Grant Application
for an
Alternative Cover Demonstration Project
At
Coal Creek Station
Underwood, North Dakota

Presented to:
Ms. Karlene Fine, Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
Bismarck, ND 58505

Submitted by:
Diane Stockdill
Great River Energy
2875 3rd St. SW
Underwood, ND 58576

Principal Investigator:
Ron Jorgenson
Golder Associates Inc.
44 Union Boulevard, Suite 300
Lakewood, Colorado 80228

Funds Requested from the North Dakota Industrial Commission: $250,000

September 30, 2003

GREAT RIVER ENERGY℠
A Touchstone Energy Cooperative

Table of Contents

List of Tables

List of Figures

List of Appendices

ABSTRACT

Handling and disposal costs associated with the management of solid waste have a significant economic impact on the North Dakota power industry. North Dakota regulations governing the operations and design of disposal facilities for coal combustion products (CCPs) specify a prescriptive final cover constructed with soils that is more conservative than covers required in adjoining western states. Federal and State of North Dakota regulations allow for alternative cover designs, provided that performance equivalence is demonstrated using science and engineering.

Using alternative cover designs may reduce the high costs associated with the closure of coal combustion landfill sites in North Dakota while providing equal or better protection of the environment. The prescriptive covers currently required in North Dakota are more costly due to higher construction costs, loss of available disposal airspace, direct and indirect costs to haul and place additional earthen materials, and the loss of valuable soil resources with little or no additional environmental benefit.

The proposed Alternative Cover Demonstration Project is a field demonstration to evaluate and demonstrate the performance of alternative earthen landfill cover designs in the State of North Dakota. The standard of success for the project will be equivalency (or superior performance) relative to the prescriptive landfill cover required for landfills containing coal combustion products. Successfully meeting this objective will pave the way for use of less costly and more environmentally protective covers for landfills in North Dakota used for CCPs.

Great River Energy's (GRE) project team consists of Golder Associates Inc. (Golder) as project designer and manager, and Dr. Craig Benson and Mr. William Albright, principal investigators (PIs) of the U.S. Environmental Protection Agency's (EPA) Alternative Cover Assessment Project (ACAP), as consultants. Data obtained during the project evaluations will assist the EPA's ACAP program and will provide for some national recognition of the projects efforts.

Total project cost is estimated to be $500,000. Grant applicants are requesting a $250,000 match from the North Dakota Industrial Commission.

PROJECT SUMMARY

North Dakota coal fired power plants generate the following solid waste materials or CCPs :

- fly ash
- bottom ash
- flue gas desulphurization (FGD) waste (dry and wet)
- pyrites and economizer ash.

Handling and disposal costs associated with the management of these wastes have a significant economic impact on the power industry. North Dakota's Solid Waste Management Rules (North Dakota Administrative Code, amended May 1, 1999) regulate all solid waste disposal activity. Rules designate landfill requirements for bottom ash in Inert Waste Landfills (33-20-05.1) and for all other coal-fired waste in Small Volume Industrial Waste Landfills and Special Waste Landfills (33-20-07.1). A separate category is established for Large Volume Industrial Waste and Municipal Solid Waste Landfills (33-20-10). Each category of landfill has prescriptive cover design criteria.

Federal requirements for solid waste landfills ("Closure Criteria"of Subpart F, 40 CFR 258.60) require 1) a minimum of 18" of earthen material to minimize percolation (percolation layer), and 2) a vegetative layer consisting of a minimum 6" of earthen material that is capable of sustaining plant growth to minimize erosion of the final cover. North Dakota has primacy for solid waste regulations. However, North Dakota's solid waste rules are more conservative than those of neighboring states as depicted in Table 1.

TABLE 1: SUMMARY OF EPA'S AND SURROUNDING STATES CCP LANDFILL COVER REQUIREMENTS

REGULATION	Compacted Soil or Percolation Layer		Subsoil	Topsoil or Erosion Layer	Total
	Thickness (in)	Permeability (cm/sec)	Thickness (in)	Thickness (in)	Thickness (in)
EPA RCRA Subtitle D[1]	18	1×10^{-5}		6	24
Montana	18	1×10^{-5}		6	24
Nebraska		None	24		24
South Dakota	18	1×10^{-5}		6	24
Minnesota	24	None		6	30
Wyoming	24	1×10^{-7}		6	30
Iowa	24	None	12	0	36
North Dakota	24	1×10^{-7}	30	6	60

[1] The final cover system must be comprised of an erosion layer underlain by an percolation layer as follows (40 CFR, Parts 258.60):

(1) a minimum of 18 inches of earthen material that has a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1×10^{-5} cm/sec, whichever is less, and
(2) The erosion layer must consist of a minimum of 6 inches of earthen material that is capable of sustaining native plant growth.

North Dakota's closure rules allow for alternative cover designs. Rule 33-20-07.1-02 addresses closure criteria for special waste landfills and states that "the total depth of the cover must be five feet or more, or as necessary to meet the requirement of subdivision h of subsection 4 of section 33-20-07.1-01." Subdivision h is a requirement for demonstration of factors such as geology and hydrology of the site, characteristics of the waste, or engineering design. The North Dakota Department of Health (NDDH) has been reluctant to approve alternative covers based on EPA-accepted models and engineering practice, in part because field data are not available for sites in North Dakota demonstrating the efficacy of alternative covers. This project will provide actual field performance data on three different soil cover designs. These data, supported by appropriate engineering, are intended to provide NDDH with sufficient evidence to approve the use of alternative covers in the state of North Dakota.

The goal of this project is to compare the performance of prescriptive and alternative landfill covers, monitored over a period of three years. The three covers to be evaluated are:

- **Special Waste Landfill (SWL) Cover (5-foot landfill) --** Authorized by NDAC Chapter 33-20-07.1, this is the approved landfill cover for CCPs in the state of North Dakota.
- **Municipal Waste Landfill (MWL) Cover (3-foot landfill)** -- Authorized by NDAC 33-20-06.1-02, this cover is already approved by the NDDH for MSW landfills and has a long history of adequate performance in North Dakota.
- **Evapotranspiration (ET) Cover** – EPA's ACAP program has done extensive research on ET covers and has found that, in semi-arid areas of the US, ET cover performance is equivalent to or superior than conventional soil covers such as the MWL and SWL covers.

Modeling results (using HELP and UNSAT-H) predict the cover performance of the 3' Municipal Waste Landfill cover to be equivalent to the 5' Special Waste landfill cover in terms of percolation. Figure 1 below depicts the rate of percolation of water over time from the base of the MWL (3 foot) , SWL (5 foot),, and ET covers.

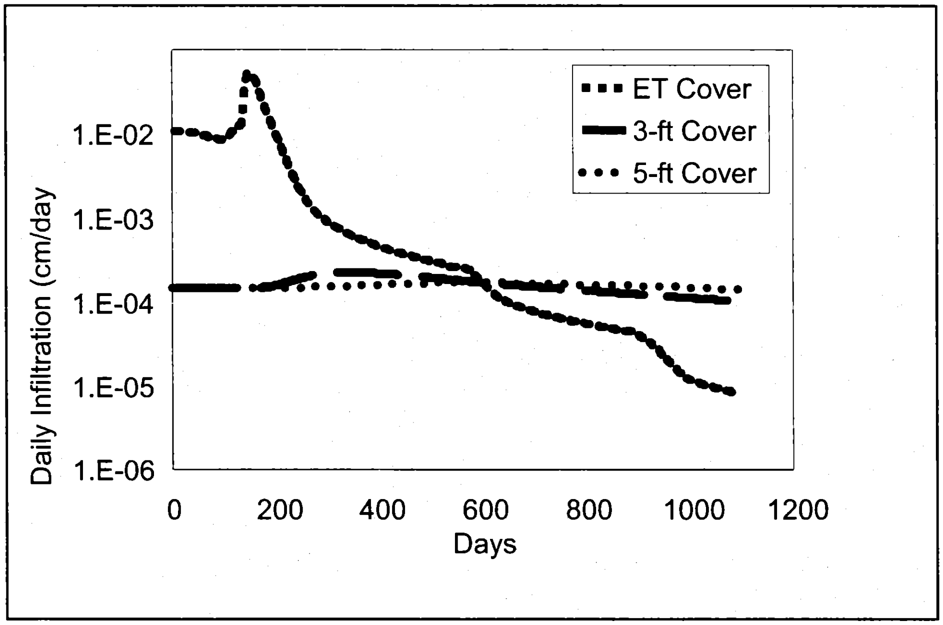


Figure 1: Percolation from the base of the cover as predicted by the model UNSAT-H.

Initially the ET cover transmits more percolation; however, in the second year, as plant growth is fully established, the ET cover outperforms both conventional covers. The model predicts that the 3' and 5' covers perform similarly. In addition, coal combustion wastes are substantially more stable than municipal waste (resulting in less settlement or settlement differential) and CCP leachate is less toxic than MSW leachate.

Golder Associates and Great River Energy have designed this project based on the work of Dr. Craig Benson and Mr. William Albright. Dr. Benson and Mr. Albright will provide technical support during this alternative cover demonstration. The design approach detailed in this report is similar to the approach used for field demonstrations across the United States in the ACAP study.

Test plots will be constructed in accordance with the ACAP Test Section Installation Instructions; Alternative Cover Assessment Program (Benson, et al. 1999). Each plot will contain a test lysimeter, which will be used to collect the percolation from the cover system. The lysimeters will be sloped and contain a drainage geocomposite to direct the flow of water to a sump for collection and measurement. The test plots will be instrumented with three groups of sensors consisting of water content reflectometers and heat dissipation units. The sensor nests are at different depths within the lysimeters. The site will be instrumented with devices to measure precipitation, wind speed and direction, relative humidity, temperature, and other weather-related factors that play a role in cover performance. A data logger will provide information for analysis on a continuous basis.

Performance of the three cover systems will be monitored for a period of three years after construction and evaluated objectively at the end of the period. The main criterion by which the cover systems will be judged is the amount of percolation that is measured at each test plot during Years 2 and 3 of the monitoring period. The Standard of Success for the Alternative Cover Demonstration Project will be equivalency between the performance of the SWL cover and the performance of the alternative covers (MWL and ET covers).

Data from the full-scale test plots will provide field data measurements on landfill cover performance in North Dakota, and will help in the acceptance of alternative covers for coal combustion landfills. The power industry will benefit from this project through reduced expenses associated with cover construction, more rapid permitting of disposal facilities, and an increase in useable air space. The total project cost for the field-scale cover system demonstration is expected to be $500,000.

PROJECT DESCRIPTION

The Alternative Cover Demonstration Project will evaluate the in situ performance of the three landfill cover designs depicted below.

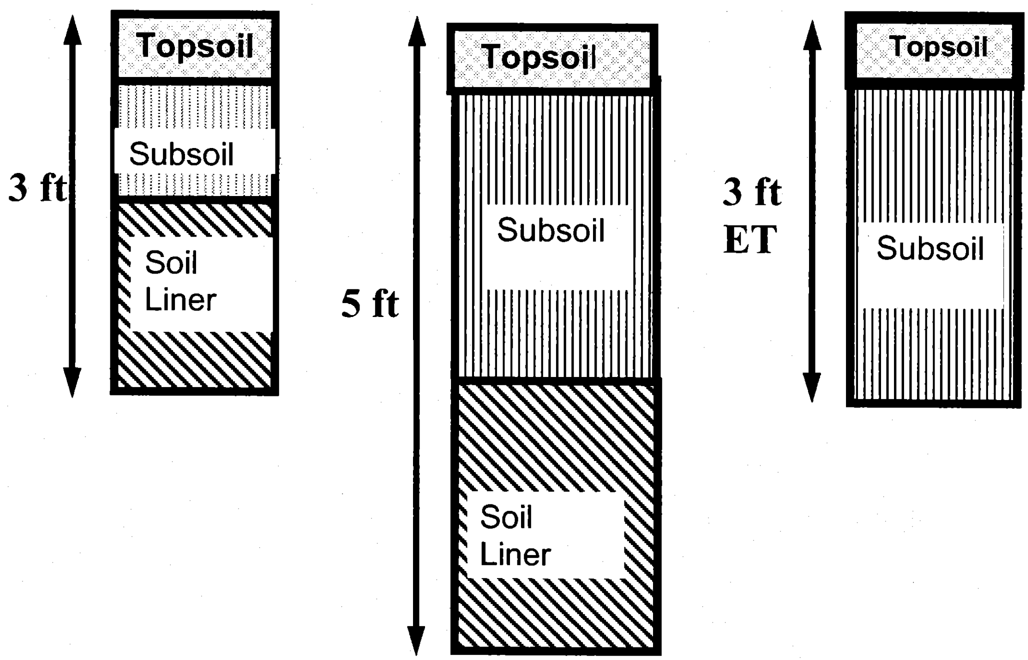


Figure 2: Landfill Cover Designs

TABLE 2: TOPSOIL, SUBSOIL, AND LINER THICKNESSES FOR DEMONSTRATION PROJECT

Required Layer	Municipal Waste Cover*	Special Waste Cover**	Evapotranspiration Cover
Topsoil with adapted grasses	6"	6"	6"
Subsoil	12"	30"	30"
Compacted clay-rich layer	18"	24"	0

*According to NDAC Chapter 33-30-06.1
**According to NDAC Chapter 33-20-07.1

Cover Section Rationale

The rationale for the selection of the three landfill covers is:

- **Special Waste Landfill Cover (5-foot landfill)** - This is the approved landfill cover for CCPs in the state of North Dakota (NDAC Chapter 33-20-07.1) and will be the standard used to compare the alternative covers.
- **Municipal Waste Landfill Cover (3-foot landfill)** –This cover is already approved by the NDDH (NDAC 33-20-06.1-02) and has a long history of adequate performance in North Dakota. Modeling results made using the widely accepted programs HELP and UNSAT-H indicate that the cover performance of the 3' MWL cover is equivalent to that of the 5' SWL cover in terms of percolation. In addition, coal combustion wastes are substantially more stable than municipal waste (resulting in less settlement or settlement differential) and CCP leachate is less toxic than MSW leachate.
- **Evapotranspiration (ET) Cover** - Extensive research on ET covers has found that in semi-arid areas of the United States, the ET cover can perform as well as, if not superior to, conventional covers employing compacted clay barriers such as the MWL and SWL covers. Moreover, ET covers have been found to be less costly to construct and maintain than covers having designs comparable to the MWL and SWL covers.

Alternative Cover Assessment Program (ACAP)

The U.S. EPA initiated the ACAP program in 1998. The key component of ACAP is a network of field-scale tests located throughout the United States. There are currently 11 field-scale test sites in the United States testing numerous cover designs. Three of the host sites have successfully applied for final cover permits based on results from the program, with a fourth application pending. No actual performance data are available for the area in and around North Dakota.

Dr. Craig Benson and Mr. William Albright, the PIs of ACAP, have authored the Test Section Installation Instructions, Alternative Cover Assessment Program. In support of the Alternative Cover Demonstration Project, Dr. Benson and Mr. Albright will act as sub-consultants to Golder Associates and Great River Energy. This project will build on the ACAP effort, incorporating knowledge and lessons-learned from existing field–scale tests.

Test Plot Construction

The test plots will be 10 m x 20 m wide and 1 m to 2 m deep. A brief description of the test plots is included in this project description. Further details can be found in Appendix A, "Test Section Installation Instructions, Alternative Cover Assessment Program." The document provides detailed construction instructions and quality assurance/quality control (QA/QC) recommendations.

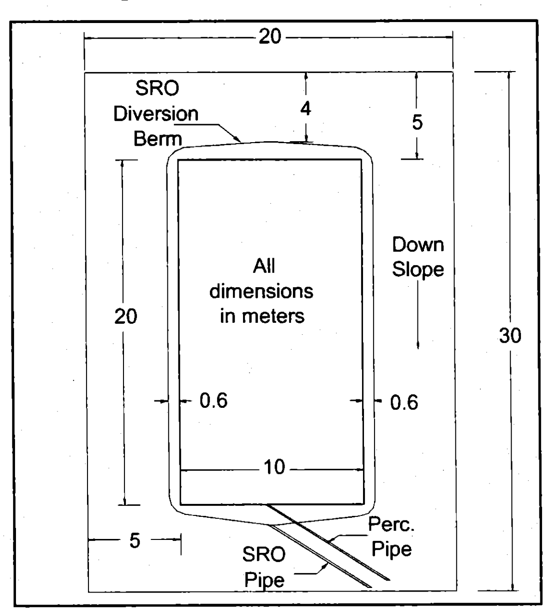


Figure 3: Test Plot Overview

Construction of Test Plots

The lysimeter pans will be located at the Coal Creek Station Section 16 Special Waste Landfill. This disposal area contains fly ash and wet FGD material and is permitted by the State of North Dakota (SP-091). The test plot area will be designed in a manner consistent with ACAP specifications and a geomembrane will be used to line the lysimeter pan in the monitoring area. The geomembrane will be textured on both sides and leak checks will be performed in accordance with established quality guidelines on all test plots.

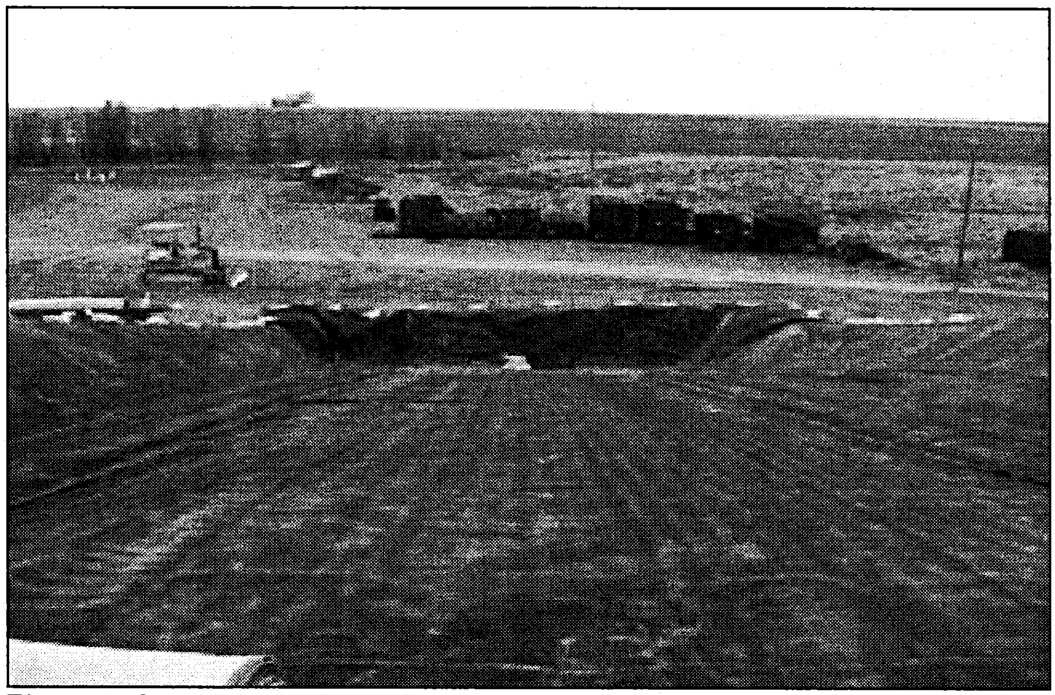


Figure 4: Geosynthetics in Lysimeter Pan

At each test plot a geocomposite drainage layer will be used to collect percolation from the cover. This layer has two purposes; it protects the geomembrane and allows rapid lateral transmission of percolation to a collection and measurement system. The geocomposite drainage layer will have non-woven polypropylene geotextiles on both sides. A sump test pipe will be installed at the downslope end of the lysimeter. This apparatus will be used throughout the project to verify that the sump and/or the collection pipe are not clogged. A PVC pipe will drain the sump. The pipe will be installed in a narrow trench extending from the lowest point in the sump to the precipitation measurement equipment. The riser pipe will extend from the drainage pipe in the sump. The geomembrane will be carefully cut around the periphery of the pipe so that the pipe will penetrate into the sump area. A prefabricated sump boot will be placed over the riser pipe so that the top end of the riser pipe will be flush with the surface of the sump.

A layer of soil 300 to 450 mm deep will then be placed on the top of the geocomposite drainage material to simulate the interim cover soil typically used in landfills. A root barrier will be placed on top of the interim cover layer to prevent roots from reaching the geocomposite drain. The root barrier will be made up of a nonwoven geotextile containing nodules impregnated with the herbicide trifluralin. The surface of each lysimeter will be delineated on the surface by diversion berms that prevent water from surrounding areas from reaching the lysimeter and direct any runoff from the test section to a collection point.

Surface slopes of the test sections will be representative of site conditions. The cover soils are described in Table 2. The following diagram (Figure 5) depicts a cross-sectional view of the test plot.

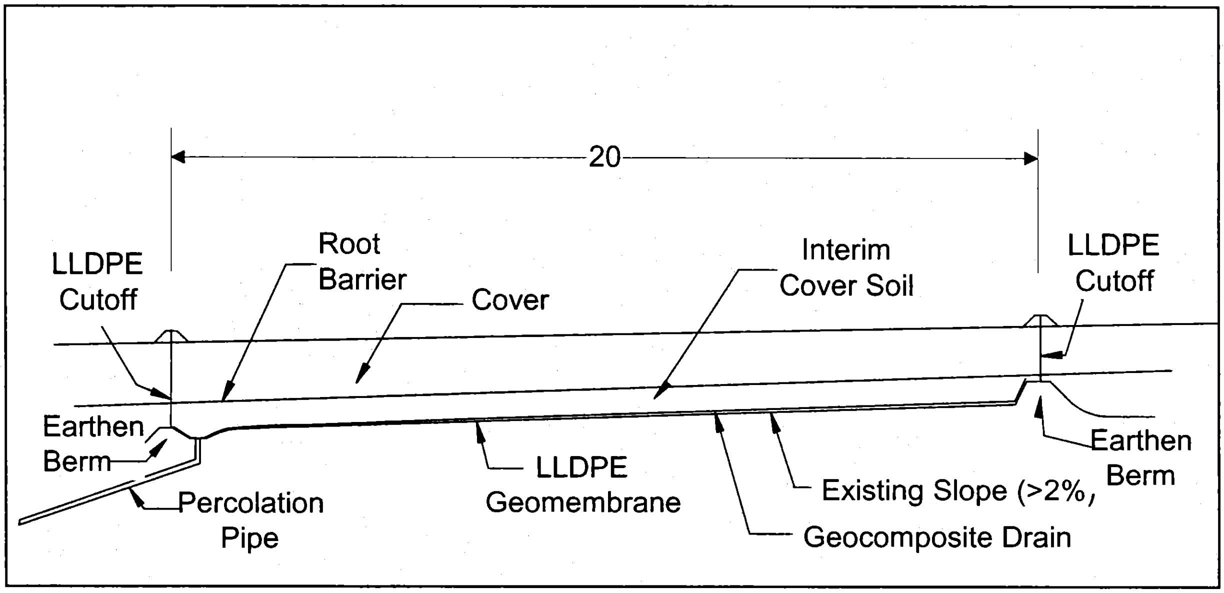


Figure 5: Cross-sectional View of Test Plot

<u>Instrumentation</u>

Each lysimeter will be equipped with a dosing siphon, an automated drainage mechanism that drains the collection basin when a specified volume of water accumulates. A float switch then sends a signal to the data logger indicating that the basin has accumulated and drained a known volume of water. A pressure switch at the bottom of the siphon basin is used to verify the activation of the siphon and to monitor the rate of water accumulation. Calibration of basin volumes, transducers, and tipping buckets will be performed annually.

The test plots will be instrumented with three groups of sensors consisting of water content reflectometers and heat dissipation units. The sensor nests are at different depths within the lysimeters. A weather station with a pyranometer, temperature and humidity sensor, and wind sentry will be installed. All sensors will be wired to a data logger, which will be connected to a telemetry unit.

The telemetry unit will allow remote communication with the data logger and will enable data to be downloaded, stored, and analyzed for performance and system status. Data will be collected each day.

Measurements

During the three-year project, data will be recorded on a data logger connected to a telemetry unit. Measurements are normally taken at one-hour intervals; however, at times of intense activity, for example, such as during an intense rain event, data will be taken at intervals as short as 15 seconds.

Measurements will include:

1. Actual Precipitation (natural and sprinkler)
2. Surface Water Runoff
3. Percolation
4. Air and Soil Temperature
5. Wind Speed
6. Soil Water Content or Soil Moisture Potential
7. Solar Radiation
8. Humidity.

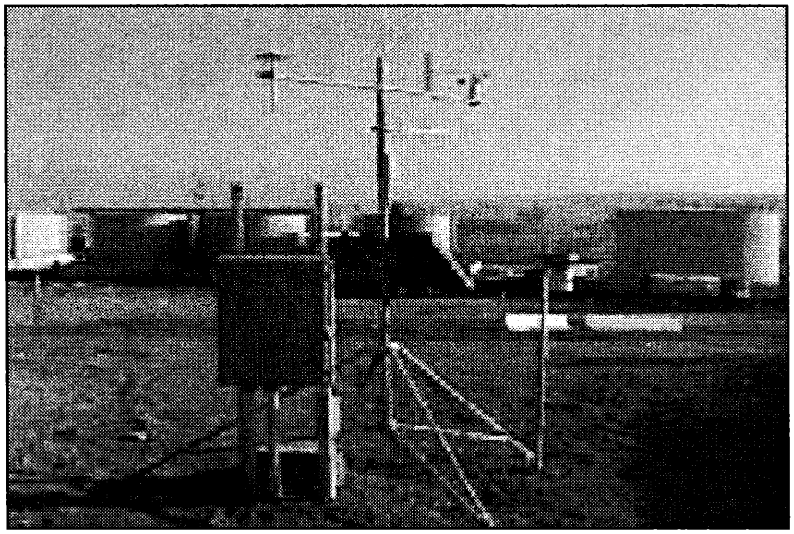


Figure 6: Weather Station from ACAP Demonstration Site

After the quality of the data is assured, they will be placed in the public domain using methods employed with the other ACAP sites.

Vegetation

A mixture of cool and warm season grass species native to North Dakota will be planted on the test plots. Based on recommendations from plant scientists, plants will be selected that are best suited to the climate and soil characteristics of the site. Other factors in plant determinations will be root mass density versus root depth, leaf area index and leaf area index with seasonal changes.

Artificial Precipitation

Since performance of the ET cover is dependent upon plant water storage and transpiration, construction of the test plots will occur in the spring to allow time for vegetation growth. A sprinkling system may be used to water the test plots in periods of lower-than-average naturally occurring rainfall. Care will be taken during sprinkling to avoid damage to the plant and soil communities.

STANDARD OF SUCCESS

The goal of the Alternative Cover Demonstration Project is to demonstrate the effectiveness of alternative covers for coal combustion landfills in North Dakota. The Standard of Success will be an equivalency between the performance of the prescriptive Special Waste landfill cover and the alternative covers. The project will monitor measurements for a three-year period. Year 1 will be an equilibrating year. Percolation from the alternative covers for Years 2 and 3 will be averaged separately and compared to the average percolation measured in the Special Waste landfill cover in those years.

Three sources of uncertainty exist in the method by which the percolation data are measured and analyzed. Uncertainty is introduced into the field-scale testing in the following ways:

1. The data obtained by the percolation measuring equipment, while relatively precise, are not without some inherent uncertainty. The accuracy of the lysimeters that will be used for the project is ± 0.5 mm per year of test duration.

2. Spatial variability exists in the materials used to construct the test plots. The error introduced in the percolation measurements due to variability in the hydraulic properties of the soil is estimated to be ± 0.3 mm per year of test duration.

3. Temporal variability is introduced by differences in annual percolation rate due to variations in meteorological and vegetative conditions. Temporal variability is quantified at ± 1.0 mm per year of test duration in semi-arid regions.

These sources of uncertainty must be taken into account when determining whether two cover designs qualify as equivalents. Consistent with ACAP practice using the measurement accuracies noted earlier, an alternative cover will be deemed equivalent if there is overlap between its average annual percolation rate in Years 2 and 3 ± 2.4 mm and the average annual percolation rate for the prescriptive cover in Years 2 and 3 ± 2.4 mm.

BACKGROUND

Golder Associates Inc. (Golder) will be the project designer and manager. Golder is one of the leading waste containment design consulting companies in the world. Golder has worked on 5 of the 10 largest landfills as reported by Waste News, and is ranked 7th by the Engeineering News Record in 2003 for solid waste and 5th for hazardous waste. Golder personnel were instrumental in the development of the RCRA Subtitle C (hazardous waste) alternative final cover test plots at the Rocky Mountain Arsenal (RMA), a large Superfund site located near Denver, Colorado. Working for the U.S. ARMY and as part of the Project Management team, Golder also developed construction methodologies, reviewed the results of unsaturated flow modeling, and performed an extensive borrow characterization program that lead to the design and permitting of alternative covers at the RMA. The design for RMA utilizes alternative covers that will be constructed in lieu of the RCRA Subtitle C covers on more than 400 acres where hazardous waste will remain in-place due to concerns about excavation and relocation. The alternative covers have been designed to be functional equivalent to, or superior to , in terms of limiting percolation from the base the cover (i.e., the water that drains into the underlying waste), than RCRA Subtitle C composite cover systems.

Golder and Great River Energy's project team also includes Dr. Craig Benson and Mr. William Albright, principal investigators (PIs) of U.S. Environmental Protection Agency's (EPA) Alternative Cover Assessment Project (ACAP) effort. The EPA undertook the ACAP program in 1998 to address industry and regulators concerns about lack of information on performance of alternative earthen final covers. The program brings together private-sector groups, regulatory bodies and research organizations. Field-scale test sections have been established at 11 landfill sites across the country. Site owners include local public agencies, private corporations, and federal government entities.

The ACAP approach is being used nationwide as the basis for equivalency demonstrations for alternative covers. The project's design approach will utilize ACAP design methodologies so that the data will be consistent with those that are obtained at for other ACAP sites and can be used for nationwide policy decisions that may ultimately affect sites in North Dakota. Dr. Benson and Mr. Albright will support Great River Energy and Golder Associates in this demonstration project. Data obtained during the project evaluations will assist the EPA's ACAP program and will provide for some national recognition of the projects efforts.

QUALIFICATIONS

RON JORGENSON - ASSOCIATE

Mr. Jorgenson is an Associate with Golder and has roughly twenty years of professional experience including management of multi-disciplinary, technical diverse projects for the mining and power industries. Mr. Jorgenson's power experience includes specialization in the design, permitting, and evaluation of coal combustion by-product (CCB) waste containment facilities. This experience includes evaluation of alternative waste disposal options and the design of numerous containment facilities for several power producers. As the project manager for design and permitting of numerous CCB containment facilities, the team was successful in permitting new and innovative designs that resulted in large initial and operational capital savings for a number of clients. Mr. Jorgenson's experience includes the preparation of long range plans including operational financial evaluations for sites where the waste volumes exceeded 1 million tons annually. These operational evaluations focused on short and long term designs, regulatory issues, and operational constraints. The goal of the financial evaluations was to provide the client with cost effective containment designs that included long range planning and cost forecasts.

CRAIG H. BENSON, PHD, PE

Craig H. Benson PhD, PE is Professor of Civil and Environmental Engineering and Geological Engineering at the University of Wisconsin-Madison, where he has been a member of the faculty since January 1990. Dr. Benson has a BS from Lehigh University and MSE and PhD degrees from the University of Texas at Austin. All degrees are in

Civil Engineering, with the MSE and PhD degrees specializing in geo-engineering. Dr. Benson is a licensed professional engineer.

For the last 15 years, Dr. Benson has been conducting experimental and analytical research on barriers to flow and contaminant transport, and is regarded as one of the leading international experts on the performance of barrier systems. Dr. Benson has been conducting research on the effectiveness of alternative earthen final covers (AEFCs) for waste containment as one of his primary scholarly thrusts. This research has included laboratory studies, large-scale field experiments, and modeling. Dr. Benson consulted on the first AEFC approved for a composite-lined facility in the United States. He has received several awards for his work, including the Presidential Young Investigator Award from the National Science Foundation and the Distinguished Young Faculty Award from the US Dept. of Energy. Dr. Benson has also received the Huber Research Prize as well as the Croes, Middlebrooks, Collingwood, and Casagrande Awards from the American Society of Civil Engineers. Dr. Benson is an active member of the Geo-Institute and is chair of ASTM committee D18.04 on Hydrologic Properties of Soil and Rock.

Dr. Benson is one of the principal investigators for USEPA's Alternative Cover Assessment Project (ACAP). He was intimately involved in design of the ACAP test sections, and acted as the engineer-of-record during construction. Currently he is collaborating with the Desert Research Institute on interpretation of data being collected from the ACAP test sections.

MR. WILLIAM ALBRIGHT

Bill Albright has 20 years of research experience in environmental science. His research interests have included arid lands soil physics, regional air pollution, atmospheric chemistry and weather modification, plant ecological physiology. He has been active in field and laboratory estimations of recharge in very dry soils. He has participated in the development of landfill facility design for the disposal of radioactive waste for the U.S. Department of Energy at the Nevada Test Site. He has been involved in the development of alternative landfill cover designs for sites in the arid and semi-arid portions of the country. He is currently investigating the processes of recharge and solute movement in the unsaturated zone within irrigated lands in the Great Basin. Albright is director of the DRI Soil Physics Lab.

Bill Albright is principle investigator for the USEPA's Alternative Cover Assessment Program (ACAP). The primary goal of ACAP is to establish a cooperative program with federal, state, and private sector entities to conduct a regional evaluation of landfill cover facilities. ACAP is currently conducting field-scale testing of landfill covers at several sites across the country. Data collected from the program will guide the development of improvements in cover design and evaluation.

VALUE TO NORTH DAKOTA

Cost Implications

There are both direct and indirect cost implications for the state of North Dakota and its power industry. The thicker covers currently prescribed in North Dakota result in higher direct costs to the industry, such as:

1. Costs for construction of a new landfill area to replace the airspace that would be lost to the thicker layer.
2. Added costs to haul and place additional earthen material.
3. Associated construction costs (i.e. construction quality assurance, survey) for a new landfill.
4. Loss of available resources for reclamation of areas disturbed during mining activities.

Clearly, direct cost savings may be realized by using alternative covers if they can be demonstrated to be more efficient and equally protective of the environment. Indirect costs are also minimized by using alternative covers. Indirect costs that could be reduced by using alternative covers include:

1. Permitting costs associated with a new landfill
2. Internal costs to maintain a new landfill area
3. Environmental monitoring at a new landfill area.

Previous analysis in the Alternative Cover Analysis Report (Golder 2002) combined these direct and indirect costs for a Special Waste landfill having a 150-acre footprint.

The additional costs associated with the NDDH prescriptive 5' cover compared with an engineered 3'cover amounted to $4,700,000 for the 150-acre footprint. Assuming a typical landfill design is used, the additional cost of CCP disposal for the NDDH prescriptive cover is approximately 23.5 cents per disposed ton. Alternative cover designs present similar opportunities for direct and indirect cost savings for North Dakota power producers, who burn about 30,000,000 tons of coal annually, and represent an important component of the state's economy.

Environmental Implications

This study will demonstrate how landfill covers perform in North Dakota and will provide valuable information to North Dakota citizens and regulators. Field data will be provided to the ACAP program, providing EPA with data for this region of the US. ACAP sites are indicated by black dots on the map in Figure 7.

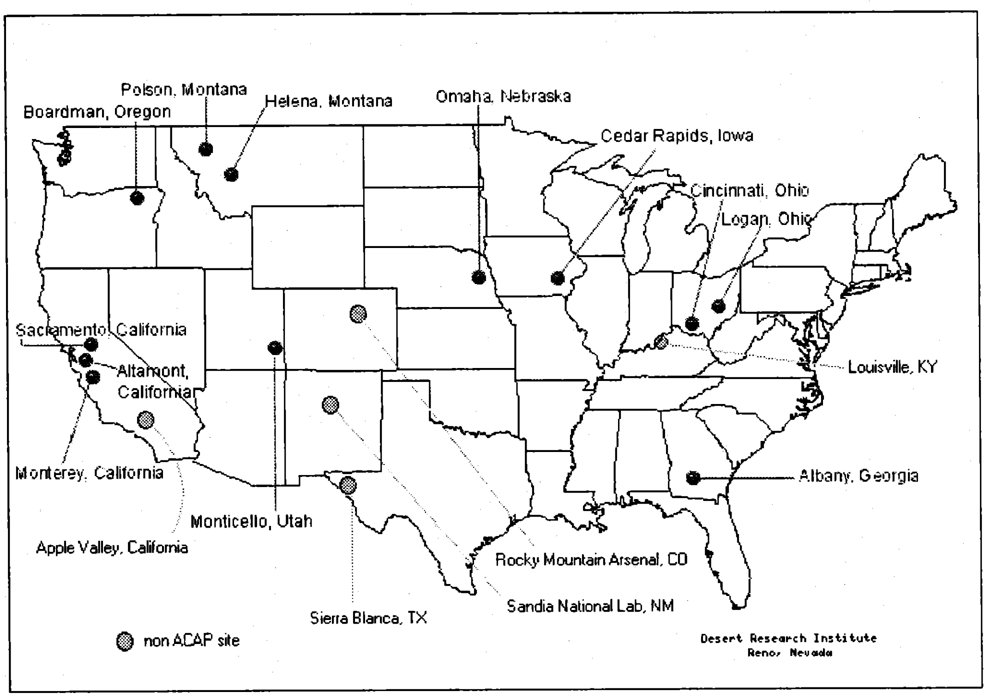


Figure 7: ACAP Sites

Models predict that alternative covers will not negatively impact the environment, and will likely be more protective over the life of the facility. This project will provide field data to compliment modeling data.

Efficient use of North Dakota resources has an additional indirect benefit in that fewer acres will be disturbed to accommodate cover requirements. Avoiding disruption of additional acreage can prevent loss of native habitat, cropland disturbance, and loss of wildlife habitat.

MANAGEMENT

Great River Energy is the project funder and will host the demonstration site. The project design, management and communications will be the responsibility of Ron Jorgenson, project manager. Mr. Jorgenson will be responsible for directing the project schedule and subcontractors. He will ensure that the project proceeds in a timely manner and within the project budget of $500,000. Dr. Craig Benson and Mr. William Albright from EPA's ACAP program will support Golder's effort. Figure 8 is the organization chart for the project.

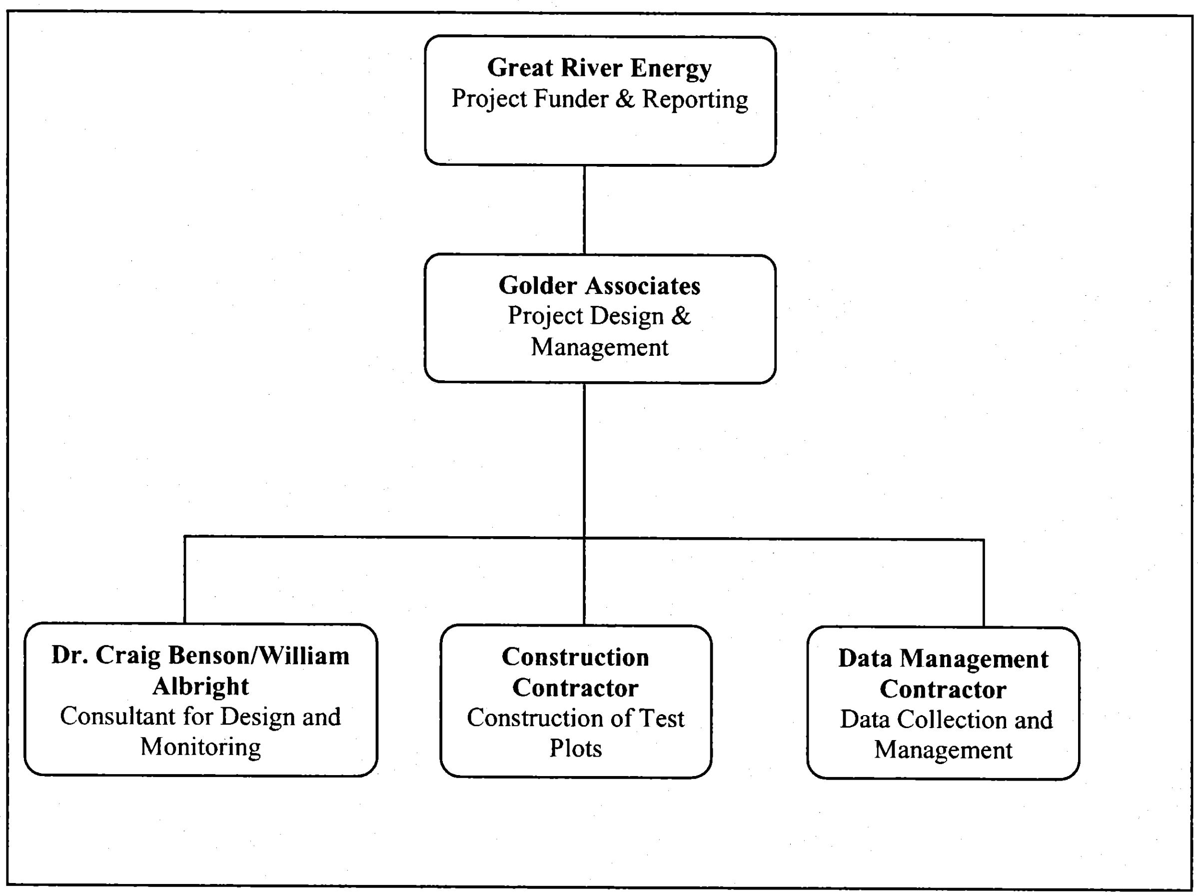


Figure 8: Project Management

Initial work is divided into three tasks, design, construction and monitoring and analysis. Management of each task will be cooperative, with specific requirements designated according to expertise.

Design Work

Project design will be completed during the period leading up to the spring of 2004. Activities include the ongoing planning and coordination involving the design and monitoring efforts, producing and revising work plans for the construction team to use, and preparing a report detailing the proposed alternative cover project. Dr. Benson and Mr. Albright will support Golder in performing some of these duties.

Other tasks include limited laboratory testing of soil materials for use in the field demonstration construction. Testing will include Proctor compaction, determination of the soil-moisture characteristic curve, and hydraulic conductivity testing on site-specific soil.

Engineering design work will continue over the course of the project. Once a year, a project engineer will be deployed to perform various on-site monitoring duties. In addition, telemetry equipment installed at the test plot site will allow remote, real-time monitoring of field data on a continuous basis.

Test Plot Construction

Field-scale demonstration test plots will be constructed to observe the performance of the three cover systems side-by-side. GRE work crews will prepare the subgrade as specified in the work plans developed by Golder Associates. Contractors will be hired to construct the cover systems, including installation of instrumentation, soil liners and geosynthetic materials.

Devices to measure precipitation, wind speed and direction, relative humidity, temperature and other weather-related factors that play a role in the performance of the covers will be installed by qualified contractors. Water content reflectometers and heat dissipater units will also be used. In addition, precise measurement of percolation through the cover systems will necessitate construction of collection basins in accordance with ACAP guidelines.

Construction will be monitored by a Golder field or staff engineer. Either Dr. Benson or Mr. Albright of ACAP will be on-site observing the work during the two weeks of construction that are considered the most critical. An independent testing laboratory will be retained to perform quality control duties. A construction record, including photographs of the test plots, will be taken during placement.

Monitoring and Analysis

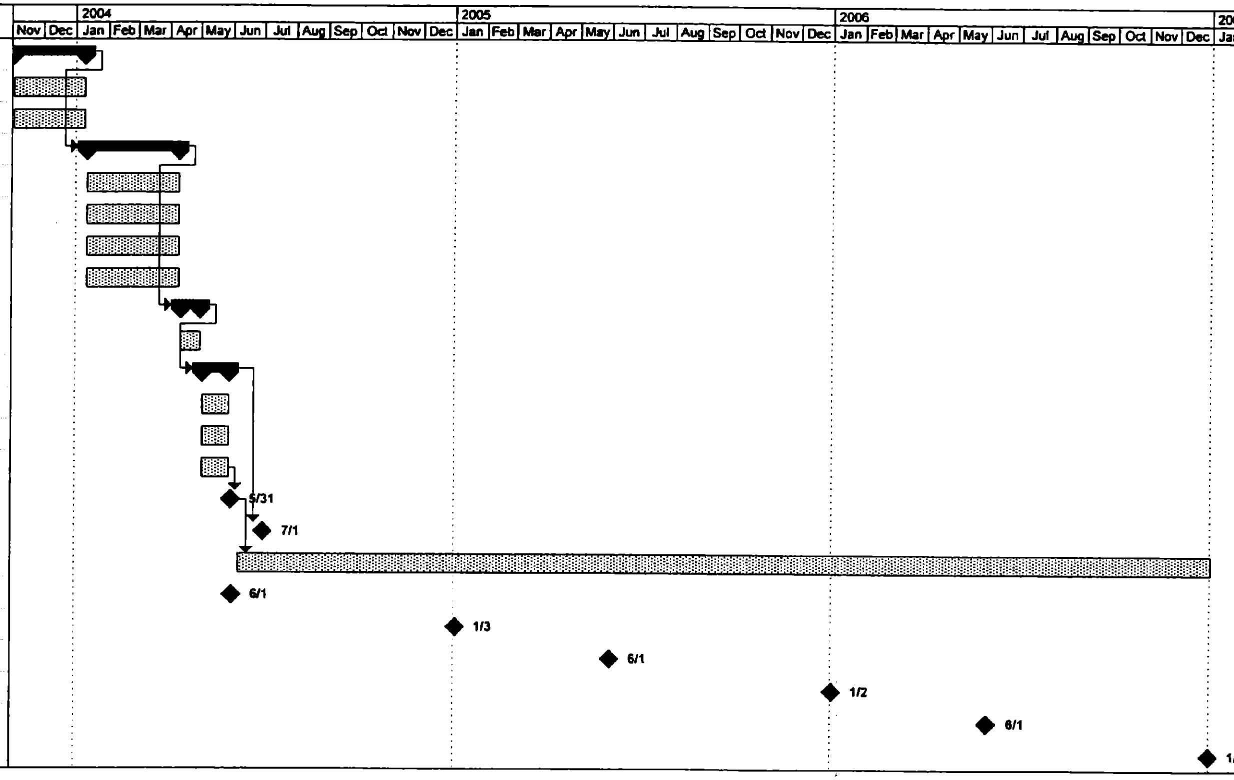
QA/QC of the continuous monitoring data will be performed by Golder. After the quality of the data is assured, they will be placed in the public domain using methods employed with the other ACAP sites

Project Communications

To manage the project, GRE's project team will implement a management control system that is based upon system and communication platforms that have proven to be effective. Mr. Ron Jorgenson will be the focal point for all project communications, including communicating project status and pertinent issues with GRE. The day-today project communications will be accomplished primarily through the use of the internet and email. Drawing files too large to be sent through regular email will be posted to an FTP web site for staff access and review. Project conference calls will be scheduled on an as-needed basis with the senior project team, and various subcontractors. Semi-annual project updates will be provided to the North Dakota Industrial Commission. At the end of the three-year period, a final report containing the findings of the demonstration will be submitted to the North Dakota Industrial Commission.

Alternative Cover Demonstration Project Timetable

ID	Task Name
1	**Design Work**
2	Design Test Cells
3	Design Monitoring Plan
4	**Planning Work**
5	Order Monitoring Equipment
6	Produce Construction Work Plans and Drawings
7	Laboratory Testing of Soils
8	Secure a Contractor
9	**Site Preperation**
10	GRE Grades Test Plot Site
11	**Test Plot Construction**
12	Install Soil Liners, Geosynthetic Materials, and Covers
13	QA/QC on Lysimeter Pans
14	Install Instrumentation
15	Instrumentation Startup
16	Produce Record of Construction of Lysimeter Pans, QA/QC Activities
17	Monitoring and Analysis of Data
18	1st Semi-Annual Report
19	1st Annual Report
20	2nd Semi-Annual Report
21	2nd Annual Report
22	3rd Semi-Annual Report
23	Final Report to NDIC



BUDGET

The total project cost estimate is $500,000. We are requesting matching funds of $250,000. The project budget contains material and contractor costs, construction management costs, engineering and design costs and costs associated with reporting and data management. Time and expenses incurred during the development of the application will not be submitted to NDIC for reimbursement.

- Material Costs - $92,000

  Material costs include geosynthetics, soil/concrete, lumber, pipe and fittings, basin/tank, all data collection instrumentation and cables. A detailed listing is provided in Appendix B-1: Material and Construction Costs.

- Contractor Costs - $41,000

  Contractor costs includes mobilization, survey costs, quality control testing, geosynthetic installation, topsoil placement, clay liner placement and general grading and embankment construction. A detailed listing is provided in Appendix B-1: Material and Construction Costs.

- Construction Management - $75,000

  Includes estimates for field engineers, construction management and consultant (Dr. Benson/Mr. Albright) invoices. Attachment B-2 Construction Management contains a detailed spreadsheet of construction management costs.

- Engineering Design - $255,000

  Includes planning and design work for the project. Engineering design also includes monitoring costs and the costs associated with annual site visits. Appendix B-3 Engineering Design Costs contains a breakdown of engineering design costs.

- Reporting and Data Management - $37,000

  Includes NDIC-required reporting and management of data gathered in the Alternative Cover Demonstration Project. Appendix B-4 Reporting and Data Management costs contains detailed information for reporting and data management.

MATCHING FUNDS

Great River Energy has agreed to provide a total contribution of $250,000 to the Alternative Cover Demonstration Project. We are requesting that the North Dakota Industrial Commission join us in supporting this project by committing an additional $250,000 to this project through the Lignite Research Council.

Tax Liability

I, Douglas J. Paumen, certify that Great River Energy does not have any outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

Douglas J. Paumen Manager, Financial Services	9/30/03 Date

Confidential Information

All data will be placed in the public domain as part of ACAP. The final report summarizing the project and its findings will be public information

REFERENCES

Benson, C.H., Abichou, T., Wang, X., Gee, G.W., and Albright, W.H.. 1999. *Test Section Installation Instructions, Alternative Cover Assessment Program* (Geo Engineering Report 99-3). Madison, WI: University of Wisconsin Geo Engineering Program. http://www.uwgeotech.org/pubs/gr_benson_test.pdf

Golder Associates, Inc. 2002. *Coal Creek Station Alternative Cover Analysis Report*, submitted to the North Dakota Department of Health, Division of Waste Management by Great River Energy. (Golder Project No. 003-2184). Lakewood CO : Golder.

North Dakota. 1999. *Solid Waste Management Rules* (33-20 North Dakota Administrative Code, amended May 1, 1999).

Test Section Installation Instructions

Alternative Cover Assessment Program

by

Craig H. Benson, Tarek Abichou, and Xiaodong Wang
University of Wisconsin-Madison

Glendon W. Gee
Battelle Pacific Northwest National Laboratory

William H. Albright
Desert Research Institute

Environmental Geotechnics Report No. 99-3

Environmental Geotechnics Program
Depts. of Civil and Environmental Engineering, Geological Engineering
University of Wisconsin-Madison
Madison, Wisconsin 53706

December 17, 1999

J:\Research & Development\LRC\Grant Rounds\Grant Round L (50)\Proposals\Proposal F-Alternative Cover Demonstration Project\Test_Section_Installation_Instructions V.1.doc

TABLE OF CONTENT

1. INTRODUCTION

This document describes installation procedures for test sections constructed for the Alternative Cover Assessment Program (ACAP). An ACAP test section is designed to simulate an earthen alternative cover for a waste containment facility. Each test section contains a lysimeter pan to collect percolation from the base of the cover; a collection system for surface runoff; and sensors to monitor hydrologic variables within the cover soils, percolation and runoff volumes, and meteorological data. This document is divided into seven main sections. These sections include this introduction and describe the following construction activities:

- installation of the lysimeter pan and associated plumbing,
- placement of the cover soils,
- installation of the surface runoff collection system,
- installation of the instrumentation, and
- vegetation.

Calibration, wiring, programming, and testing of the instruments and data collection system are not included in this document. Calibration and testing procedures are described in the Quality Assurance Project Plan (QAPP). Wiring of the instruments and programming are described in the Standard Operating Procedure for Datalogger Programming and Data Checking for ACAP Sites.

Protocols to check each system after installation are described in each of the main sections. The Resident Engineer (a member of the ACAP team designated on a site-specific basis) is responsible for construction of the test section. The Resident Engineer and Field Manager must approve changes or modifications to the construction protocols. When changes involve modification of a critical component of the test section, the entire ACAP team should be notified. Approval of such modifications by the entire team is necessary before implementation of such changes. ASTM standards are frequently referenced throughout this document. All referenced standards are included in Appendix I. Specification sheets for materials used during this project are in Appendix II.

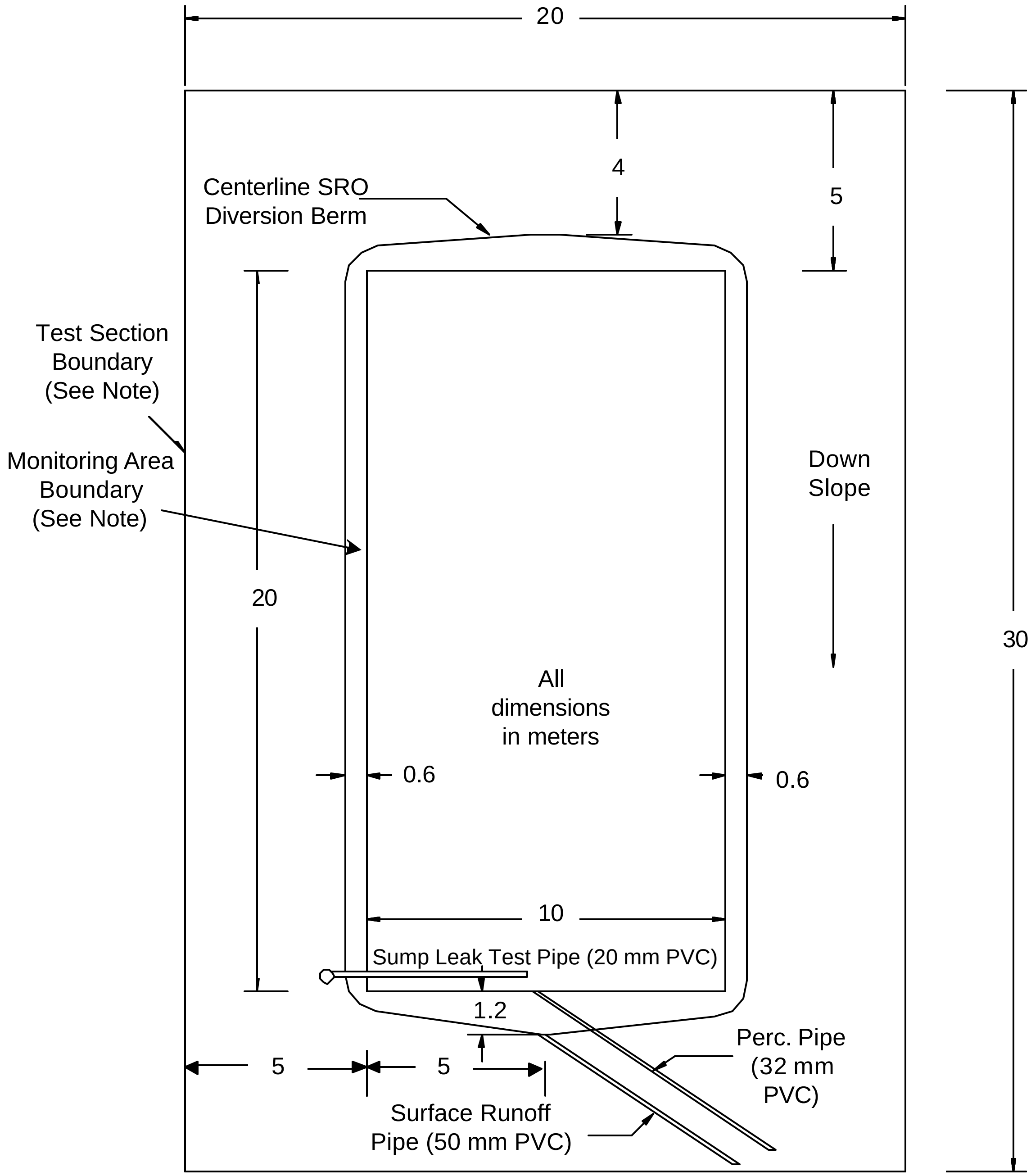
2. LYSIMETER PAN

Locate the area where the test section is to be installed as specified by the site owner. The lysimeter pan should be located in the central portion of the test section, as shown in plan view in Fig. 1. Subgrade and cover soils are to be placed over the entire test section area. That is, the cover profile should be constructed inside and outside of the lysimeter pan, which constitutes the monitoring area. Geosynthetics are to be placed only in the monitoring area. The area where the test section is located should be stripped of topsoil and prepared to the grade required for the base of the lysimeter. Areas with soft materials should be over-excavated and replaced with new materials. These materials should be placed using methods described in Sec. 2.1.1. When filling is not required, the entire test section location should be proof-rolled until meeting the approval of the Resident Engineer.

2.1 Subgrade Preparation

2.1.1. Placement and Compaction

Subgrade should consist of local soils. Moderately cohesive finer textured soils (% fines > 30% as per ASTM D 422) are preferred. The Resident Engineer shall approve subgrade soils before placement. When fill must be placed to achieve the desired elevations, the fill must be placed in loose lifts having a thickness ≤ 300 mm (12 in) or in accordance with instructions provided by the Resident Engineer. For cohesive soils, compact the subgrade to a dry unit weight ≥ 90% of the maximum dry unit weight per ASTM D 698. The compaction water content of cohesive subgrade shall be less than optimum water content (OWC) defined per ASTM D 698. Cohesionless soils should be densified to obtain a relative density > 90% per ASTM D 4253. At least four measurements of water content and dry unit weight shall be made at random locations in each lift to check compaction. ASTM methods D 2922, D 2167, or D 1556 shall be used. Soft regions or inadequately compacted regions identified by testing or by the Resident Engineer shall be re-worked until their condition meets the satisfaction of the Resident Engineer and the aforementioned compaction requirements.



Note: Subgrade and cover soil should be placed over the entire test section area, not only over the the monitoring area.

Fig. 1. Plan view of test section.

The final lift of subgrade shall contain particles no larger than 12 mm (0.5 in) exposed on the surface. Ridges, depressions, equipment tracks, or other variations in the subgrade surface shall not exceed 12 mm (0.5 in). If such variations exist, they shall be smoothed and subsequently compacted by hand to the satisfaction of the Resident Engineer. The Resident Engineer shall approve the final surface of the subgrade before placement of overlying soils or geosynthetics.

2.1.2. Grading of Subgrade and Diversion Berms

The surface of the subgrade in the monitoring area shall be sloped towards the centerline at a grade ≥ ± 2%, but ≤ ± 5% as shown in Fig. 2. Centerline of the subgrade shall be sloped towards the sump at the natural grade and/or at a grade of ± 2% (Note: ± is used to indicate that these values refer to an average or an overall slope). Elevation of the center of the sump area shall be the lowest point in the monitoring area.

Perimeter berms can be constructed of subgrade soil along the periphery of the monitoring area (Figs. 2, 3) if desired by Resident Engineer and/or to facilitate installation of the lysimeter pan. Compaction and surface finish of the berms shall meet the same requirements as the subgrade soil as described in Sec. 2.1.1.

2.2 Sump Drainage Pipe

Schedule 40 PVC pipe [32-mm-diameter (1.25 in)] drains the sump as shown in Fig. 4. Install the pipe in a narrow trench extending from the lowest point in the sump through the bottom perimeter berm. Place a section of pipe long enough to daylight from the outer edge of the berm and ensure that the slope of the pipe is at least ± 2%. Solvent weld all PVC joints following instructions provided by the pipe manufacturer.

Compact subgrade soil on top of the trench to the satisfaction of the Resident Engineer. Leave an annulus along the riser in the center of the sump where the sump boot attaches.

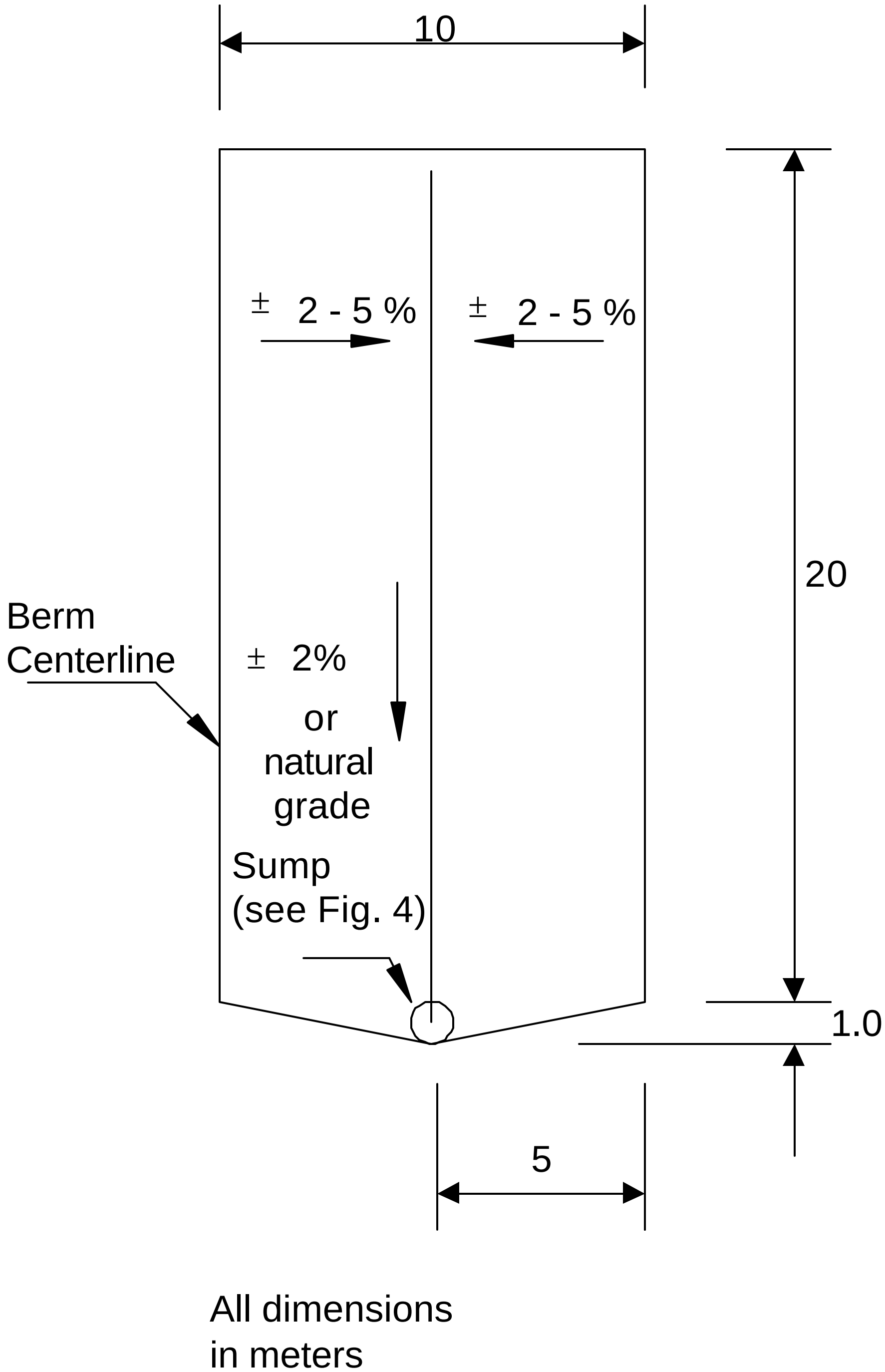
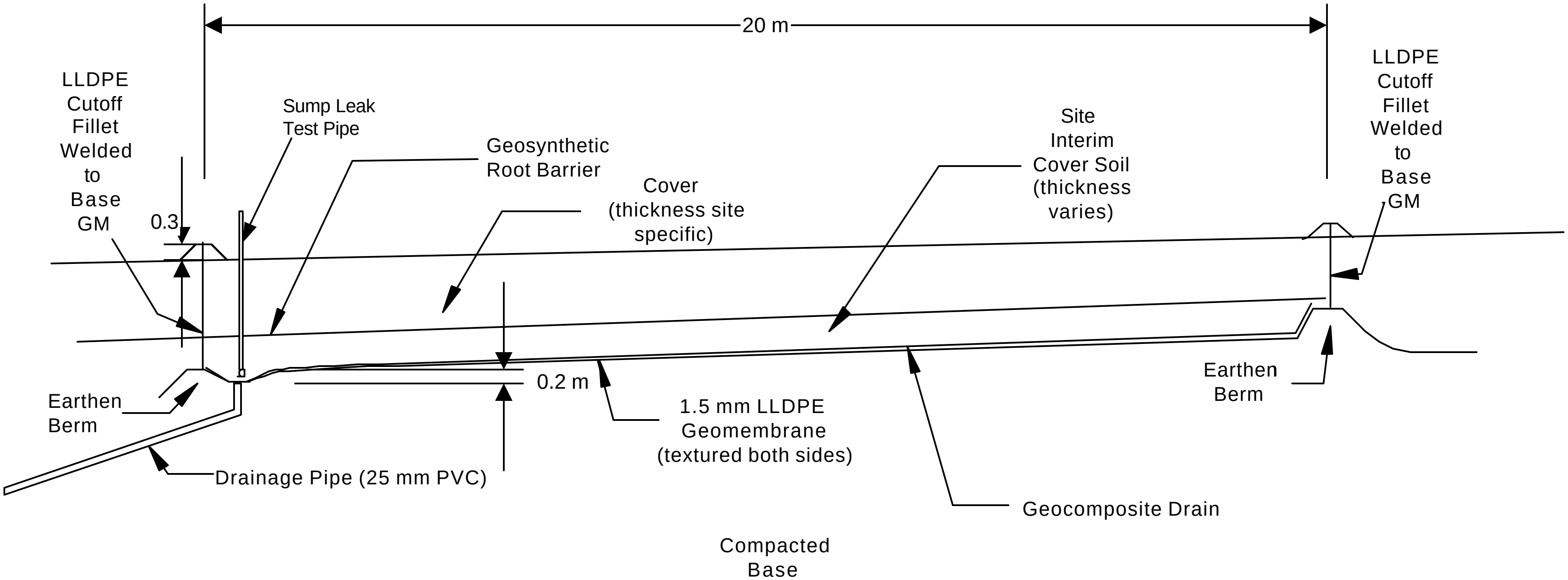


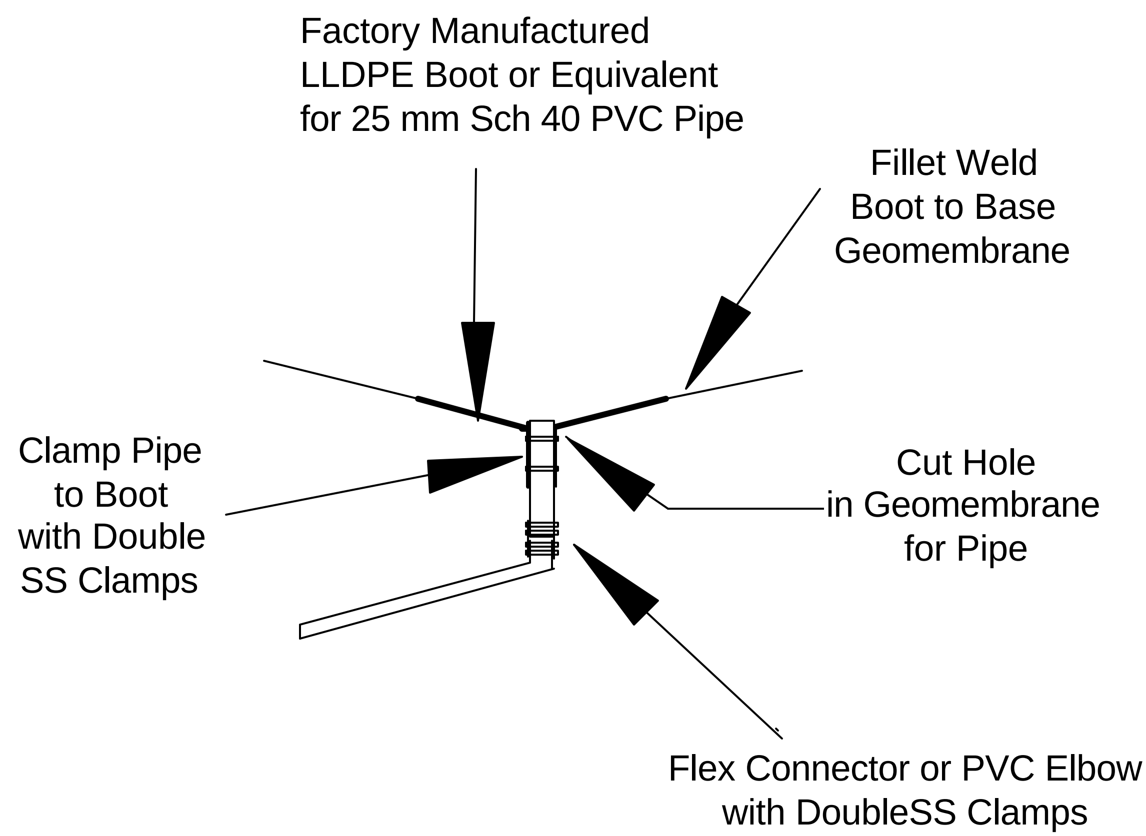
Fig. 2. Plan view showing grading of subgrade for lysimeter pan.



Notes:

1. Base shall be approved fill (fines > 30%) compacted to >95% of max. dry unit weight based on ASTM D 698 and dry of optimum water content.
2. Smooth base before placing geomembrane. Eliminate all ridges, depressions, etc. > 25 mm in height. Remove all stones, etc. larger than 10 mm.
3. Place geomembrane in early mornining and ensure good contact with all surfaces. No gaps shall exist between base and geomembrane.
2. Vertical cutoff sheets shall be fillet welded to base geomembrane
3. Geocomposite drain is geonet with non-woven geotextile heat bonded to both sides. Install using rub sheet.
4. Interim cover soil shall be placed on geocomposite drain from the edges. No equipment can travel on geomembrane or geocomposite drain. Once spread in 450 mm loose lift, compact to >85% of max. dry unit weight based on ASTM D 698.

Fig. 3. Cross-section of test section.



Notes:
1. Slope base of sump inwards to pipe
2. Pipe end shall be flush with surface of boot.
3. Silicone caulk connection between pipe and boot as well as pipe and flex clamp before tightening SS clamps
4. Sump must past leak test before geocomposite drainage layer is placed.

Fig. 4. Schematic of lysimeter sump.

Check the drainage pipe for leaks by installing a sight tube on the downstream end of the pipe (Fig. 5). Fill the pipe with water until it overflows at the upstream end. Cap the upstream end of the pipe with parafilm (or similar material) and a rubber band or tape. Pierce the parafilm cap with a needle to form a small hole for pressure equilibration. Place a similar cap on the top of the sight tube.

Monitor water elevations in the sight tube and in an identical adjacent sight tube with a sealed base for 40 min. Correct elevations in the sight tube plumbed to the sump using data collected from the adjacent sealed sight tube to account for solar, temperature, and barometric effects if necessary. The pipe is considered leak-free if the water elevation in the sight tube varies by ≤ 3 mm during the monitoring period and the water elevation has no discernable temporal trend. If this criterion is not met, determine the location of the leak, seal the leak to the satisfaction of the Resident Engineer, and then conduct the leak test again. Repeat this procedure until the criterion has been met satisfactorily and the Resident Engineer approves the pipe installation.

2.3 Geomembrane and Geocomposite Drain Installation

2.3.1. Deployment and Welding of Geomembrane

LLDPE geomembrane (GSE Ultraflex Textured VFPE or equivalent) is to be used to line the lysimeter pan. The geomembrane shall be textured on both sides and shall be at least 1.5 mm (60 mil) thick. High-density polyethylene (HDPE) or PVC geomembrane shall not be used.

Move the roll of geomembrane to the side of the lysimeter using a loader equipped with a gantry bar or similar equipment. Suspend the roll of geomembrane above the ground surface during movement and deployment onto the subgrade. If the geomembrane is wrapped, remove the wrapper once the roll has been transported to the top of the lysimeter. Unroll the geomembrane from the side of the lysimeter by hand and gently pull the geomembrane by hand across the lysimeter to the other side so that the edge of the geomembrane runs perpendicular to the slope.

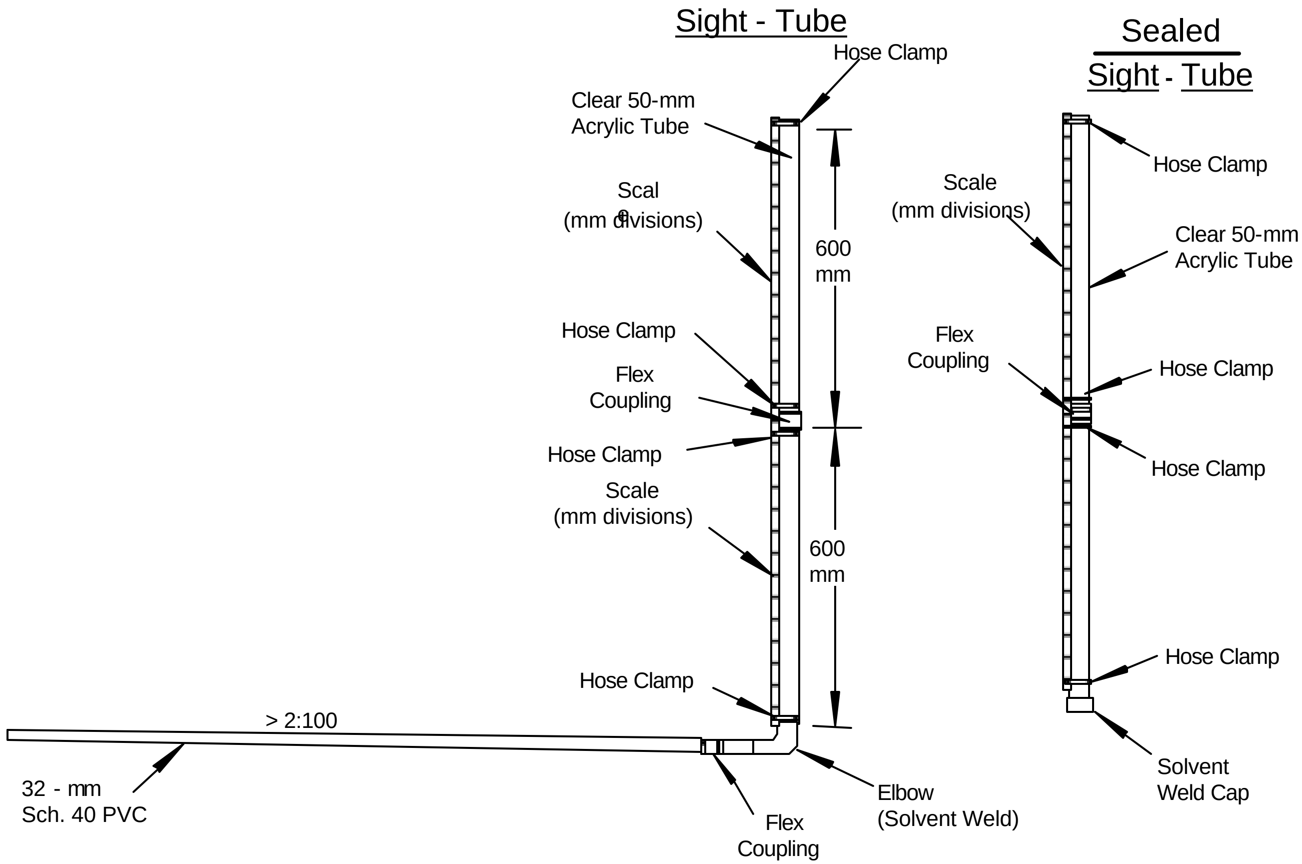


Fig. 5. Leak testing set-up

Extend the geomembrane at least 1 m past the top of the downslope, upslope, and side subgrade berms. The geomembrane can be extended farther, as needed, if the sidewall is to be part of the lysimeter pan. Cut the geomembrane from the roll and anchor it around the edge by covering the geomembrane with subgrade soil. Leave the geomembrane uncovered for a least 1 m along the interior edge (i.e., where the geomembrane panels will be welded).

Install adjacent strips of geomembrane to complete lining of the monitoring area using the same procedures employed for the first strip. Use an overlap of at least 150 mm and shingle the overlap downslope. Weld the two geomembranes using the dual-track hot wedge welding technique as per the instructions by the geomembrane manufacturer. Test welds should be performed at the beginning of any welding activities. Peel and shear destructive tests should be performed on test welds per the installer manual. No welding should be allowed until test welds are accepted by the Resident Engineer. Check the dual -Track welds for leaks using air pressure per ASTM D 5820. Check extrusion welds using a vacuum box supplied by the installer. Sweep the geomembrane and inspect the entire area of the geomembrane for defects. Repairs of any leaks or defects should be performed in accordance with the installer manual and to the satisfaction of the Resident Engineer. The geomembrane installation procedures may vary depending on the location of the test section and the topography of the adjacent terrain. The Resident Engineer along with the geosynthetic installer can adjust these procedures as needed.

2.3.2 Installation of Sump Boot

Locate the riser from the drainage pipe in the sump. Carefully cut the geomembrane around the periphery of the pipe so that the pipe penetrates into the sump area. Loosen the clamps at the flex connection and remove the riser pipe. Place a prefabricated sump boot over the riser pipe so that the top end of the riser pipe is flush with the surface of the sump (Fig. 4). Liberally smear silicon caulk (GE Silicon II or equivalent) between the boot and the pipe, and then clamp the boot to the pipe using two stainless steel hose clamps. Fill the surface groove between the riser pipe and boot with caulk. Remove any excess caulk from the surface of the boot, and then allow the caulk to cure for at least 120 min.

After curing, insert the riser pipe into the flex connection. Adjust the elevation of the riser pipe so that the geomembrane rests flush against the subgrade, and then tighten the hose clamps securely. Backfill any open area surrounding the riser pipe with subgrade soil and form a firm surface for the geomembrane. Extrusion-weld the boot to the geomembrane deployed previously. Check the extrusion welds using a vacuum box per ASTM D 5641, or a spark test per ASTM D 6365. Identify and repair any leaks identified until the criteria in D 5641 are met and to the satisfaction of the Resident Engineer.

Leak test the geomembrane by installing and filling a sight tube on the downstream end of the drainage pipe using the same procedures described in Section 2.2 and shown in Fig. 5. Fill the bottom end of the lysimeter with water until the water surface covers the sump area. Place a clear 0.1-mm-thick (4 mil) polyethylene sheet over the water surface to prevent evaporation and to minimize fluctuations in the standpipe level caused by wind rippling.

Monitor water elevation in the sight tube and an identical adjacent sight tube with a sealed base for 40 min. If necessary, correct elevations in the sight tube plumbed to the sump using data collected from the adjacent sealed sight tube to account for solar, temperature, and barometric effects. The geomembrane is considered leak-free if the water elevation in the sight tube varies by $\leq$ 3 mm during the monitoring period and the water elevation has no discernable temporal trend. If this criterion is not met, determine the location of the leak, seal the leak to the satisfaction of the Resident Engineer, and then conduct the leak test again. Repeat this procedure until the criterion has been met satisfactorily and the Resident Engineer approves the pipe installation. After approval, remove the water from the lysimeter.

2.3.3 Deployment and Seaming of Geocomposite Drain

A geocomposite drainage layer shall be used for collecting percolation from the cover soils. The geocomposite drainage layer (GSE Fabrinet or equivalent) shall have non-woven polypropylene geotextiles on both sides, both of which are heat bonded to a polyethylene geonet in the interior. The geotextiles shall have a minimum mass per unit area of 200 g/m^2 (6 oz/yd^2).

A rubsheet consisting of 0.1-mm-thick polyethylene (4 mil) may be used to facilitate installation of the geocomposite drain. If a rubsheet is used, unroll a 0.1-mm-thick (4 mil) polyethylene rubsheet over the area of the lysimeter on which the first sheet of geocomposite drain will be placed. Lightly anchor the rubsheet with soil on along the outside edge of the upper and lower berms. Move a roll of geocomposite drain to the top of the lysimeter by hand or using a loader equipped with a gantry bar or similar equipment. Suspend the roll above the ground surface while moving it and during deployment onto the geomembrane. If the geocomposite drain is wrapped, remove the wrapper once the roll has been transported to the top of the lysimeter. Unroll the geocomposite drain from the top of the lysimeter by hand and gently pull the geocomposite drain over the rubsheet by hand towards the base of the lysimeter. Extend the geocomposite drain to the top of the downslope, upslope, and side subgrade berms. Cut the geocomposite drain from the roll.

Anchor the geocomposite drain to the geomembrane. Gently move the rubsheet near the top of the lysimeter to expose 1 m of interface between the geomembrane and the geocomposite drain. Press the geocomposite drain against the geomembrane until the two geosynthetic layers lock together in a manner similar to hook-and-loop attachments often referred to as “Velcro.” Once anchored, pull out the remaining rubsheet and press the remainder of the geocomposite drain against the geomembrane.

Install the remaining sections of geocomposite drain using the same procedure until the interior surface of the lysimeter pan is covered. If the overlap between the geocomposite drain is less than 0.6 m, join the geonets in adjacent sections using plastic cable ties 1 m (36 in) on center. Pull strips on the cable ties shall be oriented upwards to minimize the potential for puncturing the geomembrane.

2.3.4 Sump Test Pipe

Install a sump test pipe at the downslope end of the lysimeter. This apparatus is not intended for quality control, but is to be used throughout the project to verify that the sump and/or the collection pipe are not clogged. One end of the pipe shall be placed on top of the sump and wrapped in geotextile. The other end of the sump test pipe shall exit the lined lysimeter area through a boot and then be extended vertically above final grade. All elbows and slip joints shall be solvent welded.

2.3.5 Sidewall Geomembranes

When appropriate, sidewall panels are to be constructed using the same geomembrane as the base of the lysimeter (Section 2.3.1). Two sidewall panels should be prepared that are 22 m long and at least 2 m wide (side panels) and another two panels should be prepared that are 12 m long and at least 2 m wide (top and bottom panels). The width of the panels depends on the thickness of the test section. In general, the panel width should be at least 300 mm wider than the thickness of the test section. These panels can also be an extension of the base liner and therefore do not need to be seamed to the base liner. Feasibility of the latter approach depends on the location of the test section and the topology of the surrounding area. The installer, with the approval of the Resident Engineer, can modify the layout as needed. The Resident Engineer shall determine the type of sidewall to be used (i.e., welded panels or base liner extension). When separate sidewall panels are to be used, center the panels along the edge of the top, bottom, and side berms of the lysimeter and place them flat with the top edge falling outside the monitoring area. Extrusion weld the panel to the to the bottom geomembrane along the crest of the berm to the satisfaction of the Resident Engineer. For each sidewall panel, extend the welds from corner to corner of the berm (see detail in Fig. 6).

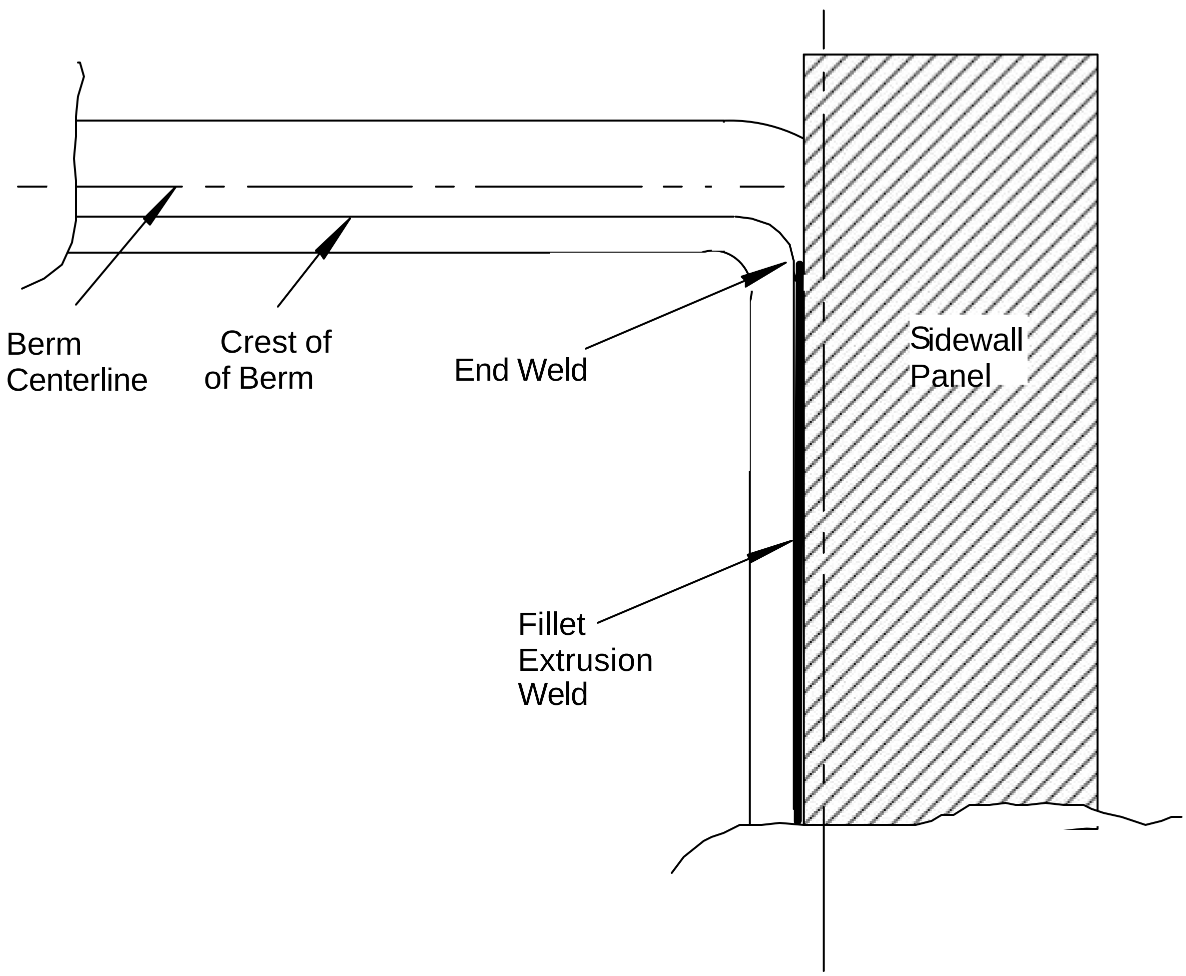


Fig. 6. Welds for sidewall geomembrane panels.

3. PLACEMENT OF COVER SOILS AND RELATED ACTIVITIES

Cover soils consist of those soils that comprise the cover profile being tested. The cover soils consist of interim cover soil, final cover soil, and a topsoil layer. The thickness of each of layer is specified in the cover design report submitted by the consulting engineer. A geosynthetic root barrier is also to be installed between the interim cover soil and the final cover soil.

3.1 Interim Cover Soil

When specified in the cover design, the interim cover soil used prior to placement of the final cover shall be the first layer of soil placed on the lysimeter. This soil shall be identified in the cover design report for the site. The Resident Engineer shall approve the interim cover soil before placement begins.

Place the interim cover soil around the outside edge of the lysimeter directly adjacent to the sidewall geomembrane. Place interim cover soil inside the lysimeter boundaries. Work from the top end of the slope in a loose lift thickness ≥ 450 mm (18 in) or as specified in the cover design. Gradually extend the soil layer from the top berm, along the side berms, and then downward to form a working platform for equipment. At no time shall motorized equipment contact the geosynthetics in the base of the lysimeter. Collect four grab samples (12 kg, 26 lb) from random locations for laboratory analysis.

Compact soil on both sides of the sidewall geomembrane with a motorized hand tamper (jumping jack) to ensure a tight interface between the soil and geomembrane. Compact the remaining interim cover soil using lightweight equipment until the interim cover soil has a dry unit weight in excess of 85% of the maximum dry unit weight per ASTM D 698 (cohesive soil) or D 4253 (cohesionless soil) or the dry unit weight specified by the consulting engineer. Check the dry unit weight in at least four randomly selected locations inside the lysimeter boundaries using D 2922, D 2167, or D 1556. Ensure the soil is firm enough for placement of subsequent layers as per direction of the Resident Engineer. Place soil outside the lysimeter area using similar methods.

Collect two 200-mm-diameter block samples using ASTM D 4220 and two thin-walled tube samples. If the soil conditions preclude sampling with these methods, note the conditions and indicate that hydrological tests should be conducted using soils from the grab samples.

3.2 Seaming the Sidewall Geomembrane

Locate one end of the sidewall geomembrane that is welded to the bottom berm, or that is an extension of the bottom liner. Excavate soil placed at the corners and in the vicinity of the end of the geomembrane. Clean the surfaces of the geomembrane carefully, and extrusion weld the sidewall geomembrane at the corners (Fig. 7). Extend the weld from the lysimeter to the top of the interim cover soil. Repeat this procedure for the other end of the sidewall geomembrane welded to the bottom berm, and then for the two ends of the sidewall geomembrane welded to the top berm. Extrusion weld the two downslope corners as far up as practical.

Do not weld the upslope corners until the soil has been placed inside the lysimeter area. The upslope side of the lysimeter should be used for access in and out of the lysimeter for placement of the cover soil. While placing soil, the sidewall liner at the upslope side of the test section should be protected from being damaged by equipment traffic. The geomembrane should be sandwiched between two layers of non-woven geotextile. A layer of sand at least 200 mm thick should be placed on top of the geotextile to serve as an additional cushion against puncture. The sand layer is removed when the sidewall is to be raised into vertical position.

3.3 Root Barrier Layer

Place the root barrier layer (Reemay Biobarrier or equivalent) directly on top of the interim cover soil with minimum wrinkling. Panels of the root barrier shall be placed parallel to the slope of the test section. Overlap the root barrier panels about 25 mm, and ensure that the herbicidal nodules are oriented upwards. Anchor the root barrier layer along the upslope and downslope ends of the lysimeter area adjacent to the vertical geomembrane comprising the sidewall of the lysimeter.

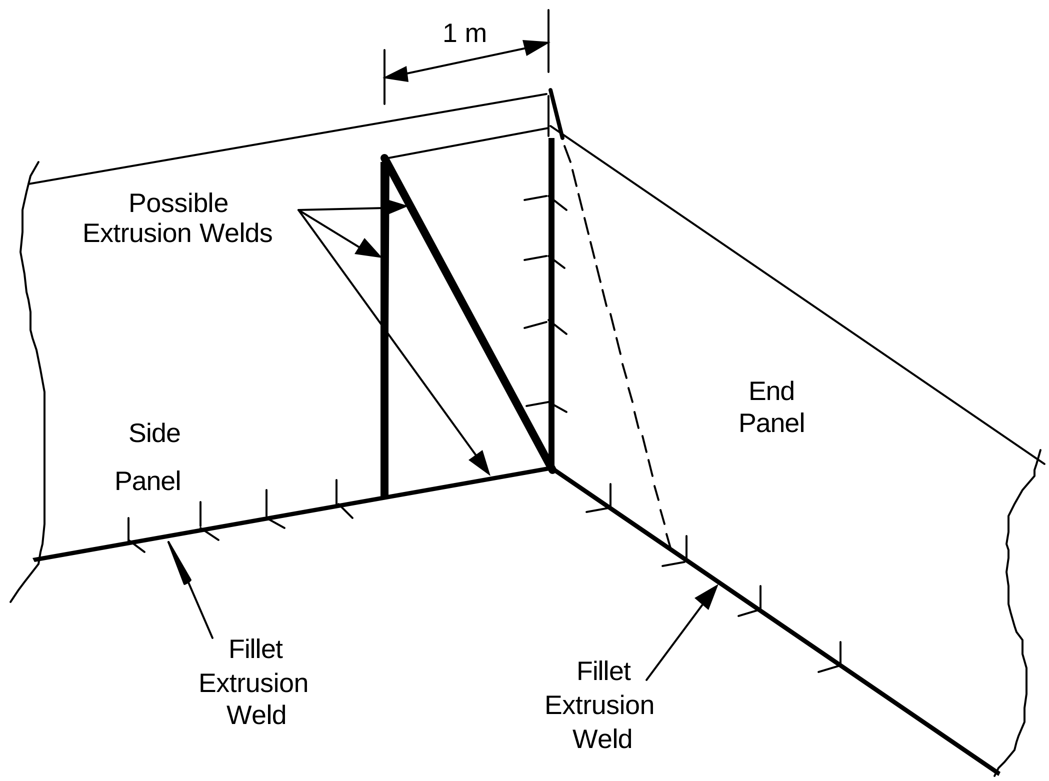


Fig. 7. Welding of sidewall geomembranes.

Ensure that the root barrier layer is not contacting the geocomposite drainage layer or the bottom geomembrane in the lysimeter.

3.4 Final Cover Soils

Place the final cover soils following methods (i.e., lift thickness, compaction water content, percent compaction, etc) described in the cover design report submitted by the consulting engineer for the site. If the consulting engineer specifies no methods, use the methods described in Sec 3.4.1-3.4.3. Methods to be used near the edges of the lysimeter are described in Sec. 3.5.

3.4.1 Cohesive Final Cover Soils

Adjust the moisture content of the soil, if necessary, prior to placement in the monitoring area. Soils that are too wet shall be spread in thin layers outside the monitoring area and disked intermittently until the water content of the soil is appropriate. In semi-arid or arid regions, the water content should be at least 1 percentage point dry of optimum water content per ASTM D 698. Water may be added to soils that are very dry to control dust. However, no cover soil in the monitoring area should have water content exceeding 1 percentage point dry of optimum water content per ASTM D 698.

Place cohesive cover soils in loose lifts no thicker than 450 mm by pushing the soils downslope from the bottom or the top of the test section using a front-end loader, bulldozer, scraper or other suitable equipment that would ordinarily be used for construction of a full-scale cover. Check the loose lift thickness on a regular basis. Re-grade the soil if necessary. After grading, collect four grab samples (12 kg, 26 lb) from random locations in the lift for laboratory analysis.

Compact the cover soil using the method described by the consulting engineer. If no method is specified, use a tamping foot compactor, rubber tire compactor, bulldozer tracks, or another technique approved by the Resident Engineer until the soil has a dry unit weight in excess of 85% of the maximum dry unit weight per ASTM D 698 (cohesive soil). Smooth drum compactors shall not be used. Ensure compaction is uniform. Check the dry unit weight in at least four locations inside the lysimeter area using D 2922, D 2167, or D 1556. Also, collect two 200-mm-diameter block samples from the lift using ASTM D 4220 and two thin-walled tube samples from the lift. Fill in the excavations caused by the sampling activities with the same final cover soil and compact the soil using motorized hand tamper (jumping jack) to ensure equal compaction in all location of test section. The Resident Engineer shall approve each lift of cover before subsequent lifts are placed.

3.4.2 Cohesionless Final Cover Soils

Cohesionless soils that are too wet shall be spread in thin layers outside the test section and disked intermittently until the water content of the soil is acceptable for placement according to the Resident Engineer. Place cohesionless cover soils in loose lifts no thicker than 450 mm (18 in) by pushing the soils downslope from the top of the test section using a loader, bulldozer, scraper or other suitable equipment that would ordinarily be used for construction of a full-scale cover. Check the loose lift thickness on a regular basis. Re-grade the soil if necessary. After grading, collect four grab samples (12 kg, 26 lb) from random locations in the lift for laboratory analysis.

Densify the cover soil with the method specified by the consulting engineer. If no method is specified, use a vibratory compactor or bulldozer tracks, or another technique approved by the Resident Engineer until the soil has a dry unit weight in excess of 85% of the maximum dry unit weight per ASTM D 4253. Ensure compaction is uniform by applying an even number of passes across the entire test section. Check the dry unit weight in at least four locations inside the lysimeter area using D 2922, D 2167, or D 1556. Also, collect two 200-mm-diameter block samples from the lift using ASTM D 4220 and two thin-walled sampling tube samples from the lift. If sampling is not possible due to soil conditions, note these conditions and indicate that hydrologic tests should be conducted on soil from the grab samples. Fill in the excavations caused by the sampling activities with the same final cover soil and compact using a motorized hand tamper (jumping jack) to ensure equal compaction in all location of test section. The Resident Engineer shall approve each lift of cover before subsequent lifts are placed.

The thickness of each lift should be verified using surveys of the bottom and top of each lift. The thickness of each lift should be on average (± 50 mm) equal to that specified by the Resident Engineer or the consulting engineer. The overall thickness of each component of the final cover (interim cover, gas collection layer, etc), should be at least equal to that specified by the cover design report.

3.4.3 Interfaces Between Layers of Different Texture

In cover designs that employ layers of different texture, soils at the textural interface shall be placed using the method specified by the consulting engineer. If no method is specified, place the soil in a manner that minimizes mixing of the two soils at their interface. The method to be used shall be approved by the Resident Engineer. The method should be similar to that to be used in the construction of the full-scale cover at the facility.

A geotextile may be used as a separating layer. Non-woven geotextiles shall be used that have a mass per unit area of at least 130 g/m^2 (4 oz/yd^2) and an apparent opening size (per ASTM D 4751) < 0.6 mm if the finer textured soil contains less than 50% fines or < 0.3 mm if the finer textured soil has more than 50% fines. The geotextile shall be anchored at the upslope and downslope ends of the lysimeter area adjacent to the vertical geomembrane comprising the sidewall of the lysimeter (see Fig. 7).

3.5 Compacting Adjacent to the Sidewall Geomembrane

Place cover soil around the inside and outside edges of the lysimeter directly adjacent to the sidewall geomembrane. Compact soil on both sides of the sidewall geomembrane with a motorized hand tamper (jumping jack) to ensure a tight interface between the soil and geomembrane. After each lift of cover soil has been compacted, excavate a narrow trench adjacent to the geomembrane sidewall by hand as shown in Fig. 8. Fill this narrow trench with powdered bentonite (CETCO Super Gel-X or equivalent) and then cover the bentonite with a thin layer of the soil excavated from the trench.

3.6 Topsoil (Vegetative Layer)

Place the topsoil layer following the method specified by the consulting engineer. If no method is specified, the topsoil layer should be a layer 150 mm to 200 mm (6 to 8 in) thick consisting of material that will support plant growth and allow water infiltration. If available, topsoil that has been removed from the borrow area should be used. The vegetative layer can consist of other material that is available on site and is approved by the Resident Engineer. Seeding of the topsoil layer should be conducted following the re-vegetation plan prepared by the consulting engineer.

The topsoil layer should be placed with minimal compaction. Measure the dry unit weight in at least four locations inside and two locations outside the lysimeter area using D 2922, D 2167, or D 1556. Collect four grab samples, two 200-mm-diameter blocks using ASTM D 4220, and two thin-walled tube samples. Fill in the excavations caused by the sampling activities with the same soil and compact using hand shovels to ensure equal compaction in all locations of the layer. If sampling is not practical due to the soil conditions, note the conditions and indicate that hydrological tests should be conducted using soil from the grab samples.

4. SURFACE RUNOFF COLLECTION BERMS

4.1 Diversion Berms

Construct berms for surface runoff collection along the edge of the lysimeter as shown in Fig. 1. Place soil on either side of the sidewall geomembrane as shown in Fig. 9. Compact with a motorized hand tamper and/or with construction equipment such as a loader until the soil is firm. Slope the swale along the bottom berm at ± 2% to ensure flow to the centerline of the test section.

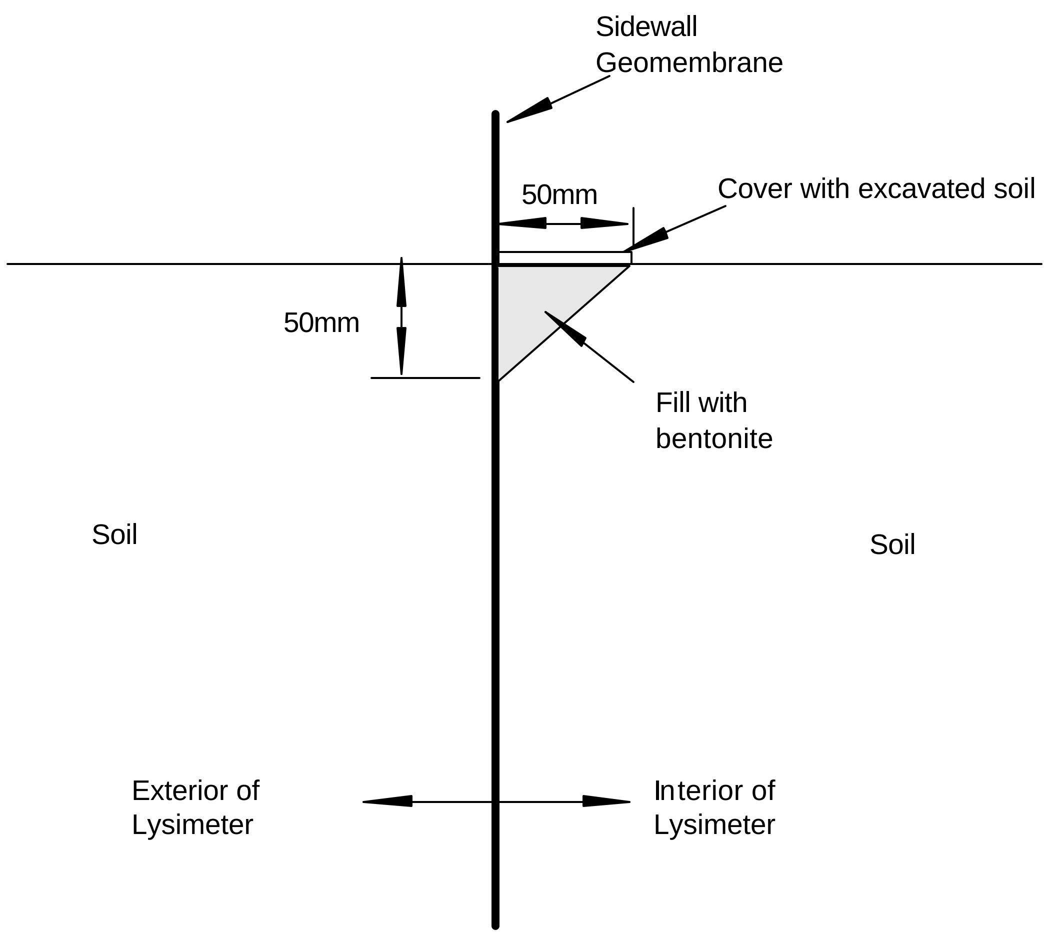


Fig. 8. Anti-seep detail along sidewall geomembrane.

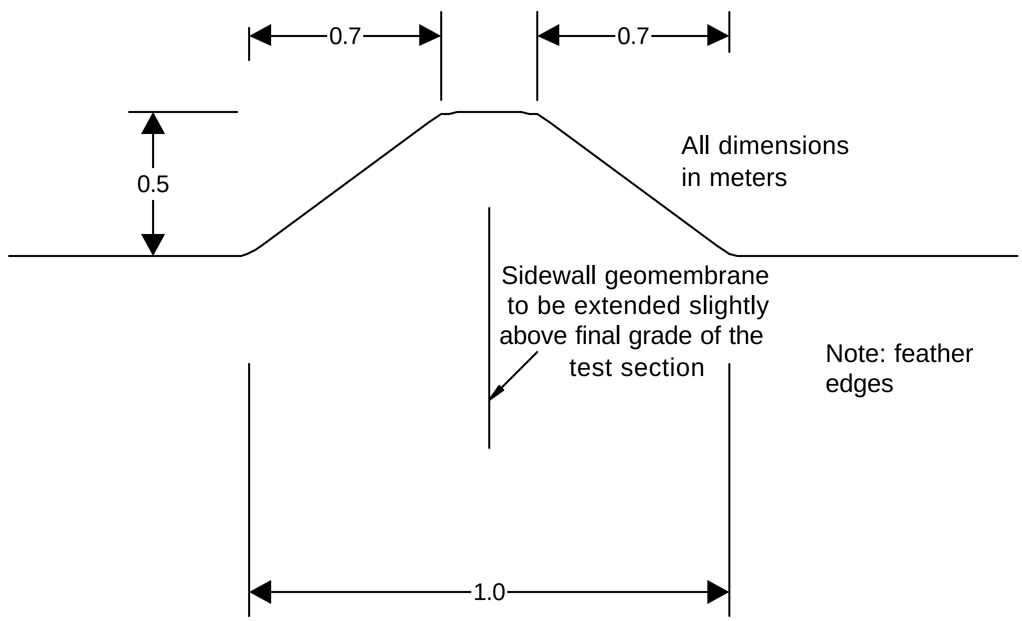


Fig. 9. Diversion berm for surface runoff.

4.2 Surface Run-Off (SRO) Collection Point

Install a collection pipe in a trench at the centerline of the lower berm as shown in Fig. 10. Ensure the invert of the collection pipe is at the lowest point in the bottom berm. Install the anti-seep collar around the pipe and tighten the clamps. Extrusion weld the collar to the sidewall geomembrane. Backfill the trench with soil and compact to the similar density as the surrounding soil and to the satisfaction of the Resident Engineer. Feather the soil in the interior berm to ensure water drains to the invert of the pipe. Cover the upstream end of the pipe with a section of GSE Fabrinet (or equivalent) and spike the Fabrinet to the berm or attach a wire mesh (or equivalent) to the open end of the pipe using a hose clamp.

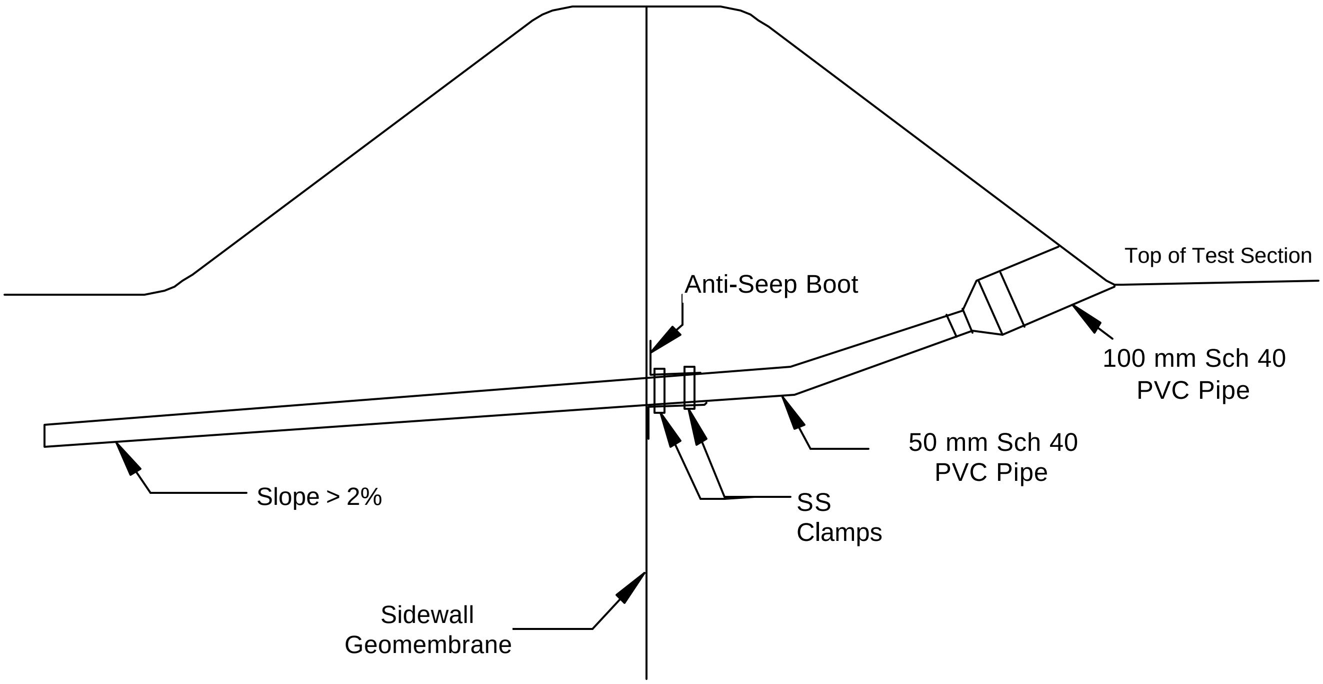
5. COLLECTION SYSTEM

5.1 Sedimentation Tanks

Install the sedimentation tank (Diverse Plastics A3042, or equivalent) between the surface runoff collection point and the collection basin. Install the tank approximately 1 m away from the surface runoff collection basin as shown in Fig. 11. Locate the tank so that the final water elevation is below frost depth. Install one hole on the upstream side of the sediment collection tank and another on the down stream side (Fig. 11) using a hole saw. Locate the holes so that the pipe coming from the test section maintains its slope to the collection basin. Use bulkhead fittings to attach the pipe to the sedimentation tank as shown on Fig. 11. Fill the sedimentation tank with water to the outflow elevation after installation.

5.2 Dosing Siphon

Install the basins with the dosing siphons (Orenco Model 214 Modified) at a location that will permit a pipe slope of at least ± 2% from the test section to the basin and to ensure that the top elevation of the inflow pipe is below frost depth. If necessary, excavate overburden to form a pocket for the basin (Fig. 12). Leak test the basin before any backfilling. Compact the base of this pocket until it is firm. Place a pressure-treated wooden platform in the base of the pocket on a layer of sand and ensure that the platform is level.



Notes:
1. Slope swale in lower berm to collection pipe.
2. Cover opening of collection pipe with 10 mm x 10 mm galvanized wire mesh or geonet.
3. Ensure invert of 100 mm pipe is at lowest point in swale.
4. Weld Anti-seep boot. Seal boot-pipe connection with silicon caulk before clamping.

Fig. 10. Detail of SRO collection point.

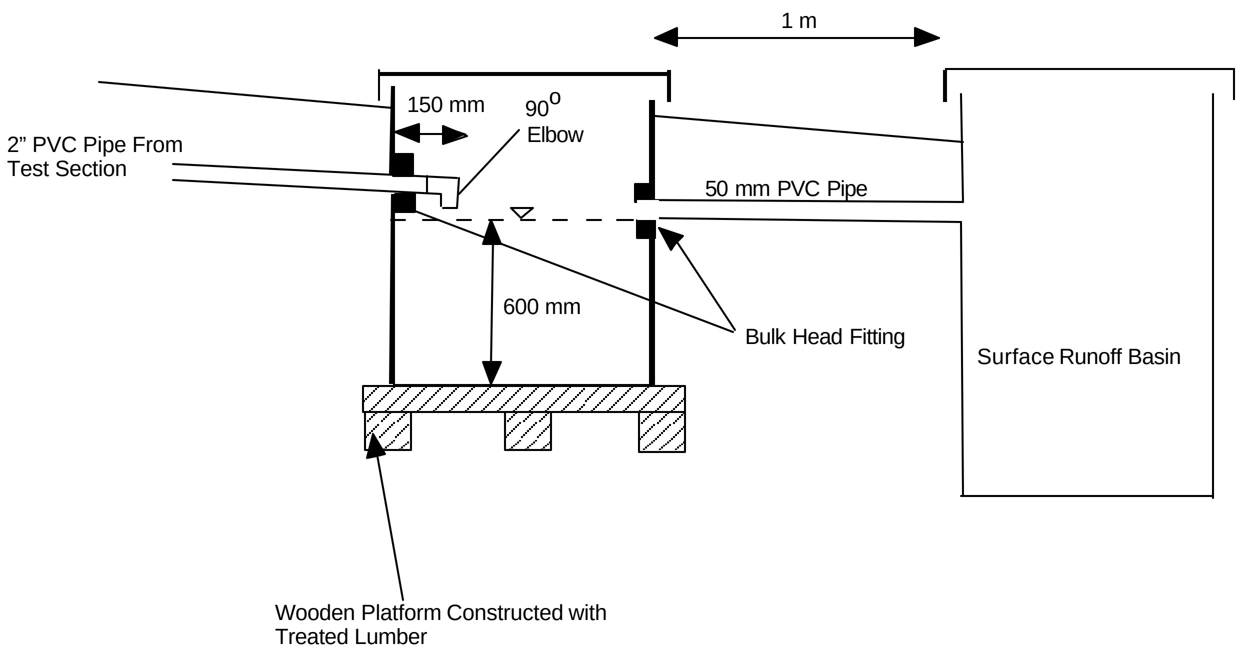


Fig. 11. Schematic of sedimentation tank.

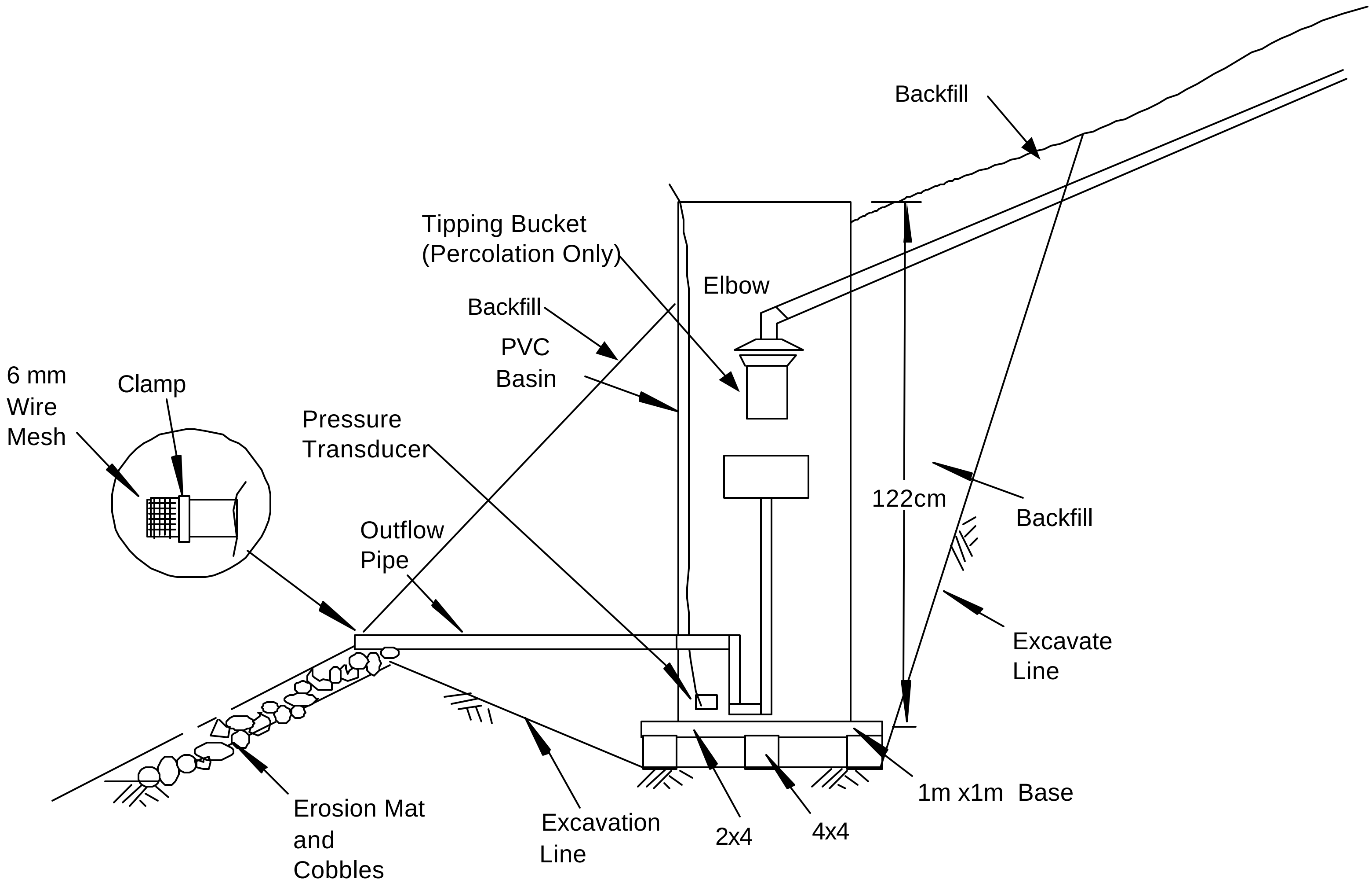


Fig. 12. Installation of dosing siphon.

Place the basin on the platform and carefully backfill the pocket up to the outflow port. Install a 100-mm-diameter outflow pipe (Fig. 12) following the manufacturer's recommendations. Use clamped rubber coupling to connect the outflow pipe to the basin. Backfill carefully around the pipe using sand and then backfill the remainder of the pocket using the excavated soil. Install erosion mat and place cobbles (or other erosion control device) to minimize erosion at the outflow. Install a screen on the outflow end of the pipe to prevent animal intrusion. Fill the basin with water to just below the discharge elevation. Measure the depth of water in the dosing siphon from the upper surface of the outer chamber at 5-min intervals for 30 minutes. If the water level drops more than 3 mm during this period, find and repair the leak. Then re-test the dosing siphon.

Calibrate the dosing siphon by placing a known volume of water into the basin until discharge begins. Mark the elevation at which discharge begins. Repeat this procedure two more times to check the calibration. If the calibration or flush elevation deviates significantly, find the source of the problem, correct it, and re-calibrate the dosing siphon.

Install a tipping bucket in the basin used to collect percolation from the test section as shown in Fig. 12. Attach the tipping bucket to the air pipe of the siphon with hose clamps as shown in Fig. 13. Ensure the tipping bucket is level after installation. Adjust if necessary. Drill one hole into the side of each basin for the pipe from the test section. For the percolation pipe, drill a 45-mm-diameter hole (1.75 in). A 65-mm-diameter (2.5 in) hole should be drilled into the side of the basin receiving surface run off. Collect the drill cuttings and dispose of them.

Install PVC pipes from the lysimeter (percolation or surface runoff) to the basins. Grade soil beneath the pipe as necessary to ensure the pipe has bedding with monotonic grade. Install a 90^{o} elbow on the end of the pipe inside the basin to ensure water flows downward. For the basin collecting percolation, align the center of the outflow end of the elbow with the center of the tipping bucket.

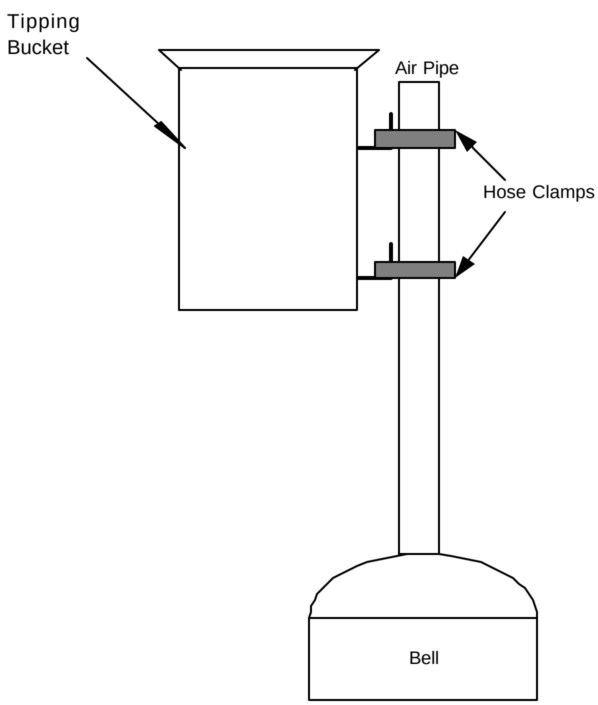


Fig. 13. Installation of tipping bucket in dosing siphon.

6. INSTRUMENTATION

6.1 Installation of Water Content Reflectometers, and Heat Dissipation Units.

Water content reflectometers and heat dissipation units shall be installed in three nests as shown in Fig. 14. If possible, the instruments should be placed after each lift has been installed by burying them by hand and routing the wires in conduit to a common point on the side of the test section. If the instruments cannot be installed after each lift, excavate a hole for each nest 450-mm across by 200-mm wide down to the root barrier. Cut a flap in the root barrier and continue to excavate 150 mm into the interim cover soil. Keep excavation spoils from the cover and interim cover layers separate. Install a water content reflectometer (WCR) at the base of the hole by hand as shown in Fig. 15. Press the WCR horizontally (or at the angle of the slope) into the interim cover soil, with the rods oriented upslope. The WCR can also be installed vertically, except in the topsoil layer, with approval of the Resident Engineer and/or the Field Manager. In this layer the WCR should be placed horizontally at mid-depth unless another orientation is approved by the Resident Engineer and/or the Field Manager. Install a heat dissipation unit (HDU) in a cylindrical horizontal hole oriented upslope (15 mm diameter, 30 mm long) adjacent to the water content reflectometer. HDUs shall be soaked in water prior to placement. Soil around HDUs shall be soaked with water to ensure good hydraulic contact between the sensor and the soil. Route the wires along the base of the hole to the opposite wall and then route them upward as shown in Fig. 15. Backfill the hole with interim cover soil and tamp to the same density at which it was originally placed.

Install another WCR and HDU at this depth using the procedure described previously. Route the wires to the back of the hole and bundle all wires together with a cable tie. Install a sheet of 0.1 mm (4 mil) polyethylene around the wires as an anti-seep collar. Locate the collar 100 mm above the location of the instruments. Place a small quantity of bentonite CETCO Super Gel-X (or equivalent) on top of and around the anti-seep collar (Fig. 15). Backfill the hole and tamp to the original density.

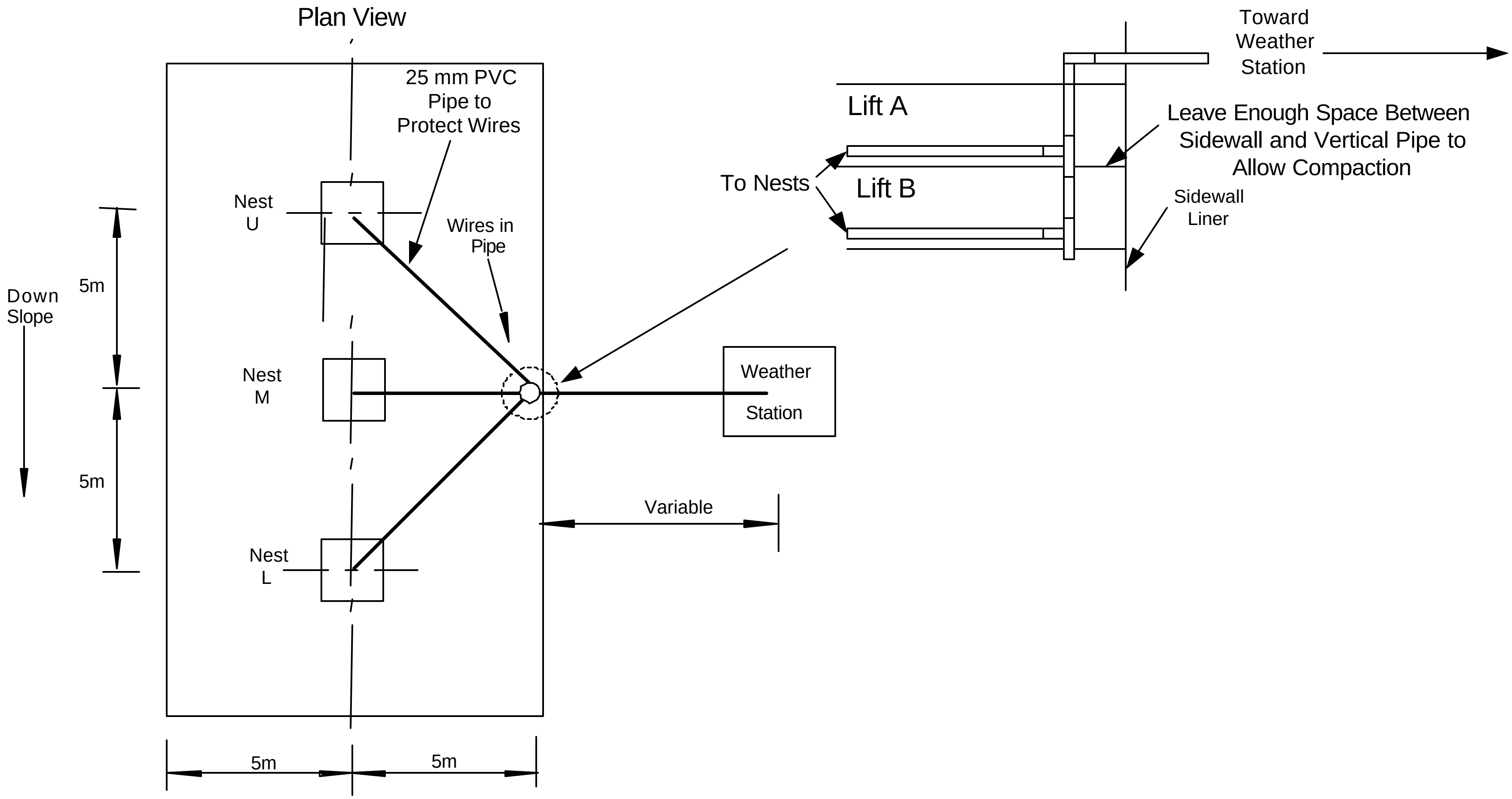


Fig. 14. Locations of instrumentation nests and weather station.

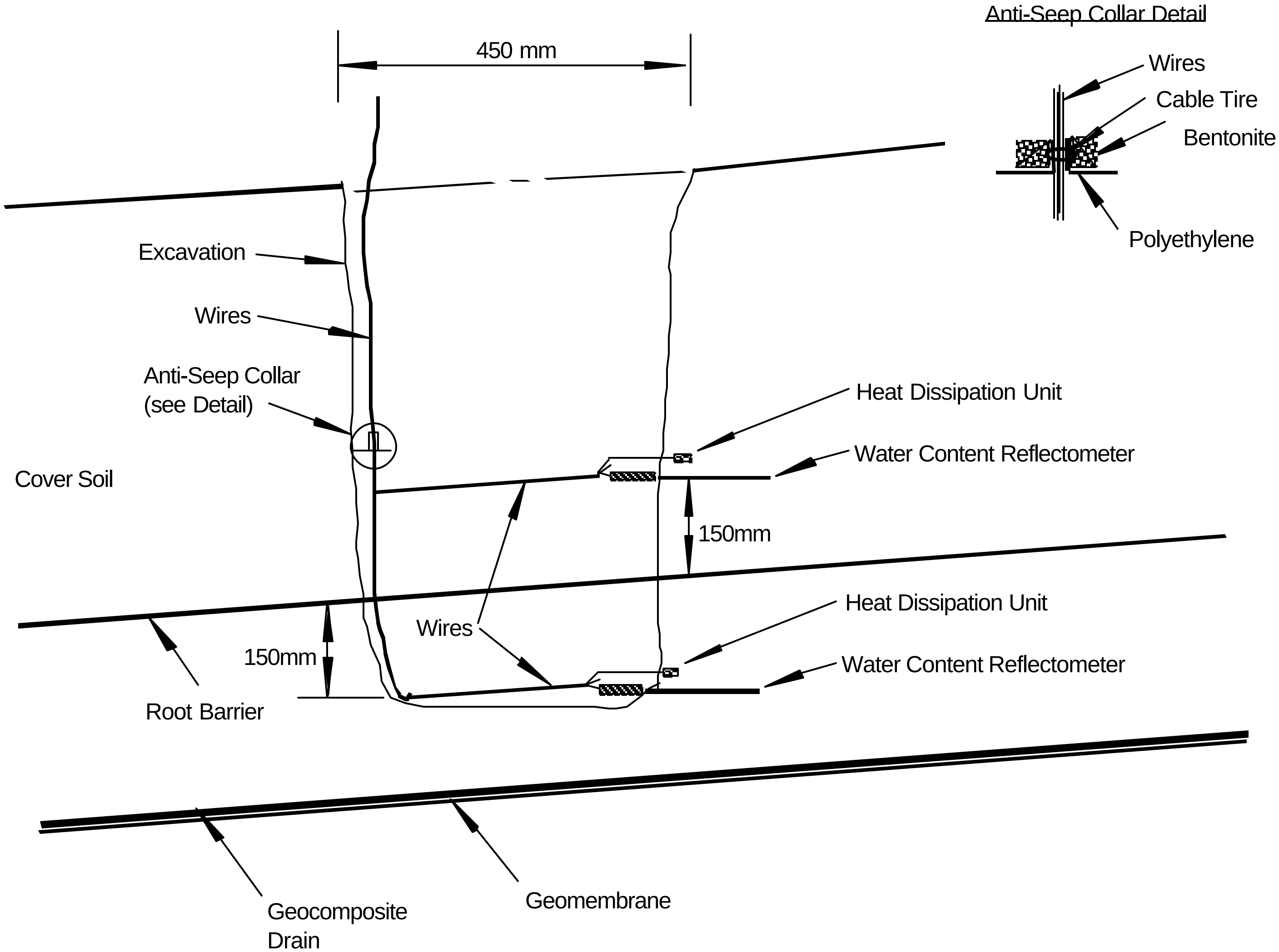


Fig. 15. Installation of instruments in an instrumentation nest.

Place the remaining four WCRs and HDUs at an equal spacing. Bundle the wires at each probe with cable ties, install an anti-seep collar, and backfill to the depth for the next set of instruments. The uppermost set of instruments shall be placed at mid-depth of the topsoil layer. Feather the surface of the backfill so that no water will collect at the surface of the excavation.

6.2 Routing of Wiring to Datalogger

Place the wires from each nest in PVC conduit and route the conduit in a small trench 150 mm deep excavated along the surface of the test section as shown in Fig. 14. Pass the wires through the surface runoff berm and the sidewall geomembrane. Route the wires to the surface at the weather station. Backfill the trench and compact to the original density of the soil. Feather the surface of the backfill so that the trench does not affect surface flow.

6.3 Weather Station

Install the tripod and grounding rod for the weather station adjacent to the test section following the manufacturer's recommendations. Anchor the ground concrete footings using the anchorage spikes. Bolt the data acquisition cabinets to the tripod. Install the pyranometer, temperature and humidity sensor, and wind sentry on the tripod following the manufacturer's recommendations. Wire all sensors, including those installed in the test section, following the Standard Operating Procedure for Datalogger Programming and Data Checking for ACAP Sites.

Embed a 32-mm-diameter and 2.5-m-long galvanized steel pipe into the existing soil for the rain gauge. Locate this pipe near and upwind from the weather station. Clamp the rain gauge to the pipe following the manufacturer's instructions. Ensure the top of the steel pipe is below the uppermost surface of the rain gauge. Fasten the wire from the rain gauge to the pipe with cable ties at 150-mm centers. Route this wire to the weather station in a small trench approximately 150 mm deep. Backfill this trench and tamp by hand to the surrounding density. Wire the rain gauge to the datalogger following the DRI wiring instructions.

6.4 Dosing Siphons

Install a PVC pipe in the basin of the dosing siphon to hold the pressure transducer. Attach the transducer to the pipe so the sensing element is 300 mm above the bottom of the basin. Route the wire from the transducer, the wire from the dose meter, and the wire from tipping bucket (percolation tank only) through a 12-mm-hole drilled in the side of the basin. Locate the hole approximately 150 mm from the top of the basin. Seal the hole with caulk (GE Silicon II or equivalent). Allow the caulk to cure for at least 120 min.

Excavate a narrow trench (50 mm wide, 150 mm deep) from the dosing siphons to the weather station. Place the wires in conduit, lay the conduit in the trench, and backfill. Compact the backfill using a hand tamper. Attach the wires to the datalogger following the Standard Operating Procedure for Datalogger Programming and Data Checking for ACAP Sites.

7. VEGETATION

Prepare the surface of the test section for seeding following the procedure described by the consulting engineer or in the site-specific design report. The vegetation plan will specify the plant species, placement density, and fertility requirements for the vegetative cover. Site operators may work with ACAP to develop the vegetation plan.

APPENDIX I: ASTM STANDARDS

APPENDIX II: MATERIAL SPECIFICATIONS

(Spec Sheets for Gel-X not included yet)

APPENDIX III: PHOTOGRAPHIC ILLUSTRATION OF INSTALLATION METHODS

APPENDIX B: BUDGET SPREADSHEETS

APPENDIX B-1 MATERIAL AND CONSTRUCTION COSTS -

CONTRACTOR CONSTRUCTION	UNIT COST	UNITS	NO. UNITS	TOTAL COST
LABOR				
MOBILIZATION	$15,000.00	LS	1	$15,000
SURVEY	$6,000.00	LS	1	$6,000
CQC TESTING	$750.00	DAY	10	$7,500
LLDPE INSTALLATION	$16,600.00	LS	1	$16,600
TOPSOIL	$3.00	CU YD	500	$1,500
GENERAL EMBANKMENT	$5.00	CU YD	2800	$14,000
CLAY LINER	$7.00	CU YD	1100	$7,700
MISCELLANEOUS LABOR	$12,000.00	FA	1	$12,000
GEOSYNTHETICS				
LLDPE GEOMEMBRANE	$3,861.00	ROLL	2	$7,722
DRAINAGE GEOCOMPOSITE	$1,680.00	ROLL	3	$5,040
GEOSYNTHETIC ROOT BARRIER	$414.00	ROLL	15	$6,210
SHIPPING AND HANDLING	$2,000.00	LS	1	$2,000
SOIL/CONCRETE				
BENTONITE	$12.00	SACK (60-LB)	15	$180
CONCRETE	$3.18	SACK (60-LB)	10	$32
LUMBER				
4' X 8' X 1/2" PLYWOOD	$14.59	EA	60	$875
2" X 4" X 10'	$3.88	EA	70	$272
2" X 4" X 8' PRESSURE-TREATED	$3.67	EA	20	$73
4" X 4" X 8' PRESSURE-TREATED	$7.57	EA	12	$91
2" DECK SCREWS	$21.93	BOX	1	$22
PIPE AND FITTINGS				
1-1/4" PVC PIPE	$0.29	LF	200	$58
2" PVC PIPE	$0.49	LF	300	$147
4" PVC PIPE	$1.50	LF	120	$180
1/2" CONDUIT	$0.22	LF	200	$44
1-1/4" PVC COUPLING	$0.29	EA	20	$6
2" PVC COUPLING	$0.79	EA	30	$24
4" PVC COUPLING	$2.73	EA	15	$41
1-1/4" FLEXIBLE COUPLING	$4.00	EA	8	$32
2" FLEXIBLE COUPLING	$4.00	EA	8	$32
4" X 2" PVC BUSHING	$3.10	EA	6	$19
1-1/4" 90° PVC ELBOW	$0.50	EA	6	$3
2" 90° PVC ELBOW	$0.50	EA	6	$3
1-1/4" 45° PVC ELBOW	$0.50	EA	6	$3
2" 45° PVC ELBOW	$0.50	EA	6	$3
2" HOSE CLAMPS	$1.29	EA	10	$13
3" HOSE CLAMPS	$1.49	EA	10	$15
5" HOSE CLAMPS	$1.99	EA	6	$12
PVC SOLVENT CEMENT	$10.40	QT	2	$21
PVC PRIMER	$10.40	QT	2	$21
SILICON CAULK	$3.49	TUBE	3	$10
THREADED CAP (MALE)	$0.52	EA	3	$2
SIGHT TUBE CAP	$0.50	EA	3	$2
1-1/4" SLIP/THREAD (FEMALE-FEMALE)	$0.29	EA	3	$1
CLEAR ACRYLIC SIGHT TUBE	$2.00	EA	6	$12
SCALE	$3.00	EA	6	$18
1/8" WIRE MESH	$1.59	SQ FT	9	$14
BASIN/TANK				
DOSING SIPHON	$125.00	EA	6	$750
DOSING SIPHON CERTIFICATE	$50.00	EA	6	$300
TIPPING BUCKET	$300.00	EA	3	$900
SEDIMENTATION TANK	$180.00	EA	3	$540
SEDIMENTATION TANK COVER	$32.00	EA	3	$96
PERCOLATION BASIN	$240.00	EA	6	$1,440
PUMP SWITCH	$53.00	EA	6	$318
2" PVC BULKHEAD FITTING	$15.00	EA	6	$90
DATA COLLECTION				
PRESSURE TRANSDUCER	$856.61	EA	7	$5,996
DATA LOGGER	$2,550.00	EA	1	$2,550
REFLECTOMETER	$184.50	EA	42	$7,749
HEAT DISSIPATOR UNIT	$90.00	EA	14	$1,260
8-CHANNEL EXCITATION MODULE	$205.00	EA	2	$410
TELEMETRY PHONE PACKAGE	$600.00	EA	1	$600
TELEMETRY MODEM	$375.00	EA	1	$375
TELEMETRY ANTENNA	$150.00	EA	1	$150
CUP ANEMOMETER/POTENTIOMETER	$545.00	EA	1	$545
CROSS-ARM MOUNT	$70.00	EA	1	$70
PYRANOMETER	$250.00	EA	1	$250
FIXTURE	$50.00	EA	1	$50
CROSS-ARM STAND	$55.00	EA	1	$55
THERMISTOR/HYGROMETER	$510.00	EA	1	$510
SOLAR RADIATION SHIELD	$165.00	EA	1	$165
10' GALVANIZED TRIPOD	$310.00	EA	1	$310
20W SOLAR PANEL	$350.00	EA	1	$350
LEAD ACID BATTERY	$95.00	EA	1	$95
12V CHARGE REGULATOR	$175.00	EA	1	$175
18V AC CHARGER	$35.00	EA	1	$35
CABLE				
POTENTIOMETER CABLE	$0.50	LF	11	$6
THERMISTOR CABLE	$0.50	LF	5	$3
PYRANOMETER CABLE	$0.25	LF	11	$3
TIPPING BUCKET CABLE	$0.25	LF	100	$25
REFLECTOMETER CABLE	$0.64	LF	4200	$2,688
HEAT DISSIPATOR UNIT CABLE	$0.40	LF	1400	$560
DATA COLLECTION CABLE	$0.22	LF	4	$1
POWER/RESET CABLE	$10.00	EA	1	$10
SIGNAL CABLE	$10.00	EA	1	$10
CABLE TIES	$10.00	BOX	1	$10
		GRAND TOTAL		***$133,000***

APPENDIX B-2 CONSTRUCTION MANAGEMENT COSTS

ENGINEERING CM & CQA	UNIT COST	UNITS	NO. UNITS	TOTAL COST	PROJECT MGMT. & PLANNING	CM	SPECIFICATIONS & CONTRACT	INSTRUMENTATION
PERSONNEL								
SENIOR CONSULTANT	$135	HR	76	$10,260	40	24	8	4
SENIOR PROJECT MANAGER	$125	HR	0	$0				
SENIOR ENG./HYDR.	$90	HR	0	$0				
PROJECT ENG./HYDR./GEOP.	$75	HR	36	$2,700	12	8	16	
STAFF ENG./HYDR./GEOP.	$65	HR	72	$4,680	16	8	40	8
FIELD ENGINEER	$65	HR	180	$11,700		180		
DRAFTING/CAD	$75	HR	8	$600	8			
WORD PROC./CLERICAL	$45	HR	16	$720	8		8	
TOTAL CM/CQA SERVICES		**HR**	**388**	**$30,660**	**$8,300**	**$16,060**	**$5,240**	**$1,060**
DIRECT COSTS								
ITEMS								
SUBCONSULTANT				$20,000	$2,640	$16,700	$660	$0
PER DIEM				$4,300	$100	$4,200	$0	$0
AIRFARE				$4,000	$1,000	$3,000	$0	$0
VEHICLE RENTAL				$2,090	$90	$2,000	$0	$0
LABORATORY ANALYSES AND TESTING				$9,000	$0	$9,000	$0	$0
COMMUNICATION (3% of labor charges)				$920	$249	$482	$157	$32
MISCELLANEOUS (10% of direct cost)				$4,031	$408	$3,538	$82	$3
TOTAL DIRECT COSTS				**$44,340**	**$4,487**	**$38,919**	**$899**	**$35**
GRAND TOTAL				***$75,000***	***$12,787***	***$54,979***	***$6,139***	***$1,095***

APPENDIX B-3 ENGINEERING DESIGN COSTS

ENGINEERING DESIGN	UNIT COST	UNITS	NO. UNITS	TOTAL COST	PROJECT MGMT. & PLANNING	MEETINGS	DRAFT WORK PLANS	FINAL WORK PLANS	REPORT	MONITORING
PERSONNEL										
SENIOR CONSULTANT	$135	HR	558	$75,330	390	112	8	4	32	12
SENIOR PROJECT MANAGER	$125	HR	26	$3,250		16	2		8	
SENIOR ENG./HYDR.	$90	HR	0	$0						
PROJECT ENG./HYDR./GEOP.	$75	HR	232	$17,400	72	16	60	12	72	
STAFF ENG./HYDR./GEOP.	$65	HR	436	$28,340	72		120	12	112	120
FIELD ENG.	$65	HR	0	$0						
DRAFTING/CAD	$75	HR	24	$1,800			16	8		
WORD PROC./CLERICAL	$45	HR	88	$3,960	32	12	16	4	24	
TOTAL DESIGN SERVICES		**HR**	**1,364**	**$130,080**	**$64,170**	**$18,860**	**$15,550**	**$3,000**	**$19,080**	**$9,420**
DIRECT COSTS										
ITEMS										
SUBCONSULTANT				$75,261	$13,200	$29,040	$1,320	$1,320	$6,600	$23,780
PER DIEM				$4,400	$0	$3,800	$0	$0	$0	$600
AIRFARE				$22,000	$0	$19,000	$0	$0	$0	$3,000
VEHICLE RENTAL				$1,500	$0	$1,200	$0	$0	$0	$300
LABORATORY ANALYSES AND TESTING				$6,500	$0	$0	$5,000	$0	$0	$1,500
COMMUNICATION (3% of labor charges)				$3,902	$1,925	$566	$467	$90	$572	$283
MISCELLANEOUS (10% of direct cost)				$11,356	$1,513	$5,361	$679	$141	$717	$2,946
TOTAL DIRECT COSTS				**$124,920**	**$16,638**	**$58,966**	**$7,466**	**$1,552**	**$7,890**	**$32,409**
GRAND TOTAL				***$255,000***	***$80,808***	***$77,826***	***$23,016***	***$4,552***	***$26,970***	***$41,829***

APPENDIX B-4 REPORTING AND DATA MANAGEMENT COSTS

ENGINEERING DESIGN	UNIT COST	UNITS	NO. UNITS	TOTAL COST	PROJECT MGMT. & PLANNING	MEETINGS	DRAFT WORK PLANS	FINAL WORK PLANS	REPORT	MONITORING
PERSONNEL										
SENIOR CONSULTANT	$135	HR	68	$9,180	40	8			20	
SENIOR PROJECT MANAGER	$125	HR	0	$0					0	
SENIOR ENG./HYDR.	$90	HR	0	$0						
PROJECT ENG./HYDR./GEOP.	$75	HR	98	$7,350	10	8			80	
STAFF ENG./HYDR./GEOP.	$65	HR	50	$3,250	10				40	
FIELD ENG.	$65	HR	0	$0						
DRAFTING/CAD	$75	HR	8	$600					8	
WORD PROC./CLERICAL	$45	HR	12	$540	4				8	
TOTAL DESIGN SERVICES		**HR**	**236**	**$20,920**	**$6,980**	**$1,680**	**$0**	**$0**	**$12,260**	**$0**
DIRECT COSTS										
ITEMS										
SUBCONSULTANT				$10,190	$3,960	$5,280	$0	$0	$950	$0
PER DIEM				$600	$0	$600	$0	$0	$0	$0
AIRFARE				$3,000	$0	$3,000	$0	$0	$0	$0
VEHICLE RENTAL				$200	$0	$200	$0	$0	$0	$0
LABORATORY ANALYSES AND TESTING				$0	$0	$0	$0	$0	$0	$0
COMMUNICATION (3 % of labor charges)				$628	$209	$50	$0	$0	$368	$0
MISCELLANEOUS (10% of direct cost)				$1,462	$417	$913	$0	$0	$132	$0
TOTAL DIRECT COSTS				**$16,080**	**$4,586**	**$10,043**	**$0**	**$0**	**$1,450**	**$0**
GRAND TOTAL				***$37,000***	***$11,566***	***$11,723***	***$0***	***$0***	***$13,710***	***$0***