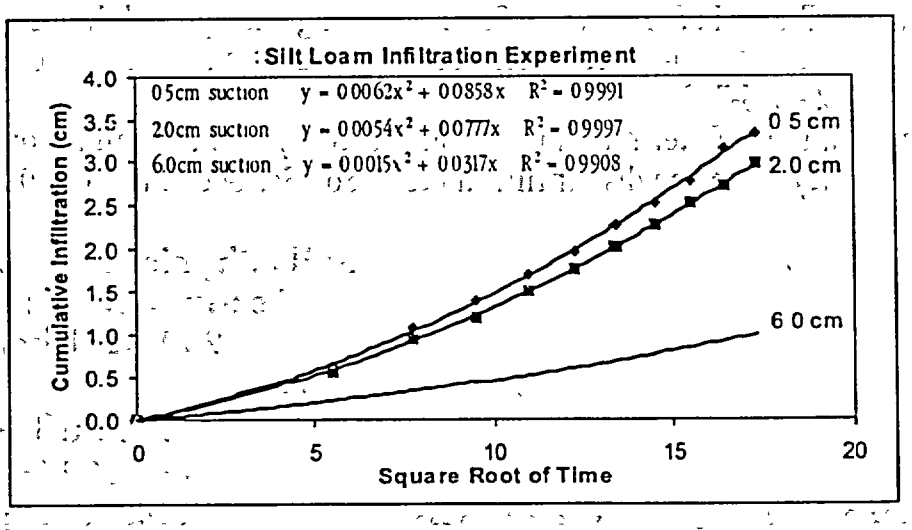
Hydraulic conductivity is measured as follows:

1. **Fill the infiltrometer.** - Immerse in a container of water and replace the stopper while the infiltrometer is under water.
2. **Record starting volume.** - Use a ring stand and clamp to suspend the infiltrometer vertically over a smooth, level soil surface.
3. **Start inflitration.** - At time zero, slide the infiltrometer down to make solid contact with the soil surface.
4. **Record volume and time.** - Record volume at regular time intervals as the water infiltrates.

A typical data set for a 2.0 cm suction infiltrometer will look like the first and second columns of Table 2.

Table 2. Silt Loam Infiltration Experiment with 2.0 cm suction

Time (sec)	Volume (ml)	Square Root time	Infiltration (cm)
0	5	0.00	0.00
30	11	5.48	0.76
60	14	7.75	1.14
90	17	9.49	1.52
120	20	10.95	1.89
150	23	12.25	2.27
180	25	13.42	2.53
210	27	14.49	2.78
240	29	15.49	3.03
270	31	16.43	3.28
300	33	17.32	3.54



The volume is converted to depth of water infiltrated by subtracting the starting volume reading and dividing by the area of the disk on the infiltrometer, 7.94 cm^2. The result is shown in the 4th column of Table 2. An easy way to find C_1 and C_2 in eq. 1 is to use the square root of time as the independent variable and fit a quadratic equation to the data, constraining the solution to go through zero. The square root of time is in column 3 of Table 2. A quadratic is simple to fit in an Excel spreadsheet. Select columns 3 and 4 from the table and produce an XY (scatter) plot. Then double click on the graph and right click on one of the points on the line. Select "Trend Line" from the menu. Select the polynomial 2nd order from Type, and set intercept to zero, display equation, and display R square from Options. The result for the three infiltrometers is the graph below Table 2. From this the value of C_1 is read directly. The hydraulic conductivity is calculated for the silt loam soil using Table 1 and eq. 2:

	0.5 cm	2.0 cm	6.0 cm	
$k =$	$\frac{0.0062}{9.1}$	$\frac{0.0054}{8.1}$	$\frac{0.0015}{6.0}$	
$k =$	6.8×10^{-4}	6.7×10^{-4}	2.5×10^{-4}	$cm\ s^{-1}$

References:

Carsel, R. F. and R. S. Parrish. 1988. "Developing joint probability distributions of soil water retention characteristics." Water Resour. Res. 24: 755-769.

Zhang, R. 1997. "Determination of soil sorptivity and hydraulic conductivity from the disk infiltrometer." Soil Sci. Soc. Am. J. 61: 1024-1030.

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Appendix F
Lakeview Top Slope Soil Classification

GRAIN SIZE ANALYSIS–MECHANICAL Data Sheet 5

Project ~~LKV~~ LTSM Job No. 3508.09.001

Location of Project LKV Boring No. _____ Sample No. C3, C7, C11 composite

Description of Soil loam, lt brn Depth of Sample surface

Tested By G. Smith Date of testing 11-17-00

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

200 wash

	pre	post	
Wt. of dry sample + container	1007.3	815.2	815.2
Wt. of container	Evap #2 493.8	493.8	494.3
Wt. of dry sample, W_s	513.5	321.4	320.9 – sieve analysis

washed -200 = 192.1 g

Sieve analysis and grain shape

Sieve no / wt.	Diam. (mm)	Wt. retained: sieve + sample	Wt. retained: sample	% retained	% passing	adj % pass
#3 ~~#4~~ 510.8	~~4.76~~ 6.68	530.4	19.6	3.8	96.2	
#10 475.0	2.00	499.0	24.0	4.7	91.5	100.0
#20 475.8	0.84	504.5	28.7	5.6	85.9	93.9
#40 394.8	0.425	429.9	32.1	6.3	79.6	87.0
#100 368.3	0.15	480.5	112.2	21.9	57.7	63.1
#200 390.4	0.074	487.9	97.5	19.0	38.7	42.3
PAN / ~~344.0~~ 344.0	—	351.1	7.1 + 192.1 = 199.2	38.8	-0.1 ok	0.1
			Σ = 513.3	100.1 ok		

0.5 loss

(513.3 / 513.5) × 100 = 100% ok <<1%

% passing = 100 − Σ % retained.

N = 50 / .577 = 86.7 g passing #100 for hydrometer test!

GRAIN SIZE ANALYSIS-HYDROMETER METHOD Data Sheet 7

Project LTSM Job No. 350809001

Location of Project LKV Boring No. — Sample No. C3, C7 & C11 composite

Description of Soil SM-SC, sandy loam Depth of Sample surface

Tested By G. Smith Date of Testing 11/21/00

Hydrometer analysis

Hydrometer no. 152H G_s of solids = 2.65 assumed a = 1.00

Dispersing agent Calgon Amount 125 ml Wt. of soil, W, 68.8 g

Zero correction 50 @ 18°C Meniscus correction 1.0

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_c	% Finer	Hyd. Corr. only for meniscus R	L from Table 6-5	$\frac{L}{t}$	K from Table 6-4	D, mm
11/21	8:55	0									
9	8:56	1	20	39	34	49.4	40	9.7	9.7	0.0137	0.043
	:57	2		35	30	43.6	36	10.4	5.2		0.031
	:58	3	↓	32	27	40.0	33	10.8	3.6	↓	0.026
	:59	4	20	30	25	37.1	31	11.15	2.8	0.0137	0.023
	10:05	10	19	27	21.5	31.8	28	11.7	1.17	0.01375	0.015
	10:25	30	19	20	14.5	21.6	21	12.9	0.43	0.01375	0.009
	10:55	60	20	16	11.5	16.9	17	13.4	0.22	0.0136	0.006
	11:25	90	21	16	11.5	16.3	17	13.5	0.15	0.0135	0.005
	16:48	413	20	12	7	10.2	13	14.2	0.034	0.0137	0.003
11/22	9:55	1440	19	9	4	6.1	10	14.6	0.010	0.0138	0.0014
	14:46	1731	20	9	4	5.8	10	14.7	0.008	0.0137	0.0012

$R_c = R_{actual}$ − zero correction + C_T % finer = $R_c(a)/W_s$ $D = K\sqrt{L/t}$

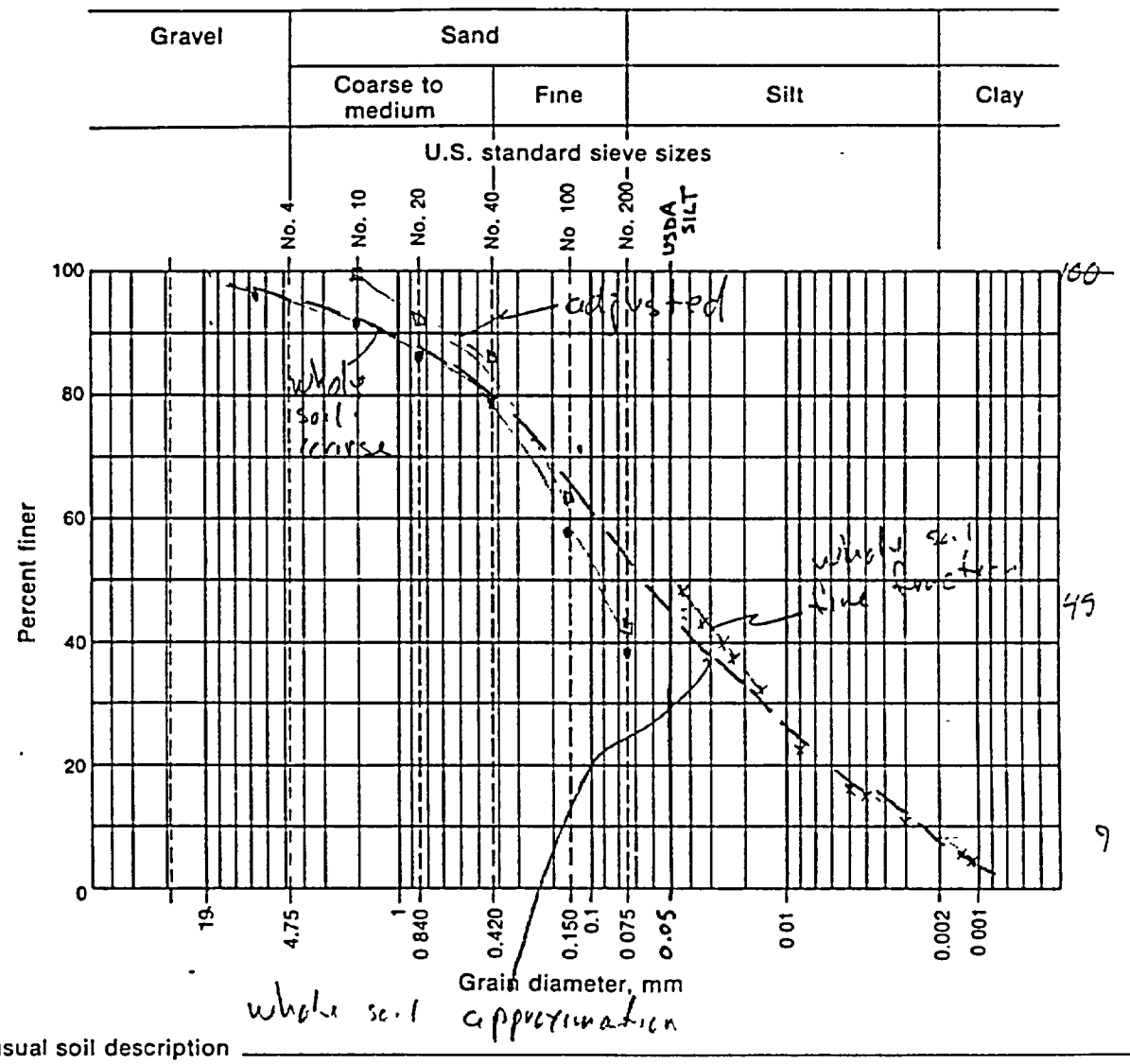
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project LTSM Job. No. 35080901

Location of Project LKV Boring No. – Sample No. C3, C7 & C11 composite

Description of Soil SM-SC, sandy loam Depth of Sample surface

Tested By. G. Smith Date of Testing 11/27/00



Visual soil description

Soil classification:

USDA - Sandy loam ~~System~~

USCS - SM

assume low plasticity Atterberg

Appendix G
Lakeview Top Slope Soil Moisture Contents and Index Properties

Moisture Content & Volumetric Moisture

point	wet wt (g)	dry wt (g)	water content (%)	total sample volume (cc)	dry density (g/cc)	SG	void ratio	porosity	% saturation	%	θ_t decimel #
C8	19 43	17 47	11 22	19 90	0 88	2 65	2 02	0 67	14 73	9 85	0 098
C10	21 57	19 04	13 29	20 75	0 92	2 65	1 89	0 65	18 65	12 19	0 122
E8	27.77	25 01	11 04	21 35	1.17	2 65	1 26	0 56	23 17	12 93	0 129
B8	18 81	16 86	11 57	14 30	1.18	2 65	1 25	0 56	24 57	13 64	0 136
A8	26 50	23 23	14 08	23 25	1 00	2 65	1 65	0 62	22 58	14 06	0 141
D9	26 00	23 25	11 83	19 55	1.19	2 65	1 23	0 55	25 52	14 07	0 141
B6	12 09	10 62	13 84	10 40	1 02	2 65	1 60	0 61	23 00	14 13	0 141
E4	12 87	11 14	15 53	11 60	0 96	2 65	1 76	0 64	23 39	14 91	0 149
B9	19 77	17 52	12 84	14 65	1 20	2 65	1 22	0 55	27 99	15 36	0 154
C5	21.19	18 92	12 00	14 50	1 30	2 65	1 03	0 51	30 84	15 66	0 157
D3	15 38	13 63	12 84	11 15	1 22	2 65	1.17	0 54	29 13	15 70	0 157
B7	24 28	21 72	11 79	16 15	1 34	2 65	0 97	0 49	32 19	15 85	0 159
D4	20 21	17 51	15 42	16 75	1 05	2 65	1.53	0 61	26 62	16 12	0 161
B5	17.48	15 17	15 23	14 30	1 06	2 65	1.50	0 60	26 94	16 15	0 162
A4	16.13	14 00	15 21	13 00	1 08	2 65	1 46	0 59	27 60	16 38	0 164
C11	29 88	26 38	13 27	21 05	1 25	2 65	1.11	0 53	31 54	16 63	0 166
A6	15.17	13 34	13 72	10 90	1 22	2 65	1.17	0 54	31 20	16 79	0 168
D10	24 67	21 33	15 66	19 40	1 10	2 65	1 41	0 59	29 42	17 22	0 172
C3	26 24	23 14	13 40	17 95	1 29	2 65	1 06	0 51	33 63	17 27	0 173
A2	26 21	23 04	13 76	17 95	1 28	2 65	1 06	0 52	34 25	17 66	0 177
B4	25 23	22 28	13 24	16 60	1 34	2 65	0 97	0 49	36 01	17.77	0 178
D7	25 40	22 42	13 29	16 70	1 34	2 65	0 97	0 49	36 17	17 84	0 178
C6	23 99	20 93	14 62	16 75	1 25	2 65	1 12	0 53	34 57	18 27	0 183
A11	26 62	23 47	13 42	16 90	1 39	2 65	0 91	0 48	39 16	18 64	0 186
A5	29 81	26 02	14 57	20 30	1 28	2 65	1 07	0 52	36 16	18 67	0 187
D8	24 34	21 25	14 54	16 45	1.29	2 65	1 05	0 51	36 65	18 78	0 188
A1	25 55	22 53	13 40	15 85	1 42	2 65	0 86	0 46	41 10	19 05	0 191
D6	28 00	24 20	15 70	19 40	1 25	2 65	1.12	0 53	37 01	19 59	0 196
D5	29 25	25 36	15 34	19 85	1 28	2 65	1 07	0 52	37 84	19 60	0 196
B2	22 06	19 03	15 92	15 45	1 23	2 65	1.15	0 54	36 64	19 61	0 196
B3	22 10	19 12	15 59	14 10	1 36	2 65	0 95	0 49	43 28	21 13	0 211
E5	24 15	20 56	17 46	16 60	1 24	2 65	1.14	0 53	40 60	21 63	0 216
B11	18 89	16 21	16 53	12 20	1 33	2 65	0 99	0 50	44 06	21 97	0 220
E7	28 63	24 35	17 58	18 60	1 31	2 65	1 02	0 51	45 48	23 01	0 230
E6	28 69	24 34	17 87	18 45	1 32	2 65	1 01	0 50	46 95	23 58	0 236
A9	13 62	11 43	19 16	9 25	1 24	2 65	1.14	0 53	44 36	23 68	0 237
A10	25 83	21 87	18 11	16 65	1 31	2 65	1 02	0 50	47.16	23 78	0 238
E9	24 03	19 80	21 36	16 60	1.19	2 65	1.22	0 55	46 34	25 48	0 255
B10	27 63	23 28	18 69	16 95	1 37	2 65	0 93	0 48	53 28	25 66	0 257
C9	28.18	24 36	15 68	14 55	1 67	2 65	0 58	0 37	71 30	26 25	0 263
C7	25.70	21.76	18 11	14 85	1 47	2 65	0 81	0 45	59 35	26 53	0 265
F8	30 09	25 04	20 17	18 30	1 37	2 65	0 94	0 48	57 06	27 60	0 276
A7	34.18	28 61	19 47	19 50	1 47	2 65	0 81	0 45	64 00	28 56	0 286
C2	36 53	30 35	20 36	21 05	1 44	2 65	0 84	0 46	64 39	29 36	0 294
C4	35 20	29 72	18 44	18 45	1 61	2 65	0 65	0 39	75 74	29 70	0 297
F6	34 73	28 63	21 31	19 25	1 49	2 65	0 78	0 44	72 22	31 69	0 317
F7	32 02	26 20	22 21	18 30	1 43	2 65	0 85	0 46	69 18	31 80	0 318
A3	33 20	25 22	31 64	19 00	1 33	2 65	1 00	0 50	84 15	42 00	0 420
							mean =	0 523	40 36		0 203

porosity	
Mean	0 5225
Standard Error	0 0090
Median	0 5160
Mode	#N/A
Standard Deviation	0 06
Sample Variance	0 004

0i	
Mean	0 203
Standard Error	0 009
Median	0.187
Mode	#N/A
Standard Deviatio	0 06
Sample Variance	0 004