ALTERNATIVE COVER FOR SATURATED, LOW-STRENGTH WASTE

A cover system in Washington State was designed to meet Resource Conservation and Recovery Act Subtitle C requirements. A compacted clay layer was proposed to cover this waste site. However, because of the low strength of the waste, an alternative cover had to be used.

The waste had physical characteristics of a non-plastic sand with high void ratio, high water content, low bearing capacity and low shear strength. The 13-acre clay lined impoundment had been accepting waste for nearly 20 years. Concern was expressed regarding the use of a stand-alone geomembrane, and so an alternate design incorporating a GCL was accepted. The GCL serves as a secondary barrier in place of the compacted clay layer, which was not possible to construct because of the low shear strength of the waste.

Observations of the cover nearly two years after construction revealed no unexpected settlement nor any signs of ponding water. The cover appeared to be performing as designed.

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Alternative Cover for Saturated, Low-Strength Waste

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ABSTRACT

A cover for a 13-hectare solids settling basin in Washington State was designed to meet Resource Conservation and Recovery Act Subtitle C requirements. A compacted clay cover system was proposed by the regulating agency but could not be constructed because of the waste's low strength. An alternative approach was proposed to and accepted by the agency.

An interim cover of woven geotextile overlain with sand was placed directly on the waste. In a limited area, geogrid was first placed on the waste. The final cover had a geosynthetic clay liner, a polyvinyl chloride geomembrane, a composite drainage net with geotextile on both sides, dredged sand, and topsoil. A complex grading plan was needed to provide adequate drainage slopes while limiting the depth of fill required. A temporary dewatering sump allows drainage of liquids from the waste beneath the cover. A construction quality assurance plan was followed during construction of the final cover, which was completed in 1992.

INTRODUCTION

The owner of an industrial plant in Washington State, who wishes to remain anonymous, closed a 13-hectare (33-acre) impoundment of semisolid state-only dangerous waste residual material (this was not produced after 1990 because of process changes.) The state closure requirements for waste designated as dangerous are the same as those under Resource Conservation and Recovery Act (RCRA) Subtitle C. The waste was contaminated with small amounts of cyanide and fluoride. It had physical characteristics of a weak, very fine-grained, non-plastic sand material; a high void ratio; high water content; low bearing capacity; and weak shearing strength.

For nearly 20 years the residue had been deposited in an above-grade, clay-lined, diked pond from which clarified liquid was pumped and recycled to the plant's air pollution control

system. The depth of the residue varied from about 5 m (16 ft) at the deposit areas around the perimeter to 1 m (3 ft) at the sump area where supernatant was removed. The owner began planning for closure of the impoundment in 1984 and had submitted a RCRA Part B permit application to the Washington State Department of Ecology (Ecology) in 1985 and 1990, proposing a single geomembrane as the barrier element in the cover. While waiting for permit approval, the owner began constructing an interim cover over the residue surface in 1990, based on recommendations made by the project consultant.

The interim cover consisted of a high-strength, woven geotextile (nonwoven in some areas) placed directly on the waste and clean and free-draining dredge sand. The sand depth varied from 60 cm to more than 120 cm (2 to 4 ft). The geotextile and sand were placed from the perimeter dike, where the waste surface was higher and relatively better drained, toward the center of the pond. The configuration of the impoundment is shown in Figure 1 as it appeared in late 1991 with interim cover over most of the surface.

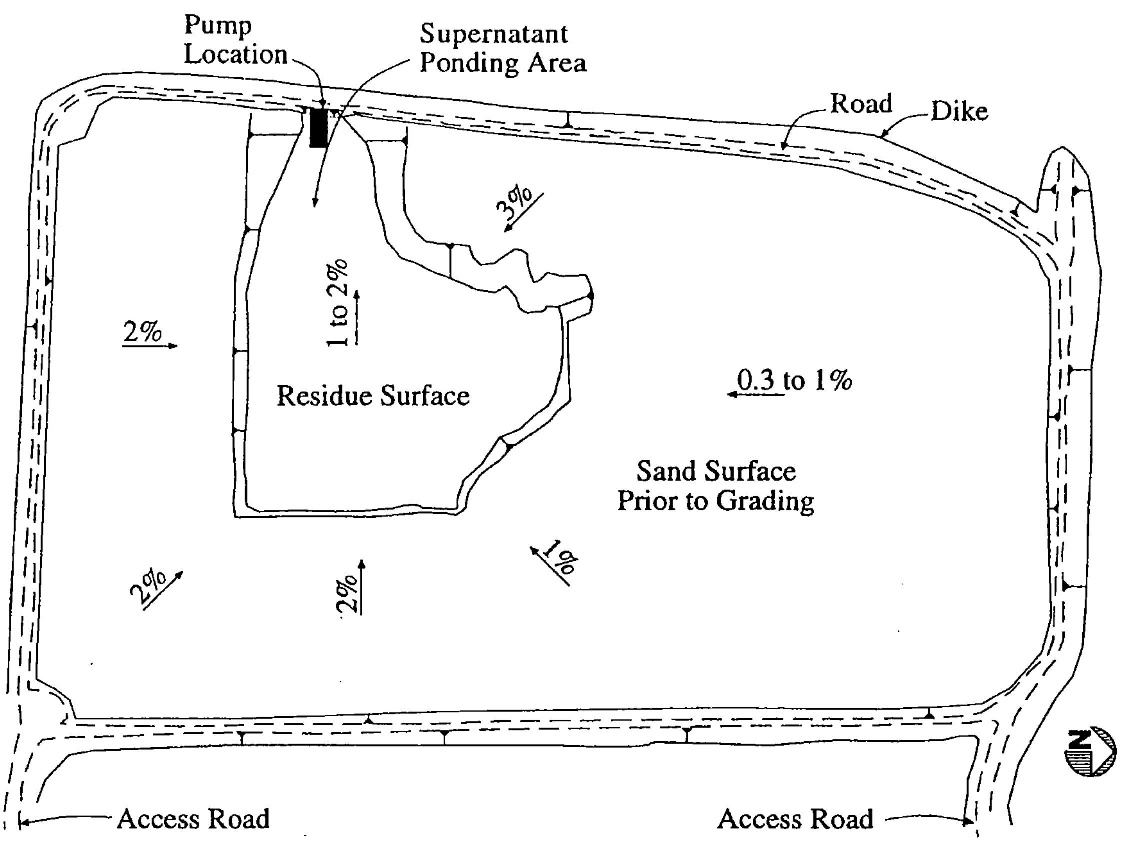

Figure 1. Partial Interim Cover

PERMIT NEGOTIATIONS REGARDING BARRIER COMPONENTS

In early 1991, Ecology expressed concern regarding the single geomembrane in the proposed cover, as a result of national publicity regarding leaking geomembranes. Stating that most, if not all, plastic-alone liner systems have a significant number of leaks, Ecology requested placement of a composite barrier to provide additional protection of ground and surface water. Ecology suggested two composite systems, each with compacted clay and a high-density polyethylene (HDPE) geomembrane, for the residue cover. These options, shown in Figure 2, were as follows:

- 60 cm (2 ft) of compacted clay—permeability 1 x 10^{-7} cm/sec or less—with a 1- to 1.5-mm (40- to 60-mil) HDPE geomembrane
- 30 cm (1 ft) of compacted clay with a combined HDPE geomembrane and bentonite blanket material

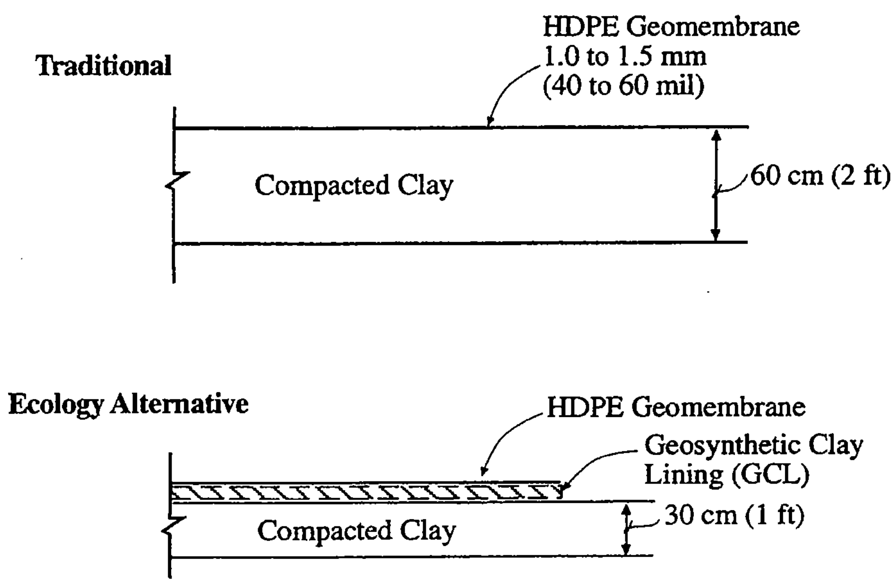

Figure 2. Composite Systems Proposed by Department of Ecology

Significantly, one of the options suggested by Ecology included a geosynthetic clay lining (GCL), which had not previously been approved in Washington for cover systems complying with RCRA Subtitle C. The agency was also willing to consider an alternative composite system proposed by the owner.

The owner's consultant, CH2M HILL, believed that the residual material lacked sufficient strength to support the heavy equipment required to compact a clay cover properly, that HDPE was not the best choice of geomembrane for the application, and that a geomembrane can be installed without leaks to provide a barrier with permeability several orders of magnitude less than that of compacted clay. The project consultant had been involved since planning for the closure began in 1984.

Two alternative barrier systems were proposed to Ecology that would meet the objective of protecting ground and surface water contamination and that could be constructed over the weak residue and dredge sand. One alternative proposed was a 1-mm (40-mil) polyvinyl chloride (PVC) geomembrane with a 6-mm (250-mil) geonet above it to allow infiltrating surface water to flow quickly off the geomembrane. The geonet was to have a nonwoven geotextile bonded to each side. The second alternative was similar to the first except that it included a 6-mm (250-mil) GCL directly under the PVC geomembrane. Ecology accepted this second alternative, which was then designed and constructed.

ALTERNATIVE COVER DESIGN

Rational for Final Cover Components. The components of the final cover are described in sequence from the interim cover (described above) to the surface of the cover. The design methods were largely empirical, based on observations at the site and on experience with materials available for use in the cover. A typical section of the cover is shown in Figure 3.

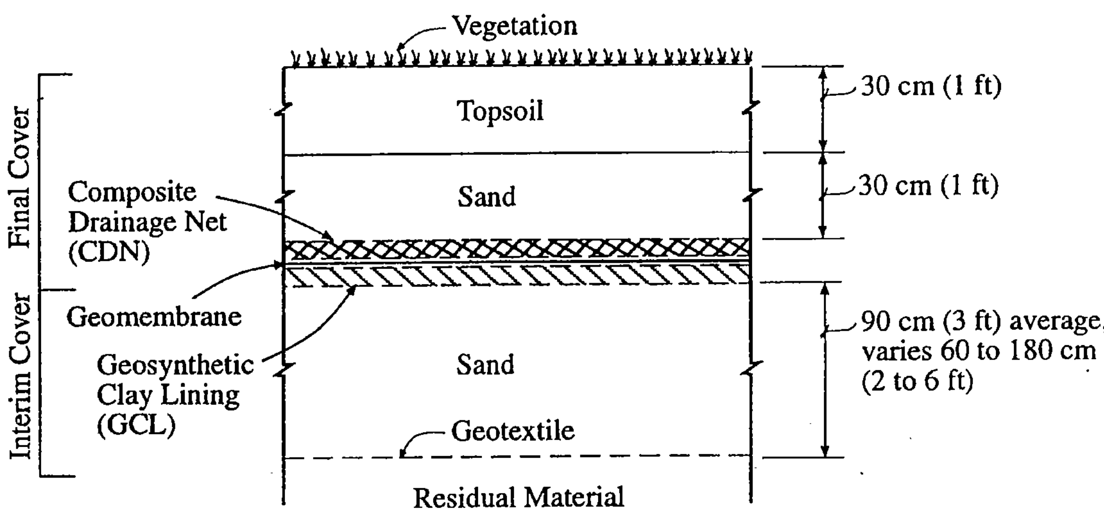

Figure 3. Cover System Cross Section

A GCL serves as the secondary barrier in place of compacted clay, which would not have been possible to place and compact over the weak residual material. Dynamic compaction effort

applied above the residue could liquify it, given its high void ratio. GCL placed immediately below the geomembrane is designed to retard any seepage through membrane penetrations by sealing at least as effectively as would a layer of natural clay soil. GCL has been demonstrated to have self-sealing properties superior to those of compacted clay (Hsin-Yu and Daniels, 1991). In addition, the cost of installing GCL was significantly less than the cost of installing compacted clay, which is not available locally. Another advantage of GCL is the smooth surface provided for seaming geomembrane. The low shear strength of many GCLs was not a significant factor for this project because only a small percentage of the surface area would exceed a 2 percent slope. The limited steeper areas—up to 3 horizontal to 1 vertical—were supported with biaxial HDPE geogrids beneath the interim cover.

The geomembrane is the primary hydraulic barrier in the cover system. PVC geomembrane has been used successfully for containment of water and industrial materials for more than 30 years (Staff, 1984). The authors believe that leak-free geomembranes are not only possible; many have been constructed, using proper design, proper installation methods, and effective quality control (QC) and quality assurance (QA) activities. The advantages of PVC geomembrane over HDPE for this application are large panel size, flexibility, puncture resistance, multiaxial elongation, tensile strength, lower coefficient of thermal expansion, and ease of field seaming (Laine, et al., 1988 and 1989). Factory seams are made under controlled conditions with strict QC.

The composite drainage net (CDN), an HDPE geonet with nonwoven polypropylene geotextile bonded to each side, generally provides transmissivity greater than that of traditional soil drainage components. Storm water that infiltrates the upper soil layers is quickly carried off the geomembrane as soon as it enters the CDN. Ecology recognized the efficiency of CDN over traditional soil drainage materials. The lower geotextile provides mechanical protection of the geomembrane from the geonet and from penetration from above (Frobel, et al., 1987). The upper geotextile prevents soil intrusion into the geonet. The rational for using a composite product rather than installing the components separately was to provide taut geotextile on both sides of the geonet to reduce intrusion into the geonet.

A 30-cm (1-ft) layer of sand and 30 cm (1 ft) of topsoil provide long-term mechanical protection for the geosynthetics below and support for the surface vegetation. The sand came from the same source as the dredged sand used in the interim cover, and it provides drainage of infiltrated water. The seed mix used was designed to control erosion and provide grasses with shallow root systems to keep out vegetation that may take deeper root.

Drainage pipes are another essential element of the cover system, providing drainage from the sand layer along the paths with the most concentrated flow. The drainage pipes are geotextile-wrapped, corrugated, and perforated HDPE pipes. The geotextile filter was needed because of the variable, uncontrolled gradation of the dredge sand.

Geosynthetics Properties Specified. The GCL was required to be natural high-swelling sodium bentonite clay, with weight correlated to moisture content (4.9 kg/m^2 [1 lb/ft^2] at 12 percent moisture). GCL properties specified included mass weight, thickness, bentonite content, wide-width tensile strength, puncture strength, grab strength, grab elongation, interface friction angle, roll dimensions, and permeability with water (1 x 10^{-9} cm/sec) under a normal load of 19 kPa (400 lb/ft^2).

Properties specified for the PVC geomembrane included thickness, specific gravity, elongation, tensile strength, tear resistance, volatility, and seam strength for factory and field seams. The seam strength was required to be 80 percent of the minimum specified parent material strength, and 1751 N/m width (10 lb/in) in peel. All seams were required to have a film tear bond when tested in peel and in shear.

The intent of the geonet specification was to achieve the maximum available transmissivity, provide sufficient compressive strength for the application, and obtain a construction cost lower than typical soil drainage materials. Properties specified included thickness (5.6 mm [220 mils]), maximum aperture size, specific gravity of the HDPE, and minimum transmissivity. The transmissivity was specified as measured between plates, without geotextile, at two different loads, in order get verifiable data undistorted by varying border conditions for review prior to material acceptance. The transmissivity required at a gradient of 1.0 and pressure of 48 kPa (1,000 lb/ft^2) was 2.1 x 10^{-2} m^2/sec (10 gal/min/ft). Actual flow in the CDN was difficult to estimate; it is a function of precipitation, topsoil infiltration, horizontal and vertical transmissivity of the sand, filter function of the upper geotextile, slope, and flow capacity.

The geotextile bonded to the geonet was required to be continuous-filament, needle-punched polypropylene. Properties specified included thickness, weight, water permitivity, grab tensile strength, grab elongation, and bond to the geonet. The upper geotextile was required to be field-seamed, and therefore to have sufficient additional material beyond the geonet edge for this purpose.

Grading Plan. The cover grades are designed in an unusual configuration (see Figure 4), which solved several design challenges. While placement of additional interim cover fill was necessary for construction of the minimal slopes needed to achieve drainage, placement of excess fill over the weak waste would compound construction difficulties and increase long-term settlement of the cover. In addition, the owner requested that the surface runoff be directed to a single drainage point, to facilitate sampling of the runoff as required for a period of time following construction. The resulting grading plan allows for the expected maximum settlement of the pond foundation as well as consolidation of the residual material. The outlet culvert, shown in Figures 4 and 5, is oversized to prevent any condition of standing water on the cover.

Design Issues. A critical part of the design was the graded sand surface, called the "working surface," which formed the basis of proper barrier function for all the geosynthetic components that would be placed over it. Dredged sand fill was placed at the north end of the cover to create

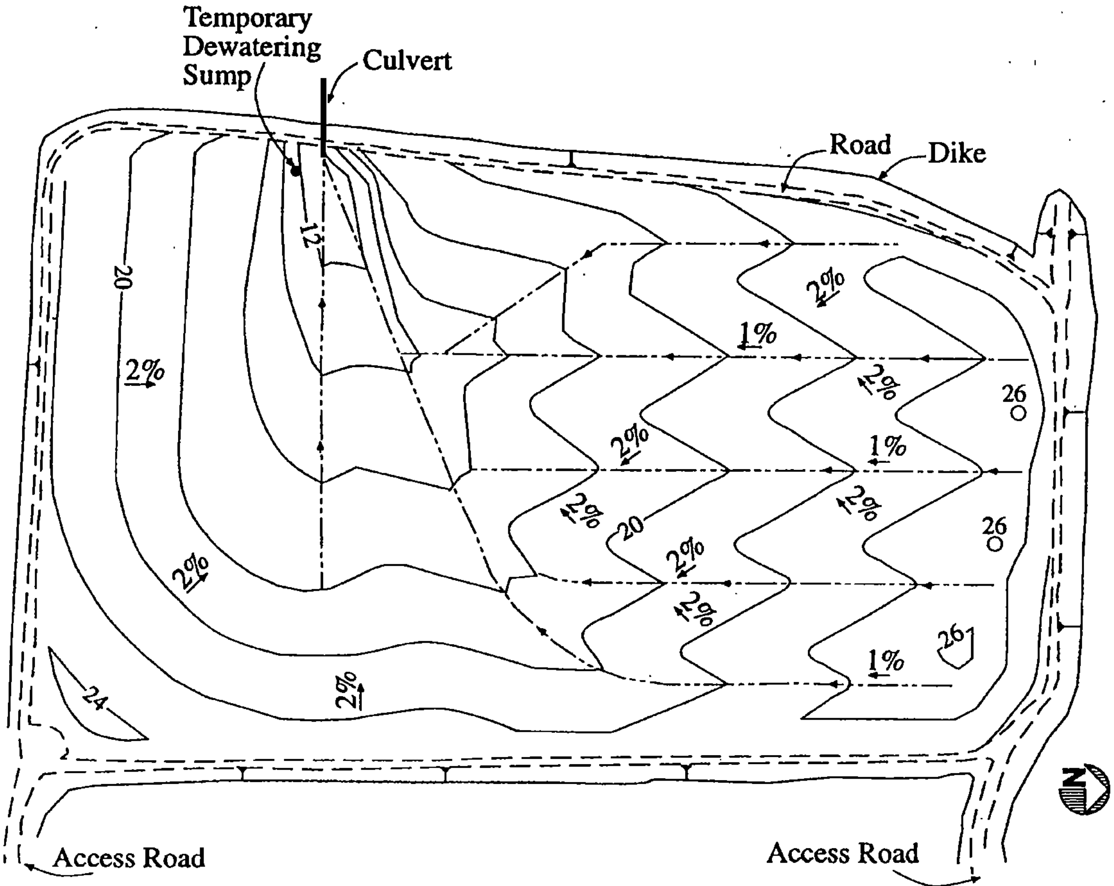

Figure 4. Final Cover Surface Contours

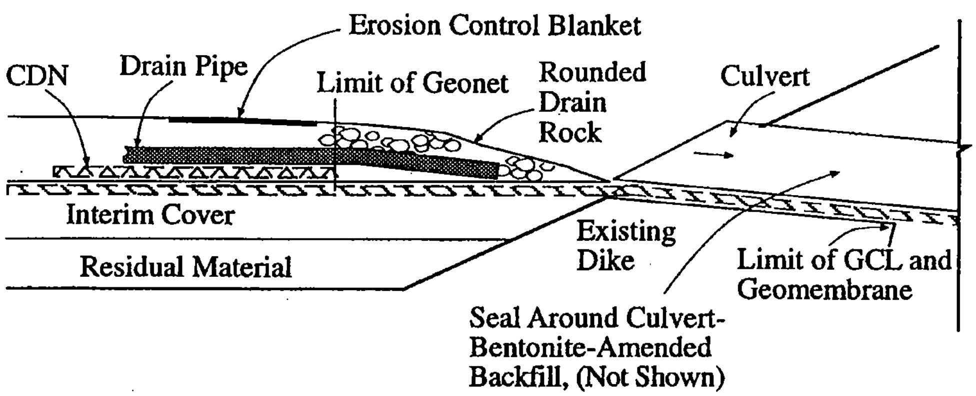

Figure 5. Single Runoff Outlet

a free-draining slope, rather than in the central area, for several reasons: the north end was the most stable portion of the impoundment, that area of the pond was better drained, and the cover could bear partially on the lower portion of the dike. Special fine-grading requirements were imposed on the contractor before GCL installation over the sand was allowed to proceed.

The outer slope of this fill, down to the dike, is steeper, at approximately 5 percent, to minimize the amount of surface runoff that would be sheet flow off the cover and could not be captured in the drainage system. While little infiltration is expected in these dike areas, the underlying CDN was extended across the perimeter road to prevent moisture collection in the subgrade.

The single runoff point requested by the owner was a culvert pipe that would accommodate continued use of the perimeter road. The culvert was oversized for flow collected from nearly the entire cover surface, drain pipes, and geonet. To avoid flow restrictions at the outlet edge of the geonet, the geonet was ended at a 2.4-m (8-ft) radius from the culvert inlet, as shown in Figure 5, allowing the flow to drain freely into gravel. The radius needed was determined based on the end geonet length needed to achieve sufficient open end area to drain the expected runoff from a 25-year design storm within about 24 hours.

Construction of the final cover was planned for the 1992 dry season after completion of the interim cover; however, early that year it became apparent that improved decanting of the residue supernatant would allow concurrent construction of the remaining interim cover and initial work on the final cover. A temporary dewatering sump was designed to allow maximum flow of water from the impoundment near the former surface pumping location. The sump was also needed to remove liquids for as long as drainage and consolidation of the residue continues. The temporary dewatering sump, shown in Figure 6, is a concrete dry well, with large perforations up to the elevation of the adjacent residue surface. Geonet was wrapped around the exterior to filter out the rounded 2.5- to 7.6-cm (1- to 3-in) gravel backfill.

A removable geotextile filter basket for the sump interior (not shown in Figure 6) was designed to filter residual fines from the liquids draining into the sump. The filter basket was designed to be removable so that clogged geotextile could be easily replaced as needed. Geotextile for this filter was selected based on laboratory permeability tests on several geotextile samples tested with residual material remaining in the impoundment.

COVER CONSTRUCTION

Completion of Interim Cover. To speed construction of the interim cover in 1992, the owner decided to place two perpendicular layers of uniaxial geogrid and several "fingers" of composite drainage net across the remaining exposed residue, shown in Figure 1. Tensar Corporation assisted the owner with this work. The temporary dewatering sump installed at that time worked well without the geotextile filter basket, allowing faster decanting of the residual material. The sump will be sealed when it is no longer needed.

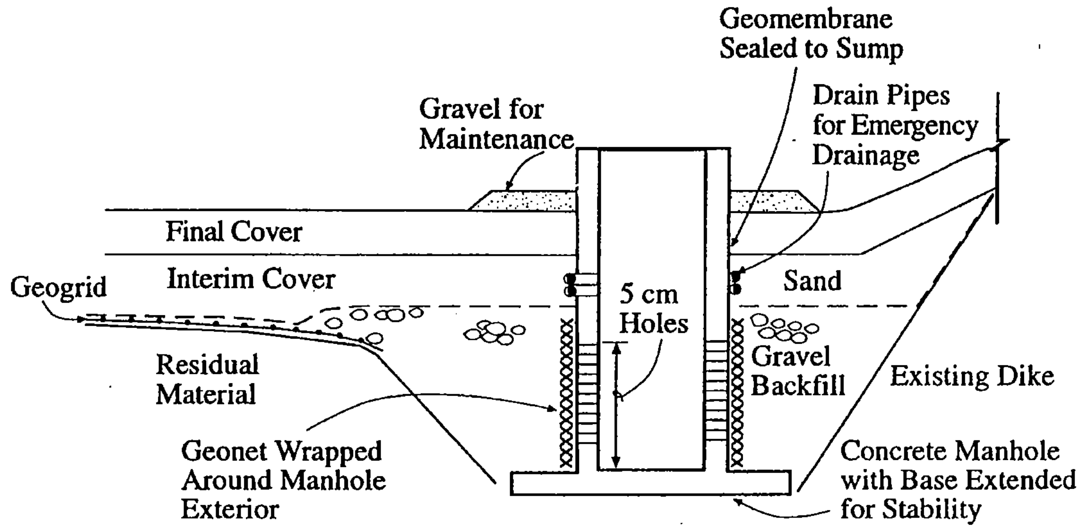

Figure 6. Temporary Dewatering Sump

Geosynthetics Installation. Placement of GCL over the sand required grooming of the surface both before and during placement, as laborers raked away tire ruts between the spreader equipment and the GCL being unrolled. The GCL panels were overlapped at least 15 cm (6 inches). To achieve this minimum, the contractor typically chose to overlap 23 cm (9 in), to allow for shrinkage after placement. The panels were shingled to drain downslope.

The GCL placed each day was protected with PVC geomembrane placed the same day, to prevent damage from precipitation. The PVC geomembrane was chemically seamed. During a heavy rainstorm, water flowed under PVC panels that were temporarily anchored but not seamed, reaching portions of the GCL beneath. The moistened GCL was allowed to dry for several days and was then checked for damage. The moistened GCL appeared to deform easily under body load; by cutting through some footprints, the engineer determined that the bentonite distribution remained uniform and that the function of the GCL would not be impaired, provided it was allowed to dry further before operations were resumed in that area.

Panels of CDN were placed on seamed geomembrane. The geonet panels were overlapped 10 cm (4 in) and tied every 1.5 m (5 ft), and the upper geotextile between panels was overlapped and seamed using a hot-air welder. Minimal wave action was created in the CDN during placement of the sand layer, because of the care the contractor took to place the sand without pushing it horizontally.

Figure 7 shows the cover construction in progress, with exposed GCL, PVC geomembrane, CDN, drain sand, and topsoil.

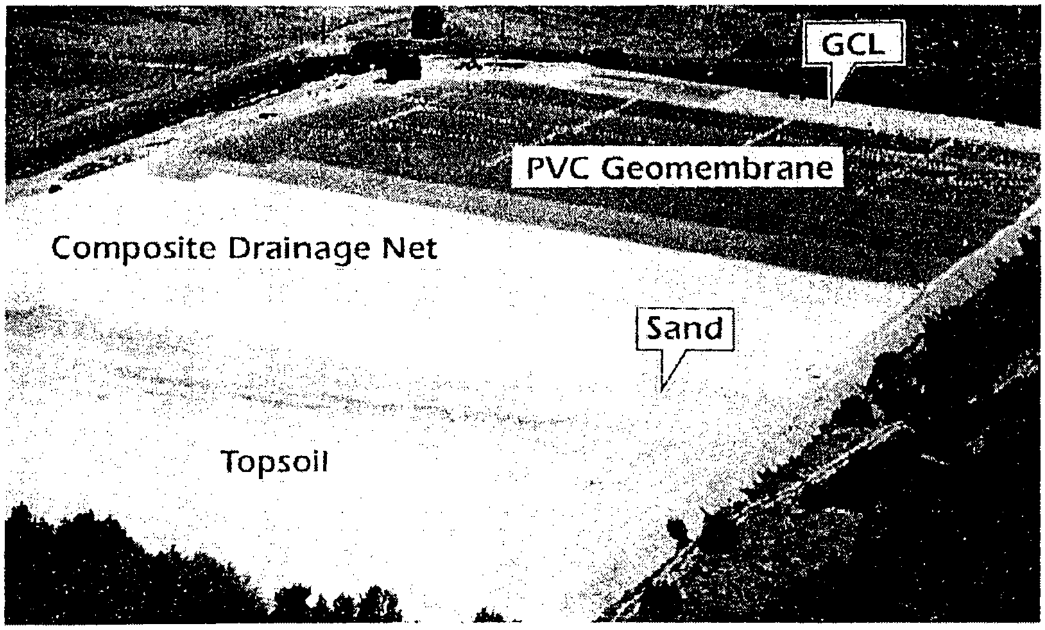

Figure 7. Cover under construction. From background to foreground, the GCL, geomembrane, composite drainage net, sand, and topsoil are visible.

<u>Construction Quality Assurance (CQA).</u> A CQA plan prepared by the project consultant provided detailed project-specific guidance for CQA personnel to perform observation, testing, and documentation of construction for the owner. The project engineer continued on the project as the CQA manager. The plan included a unique section for each geosynthetic material.

A sample of the GCL was tested for hydraulic conductivity at an effective stress of 21 kPa (432 lb/ft^2). The test indicated permeability between 5 and 6 x 10^{-9} cm/sec. The low effective stress, used to represent in situ conditions, complicated the test procedures. Without a standard test method for GCL permeability and without detailed information about effects of variability in each test condition, the test was found to show substantial conformance with the specification, meeting the intent.

The strength of PVC seams was verified by having the installer prepare a representative seam sample about every 152 m (500 ft), under field conditions very similar to those of the seams represented. The samples were tested destructively in shear and in peel. Forty-four of the 48 samples prepared met or exceeded the specified strength and were film tear bonds. Samples were then taken from the questionable seams and tested, and all met the project requirements. Thirty-four of the 48 acceptable samples had a peel strength of 5254 N/m width (30 lb/in width) or greater.

PERFORMANCE

Nearly two years after construction, the cover appeared to be in good condition, with uniform vegetation on the surface. Settlement monitoring points had been checked by the owner and no unexpected settlement was observed. No signs of ponding on the cover had been observed.

OBSERVATIONS

Sand is not an ideal base for GCL because of its easily deformable surface; however, it was the best choice for this project because of its low cost and its relatively high density without compaction. Significant labor was required to continually smooth variations such as equipment tracks and footprints on the surface. These variations often were reflected in the GCL, which was flexible and readily conformed to the sand subgrade.

The specifications allowed the contractor to propose the seaming method for the upper geotextile on the CDN; first proposed was a tack every 1.5 m, which would not have met the functional requirements for the seam. The authors recommend specifying the seam type for similar applications.

Film tear bonds can be made consistently in PVC geomembrane seamed chemically.

ACKNOWLEDGEMENTS

Richard Crim, of CH2M HILL, Inc., was the project engineer for the interim and final cover design; he also served as construction quality assurance engineer. David Lutz, of David J. Newton Associates, Inc., and formerly with CH2M HILL, Inc., was the resident engineer. Ostrander Rock & Construction Co., Inc., was the general contractor, and Environmental Liners, Inc., installed the geomembrane and CDN.

The authors thank the owner for being willing to take advantage of new technology.

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