REVISION III TO
VOLUME IV OF IV REPLACEMENT AMENDMENT TO FINAL CLOSURE PLAN

LOPEZ CANYON SANITARY LANDFILL
LAKE VIEW TERRACE

Prepared for:

Bureau of Sanitation
Solid Resources Engineering and Construction Division
Department of Public Works
City of Los Angeles
419 South Spring Street, Suite 800
Los Angeles, California 90013
(213) 473-7855

Prepared by:

GeoSyntec Consultants
2100 Main Street, Suite 150
Huntington Beach, California 92648
(714) 969-0800

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SUMMARY OF REVISIONS
FINAL CLOSURE AND POST-CLOSURE MAINTENANCE PLANS
LOPEZ CANYON SANITARY LANDFILL

This Summary of Revisions outlines the amendments to the Final Closure Plan (FCP) and the Final Post-Closure Maintenance Plan (FPCMP) for Lopez Canyon Landfill. The FCP is comprised of the Partial Closure Plan (PCP) (Volumes I through III) dated April 1993 and the Amendment to the PCP (Volume IV of IV). The initial Amendment (Volume IV of IV), dated transformed the PCP into the FCP. The FPCMP is comprised of the Partial Post-Closure Maintenance Plan (PPCMP) Volume I) dated January 1993 and the Amendment to the PPCMP (Volume II of II) dated February 1994. The Amendment (Volume II of II) transformed the PPCMP into the FPCMP.

Revision I of Volume IV of IV Replacement was submitted in June 1996 and replaced in whole the February 1994 Volume IV of IV and amended the FCP. Revision II to Volume IV of IV Replacement Amendment Final Closure Plan was initially prepared in March 1997 to address comments from the CIWMB and LEA, prior to final approval of the closure plan being granted. Applicable sections were revised and replaced the respective sections of the original June 1996 document. Revision II to Volume IV of IV Replacement amendment was submitted in October 1998 as an additional revision of applicable sections to be incorporated into the June 1996 report, to reflect conditional approval of the evapotranspirative alternative final cover for the slopes of Disposal Areas A and AB+ and the decks of Disposal Areas A and B. This document, Revision III to Volume IV of IV Replacement Amendment, is being submitted in November 2002 as an additional revision of applicable sections to be incorporated into the June 1996 report, to reflect a conditionally approved alternative final cover. Each revision to Volume IV of IV included herein supersedes the previous Volume IV of IV in its entirety.

SUMMARY TABLE OF REVISIONS TO VOLUME IV OF IV
REPLACEMENT AMENDMENT TO FINAL CLOSURE PLAN
Revision III – November 2002

The following revisions and additions to the final closure plan address the: i) final approval by the CIWMB, RWQCB and LEA of an alternative final cover on the slopes of Disposal Areas A and AB+, and the decks of Disposal Area AB+, and ii) the construction of a green waste facility on the decks of Disposal Areas A and B. Please ensure that these revisions are incorporated into your closure plan, and all previous sections discarded.

SECTIONS, DETAILS, DRAWINGS TO BE AMENDED	DESCRIPTION OF CHANGE	COMMENT
Cover Sheet	Replace	Reflects revision dates
Table of Contents of Volume IV of IV	Replace	Updated to reflect revisions/additions
Section 1: "Introduction"	Replace in Entirety	Updated to reflect revisions
Section 2: "Revised Final Cover Design	Replace in Entirety	Revised to reflect use of alphaltic cement concrete (ACC) on the decks of Disposal Areas A and B
Section 3: "Revised Final Grading Design"	Replace in Entirety	Updated to reflect construction of green waste facility on Disposal Areas A and B
Section 5: "Revised Surface Water Drainage System"	Replace in Entirety	Updated to reflect construction of green waste facility on Disposal Areas A and B
Section 7: "Revised Landfill Gas Control System"	Replace in Entirety	Updated to reflect construction of green waste facility on Disposal Areas A and B
Section 8: "Revised Landscaping and Irrigation"	Replace in Entirety	Revised to include corrected final cover costs
Section 9: "Revised Cost Estimate"	Replace in Entirety	Revised to reflect usage of ACC
Section 10: "Revised Closure Plan Implementation Schedule"	Replace in Entirety	New schedule included to reflect construction of monocover, helipad, and composting facility
Section 11: "Revised Construction Quality Assurance Plan"	Replace in Entirety	Updated to reflect CQA for ACC
Figures	Replace Figure 2.0 and remove Figure 2.2	Reflect change of final cover configuration
	Replace Figure 2.2.a	Reflect change of final cover configuration
	Add Figure 2.2.c	ACC cover on decks of Disposal Areas A and B
	Replace Figure 3.1 and Drawing 1	Final Grading Plan
	Add Figure 5.1	Drainage on decks of Disposal Areas A and B
	Add Figure 5-2	Cross section of clarifier for decks of Disposal Area B
	Replace Figure 10-1	New schedule
Appendix F: " Update Closure and Post-Closure Cost Estimate"	Replace Appendix K of FCP Volume II of IV in Its Entirety.	Revised to accommodate new cover design.
Appendix G: "Approval Letters from CIWMB, RWQCB, and LEA"	Add additional approval letters to back of Appendix G	RWQCB approval of monolithic final cover on slopes of Disposal Areas A and AB+
Appendix I: "Revised CQA Plan"	Replace in Entirety	Includes CQA for ACC
Appendix L: "Documentation on Asphaltic Cement Concrete"	Add new Appendix L	Documentation in support of ACC as an approved cover

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DRAWINGS

1. INTRODUCTION

1.1 Terms of Reference

This volume is the third revision of the amendment to the Final Closure Plan (FCP) and Final Post-Closure Maintenance Plan (FPCMP) for the Lopez Canyon Sanitary Landfill, denoted Volume IV of IV (Volume IV). Outlined below is a chronological order of revisions made to this amendment:

- Volume IV of IV Replacement Amendment to Final Closure Plan was submitted in June 1996 (the 1996 report), to replace the February 1994 Volume IV of IV in its entirety and thereby amended the Final Closure Plan and Final Post-Closure Maintenance Plan (the 1994 report) for the Lopez Canyon Sanitary Landfill (the Landfill). The objective of this first amendment was to incorporate into the Final Closure Plan (FCP) information on the closure of the deck area of Disposal Areas A and B and the deck and slopes of Disposal Areas AB+ and C sufficient to constitute a FCP for the entire landfill. The 1996 volume included revisions to the FCP necessitated by changes in the design of the landfill since submission of the 1994 FCP. These changes required revisions to the final cover, final grading plan, post-closure settlement estimates, surface-water drainage controls, soil loss analysis, landfill gas control system, landscaping and irrigation, cost estimate for closure, closure implementation schedule, and final cover construction quality assurance (CQA) plan for the landfill.

- Revision I to Volume IV of IV Replacement Amendment to Final Closure Plan was submitted to the CIWMB, RWQCB, and LEA in March 1997 (the 1997 report) to address comments from the CIWMB and LEA on the 1996 report, prior to final approval of the revised closure plan being granted. Applicable sections of the amended FCP were revised to reflect these comments. Revised sections included the final cover design, landfill gas control system, closure cost estimate, final cover performance evaluation report and CQA plan.

- Revision II to Volume IV of IV Replacement Amendment to Final Closure Plan was submitted October 1998 (the 1998 report), and included additional revisions of applicable sections to reflect a conditionally approved evapotranspirative alternative final cover. Revised sections include the final cover design, landscaping and irrigation, closure cost estimate, closure plan implementation schedule and CQA plan, with new appendices added to address monolithic cover water balance analyses and final cover performance evaluation.

- This report, Revision III to Volume IV of IV Replacement Amendment to Final Closure Plan, is being submitted in October 2002 (the 2002 report) to reflect construction of a composting facility on the decks of Disposal Areas A and B and changes in the final cover in these areas. Revised sections include the final cover of the Decks of Disposal Areas A and B, closure cost estimate, closure plan implementation schedule, the CQA plan, and a new appendix added to address the Asphaltic Cement Concrete Final Cover Configuration proposed for the composting area.

The 1996 report was prepared by GeoSyntec Consultants (GeoSyntec) for the Bureau of Sanitation, Department of Public Works of the City of Los Angeles (BOS). The March 1997 and October 1998 reports were prepared and written by BOS. GeoSyntec Consultants assisted BOS in the preparation of the technical documents which are part of these reports. This 2002 report was prepared by GeoSyntec for BOS.

1.2 Purpose of Amendment

The purpose of this amendment to the FCP is to provide the Local Enforcement Agency (LEA), Los Angeles Regional Water Quality Control Board (RWQCB), and California Integrated Waste Management Board (CIWMB) with the necessary information to consider the Partial FCP (FCP Volumes I through III) and this amendment as the FCP for the entire landfill in accordance with Title 27 of the California Code of Regulations. Closure requirements for municipal solid waste landfills are contained in Title 27, RWQCB Order No. 93-062, and in §258. of Title 40 of the Code of Federal Regulations, commonly referred to as Subtitle D of the Resource Conservation and Recovery Act (Subtitle D).

The Partial Closure Plan (PCP), Volumes I through III of the FCP was submitted in January 1993, revised in April 1993, and approved by the RWQCB on 21 July 1993, by the LEA on 4 November 1993, and by the CIWMB on 16 December 1993. The amendment to the PCP (Volume IV of IV) was first submitted in February 1994. The PCP and the amendment to the PCP constitute the FCP. The amendment to the PCP was revised in June 1996 (Volume IV of IV Replacement) and was resubmitted to replace in whole the February 1994 submittal.

Another revision (Revision I) to the amended FCP was made in March 1997 to address comments from the CIWMB and LEA prior to final approval being granted. Applicable sections of the June 1996 report were revised. By letters dated July 31, 1997, and August 5, 1997, the LEA and CIWMB found the revised closure plan technically adequate, with final approval contingent on the approval of the environmental documents.

Revision II to the amended FCP was submitted October 1998 and included revisions to applicable sections of the June 1996 report to reflect a conditionally approved evapotranspirative final cover. By letter dated 23 July 1998, the RWQCB gave conditional approval of the Alternative Final Cover at the Slopes of Disposal Areas A and AB+ and the Decks of Disposal Areas A, B, and AB+. Formal approval of the alternative final cover is subject to the results of the on-going post-construction infiltration monitoring.

This document, Revision III, is being submitted in October 2002 with revisions to applicable sections of the June 1996 report to reflect construction of a composting facility on the decks of Disposal Areas A and B and changes to the final cover in these areas.

The PCP (Volumes I through III of the FCP) was prepared in order to accommodate closure of the slopes of Disposal Areas A and B in advance of the remaining areas. The amendment to the PCP was prepared to provide the additional information on the closure of the deck areas of Disposal Areas A and B and the deck and slope areas of Disposal Areas AB+ and C required to turn the PCP into the FCP and FPCMP. The amendment to the FCP addresses the additional information on the closure of the deck area of Disposal Areas A and B, and the deck and slope areas at Disposal Areas AB+ and C resulting from the change in final elevation of the deck of Disposal Area C. The FCP proposed that the closure of the landfill be accomplished in two phases. Phase I closure included the slopes of Disposal Areas A and B. Phase I closure began in the spring of 1994. Phase I closure was to be completed by summer 1996. Phase I construction is now complete, though formal completion of Phase I awaits final approval of the conditionally-approved final cover on the slopes of Disposal Area A. As a result of the suspension of closure activities in order to allow city resources to work on future CUP areas, the Phase I closure was not completed by 1996. Phase II closure includes the top decks of Disposal Areas A and B and all of Disposal Areas AB+ and C. Phase II closure construction is currently underway.

1.3 Report Organization

The remainder of this report is organized into sections which describe the revisions necessary to transform the PCP into the FCP proposed at the site as follows:

- Section 2 presents a description of the revised final cover design for the decks of Disposal Areas A and B where the composting area will be constructed;

- Section 3 presents the revised final grading plan for the decks of Disposal Areas A and B to accommodate the composting facility;
- Section 4 presents revised post-closure settlement estimates for Disposal Areas A, B, AB+, and C resulting from the modifications to the final grading plan;
- Section 5 presents the revisions to the surface-water drainage design for the decks of Disposal Areas A and B resulting from the modifications to the final grading plan;
- Section 6 presents revised soil loss estimates for the decks of Disposal Areas A and B, and C resulting from the modifications to the final grading plan, surface-water drainage system, and final cover cross-section;
- Section 7 presents the revisions to the landfill gas control system resulting from the modifications to the final grading plan;
- Section 8 presents the revised landscaping and irrigation design resulting from the changes to the final grading plan;
- Section 9 presents revised cost estimates for implementing closure resulting from the modifications described in Sections 1 through 8;
- Section 10 presents an updated closure implementation schedule;
- Section 11 presents revisions to construction quality assurance (CQA) procedures resulting from modifications to the final cover cross-sections;

- Appendix A presents the Updated Site Facilities Map which amends the Site Facilities Map of Volume III of IV of the FCP;

- Appendix B presents the Updated Site Radius Maps which amend the Site Radius Maps of Volume III of IV of the FCP;

- Appendix C presents the Updated Ground-Water Monitoring Network which amends Drawing No. 1 of Volume II of II of the FPCMP;

- Appendix D presents the Updated Figures 1-1 and 3-1 which amend Figures 1-1 and 3-1 of Volume II of II of the FPCMP;

- Appendix E presents the Revised Post-Closure Maintenance Cost Estimate which amends Section 4 of Volume II of II of the FPCMP;

- Appendix F presents the updated Closure and Post-Closure Cost Estimates. Revised Initial Cost Estimate Worksheet which amends the Appendix K of Volume II of IV of the FCP and Table 4-1 of Volume II of II of the FPCMP;

- Appendix G presents approval letters from regulatory agencies approving the revised final cover design; and

- Appendix H presents a Final Cover Performance Evaluation report, including water balance (infiltration) and slope stability analyses for the final cover of Disposal Area C;

- Appendix I presents a revised CQA Plan for implementing the procedures presented in Section 11;

- Appendix J presents a report on the Proposed Engineered Alternative Final Cover on the Slopes of Disposal Areas A and AB+, and the decks of Disposal Areas A, B, and AB+; and

- Appendix K presents a report on the Evaluation of the Phase III West Ridge as a Borrow Source for Monolithic Soil Cover.

- Appendix L presents the supporting documentation for use of Asphaltic Cement Concrete as an Alternative Final Cover.

2. REVISED FINAL COVER DESIGN

2.1 General

The final cover for Disposal Area C has been revised from the design presented in the PCP to conform to the requirements of Subtitle D, Title 27, and RWQCB Order No. 93-062 for final covers over bottom liners which include a geomembrane. This revised final cover design was submitted to the CIWMB in February 1994 and was approved on 10 October 1995. A copy of the approval is presented in Appendix G. The final cover presented in the PCP employed an infiltration barrier layer composed of compacted soil only. The revised design for Disposal Area C incorporates a geomembrane in the infiltration barrier layer in the deck and bench areas. The geomembrane was included in the deck and bench areas in accordance with the prescribed minimum construction standards of Subtitle D and Title 27. On the slopes of the waste face, an engineered alternative final cover is employed. The alternative slope final cover was designed in accordance with state and federal regulatory standards for a performance-based design of an engineered alternative final cover.

A performance evaluation of the Disposal Area C alternative slope final cover was conducted to demonstrate compliance with applicable state and federal regulations. The performance evaluation included an infiltration analysis and a slope stability assessment for the alternative slope final cover design. The performance evaluation also included a demonstration that the construction of the prescriptive final cover provided in state and federal regulations on the side slopes was burdensome and impractical and would not promote attainment of the performance goals for final covers, as required by the state regulations. A detailed presentation of the performance evaluation is contained in the Final Cover Performance Evaluation report presented as Appendix H of this addendum. A summary of the performance evaluation is presented herein.

The final cover design for the slopes of Disposal Areas A and AB+, and the decks of Disposal Areas A, B, and AB+ was revised from the prescriptive standards outlined in Subtitle D and Title 27 to reflect an engineered alternative evapotranspirative monolithic cover. A request for approval of this alternative final cover was submitted to the RWQCB and LEA on April 8, 1998, and conditional approval was granted by the RWQCB in a letter dated July 23, 1998, and by the LEA on August 5, 1998. The design for these areas employs an evapotranspirative monolithic final cover which was shown to perform better than the Title 27 prescriptive cover in controlling infiltration in a report entitled, "Proposed Engineered Alternative Final Cover on the Slope of Disposal Areas A and AB+ and the Decks of Disposal Areas A, B, and AB+ – Lopez Canyon Restoration Project," presented in Appendix J. The use of monolithic final cover on the slopes of Disposal Areas A and AB+ was unconditionally approved by the RWQCB in a letter dated 24 October 2002. Copies of the approval letters are shown in Appendix G.

The revised final cover for the decks of Disposal Areas A and B consists of Asphaltic Cement Concrete with an internal tack-coat impregnated geosynthetic reinforcement inter-layer. This design has been demonstrated to meet the performance requirements for an engineered alternative final cover (i.e., it performs as well or better than the Title 27 prescriptive cover with respect to groundwater protection, waste isolation, and gas control). Documentation of the performance of the proposed Asphaltic Cement Concrete cover is provided in Appendix L.

2.2 Regulatory Framework

State of California regulations concerning design and construction of final covers for closure of municipal solid waste landfills are found in Title 27, and RWQCB Order No. 93-062. Federal regulations for final covers are provided in Subtitle D. State and federal regulations both provide a minimum prescriptive construction standard for the final cover of Municipal Solid Waste Landfills (MSWLFs) that includes a protective vegetative erosion control layer and a low-permeability soil infiltration barrier layer. State regulations are somewhat more restrictive than federal regulations with respect to these layers, requiring a thicker erosion control layer and an order of magnitude lower hydraulic conductivity for the barrier layer. The state and federal regulations both require that the final cover have a "permeability" less than or equal to that of any bottom liner or underlying material. This requirement is generally interpreted as an implied prescriptive requirement that a geomembrane be included in the final cover barrier layer above areas which incorporate a geomembrane in the bottom liner. This "permeability" requirement is also interpreted as a performance standard requiring less infiltration of surface water through the final cover than liquid flux through the base of the landfill.

Based upon the state and federal regulations and considering that Disposal Area C does have a geomembrane bottom liner, the prescriptive final cover for Disposal Area C is inferred to consist of (from top to bottom):

- a vegetative layer at least 12-in. (300-mm) thick and of greater thickness than the rooting depth of any vegetation planted on the final cover;
- a geomembrane infiltration barrier;
- a compacted soil barrier layer not less than 12 in. (300 mm) thick with a maximum hydraulic conductivity of 1 x 10^{-6} cm/sec;
- a foundation layer at least 24-in. (600-mm) thick; and
- a design which provides for the minimum maintenance possible.

Both federal and state regulations provide for design of an alternative to the prescriptive final cover. Federal regulations allow the director of an approved state to approve an alternative design shown to be equivalent or superior to the performance of the prescriptive design with respect to infiltration and wind and water erosion. California is an approved state.

Section 21140. of Title 27 provides for the approval of alternative final covers when the owner demonstrates that:

- "the final cover shall function with minimum maintenance and provide waste containment to protect public health and safety by controlling at a minimum, vectors, fire, odor, litter and landfill gas migration. The final cover shall also be compatible with post-closure land use."

- the engineered alternative is consistent with the performance requirements as established in 40 CFR 258.60(b), which states that the alternative final cover design shall meet or exceed the prescriptive permeability of 1 x 10^{-5} cm/sec, or less than the permeability of any bottom liner, with a minimum of 18 inches of earthen material. Additionally, provide an erosion layer that provides protection from wind and water erosion, equivalent to the prescriptive minimum of 6 inches of earthen material capable of sustaining native plant growth.

The state and federal requirement that the final cover have a "permeability" less than or equal to the bottom liner or underlying material is generally interpreted as an implied final cover infiltration performance standard that the flux through the cover should be less than the flux through the base liner. United States Environmental Protection Agency (USEPA) has confirmed this interpretation of the implied prescriptive requirement and performance standard of the Subtitle D closure requirement in the "Final rule; corrections" for Subtitle D published in the Federal Register of 26 June 1992 (Vol. 57, No. 124, pp. 28626-28628). USEPA's comments on the prescriptive and performance standards for final cover design are discussed in detail in the Final Cover Performance Evaluation report presented in Appendix H.

The Final Cover Performance Evaluation report presented in Appendix H of this addendum contains the demonstration required by state regulations that construction of the prescriptive final cover on the slopes of the waste face of Disposal Area C is both burdensome and impractical and will not promote attainment of the performance goals for final covers. On the basis of this demonstration, an engineered alternative final cover for the Disposal Area C waste slopes was developed.

The Proposed Engineered Alternative Final Cover report presented in Appendix J shows that the monolithic soil cover model provides better infiltration control than the prescriptive standard described in Title 27, thus providing better groundwater protection. Moreover, the prescriptive standard illustrates constructability that is more burdensome, quality assurance testing procedures that are more stringent, it is more susceptible to cracking, involves more labor-intensive maintenance, and is significantly higher in cost of purchase and placement of material. Based on the above findings, it was determined that the engineered alternative cover developed for the slope of Disposal Areas A and AB+, and the deck of Disposal Areas A, B, and AB+ would be more practical and would better promote attainment of performance goals.

The documentation presented in Appendix L shows that the Asphaltic Cement Concrete also meets the performance requirements for an alternative final cover for closure on the decks of Disposal Areas A and B. The Asphaltic Cement Concrete will provide better infiltration control than the prescriptive Title 27 cover and is also superior with respect to gas control and waste isolation.

2.3 Revised Final Cover Configuration

Final cover configuration for the entire landfill is shown in Figure 2-0.

2.3.1 Disposal Area C Deck/Bench Areas

The final cover on the deck and bench areas of Disposal Area C satisfies the prescriptive standard in the California regulations. The deck and bench area final cover, shown in Figure 2-1 through 2-1(f), consists of the following components (from top to bottom):

- vegetative layer at least 24-in. (600-mm) thick;
- 12 oz/yd^2 (410 g/m^2) non-woven geotextile cushion;
- 40-mil (1-mm) thick very-flexible polyethylene (VFPE) geomembrane (smooth on the deck areas and textured on the bench areas). Technical specifications are shown in Table 2-1. Note that VFPE geomembranes include very low-density polyethylene (VLDPE) and linear low density polyethylene (LLDPE), as noted in Appendices H and I;

- 12-in. (300-mm) thick barrier layer of compacted low-permeability soil, with a hydraulic conductivity no greater than 1 x 10^{-6} cm/s. A geosynthetic clay liner (GCL) with a hydraulic conductivity no greater than 5 x 10^{-9} cm/s may be used as a barrier layer for the deck area instead of the low-permeability soil. Technical specifications for GCL are shown in Table 2-2; and

- 24-in. (600-mm) thick foundation layer.

2.3.2 Disposal Area AB+ Deck Area

The final cover on the deck of Disposal Area AB+ has been modified from that presented in the PCP to delete the geotextile between the vegetative layer and the low-permeability soil barrier layer. It has also been modified from the original Amendment to the Final Closure Plan to delete the option of using a geosynthetic clay liner (GCL) as a low-permeability barrier layer. The final cover in this area was further modified to consist of a three foot single layer monolithic cover of silty sand or clayey sand with a field saturated hydraulic conductivity no greater than 3 x 10^{-5} cm/s overlying a minimum of two foot existing foundation layer. The modified final cover is presented in Figures 2-2 through 2-2(b).

2.3.3 Disposal Areas A and B Deck Areas

The final cover on the deck of Disposal Areas A and B has been modified from that presented in the PCP. Two different final cover configurations are now proposed for these areas. In the areas to be occupied by the composting facility, an Asphaltic Cement Concrete final cover will be employed. Outside of the composting facility, the final cover will consist of a three-foot evapotranspirative monolithic cover of silty sand or clayey sand with a field saturated hydraulic conductivity no greater than 3 x 10^{-5} cm/, overlying a minimum of a two-foot existing foundation layer.

The Asphaltic Cement Concrete final cover includes the following components, from top to bottom:

- a 3-in. (7.5-cm) thick Asphaltic Cement Concrete overlay;
- a non-woven fabric;
- a 40-mil (1-mm) tack coat;
- a 3-in. (7.5-cm) Asphaltic Cement Concrete underlying pavement;
- a 6-in. (15-cm) thick base course; and
- a minimum of 3 ft (0.9 m) of foundation soil.

The Asphaltic Cement Concrete final cover is shown in Figure 2-2(c).

2.3.4 Disposal Area C Slope Areas

An engineered alternative final cover was developed for the slope areas of the Disposal Area C waste face. The engineered alternative was developed on the basis of the demonstration included in Appendix H of this amendment, the Final Cover Performance Evaluation report, that inclusion of a geomembrane in the slope areas of the Disposal Area C final cover would be burdensome and impractical and would not promote attainment of the performance goals of a final cover. Use of a geomembrane in the final cover on the waste slopes was deemed burdensome and impractical due to constructability, stability, and cost considerations. Furthermore, the maintenance requirements for a slope final cover incorporating a geomembrane were deemed contrary to the performance goal of minimizing final cover maintenance.

The engineered alternative final cover design for the slope areas of the Disposal Area C waste face is shown in Figure 2-3. The final cover for the slope area consists of the following components (from top to bottom):

- vegetative layer at least 24-in. (600-mm) thick;

- 12-in. (300-mm) thick barrier layer of compacted low-permeability soil with a hydraulic conductivity no greater than 1 x 10^{-6} cm/s; and

- 24-in. (600-mm) thick foundation layer.

2.3.5 Disposal Area B Slope Areas

The same final cover used on the Disposal Area C slopes will be used on the slopes of Disposal Area B. This final cover for the B slopes is different than that which was originally submitted in the PCP. The monolithic clay cover was replaced with the final cover as described in the above section. This modification was submitted to the CIWMB on 31 May 1994 and approved on 10 October 1995. A copy of the approval letter is presented in Appendix G. This final cover is shown in Figure 2-3 and described in the preceding section. As the slopes of Disposal Area B are not underlain by a geomembrane liner, the final cover for the benches in these areas do not require a geomembrane. The final cover conforms to the prescriptive design standard.

2.3.6 Disposal Areas A and AB+ Slope Areas

The final cover for the slopes of Disposal Area A has been modified from the monolithic clay cover originally submitted in the PCP, and the 2 ft (0.6 m) foundation layer, 1 ft (0.3 m) clay layer and 2 ft (0.6 m) vegetative layer final cover as submitted in the June 1996 Amendment to the Final Closure Plan. The modified final cover consists of an engineered monolithic soil cover composed of a minimum 2 ft (0.6 m) thick foundation layer overlain by a 3 ft (0.9 m) layer of silty sand or clayey sand.

The existing interim soil cover on the slopes of Disposal Area A consists of at least 6.5 ft (2 m) of silty sand or clayey sand characterized by a hydraulic conductivity of 4.6×10^{-5} cm/s. Additionally, the Proposed Engineered Alternative Final Cover report (refer to Appendix J), shows that the existing interim soil cover demonstrates less percolation than the Title 27 prescriptive cover. Therefore, the existing slope areas of Disposal Area A meet final closure specifications. Refer to Figure 2-3(a).

The final cover for the slopes of Disposal Area AB+ has also been modified from the 2 ft (0.6 m) foundation layer, 1 ft (0.3 m) clay layer and 2 ft (0.6 m) foundation layer as submitted in the Amendment to the Final Closure Plan. The modified final cover also consists of an engineered monolithic soil cover as described for the slope areas of Disposal Area A above. However, a 3 ft (0.9 m) thick layer of sol with a field hydraulic conductivity of no greater than 3 x 10^{-5} cm/s is required to be placed in this area to meet minimal final cover thicknesses, as illustrated in Appendix J, and shown in Figure 2-3(b).

The change in the final elevation of Disposal Area C has produced a split-deck final grading plan, with the deck of Disposal Area C at elevation 1,600 ft msl and the deck of Disposal Area AB+ at elevation 1770 ft msl. This split deck has created a need for construction of a final cover on the waste slopes of Disposal Area AB+ between the decks of Disposal Areas AB+ and C. Additionally, a portion of the haul road and perimeter channel in Disposal Area AB+ will be reconstructed to include a final cover, since refuse underliesthis area. This final cover detail is shown in Figures 2-4.

2.3.7 Borrow Sources for the Alternative and Prescriptive Final Cover

Approximately 250,000 CY (188,955 m^3) of the soil necessary to construct the evapotranspirative monolithic final cover will be recovered from a native ridge regrade within the landfill. Appendix K presents a report entitled Evaluation of the Phase III West Ridge as a Borrow Source for Monolithic Soil Cover, that demonstrates the ridge to be a feasible borrow source of material for monolithic soil cover.

The additional quantity of soil to finish construction of the evapotranspirative monolithic final cover will be obtained from construction contractors either free or through purchase orders.

2.4 Infiltration Analyses

Use of an engineered alternative final cover on the waste slopes of Disposal Area C requires a demonstration that the alternative design provides equivalent protection to ground water and resistance to infiltration compared to the prescriptive design. The potential for infiltration of surface water through the alternative final cover on the slopes of the waste face was evaluated using two USEPA-developed water balance models: (i) HELP Model Version 2 [USEPA; 1984 a,b]; and (ii) the SW-168 Model developed by Fenn et al. [1975]. The infiltration calculations are included in Appendix H of this addendum, the Final Cover Performance Evaluation report.

Neither the HELP nor the SW-168 Model predicted infiltration through the cover. One factor influencing the lack of infiltration is the high percentage of run-off from the 2H:1V Disposal Area C slopes. In addition, the annual precipitation is significantly less than the annual pan evaporation rate. As a result, the soil moisture storage capacity was not exceeded in either short term or long term conditions, resulting in no infiltration through the final cover barrier layer. Because there was no infiltration through the barrier layer, the engineered alternative final cover design for the Disposal Area C slopes meets the infiltration performance standard of less infiltration through the final cover than through the bottom liner.

Likewise, use of an engineered alternative final cover on the decks of Disposal Areas A, B, and AB+, and the slopes of Disposal Areas A and AB+ demonstrate that the alternative design provides equivalent or better protection to groundwater and resistance to infiltration compared to the prescriptive design. The infiltration performance evaluation was conducted using the LEACHM Model under existing site conditions. This infiltration water balance analysis is included in Appendix J of this report.

2.5 Final Cover Slope Stability

Both one-dimensional (infinite slope) and two-dimensional slope stability analyses of the Disposal Area C final cover were performed. Slope stability calculations are included in Appendix H of this report, the Final Cover Performance Evaluation report. The one-dimensional slope stability analyses were performed using the methodology suggested by Matasovic [1991]. Two-dimensional slope stability analyses were performed using the computer program PC STABL 5M [Achilleos, 1988].

One-dimensional stability analyses yielded a minimum (static) factor of safety of 2.0 for a failure surface passing through the waste immediately below the existing foundation layer. The corresponding pseudo-static factor of safety for a seismic coefficient of 0.2 was 1.41. GeoSyntec considers this pseudo-static factor of safety acceptable based upon the conclusions of Seed [1979]. Based upon observations of the performance of slopes and embankments in earthquakes around the world, Seed [1979] concluded that slopes designed with a pseudo-static factor of safety of 1.15 for a seismic coefficient of 0.15 experienced "acceptable" deformations (less than 1 ft (0.3 m)) in earthquakes of all magnitudes and intensities. However, to substantiate this conclusion, maximum permanent seismic displacements were estimated using charts developed by Hynes and Franklin [1984] using Newmark analyses. Predicted displacements for the critical final cover failure surface were on the order of 2 in. (50 mm) for the design peak ground acceleration of 0.69 g. Two-dimensional slope stability analyses yielded a minimum (static) factor of safety of 2.86 and a pseudo-static factor of safety of 2.0.

The infiltration analyses indicated the potential for development of down slope seepage parallel to the face of the slope within the vegetative cover layer was negligible, even for the 100-year, 24-hour storm. However, stability analyses were conducted for the limiting case of seepage parallel to the slope. Stability analyses for the condition of seepage parallel to the slope yielded a minimum (static) factor of safety of 2.5 for this condition.

The final cover on the slopes of the Disposal Area AB+ waste face will have the same cross section as the final cover on the Disposal Area C waste face. However, the inclination of the slopes on the Disposal Area AB+ waste face is 2.5H:1V, flatter than the 2H:1V inclination of the slopes on the Disposal Area C waste face. As the final cover on the Disposal Area C waste face was demonstrated to be stable, separate stability calculations for the flatter Disposal Area AB+ final cover were not considered necessary.

The stability calculations are included in Appendix H of this addendum, the Final Cover Performance Evaluation report.

3. REVISED FINAL GRADING DESIGN

3.1 General

The final grading design presented in Section 4 of the FCP was revised in 1994 to account for the reduction of the final deck elevation of Disposal Area C from the permitted elevation of 1,770 ft msl to the final closure elevation of 1,600 ft. The final slope and deck grading for Disposal Area AB+ was also revised in order to accommodate the revision to the deck of Disposal Area C. The final deck grading for Disposal Areas A and B was revised to reflect the refuse settlement. Also, the grading on the slopes of Disposal Area A in the lower canyon has changed to accommodate an energy dissipator instead of a sedimentation basin. This revised grading in the Lower A Canyon was submitted to the CIWMB on 31 May 1994 and was approved on 10 October 1995. A copy of the approval letter is presented in Appendix G. The grading plan provided in this Amendment has been revised to accommodate construction of a composting facility on the decks of Disposal Areas A and B. The revised final grading plan is shown in Figure 3-1 and Drawing No. 1 of this revision.

3.2 Deck Areas

The 1994 revisions to the final grading design have resulted in a split-level deck for Disposal Areas AB+ and C. The top deck elevation of Disposal Area AB+ remains at 1,770 ft msl. However, in the 1994 grading plan, the contours of Disposal Area AB+ were modified to direct surface water runoff to a single downchute (see Section 5) and to minimize the maintenance associated with the post-closure settlements of the landfill. In re-grading the top deck of Disposal Area AB+, a minimum grade of two percent and a maximum grade of five percent was provided for the deck area immediately after closure to promote surface water runoff and control erosion.

The final grading design for the deck area of Disposal Area C was modified to correspond to the closure elevation of 1,600 ft msl. The deck area of Disposal Area C has a minimum three percent and a maximum five percent grade. The contouring of the Disposal Area C deck was designed to direct surface water runoff to one existing downchute (see Section 5) and to minimize the maintenance associated with the anticipated post-closure settlements of the landfill.

The 1994 revisions to the grading of the Disposal Areas A and B decks were made to better reflect the refuse settlement. The refuse settlement occurred in part as a result of soil stockpiles which were placed in the area. The soil stockpiles have been largely removed to reduce the need to import off-site soils. The revised grading was developed to reduce the need for substantial re-grading following removal of the soil stockpiles.

The grading plan proposed in this Amendment and shown in Figure 3-1 and Drawing 1 was developed to accommodate construction of the composting facility on the decks of Disposal Areas A and B. The final grading design has been modified to provide a relatively flat area in which to build the composting facility. The maximum elevation of the new grading plan is 17 ft below the maximum permitted elevation of 1,770 ft. The grading plan includes a minimum grade of two percent to promote surface water run-off. The contouring of the decks of Disposal Areas A and B has been designed to direct water run-off to downchutes (see Section 5) and to minimize the maintenance associated with the anticipated operations of the composting facility.

3.3 Slope Areas

The revised split-deck final grading design for Disposal Areas AB+ and C creates two slope areas: (i) below the Disposal Area C deck (Disposal Area C slope); and (ii) between the Disposal Areas AB+ and C decks (Disposal Area AB+ slope). The Disposal Area C slopes and the north facing portion of the Disposal Area AB+ slopes have about a 2H:1V (horizontal:vertical) slope with 18-ft (6-m) wide benches spaced about every 40 ft (12 m) in height. The resulting average slope is about 2.5H:1V. The west facing portion of the Disposal Area AB+ slope has about a 2.5H:1V slope with benches spaced about every 40 ft (12 m) in height. The resulting average slope is about 3.0H:1V.

The benches on the Disposal Area AB+ and C slopes are graded and banked to convey surface-water drainage along the back of the benches. The surface water runoff collected on the benches is directed to downchutes and/or channels which empty into the existing debris basins located to the south of Disposal Area C.

3.4 Access Roads and Benches

Access to the deck and slope areas of Disposal Areas AB+ and C is provided by access roads and benches which connect to the existing paved haul road at the Lopez Canyon Sanitary Landfill. Access to the slope areas is provided by the benches which lead to an unpaved access road which parallels the existing haul road along the western and northern boundaries of Disposal Areas AB+ and C. The proposed access road is connected to the existing paved haul road by two short structures which bridge over the existing perimeter channel separating the proposed access and existing haul roads.

Access to the Disposal Area C deck is provided directly from the proposed access road on the north side of the deck. Access to the Disposal Area AB+ top deck is provided directly from the adjoining top deck areas of Disposal Areas A and B and along a dirt access road at the northwestern corner of the deck.

Access to the composting facility on the decks of Disposal Areas A and B is provided directly by a new access road benching off from the main haul road on the eastern side of the decks of Disposal Area B, as shown on Figure 3-1.

3.5 Slope Stability

Slope stability of the final cover was addressed in Section 2.5 of this addendum. Slope stability analyses of the waste mass for a final deck elevation for Disposal Area C of 1,770 ft msl were previously presented by Vector Engineering [1993]. Since reducing the deck elevation to 1,600 ft msl results in a reduction in the driving forces in the stability analysis, the revisions to the final grading plan lead to improved slope stability conditions compared to those evaluated by Vector Engineering and presented in the FCP. As a result, re-analysis of the overall stability of the waste mass was not performed.

The proposed grading leads to fill slopes on the eastern edge of the decks of Disposal Areas A and B. The stability of these slopes were analyzed and shown to be stable. Appendix M details the stability analyses carried out to document the stability of these slopes.

3.6 Refuse Disposal

As a result of the revised final grading design for Disposal Areas AB+ and C, revised refuse disposal projections for each area and for the entire landfill have been prepared by the BOS. These volume projections are based on available information on subgrade elevations, the bottom liner grading plan for Disposal Area C, the revised final cover design, the revised final grading plan, and a daily cover ratio. The volume projection computations indicate total refuse disposal of about 2,600,000 tons for Disposal Area C. The revised total refuse disposal projection for the entire Lopez Canyon Sanitary Landfill is 16,500,000 tons.

5. REVISED SURFACE-WATER DRAINAGE SYSTEM

5.1 General

This section describes revisions to the surface-water drainage system design for Disposal Areas A, B, AB+, and C presented in Section 5 of the FCP. These revisions were prepared to reflect the modifications to the final grading plan presented in Section 3 of this amendment. The layout of the revised surface-water drainage system is shown on Figure 3-1 and Drawing No. 1 of this amendment, and is described in the following sections. The total watershed area and the relative proportions of deck and slope areas are essentially unchanged from the FCP, hence the total surface water run-off is also essentially unchanged from the FCP. The surface-water drainage system revisions were developed such that the total flows entering into the upper and lower debris basins, located to the south of Disposal Area C, are similar to those presented in the FCP. The various components of the revised surface-water drainage system are also essentially the same as those presented in the FCP. However, descriptions of the various surface-water drainage system components are included herein for completeness.

5.2 Disposal Area A

5.2.1 Slope Area

The surface-water drainage system on the slopes of Disposal Area A has been modified since the 1993 submittal of the PCP. The modification is that the proposed sedimentation basin in A Canyon has been changed to an energy dissipator.

5.2.2 Deck Area

The deck of Disposal Area A has been regraded to direct surface water run-off to an inlet structure located on the eastern edge of the deck, as shown on Figure 5-1. Surface water run-off collected at the inlet structure will flow into a pipe that runs towards surface drainage line E and thence into the upper sedimentation basin located on Bench B4.

5.3 Disposal Area B

5.3.1 Slope Area

The surface water drainage system on the slopes of Disposal Area B has not been modified from that shown in the 1993 PCP.

5.3.2 Deck Area

The deck of Disposal Area B has been modified to accommodate construction of the composting facility. The grading has been modified to direct the surface water run-off to an inlet structure equipped with a clarifier (Figure 5-2). Surface water run-off collected at the inlet structure will flow into a pipe connected to surface drainage line E and thence into the upper sedimentation basin located on Bench B4.

5.4 Disposal Area AB+

5.4.1 Deck Area

The top deck area of Disposal Area AB+ has been designed to direct surface water runoff to one inlet structure located along the northern perimeter of the top deck. Surface water runoff collected at the inlet structure flows into a downchute to the existing perimeter channel and into the upper debris basin. The location of the inlet structure corresponds to an area where ultimate post-closure settlements are expected to be relatively large. This design feature is intended to reduce the post-closure maintenance required for correcting surface-water drainage patterns.

5.4.2 Slope Area

Surface water runoff from the north facing slopes of Disposal Area AB+ is either: (i) collected on benches, conveyed to downchutes then into the existing perimeter channel, and into the upper debris basin; or (ii) flows directly off the slope, across the proposed access road, into the existing perimeter channel, and into the upper debris basin.

Surface water runoff from the west facing slopes is collected on the benches where it is conveyed to either: (i) two proposed downchutes, into a proposed diversion channel, to an existing downchute, and into the lower debris basin; or (ii) to the existing perimeter channel and into the upper debris basin. The proposed diversion channel is located on the lowest bench of the west facing slopes.

5.5 Disposal Area C

5.5.1 Deck Area

The deck area of Disposal Area C has been designed to direct surface water runoff to two inlet structures located along the southwest perimeter of the deck. The locations of the inlet structures correspond to areas where ultimate post-closure settlements are expected to be relatively large. This design feature is intended to reduce the post-closure maintenance required for correcting surface-water drainage patterns. The inlet structures are connected to downchutes which will convey the surface water runoff to either: (i) the upper debris basin; or (ii) the lower debris basin.

5.5.2 Slope Area

The slope area of Disposal Areas C is described in Section 3 of this amendment. Surface water runoff from the slope area is collected on benches where it is conveyed to either: (i) three proposed downchutes which lead to the upper and lower debris basins, respectively; (ii) directly into the existing perimeter channel and into the upper debris basin; or (iii) an existing downchute located to the southeast of Disposal Area C and into the lower debris basin.

5.6 Surface Water Drainage Controls

5.6.1 Benches

Surface water runoff from finished slopes will be collected by approximately 18-ft (6-m) wide benches constructed along the face of the slope at approximately 40-ft (12-m) vertical intervals. The benches will be graded so that surface water runoff will drain to the heel of the bench and then to: (i) inlet structures at the proposed downchutes; (ii) the existing perimeter channel; or (iii) the existing downchute located southeast of Disposal Area C.

5.6.2 Downchutes

The downchutes for the site will be constructed of either metal and/or polyethylene. Downchutes will be anchored to the slope. Downchutes will be designed with "slip collars" to accommodate settlement and will be capable of withstanding the anticipated differential movement between the benches. A splash wall/energy dissipater will be located at the base of the proposed downchutes located on the Disposal Area AB+ west facing slope.

5.6.3 Inlet Structures

Inlet structures will be used to direct surface water runoff from the benches and the Disposal Area AB+ and C deck areas to downchutes. The inlet structures will include metal grating to retain debris, and concrete or asphalt bases to control erosion in the vicinity of the inlet structures.

7. REVISED LANDFILL GAS CONTROL SYSTEM

7.1 General

The original landfill gas control system was installed at the Lopez Canyon Sanitary Landfill in 1989 and was upgraded in 1992. Initial start up of the system was conducted in December 1989. The landfill gas control system design consists of horizontal and vertical landfill gas wells, lateral collectors, and headers over a large portion of the landfill. The current flare station consists of nine flares. The collected landfill gas is delivered to the flare station where it is disposed of by combustion. Monitoring of the landfill gas control system is performed with perimeter monitoring probes and a landfill gas surface monitoring grid. The landfill gas monitoring system is unchanged from that presented in the FCP.

Revisions to the landfill gas control system presented in the FCP were required as a result of the modifications to the final grading plans in Disposal Area C. Revisions were made only to the layout of the landfill gas control system in this area. The specific components of the system (e.g., headers, wells, etc.) are unchanged from those described in the FCP. The revised layout of the landfill gas control system is presented as Figure 7-1 and Drawing No. 4 of this amendment. Descriptions of the system components are presented below.

7.2 Landfill Gas Control System

7.2.1 General System Layout

The existing landfill gas control system in Disposal Areas A,B, and AB+ was installed prior to the placement of final cover and consists of vertical and horizontal landfill gas wells buried in the intermediate cover which are designed to allow landfill gas condensate to flow to the sumps located at low points around the site. The system modifications was modified as described in Section 7.2.2.10 will effectively incorporate Disposal Area C into the existing landfill gas control system and accommodate any increased condensate volumes the system may experience when Disposal Area C has been added. Modification to the system to accommodate the installation of the composting facility on the Decks of Disposal Areas A and B are described in Section 7.7.3. Modifications made to the landfill gas control system during the closure and post-closure maintenance period will be submitted to the LEA and the CIWMB for approval in accordance with §17783.(d) of Title 14.

7.2.2 Disposal Area C

The design of the landfill gas control system for Disposal Area C incorporates a series of horizontal gas wells and collection header lines (see Figure 7-1 and Drawing No. 4 of this amendment). Horizontal wells and collection header lines are installed as the waste is placed.

As Disposal Area C is filled, a system of horizontal landfill gas wells will be installed. A total of five levels of horizontal landfill gas wells will be installed under the Disposal Area C deck. The horizontal spacing between adjacent landfill gas wells lines will be approximately 100 ft (30 m). The vertical distance between each layer of horizontal landfill gas wells will be approximately 40 ft (12 m). The top layer of horizontal landfill gas wells will be approximately 20 ft (6 m) below the final cover.

Each horizontal landfill gas well outlet line will be individually valved and connected to a main landfill gas collection header. The main purpose of the horizontal landfill gas wells is to allow for collection of landfill gas from the center of the landfill. Their chief advantages are lower cost and compatibility with ongoing fill operations.

7.2.3 Disposal Areas A and B

A system of horizontal pipes will be installed below the 1-ft thick foundation and the 1-ft thick subgrade layer on the deck of Disposal Area B. The horizontal pipes will be perforated HDPE pipes 4-in. in diameter and placed in gravel filled trenches. The horizontal pipes will run in an east-west direction as shown on Figure 7-1(a). The 4-in. pipes will be connected to the 12-in. pipe running in a north-south direction as shown on Figure 7-1(a). The 12-in. pipe will be connected to the active gas collection system on the northern side of the deck of Disposal Area B. The 12-in. line will be equipped with a trap and a drainage at the south end to remove gas condensate that may accumulate.

8. REVISED LANDSCAPING AND IRRIGATION

8.1 Introduction

The proposed landscape design for the closed Lopez Canyon Landfill is an interim open space landscape revegetated with California native plant materials suited for Southern California. The primary purpose of the vegetative cover will be the protection of surface soils against erosive elements such as water and wind. Secondary or indirect purposes of the cover include aesthetic enhancement and restoration and replacement of native grass and sage scrub species. The deck and slope areas of the landfill will receive vegetative types which respond to site factors such as solar orientation, degree of erosion potential, and water conservation. Figures 8-1 through 8-5 show slope and deck planting areas; with typical planting legends and details in Figures 8-6 and 8-7.

All deck and south/southwest oriented areas of the landfill will be planted with native grassland species of Southern California with additional non-native, noncompetitive grasses. Pioneer plant species will be included to rejuvenate the soil environment. All north/northeast oriented slopes will be revegetated with native shrubs and grasses typical of the local slope areas adjacent to little water, little maintenance, and will be shallow rooted to avoid penetration of the low-permeability final cover layer.

It is intended that whenever possible, the deck areas will be seeded during the rainy months in order to reduce the amount of supplemental irrigation. It is also anticipated that construction schedule demands may not allow waiting for a rainy season. There may also be little or no rain in any given year. Therefore, at the discretion of the Engineer, temporary overhead spray irrigation systems may be used to assist germination and establishment of seed on the deck areas. These systems may be rented and left in place until the vegetation is well established, a period between six and eighteen months.

As an alternative to permanent irrigation systems, temporary irrigation systems may be used for all or part of the landfill. However, permanent overhead spray irrigation systems will be designed for all slope areas. In some areas, sufficient natural vegetation may already have become established by the time irrigation construction is ready to begin. The Engineer may exercise the option to postpone installation of permanent irrigation on some slope areas, or to use temporary irrigation systems, for areas which have well established vegetation, or which are not over the waste prism and would not affect the final cover system.

A water balance study was performed to determine if irrigation of the final cover would create excess infiltration of water into the trash prism. Based on the results of the study, irrigation of the final cover to establish vegetation will not result in unacceptable percolation through the cover, even under the wettest conditions. A water balance study for the Lopez Canyon Landfill was prepared by Law Environmental dated March 27, 1992, and is included as Appendix J of Volume II of IV of the FCP. In addition, periodic monitoring of watering by a landscape architect representative will be conducted until final cover vegetation is established.

Based on the conditionally approved alternative final cover for the decks of Disposal Area AB+, and the slopes of Disposal Areas A and AB+, an important factor governing the performance of monolithic soil cover is evapotranspiration. Evapotranspiration of infiltration water from the cover soil requires the establishment of vegetation on the cover, and should display rooting depths of at least 12 to 18 in. (200 to 450 mm). Only plant species that can survive on the natural precipitation should be considered for vegetating these areas of the landfill.

These requirements are consistent with the seed mix currently established for the other areas of the landfill. The time of planting should be in the fall to coincide with the natural seasonal rains, as in the other areas of the landfill, with temporary irrigation used in the event that additional water is needed to establish vegetation. Additionally, this alternative cover system allows for a wider variety of native vegetation to establish itself, which has deeper roots than would be acceptable with the prescriptive cover, thus requiring less maintenance and removal. A water balance analysis performed on the alternative final cover determined that there is less infiltration into the landfill than the prescriptive cover, however, if any irrigation is applied, the daily volume will be monitored and recorded.

8.2 Post-Closure End Use

The proposed interim end use for the site is open space and will be planted with foothill grass plant species and inland sage scrub plant species. The vegetation established on the slopes at the completion of closure should be compatible with most ultimate end uses. The cover has been designed to accommodate irrigation so as not to limit any future end use selected for the site.

The proposed post closure use of the decks of Disposal Areas A and B is a Green Waste Recycling Facility (i.e., a composting facility). The footprint of the facility will be paved with asphalt cement concrete. Outside the asphalt cement concrete pad, the evapotranspirative final cover will be employed. A specific landscaping plan compatible with the evapotranspirative final cover will be developed for the facility.

8.3 Landscape Materials

8.3.1 General Description

All plant species for the site have been selected because of their adaptability to a limiting set of site criteria. The more important criteria includes low water consumption, tolerance of high salt content in the soils, adaptability to clay soils, ease of maintenance, low fire fuel load, shallow root systems and wind tolerance. The layout of containerized plants which is shown on the plans is intended as a general design. The actual number and layout of plants will be determined in the field by the Site Engineer based on actual conditions at the time of planting.

8.3.2 Deck and Slope Area Plant Materials

All deck and south/southwest oriented areas will be vegetated with a select grass seed mix comprised of native annual and perennial bunch grass species. Individual species selected as the vegetative cover are identified in Table 8-1. The grasses will provide a green vegetative color during the wet season and a light green/light brown color during the dry season. Several grass species are warm season perennials providing green foliage during the summer months on limited water. Their warm season perennial characteristic should limit fire fuel load buildup. Establishment of the grass should occur in the first two to three growing seasons.

All north/northeast oriented slopes will be revegetated with perennial shrubs common to the local slopes of the area. The shrubs will provide visual integration of these disposal areas to the adjacent open space areas. The ultimate height of the vegetative cover will be approximately four feet with most species reaching two feet in height. Establishment of the shrubs should occur in the fourth or fifth growing season. Individual species selected as the vegetative cover are identified in Table 8-1.

The lower slope area of Disposal Area A can be seeded and/or planted with deeper rooting shrubs. The shrubs will not threaten cover integrity since the final cover design in this area provides for a vegetative layer 10 to 40 feet thick. During cover construction, soil depths should be noted to ensure proper placement of deeper rooted plants.

Shrub and tree species common to the chaparral belt plant community can be installed on the Disposal Area A slopes where deeper vegetative soil layers will be placed. These shrubs and trees are not available in seed source and should be installed from field containers following the first stage of plant establishment. These shrub species are identified in Table 8-1.

8.3.3 Soil Amendment

Prior to seeding, a soil activator/conditioner will be applied to the decks and slopes. The soil activator will provide an available nutrient base for quick establishment and will provide a long-term fertile soil environment for full plant development. The soil activator is formulated to provide an appropriate soil environment for the native plant species proposed as a vegetative cover.

8.4 <u>Landscape Installation</u>

8.4.1 Weed Eradication

Upon completion of closure construction, and prior to seeding operations, an aggressive weed eradication program should be implemented to eliminate invasive weeds such as mustard and thistles. These undesirable plants are natural to disturbed sites of the region and their control will be necessary to ensure proper establishment of the desired plant species, to reduce fire potential, and to eliminate possible penetration of the final cover by undesirable deep rooting species. The weed eradication program for each area may be modified by the Engineer, depending upon the condition of the area and project schedule.

The initial removal of weeds may be accomplished by mechanical means and/or by herbicides, as determined during a site inspection by a State licensed Agricultural Advisor and the Engineer. During testing of the irrigation system and following the first-stage of weed removal, dormant weed seeds will germinate. Two to three weeks following the appearance of these weeds, a second eradication effort is required to kill the second generation weeds. This is usually accomplished by herbicide application. Following eradication of the second generation of weeds, the slopes are ready for planting.

After seeding and germination, each area should receive continued weed monitoring during the plant establishment period, with supplemental weed eradication activities as necessary.

8.4.2 Slope Preparation

The slopes will be constructed to limit water infiltration and allow for proper establishment of the vegetative cover. The minimum cover thickness required for vegetation will be 24 inches and may be highly compacted. Slope scarification and texturing will eliminate high run-off velocities of water and will create pockets for seed dispersal and germination. The selected method for texturing will produce surface pockets to a minimum depth of two inches normal to the slope at not greater than eight inches apart. Prior to slope texturing, the surface will be dampened to a minimum depth of two inches.

8.4.3 Hydroseeding Procedures

Seeding procedures for the deck area will be performed by mechanical drill seeding. This technique provides better contact between the seeds and the soil which will increase the germination percentages. Prior to drill seeding, and the addition of soil activators, all compacted soils should be watered to reduce soil compaction in the upper three inches of soil. This step increases the drill seeding equipment's efficiency at dropping seeds into the soil and will incorporate the soil activator with existing cover soils. Drill seeding can occur following the installation of the temporary irrigation system and weed eradication.

Installation of the slope vegetative cover will be performed by two-stage hydroseeding in the fall months after weed eradication. The two-stage hydroseed installation creates a better growth environment resulting in increased landscape coverage. The first stage of the process is an application of the seed mix and soil activator in the form of a light slurry on the textured slope. The second stage is an application of a tackifier and mulch over the seed. This process provides soil contact between the seed and soil and provides a heavy mulch cover over the seed which will reduce exposure to the sun. The tackifier prevents loss of the mulch from rain or irrigation and wind.

8.5 Irrigation System

The final cover irrigation system will consist of a pressured water supply line, the existing one million gallon (1 MG) water tank, a booster pump at the reservoir, mainline distribution networks on the irrigated areas, permanent or temporary sprinkler systems on the slopes, and irrigation controllers sufficient to operate each area of the landfill.

The existing landfill water supply system is designed to lift water from the Los Angeles Department of Water & Power main pipeline on Lopez Canyon Road to the 1 MG water tank. This system consists of two 400 gallon per minute (gpm) pumps and an above ground ten inch diameter cast iron pipeline to the 1 MG water tank at the top of the landfill. Irrigation scheduling will account for the rate of filling and depletion of the tank reservoir. This limitation will restrict the size of area which can be irrigated at full germination rates during any period. Water Management will be the responsibility of the Site Engineer.

A 485 gpm duplex booster pump station is located at the reservoir in order to pressurize the upper deck and upper slope distribution systems which do not receive sufficient head pressure from the tank. These pumps could be operated up to 24 hours per day to meet demand during critical seed germination periods, depending on the limitations of the water supply system.

Air and vacuum release valves will be located at all high points in the system. Blow-off valves will be placed at low points, with a lateral connection to the storm drain for all discharges. Pressure regulating valves will be located at main supply lines that feed slopes to reduce the water pressure to acceptable levels. Pressure relief valves will also be installed in the supply line to eliminate pressure surges. Isolation valves will be installed at a spacing of approximately 1,000 feet to provide for flexibility during operation and maintenance of the system

8.5.1 Deck Area Irrigation

The deck area irrigation system for the Lopez Canyon landfill is proposed to be a temporary manually operated system.

The major components of the system will be rented and consist of a mainline, lateral pipes, risers, manual valves, and sprinkler heads. The point of connection to the water supply for the deck systems will be a flange fitting, located at the edge of the deck area. The booster pumps may be used to provide adequate pressure for the deck systems. Sprinkler laterals will be placed directly on the ground and spring check valves will be utilized at all risers to minimize gravity drainage from the laterals. This will eliminate the wasting of water and reduce the potential for erosion. The supply system will be designed to provide a minimum of 40 psi pressure to the sprinkler heads.

8.5.2 Slope Area Irrigation System

The proposed method of irrigation for slope areas is permanent, automatically operated systems. Layout and installation details are shown in Figures 8-8 through 8-17. Typical layout will include a supply line and a lateral line placed along the outside of each bench at the top of the slopes. These pipes would be buried in the vegetative layer for protection from physical and ultraviolet (U.V.) damage. Other lateral lines may run under benches or down slopes as necessary for adequate coverage on large slope areas. Laterals on slope faces should be avoided if possible. Most mainline and lateral lines will be PVC with U.V. inhibitors. The main system distribution lines will be steel. Sleeves will be installed at bench crossing to protect the PVC pipe.

Sprinkler heads will have a gear driven rotary design with part circle coverage at the top of the slopes, and full circle heads at mid-slope where necessary. The supply system will be designed to provide a minimum of 40 psi pressure to the sprinklers. The sprinkler nozzle sizes will vary depending on the water pressure and desired coverage at each head. Check valves will be used to minimize drainage and reduce the potential for erosion and rutting.

An alternative, less expensive method for irrigating slopes will be to use temporary rental type systems. The Engineer will make the final determination of which type of system will be used, depending upon conditions and schedule requirements when the slopes are ready for irrigation and seeding. Temporary systems for slopes will include a mainline, lateral pipes, risers, manual valves, and sprinkler heads which will be placed on the surface of the cover at the outer edge of the bench above the slope. The source of irrigation water for temporary systems on slopes would be points of connection at the permanent mainlines at the end of each bench.

8.6 Description of Figures

Figures 8-1, 8-2, and 8-3 illustrate Decks A, B, C, and AB+; Slopes areas AB+ and C; and the Haul Road landscape areas. Figures 8-4 and 8-5 illustrate A and B Slopes landscaping.

Figures 8-8, 8-9, and 8-10 illustrate Decks A, B, C, and AB+; Slopes areas AB+ and C; and the Haul Road irrigation areas. Figures 8-11, 8-12, and 8-13 illustrate A and B Slopes irrigation areas.

9. REVISED CLOSURE COST ESTIMATE

9.1 General

This section presents the November 2002 revised cost estimate for closure of the Lopez Canyon Sanitary Landfill. This estimate supersedes the March 1999 cost estimate. The current cost estimate includes all modifications related to the final cover design and final grading, landfill gas control system, irrigation system, and surface-water drainage system. In addition, the City of Los Angeles maintains a fully funded trust fund for the entire value of the closure cost estimate.

9.2 Cost Estimate

Table 9-1 presents a summary of costs for the main closure categories. The revised total cost for closure implementation is in 2002 dollars. Any cost overruns that result from this cost estimate will be paid by the City. Appendix K of the FCP Volume II of IV has been revised to include the updated closure cost estimate. Appendix K is provided as Appendix M of this document.

TABLE 9-1

REVISED SUMMARY OF CLOSURE COST ESTIMATE PARTIAL CLOSURE PLAN AMENDMENT LOPEZ CANYON SANITARY LANDFILL

CLOSURE FEATURE	ESTIMATED COST (2002 Dollars)
Final Cover Construction*	$ 2,161,892
Revegetation/Irrigation*	$1,358,790
Surface-Water Drainage System Installation*	$829,870
Site Security Installation	$33,000
Other (landfill gas system modifications, ground-water monitoring modifications, vadose zone monitoring modifications, and construction management) *	$5,053,824
I. Subtotal	$9,437,376
II. Contingency Costs (20 percent)	$1,887,475
III. Total Closure Costs	$11,324,851

Note: * Cost estimate features changed from the PCP.

10. UPDATED CLOSURE PLAN IMPLEMENTATION SCHEDULE

10.1 General

The updated closure implementation schedule presented herein reflects the changes in the final grading plan presented in Section 3.

10.2 Closure Process

Closure activities initially started on the slope of Disposal Area A in the spring of 1994. However, some staff were released to the Bureau of Street Maintenance later that year due to budgetary reasons. The remaining staff were unable to continue with this slope closure. The closure of Lopez started again in July 1996, when the last shipment of refuse was received.

The closure construction process is implemented in two phases: (i) Phase I includes the slopes of Disposal Areas A and B; and (ii) Phase II will include the remainder of the landfill. The schedules will delineate the estimated time frame to complete tasks relative to the closure activities associated with the slopes of Disposal Areas A and B (Phase I) and the decks of Disposal Areas A, B, AB+, and C (Phase II).

10.2.1 Phase I Closure

Closure construction activities for Phase I terminated in 2002 after two years of monitoring of the evapotranspirative cover qualified on the slopes of Disposal Area A. Final cover for the slope of Disposal Areas A and B were granted by the regulatory agencies and these areas are now closed.

All waste materials generated from closure construction, including, but not limited to, drill cuttings, waste from clearing and grubbing, corrugated metal pipe, concrete, masonry, excavated trash, spoils, asphalt, non-salvageable gas system pipe, and all other construction debris will be disposed of on-site in Disposal Area C. In addition, all non-recyclable refuse generated at the landfill during closure construction by, but not limited to, BOS personnel, consultants, and contractors, will also be disposed of on-site in Disposal Area C.

10.2.2 Phase II Closure

Closure construction activities for Phase II began in 2001 with closure activities on the deck of Disposal Area AB+. Closure is currently on-going on the deck of Disposal Area B and will then progress to Disposal Area C and finally to the deck of Disposal Area A. Figure 10.1 shows the schedule for completion of all closure work at the site.

Placement of the final cover materials will begin after rough grading of the site. Abandonment of landfill gas wells for the slopes, if necessary, will take place in conjunction with final cover placement. As placement of the final cover progresses, landfill gas control system modifications and surface water drainage controls can be constructed. The construction of the surface water drainage controls and landfill gas control system modifications will be completed just after completion of the final cover construction.

The integration of the landfill gas control system with placement of the final cover will include lateral extensions of the horizontal landfill gas wells through the final cover to the main landfill gas collection header. Existing vertical landfill gas wells at the time of closure will also be extended up through the final cover or abandoned and redrilled, if necessary. Landscaping and irrigation will begin prior to completion of the placement of final cover.

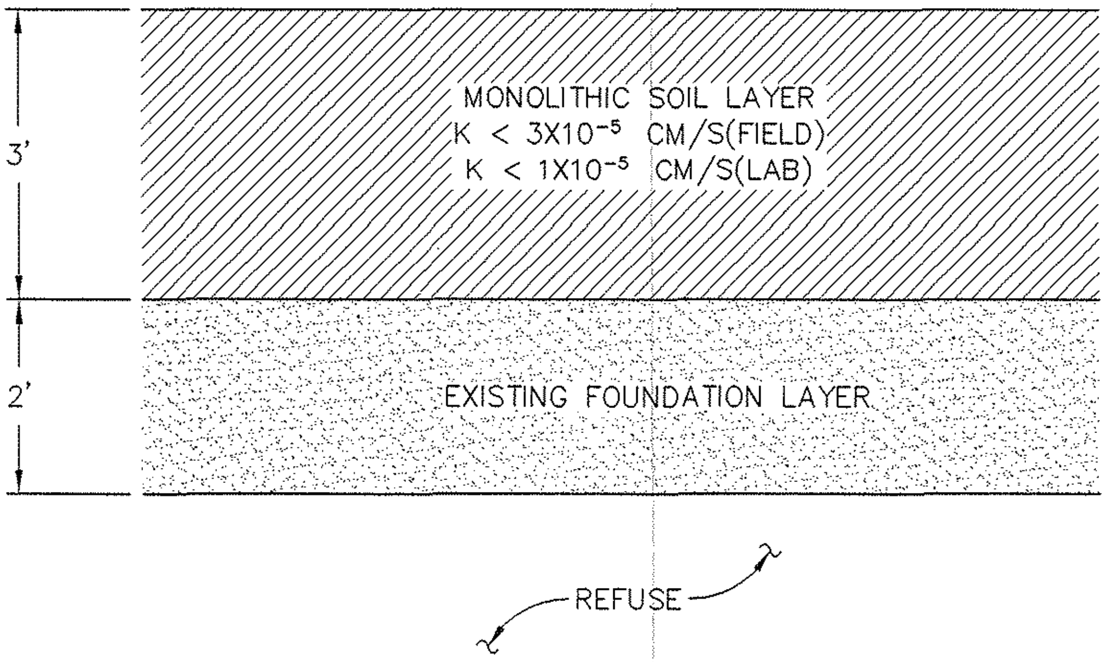
Waste materials generated during Phase II closure activities including, but not limited to, drill cuttings, waste from clearing and grubbing, corrugated metal pipe, concrete, masonry, excavated trash, spoils, asphalt, non-salvageable gas system pipe, and all other construction debris will be disposed of on-site in Disposal Area C. In addition, all non-recyclable refuse generated at the landfill during closure construction by, but not limited to, BOS personnel, consultants, and contractors, will also be disposed of on-site in Disposal Area C. Waste (construction debris and non-recyclable on-site refuse) generated after completion of closure construction will be disposed of off-site.

Upon completion of the tasks described for closure, existing site structures will be utilized for post-closure maintenance activities and potential post-closure end use. The estimated date for completion of all closure construction is 1 August 2008.

11. REVISED CONSTRUCTION QUALITY ASSURANCE PLAN

The construction quality assurance (CQA) plan presented in the PCP has been revised to reflect the changes in the final cover design presented in this amendment. The revised CQA Plan is presented in Appendix I and contains descriptions of:

- site and project control meetings;
- documentation requirements;
- VFPE geomembrane CQA;
- geotextile cushion CQA;
- soils CQA, including construction of the low-permeability soil barrier layer;
- geosynthetic clay liner CQA;
- monolithic soil cover CQA; and
- asphaltic cement concrete CQA, including the resin-impregnated geotextile interlayer.



GEOSYNTEC CONSULTANTS

MONOLITHIC SOIL FINAL COVER
DECK OF DISPOSAL AREA AB+
LOPEZ CANYON SANITARY LANDFILL
LAKE VIEW TERRACE, CALIFORNIA

FIGURE NO.	2-2(a)
PROJECT NO.	CE4100-02
DOCUMENT NO.	LP702-32
DATE:	NOVEMBER 2002

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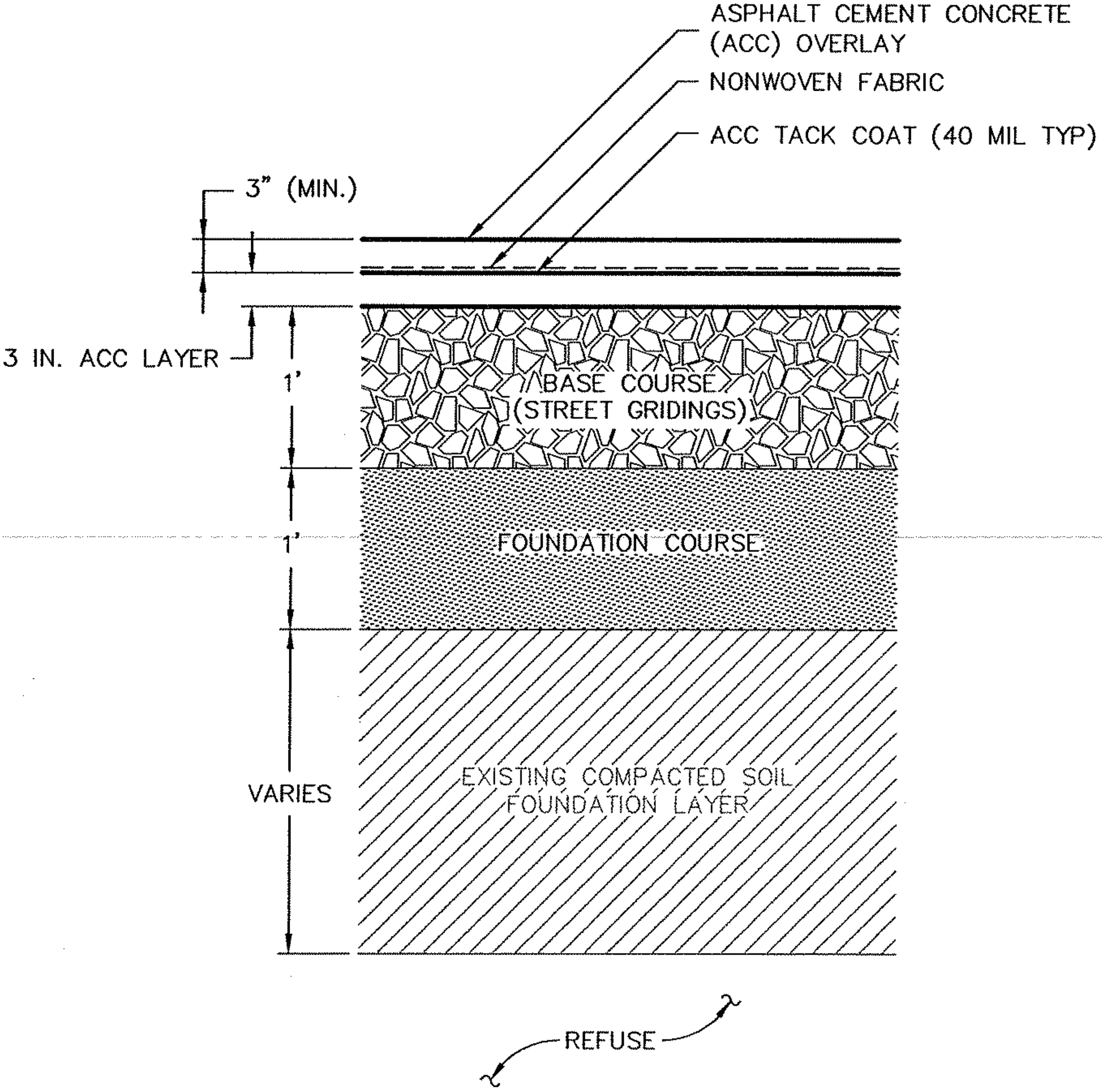

GEOSYNTEC CONSULTANTS

ASPHALTHIC CONCRETE FINAL COVER
DECK OF DISPOSAL AREAS A AND B
LOPEZ CANYON SANITARY LANDFILL
LAKE VIEW TERRACE, CALIFORNIA

FIGURE NO.	2-2(c)
PROJECT NO.	CE4100-02
DOCUMENT NO.	LP702-32
DATE:	NOVEMBER 2002

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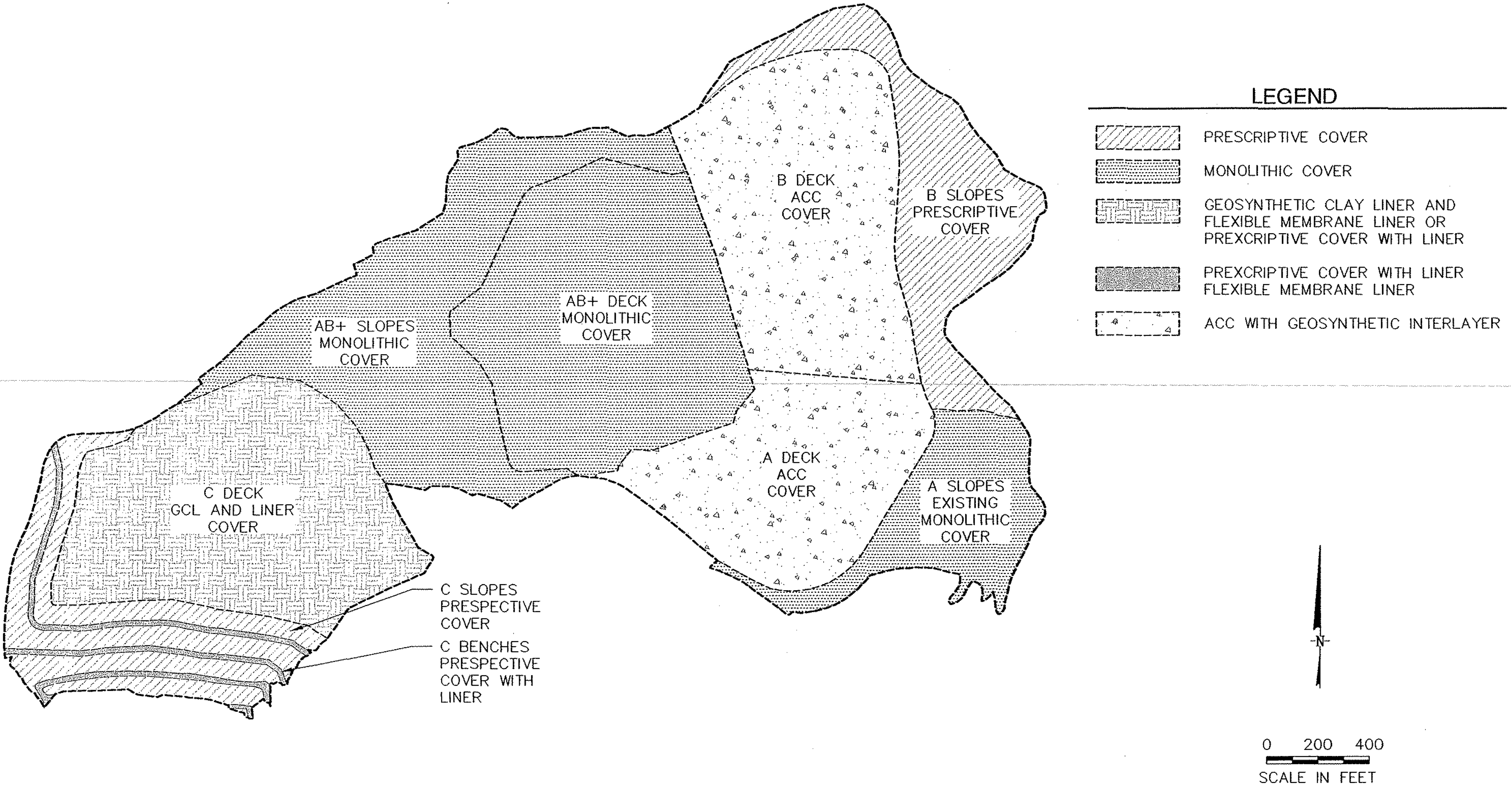

GeoSyntec Consultants

RETORATION PROJECT COVER PLACEMENT
LOPEZ CANYON SANITARY LANDFILL
LAKE VIEW TERRACE, CALIFORNIA

FIGURE NO.	2
PROJECT NO.	CE4100-02
DOCUMENT NO.	LP702-02
DATE:	NOVEMBER 2002

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GEOSYNTEC CONSULTANTS

REVISED FINAL GRADING AND SURFACE WATER DRAINAGE
PLAN DISPOSAL AREA A, B, AB+, AND C
LOPEZ CANYON SANITARY LANDFILL
LAKE VIEW TERRACE, CALIFORNIA

FIGURE NO.	3-1
PROJECT NO.	CE4100-02
DOCUMENT NO.	LP702-32
DATE:	NOVEMBER

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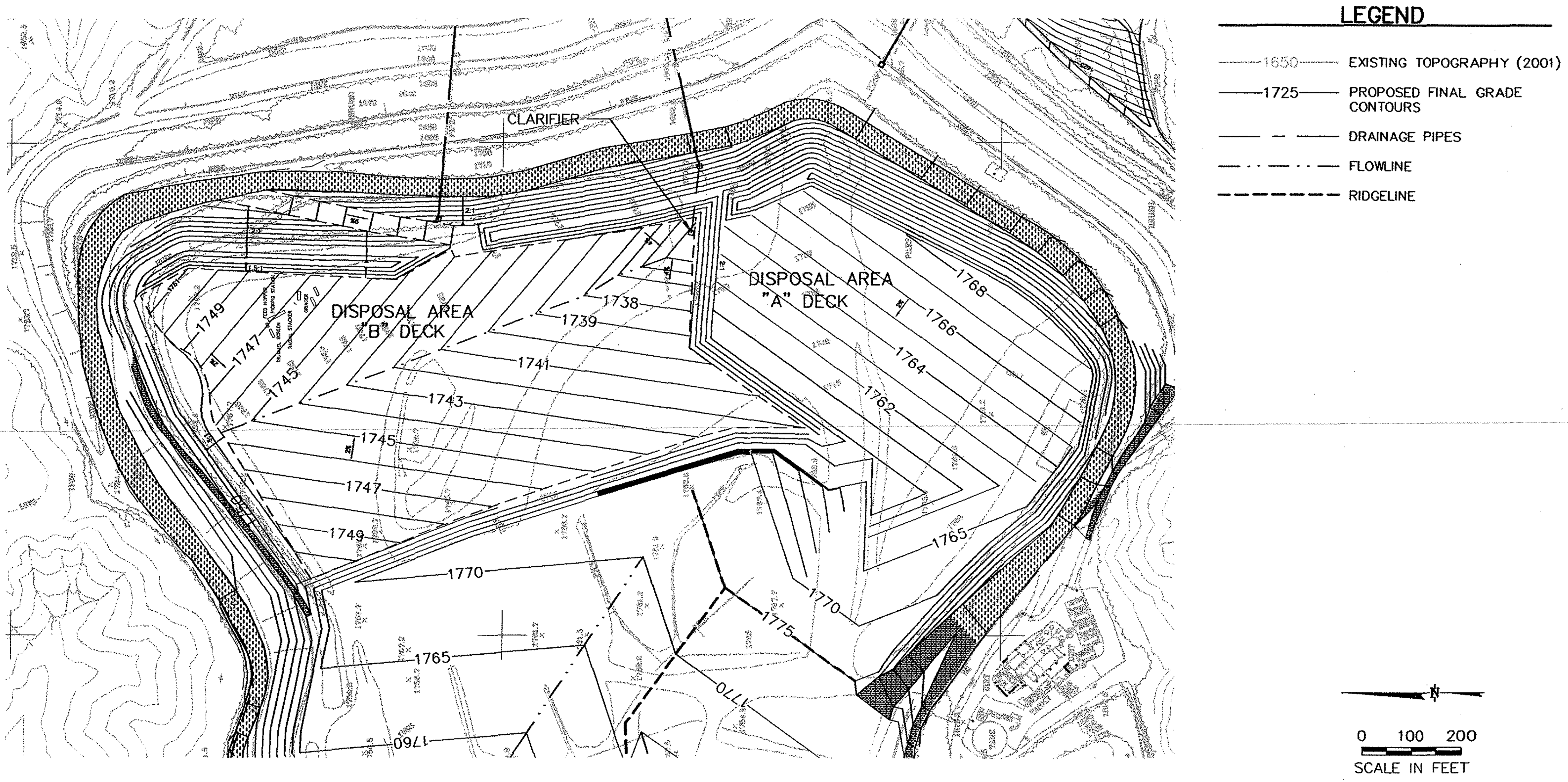

GEOSYNTEC CONSULTANTS

DRAINAGE ON DECKS OF DISPOSAL AREAS A AND B
LOPEZ CANYON SANITARY LANDFILL
LAKE VIEW TERRACE, CALIFORNIA

FIGURE NO.	5-1
PROJECT NO.	CE4100-02
DOCUMENT NO.	LP702-32
DATE:	NOVEMBER 2002

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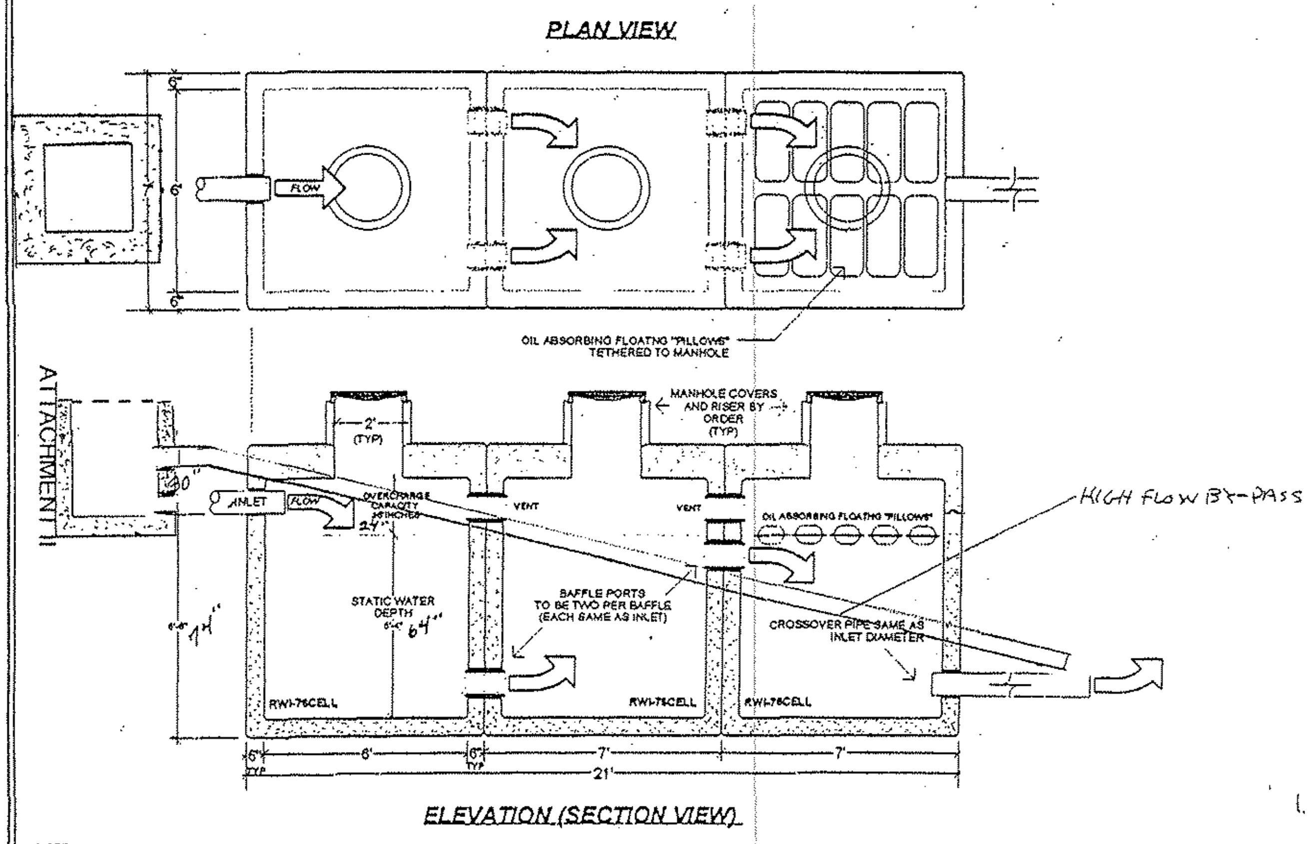


NOTE:
CAPACITY OF RWI-76 CELL IS 26.2 GALLONS PER INCH OF WATER DEPTH
TOTAL CAPACITY OF THIS THREE CELL UNIT IS 5031 GALLONS

5000 GALLON CAPACITY
3 CELL HIGH-FLOW INTERCEPTER
USING (3) RWI-76 CELLS
and 640 GALLON INSPECTION BOX

PYRAMID PRECAST CO. INC.
2438 LOCUST AVE.
- INDUSTRIAL WASTE CLARIFIERS
- SAND & GREASE INTERCEPTERS
- SEPTIC TANKS & DISTRIBUTION BOXES

RIALTO, CA 92376 (909) 823-4255

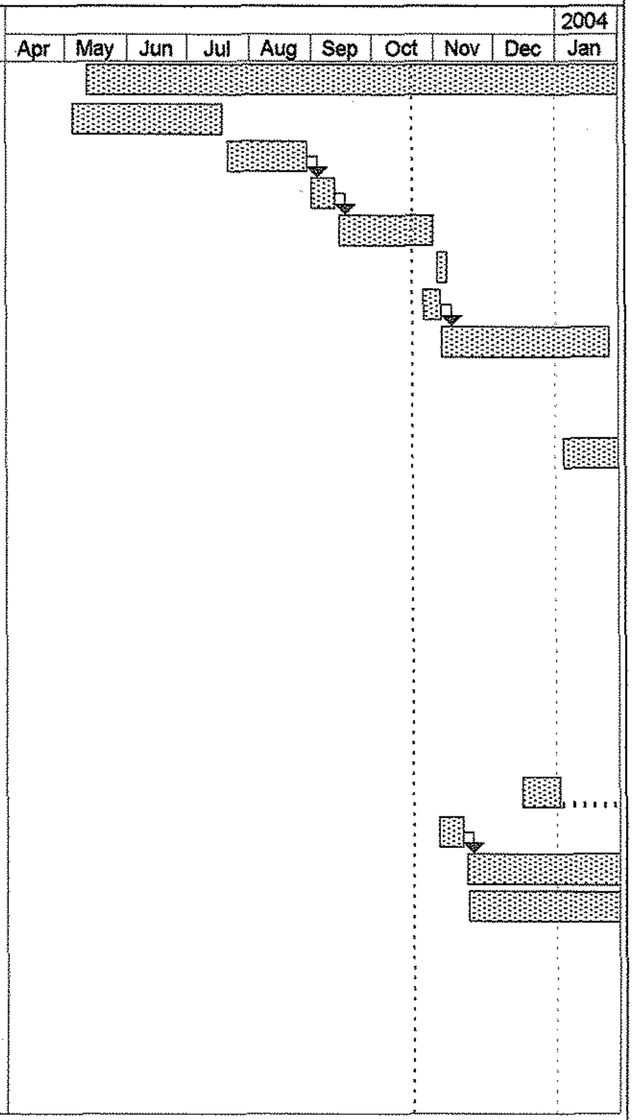
DRAWING # PG-X	NOTES:
DRAWN BY SCOTT BENART	
SCALE 1/4"= 1 FOOT	

GEOSYNTEC CONSULTANTS

CROSS-SECTION CLARIFIER DECK OF DISPOSAL AREA B LOPEZ CANYON SANITARY LANDFILL	FIGURE NO.:	5-2
	PROJECT NO.:	CE4100
	DATE:	11 NOVEMBER 2002

LOPEZ CANYON LANDFILL CLOSURE SCHEDULE

ID	ⓘ	Task Name	Duration	Start	Finish
1	▦	**B deck Closure**	**205 days?**	**Mon 5/12/03**	**Fri 2/20/04**
2	▦ ✎	QC & QA of berm construction & placement of monocover	55 days?	Mon 5/5/03	Fri 7/18/03
3	▦	QC & QA of placement of foundation layer/grindings	30 days?	Mon 7/21/03	Fri 8/29/03
4	▦	*Installation CB, clarifier and connection to exist. SD*	*10 days*	*Mon 9/1/03*	*Fri 9/12/03*
5	✎	QC & QA of installation of final cover/asphalt (for mulch)	35 days?	Mon 9/15/03	Fri 10/31/03
6	▦	*Installation of drainage pipe and connection to clarifier*	*5 days*	*Mon 11/3/03*	*Fri 11/7/03*
7	▦	Layout of aeration troughs by surveyors	7 days	Mon 10/27/03	Tue 11/4/03
8	▦	QC & QA of installation of aeration troughs	60 days	Wed 11/5/03	Tue 1/27/04
9	▦ ✎	QC & QA of installation of final cover/asphalt (for compost)	27 days	Mon 2/2/04	Tue 3/9/04
10	▦	QC & QA of installation of biofilters on AB+ deck (for compost)	37 days	Wed 3/10/04	Thu 4/29/04
11	▦	QC & QA of installation of electrical power for generators (for compost)	70 days	Mon 1/5/04	Fri 4/9/04
12					
13	▦	**B slope Closure**	**14 days**	**Mon 5/3/04**	**Thu 5/20/04**
14	▦ ✎	QC & QA of placement of monocover soil	14 days	Mon 5/3/04	Thu 5/20/04
15	▦	**Prepare final report for CRWQCB on closure of B deck and slope**	**100 days**	**Tue 6/1/04**	**Mon 10/18/04**
16					
17	▦	**Drainage Channel and Haul Road Reconstruction**	**110 days?**	**Mon 4/5/04**	**Fri 9/3/04**
18	▦	QC & QA of soil compaction	110 days?	Mon 4/5/04	Fri 9/3/04
19					
20	▦	***MMS on AB+ deck***	**960 days?**	**Mon 12/15/03**	**Fri 11/16/07**
21	▦	Relocation of MMS from A slope to AB+ deck	10 days	Mon 11/3/03	Fri 11/14/03
22	▦	Collect data (weekly, monthly - 2years min.)	535 days?	Mon 11/17/03	Fri 12/2/05
23	▦	Analyze collected data	504 days?	Tue 11/18/03	Fri 10/21/05
24	▦	**Prepare final report for CRWQCB on AB+ closure**	**100 days**	**Mon 1/2/06**	**Fri 5/19/06**
25					
26	▦ ✎	***AB+ slope Closure (area 4)***	**217 days?**	**Mon 1/3/05**	**Tue 11/1/05**
27	▦	**Prepare final report for CRWQCB on closure of AB+slope**	**90 days**	**Mon 11/7/05**	**Fri 3/10/06**
28					



Project: Closure Schedule_A
Date: Tue 10/21/03

Task	▨	Milestone	◆	External Tasks	▨
Split	┈┈┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

FIGURE 10.1

LOPEZ CANYON LANDFILL CLOSURE SCHEDULE

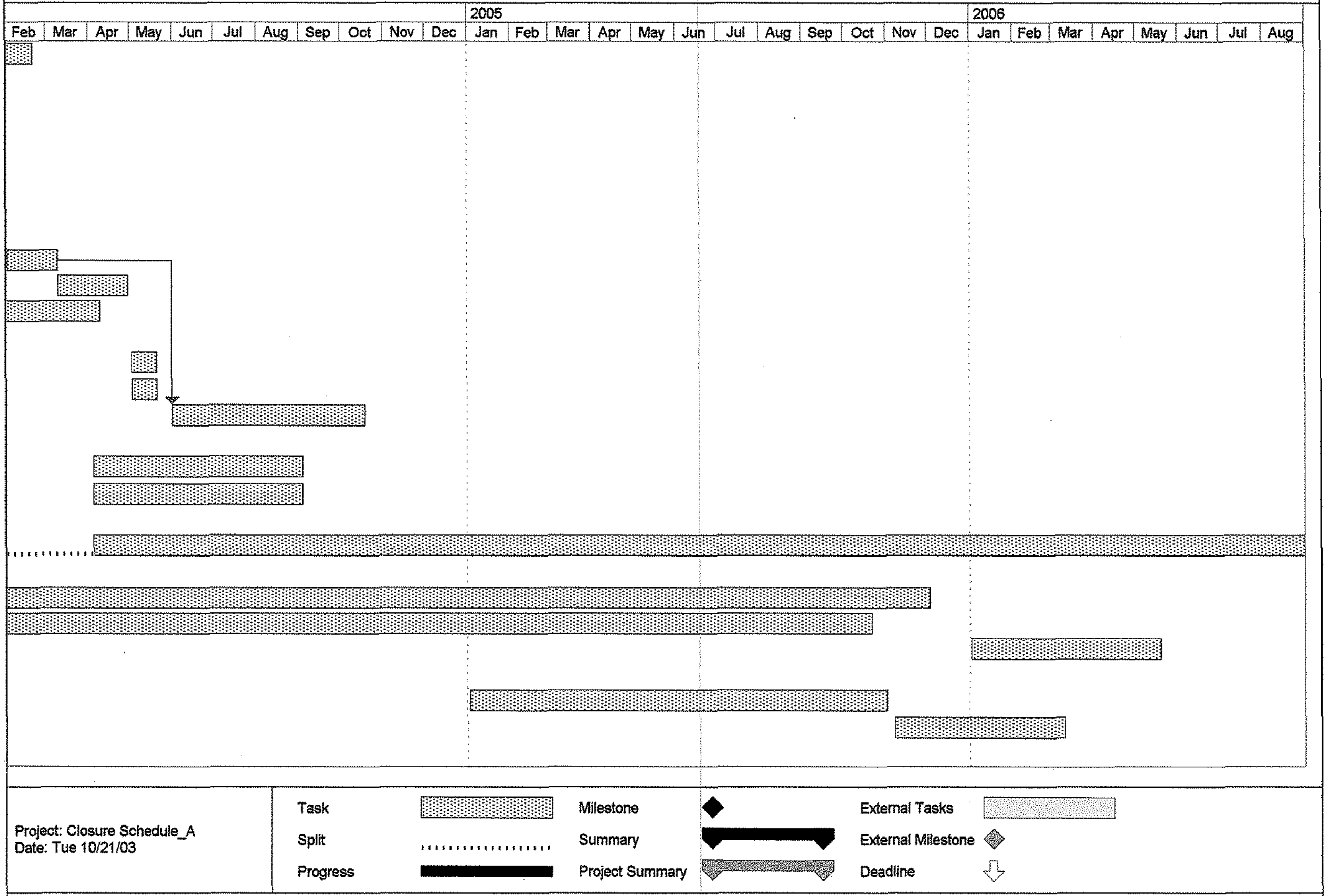
ID	❶	Task Name	Duration	Start	Finish	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2004 Jan
29	▦ ✎	*C deck Closure*	285 days	Mon 1/9/06	Fri 2/9/07										
30															
31	▦ ✎	*C slope Closure*	195 days?	Mon 2/12/07	Fri 11/9/07										
32		**Prepare final report for CRWQCB on closure of C deck and slope**	150 days	Mon 11/12/07	Fri 6/6/08										
33															
34	▦ ✎	*A deck Closure*	130 days	Mon 11/12/07	Fri 5/9/08										
35		**Prepare final report on A deck closure**	60 days?	Mon 5/12/08	Fri 8/1/08										

Project: Closure Schedule_A
Date: Tue 10/21/03

Task	▨	Milestone	◆	External Tasks	▨
Split	┈┈┈┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

FIGURE 10.1

LOPEZ CANYON LANDFILL CLOSURE SCHEDULE



Project: Closure Schedule_A
Date: Tue 10/21/03

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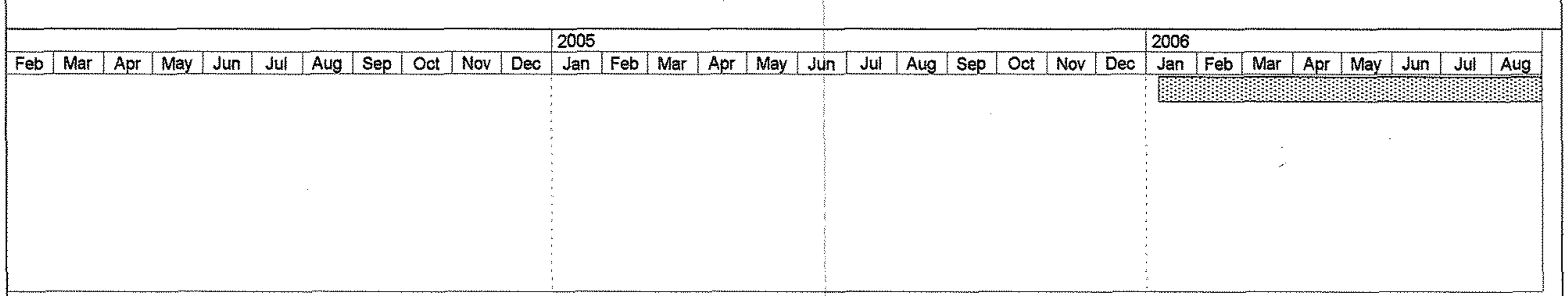
FIGURE 10.1

LOPEZ CANYON LANDFILL CLOSURE SCHEDULE

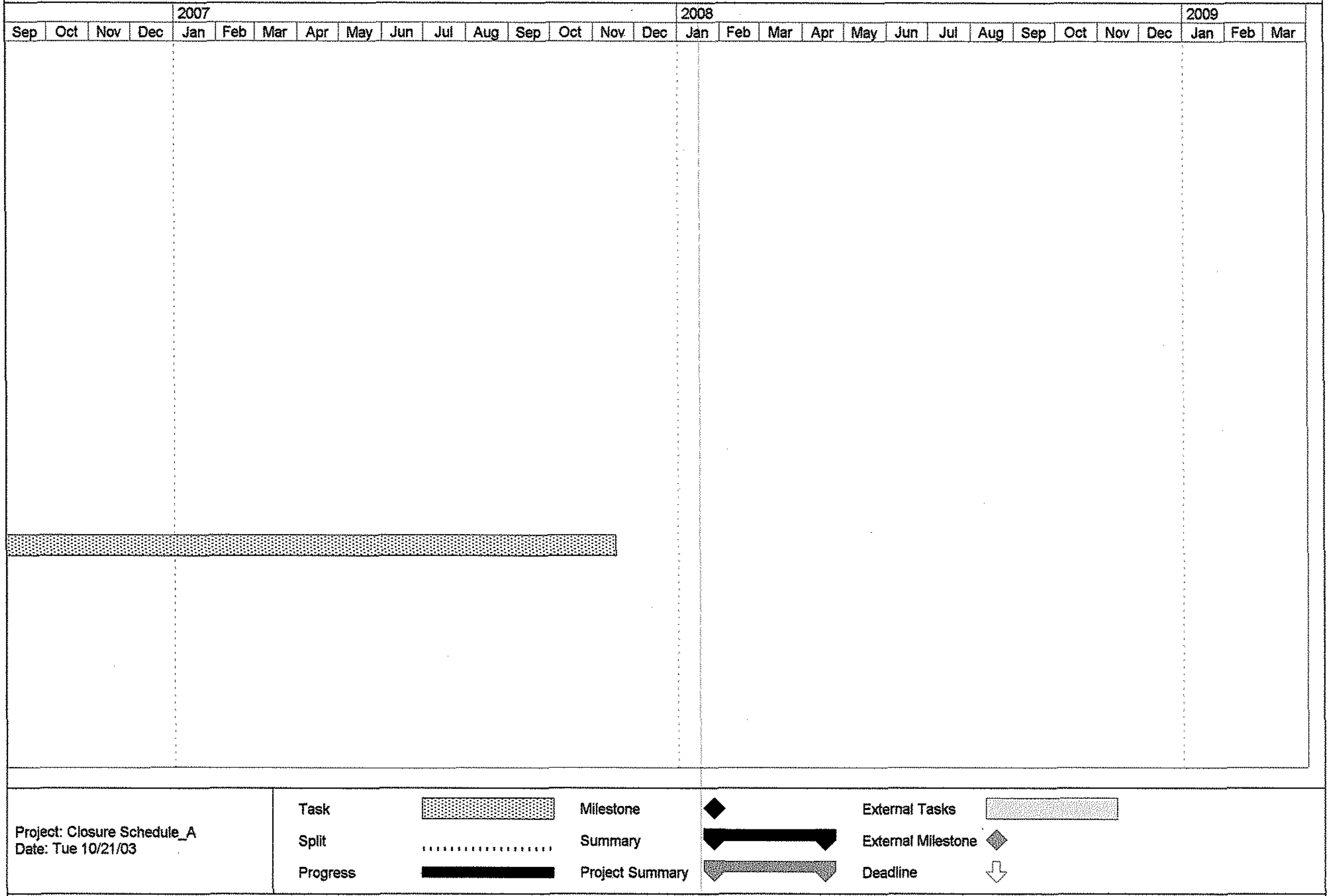


Project: Closure Schedule_A
Date: Tue 10/21/03

Task	▨	Milestone	◆	External Tasks	▨
Split	┈┈┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

FIGURE 10.1

LOPEZ CANYON LANDFILL CLOSURE SCHEDULE

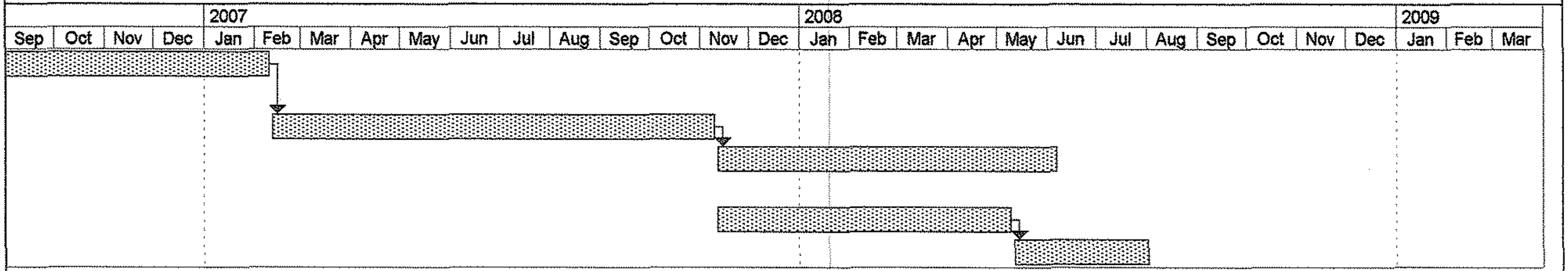


Project: Closure Schedule_A
Date: Tue 10/21/03

I:/LPZ/CLOSURE/Closure Schedule_A

FIGURE 10.1

LOPEZ CANYON LANDFILL CLOSURE SCHEDULE



Project: Closure Schedule_A
Date: Tue 10/21/03

Task	▨	Milestone	◆	External Tasks	▨
Split	…………	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

FIGURE 10.1

LEGEND

1650	EXISTING TOPOGRAPHY (2001)
1725	PROPOSED FINAL GRADE CONTOURS
▬ ▬ ▬	DRAINAGE PIPES
— · · —	FLOWLINE
- - - -	RIDGELINE

200 100 0 200 400
SCALE IN FEET

GEOSYNTEC CONSULTANTS
2100 MAIN STREET, SUITE 150
HUNTINGTON BEACH, CALIFORNIA 92648
TELEPHONE: (714) 969-0800

PROJECT:
LOPEZ CANYON LANDFILL
LAKE VIEW TERRACE, CALIFORNIA

TITLE:

REVISED FINAL GRADING AND SURFACE WATER DRAINAGE PLAN DISPOSAL AREA A, B, AB+, AND C

MARK	DATE	REVISION	BY	APPROVED

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

SEAL

DATE: OCTOBER 2002
DESIGN BY: ---
DRAWN BY: LPR
CHECKED BY: ---
REVIEWED BY: MLD
APPROVED BY: THH

SCALE: AS SHOWN
JOB NO.: CE4100-02
FILE NO: 4100-028
DOCUMENT NO: -----
DRAWING NO: 1 OF --

INITIAL COST ESTIMATE WORKSHEET
(rev. 3/99)

SITE DESCRIPTION

The following questions will provide general information regarding the site description, the type of waste accepted at the site and basic geological information. This information will aid in assessing factors that may affect the initial cost estimates.

Prepared By: GeoSyntec Consultants Revised by: City of Los Angeles Bureau of Sanitation

General Site Information:

Name of Solid Waste Landfill	Lopez Canyon Sanitary Landfill
Solid Waste Facilities Permit Number	19-AA-0820
Facility Operator	CITY OF LOS ANGELES BUREAU OF SANITATION
Site Owner	CITY OF LOS ANGELES BUREAU OF SANITATION

Site Location (California coordinates, township & range or longitude/latitude, preferred)

Section 6

Assessors Parcel Number

Site Address 11950 Lopez Canyon Road, Lakeview Terrace, CA 91342

1. What is the existing State Water Resources Control Board classification of the solid waste landfill? (mark the appropriate response)

NEW If Waste Discharge Requirements (WDR) revised since 11-84	OLD
____ Class I	____ Class I
	X Class II-1

Note: The solid waste landfill is excluded from these requirements, if the facility is a hazardous waste facility or co-disposal facility of both hazardous and nonhazardous waste as a RCRA Subtitle C facility subject to specific closure plan requirements.

____ Class II	____ Class II-2
X Class III	____ Class III

2. What is the anticipated closing date for the existing permitted landfill? Proposed expansions which have not been approved by the Board and LEA are not to be included in these calculations. Include calculations supporting the estimate date. (Attach additional sheets as necessary.)

month February, year 1996

Note: All facilities with an anticipated closure date of September 28, 1992, or earlier, will be required to submit their closure and postclosure maintenance plan no later than July 1, 1990.

Type of Fill

3. Type of fill (check appropriate type)

____	Trench	X	Canyon
X	Area	____	Other (describe)
____	Pit		

Volume of Waste

4.	What is the estimated in-place volume of landfilled wastes at the site in cubic yards?	13,320,000
5.	What is the design capacity of the site in cubic yards?	26,562,000
6.	Minimum thickness of waste (ft)?	25'
7.	Average thickness of waste (ft)?	120'
8.	Maximum thickness of waste (ft)?	245'
9.	Average height above surrounding terrain (ft)?	N/A
10.	Typical inclination of side slopes, in slope ratio (horizontal:vertical)? (e.g., 5:1, 2:1)	2:1

Note:

11.	Quantity of waste typically received (tons/day)?	4,000
12.	Total permitted site acreage?	399
13.	Waste disposal area acreage?	161

Waste Description

14. Estimate of solid waste received (total of entries for residential, commercial, industrial, demolition and other should add up to 100%).

% Residential_85_	% Commercial
% Industrial_____	% Demolition

% Other (special waste streams, such as ash, auto shredder waste, infectious waste, sludge, asbestos)

Describe material under "other" and give its percentage.

Material	Percentage
Street Sweeping	15

Resid. + Indus. + Comm. + Demo. + Other = 100%

Site Geology and Groundwater Data

15. Briefly describe the underlying geology of the site. (Mark as many boxes that apply).

X	Shallow alluvium <50'		Deep alluvium >50'
X	Sedimentary		Igneous
	Metamorphic		

a. What is the name of the nearest major fault?	San Fernando Zone
b. Distance from site (miles)?	Onsite
c. On-site fault(s), if known?	Yes

16. What are the groundwater characteristics?

a. What is the depth to groundwater (ft)?	A seasonal water table was obtained from MW 88-5 drilled to a depth of 42 ft or 1429.7 ft MSL

This will be the range of water levels, from well data, in a groundwater well network. Note: Consider seasonal variations from rainy to dry periods, wet and dry years, well locations and variations in the subsurface geology.

Highest recorded level (depth in ft) ELEV. 42 ft, 1429.7 ft MSL

Well Number MW 88-5 Date Recorded 3/9/88

Lowest recorded level (depth in ft) ELEV. N/A

Well Number N/A Date Recorded N/A

Typical N/A

b. What direction does the groundwater flow?

The apparent ground water flow direction is north to south.

c. What is the groundwater gradient?

Data is insufficient to determine ground water gradient.

CLOSURE COSTS

Final Cover

17. Area of Landfill for Final Cover

a. Area of top deck to be capped (ft^2) A_d= 3,673,850

b. Area of side slopes to be capped (ft^2) A_s= 2,985,603
(map area)

Side Slopes Horizontal:Vertical	Conversion Factor (C)
5 : 1	1.02
4 : 1	1.03
3 : 1	1.05
2½: 1	1.08
2 : 1	1.12
1¾: 1	1.15

18. Final Cover Soil - Foundation Layer (Already in place)

a. Thickness

1) Top deck (minimum 3 feet of soil)

T_d = (□ 3') 0

2) Side slope (minimum 3 feet normal to slope)
T_s = (□ 3') 0

b. Volume = [(T_d x A_d) + (T_s x A_s x Conv. factor)]/27 (yd^3)

c. % Native soil

d. Native material acquisition cost (excavation, hauling,etc.) ($/$yd^3$)

e. Native soil cost ($)
(Line 18b x Line 18c x Line 18d)

f. % Imported soil

g. Imported material acquisition cost (purchase, delivery, etc.)
($/$yd^3$)

h. Imported soil cost ($)
(Line 18b x Line 18f x Line 18g)

i. Placement, grading and compaction (to achieve relative compaction of .90) unit cost ($/$yd^3$)

j. Placement, grading and compaction cost ($)
(Line 18b x Line 18i)

k. Subtotal final cover soil ($) $0
(Line 18e + Line 18h + Line 18j)

19. Clay Layer

a. Area to be capped (ft^2) of A, B and AB+Decks 0

b. Thickness (ft) (minimum 1 foot) 1.00

c. Volume (yd^3)
(Line 19a x Line 19b)/27 0

d. % On-site Clay 0

e. On-site material acquisition cost (excavation, hauling, etc.)
($/$yd^3$) $0

f. On-site clay cost ($)
(Line 19c x Line 19d x Line 19e) $0

g. % Imported Clay 0

h.	Imported material acquisition cost (purchase, delivery, etc.) ($/yd^3)	$13.80
i.	Imported clay cost ($) (Line 19c x Line 19g x Line 19h)	$0
j.	Placement/spreading, grading, compaction (to achieve permeability no greater than 1 x 10-6 cm/sec) unit costs ($/yd^3)	$8.35
k.	Placement, grading and compaction cost ($) (Line 19c x Line 19j)	$0
l.	Subtotal clay costs ($) (Line 19f + Line 19i + Line 19k)	$0

20. Synthetic Membrane

Note: This item must be estimated in addition to the clay barrier layer unless/until an alternative final cover design has been approved in the closure plan.

a.	Type of membrane (e.g., HDPE, CPE, PVC)	VFPE
	Thickness (minimum 30 mils)	40
b.	Quantity (ft^2)	1,051,158
c.	Purchase, delivery and installation unit cost ($/ft^2)	$0.35
d.	Synthetic layer testing (percent of total synthetic membrane unit cost) (%/100)	0.15
e.	Synthetic layer costs ($) (Line 20b x Line 20c x (1 +20d)	$423,091

21. What other types of materials/layers are included in the design (e.g., asphalt-tar, gravel for gas venting)?

16 oz.geotextile cushion layer, 1 ft. thick drainage layer, 8 oz. geotextile filter layer, 1 ft. thick erosion layer

a. Geotextile filter (8 oz. nonwoven)

1)	Quantity (ft^2)	0
2)	Purchase, delivery and installation unit cost ($/ft^2)	$0
a.	Synthetic layer testing (% of total synthetic membrane unit cost) (%/100)	0.15

    3) Geotextile layer costs ($) — $0

b. Drainage layer (1-ft thick sand layer, min. $k=10^{-2}$ cm/sec)

    1) Quantity (yd^3)

    2) Purchase, delivery and installation unit cost ($/$yd^3$)

    3) Drainage layer costs — $0

c. Erosion layer (2-ft thick native soil layer) (A,B, AB+ and C)

    1) Volume of soil on deck areas (A,B, and AB+) (yd^3) — 0

    2) Purchase, delivery and installation on decks unit cost ($/$yd^3$) — $7.46

    3) Volume of screened soil on slope areas (1 ft cushion layer) on C Deck Area) (yd^3) — 36,381

    4) Purchase, delivery and installation on slopes unit cost ($/$yd^3$) — $11.60

    5) Volume of Soil on Deck Area (erosion layer)(yd^3) — 36,381

    6) Purchase, Delivery, and Installation (deck unit cost)($/$yd^3$) — $7.46

    7) Volume of Soils on Slope Areas(C)(yd^3) — 30,383

    8) Purchase, Delivery, and Installation of Slopes (unit cost)($/$yd^3$) — $7.96

    9) Total cost of erosion layer
    (Line 21c.1x Line 21c.2 + Line 21c.3 x Line 21c.4 +
    Line 21c.5 x Line 21c.6 + Line 21c.7 x Line 21c.8) — $935,271

d. Total other types of layers ($)
(Line 21a.3 + Line 21b.3 + Line 21c.9) — $935,271

NOTE: Thickness of individual layers may be modified depending on the integrated cover design.

22. Construction Quality Assurance

The following cost estimates apply to the quality assurance activities necessary to ensure that the final cover is installed properly, as specified in the design parameters, and fulfill the conditions mandated by regulations.

a. Monitoring costs incurred while evaluating the final cover system components:

1) Laboratory test fees (e.g., soil permeability, soil density and moisture content) ($) — $136,990

	2)	Field test expenditures (e.g., test pad field permeability tests, relative compaction tests) ($)	$125,000
	b.	Inspections (e.g., initial inspection of native and imported soil or clay, visual check of completed cover) ($)	$244,000
	c.	Reporting costs (e.g., daily reporting procedures, corrective measure report, as-built reports) ($)	$63,040
	d.	Engineering design costs ($)	$234,500
	e.	Quality assurance costs ($) (Line 22a1 + Line 22a2 + Line 22b + Line 22c + Line 22d)	$803,530
23.		Final Cover Subtotal ($) (Line 18k + Line 19l + Line 20e + Line 21d+ Line 22e)	$2,161,892

Revegetation

24.		Soil Preparation	
	a.	**Area to be vegetated, including closed areas that need replanting (acres) ((Line 17a + Line 17b) - Line 90a) / 43560**	**124**
	b.	Preparation unit cost ($/acre)	$0
	c.	**Soil preparation subtotal ($) (Line 24a x Line 24b)**	**$0**
25.		Planting	
	a.	Type of vegetation	Annual and perennial native grasses and flowers
	b.	Planting unit cost (e.g., seeding, sprigging, plugs) (include cost of seeds, sprigs, plugs) ($/acre)	$2,500
	c.	**Planting cost ($) (Line 24a x Line 25b)**	**$310,000**
26.		Fertilizing	
	a.	Type of fertilizer	Root stimulant
	b.	Fertilizer unit cost ($/acre)	$0
	c.	**Fertilizing cost ($) (Line 24a x Line 26b)**	**$0**

27. Mulching

a. Mulch unit cost ($/acre) $0

b. Mulching cost ($)
(Line 24a x Line 27a) $0

28. Irrigation installation cost ($) (temporary) $1,075,790

29. Revegetation Subtotal ($)
(Line 24c + Line 25c + Line 26c + Line 27b + Line 28) $1,358,790

Landfill Gas Monitoring and Control

30. Does the landfill have a gas monitoring network?

YES X NO

If NO,

a. What will be the spacing between monitoring wells
(□ 1000 ft)?

b. What criteria was used to select this spacing?

c. Total number of gas monitoring wells?

Note: Depth of probes should equal at least 1 x depth of refuse within 1000'.

d. Number of probes per wellbore?

Suggested minimum;

1. Surface (5-10 ft)
2. Intermediate (half the depth of boring)
3. Deep (to depth of boring)

e. Cost of Design ($) 0.00

f. Cost of drilling, materials ($) 0.00

g. Cost of installation ($) 0.00

h.	Subtotal for monitoring network ($) (Line 30e + Line 30f + Line 30g)	0.00

If YES,

i.	How many gas monitoring wells are in place?	52
j.	What is the lateral spacing between gas monitoring wells?	<1,000 ft
k.	What is the number of probes per wellbore?	one to four
l.	Additional monitoring wells required at closure?	None
m.	Number of probes per boring?	N/A
n.	Cost to expand existing monitoring network (design, drilling, and installation)?	$0.00

31. Is there a gas control system operating at the landfill?

YES X NO

If YES,

a.	What type(s) (e.g., recovery, perimeter extraction, air injection, etc.) is/are in place?	Extraction
b.	What type of system will be installed during closure?	None
c.	Cost of design ($)	0.00
d.	Cost of materials ($)	0.00
e.	Cost of installation ($)	0.00
f.	Subtotal for control system ($) (Line 31c + Line 31d + Line 31e)	0.00

32.	Landfill Gas Subtotal ($) (Line 30h + Line 30n + Line 31f)	0.00

Groundwater Monitoring Installations

33. Does the landfill have a ground-water monitoring network?

YES X NO

If YES,

a.	Number of upgradient (minimum 1) wells	4
b.	Number of downgradient (minimum 3) wells (number of background wells)	7

If less than minimum or NO,

c.	Number of wells to be installed (minimum 1 upgradient and minimum 3 downgradient).	0
d.	Drilling total footage (ft)	0
e.	Cost of design ($)	0
f.	Developing, installing, materials ($)	

34.	Groundwater monitoring subtotal ($) (Line 33e + Line 33f)	$0

Drainage

35. Is there a surface water runon and runoff control system existing at the site:

YES X NO

If NO,

a.	What will be the estimated cost of installation and construction of the drainage conveyance system to accommodate anticipated runoff (e.g., diversion ditches, downdrains, energy dissipators) and protection from runon (e.g., dikes, levees, protective berms)? ($)	$747,283
b.	Cost of grading and drainage design ($)	$82,587
c.	Drainage subtotal ($) (Line 35a + Line 35b)	$829,870

Security

36. Is there a security system established at the landfill (e.g., fencing, access gates, locks on the gates, informational signs)?

YES X NO

a. What is presently in place at the site? (mark appropriate boxes)

X	Fencing	X	Locks
X	Gates		Other (describe)
X	Signs		

b. What will be the estimated cost of installing a security fence, access gates with locks, and/or informational signs (e.g., either around site perimeter or around enclosures) to protect equipment and the public and is compatible with postclosure use? $33,000

c. What will be the estimated cost of dismantling and removing security equipment not necessary after closure and incompatible with postclosure use? $00

d. Security system costs ($)
(Line 36b + line 36c) $33,000

SUPPLEMENTAL DATA

37. Itemize cost on additional worksheets for closure procedures, specific to this solid waste disposal site, and attach at the end of this worksheet. Make sure each page is appropriately labeled with site name and SWIS number.

Other Closure Costs
(Lines: 55l + 80s + 81d + 84i + 85n 89f + 90f) $3,891,799

Administrative Costs - Construction Management
(Line 88) $1,162,025

POSTCLOSURE MONITORING AND MAINTENANCE COSTS

Revegetation

38. Fertilizing (first 2 years)

a. Area to be fertilized (acres) 124

b. Type of fertilizer 7-1-7 starter and 8-5-1 slow release

c. Fertilizer unit cost ($/acre/yr) $1,000

d. Fertilizing cost (first 2 years)
(Line 38a x Line 38c) $248,000

e. Fertilizing costs for the four year period $496,000

39. Irrigation (first 4 years)

a. Type of irrigation system Overhead spray

b. Quantity (gallon/day) $127,406

c. Unit cost ($/gallon) $0.0011

d. How many irrigation days per week? 7

e. Annual irrigation costs ($/yr)
{(Line 39b x Line 39c) x Line 39d} x 52 wk/yr $51,013

f. Annual maintenance costs ($/yr) $56,988

g. Irrigation costs ($/yr)
(Line 39e + line 39f) $108,000

h. Irrigation costs for a four-year period $432,000

40. Revegetation Subtotal (first 4 years)
(Line 38e + Line 39h) $928,000

Leachate Management

41. Does the solid waste disposal site have a liner?

YES X (Disposal Area C) NO X (Disposal Areas A,B, and AB+)

42. Does the landfill have a leachate collection/removal system? (e.g., leachate barrier and recovery system, dendritic system)

YES X NO If YES,

a. What type of system? A leachate seepage cut-off barrier wall at the downstream end of disposal area AB+ with a gravel collector placed upstream of the barrier wall. The leachate collection and removal system for Disposal Area C consists of a drainage blanket on the liner with an integrated drainage system on the bottom canyon.

b. Annual cost of operation and maintenance of system ($/yr). $29,000

43.		List types of leachate (including leachate-affected water and landfill gas condensate) treatment used and that will continue to be used during closure and postclosure maintenance (e.g., discharge to sewer, on-site or off-site management).	
	a.	Type of treatment (on-site). Landfill Gas Condensate pH Adjustment (Note: Leachate production is not anticipated and has not been detected to-date.)	
	b.	Volume/unit frequency (e.g., gals/day, gals/month)	210 gal/day
	c.	Unit cost of treatment ($/gal.)	$0.38/gal
	d.	Annual costs of on-site treatment. ($/yr)	$29,127
44.		Type of treatment (off-site)	N/A
	a.	Volume/unit frequency (e.g., gals/day, gals/month)	N/A
	b.	Unit cost of treatment - including hauling ($)	N/A
	c.	Annual costs of off-site treatment. ($/yr)	$0
	d.	Other (explain)	
45.		Leachate sampling and testing	
	a.	Number of samples/round	1
	b.	Sampling costs/round ($)	$40
	c.	Frequency of sampling per year	52
	d.	Annual sampling costs ($/yr) (Line 45b x Line 45c)	$2,080
	e.	Testing costs/sample ($)	$58
	f.	Annual testing costs ($/yr) (Line 45a x Line 45c x Line 45e)	$3,016
	g.	Annual sampling/testing cost subtotal ($) (Line 45d + Line 45f)	$5,096
46.		Leachate management costs ($/yr) (Line 42b + Line 43d + Line 44c + Line 45g)	$63,223

Monitoring

47. Gas Monitoring Systems

a.	Monitoring devices of principal gases (e.g., Gastech, OVA, etc.)	OVA Meters Gas Chromatography Flame Ionization Detector
b.	Frequency of monitoring (e.g., daily, weekly, monthly)	
	Note: See supplemental cost worksheets for additional gas monitoring costs.	
c.	On-site annual monitoring costs for principal gases? ($/yr)	$0.00
d.	Annual sampling costs for trace gases ($/yr)	$0.00
e.	Annual testing costs for trace gases ($/yr)	$0.00
f.	Assumed replacement frequency, of probes, in years.	52
g.	Installation unit cost for probes ($)	$2,500
h.	Annual replacement costs ($) (Line 30i x Line 47g)/Line 47f	$2,500
i.	Annual maintenance costs ($/yr)	$3,000
j.	Gas monitoring subtotal ($/yr) (Line 47c + Line 47d + Line 47e + Line 47h + Line 47i)	$5,500

48. Is the vadose (unsaturated) zone monitored at this landfill?

YES ________ NO ___X___

If YES,

a. What type of monitoring procedures and equipment are utilized? (e.g., vacuum/pressure lysimeter)

b. How many monitoring devices are utilized?

c. Annual sampling costs ($/yr)

d. Annual testing costs ($/yr)

e. Assumed replacement frequency, of devices, in years

f. Installation unit cost of devices ($)

	g.	Annual replacement cost ($/yr) (Line 48b x Line 48f)/Line 48e	
	h.	Annual maintenance costs ($/yr)	
	i.	Vadose zone monitoring subtotal ($/yr) (Line 48c + Line 48d + Line 48g + Line 48h)	$0.00
49.	Ground-Water Monitoring		
	a.	Number of wells	12
	b.	Frequency of monitoring, per year	4
	c.	Analytical methods (e.g., EPA 601 and 602 or 624, and 625) EPA 624 and 625, and 8080, Metals (unfiltered), pH, electrical conductivity, BOD, COD, TDS, Total Hardness	
	d.	Number of samples/round	1
	e.	Testing costs/sample ($)	$1,700
	f.	Annual groundwater sampling & testing costs ($/yr) [(Line 49d x Line 49e) x Line 49a] x Line 49b	$81,600
	g.	Annual monitoring costs ($/yr)	$5,267
	h.	Assumed replacement frequency, of wells, in years	20 years
	i.	Installation unit cost of wells ($)	$8,333
	j.	Annual replacement cost ($/yr) (Line 49a x Line 49i)/Line 49h	$5,000
	k.	Annual maintenance costs ($/yr)	$2,400
	l.	Ground-water monitoring subtotal ($/yr) (Line 49f + Line 49g + Line 49j + Line 49k)	$94,267
50.	Monitoring Cost Subtotal ($/yr) (Line 48i + Line 49l)		$94,267

See supplemental worksheets for additional monitoring costs.

Drainage

51. How often do you anticipate the need to perform maintenance activities (e.g., clear material from runoff surface water conveyances, erosion repair, minor grading, repair of articulated drains; also problems with runon maintenance and repairs of levees, dikes, protective berms)?

    Once during the summer months and after each heavy rainfall.

    a. Annual maintenance costs ($/yr) $37,000

Security

52. What are the estimated annual maintenance costs to repair/replace fencing, gates, locks, signs, and/or other security equipment at the landfill site? ($/yr) $7,000

Inspection

53. What will be the routine maintenance inspection frequency of the landfill during postclosure (minimum semi-annually)?

    Varies (see Post-Closure Plan)

    a. Inspection unit cost ($) $0.00

    b. Annual inspection costs during the postclosure care period? ($/yr) $300,000

    Components that should be inspected include, but are not limited to:

    - Final cover - erosion damage
    - Final grading - ponding caused by settlement
    - Drainage control systems - continuity of articulated drains, sediment choked conduits
    - Gas collection/control systems
    - Leachate collection and treatment systems effectiveness, and continuity
    - Security - fences, gates and signs
    - Vector and fire control
    - Monitoring equipment
    - Litter control

SUPPLEMENTAL DATA

54. Itemize annual costs on additional worksheets for monitoring and postclosure maintenance procedures, specific to this solid waste disposal site, and attach at the end of this worksheet. Make sure each page is appropriate labeled with site name and SWIS number.

    Other-Annual Postclosure Maintenance Costs
    (Lines 66c, 67c, 68c, 69f, 70e, 71b, 72g, 73d, 74b
    75d, 76b, 78d, and 79b) $390,150
    Administrative Costs

SUMMARY OF COST ESTIMATES

Facility Name Lopez Canyon SWIS #19-AA-0820

Closure

Final Cover (Line 23)	$2,161,892
Revegetation (Line 29)	**$1,358,790**
Landfill Gas Monitoring and Control (Line 32)	$0
Groundwater Monitoring Installations (Line 34)	$0
Drainage Installation (Line 35c)	$829,870
Security Installation (Line 36d)	$33,000
Other (Line 37)	**$5,053,824**
I. Subtotal Closure	**$9,437,376**
II. Subtotal I x 20% Contingency Costs	**$1,887,475**
Total Closure Cost	**$11,324,851**

Monitoring and Postclosure Maintenance

Leachate Management (Line 46)	$63,223
Water Monitoring (Line 48i + 49l)	$94,267
Drainage (Line 51a)	$37,000
Security (Line 52)	$7,000
Inspection (Line 53b)	$300,000
Landfill Gas Management (Line 47j, 56e, 57d, 58b,59c, 60e, 61e, 62e, 63e, 64d, 65c)	$277,500
Other (Line 54)	$390,150
Final Cover Maintenance (82f, 83b)	$18,658
III. Subtotal	$1,187,798

IV. Subtotal III x 30 years		$35,633,940
V. Revegetation (Line 40)		**$928,000**
TOTAL COSTS	**Total Postclosure Maintenance Cost**	**$47,886,791**

(Item I, Item II, Item IV, Item V)
(Total Closure and Postclosure Maintenance Cost)

N/A: NOT APPLICABLE TOWARDS CLOSURE
SUPPLEMENTAL WORKSHEETS

55. Clay Layer (C Deck)

a.	Area to be capped (ft^2) of C Deck	982,278
b.	Thickness (ft) (minimum 1 foot)	1.00
c.	Volume (yd^3) (Line 55a x Line 55b)/27	36,381
d.	% On-site Clay	100
e.	On-site material acquisition cost (excavation, hauling, etc.) ($/$yr^3$)	0
f.	On-site clay cost ($) (Line 55c x Line 55d x Line 55e)	$0
g.	% Imported clay	0
h.	Imported material acquisition cost (purchase, delivery, etc.) ($/$yd^3$)	13.80
i.	Imported clay cost ($) (Line 55c x Line 55g x Line 55h)	$0
j.	Placement/spreading, grading, compaction (to achieve permeability no greater than 1×10^{-6} cm/sec) unit costs ($/$yd^3$)	8.37
k.	Placement, grading and compaction cost ($) (Line 55c x Line 55j)	$304,509
l.	Subtotal clay costs ($) (Line 55f + Line 55i+ + Line 55k)	$304,509

GAS RECOVERY SYSTEM MONITORING

56.	a.	Monitoring devices of principal gases (e.g., Gastech, OVA, etc.) Kuetz velocity meter, thermometer, magnehelic, differential pressure gauge, Gas-tech NP-204	
	b.	Frequency of monitoring (e.g., daily, weekly, monthly)	Quarterly
	c.	On-site monitoring costs? ($/yr)	$16,000
	d.	Annual analysis costs ($/yr)	$3,000
	e.	Gas Recovery System monitoring subtotal ($/yr) Line 56c + Line 56d)	$19,000
57.		Gas Migration Control System - Gas Collection Indicator Probe (GCIP) Monitoring	
	a.	Monitoring devices of principal gases (e.g., Gastech, OVA, etc.) OVA, Gas Tech NP-204, Magnehelic, Differential Pressure Gauge, Barometer	
	b.	Frequency of monitoring (e.g., daily, weekly, monthly)	Quarterly
	c.	On-site monitoring costs? ($/yr)	$7,000
	d.	Gas Migration System - (GCIP) Monitoring Subtotal ($/yr)	$7,000
58.		Visual Inspection of Landfill Surface	
	a.	Frequency of monitoring (e.g., daily, weekly, monthly)	Weekly
	b.	On-site monitoring costs? ($/yr)	$20,000
59.		Instantaneous Surface Emissions Monitoring	
	a.	Monitoring devices of principal gases (e.g., Gastech, OVA, etc.)	Organic Vapor Analyzer
	b.	Frequency of monitoring (e.g., daily, weekly, monthly)	
	c.	On-site monitoring costs? ($/yr)	$28,000
60.		Integrated Surface Emissions Monitoring	
	a.	Monitoring devices of principal gases (e.g., Gastech, OVA, etc.)	Organic Vapor Analyzer, Integrated Surface Sampler

b.	Frequency of monitoring (e.g., daily, weekly, monthly)	
c.	On-site monitoring costs? ($/yr)	$74,500
d.	Annual analysis costs ($/yr)	$10,000
e.	Integrated Surface Emissions monitoring subtotal ($/yr)	$84,500
61.	Sampling Gas in Branch Line, Probes, and Headers	
a.	Monitoring devices of principal gases (e.g., Gastech, OVA, etc.)	Kurtz Velocity Meter, Magnehelic Differential Pressure Gauge, Gas Tech NP-204
b.	Frequency of monitoring (e.g., daily, weekly, monthly)	Quarterly
c.	On-site monitoring costs? ($/yr)	$1,000
d.	Annual analysis costs ($/yr)	$5,500
e.	Sampling gas in branch lines, probes and headers subtotal ($/yr)	$6,500
62.	Ambient Air Sampling at Perimeter of the Site	
a.	Monitoring devices of principal gases (e.g., Gastech, OVA, etc.)	Integrated Ambient Air Sampling Unit, Line Monitoring Station, Organic Vapor Analyzer
b.	Frequency of monitoring (e.g., daily, weekly, monthly)	Quarterly
c.	On-site monitoring costs? ($/yr)	$10,000
d.	Annual analysis costs ($/yr)	$35,000
e.	Integrated Surface Emissions monitoring subtotal ($/yr)	$45,000
63.	Gas Recovery System - Flare Station Sampling	
a.	Monitoring devices of principal gases (e.g., Gastech, OVA, etc.)	Tedlar Bag, Organic Vapor Analyzer
b.	Frequency of testing (e.g., daily, weekly, monthly)	Quarterly
c.	On-site monitoring costs? ($/yr)	$500

d.	Annual analysis costs? ($/yr)	$2,500
e.	Flare Station Sampling subtotal ($/yr)	$3,000

64. Flare Source Testing

a.	Frequency of testing (e.g., daily, weekly, monthly)	Annually
b.	On-site monitoring costs ($/yr)	0.00
c.	Annual analysis costs ($/yr)	$52,000
d.	Flare Source Testing subtotal ($/yr)	$52,000

65. Gas Recovery System Monitoring - Sumps and Condensate Drain Lines

a. Monitoring devices of principal gases (e.g., Gastech, OVA, etc.)

OVA meters, Gas Chromatography, Gas Sampling Equipment

b.	Frequency of monitoring (e.g., daily, weekly, monthly)	Weekly
c.	On-site monitoring costs? ($/yr)	$7,000

66. Reseeding and Mulching

a.	Labor	$13,150
b.	Materials	$13,000
c.	Reseeding and Mulching Total ($/yr.)	$26,150

67. Monitoring Supervisor

a. Duties

Supervise and coordinate post-closure monitoring activities and provide QA/QC.

b.	On-site costs ($/yr)	$90,000
c.	Supervisor subtotal ($/yr)	$90,000

68. Health and Safety Officer

a. Duties

Supervise, coordinate, and administrate health and safety
activities relative to post-closure monitoring and maintenance.

b.	On-site costs ($/yr)	$38,000
c.	Health and Safety subtotal ($/yr)	$38,000

69. Monitoring Equipment Maintenance and Repair

a. Monitoring Devices

Organic Vapor Analyzer, Kurz Velocity Meters, Thermometers, Magnehelic, Differential Pressure Gauges, Gas Tech NP-204, Wind Monitoring Stations, Integrated Ambient Air Sampling units, Vacuum Pumps, Integrated Surface Sampler, Barometer

b.	Frequency of maintenance	Monthly
c.	Frequency of Repair	As Required
d.	On-site maintenance and repair costs ($/yr)	$40,000
e.	Replacement parts costs ($/yr)	$15,000
f.	Equipment Maintenance and Repair subtotal ($/yr)	$55,000

70. Monitoring Equipment Replacement Amortization

a. Monitoring Devices

Organic Vapor Analyzer, Kurz Velocity Meters, Thermometers, Magnehelic, Differential Pressure Gauges, Gas Tech NP-204, Wind Monitoring Stations, Integrated Ambient Air Sampling units sample train, Integrated Surface Sampler, Organic Vapor Monitor

b.	Average equipment life or replacement cycle.	Every 5 years

c. Equipment Cost List

OVA - 8 @	$8,500/ea.	$68,000
Kurz - 5 @	$1,200/ea.	$6,000
Magnehelic - 5 @	$300/ea.	$1,500
NP-204 - 2 @	$1,500/ea.	$3,000
Wind Station - 3 @	$2,700/ea.	$8,100
Ambient Air Sampling Unit - 5 @	$2,200/ea.	$11,000
Sample Train - 4 @	$2,500/ea.	$10,000
Surface Sampler - 5 @	$750/ea.	$3,750
OVM - 2 @	$1,800/ea.	$3,600
	TOTAL	$114,950

d.	Amortization Costs ($/yr)	$23,000

e.	Amortization Subtotal ($/yr)	$23,000
71.	Monitoring Materials	
a.	Material Items	
	Tedlar bags, Tygon Tubing, Calibration Gases, Safety Equipment, Misc. Tools, cleaning and maintenance supplies	
b.	On-site Material Costs ($/yr)	$25,000
72.	Monitoring Vehicles	
a.	Type of Vehicles	
	4-Wheel drive vehicles	
b.	Number of Vehicles	6
c.	Unit cost of vehicles	$18,000
d.	Average vehicle life or replacement cycle	5 years
e.	Estimated trade-in value	$2,000
f.	Amortization costs ($/yr)	$16,000
g.	Monitoring Vehicle Cost ($/yr)	$19,000
73.	Weather Station Management	
a.	Number of Stations	3
b.	Frequency of monitoring	Weekly
c.	On-site monitoring costs ($/yr)	$72,000
d.	Weather Station Management Subtotal ($/yr)	$72,000
74.	Subdrain Collection System Maintenance	
a.	Frequency of monitoring (e.g., daily, weekly, monthly)	As Required
b.	On-site monitoring costs? ($/yr)	$5,000
75.	Subdrain Collection System Sampling	
a.	Frequency of monitoring, per year	Quarterly

	b.	On-site monitoring costs? ($/yr)	$3,000
	c.	Annual analysis costs ($/yr)	$2,000
	d.	Subdrain Collection System Monitoring subtotal ($/yr)	$5,000
76.	Outfall System Inspection		
	a.	Frequency of monitoring, per year	Quarterly
	b.	On-site monitoring costs? ($/yr)	$10,000
77.	Final Closure/Post-Closure Plan Preparation		$0.00
78.	Surface Water Monitoring		
	a.	Frequency of monitoring, per year	Two times annually during discharges
	b.	On-site monitoring costs	$3,000
	c.	Annual analytical costs	$12,000
	d.	Annual surface water sampling & testing costs ($/yr) Line 78b + 78c	$15,000
79.	Gas Recovery System Monitoring - Sumps and Condensate Drainlines		
	a.	Frequency of monitoring	Weekly
	b.	On-site monitoring costs? ($/yr)	$7,000
80.	Slope Liners		
	a.	Total Area to be Capped (ft^2) (Line 17b x Conv. Factor)	3,343,875
	b.	Area of A and B slopes to be capped (ft^2)	2,103,704 completed
	b1.	Area of B Slopes to be capped with clay	1,222,660 completed
	b2.	Area of A Slopes to be capped monolithically	881,104
	c.	Area of AB+ and C slopes to be capped (ft^2)	1,240,171
	c1.	Area of AB+ slopes to be capped (ft^2) monolithically	830,000
	c2.	Area of C slopes to be capped (ft^2) with clay	410,171
	d.	Thickness (ft) on slopes of Disposal Area C	1.00
	e.	Thickness (ft) on slopes of Disposal Area AB+	3.00

	f.	Volume of slope areas (to be closed) (yd^3)	
	f1.	Volume of slope areas AB+ (mono) (yd^3) (Line 80c.1 x Line 80c) / 27	92,222
	f2.	Volume of Slope Area C (clay) (yd^3) (Line 80c.2 x Line 80d) / 27	15,191
	g.	Percent On-Site Clay	100
	h.	On-Site Material Acquisition Cost (excavation, hauling, etc.) (\$/yd^3)	\$0
	i.	On-Site Clay Cost (\$)	\$0
	j.	Percent Imported Clay	0
	k.	Imported Material Acquisition Cost (purchase, delivery, etc.) (\$/yd^3)	\$13.80
	l.	Imported Clay Cost (\$) (Line 80f.2) x Line 80j x Line 80k)	\$0
	m.	Placement/Spreading, Grading, Compaction (to achieve permeability no greater than 1 x 10^{-6} cm/sec) Unit Costs (\$/yd^3)	\$15.91
	n.	Placement, Grading, and Compaction Cost (\$) (Line 80f.2) x Line 80m)	\$241,689
	o.	Subtotal Clay Cost (\$) (Line 80f + Line 80i + Line 80n)	\$241,689
	p.	Percent On-Site Soil for Monolithic Soil Cover	0
	q.	Purchase, Delivery, and Installation on slopes unit cost (\$/yd^3)	\$7.96
	r.	Cost of Monolithic Soil Cover Layer on Slopes AB+ (Line 80f.1) x Line 80q)	\$734,087
	s.	Cost of Slope Liners (Line 80o + Line 80r)	\$975,776
81.		Geotextile Cushion (12 oz./yd^3 nonwoven)	
	a.	Quantity (ft^2)	1,051,158
	b.	Purchase, delivery and installation unit cost (\$/ft^2)	\$0.20
	c.	Cushion fabric testing (percent of total cushion fabric unit cost (%/100)	0.15

d.	Geotextile layer cost ($) (Line 81a x Line 81b x [1 + 81c])	$241,766

FINAL COVER MAINTENANCE

82. Repair and Replacement of VLDPE Geomembrane and of Geotextile Cushion

a.	Assumed repair/replacement frequency	Annually
b.	Assumed area of repair/replacement (ft^2)	5,000
c.	Purchase, delivery and installation unit cost ($/ft^2)	$1.10
d.	Cost of repair/replacement ($)	$5,500
e.	Annual cost of providing construction quality assurance (CQA) during the repairs (25% of the construction cost) ($)	$1,375
f.	Total annual cost of repairs ($)	$6,875

83. Final Cover Earthen Repair

a.	Assumed area to be repaired (ft^2)	17,500
b.	Total annual cost of earthen cover repair (including CQA during the repair) ($)	$11,783

84. Rebuilding of Haul Road and Channel

a.	Total length of the Haul Road to rebuild (ft)	2,000
b.	Haul Road rebuild unit cost ($/ft)	$90.25
c.	Total Haul Road rebuild cost ($) (Line 84a x Line 84b)	$180,500
d.	Total length of channel to rebuild	1,660
e.	Channel rebuild unit cost ($/ft)	$21
f.	Total channel rebuild cost ($) (Line 84d x Line 84e)	$34,800
g.	Total rebuild cost ($) (Line 84c + Line 84f)	$215,300
h.	Design cost ($) (20%/100 Line 84g)	$43,060

i.	Total Haul Road and Channel Cost (Line 84g + Line 84h)	$258,360
85.	Gas System Modifications	
a.	Decommission Existing Swallow Vertical Wells	
1.	Wells at 12.5' (#12)	150 ft
2.	Wells at 37.5' (#43)	1,613 ft
3.	Wells at 62.5' (#56)	3,500 ft
b.	Subtotal Decommissioning Wells @ $5/ft	$26,315
c.	Abandonment Materials and Labor	
1.	Sand - 524 bags @ $4.59/bag	$2,405
2.	Bentonite Chips - 183 bags @ $9.90/bag	$1,812
3.	Labor (2 per Crew) - 68 hours @ $32.50/hr	$2,210
4.	Backhoe - 68 hours @ $90/hr	$6,120
5.	Foreman - 68 hours @ $35/hr	$2,380
6.	Water Truck - 68 hours @ $60/hr	$4,080
d.	Subtotal Abandonment Materials and Labor	$19,007
e.	New Shallow Well Construction - 9,684 LF @ $36/ft	$348,624
f.	Well Disconnection Materials and Labor (Disposal Area C) - 186 @ $32.50 ea.	$348,624
g.	Well Connection Materials	
1.	2" Side Gate Valve - 350 @ $12 ea.	$4,200
2.	6" PVC Tee - 350 @ $53 ea	$18,550
3.	6" Cap PVC - 350 @ $60.48 ea	$21,168
4.	6" x 2" PVC Rod - 350 @ $84 ea	$29,400
5.	2" PVC El - 350 @ $2.50 ea	$875
6.	1" Make Adapter - PVC - 350 @ $3 ea	$1,050
7.	1" PVC Cap - 350 @ $2.53 ea	$886
8.	2" Flex Cplg. - 350 @ $79.44 ea	$27,804
9.	2" PVC Pipe - 350 @ $5 ea	$1,750
h.	Connection Assembly - Labor 350 @ $21.65 ea.	$7,578
i.	Connection Installation - 350 @ $26.40 ea.	$9,240
j.	Subtotal Well Connection Materials	$122,501
k.	Relocate and Replace Header System - 29,080 LF @ $8/ft	$232,640
l.	Relocate Condensate Sumps - 0 @ $2,450 ea.	$0

	m.	Gas Well Protection - 133 @ $557/ea	$74,081
	n.	Total Gas System Modifications (Line 85b + Line 85d + Line 85e + Line 85f + Line 85j + Line 85k + Line 85l + Line 85m)	$829,213
86.		Groundwater Monitoring Well Abandonment and Replacement at Closure	$0
87.		Lysimeter Abandonment and Replacement at Closure	$0
88.		Construction Management - QA/QC (Note: does not include final cover QA/QC)	$1,655,629
89.		Deck Liners - Disposal Area AB+ Monolithic Soil Cover	
	a.	Total Area to be Capped (decks of Disposal Area AB+) (ft^2)	1,376,060
	b.	Thickness (ft) on decks of Disposal Area AB+	3.00
	c.	Volume of decks of Disposal Area AB+(yd^3)	152,896
	d.	Percent on-site soil for monolithic soil cover	0
	e.	Purchase, delivery and installation on decks unit cost ($/yd^3)	$4.27
	f.	Cost of monolithic soil cover layer on decks off Disposal Area AB+ (Line 89c x Line 80e)	$652,864
90.		Deck Liner Disposal Areas A and B – Geotextile Interlayer System	
	a.	Total area to be capped (decks of Disposal Areas A and B) (ft^2)	1,258,622
	b.	Thickness (ft) on Decks of Disposal Areas A and B	0.5
	c.	Volume of Decks of Disposal Areas A and B (yd^3)	25,483
	d.	Purchase, delivery, and installation of geotextile, unit cost ($/ft^2)	0.25
	e.	Purchase, delivery, and installation of tack coat, unit cost ($/ft^2)	0.25
	f.	Cost of Geotextile Interlayer System on decks of Disposal Areas A and B (line 90a x (Line 90d + Line 90e))	$629,311

APPENDIX G

APPROVAL LETTERS FROM CIWMB, RWQCB, AND LEA

California Regional Water Quality Control Board

Los Angeles Region

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320 W. 4th Street, Suite 200, Los Angeles, California 90013
Phone (213) 576-6600 FAX (213) 576-6640 - Internet Address: http://www.swrcb.ca.gov/rwqcb4

October 24, 2002

Stephen A. Fortune, Division Manager
Bureau of Sanitation
City of Los Angeles
419 South Spring Street, Suite 800
Los Angeles, CA 90013

Dear Mr. Fortune:

FINAL PERFORMANCE REPORT OF THE MONOLITHIC COVER ON THE SLOPES OF DISPOSAL AREAS A AND AB+ -LOPEZ CANYON LANDFILL (FILE No. 69-068)

Reference is made to your letter to this Regional Board dated October 16, 2002, transmitting a technical report entitled *Alternative Final Cover Water Balance Performance Evaluation, Slopes of Disposal Area A and AB+, Lopez Canyon Sanitary Landfill, Lake View Terrace, California.* The report is the third in a series of three reports on the water balance performance evaluation of the monolithic final cover at Disposal Areas A and AB+ of the Lopez Canyon Landfill. The other two reports were submitted to this Regional Board previously on April 3, 2000, and March 21, 2001, respectively.

The water balance performance evaluation has been conducted by the City following the requirements of our letter to you dated July 23, 1998, which conditionally approved the use of monolithic final cover on the decks of Disposal Areas A, B, and AB+, and the slopes of Disposal Areas A and AB+. The condition for us to approve the use of monolithic cover at the site was that monitoring data collected after the installation of the final cover must support the conclusion of computer modeling, which predicted that the monolithic final cover exceeds the infiltration control performance of a prescriptive cover required in California Code of Regulations (CCR), Title 27.

We have reviewed the data submitted and concur with you that the data provided in those reports demonstrate that percolation through the monolithic cover is less than what is predicted through a prescriptive final cover required in CCR Title 27. The condition of our July 23, 1998, letter on the use of monolithic cover on the slopes of Disposal Areas A and AB+ is therefore fulfilled. The use of monolithic cover on those slopes is hereby approved without condition. Please note that this unconditional approval of the use of monolithic cover does not cover the decks of Disposal Areas A, B, and AB+, where monitoring data has yet to be collected.

Your letter also requested that we instruct the California Integrated Waste Management Board (CIWMB) to release $2,400,000 out of the $4,800,000 in your Closure Trust Fund that was set

California Environmental Protection Agency
****The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption****
****For a list of simple ways to reduce demand and cut your energy costs, see the tips at: http://www.swrcb.ca.gov/news/echallenge.html****
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up as a contingency should the monolithic cover fail to perform as predicted. We are forwarding this letter to the CIWMB. They will determine if the release of these funds is appropriate.

Should you have any questions, please contact Dr. Wen Yang at (213) 620-2253.

Sincerely,

Rodney H. Nelson

Rodney H. Nelson
Senior Engineering Geologist
Landfills Unit

Cc: Peter Janicki, Remediation, Closure and Technical Assistance Branch, CIWMB
Scott Walker, Permitting and Enforcement Division, CIWMB
Joe Maturino, Department of Environmental Affairs, City of Los Angeles (LEA)
Kelly Gharios, Bureau of Sanitation, City of Los Angeles
Tarik Hadj-Hamou, GeoSyntec Consultant, Huntington Beach

APPENDIX I

REVISED CQA PLAN

CONSTRUCTION QUALITY ASSURANCE PLAN
FINAL COVER CONSTRUCTION
DISPOSAL AREAS "A," "B," AND "AB+"

LOPEZ CANYON SANITARY LANDFILL
LAKEVIEW TERRACE

Prepared for:

Bureau of Sanitation
Department of Public Works
City of Los Angeles
419 South Spring Street, Suite 800
Los Angeles, California 90013
(213) 473-7855

Prepared by:

GeoSyntec Consultants
2100 Main Street, Suite 150
Huntington Beach, California 92648
(714) 969-0800

GeoSyntec Consultants Project No. CE4100-02

Revised: 1 November 2002

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TABLES

1. INTRODUCTION

1.1 Purpose of the Construction Quality Assurance Plan

The purpose of the Construction Quality Assurance (CQA) Plan is to address the CQA procedures and monitoring requirements for construction of the final cover for the slopes of Disposal Areas A, B, and AB+ and the decks of Disposal Areas A, B, and AB+ of the Lopez Canyon Sanitary Landfill, owned and operated by the City of Los Angeles (City). Construction of the final cover soil components will be performed by the City's own operations personnel.

1.2 Units

In this CQA Plan, all properties and dimensions are expressed in U.S. units with "approximate equivalent" SI units in parentheses. It should be noted that the conversion is typically only accurate within ten percent due to rounding. In cases of conflict or clarification, the U.S. units will be deemed to govern.

1.3 References

The CQA Plan includes references to test procedures of the American Society for Testing and Materials (ASTM).

2. DUTIES OF SOILS CQA PERSONNEL

2.1 General

For construction of the final cover system over the decks of Disposal Areas A, B, and AB+, the Soils CQA Consultant's personnel shall include:

- the Soils CQA Managing Engineer, who operates from the office of the Soils CQA Consultant and who conducts periodic visits to the site as required; and
- Soils Field Monitors, who are located at the site.

The duties of the Soils CQA Personnel are discussed in the following subsections.

2.2 Soils CQA Managing Engineer

The Soils CQA Managing Engineer or his designated representative:

- reviews the final cover system design and construction plans;
- reviews all other site-specific documentation and proposed grades; unless otherwise agreed, such reviews are for familiarization and for evaluation of constructibility only, and hence the Soils CQA Managing Engineer and the Soils CQA Consultant assume no responsibility for the design;
- attends the resolution and/or preconstruction meeting;
- administers the Soils CQA program including assigning and managing all on-site Soils CQA personnel, reviewing all field reports, and providing Engineering review of all Soils CQA related activities;

- provides quality control of Soils CQA documentation and conducts site visits;
- reviews all changes to the final cover system design and construction plans;
- familiarizes all Soils Field Monitors with the site, project documents, and the Soils CQA requirements;
- manages the daily activities of the Soils Field Monitors;
- attends Soils CQA-related meetings (e.g., resolution, pre-construction, weekly);
- prepares or oversees the ongoing preparation of the record drawings;
- verifies the calibration and condition of on-site Soils CQA equipment;
- reviews all Soils Field Monitors' daily reports and logs;
- reports to the Landfill Engineer and documents any reported relevant observations by the Soils Field Monitors;
- oversees the collection and shipping of all laboratory test samples;
- reviews results of laboratory testing and makes appropriate recommendations;
- reports any unresolved deviations from the CQA Plan and construction plans to the Landfill Engineer; and

- prepares the final report.

2.3 Soils Field Monitors

The duties of the Soils Field Monitors include, as assigned by the Soils Site CQA Manager, monitoring and documenting construction of all soils components of the final cover.

The duties of the Soils Field Monitors include:

- acts as the on-site (resident) representative of the Soils CQA Consultant;
- monitoring of material stockpiles;
- assuring proper surface-water drainage away from soil stockpiles;
- collecting soils samples for material conformance testing;
- preparing daily field reports;
- recording Soils CQA activities on field logs;
- reporting problems to the Soils Site CQA Managing Engineer and Landfill Engineer;
- assisting with collection of soil samples from the constructed soils components in accordance with the CQA Plan;
- monitoring soil placement and compaction operations;
- visually examining the soils as placed; and

- monitoring soil layer repair operations.

In addition to these specific duties, all Soils Field Monitors will take note of any on-site activities that could result in damage to the soils components of the final cover. Any observations so noted by the Soils Field Monitors will be reported immediately to the Landfill Engineer and Soils Site CQA Managing Engineer.

3. SITE AND PROJECT CONTROL

3.1 Project Coordination Meetings

To guarantee a high degree of quality during construction, clear, open channels of communication are essential. To this end, meetings of key project personnel are necessary.

3.1.1 Resolution Meeting

Following the completion of the design and plans for the project, a Resolution Meeting will be held. This meeting will include the Soils CQA Managing Engineer, the Soils Field Monitors, the Landfill Engineer, and the Landfill Manager (or designated representatives).

The purpose of this meeting is to begin planning for coordination of construction tasks, anticipate any installation problems which might cause difficulties and delays in construction, and, above all, present the CQA Plan to all of the parties involved. It is very important that the criteria regarding testing, repair, etc., be known and accepted by all parties prior to construction of the soil components of the final cover.

The first part of the Resolution Meeting may be devoted to a review of the design drawings for familiarity. This is different from the peer review of the design, including design calculations, which should have been carried out previously.

The Resolution Meeting should include all of the following activities:

- distribute any relevant documents to all parties;
- review critical design details of the project;
- review this CQA Plan;

- review the construction plans;
- make any appropriate modifications to the design criteria and construction plans so that the fulfillment of all design specifications or performance standards can be determined through implementation of the CQA Plan;
- reach a consensus on the quality control procedures, especially on methods of determining acceptability of the soil materials comprising the final cover;
- assign the responsibilities of each party;
- establish work area security and safety protocol;
- confirm the methods for documenting observations, reporting, and distributing documents and reports; and
- confirm the lines of authority and communication.

The Landfill Engineer shall appoint one of the meeting attendees to record the discussions and decisions of the meeting. The record of the meeting shall be documented by the appointee in the form of meeting minutes which will be subsequently distributed to all attendees.

3.1.2 Preconstruction Meeting

A Preconstruction Meeting will be held at the site prior to construction of final cover soil components. As a minimum, the Preconstruction Meeting will be attended by the Soils CQA Managing Engineer, the Landfill Engineer, and the Landfill Manager (or designated representatives). The Preconstruction Meeting may be held concurrently with the Resolution Meeting.

Specific requirements for this meeting are to:

- make any appropriate modifications or clarifications to the CQA Plan;
- review the responsibilities of each party;
- review lines of authority and communication;
- review methods for documenting and reporting, and for distributing documents and reports;
- establish protocols for testing;
- establish protocols for handling deficiencies, repairs, and retesting;
- review construction plans;
- review the time schedule for all operations;
- review repair procedures; and
- conduct a site reconnaissance to observe the site and to establish soil stockpiling locations.

A person in attendance at the meeting shall be appointed by the Landfill Engineer to record the discussions and decisions of the meeting in the form of meeting minutes. Copies of the meeting minutes will be distributed to all attendees.

3.1.3 Progress Meetings

A weekly progress meeting will be held between the Soils CQA Managing Engineer, the Landfill Engineer, the Landfill Manager (or their designated representatives), and any other concerned parties. The progress meetings will be used to discuss current progress, planned activities for the upcoming week, and any new business or revisions to the work. The Soils CQA Managing Engineer will document any problems, decisions, or questions arising at this meeting in their daily reports. Any matter requiring action which is raised in this meeting will be reported to the appropriate parties. Minutes of the weekly progress meetings shall be documented by the Landfill Engineer or his representative and distributed to all appropriate parties.

3.1.4 Problem or Work Deficiency Meeting

A special meeting will be held when and if a problem or deficiency is present or likely to occur. The meeting will be attended by the Landfill Engineer, the Landfill Manager, the Soils CQA Managing Engineer (or their designated representatives), and other parties as appropriate. If the problem requires a design modification, the Landfill Engineer should either be present at, consulted prior to, or notified immediately upon conclusion of this meeting. The purpose of the work deficiency meeting is to define and resolve the problem or work deficiency as follows:

- define and discuss the problem or deficiency;
- review alternative solutions;
- select a suitable solution agreeable to all parties; and
- implement an action plan to resolve the problem or deficiency.

The Landfill Engineer shall appoint one attendee to record the discussions and decisions of the meeting. The meeting record shall be documented in the form of meeting minutes and copies will be distributed to all affected parties.

3.2 Project Control Visits

Periodically, the construction site will be visited by the Soils CQA Managing Engineer, or his designated representative.

4. DOCUMENTATION

4.1 General

An effective CQA plan depends largely on recognition of all construction activities that should be monitored and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Consultant will document that all quality assurance requirements have been addressed and satisfied.

The Soils CQA Managing Engineer will maintain signed reports containing descriptive remarks, data sheets, and logs to verify that all monitoring activities have been carried out. The Soils CQA Managing Engineer will also maintain at the job site a complete file of plans, a CQA plan, checklists, test procedures, daily logs, and other pertinent documents.

4.2 Daily Recordkeeping

Standard reporting procedures will include preparation of daily CQA documentation which, at a minimum, will consist of: (i) field notes, including memoranda of meetings and/or discussions with the Landfill Engineer or Landfill Manager; (ii) CQA monitoring logs, and testing data sheets; and (iii) construction problem and solution summary sheets. This information will be regularly submitted to and reviewed by the Soils CQA Managing Engineer.

4.2.1 Monitoring Logs and Testing Data Sheets

Monitoring logs and testing data sheets will be prepared daily. At a minimum, these logs and data sheets will include the following information:

- an identifying sheet number for cross referencing and document control;

- date, project name, location, and other identification;
- data on weather conditions;
- a Site Plan showing work areas and locations selected for recovery of random sampling for CQA testing;
- descriptions and locations of ongoing construction;
- equipment and personnel in each work area;
- descriptions and specific locations of areas, or units, of work being tested and/or observed and documented;
- locations where in-situ CQA tests and samples for laboratory CQA tests were taken;
- a summary of test results;
- calibrations or recalibrations of test equipment, and actions taken as a result of recalibration;
- decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of nonconforming test results; and
- signature of the Soils Field Monitor.

In any case, all logs must be completely filled out with no items left blank. A blank monitoring log is attached.

4.2.2 Construction Problems

The Landfill Engineer will be made aware of any significant recurring nonconformance with the construction plans or CQA Plan. The cause of the nonconformance will be determined and appropriate changes in procedures or specifications will be recommended. These changes will be submitted to the Landfill Engineer for approval. When this type of evaluation is made, the results will be documented, and any revision to procedures or specifications will be approved by the Landfill Engineer.

A summary of all supporting data sheets, along with final testing results and the Soils CQA Managing Engineer's approval of the work, will be required upon completion of construction.

4.3 Design and/or Specifications Changes

Design and/or specifications changes may be required during construction. In such cases, the Soils CQA Managing Engineer will notify the Landfill Engineer.

Design and/or specifications changes will be made only with the written agreement of the Landfill Engineer, and will take the form of an amendment to the construction plans and CQA Plan.

4.4 Final Report

At the completion of the work, the Soils CQA Consultant will submit to the Landfill Engineer a signed and sealed final report. This report will document that: (i) work has been performed in compliance with the construction plans; (ii) physical sampling and testing has been conducted at the appropriate frequencies specified in the CQA Plan; and (iii) required CQA documentation has been completed.

At a minimum, this report will include:

- summaries of all construction activities;
- monitoring logs and testing data sheets including sample location plans;
- construction problems and solutions summary sheets;
- changes from design and material specifications;
- record drawings; and
- a summary statement indicating compliance with the construction plans and the CQA Plan which is signed and sealed by a Registered Civil Engineer or Certified Engineering Geologist in the State of California.

The record drawings will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., depths, plan dimensions, elevations, soil component thicknesses, etc.). These documents will be prepared by the Landfill Engineer, reviewed for accuracy by the Soils CQA Managing Engineer, and included as part of the CQA plan documentation.

5. PRESCRIPTIVE COVER CONSTRUCTION QUALITY ASSURANCE

5.1 General

This section defines the construction quality assurance activities for the areas where a Title 27 prescriptive cover is constructed. Soils CQA will be performed on all soil components used during construction of the final cover. The criteria to be used for the determination of acceptability of the construction work will be as identified in Table 5-1.

5.2 Monitoring

The Soils CQA Consultant will monitor and document the construction of all soils components. Monitoring the construction work includes the following:

- monitoring the quality of the material stockpiles, obtaining borrow soil samples for conformance testing;
- testing to determine the moisture content and unit weight of each lift during placement and compaction of soil used in construction of the foundation, low-permeability soil barrier, and vegetative layers;
- recording test results and locations;
- noting any deficiencies;
- monitoring the thickness of lifts as loosely placed and as compacted;
- monitoring that the total thickness of the foundation, low-permeability soil barrier, and vegetative layers is as indicated on the construction plans;

- monitoring the action of the compaction and heavy hauling equipment on the construction surface (i.e., penetration, pumping, cracking, etc.); and
- monitoring the repair of nonconforming areas and testing perforations.

Monitoring the earthwork for the foundation layer specifically includes the following:

- monitor clearing, grubbing, and stripping of the existing interim cover surface;
- monitor the scarification of the interim cover surface to a depth of 6 to 8 in. (150 to 200 mm) and recompaction;
- reviewing documentation of quality control test results;
- visually monitoring the physical condition of the material during placement; and
- visually monitoring the foundation layer stability under the action of the compaction equipment.

Monitoring the earthwork for the compacted low-permeability soil barrier layer specifically includes the following:

- reviewing documentation of the quality control test results;
- monitoring the soil for deleterious material;
- monitoring moisture conditioning and preprocessing, if any, of the borrow soil material;

- monitoring that the surface of each lift is scarified to a depth of 2 to 4 in. (50 to 100 mm) prior to placement of the following lift;
- recording the construction equipment used for material placement;
- performing BAT hydraulic conductivity tests and recording the test results and location; and
- monitoring the protection of the final surface of the low-permeability soil barrier layer from excessive moisture loss prior to placement of the vegetative cover layer.

Monitoring the earthwork for the vegetative layer specifically includes the following:

- reviewing documentation of the quality control test results;
- monitoring soil for deleterious material;
- monitoring the thickness of lifts during placement of the materials;
- recording field density and field moisture content measurement at location of each test on test logs.

5.3 Laboratory and Field Tests

The laboratory and field test methods, laboratory and field testing frequencies, and criteria used to determine acceptability are presented in Table 5-1. A special testing frequency will be used at the discretion of the Landfill Engineer or the Soils CQA Consultant when visual observations of construction performance indicate a potential or recurring deficiency.

5.4 Survey

The top of the low-permeability soil barrier shall be surveyed before the installation of the immediately overlying vegetative cover layer. The thickness of the low-permeability soil barrier shall be determined by comparing the survey of the finished foundation layer and the top of the low-permeability soil barrier layer.

5.5 Deficiencies

5.5.1 General

If a defect is discovered in the earthwork product, the Soils Site Monitor will immediately inform the Soils CQA Managing Engineer or his designated representative. The Soils Site Monitor, in consultation with the Soils CQA Managing Engineer, will determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, extent of the deficient area will be determined by additional tests, observations, a review of records, or other means that the Soils CQA Managing Engineer deems appropriate.

If the defect is related to adverse site conditions, such as overly wet soils or surface desiccation, the Soils Site Monitor, in consultation with the Soils CQA Managing Engineer, will define the limits and nature of the defect.

5.5.2 Notification

After determining the extent and nature of a defect, the Soils CQA Site Manager will notify the Landfill Engineer and Landfill Manager and schedule appropriate retests when the work deficiency is to be corrected.

5.5.3 Corrective Action

At locations where the field testing of the soil indicates that the compacted unit weight, moisture content, or field or laboratory hydraulic conductivities do not meet the requirements presented in Table 5-1, the failing area will be reworked as indicated below:

- If the results of any in-situ moisture or dry density, or field hydraulic conductivity value fails to meet the specified criteria presented in Table 5-1, two additional tests of the same type will be performed in the vicinity of the failed test. If either of the two additional tests results in a failure, then this area of the low-permeability soil barrier will be considered in nonconformance and will be removed, reworked, and recompacted to meet the requirements specified in Table 5-1.
- Perform in-place density and moisture content testing in the vicinity of a nonconforming area to evaluate deficiency in-place density and moisture content.
- Obtain samples of low-permeability soil liner material from nonconforming areas for potential laboratory testing to evaluate differences in soil properties that could contribute to the nonconforming test results.

Criteria to be used for determination of acceptability will be as identified herein. Other tests conducted on hydraulic conductivity samples will consist of Atterberg limits and grain size distribution.

5.5.4 Repairs and Retesting

The City's work force will correct the deficiency to the satisfaction of the Soils CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the Soils CQA Consultant will develop and present to the Landfill Engineer suggested solutions for approval.

All retests recommended by the Soils CQA Consultant must verify that the defect has been corrected before any additional work is performed by the City's work force in the area of the deficiency. The Soils CQA Consultant will also verify that all installation requirements are met.

Penetrations into the compacted low-permeability soil barrier resulting from sampling or other activities shall be properly backfilled with hand-tamped select low-permeability material and/or bentonite powder. CQA personnel will repair nuclear density, sand cone, and BAT hole perforations. The City's work force shall repair perforations and/or excavations resulting from CQA sampling and testing. All repairs will be inspected by the Site Soils Monitor for compliance.

6. MONOLITHIC SOIL COVER CONSTRUCTION QUALITY ASSURANCE

6.1 General

Soils CQA will be performed on all soil components used during construction of the monolithic soil final cover. The criteria to be used for the determination of acceptability of the construction work will be as identified in Table 5-1.

6.2 Monitoring

The Soils CQA Consultant will monitor and document the construction of all soils components. Monitoring the construction work includes the following:

- monitoring the quality of the material stockpiles, obtaining borrow soil samples for conformance testing;
- testing to determine the moisture content and unit weight of each lift during placement and compaction of soil used in construction of the foundation, and monolithic soil layers;
- recording test results and locations;
- noting any deficiencies;
- monitoring the thickness of lifts as loosely placed and as compacted;
- monitoring that the total thickness of the foundation and monolithic soil layers is as indicated on the construction plans;
- monitoring the action of the compaction and heavy hauling equipment on the construction surface (i.e., penetration, pumping, cracking, etc.); and

- monitoring the repair of nonconforming areas and testing perforations.

Monitoring the earthwork for the foundation layer specifically includes the following:

- monitor clearing, grubbing, and stripping of the existing interim cover surface;
- monitor the scarification of the interim cover surface to a depth of 6 to 8 in. (150 to 200 mm) and recompaction;
- reviewing documentation of quality control test results;
- visually monitoring the physical condition of the material during placement; and
- visually monitoring the foundation layer stability under the action of the compaction equipment.

Monitoring the earthwork for the monolithic soil layer specifically includes the following:

- reviewing documentation of the quality control test results;
- monitoring soil for deleterious material;
- monitoring the thickness of lifts during placement of the materials; and
- recording field density and field moisture content measurement at location of each test on test logs.

6.3 Laboratory and Field Tests

The laboratory and field test methods, laboratory and field testing frequencies, and criteria used to determine acceptability are presented in Table 6-1. A special testing frequency will be used at the discretion of the Landfill Engineer or the Soils CQA Consultant when visual observations of construction performance indicate a potential or recurring deficiency.

6.4 Survey

The top of the monolithic soil layer shall be surveyed immediately following the installation end of construction. The thickness of the monolithic soil layer shall be determined by comparing the survey of the finished foundation layer and the top of the monolithic soil layer.

6.5 Deficiencies

6.5.1 General

If a defect is discovered in the earthwork product, the Soils Site Monitor will immediately inform the Soils CQA Managing Engineer or his designated representative. The Soils Site Monitor, in consultation with the Soils CQA Managing Engineer, will determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, extent of the deficient area will be determined by additional tests, observations, a review of records, or other means that the Soils CQA Managing Engineer deems appropriate.

If the defect is related to adverse site conditions, such as overly wet soils or surface desiccation, the Soils Site Monitor, in consultation with the Soils CQA Managing Engineer, will define the limits and nature of the defect.

6.5.2 Notification

After determining the extent and nature of a defect, the Soils CQA Site Manager will notify the Landfill Engineer and Landfill Manager and schedule appropriate retests when the work deficiency is to be corrected.

6.5.3 Corrective Action

At locations where the field testing of the soil indicates that the compacted unit weight, moisture content, or laboratory hydraulic conductivities do not meet the requirements presented in Table 6-1, the failing area will be reworked as indicated below:

- If the results of any in-situ moisture or dry density, or field hydraulic conductivity value fails to meet the specified criteria presented in Table 6-1, two additional tests of the same type will be performed in the vicinity of the failed test. If either of the two additional tests results in a failure, then this area will be considered in nonconformance and will be removed, reworked, and recompacted to meet the requirements specified in Table 6-1.

- Perform in-place density and moisture content testing in the vicinity of a nonconforming area to evaluate deficiency in-place density and moisture content.

- Obtain samples of soil material from nonconforming areas for potential laboratory testing to evaluate differences in soil properties that could contribute to the nonconforming test results.

Criteria to be used for determination of acceptability will be as identified herein. Other tests conducted on hydraulic conductivity samples will consist of Atterberg limits and grain size distribution.

6.5.4 Repairs and Retesting

The City's work force will correct the deficiency to the satisfaction of the Soils CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the Soils CQA Consultant will develop and present to the Landfill Engineer suggested solutions for approval.

All retests recommended by the Soils CQA Consultant must verify that the defect has been corrected before any additional work is performed by the City's work force in the area of the deficiency. The Soils CQA Consultant will also verify that all installation requirements are met.

Penetrations into the compacted low-permeability soil barrier resulting from sampling or other activities shall be properly backfilled with hand-tamped select low-permeability material and/or bentonite powder. CQA personnel will repair nuclear density and sand cone hole perforations. The City's work force shall repair perforations and/or excavations resulting from CQA sampling and testing. All repairs will be inspected by the Site Soils Monitor for compliance.

7. ASPHALTIC CEMENT CONCRETE

7.1 General

Key elements of a successful asphaltic cement concrete with fabric interlayer geotextile cover system installation include:

- preparation of foundation
- placement of bottom layer of asphalt;
- application of tack coat;
- checking application rates and temperatures;
- placement of paving fabric; and
- placement of overlay.

The Soils CQA Consultant will monitor and document the construction of all components of the cover system.

7.2 Material Requirements

7.2.1 Asphalt Cement Concrete

Asphalt cement concrete (ACC) and accessories (i.e., tacking agent) shall conform to the requirements outlined in the Technical Specifications.

7.2.2 Paving Fabric

Paving fabric shall conform to the requirements outlined in the Technical Specifications.

7.2.3 Testing Activities

ACC testing will be performed for material qualification and material conformance. Material qualification tests are used to evaluate the conformance of the ACC for qualification of the source prior to construction.

The Contractor will be responsible for submitting material qualification test results to the Soils CQA Consultant and the Landfill Engineer for review. The CQA Laboratory will perform the conformance testing and CQC testing. Aggregate testing will be conducted in general accordance with the current versions of the corresponding American Society for Testing and Materials (ASTM) test procedures. The test methods indicated in Table 7-1 are those that will be used for this testing unless the test methods are updated or revised prior to construction. Revisions to the test methods will be reviewed and approved by the Soils CQA Manager and the Landfill Engineer prior to their usage.

7.2.4 Sample Frequency

The frequency of ACC testing for material qualification will conform to the minimum frequencies presented in Table 7-1. The actual frequency of testing required will be increased by the Soils CQA Consultant as necessary if variability of materials is noted at the site, during adverse conditions, or to isolate failing areas of the construction.

7.2.5 Sample Selection

With the exception of qualification samples, sampling locations will be selected by the Soils CQA Consultant. Conformance samples will be obtained from borrow pits and/or stockpiles of material. The Contractor must plan the work and make gravel available for sampling in a timely and organized manner so that the test results can be obtained before the material is installed. The Soils CQA Consultant must document sample locations so that failing areas can be immediately isolated. The Soils

CQA Consultant will follow standard sampling procedures to obtain representative samples of the proposed gravel materials.

7.3 CQA Monitoring Activities

7.3.1 Surface Preparation

The Soils CQA Consultant will monitor and document the foundation layer is prepared as per the project specifications before the binder and fabric are placed. In general, monitoring the surface preparation includes the following activities:

- Existing pavement is free of dirt, water, oil and debris;
- Cracks greater than 1/8-in. wide are filled; and
- Uneven, rough or unstable areas are repaired.

7.3.2 Bottom Asphalt Layer

The Soils CQA Consultant will monitor and document the installation and compaction of the bottom asphalt layer. In general, monitoring of the compaction of the bottom asphalt layer includes the following activities:

- Fabric saturation:

- Minimum compacted lift thickness (3 in);

- Overlay does not displace hot mix or expose fabric;

- Confirm saturation;

- Verify asphalt temperature by a noncontact thermometer to be between 150 and 325 degrees farenheit;

- Verify that asphalt aggregates are sufficiently coated (greater than 90% of the surface area, as per ASTM D 2489);
- Verify that the asphalt mix release agent used in the hauling trucks is approved (i.e.: not diesel fuel, as this will tend to dissolve the asphalt mix);
- Maximum speed of the placement of the overlay does not exceed 40 feet per minute; and
- Maximum speed of the roller compactor does not exceed 3 miles per hour.

7.3.3 Tack Coat Application

The Soils CQA Consultant will monitor and document the tack coat is applied as per the project specifications before the fabric is placed. In general, monitoring the binder application includes the following activities:

- Check overlapping and width of spray pattern;
- Binder application rate test:
    - Weight test unit;
    - Place test unit on pavement immediately prior to tack coat application;
    - Remove coated test unit from pavement;

  - Weigh unit; deduct test unit weight and fabric weight (if applicable); and
  - Calculate tack coat rate and compare to project specifications.

7.3.4 Paving Fabric Geotextile

The Soils CQA Consultant will monitor and document the installation of the paving fabric geotextile. In general, monitoring the installation of the geotextile includes the following activities:

- reviewing documentation of the material qualification test results provided by the Contractor;
- sampling and testing for conformance of the materials to the *Technical Specifications*;
- documenting that the geotextile is installed using the specified equipment and procedures;
- documenting that the geotextile is constructed to the lines and grades shown on the *Drawings*;
- monitoring that the construction activities do not cause damage to underlying geosynthetic materials;
- Fabric is placed smooth side up, fuzzy side down; and
- Wrinkles are 1 in. or less.

7.3.5 Overlay

The Soils CQA Consultant will monitor and document the installation and compaction of the overlay. In general, monitoring of the compaction of the overlay includes the following activities:

- Fabric saturation:
- Minimum compacted lift thickness (3 in);
- Overlay does not displace hot mix or expose fabric;
- Confirm saturation;
- Verify asphalt temperature by a noncontact thermometer to be between 150 and 325 degrees farenheit;
- Verify that asphalt aggregates are sufficiently coated (greater than 90% of the surface area, as per ASTM D 2489);
- Verify that the asphalt mix release agent used in the hauling trucks is approved (i.e.: not diesel fuel, as this will tend to dissolve the asphalt mix);
- Maximum speed of the placement of the overlay does not exceed 40 feet per minute; and
- Maximum speed of the roller compactor does not exceed 3 miles per hour.

7.3.6 Deficiencies

If a defect is discovered in the geotextile, the Soils CQA Consultant will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the Soils CQA Consultant will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the Soils CQA Consultant deems appropriate.

7.3.7 Notification

After evaluating the extent and nature of a defect, the Soils Field Monitor will notify the Soils CQA Managing Engineer and Landfill Engineer and schedule appropriate re-tests when the work deficiency is to be corrected.

7.3.8 Repairs and Re-Testing

The Contractor will correct the deficiency to the satisfaction of the CQA Site Manager. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the Soils CQA Consultant will develop and present to the Landfill Engineer suggested solutions for approval.

All re-tests recommended by the Soils CQA Consultant must verify that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The Soils CQA Consultant will also verify that installation requirements are met and that submittals are provided.

7.3.9 Review of Quality Control

7.3.9.1 Material Properties Certification

The Manufacturer will provide the Landfill Engineer and the Soils CQA Consultant with the following:

- a properties sheet including, at a minimum, all specified properties, measured using test methods indicated in the *Technical Specifications*, or equivalent;

- the sampling procedure and results of testing; and

- a certification that property values given in the properties sheet are guaranteed by the Manufacturer.

The Soils CQA Consultant will document that:

- the property values certified by the Manufacturer meet all of the *Technical Specifications*; and

- the measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

7.3.9.2 Tack Coat Certification

The Manufacturer will also provide the Landfill Engineer and the Soils CQA Consultant with the following information concerning the tack coat used in the asphalt:

- the origin (tack coat Supplier's name and tack coat production plant), identification (brand name, lot number), and production date of the binder; and

- the raw material quality control certificates.

The Soils CQA Consultant will:

- evaluate that the quality control certificates have been provided at the specified frequency, and that the certificate identifies the rolls related to it; and
- review the quality control certificates and evaluate that the certified properties meet the specifications.

TABLE 5-1
SOILS FIELD AND LABORATORY TESTING SUMMARY
TITLE 27 FINAL COVER CONSTRUCTION
LOPEZ CANYON SANITARY LANDFILL

TEST METHOD	MINIMUM TESTING FREQUENCY	ACCEPTANCE CRITERIA
FOUNDATION AND VEGETATIVE LAYERS		
Grain Size Distribution (ASTM D 422)	1 test per 10,000 yd^3 (7,650 m^3)	Maximum particle size of 6 in.
Modified Proctor (ASTM D 1557)	1 test per 10,000 yd^3 (7,650 m^3)	N/A
In-Place Moisture/ Density Nuclear Method (ASTM D 2911)	1 test per 1,000 yd^3 (765 m^3)	Dry density no less than 90% of the max. dry density for the foundation layer, no less than 85% of the max dry density for the vegetative layer moisture content no less than the optimum moisture content, as measured by ASTM D 1557.
In-Place Moisture/Density Sand Cone Method (ASTM D 1556)	1 test per 10,000 yd^3 (7,650 m^3)	Dry density no less than 90% of the max. dry density for the foundation layer, no less than 85% of the max dry density for the vegetative layer moisture content no less than the optimum moisture content, as measured by ASTM D 1557.
LOW-PERMEABILITY SOIL BARRIER LAYER		
Grain Size Distribution (ASTM D 422)	1 test per 5,000 yd^3 (3,820 m^3)	Minimum fines content of 50%. Maximum particle size of 3 in. (75 mm).
Atterberg Limits (ASTM D 4318)	1 test per 5,000 yd^3 (3,820 m^3)	Criteria to be determined by Engineer prior to construction following test pad evaluation.
In-Place Moisture/ Density Nuclear Method (ASTM D 2911)	1 test per 250 ^{yd3} (190 m^3) Minimum of 4 tests per day	Criteria to be determined by Engineer prior to construction following test pad evaluation.
In-Place Moisture/Density Sand Cone Method (ASTM D 1556)	1 test per 2,500 yd^3 (1,900 m^3)	Criteria to be determined by Engineer prior to construction following test pad evaluation.
Modified Proctor (ASTM D 1557)	1 test per 5,000 yd^3 (3,820 m^3)	N/A
BAT Hydraulic Conductivity	1 test per 2,000 yd^3 (1,530 m^3)	Maximum saturated hydraulic conductivity of 1 x 10^{-6} cm/s based upon correlation between BAT test and in situ hydraulic conductivity from test pad.

TABLE 6-1
SOILS FIELD AND LABORATORY TESTING SUMMARY
MONOLITHIC SOIL FINAL COVER
LOPEZ CANYON SANITARY LANDFILL

TEST METHOD	MINIMUM TEST FREQUENCY	ACCEPTANCE CRITERIA
In-Place Moisture/Density Nuclear Method (ASTM D 2911)	1 per 1,000 yd^3	Dry density no less than 90% of the maximum dry density. Moisture content within ±2 percent of optimum moisture content
Standard Proctor Compaction Test (ASTM D 698)	1 per 10,000 yd^3 (7,650 m^3)	N/A
In-Place Density and Moisture Content (Sand-Cone) (ASTM D 1556)	1 per 10,000 yd^3 (7,650 m^3)	Dry density no less than 90% of the maximum dry density. Moisture content within ±2 percent of optimum moisture content
Particle Size Analysis (ASTM D 422)	1 per 5,000 yd^3 (3,825 m^3)	No particle greater than 4 inches at least 25 percent passing No. 200 sieve
Atterberg Limits (ASTM D 4318)	1 per 5,000 yd^3 (3,825 m^3)	Plasticity Index less than 15
Laboratory Permeability (ASTM D 5084)	1 per 10,000 yd^3 (7,650 m^3)	Hydraulic Conductivity no greater than 1×10^{-5} cm/sec

Note: Since Atterberg Limit and grain-size distribution testing will be performed on representative materials during processing of stockpile materials, additional tests will be conducted only on materials obtained for laboratory permeability analysis.

TABLE 7-1

ASPHALT CEMENT CONCRETE CONFORMANCE TESTING REQUIREMENTS

LOPEZ CANYON SANITARY LANDFILL

MEASUREMENT	TEST METHOD	FREQUENCY
In Place ACC Density	ASTM D 2950	1 test per 500 yd^2 (418 m^2)
Inspection of Completed Paving Fabric Interlayer System	ASTM D 5361	1 test per 2000 yd^2 (1672 m^2)
Permeability of Core Sample	ASTM D 5361; ASTM 5084	1 test per 2000 yd^2 (1672 m^2)
Application Rate of Applied Tack Coat	**SEE NOTE 1**	1 test per 1000 yd^2 (836 m^2)

Notes:

1- No official standard exists, but the Asphalt Interlayer Association recommends testing application rates by placing a 12 in. x 12 in. square piece of cardboard on the area to be tacked. By weighing the cardboard before and after application, the application rate can be calculated. For the desired application rate of 0.22 - 0.28 gallons/yd^2 applied at the desired temperature range of 290 - 325°F, the net weight change of the cardboard will be 3.0 to 3.8 ounces.

APPENDIX L

DOCUMENTATION ON ASPHALTIC CEMENT CONCRETE

APPENDIX L

Asphaltic Cement Concrete Final Cover Configuration

Recent studies [Marienfield, 1998] have shown that the use of reinforcing fabric membrane interlayers, or paving fabrics, can significantly reduce infiltration through asphalt pavement. Paving fabric interlayers typically consists of an asphalt cement tack coat sprayed on grade overlain by a 4 oz/yd^2 (135 g/m^2) nonwoven fabric. An asphalt cement concrete (ACC) overlay with a minimum thickness of 1.5 in. (3.8 cm) is then placed on top of the nonwoven fabric. The 1.5 in. (3.8 cm) thick ACC overlay provides the necessary amount of heat and pressure to reactivate the tack coat and draw it up into the fabric and to bond the tack coat and fabric with the ACC overlay. The resultant interlayer is a relatively thick asphalt-saturated fabric reinforced interlayer. This interlayer serves as both a waterproofing membrane and a stress-absorption layer. This interlayer controls infiltration by serving as a barrier layer and by inhibiting cracking of the asphalt. Laboratory evaluation of various application rates of tack coat indicates that a minimum tack coat application rate of approximately 0.20 gallons/yd^2 (0.90 liters/m^2) provides a permeability of less than 1×10^{-6} cm/s [Marienfield, 1998].

This type of asphaltic concrete pavement system is well suited as an alternative final cover option for closure under the proposed composting facility. Case studies have also shown that a hydraulic mix compacted to 98 percent theoretical maximum density at 2 percent air voids will typically offer a permeability of $1x10^{-7}$ cm/sec. Case studies have also shown that the permeability of the asphaltic concrete cover can be significantly lower that $1x10^{-7}$ cm/sec in a 2-in (51-cm) thick asphalt section and has been recorded as low as $1x10^{-10}$ cm/sec in a 3-in (76-mm) thick section, when the asphalt content is greater than 4.75 percent. The mix design for the for the asphalt concrete pavement at Lopez Canyon shall require an asphalt content of 4.75 percent or greater. The inclusion of the paving fabric in the pavement section not only provides additional infiltration control but also improves the performance of the pavement.

The proposed asphaltic concrete final cover consists of the following components, from top to bottom:

- a 3-in. (7.5-cm) thick ACC overlay;
- a nonwoven fabric;
- a 40-mil (1-mm) tack coat;
- a 3-in. (7.5-cm) thick of underlying pavement;
- a 1-ft (0.3m) thick base course built with reclaimed street grindings; and
- a 1-ft (0.3-m) thick soil foundation course.

A cross section of the asphaltic concrete alternative final cover design is presented as Figure 1.

Laboratory testing of paving fabrics have indicated that the ACC overlay densities and permeabilities can vary with compactive effort and uniformity of the tack coat. The amount of applied tack coat is considered to be the most significant consideration with paving fabric interlayer systems. The primary consideration in this regard is in providing a sufficient amount of tack coat in order for the fabric to become fully impregnated, thereby minimizing the permeability of the paving fabric [Marienfield, 1998]. The amount of applied tack coat will be monitored as part of CQA activities during closure construction to establish that at least 0.20 gallons/yd^2 (0.90 liters/m^2) is applied to the fabric interlayer.

Marienfield, M.L. and Baker, T.L. [1998], "Paving Fabric Interlayer System as a Pavement Moisture Barrier," *77th Annual Meeting of the Transportation Research Board*, January 1998, 31 p.

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Paving Fabric Interlayer System As A Pavement Moisture Barrier

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Submitted by:

Mark L. Marienfeld, P.E.
Technical Manager
Amoco Fabrics and Fibers Company
900 Circle 75 Parkway, Suite 550
Atlanta, GA 30339
Phone: (770) 984-4439
Fax: (770) 956-2430

Thomas L. Baker, P.E.
Senior Research Engineer
Amoco Fabrics and Fibers Company
260 The Bluffs
Austell, Georgia 30168
Phone: (770) 944-4718
Fax: (770) 944-4745

INTRODUCTION

Moisture frequently is the root cause of damage to pavements. Although the sources of the water and the mechanics of how moisture damages a pavement are understood, these principles are not widely incorporated into design. In some cases it may be difficult to incorporate drainage improvements into pavement rehabilitation. For these reasons, pavement rehabilitation techniques generally address the repair of actual pavement damage instead of treating the moisture problem, the root cause.

There has been relatively little research and development work done in the area of pavement structure moisture measurement. The control of moisture has not generally been a focus of pavement design or maintenance. The technology to control the moisture sources is, however, available but not widely recognized or practiced compared to traditional pavement repair technologies. There are two general ways to control moisture in pavement structures; by the use of subsurface drainage, or by capping (sealing) the pavement to reduce infiltration through the pavement. The latter is the focus of this report as the sealing effectiveness of paving fabric interlayer systems is examined.

THE PROBLEM -- MOISTURE WITHIN PAVEMENT STRUCTURES

The primary source of moisture in pavement structures is water which infiltrates through the pavement from precipitation events. Moisture can also enter a pavement from subsurface sources such as from lateral seepage from a drainage ditch or from subsurface flow such as from a spring. In most areas, these water sources are secondary to water coming through the pavement itself. Extensive studies have been done examining this surface infiltration. An FHWA study *(1)* of numerous pavement sections found that 33 to 50 percent of the precipitation water hitting an asphalt cement concrete (ACC) pavement and 50 to 67 percent for Portland cement concrete (PCC) pavement could infiltrate through the pavement to the road base. Studies of edgedrain effectiveness *(2)* had similar results. In these studies, sections of pavement are isolated and rainfall amounts on that pavement are measured. Then, the corresponding amount of water that went through that pavement and was recovered by a highway edgedrain was measured. In individually monitored rainfall events, edgedrains recovered very high percentages, up to 80 percent *(2)*. Yearly rainfall totals versus edgedrain discharge in this study showed as high as 32 percent recovery of water that infiltrated through the pavement. Ridgeway *(3)* found global infiltration rates of about 0.001 to 0.002 mm/sec. A summary of previous work in Ridgeway *(4)* for seven new ACC pavements had average potential infiltration rate of 0.32 mm/sec and five old ACC pavements had average potential infiltration rate of 0.015 mm/sec. In another study by Los Angeles County, California, *(5)* it was shown that the permeability of ACC pavements is highly dependent on the amount of compaction achieved. Tightly controlled compaction efforts can achieve a low permeability pavement yet, too often, the actual level of compaction results in a pavement which can pass a significant amount of water to the pavement base. Even the addition of rubber to the mix showed little increase in the waterproofing effectiveness of the pavements tested. Therefore, sound pavements are quite permeable and water infiltration through the pavement is the general source of moisture in the pavement base. Cracking can increase the water infiltration rates up to nearly 100 percent and further increase moisture problems in the pavement structure.

The problems caused by the presence of water in a pavement structure are many. If a pavement base becomes saturated, pore water pressures due to traffic loading can override the load spreading support function of the base stone, forcing the traffic load to be applied to the subgrade in a small area. This localized loading may exceed the bearing capacity of the subgrade causing progressive failure of the pavement. If a pavement base is saturated as little as 10 percent of the time, the useful life of the pavement can be reduced by 50 percent *(1)*. The results of cyclic load tests on a crushed stone and a gravel, presented in Ridgeway *(4)*, suggest that until saturation gets below about 60 percent to 70 percent, large deformation can be expected. Pore pressures can also result in significant scouring and jetting pressures. Water jetting from cracks or joints can transport base and subgrade materials to the road surface creating a void and eventual pavement failure.

Another way moisture damages pavement structures is by weakening the subgrade soil. Ultimately, it is the subgrade which bears the load of the pavement. It is customary to perform soaked CBR or undrained triaxial testing to determine the bearing capacity of a subgrade. It is the author's opinion that these tests usually overestimate the subgrade soil strength for a cohesive subgrade beneath a wet base. The constant loading and unloading of the subgrade, while exposed to water, can actually remold the soil resulting in a lower shear strength and a higher moisture content than is currently simulated by 96 hour laboratory soaking. Further research in this area, to better simulate the moisture and stress conditions for subgrade testing, is encouraged. Evidence of the weakening of the subgrade is the frequently observed migration of the subgrade soil up into a base stone if no separation geotextile is used. This migration destroys the strength of the base stone layer. As little as 10 percent fines in the base stone has been shown to dramatically reduce the resilient modulus of an aggregate *(6)* due to loss of good rock to rock contact when compared to the same material with a lower fines content. At the same time the added fines content will dramatically lower the permeability (drainability) of the base *(4)*.

Freeze/thaw damage is another moisture related effect. Freeze/thaw damage can occur in the base, subbase, or subgrade depending on the porosity and permeability of each layer and the depth of frost penetration. It may be difficult in cold regions to maintain a drainable pavement base throughout the cold season. A practical alternative where water migration from the surface is the principal source of moisture leading to freeze/thaw damage may be to keep the moisture out of the base structure by providing a sealing layer in the pavement.

Pavements are exposed to different levels of moisture damage depending on how quickly the pavement structure drains after receiving rain infiltration. For a given amount of infiltration, drainage time is a function of the type of stone, the gradation of the base, the thickness of the base, the contamination of the base by subgrade intrusion, and the slope of the base layer.

AASHTO STRUCTURAL CREDIT FOR GOOD DRAINAGE

AASHTO Guide for Design of Pavement Structures, 1993 *(7)* provides for a structural credit or a structural penalty to a flexible pavement design based on the effectiveness of the drainage system. Drainage coefficients are applied to the structural number (SN) of the pavement's untreated base and subbase materials. These coefficients may represent the most significant variable in pavement design ranging from 1.4 to 1.2 for excellent drainage to 0.95 down to 0.4 for very poor drainage. This means that potentially, an aggregate base material, if supplied with an effective drainage system can be assigned up to three times the SN of the same base aggregate which is not allowed to drain. It also means that a base with fines, such as a crusher run base, would be greatly penalized from an SN standpoint while a clean free draining base with a drainage system would receive a significant structural bonus. These factors are often overlooked for several reasons. One is that an aggregate with appreciable fines content may be less expensive. Second, tighter bases have been traditionally used to help choke off fines upward migration from the subgrade. Also, constructability problems may be encountered with open bases.

Even roads without an aggregate base can hold moisture in the asphalt pavement or the treated base which is detrimental to the subgrade and to the pavement structure. AASHTO 1993 *(7)* states that although the drainage coefficients are only applied to untreated base or subbase, improved drainage is also beneficial to pavements with treated bases and no bases. The

AASHTO design method also utilizes structural penalties or credits for rigid pavements based on the drainability of the pavement.

All of the above reasons to use a low permeability base have minimal impact on the pavement cost compared to the effect of the drainage coefficients, yet this area has not received the attention it should in research and in field application. Studies by both Cedergren *(1)* and McEnroe *(8)* agree that a base must have permeabilities greater than 1 mm/sec to achieve AASHTO excellent drainage and 10^{-1} to 1 mm/sec to be classified as good drainage. In a study by Roy *(9)*, hydraulic conductivity tests were carried out on three different granular bases of different origin (granite, limestone, and shale), characterized with fines contents of 2, 7, and 12 percent. The study shows a one to three orders of magnitude reduction in permeability going from 2 percent to 7 percent fines depending on the type of rock. The work is continuing but it suggests that a 7 percent maximum fines specification, for example, allows too much fines. Similar results are also reported in Ridgeway *(4)*.

Ridgeway *(4)* makes the point that drainage systems will only remove free water that is not held by capillary forces. The consequence of this is that bases with over about 5 percent to 10 percent fines will tend to always be in a state of relatively high saturation, up to 85%. The implication is that less additional infiltration water than may be anticipated will be necessary to fully saturate the base. Often, bases assumed to be free draining have significantly more fines than discussed above. Fines content can also increase as a result of aggregate compaction or abrasion, decreasing the permeability of the stone layer. Therefore, the drainability of pavement bases is often over estimated. These bases must also be tied into an effective system to drain the water. The technology exists to place a truly free draining base stone layer without the fear of subgrade fines contamination by placing a separation geotextile between the subgrade soil and the base stone. In many existing roads the bases have poor to very poor drainage by AASHTO definition. This limited permeability is due to the original design allowing a low permeability base or due to fines contamination of an originally free draining base layer for lack of a separation geotextile.

EDGEDRAINS

When considering rehabilitation of an existing pavement, one way to increase the effective support of the subgrade, subbase, and base layers is to improve the drainage and reduce the length of time the base is saturated. This would allow the use of a higher AASHTO drainage coefficient and thus a higher pavement structural number. This can be accomplished by the installation of pavement edgedrains if the base is permeable enough to transmit water to the edgedrain system. However, most existing flexible pavements do not have a free draining base and placing an edgedrain is not always an effective solution. Studies have been done looking at the effectiveness of highway edgedrains *(2, 10)*. Lack of drainage has often been blamed on the type of edgedrain used or on damage or clogging of the drain, when slow drainage of the base course may be the problem. These edgedrain tests show some bases draining over a long period (e.g., over a week) or maybe not even draining. Therefore, edgedrains are helpful only if they significantly increase the speed in which water is removed from beneath a pavement. Some reports indicate that where base permeabilities are less than 10^{-1} to 1 mm/sec, edgedrains may not improve drainage of the pavement *(4)*. Thus, the number of cases where an edgedrain may improve the drainage may be limited. In these cases a possible solution to moisture rehabilitation is to use a durable seal such as a paving fabric interlayer to limit moisture infiltration through the pavement.

SEALING A PAVEMENT

There are several methods that have been used over the years to limit surface water infiltration through a pavement. These methods include interlayers of modified asphalts, asphalt and chip, asphalt and fiber, and fabric reinforced asphalt. Other methods include surface treatments such as chip seals, slurry seals and various other surface dressings. The effectiveness of the systems vary widely. Surface treatments tend to be short lived with cracking and infiltration returning quickly. Interlayers are protected by the overlay and as such tend to stay in place and be more effective. The costs of the systems also vary so transportation agencies must perform a cost benefit analysis to decide which system to use.

An effective hydraulic barrier within a pavement can be evaluated based on the typical infiltration rates observed in the previously mentioned studies and the approximate time it takes to saturate the base. Based on these studies, typical pavement infiltration rates might be on the order of 0.002 to 0.005 mm/sec. For a normal range of pavement widths, slopes, base thickness and base porosity and initial saturation it may take about 1 to 5 hours to saturate the base material. At the low permeabilities common for bases it may then take from 60 days to more than a year for the base to drain back down to 50% saturation. In this period it may be likely that an additional rain may occur such that the base never fully drains back to 50% saturation. A moisture barrier that can reduce the infiltration rate by an order of magnitude would also increase the length of time that it takes initially to saturate the base by an order of magnitude. For the example cited, that would increase the length of time that it must rain to saturate the pavement base to on the order of 10 to 50 hours. By extending the time to saturate the base, it becomes less likely that the pavement will experience a rainfall event of sufficient length and intensity that the base will become saturated and even less likely that rainfall events of that duration will recur frequently enough that the base can not drain. Thus to be effective, a moisture barrier should reduce the pavement permeability by at least one order of magnitude.

The focus of this report is the waterproofing effectiveness of fabric reinforced membrane interlayers, commonly referred to as paving fabrics. According to the Industrial Fabrics Association International, paving fabric usage has exceeded 100 million square meters per year for several years now in the U.S. Although many engineers think the paving fabric system is mainly used as a stress relieving interlayer to retard reflective and fatigue cracking, a principal function of the system is waterproofing. Briefly, the system involves spraying approximately 1.1 liters per square meter (0.25 gallons per square yard) of asphalt cement tack coat then applying a nonwoven fabric of about 135 grams per square meter (4 ounces per square yard) onto the tack coat. The asphalt cement concrete (ACC) overlay is then placed on top of the fabric. The heat and pressure of the overlay reactivates the asphalt tack coat drawing it up into the fabric and bonding it to the overlay. The resultant interlayer is a fairly thick asphalt saturated fabric reinforced layer. This layer forms a waterproofing membrane and a stress absorption layer. The system is also effectively applied beneath chip seal surfacing.

MOISTURE BARRIER EVALUATION OF PAVING FABRIC INTERLAYER SYSTEMS

Both field and laboratory investigations have been carried out to determine the effectiveness of these paving fabric interlayer systems in stopping surface water infiltration through the pavement. Laboratory investigations included permeability testing of core samples from roads with varying years of service containing a paving fabric system and permeability testing on pavement sections produced in the lab. Field testing included the monitoring of moisture contents beneath pavements with and without paving fabric systems and a large scale field permeability evaluation of a pavement containing a paving fabric system. The following is a discussion of the laboratory and field investigations.

LABORATORY INVESTIGATIONS

The following is a synopsis of several laboratory evaluations of the paving fabric interlayer system. Inherent problems with laboratory evaluations include lack of adequate size setup compared to the field, variations in the permeability of the asphalt cement concrete, the difference between small area permeability versus global or large area field permeabilities, and tightly controlled asphalt tack coat quantities which is not always the case in field applications. The following studies were aimed at determining the amount of water which can infiltrate through a pavement having a paving fabric interlayer system in place.

Bushey, 1976 *(11)*

This study reviewed the performance of a number of test installations in California that included paving fabric as well as other proposed treatments to reduce reflective cracking. Cores were obtained for testing up to two years after the overlay had been placed. The section that included paving fabric was placed with a tack coat of 0.9 liters per square meter (0.20 gallons per square yard) and had ACC overlays of 60 mm (0.2 feet) and 90 mm (0.3 feet). Control sections with no fabric were constructed with 60 and 90 mm (0.2 and 0.3 feet) overlays.

Permeability tests were performed on some of the cores. A vacuum system was employed and the amount of water that had been pulled through the core after 100 seconds reported. Six cores containing paving fabric and three control cores were tested. The tests of the control cores measured 0 to 8.25 ml of water in 100 seconds and averaged 3.6 ml. The cores containing paving fabric had 0 to 0.04 ml of water after 100 seconds and averaged 0.01 ml. This indicated a substantial waterproofing benefit, greater than two orders of magnitude improvement, with the paving fabric interlayer system.

Some of the cores were taken where cracks extended through the overlay. In areas where paving fabric was present the, fabric was found to be intact and still providing a water barrier.

Guram, 1983 ***(12)***

Twelve sites across the United States were cored in an effort to quantify the waterproofing effect of paving fabric. At each site, control sections without paving fabric and sections with paving fabric were sampled. In areas where paving fabric was present an effort was made to take cores in cracked and uncracked areas. A total of 63 cores were taken for testing. The cores were tested using constant head tests in two configurations. First the test was performed with a gravity head of 89 mm (3.5 inches) of water. The second series of tests also used a constant head of 89 mm (3.5 inches) of water and a vacuum of 138 kPa (20 psi) on the bottom of the specimens. The water flow was collected for 15 minutes and a permeability calculated for the core. After testing, the paving fabric was removed from the core and the asphalt tack retained by the fabric was determined.

On the average, the cores containing paving fabric had about one to two orders of magnitude lower permeability (10^{-4} to 10^{-6} mm/sec) than the control section cores (10^{-3} to 10^{-4} mm/sec). The asphalt extraction from the paving fabric indicated that a relatively high percentage of the samples had less than the recommended amount of tack coat in the fabric. This suggests that with improved construction inspection and control, better saturation of the paving fabric with asphalt cement tack could be expected. Thus, with this improvement the paving fabric may provide a more impermeable barrier than indicated by the test results.

The results of tests on the cores where a crack was present both above and below the paving fabric indicated that the permeability was still relatively low at about 10^{-2} to 10^{-3} mm/sec. This suggests that even when underlying cracks reflect to the surface, the paving fabrics still provide a good barrier to limit intrusion of water into the pavement subgrade.

Smith, 1984 *(13)*

This work was performed in an attempt to quantify in-service performance of fabric interlayers as well as the amount of tack coat to be used with various paving fabrics. The study included 12 different paving fabrics. Tests were configured to simulate in-service conditions and fabric behavior. The performance characteristics simulated included fabric asphalt retention, flexural fatigue, interlayer shear, differential movement, fabric heat resistance and permeability.

The asphalt retention testing was performed using a melt through technique. For typical nonwoven paving fabrics, acceptable tack coat rates of 0.9 to 1.4 liters per square meter (0.20 to 0.30 gallons per square yard) were reported.

The permeability tests were performed on a 50 mm (two inch) high block with a paving fabric in the middle. A falling head test was then performed on the assembly. The tests were performed for an hour starting at a head of 200 mm (eight inches). In 33 of 36 trials the, the paving fabrics used allowed significantly less water flow than a control with no paving fabric. At the end of the permeability tests the fabric was removed and rated visually.

This study also showed the results of permeability tests of cores from ACC and Portland cement concrete (PCC) pavements with ACC overlays and paving fabric, with some cracking in the ACC overlay. Where the original pavement was ACC, the fabric was found to be intact and still providing waterproofing after the overlay had cracked. In the case of a PCC original pavement, the fabric was ruptured due to excessive joint movement and no longer provided waterproofing.

Lancaster, 1994 *(5)*

The purpose of this work was to study the sensitivity of the permeability of ACC mixes to three variables. The variables included binder type, amount of binder and degree of compaction of the core. The principal variable was the binder type. Both regular asphalt cement, AR-4000, and a rubber asphalt were used. The amount of binder varied from 7.6 percent to 9.2 percent for the rubber asphalt and 5.0 percent to 5.6 percent for the samples using AR-4000. The rubber asphalts were tested at relative compactions of 90 percent and 95 percent. The cores containing AR-4000 were all compacted to about 95 percent. A core containing paving fabric was also tested. The paving fabric contained a 0.8 liters per square meter (0.18 gallons per square yard) tack coat. The core containing paving fabric had an asphalt content of 5.3 percent.

The results were based on falling head permeability tests performed on the cores. The cores with a rubber asphalt content of 7.6 percent had permeabilities of about 10^{-1} to 10^{-3} mm/sec depending on the degree of compaction. An average permeability of about 10^{-4} mm/sec was measured on the highly compacted cores containing 5.6 percent AR-4000 binder. However, this study also showed the great variability in permeability of ACC cores compacted to different degrees. Achieving a compaction level where ACC pavement has a low permeability is difficult and often not attained. The level of compaction is not as critical to achieving low permeabilities when a paving fabric moisture barrier is used. The core containing paving fabric even had a somewhat smaller amount of binder but achieved a permeability of about 10^{-5} mm/sec.

Baker, 1997 ***(14)***

The permeability of the paving fabric system was investigated along with the sensitivity of the permeability to various asphalt contents. An equipment setup and melt-through procedure which closely models the steps in the installation of paving fabric was used to impregnate the fabric. An objective measurement of effectiveness was desired, so permeability tests were performed on the asphalt saturated paving fabric samples. The paving fabric used throughout this investigation was a staple fiber, needle punched, nonwoven fabric made from polypropylene weighing approximately 135 grams per square meter (4 ounces per square yard).

Various amounts of AC-20 asphalt tack coat were applied to the fabric in the field installation simulation. Then from the asphalt saturated paving fabric samples, specimens were cut to perform water permeability tests. The permeability tests were performed using a modified version of falling head method given in ASTM D 4491, permittivity for geotextiles. The modification consisted of increasing the initial head of the water over the sample to attain flow through some of the samples.

For the paving fabric used in this investigation the manufacturer recommends a tack coat application rate of 1.1 liters per square meter (0.25 gallons per square yard), anticipating that about 0.23 liters square meter (0.05 gallons per square yard) will be absorbed by the existing pavement and the new overlay. This implies that 0.9 liters per square meter (0.20 gallons per square yard) will be available to the paving fabric. At an available tack coat rate of 0.9 liters per square meter (0.20 gallons per square yard) the results of these tests indicate that the fabric would absorb over about 0.68 liters per square meter (0.15 gallons per square yard). This closely conforms to the results of cores taken by Guram *(12)* where the average asphalt retention of the paving fabrics was 0.72 liters per square meter (0.16 gallons per square yard).

The results of permeability tests performed on specimens cut from the asphalt absorption tests are shown in Figure 1. From Figure 1 it can be seen that very little improvement in waterproofing can be expected until the absorbed tack coat is at levels above 0.68 liters per square meter (0.15 gallons per square yard/). At absorbed tack coat levels above 0.73 to 0.77 liters per square meter (0.16 to 0.17 gallons per square yard) the paving fabric starts to achieve permeabilities of 5 x 10^{-6} mm/sec or less which will greatly enhance the waterproofing of a pavement. These levels are consistent with manufacturer's recommended tack coat rates for paving fabrics of the weights used in this study.

Laboratory Testing Summary

The paving fabric interlayer system is providing much improved moisture barrier properties compared to asphalt cement concrete or even rubber modified asphalt cement concrete alone. Even with the limitations on laboratory testing, results of permeability tests of pavements with the paving fabric system were generally one or more orders of magnitude less permeable than ACC without a paving fabric. It was shown that ACC densities and permeabilities can be widely variable due to compactive efforts. The principal causes for variations in the paving fabric interlayer system permeability are the amount and uniformity of the asphalt cement tack coat. The amount of tack coat should be a controllable amount. Although easily monitored, this is probably the greatest concern with paving fabric interlayer systems--making sure the fabric is installed with sufficient tack asphalt to become impermeable.

The other fact summarized by these investigations is in cores from actual ACC pavements, that the asphalt saturated fabric system is quite durable and pliable and can remain a waterproofing membrane even at the bottom of a crack which has opened up in the overlay.

FIELD INVESTIGATIONS OF MOISTURE BARRIER EFFECTIVENESS

The paving fabric interlayer system is widely recognized to extend the service life of overlays. Caltrans has done extensive research on paving fabrics. Their findings indicate that using the paving fabric interlayer can provide extended service life equivalent to placing an extra 30 mm (1.2 inches) of overlay thickness *(15)*. The life extension is attributed to both the stress absorbing function which can retard reflective cracking and the waterproofing function. In the waterproofing function, the paving fabric can maintain a lower moisture content beneath the pavement. Maintaining the materials at a lower level of moisture can result in maintaining the strength of the materials at a higher level. Exactly which function contributes the most to the performance of the paving fabric system is not known and may change from stress absorption to waterproofing depending on the pavement condition and environment. Although many papers written on the performance of paving fabrics cite the waterproofing benefits, there has been limited actual field quantification of the waterproofing. The previously discussed laboratory studies verified the waterproofing in both laboratory made up pavement sections and in many cores from actual pavements. Field studies have been performed including field core evaluations, investigation of the moisture levels beneath pavements with and without the paving fabric system and investigation of the subgrade strength improvement due to lowering of the moisture content beneath a paving fabric system. Also, a large field permeability test was conducted on a paving fabric interlayer system. The following is a discussion of these field studies.

Pourkhosrow, 1985 *(16)*

Experimental installations were made with thin ACC overlays and chip seals over existing ACC pavements. After two years, cores were taken where cracks had reflected through the overlay and visually examined. The visual examination indicated that where polypropylene, needle punched, nonwoven paving fabric was used, the asphalt saturated fabric was still intact.

Button, 1989 *(17)*

In this study performance of paving fabric in several locations in Texas was examined and compared to control sections. At a section near Amarillo, five different paving fabrics as well as control sections for comparison were installed. A 30 mm (1.25 inch) overlay was placed over 100 mm (4 inches) of existing asphalt. After rains, sections containing fabric exhibited less pumping deformation than control sections. This implies that the subgrade modulus was higher in the paving fabric sections due to lower moisture contents than in the control sections. This benefit was still realized even after some cracking in the thin overlay treatment.

Sutherland 1990 *(18)*

Paving fabric systems are extensively used in Australia in combination with chip seal type surfacing. These treatments are used in areas of expansive clays serving the dual purpose of stopping surface water infiltration and stopping evaporation from the clay. This keeps the expansive clay inactive due to the maintenance of a fairly constant moisture level. In an Australian field study using paving fabrics under chip seal treatments, the moisture sensitive clay subgrade remained well below optimum moisture maintaining a stable bearing surface. Adjacent sections without the paving fabric system were at optimum moisture or higher yielding a weaker clay subgrade condition. Also, moisture levels under the paving fabric remained stable (±2 percent) despite seasonal weather variations. This keeps swelling clays from shrinking and swelling.

Phillips, 1993 *(19)*

In this field investigation, pavements with a paving fabric seal performed for significantly more traffic cycles than pavements without the paving fabric system even though the pavements with fabric were exposed to water and the conventionally sealed pavements were not. It was interesting that the only areas that experienced active swelling of the clays on the roads with fabric were the edges where water had entered laterally. The report suggests extending the fabric system into the shoulder to guard the traffic lanes against swelling clay damage. The study also ran tests on core samples with and without the fabric seal. No infiltration was noted in the fabric sealed sections while there was infiltration without the fabric.

Rahman, 1996 *(2)*

This study was performed to evaluate the effectiveness of drainable bases and edgedrain systems in the state of Oklahoma. Five pavement sections were monitored for up to three years. The five sections of pavement had varying degrees of permeable bases and had some differences in edgedrain systems.

The data presented for the monitored sections included the total rainfall, total duration of rainfall, peak rainfall, peak outflow from the edge drains, total outflow from the edge drains and the percentage of the rainfall flowing from the edge drains. In the areas of the free draining base, the outflow from the edge drains was up to about 80 percent of the rainfall but generally about 20 percent to 40 percent. Based on the assumption that where free draining base is present the total outflow from the edge drains represents the infiltration through the pavement during a rain event, global infiltration rates of up to $4x10^{-3}$ mm/sec can be inferred from the data, however values of about 3 to 5 x 10^{-4}mm/sec were more typically measured in this study.

Flow tests were performed on the three sites with free draining base and confirmed that the bases did allow the free passage of water. Interpretation of the results of the flow tests suggests permeabilities on the order of 1 to 10 mm/sec for the asphalt stabilized base and 1 mm/sec for the cement stabilized free draining base.

One of the pavement sections consisted of a break and seat PCC pavement with broken sections averaging in the 100 to 300 mm (4 to 12 inch) size. Over the broken and seated concrete, a leveling course was placed followed by a paving fabric system and a surface course. The edgedrains in this section of highway show almost no response to precipitation events. This lack of response was initially thought to be due to a lack of permeability of the break and seat base or due to rock flour from the break and seat base clogging the edgedrain system. Another potential reason for no response was that the in place paving fabric system was stopping the infiltration of precipitation water into the road base. There was no way of knowing without further testing.

In 1997, the state of Oklahoma returned to this site to determine why water was not draining from the pavement. In their investigation, they cored through the paving fabric system to the top of the break and seat base layer. A percolation flow test was then run by pumping water into the hole to see if it would flow to the edgedrain system. The water did flow and the break and seat base was determined to have an AASHTO drainage capacity of "good". Therefore, since the base was drainable, the most probable reason that water was not flowing from the pavement after a rain was the paving fabric system restricting the infiltration from reaching the base layer. This, in a sense, was a large scale field permeability test of an in-place paving fabric system. The average actual flow to the edgedrains in this pavement was less than 1 percent of precipitation some of which could have "backed" into the edgedrain from the pavement shoulder. Any agency having such a section of pavement, with a permeable base, edgedrains, and a paving fabric interlayer system, has the necessary ingredients to run such a test to verify the barrier properties of the paving fabric system.

The results of this testing raise the interesting question of whether pavement drainage is needed if the precipitation water can be stopped before it reaches the pavement base. Most pavements to be rehabilitated do not have a free draining base and therefore cannot be effectively drained with an edgedrain. A potential way to decrease the water in these pavement bases is to limit surface water infiltration. When a properly installed paving fabric interlayer system keeps the water from the base, this equates to at least the good to excellent AASHTO drainage classification since there is limited water dwell time in the pavement base. Therefore, it may be possible to apply a structural credit, normally used for improved drainage, where a paving fabric system is used.

Al-Qadi, 1997 *(20)*

The final field test reported herein was done by Al-Qadi *(20)*. Here, a ground penetrating radar (GPR) system was employed to detect the presence of moisture beneath pavements with and without paving fabric membrane systems. Two roads were evaluated in Kernersville, North Carolina. Each road had sections with and without the paving fabric membrane system. The GPR antenna was built into a durable box which was pushed along the pavement surface. Microwave signals penetrated the pavement and the reflectance or absorption of these microwaves were monitored. The output signal is examined on site and stored for future analysis.

The criterion used to determine if moisture exists below the pavement layer is by monitoring changes in the amplitude of the first reflected signal. When the amplitude of the first reflected signal is high, moisture presence is also high. Otherwise, the changes in the signal would be minimal and would only result from the change in dielectric properties of the pavement layers. Different color codes can be used in the output scan to enhance the reflected signals.

The results of the testing on both roads showed significantly higher moisture levels in the road base and subgrade in the sections without the paving fabric interlayer system. This GPR system shows promise as a pavement evaluation tool since, as discussed earlier, moisture in pavements is one of the most important factors in pavement service life yet is rarely monitored or measured.

Summary Of Field Evaluations

The field investigations were found to be in good general agreement with the laboratory studies. Where flows were monitored, the field results verified greater than one order of magnitude reduction in pavement permeability due to the presence of the paving fabric interlayer system. Lower moisture levels in the pavement structure were also indicated by observed strength increases in pavement support structures when a paving fabric interlayer system was used. Nondestructive ground penetrating radar technology also appears to be a useful tool and did verify lower moisture contents beneath pavements containing paving fabric interlayer systems.

CONCLUSIONS

The following conclusions are drawn based on the laboratory and field evaluations of the waterproofing effectiveness of a paving fabric interlayer system:

- Both laboratory and field pavement cores indicate that the presence of a properly installed paving fabric interlayer system reduces the permeability of a pavement by one to three orders of magnitude. By reducing the infiltration by one or more orders of magnitude, the system becomes an efficient moisture barrier to enhance pavement performance.
- Enhanced AASHTO design pavement structural benefits, based on improved drainage, should be considered when a paving fabric system is used. Benefits can be incorporated by using larger drainage coefficients in AASHTO new pavement and rehabilitation designs.

- The moisture levels beneath the pavement layers are decreased below pavements with paving fabric interlayers. This maintains the strength of the subgrade and subbase layers, limiting damage due to saturated condition pore pressures.
- To provide a continuous moisture barrier, the paving fabric must be saturated with enough asphalt cement - generally about 0.72 to 0.9 liters per square meter (0.16 to 0.20 gallons per square yard). An additional 0.23 liters per square meter (0.05 gallons per square yard are necessary to adhere the paving fabric to the overlay and existing pavement. Lesser amounts of asphalt cement diminish the waterproofing effect. Field installation quality control is important.
- Pavement drainage improvement is only a viable option for rehabilitation if pavement bases have a permeability greater than 1 to 10^{-1} mm/sec. When drainage improvement is not an option, placement of a paving fabric moisture barrier should be considered.

More research is needed in the whole area of moisture in pavements and improved tools need to be developed for better monitoring and measurement. Meanwhile, the economical technology does exist to create a moisture barrier in a pavement using paving fabric interlayer systems.

REFERENCES

(1) Cedergren, H. R., *Drainage of Highway and Airfield Pavements*, John Wiley and Sons, Inc., New York, 1974.

(2) Rahman, M., Curtis, T., Zaman, M., *Field Evaluation of Drainable Bases in Oklahoma*, Report Item 2181: ORA 125-4299, Oklahoma Department of Transportation, 1996.

(3) Ridgeway, H. H., Infiltration of Water Through the Pavement Surface, *Transportation Research Record 616*, TRB, National Research Council, Washington, D.C., 1976, pp. 98-100.

(4) Ridgeway, H. H., Pavement Subsurface Drainage Systems, *National Cooperative Highway Research Program Synthesis of Highway Practice 96*, TRB, National Research Council, Washington, D.C., 1982.

(5) Lancaster, F. E., *Permeability Test Results*, Personal Communication, 1994.

(6) Jorenby, B.N, R.G. Hicks, Base Course Contamination Limits, *Transportation Research Record 1095*, TRB, National Research Council, Washington, D.C., 1986, pp
86- 101.

(7) AASHTO, *Guide for Design of Pavement Structures*, American Association of State Highway and Transportation Officials, 1993.

(8) McEnroe, B. M., *Drainability of Granular Bases for Highway Pavements*, Paper 940146, 73rd Annual Meeting Transportation Research Board, National Academy of Sciences, 1994.

(9) Roy, M., J. Cote, J-M Konrad, C. Robert, *Characterization of Unsaturated Granular Bases for Drainage Consideration During Spring Thaw*, International Symposium on Thin Pavements, Surface Treatments and Unbound Roads, 1997.

(10) Koerner, R.M., G.R. Koerner, A.K. Fahim, R.F. Wilson-Fahmy, *Long-Term Performance of Geosynthetics In Drainage Applications*, NCHRP Report 367, TRB, National Research Council, Washington, D.C., 1994.

(11) Bushey, Roy W., *Experimental Overlay to Minimize Reflection Cracking*, FHWA/CA/TL-3167-76-28, California Department of Transportation, 1976.

(12) Guram, S.S., *Evaluation of Petromat Membrane System as a Waterproof Membrane*, Internal Communication, Phillips Fibers Corp., 1983.

(13) Smith, Roger D., *Laboratory Investigation of Fabric Interlayers for Asphalt Concrete Paving (Final Report)*, FHWA/CA/TL-84-06, California Department of Transportation, 1984.

(14) Baker, T.L., *Results of Melt Through Asphalt Absorption and Permeability Tests*, Internal Communication, Amoco Fabrics and Fibers Co., 1997.

(15) Predoehl, N.H., *Evaluation of Paving Fabric Test Installations in California,* FHWA/CA/TL-90/02, California Department of Transportation, 1990.

(16) Pourkhosrow, G., *Nonwoven Polyester and Polypropylene Engineering Fabrics in Oklahoma Pavements*, Oklahoma Department of Transportation, 1985.

(17) Button, Joe W., *Overlay Construction and Performance Using Geotextiles*, 68th Annual Meeting Transportation Research Board, National Academy of Sciences, 1989.

(18) Sutherland, M., Phillips, P., "Geotextile Reinforced Sprayed Seal Roads in Rural Australia", *Proceedings of the Fourth International Conference on Geotextiles, Geomembranes and Related Products*, A.A. Balkema, Rotterdam, 1990, pp 209- 212.

(19) Phillips, P., "Long Term Performance of Geotextile Reinforced Seals to Control Shrinkage on Stabilized and Unstable Clay Bases", *Reflective Cracking of Pavements*, RILEM, 1993, pp. 406-412.

(20) Al-Qadi, I., *Petromat Evaluation in Kernersville, NC*, Communication Virginia Polytechnic Institute with Amoco Fabrics and Fibers, 1997.

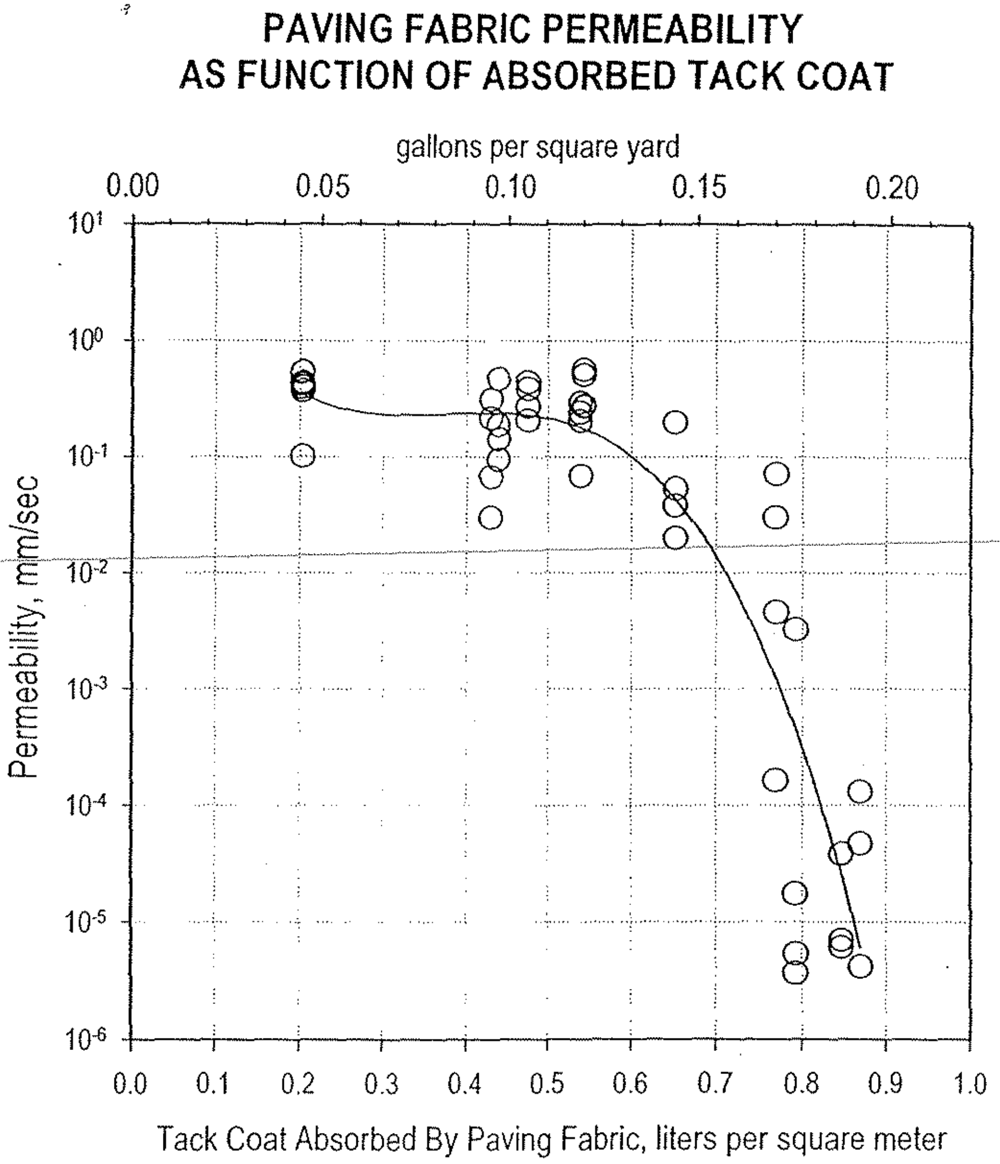

Figure 1 - **Results of permeability tests on specimens cut from melt through asphalt absorption tests.**

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PAVING FABRIC INTERLAYER AS A PAVEMENT MOISTURE BARRIER

by Mark L. Marienfeld and Thomas L. Baker,
Amoco Fabrics and Fibers Company

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FOREWORD

L. David Suits, Chairman

Paving fabric interlayer systems have been used in more than 230,000 lane-kilometers (142,000 lane-miles) of pavement in the U.S. Paving fabrics are a special class of geosynthetic that provide the generally acknowledged functions of a stress-absorbing interlayer and a waterproofing membrane *(1)*. The stress-related performance has been easily verified by the observed reductions of cracking in pavement overlays. The waterproofing benefit is not easily verified, yet improved overlay performance can also be attributed to a lower moisture content in a pavement base and subgrade. This circular examines the waterproofing effectiveness of the paving fabric interlayer system. A compilation of studies that collectively verify and quantify the effectiveness of waterproofing is presented in the circular. The studies cited provide useful information on the use of paving fabrics.

The waterproofing effectiveness of an asphalt cement saturated fabric layer has been investigated both in the laboratory and in pavements in the field. Results of the moisture barrier system testing from various laboratories are presented. Next, this circular reports on field evaluations of the moisture barrier in pavements. These evaluations utilized some interesting measures, including large-scale pavement permeability testing and ground penetrating radar.

The general problem of water in a pavement section will be discussed, including sources of water and the detrimental effects of the water. The circular discusses the use of proper pavement drainage, to achieve significant benefits from AASHTO design drainage coefficients. However, for existing pavements retrofitting a drainage system is often not an effective rehabilitation option. It appears that pavement waterproofing may be the most practical option for solving pavement moisture problems.

The objective of this circular is to provide a source of background information for persons who are unfamiliar with the use of geotextiles, commonly referred to as paving fabrics, as moisture barriers in pavements. The problem of moisture in pavements is first reviewed. This circular then presents the mechanics by which moisture barriers work and provides a summary of work conducted by others in investigating their effectiveness. Also provided is a reference list of other works that have been used in developing the circular.

The circular has undergone peer reviews by representatives of the Transportation Research Board Committee on

Geosynthetics and was also submitted for review by representatives of three pavement committees within the Group 2 Council. Based on review results, the Geosynthetics Committee recommended this information for publication as a circular.

Keywords: Pavements, waterproofing, paving fabrics, geotextiles, geosynthetics

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Paving Fabric Interlayer System as a Pavement Moisture Barrier

by Mark L. Marienfeld, P.E.

and Thomas L. Baker, P.E.

INTRODUCTION

Moisture frequently is the root cause of damage to pavements. Although the sources of water and the mechanics of how moisture damages a pavement are understood, these principles are not widely incorporated into design. In some cases it may be difficult to incorporate drainage improvements into pavement rehabilitation. For these reasons, pavement rehabilitation techniques generally address the repair of actual pavement damage instead of treating the moisture problem, the root cause.

Although many agencies have studied pavement moisture, the authors could find little widely published literature in the area of pavement structure moisture measurement. The control of moisture has not generally been a focus of pavement design or maintenance. The technology to control the moisture sources is, however, available but not widely recognized or practiced compared to traditional pavement repair technologies. There are two general ways to control moisture in pavement structures: by the use of subsurface drainage or by capping (sealing) the pavement to reduce infiltration through the pavement. The latter is the focus of this circular, which examines the sealing effectiveness of paving fabric interlayer systems. A paving fabric interlayer system consists of a nonwoven geotextile, paving fabric, of about 140 grams per square meter (4.1 ounces per square yard) that is field applied over an asphalt cement tack coat of approximately 1.1 liters per square meter (0.25 gallons per square yard). The fabric and asphalt tack coat combine to form an interlayer system when covered with an asphalt concrete (AC) overlay or a chip seal surface treatment.

THE PROBLEM -- MOISTURE WITHIN PAVEMENT STRUCTURES

The primary source of moisture in pavement structures is rainwater, which infiltrates through the pavement. Moisture can also enter a pavement from subsurface sources such as from lateral seepage from a drainage ditch or from subsurface flow such as from a spring. In most areas, these water sources are secondary to rainwater coming through the pavement itself. Extensive studies have been done to examine surface infiltration of rainwater. An FHWA study *(2)* of numerous pavement sections found that 33 to 50 percent of the precipitation water falling on an AC pavement and 50 to 67 percent for portland cement concrete (PCC) pavement could infiltrate through the pavement to the road base. Oklahoma studies of edgedrain effectiveness *(3)* found similar results. In these studies, sections of pavement were isolated to measure rainfall amounts. Then, the corresponding amount of water that infiltrated that pavement section was recovered by a highway edgedrain and measured. In individually monitored rainfall events, edgedrains recovered very high percentages, up to 80 percent *(3)*. Comparing the total amount of rainfall for a year to the total discharge for the year showed as high as 32 percent recovery of water that infiltrated through the pavement in this study. Ridgeway *(4)* found global infiltration rates of about 0.001 to 0.002 mm/sec. A summary of previous work by Ridgeway *(5)* for seven new AC pavements had an average potential infiltration rate of 0.32 mm/sec, and five old AC pavements had an average potential infiltration rate of 0.015 mm/sec. In another study by Los Angeles County, California *(6)*, it was shown that the permeability of AC pavements is highly dependent on the amount of AC pavement compaction achieved. Tightly controlled compaction efforts reduce the permeability of a pavement. Often, however, the design mix and/or the level of compaction achieved may result in a pavement that can pass a significant amount of water to the pavement base. Tests *(6)* have indicated the addition of rubber to the asphalt mix resulted in little improvement in the waterproofing effectiveness of the pavements. Therefore, sound pavements are quite permeable and water infiltration through the pavement is the general source of moisture in the pavement base. Pavement cracking can increase the water infiltration rates up to nearly 100 percent and further increase moisture problems in the pavement structure.

The problems caused by the presence of water in a pavement structure are many. If a pavement base becomes saturated, pore water pressures due to traffic loading can negate the load spreading support function of the base stone. Consequently, the traffic load will be applied to the subgrade over a small area. This localized loading may exceed the bearing capacity of the subgrade, causing progressive failure of the pavement. If a pavement base is saturated as little as 10 percent of the time, the useful life of the pavement can be reduced by 50 percent *(2)*. The results of cyclic load tests on crushed stone and on gravel suggest that saturation levels above about 60 percent to 70 percent can result in large deformations *(5)*. Pore pressures can also result in significant scouring and jetting pressures. Water jetting from cracks or joints can transport base and subgrade materials to the road surface, creating a void under the pavement and eventual pavement failure.

Another way moisture damages pavement structures is by weakening the subgrade soil. Ultimately, the subgrade bears the load of the pavement. It is customary to perform soaked CBR or undrained triaxial testing to determine the bearing capacity of a subgrade. It is the authors' opinion that these tests usually overestimate the subgrade soil strength for a cohesive subgrade beneath a wet base. The constant loading and unloading of the subgrade, while exposed to water, can remold the soil, resulting in a lower shear strength and a higher moisture content than is currently simulated by 96-hour laboratory soaking required for the CBR test. Further research in this area, to better simulate the moisture and stress conditions for subgrade testing, is encouraged. Evidence of the weakening of the subgrade is the frequently observed migration of the subgrade soil up into a base stone if no separation geotextile is used. This migration deteriorates the strength of the base stone layer. A level of fines in the base stone as low as 10 percent has been shown to dramatically reduce the resilient modulus of an aggregate base course *(7)* due to loss of good rock-to-rock contact when compared to the same material with a lower fines content. The added fines content will also dramatically lower the permeability (drainability) of the base *(5)*.

Another moisture-related effect is freeze/thaw damage, which can occur in the base, subbase, or subgrade depending on the porosity and permeability of each layer and the depth of frost penetration. It may be difficult in cold regions to maintain a drainable pavement base throughout the cold season. A practical alternative where water migration from the surface is the principal source of moisture leading to freeze/thaw damage may be to keep the moisture out of the base structure by providing a sealing layer in the pavement.

Pavements are exposed to different levels of moisture damage depending on how quickly the pavement structure drains after receiving rainwater infiltration. For a given amount of infiltration, drainage time is a function of the type of stone, the gradation of the base, the thickness of the base, the contamination of the base by subgrade intrusion, and the slope of the base layer.

STRUCTURAL CREDIT FOR GOOD DRAINAGE

The American Association of State Highway and Transportation Officials' (AASHTO's) *Guide for Design of Pavement Structures*, 1993 *(8)* provides for a structural credit or a structural penalty to a flexible pavement design based on the effectiveness of the drainage system. Drainage coefficients are applied to the structural number (SN) of the pavement's untreated base and subbase materials. These coefficients may represent the most significant variables in pavement design and range from 1.4 to 1.2 for excellent drainage to 0.95 down to 0.4 for very poor drainage. This implies that an aggregate base material with an effective drainage system can be assigned up to three times the SN of the same base aggregate that is not allowed to drain. It also means that a base with fines, such as a crusher run base, would be greatly penalized from an SN standpoint, while a clean free-draining base with a drainage system would receive a significant structural bonus. These factors are often overlooked for several reasons. One is that an aggregate with appreciable fines content may be less expensive. Second, tighter, or denser, bases have been traditionally used to help choke off upward migration of fines from the subgrade. Also, constructibility problems may be encountered with open bases.

Roads without an aggregate base can hold moisture in the asphalt pavement or the treated base, which is detrimental to the subgrade and to the pavement structure. AASHTO 1993 *(8)* states that although the drainage coefficients are only applied to untreated base or subbase, improved drainage is also beneficial to pavements with treated bases and no bases. The AASHTO design method also utilizes structural penalties or credits for rigid pavements based on the drainability of the pavement.

All the benefits of a dense, low-permeability base have minimal impact on the pavement cost compared to the effect of the drainage coefficients, yet this area has not received the attention it should in research and in field application. Studies by Cedergren *(2)* and McEnroe *(9)* agree that a base must have permeabilities greater than 1 mm/sec to achieve AASHTO excellent drainage and 10^{-1} to 1 mm/sec to be classified as good drainage. In a study by Roy et al. *(10)*, hydraulic conductivity tests were carried out on three different granular bases (granite, limestone, and shale), characterized with fines contents of 2, 7, and 12 percent. The study showed one to three orders of magnitude reduction in permeability between 2 percent and 7 percent fines depending on the type of rock. The work is continuing, but it suggests that a 7 percent maximum fines specification, for example, allows too many fines to achieve proper drainage. Similar results were also reported by Ridgeway *(5)*.

Ridgeway *(5)* makes the point that drainage systems will only remove free water that is not held by capillary forces. The consequence of this is that bases with over about 5 percent to 10 percent fines will tend to always be in a state of relatively high saturation, up to 85%. The implication is that only a small amount of additional water infiltration will fully saturate the base. Often, the drainability of a pavement base is overestimated because bases assumed to be free-draining have significantly more fines than discussed above. The high fines content may result from migration of fines from the subgrade, as previously described, or result from deterioration of the base course aggregate during construction. Bases must also be tied into effective drainage systems to promote rapid drainage.

The technology exists to place a truly free-draining base stone layer without the fear of subgrade fines contamination by placing a separation geotextile between the subgrade soil and the base stone. In many existing roads, the bases have poor to very poor drainage by AASHTO definition. This limited permeability is due to the original design including a low-permeability base or due to fines contamination of an originally free-draining base layer resulting from the lack of a separation geotextile.

EDGEDRAINS

When considering rehabilitation of an existing pavement, one way to increase the effective support of the subgrade, subbase, and base layers is to improve the drainage and reduce the length of time the base is saturated. This would allow the use of a higher AASHTO drainage coefficient and thus a higher pavement structural number. This can be accomplished by the installation of pavement edgedrains if the base is permeable enough to transmit water to the edgedrain system. However, most existing flexible pavements do not have a free-draining base, and placing an edgedrain is not always an effective solution. Studies have been conducted looking at the effectiveness of highway edgedrains (3, 11). Lack of drainage has often been blamed on the type of edgedrain used or on damage or clogging of the drain, when slow drainage of the base course may be the problem. These edgedrain tests show some bases draining over a long period (e.g., over a week) or maybe not even draining. Therefore, edgedrains are helpful only if they significantly increase the rate at which water is removed from beneath a pavement. Some reports indicate that where base permeabilities are less than 10^{-1} to 1 mm/sec, edgedrains may not improve subsurface drainage of the pavement (5). Thus, the number of cases where an edgedrain may improve the drainage may be limited. In these cases a possible solution to moisture rehabilitation is to use a durable seal such as a paving fabric interlayer to limit moisture infiltration through the pavement.

SEALING A PAVEMENT

Several methods have been used over the years to limit surface water infiltration through a pavement. These methods include interlayers of modified asphalts, asphalt and chip, asphalt and fiber, and fabric-reinforced asphalt. Other methods include surface treatments such as chip seals, slurry seals, and various other surface dressings. The effectiveness of the systems varies widely. Surface treatments tend to be short-lived, with cracking and infiltration returning quickly. Interlayers are protected by the overlay and as such tend to stay in place and be more effective. The costs of the systems also vary, so transportation agencies must perform a cost-benefit analysis to decide which system to use.

An effective hydraulic barrier within a pavement can be evaluated based on the typical infiltration rates observed in the previously mentioned studies and the approximate time it takes to saturate the base. Based on these studies, typical pavement infiltration rates might be on the order of 0.002 to 0.005 mm/sec. For typical pavement widths, slopes, base thickness and base porosity, and initial saturation it may take about 1 to 5 hours to saturate the base material. At the low permeabilities common for bases it may then take from 60 days to more than a year for the base to drain down to 50% saturation. In this period it may be likely that an additional rain may occur such that the base never fully drains down to 50% saturation. A moisture barrier that can reduce the infiltration rate by an order of magnitude would also increase the length of time required to initially saturate the base by an order of magnitude. For the example cited, that would increase the length of time that it must rain to saturate the pavement base to approximately 10 to 50 hours. By extending the time to saturate the base, it becomes less likely that the pavement will experience a rainfall event of sufficient length and intensity that the base will become saturated and even less likely that rainfall events of that duration will recur frequently enough that the base cannot drain. Thus to be effective, a moisture barrier should reduce the pavement permeability by at least one order of magnitude, and proper surface drainage should be addressed.

The focus of this circular is on the waterproofing effectiveness of fabric-reinforced membrane interlayers, commonly referred to as paving fabrics. According to the Industrial Fabrics Association International, paving fabric usage has exceeded 100 million square meters per year for the past several years in the U.S. Although many engineers think the paving fabric system is mainly used as a stress-relieving interlayer to retard reflective and fatigue cracking, a principal function of the system is waterproofing (1). Briefly, the system involves spraying approximately 1.1 liters per square meter (0.25 gallons per square yard) of asphalt cement tack coat and then applying a nonwoven fabric of about 140 grams per square meter (4.1 ounces per square yard) onto the tack coat. The AC overlay is then placed on top of the fabric. The heat and pressure of the overlay reactivate the asphalt tack coat, drawing it up into the fabric and bonding it to the overlay. The resultant interlayer is a fairly thick asphalt-saturated fabric-reinforced layer. This layer forms a waterproofing membrane and a stress absorption layer. The system can also be effectively applied beneath chip seal surfacing.

AASHTO has published a national geotextile guideline specification, AASHTO M 288-96, that includes paving fabric (12). This specification requires a unit weight of 140 grams per square meter, a grab tensile strength of 450 Newtons with greater than 50% elongation, and a melting point of 150°C. The specification also provides guidance on construction details including tack coat application.

MOISTURE BARRIER EVALUATION OF PAVING FABRIC INTERLAYER SYSTEMS

Several researchers have conducted field and laboratory investigations to determine the effectiveness of paving fabric interlayer systems in minimizing surface water infiltration through the pavement. Laboratory investigations included permeability testing of pavement core samples taken from roads containing a paving fabric with varying years of service and permeability testing on pavement specimens produced in the lab. Field testing included the monitoring of moisture contents within the pavement structure with and without paving fabric systems and a large-scale field permeability evaluation of a pavement containing a paving fabric system. The following is a discussion of the laboratory and field investigations.

LABORATORY INVESTIGATIONS

The following is a synopsis of several laboratory evaluations of the paving fabric interlayer system. Inherent problems with laboratory evaluations include limited area tested compared to the field, variations in the permeability of the asphalt concrete, the difference between small area permeability versus global or large area field permeabilities, and better control of asphalt tack coat quantities than is often achieved in field applications. The following studies were aimed at determining the amount of water that can infiltrate through a pavement having a paving fabric interlayer system in place.

Bushey, 1976 (13)

This study reviewed the performance of a number of test installations in California that included paving fabric as well as other proposed treatments to reduce reflective cracking. Up to two years after the overlay had been placed pavement cores were obtained for testing. The section that included paving fabric was placed with a tack coat of 0.9 liters per square meter (0.20 gallons per square yard) and had AC overlays of 60 mm (0.2 feet) and 90 mm (0.3 feet). Control sections with no fabric were constructed with 60 and 90 mm (0.2 and 0.3 feet) overlays.

Permeability tests were performed on some of the cores. A vacuum system was employed and the amount of water that had been pulled through the core in 100 seconds was recorded. Six cores containing paving fabric and three control cores were tested. Test results for the control cores showed 0 to 8.25 ml of water in 100 seconds and averaged 3.6 ml. The cores containing paving fabric had 0 to 0.04 ml of water in 100 seconds and averaged 0.01 ml. This indicated a substantial waterproofing benefit, greater than two orders of magnitude improvement, with the paving fabric interlayer system.

Some of the cores were taken where cracks extended through the overlay. In areas where paving fabric was present, visual observations indicated that the paving fabric moisture barrier system was still intact.

Guram, 1983 *(14)*

Twelve sites across the United States were cored in an effort to quantify the waterproofing effect of paving fabric. At each site, control sections without paving fabric and sections with paving fabric were sampled. In areas where paving fabric was present an effort was made to take cores in cracked and uncracked areas. A total of 63 cores were taken for testing. The cores were tested using constant head tests in two configurations. First the test was performed with a gravity head of 89 mm (3.5 inches) of water. The second series of tests also used a constant head of 89 mm (3.5 inches) of water and a vacuum of 138 kPa (20 psi) on the bottom of the specimens. The water flow was collected for 15 minutes and a permeability calculated for the core. After testing, the paving fabric was removed from the core and the asphalt tack retained by the fabric was determined.

On the average, the cores containing paving fabric had about one to two orders of magnitude lower permeability (10^{-4} to 10^{-6} mm/sec) than the control section cores (10^{-3} to 10^{-4} mm/sec). The asphalt extraction from the paving fabric indicated that a relatively high percentage of the samples had less than the recommended amount of tack coat in the fabric. This suggests that with improved construction inspection and control, better saturation of the paving fabric with asphalt cement tack could be expected. Thus, with this improvement the paving fabric may provide a better barrier than indicated by the test results.

The results of tests on the cores where a crack was present both above and below the paving fabric indicated that the permeability was still relatively low at about 10^{-2} to 10^{-3} mm/sec, which was lower than the control section without paving fabric. This suggests that even when underlying cracks reflect to the surface, the paving fabrics still provide a good barrier to limit intrusion of water into the pavement subgrade.

Smith, 1984 *(15)*

This work was performed in an attempt to quantify in-service performance of fabric interlayers and the amount of tack coat required with various paving fabrics. The study included 12 different paving fabrics. Tests were configured to simulate in-service conditions and fabric behavior. The performance characteristics simulated included fabric asphalt retention, flexural fatigue, interlayer shear, differential movement, fabric heat resistance, and permeability.

The asphalt retention testing was performed using a melt-through technique described in the report. For typical nonwoven paving fabrics, acceptable tack coat rates of 0.9 to 1.4 liters per square meter (0.20 to 0.30 gallons per square yard) were reported.

The permeability tests were performed on a 50 mm (two inch) high block of asphalt concrete with a paving fabric in the middle. A falling head test was then performed on the assembly. The tests were performed for an hour starting at a head of 200 mm (eight inches). In 33 of the 36 trials, the paving fabrics used allowed significantly less water flow than a control with no paving fabric.

This study also investigated cores from AC and PCC pavements with AC overlays and paving fabric, with some cracking in the AC overlay. Where the original pavement was AC, the fabric was found to be intact and still providing waterproofing after the overlay had cracked. In the case of a PCC original pavement, the fabric was ruptured due to excessive joint movement and no longer provided waterproofing.

Lancaster, 1994 *(6)*

The purpose of this work was to study the sensitivity of the permeability of AC mixes to three variables. The variables included binder type, amount of binder, and degree of compaction of the AC pavement core. The principal variable was the binder type. Both regular asphalt cement, AR-4000, and a rubber asphalt were used. The amount of binder varied from 7.6 percent to 9.2 percent for the rubber asphalt and 5.0 percent to 5.6 percent for the samples using AR-4000. The rubber asphalts were tested at relative compactions of 90 percent and 95 percent. The cores containing AR-4000 were all compacted to about 95 percent. A core containing paving fabric was also tested. The paving fabric contained a 0.8 liters per square meter (0.18 gallons per square yard) tack coat. The core containing paving fabric had an asphalt content of 5.3 percent.

Falling head permeability tests were performed on the cores and the results are as follows. The cores with a rubber asphalt content of 7.6 percent had permeabilities of about 10^{-1} to 10^{-3} mm/sec depending on the degree of compaction. An average permeability of about 10^{-4} mm/sec was measured on the highly compacted cores containing 5.6 percent AR-4000 binder. However, this study also showed the great variability in permeability of AC cores compacted to different degrees. It is possible to achieve a satisfactory compaction level so that the pavement does not exhibit permanent deformation but is difficult to attain a high enough level of compaction to significantly reduce the permeability of the AC pavement. From a permeability viewpoint the level of compaction is not as critical when a paving fabric moisture barrier is used. The core containing paving fabric had a somewhat smaller amount of binder but achieved a permeability of about 10^{-5} mm/sec.

Baker, 1997 *(16)*

The permeability of the paving fabric system was investigated along with the sensitivity of the permeability to various asphalt contents. An equipment setup and melt-through procedure that closely models the steps in the installation of paving fabric was used to impregnate the fabric. An objective measurement of effectiveness was desired, so permeability tests were performed on the asphalt-saturated paving fabric samples. The paving fabric used throughout this investigation was a staple fiber, needle-punched, nonwoven fabric made from polypropylene weighing approximately 140 grams per square meter (4.1 ounces per square yard).

Various amounts of AC-20 asphalt tack coat were applied to the fabric in the field installation simulation. Then, specimens were cut from the asphalt-saturated paving fabric samples to perform water permeability tests. The permeability tests were performed using a modified version of the falling head method given in ASTM D 4491, permittivity for geotextiles. The modification consisted of increasing the head of the water over the sample to attain flow through low-permeability samples.

For the paving fabric used in this investigation the manufacturer recommends a tack coat application rate of 1.13 liters per square meter (0.25 gallons per square yard), anticipating that about 0.23 liters per square meter (0.05 gallons per square yard) will be absorbed by the existing pavement and the new overlay. This implies that 0.91 liters per square meter (0.20 gallons per square yard) will be available to the paving fabric. If a tack coat rate of only 0.91 liters per square meter (0.20 gallons per square yard) is applied to a pavement, the results of these tests indicate that the fabric would be allowed to absorb only about 0.68 liters per square meter (0.15 gallons per square yard). This closely conforms to the results of cores taken by Guram *(14)* where the average asphalt retention of the paving fabrics was 0.72 liters per square meter (0.16 gallons per square yard).

The results of permeability tests performed on specimens cut from the asphalt absorption tests are shown in Figure 1. Applied tack coat values shown on Figure 1 include the amount of asphalt actually absorbed into the paving fabric during these tests plus 0.23 liters per square meter (0.05 gallons per square yard), which is typically required to bond the interlayer to the pavement layers. On Figure 1 it can be seen that minor improvement in waterproofing can be expected until the tack coat application is at levels above 0.91 liters per square meter (0.20 gallons per square yard). At tack coat levels above 1.04 to 1.09 liters per square meter (0.23 to 0.24 gallons per square yard) the paving fabric starts to achieve permeabilities of 10^{-5} mm/sec or less, which will greatly enhance the waterproofing of a pavement. These levels are consistent with manufacturers' recommended tack coat rates for paving fabrics of the weights used in this study.

Laboratory Testing Summary

The paving fabric interlayer system provides much improved moisture barrier properties compared to asphalt concrete or even rubber modified asphalt concrete alone. Even with the limitations on laboratory testing, results of permeability tests of pavements with the paving fabric system were generally one or more orders of magnitude less permeable than AC without a paving fabric. It was shown that AC densities and permeabilities can be widely variable due to compactive efforts. The principal causes for variations in the paving fabric interlayer system permeability are the amount and uniformity of the asphalt cement tack coat. The amount of tack coat should be a controllable amount. Although easily monitored, this is probably the greatest concern with paving fabric interlayer systems--making sure that the fabric is installed with sufficient tack asphalt to become impermeable, which is essential to the performance of paving fabric systems.

These investigations indicate that, in cores from actual AC pavements, the asphalt-saturated fabric system is quite durable and pliable and can remain a waterproofing membrane even at the bottom of a crack that has opened up in the overlay.

FIELD INVESTIGATIONS OF MOISTURE BARRIER EFFECTIVENESS

The paving fabric interlayer system is widely recognized to extend the service life of overlays. Caltrans has done extensive research on paving fabrics. Based on the evaluation of numerous test sites, their findings indicate that using the paving fabric interlayer can provide extended service life equivalent to placing an extra 30 mm (1.2 inches) of overlay thickness *(17)*. The life extension is attributed to both the stress-absorbing function, which can retard reflective cracking, and the waterproofing function, which protects the pavement structure. In the waterproofing function, the paving fabric can help maintain a lower moisture content beneath the pavement by minimizing rainwater infiltration through the pavement. Maintaining the materials at a lower level of moisture can result in maintaining the strength of the materials at a higher level. Exactly which of the these two functions of the paving fabric system provides the greatest benefit to the pavement structure is difficult to quantify. The relative contribution of the two functions seems to depend on the pavement condition and the environment. Although many papers written on the performance of paving fabrics cite the waterproofing benefits, there has been limited actual field quantification of the waterproofing. The previously discussed laboratory studies verified the waterproofing in both laboratory-produced specimens and in cores from actual pavements. Field studies have been performed, including field core evaluations, investigation of the moisture levels beneath pavements with and without the paving fabric system, and investigation of the subgrade strength improvement due to lowering of the moisture content beneath a paving fabric system. Also, a large field permeability test was conducted on a paving fabric interlayer system. The following is a discussion of these field studies.

Pourkhosrow, 1985 *(18)*

A study was performed in Oklahoma to evaluate the performance of paving fabric in retarding reflective cracking and in reducing water infiltration through cracks in AC pavements. Experimental installations were made with thin AC overlays and chip seals over existing AC pavements. After two years, cores were taken where cracks had reflected through the overlay and visually examined. The visual examination indicated that where polypropylene, needle-punched, nonwoven paving fabric was used, the asphalt-saturated fabric was still intact.

Button, 1989 *(19)*

In this study, performance of paving fabric in several locations in Texas was examined and compared to control sections. At a section near Amarillo, five different paving fabrics as well as control sections for comparison were installed. A 30 mm (1.25 inch) overlay was placed over 100 mm (4 inches) of existing asphalt. After rains, sections containing fabric exhibited less pumping deformation than control sections. This implies that the subgrade modulus was higher in the paving fabric sections due to lower moisture contents than in the control sections. This benefit was realized even after some cracking in the thin overlay treatment had occurred.

Sutherland and Phillips, 1990 *(20)*

Paving fabric systems are extensively used in Australia in combination with chip seal type surfacing. These treatments are used in areas of expansive clays serving the dual purpose of limiting surface water infiltration and limiting evaporation from the subgrade clay. This keeps the expansive clay inactive by maintaining a fairly constant moisture level. In this field study using paving fabrics under chip seal treatments, the moisture-sensitive clay subgrade remained well below optimum moisture, maintaining a stable bearing surface. Adjacent sections without the paving fabric system were at optimum or higher moisture content, yielding a weaker clay subgrade condition. Also, moisture levels under the paving fabric remained stable (± 2 percent) despite seasonal weather variations. This limits swelling and shrinking of expansive clays.

Phillips, 1993 *(21)*

In this Australian field investigation, pavements with a paving fabric seal performed better for significantly more traffic cycles than pavements without the paving fabric system even though the pavements with fabric were exposed to water and the conventionally sealed pavements were not. It was interesting that the only areas that experienced active swelling of the clays on the roads with fabric were the edges where water had entered laterally. The report suggests extending the fabric system onto the shoulder to guard the traffic lanes against swelling clay damage. The study also included tests on core samples with and without the fabric seal. No infiltration was noted in the fabric-sealed sections, while there was infiltration in sections without the fabric.

Rahman et al., 1996 *(3)*

In 1996 this study was performed to evaluate the effectiveness of drainable bases and edgedrain systems in the state of Oklahoma. Five pavement sections were monitored for up to three years. The five sections of pavement had varying degrees of permeable bases and had some differences in edgedrain systems.

The data presented for the monitored sections included the total rainfall, total duration of rainfall, peak rainfall, peak outflow from the edgedrains, total outflow from the edgedrains, and the percentage of the rainfall flowing from the edgedrains. In the areas of the free-draining base, the outflow from the edgedrains was up to about 80 percent of the rainfall but generally about 20 percent to 40 percent. Based on the assumption that where free-draining base is present the total outflow from the edgedrains represents the infiltration through the pavement during a rain event, global infiltration rates of up to 4×10^{-3} mm/sec can be inferred from the data; however, values of about 3×10^{-4} to 5×10^{-4} mm/sec were more typically measured in this study.

Flow tests were performed on the three sites with free-draining base and confirmed that the bases did allow the free passage of water. Interpretation of the results of the flow tests suggests permeabilities on the order of 1 to 10 mm/sec for the asphalt-stabilized base and 1 mm/sec for the cement-stabilized free-draining base.

One of the pavement sections consisted of a break and seat (crack and seat) PCC pavement with broken sections averaging in the 100 to 300 mm (4 to 12 inch) size. Over the broken and seated concrete, a leveling course was placed followed by a paving fabric system and a surface course. The edgedrains in this section of highway showed almost no response to precipitation events. This lack of response was initially thought to be due to a lack of permeability of the break and seat base or due to rock flour from the break and seat base clogging the edgedrain system. Another potential reason for no response was that the in-place paving fabric system was stopping the infiltration of precipitation water into the road base.

In 1997, the researchers returned to this site to determine why water was not draining from the pavement. In their investigation, they cored through the paving fabric system to the top of the break and seat base layer. A percolation flow test was then run by pumping water into the hole to see if it would flow to the edgedrain system. The water did flow, and the break and seat base was determined to have an AASHTO drainage capacity of "good." Therefore, since the base was drainable, the most probable reason that water was not flowing from the pavement after a rain was the paving fabric system restricting the infiltration from reaching the base layer. This, in a sense, was a large-scale field permeability test of an in-place paving fabric system. The average actual flow to the edgedrains in this pavement was less than 1 percent of precipitation, some of which could have "backed" into the edgedrain from the pavement shoulder. Any agency having such a section of pavement, with a permeable base, edgedrains, and a paving fabric interlayer system, has the necessary ingredients to run such a test to verify the barrier properties of the paving fabric system.

The results of this testing raise the interesting question of whether pavement drainage is needed if the precipitation water can be stopped before it reaches the pavement base. Most pavements to be rehabilitated do not have a free-draining base and therefore cannot be effectively drained with an edgedrain. A potential way to decrease the water in these pavement bases is to limit surface water infiltration. When a properly installed paving fabric interlayer system keeps the water away from the base, this equates to at least the good to excellent AASHTO drainage classification since there is limited water dwell time in the pavement base. Therefore, it may be possible to apply a structural credit, normally used for improved drainage, where a paving fabric system is used.

Al-Qadi, 1997 *(22)*

The final field test reported herein was done by Al-Qadi *(22)*. Here, a ground penetrating radar (GPR) system was employed to detect the presence of moisture beneath pavements with and without paving fabric membrane systems. Two roads were evaluated in Kernersville, North Carolina. Each road had sections with and without the paving fabric membrane system. The GPR antenna was built into a durable box, which was pushed along the pavement surface. Microwave signals penetrated the pavement, and the reflectance or absorption of these microwaves was monitored. The output signal was examined on site and stored for future analysis.

Changes in the amplitude of the first reflected signal were used as the criterion to determine if moisture existed below the pavement layer. When the amplitude of the first reflected signal is high, moisture presence is also high. Otherwise, the changes in the signal would be minimal and would only result from the change in dielectric properties of the pavement layers. Different color codes can be used in the output scan to enhance the reflected signals.

The results of the testing on both roads showed significantly higher moisture levels in the road base and subgrade in the sections without the paving fabric interlayer system. This GPR system shows promise as a pavement evaluation tool since, as discussed earlier, moisture in pavements is one of the most important factors in pavement service life yet it is rarely monitored or measured.

Summary of Field Evaluations

The field investigations were found to be in good general agreement with the laboratory studies. Where flows were monitored, the field results verified greater than one order of magnitude reduction in pavement permeability due to the presence of the paving fabric interlayer system. Lower moisture levels in the pavement structure were also indicated by observed strength increases in pavement support structures when a paving fabric interlayer system was used. Nondestructive ground penetrating radar technology also appears to be a useful tool and did verify lower moisture contents beneath pavements containing paving fabric interlayer systems.

CONCLUSIONS

The following conclusions are drawn based on the laboratory and field evaluations of the waterproofing effectiveness of a paving fabric interlayer system:

- Both laboratory and field pavement cores indicate that the presence of a properly installed paving fabric interlayer system reduces the permeability of a pavement by one to three orders of magnitude. By reducing the infiltration by one or more orders of magnitude, the system becomes an efficient moisture barrier to enhance pavement performance.
- In the AASHTO pavement design methodology, structural benefits, based on improved drainage, should be considered when a paving fabric interlayer system is used because reduced infiltration equates to improved drainage. Benefits can be incorporated by using larger drainage coefficients in AASHTO new pavement and rehabilitation designs.
- The moisture levels beneath the pavement layers are decreased below pavements with paving fabric interlayers. This maintains the strength of the subgrade, subbase, and base layers, limiting damage due to saturated condition pore pressures.
- To provide a continuous moisture barrier, sufficient asphalt cement tack coat quantity must be used to saturate the paving fabric and bond the interlayer system - generally about 1.04 to 1.13 liters per square meter (0.23 to 0.25 gallons per square yard). Lesser amounts of asphalt cement diminish the waterproofing effect. The tack coat must also be uniformly applied. Field installation quality control is important.
- Pavement drainage improvement is only a viable option for rehabilitation if pavement bases have a permeability greater than 1 to 10^{-1} mm/sec. When drainage improvement is not an option, placement of a paving fabric moisture barrier should be considered.

More research is needed in the area of moisture in pavements, and improved tools need to be developed for better monitoring and measurement. Meanwhile, cost-effective technology exists to create a moisture barrier in a pavement using paving fabric interlayer systems.

REFERENCES

(1) Maxim Technologies, Inc., *Nonwoven Paving Fabric Study, Final Report*, submitted to Industrial Fabrics Association International, 1997.

(2) Cedergren, H. R., *Drainage of Highway and Airfield Pavements*, John Wiley and Sons, Inc., New York, 1974.

(3) Rahman, M., T. Curtis, M. Zaman, *Field Evaluation of Drainable Bases in Oklahoma*, Report Item 2181: ORA 125-4299, Oklahoma Department of Transportation, 1996.

(4) Ridgeway, H. H., Infiltration of Water Through the Pavement Surface, *Transportation Research Record 616*, TRB, National Research Council, Washington, D.C., 1976, pp. 98-100.

(5) Ridgeway, H. H., Pavement Subsurface Drainage Systems, *National Cooperative Highway Research Program Synthesis of Highway Practice 96*, TRB, National Research Council, Washington, D.C., 1982.

(6) Lancaster, F. E., *Permeability Test Results*, Personal Communication, 1994.

(7) Jorenby, B.N, R.G. Hicks, Base Course Contamination Limits, *Transportation Research Record 1095*, TRB, National Research Council, Washington, D.C., 1986, pp. 86-101.

(8) AASHTO, *Guide for Design of Pavement Structures*, American Association of State Highway and Transportation Officials, 1993.

(9) McEnroe, B. M., Drainability of Granular Bases for Highway Pavements, *Transportation Research Record 1434*, TRB, National Research Council, Washington, D.C., 1994, pp. 23-28.

(10) Roy, M., J. Cote, J.-M. Konrad, C. Robert, *Characterization of Unsaturated Granular Bases for Drainage Consideration During Spring Thaw*, International Symposium on Thin Pavements, Surface Treatments and Unbound Roads, 1997.

(11) Koerner, R.M., G.R. Koerner, A.K. Fahim, R.F. Wilson-Fahmy, *Long-Term Performance of Geosynthetics in Drainage Applications*, NCHRP Report 367, TRB, National Research Council, Washington, D.C., 1994.

(12) American Association of State Highway and Transportation Officials, Geotextile Specification for Highway Applications, AASHTO Designation M 288-96, 1998, pp. 745-755.

(13) Bushey, R. W., *Experimental Overlay to Minimize Reflection Cracking*, FHWA/CA/TL-3167-76-28, California Department of Transportation, 1976.

(14) Guram, S.S., *Evaluation of Petromat Membrane System as a Waterproof Membrane*, Internal Communication, Phillips Fibers Corp., 1983.

(15) Smith, R. D., *Laboratory Investigation of Fabric Interlayers for Asphalt Concrete Paving (Final Report)*, FHWA/CA/TL-84-06, California Department of Transportation, 1984.

(16) Baker, T.L., *Results of Melt Through Asphalt Absorption and Permeability Tests*, Internal Communication, Amoco Fabrics and Fibers Co., 1997.

(17) Predoehl, N.H., *Evaluation of Paving Fabric Test Installations in California*, FHWA/CA/TL-90/02, California Department of Transportation, 1990.

(18) Pourkhosrow, G., *Nonwoven Polyester and Polypropylene Engineering Fabrics in Oklahoma Pavements*, Oklahoma Department of Transportation, 1985.

(19) Button, Joe W., *Overlay Construction and Performance Using Fabrics*, Paper presented at the 68th Annual Meeting of the Transportation Research Board, 1989.

(20) Sutherland, M., P. Phillips, Geotextile Reinforced Sprayed Seal Roads in Rural Australia, *Proceedings of the Fourth International Conference on Geotextiles, Geomembranes and Related Products*, A.A. Balkema, Rotterdam, 1990, pp. 209-212.

(21) Phillips, P., Long Term Performance of Geotextile Reinforced Seals to Control Shrinkage on Stabilized and Unstable Clay Bases, *Reflective Cracking of Pavements*, RILEM, 1993, pp. 406-412.

(22) Al-Qadi, I., *Petromat Evaluation in Kernersville, NC*, Communication, Virginia Polytechnic Institute with

Amoco Fabrics and Fibers, 1997.

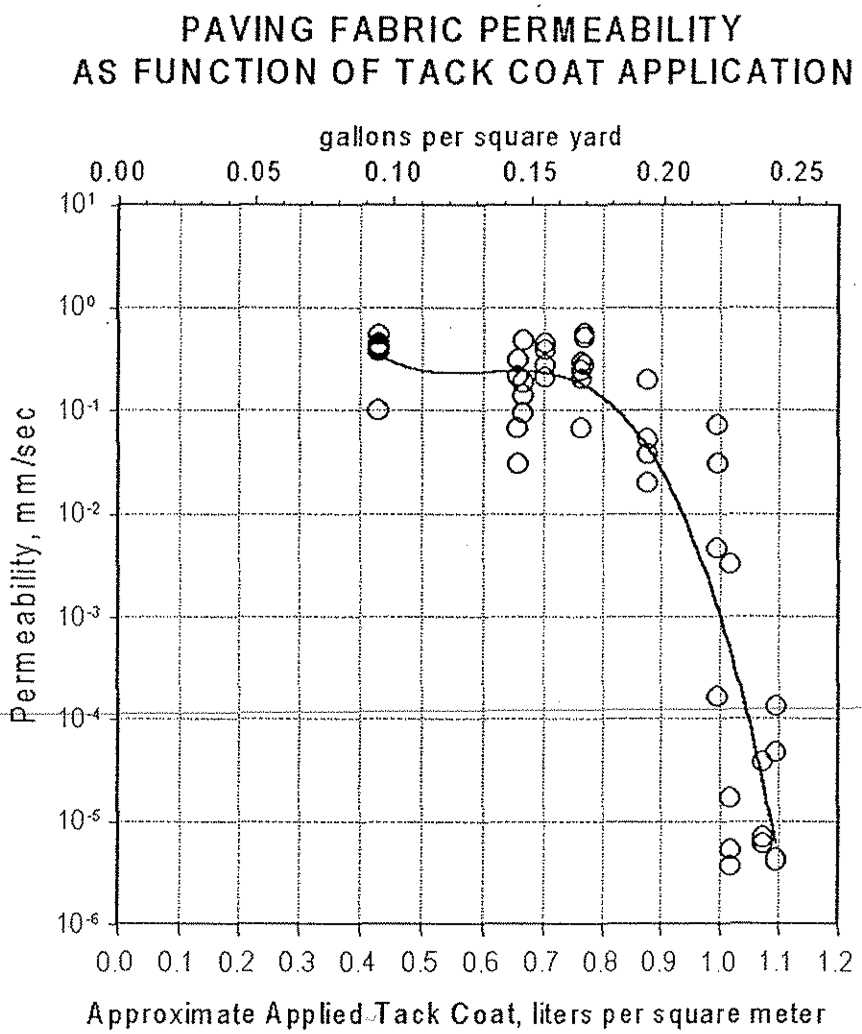

Figure 1 - Results of permeability tests on paving fabric specimens cut from melt through asphalt absorption tests. The asphalt quantity is the amount absorbed by the paving fabric plus the required 0.23 l/m2 (0.05 gal/yd2) for interlayer system bonding.

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