EIS/40/997/Geosynthetic

Crandon Mining Company

Geosynthetic Material Decision Matrices for Crandon Project Containment Facilities

Crandon Project
Crandon, Wisconsin

April 1997

Prepared by
Foth & Van Dyke
engineers · architects · scientists

Scope ID: 93C049

Crandon Mining Company

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April 30, 1997

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190 Fifth Street East
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Mr. Bill Tans
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101 South Webster Street
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Dear Mr. Ballman and Mr. Tans:

Re: Crandon Project - Geosynthetic Material Decision Matrices

In its May 30, 1996 letter to Crandon Mining Company (CMC) regarding the Crandon Project tailings management area (TMA), the U.S. Army Corps of Engineers (USCOE) requested that CMC prepare a project specific decision matrix for each geosynthetic material planned for use in the TMA, reclaim ponds, sedimentation traps, etc. Based on conversations with the USCOE, CMC understands that the development of the decision matrix will address Comments 11 through 16 of the USCOE's May 30, 1996 letter.

In response to the USCOE's request, CMC is providing the enclosed report titled *Geosynthetic Material Decision Matrices for Crandon Project Containment Facilities*. The report outlines the process to be used in the future to evaluate substitute geosynthetics for application to the TMA and other project facilities.

If you have any questions or comments on the enclosed documents, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
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Geosynthetic Material Decision Matrices for Crandon Project Containment Facilities

Scope ID: 93C049

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Prepared by
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April 1997

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Geosynthetic Material Decision Matrices for Crandon Project Containment Facilities

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1 Introduction

The proposed design for the Crandon Project tailings management area (TMA) and other project containment facilities includes several geosynthetic components. The use of geosynthetics in containment applications has progressively evolved as new products and new applications have been introduced. The pace of this evolution is such that it is very likely that some geosynthetic materials will be phased out and new materials phased in prior to the end of the proposed 28 year operating life of a facility such as the TMA. To address these potential changes, applicants, designers and many regulators desire designs that have the flexibility to incorporate improved materials in the future.

CMC proposes that decision matrices be used for future evaluation of alternative geosynthetics after the Crandon Project permitting process specifying certain geosynthetics has been completed. Alternative geosynthetics would only be allowed if they are shown to be equal to or superior to the originally specified products. The decision matrices would include material property requirements; methods of evaluating material properties including specific standard tests; and the actions to be taken based on those evaluations. The decision matrices would apply to geosynthetics used for the Crandon Project in containment applications, such as; the TMA, reclaim pond, wastewater storage basins, treated water discharge lagoons, tailings transport pipeline ditch, etc. The discussion that follow in this report is directed specifically at the project's TMA. The decision matrices and the logic presented relative to their use are directly applicable to the other project containment facilities as well.

Due to the specific considerations involved in evaluating and selecting geosynthetics for different applications, individual decision matrices for each geosynthetic material proposed for use in a containment facility (i.e., geomembrane for the liners; geomembrane for TMA cap barrier; geotextiles for cushioning, separation and filtration; geocomposites for sidewall drainage; and the geosynthetic clay liner in the composite barriers of both liners and the TMA cap) are needed. Descriptions of the proposed decision matrix for each material and a discussion of how each matrix would be applied is presented in Sections 2 through 7.

It should be noted that the discussion that follows references numerous standard methods and procedures that are currently used to test and evaluate materials of construction. Should testing methods change, the new methodology would be substituted for evaluations to be completed in accordance with the procedures outlined in the appropriate decision matrix.

2 Use of Decision Matrices

The decision matrices presented in this document are not meant to replace the specifications for geosynthetics and required installation documentation as required in the project's Construction Quality Assurance (CQA) Manual. They provide guidance on the principles on which the material selection and CQA requirements were based so that if in the future nonavailability of the currently specified material or availability of a better material makes it necessary to revise the product specifications, these can be accomplished without violating the permit conditions. For example, HDPE is proposed in the permit documents for use as a liner and TMA cap geomembrane material. If it is approved, the basis for the approval is not only the absolute values of certain physical properties of HDPE, but the fact that it is accepted as the best material for containment of most materials including the tailings and expected leachates from the TMA. Therefore, substitution of HDPE in the future should not be based solely on the physical properties of HDPE, but the intangible aspect of striving for an equal or better material from the aspects of installation and performance. On the other hand, even if a new material available in the future becomes the "best" material based on industry experience, that material would also have to meet certain of the physical properties of HDPE, the material currently proposed. This is because the permitting process quantitatively evaluates the performance of the proposed system. Changes in material properties which adversely affect those quantitative evaluations cannot be accepted within the bounds of the permit.

During the evaluation of an alternate material using the decision matrix, any conflicts that arise should be resolved using the conditions in the CQA manual rather than the decision matrices because the CQA manual is based on the geosynthetic materials selected for the project facilities.

3 Liner Geomembrane

The May 1995 Crandon Project TMA Feasibility Report (Foth & Van Dyke, 1995) and subsequent addenda (Foth & Van Dyke, 1996a and b, and 1997), hereafter collectively referred to as the Feasibility Report, discuss both design principles and methods, and identifies high density polyethylene (HDPE) as best suited for use in the TMA base liner. Figure 1 presents a decision matrix that can be employed at any future date to evaluate and select an alternative geomembrane for use in the base liner.

The matrix has four columns. The extreme left column contains the design/performance requirements which are based on the design computations presented in the Feasibility Report. The second column describes the methods for evaluating the alternative material. The third column illustrates the decision process. The fourth column indicates the action to be taken based on the material evaluations and subsequent decision process. A detailed discussion describing how the matrix is applied to a material for each design/performance requirement follows.

3.1 Chemical Compatibility

The geomembrane base liner decision matrix (Figure 1) includes two design/performance requirements. The first relates to geomembrane compatibility with tailings and leachate. The second relates to the longevity of the geomembrane. Each is discussed below.

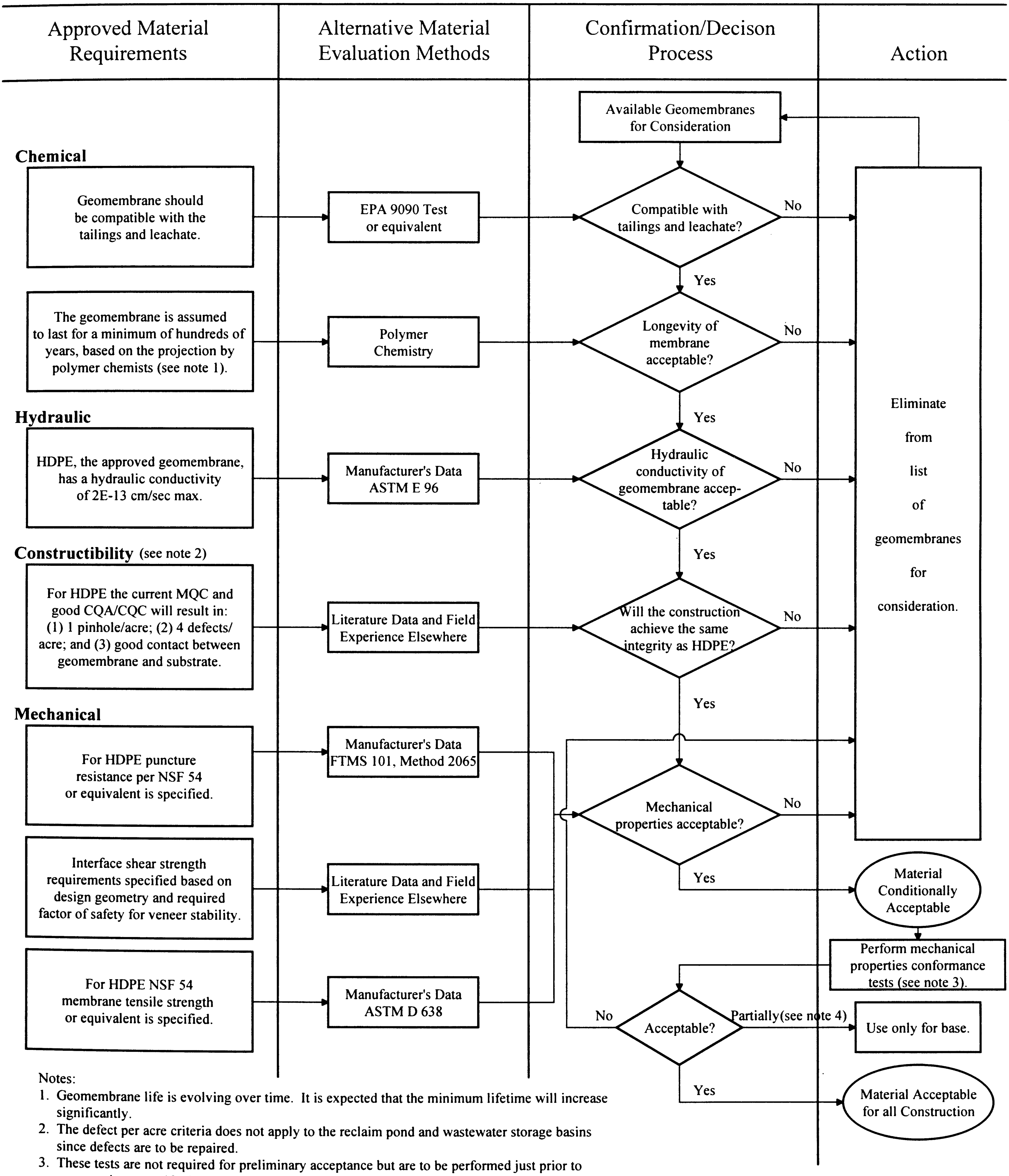
3.1.1 Compatibility

One of the primary requirements for geomembranes in liner applications is chemical compatibility with the materials they come in contact with. In the case of the Crandon Project TMA, the liner will be in contact with the geosynthetic clay liner (GCL) below and the drainage medium (processed till, sand, or a geocomposite) above.

The liner will also come in contact with mine water before the start of tailings deposition, and after with process water and/or leachate as the process water and the tailings react. The leachate could include lower pH conditions. In view of the above, compatibility needs to be established between the geomembrane and the liquids described.

EPA's 9090 test is the current standard compatibility test for geomembranes. To assess compatibility, the evaluation of an alternative geomembrane would be accomplished by the EPA 9090 test, or equivalent, using both process water and a manufactured leachate with characteristics as defined by the TMA source term characterization work. If the EPA 9090 test shows that statistically significant changes in wide width tensile strength and water vapor transmission do not exceed 10 percent, the material will be considered to be compatible with the tailings and leachate, and the analysis will continue to the next step. If the material is determined to be incompatible, it will be eliminated from further consideration.

Figure 1
Crandon Project
Decision Matrix for Geomembrane Application for Base Liners



Notes:
1. Geomembrane life is evolving over time. It is expected that the minimum lifetime will increase significantly.
2. The defect per acre criteria does not apply to the reclaim pond and wastewater storage basins since defects are to be repaired.
3. These tests are not required for preliminary acceptance but are to be performed just prior to construction to verify that the material meets the design requirements.
4. Passes mechanical properties conformance tests except for interface shear test.

3.1.2 Longevity

When disposed of as a waste material in landfills, plastics are considered indestructible and permanent without the possibility of deterioration. When plastics are used as liners for containment purposes, their longevity is at times questioned. Based on the December 1996 report prepared by GeoSyntec Consultants of Boca Raton, Florida, titled *Assessment of Long-Term Performance of the Proposed HDPE Geomembrane Liner and Cap at the Crandon Project TMA Facility* (GeoSyntec, 1996), ". . . the HDPE geomembrane liner and cap at the TMA facility should function as designed for a very long time (e.g., hundreds of years) without deterioration in performance."

If an alternative geomembrane is considered in the future as a substitute for the currently specified material (HDPE) and polymer chemists estimate its lifespan will meet the lifespans for materials available at the time of evaluation, it will be deemed to meet the longevity design/performance requirements.

3.2 Hydraulic Conductivity

In the water balance computations discussed in the TMA Feasibility Report, the geomembrane hydraulic conductivity used corresponds to that of HDPE. Even though minor changes in the hydraulic conductivity of the geomembrane, normally estimated from water vapor transmission tests (ASTM E96), will not change the computed percolation from the site significantly, the decision matrix specifies that the maximum allowable hydraulic conductivity for alternative geomembranes will be $2x10^{-13}$ cm/sec as estimated based on the ASTM E96 water vapor transmission test, or equivalent.

3.3 Constructibility

Constructibility issues are important to geomembrane performance, but are critical only if the construction practices impact the quantitative results used in the design and evaluation of the system containing the geomembranes. Therefore a substitute geomembrane would be acceptable from a constructibility standpoint if it can be installed to the same degree of integrity as HDPE. This qualitative comparison will be largely based on experience in the field elsewhere. Other issues to be considered in this regard are ease of installation and ability to weld, including to previously placed HDPE, in a timely fashion.

3.4 Mechanical Properties

3.4.1 Required Properties for an Alternative Geomembrane

The relevant geomembrane mechanical properties when considering an alternative material are tensile strength, puncture resistance, and interface shear strength characteristics. The tensile strength and puncture resistance properties described in the NSF 54 specifications (NSF, 1993) for an HDPE 60 mil liner have been specified in the TMA design presented in the Feasibility Report and will be the minimum acceptable values for an alternative geomembrane.

Interface shear strength is an important parameter to verify stability of the cover soils (soil veneer) during the operation period of the TMA. The friction angle value specified (a minimum 21.2°) in Appendix C of Addendum No. 3 to the Feasibility Report (Foth & Van Dyke, 1997) is for the loading conditions anticipated in the field without any excess pore water pressure considered (i.e., total stress strength parameter). Interface shear strength values for an alternative geomembrane that are less than that specified will result in a factor of safety smaller than the design factor of safety and will not be considered as acceptable.

3.4.2 Verification of Properties for an Alternative Geomembrane

The acceptability of an alternative geomembrane will be evaluated as follows. For tensile properties and puncture resistance, manufacturers' data will be compared to NSF 54 specifications (NSF, 1993) to determine preliminary acceptability of the alternative material. Standardization of testing methods and the awareness of the strict QA/QC procedures which occur during construction, plus efforts by geosynthetic societies and trade organizations have established the credibility of material properties published by manufacturers. Therefore, manufacturers' data are sufficient and appropriate for preliminary acceptance of an alternative geomembrane. However, during the construction stage, the QA/QC procedures outlined in Appendix A of Addendum No. 3 to the Feasibility Report (Foth & Van Dyke, 1997) require that manufacturers' QC test data be obtained for each roll of material. In addition, the procedures outlined in Appendix A also require conformance testing (ASTM D 638 as modified by NSF 54 Appendix A for tensile properties and FTMS 101C, Method 2065 for puncture resistance) on a specified number of rolls. These procedures will assist in verifying that the material in the field meets the design requirements.

In the case of interface strength, there is a slight difference in the proposed procedure. The required strength properties for the HDPE liner and GCL interface specified in the Feasibility Report were arrived at based on facility geometry, the required factor of safety, and a total stress analysis. The interface strength, then, must be obtained as a total stress strength parameter, i.e., using a test which simulates the most critical loading condition in the field. For the soil veneer stability over the base liner of the TMA along the lower interface between the geomembrane and the GCL, the most critical loading condition is a slow rate of shear with drainage permitted after the GCL is saturated. Therefore, the test performed should be a direct shear box test at a very low rate of displacement and under saturated conditions.

For evaluating failure potential along the upper interface, i.e., between the geomembrane and the cushioning geotextile or the geomembrane and the geocomposite, a similar test can be performed with the GCL being replaced by the geocomposite or geotextile. Since excess pore water pressures are not likely to develop, the total and effective stress shear tests and analyses will be exactly the same. The stability of the soil veneer under extreme conditions of rainfall which could lead to the development of steady flow parallel to the slope and ultimately to erosion, will be managed through repairing the erosion occurrences.

During the placement of cover soils on the sideslope, very little movement will occur along the interfaces, if at all. This is because the construction specifications will require oversight of soil placement, prevention of pushing more than 1 ft of soil ahead of the low ground pressure machinery that will be used, and avoiding large braking forces. Thus, the peak strength (along the interface) will be the appropriate total stress strength. However, to be conservative, especially for the lower interface, the residual strength available in published literature/field experience will be used for preliminary selection.

Before construction starts, it is anticipated that a pre-construction report will be prepared. By that time, the availability and acceptability of the materials would have been finally evaluated and a final selection made, not only of the geomembrane, but also of the materials which form the critical interfaces. Therefore, interface shear tests (ASTM D 5321, or equivalent) will be performed prior to installation at the rate of one test per 400,000 square feet of geomembrane expected to be installed on the sideslopes. The tests will be conducted on the interfaces (both above and below the membrane) under saturated conditions with drainage permitted (low rates of displacement). These tests will be run to large strains to obtain residual strengths. If the interface strength values from these tests (residual strengths) do not meet the design requirements, the alternative geomembrane will be rejected. If they meet the requirements, the material will be accepted for use in TMA construction.

3.5 Summary

In summary, the decision matrix in Figure 1 illustrates how CMC would proceed to evaluate a material other than HDPE as an alternative geomembrane liner. Chemical, hydraulic, and mechanical requirements of the geomembrane design will be evaluated for the proposed alternative material against the criteria established above. Installation requirements the alternative material will need to meet include compatibility with the previously installed geomembrane to which the alternative material may have to be welded, potential installation defects, etc. Unquantifiable features which facilitate an easier installation may be considered based on engineering judgement, but only if the other requirements as shown on the decision matrix are met first.

4 Final Cover Geomembrane

The Feasibility Report discusses both design principles and methods, and identifies high density polyethylene (HDPE) as best suited for use in the TMA final cover. Figure 2 presents a decision matrix that can be employed at any future date to evaluate and select an alternative geomembrane for use in the final cover.

The matrix has four columns. The extreme left column contains the design/performance requirements which are based on the design computations presented in the Feasibility Report. The second column describes the methods for evaluating the alternative material. The third column illustrates the decision process. The fourth column indicates the action to be taken based on the material evaluations and subsequent decision process. A detailed discussion describing how the matrix is applied to a material for each design/performance requirement follows.

4.1 Environmental Factors

For the TMA, the shallow final cover slopes eliminate design concerns associated with the stability against failure along the interface of the geomembrane and the adjacent layers above and below. However, the following three environmental factors need to be considered qualitatively while selecting a suitable geomembrane for final cover applications.

- Temperature variations;
- Penetration by plant roots;
- Burrowing animals.

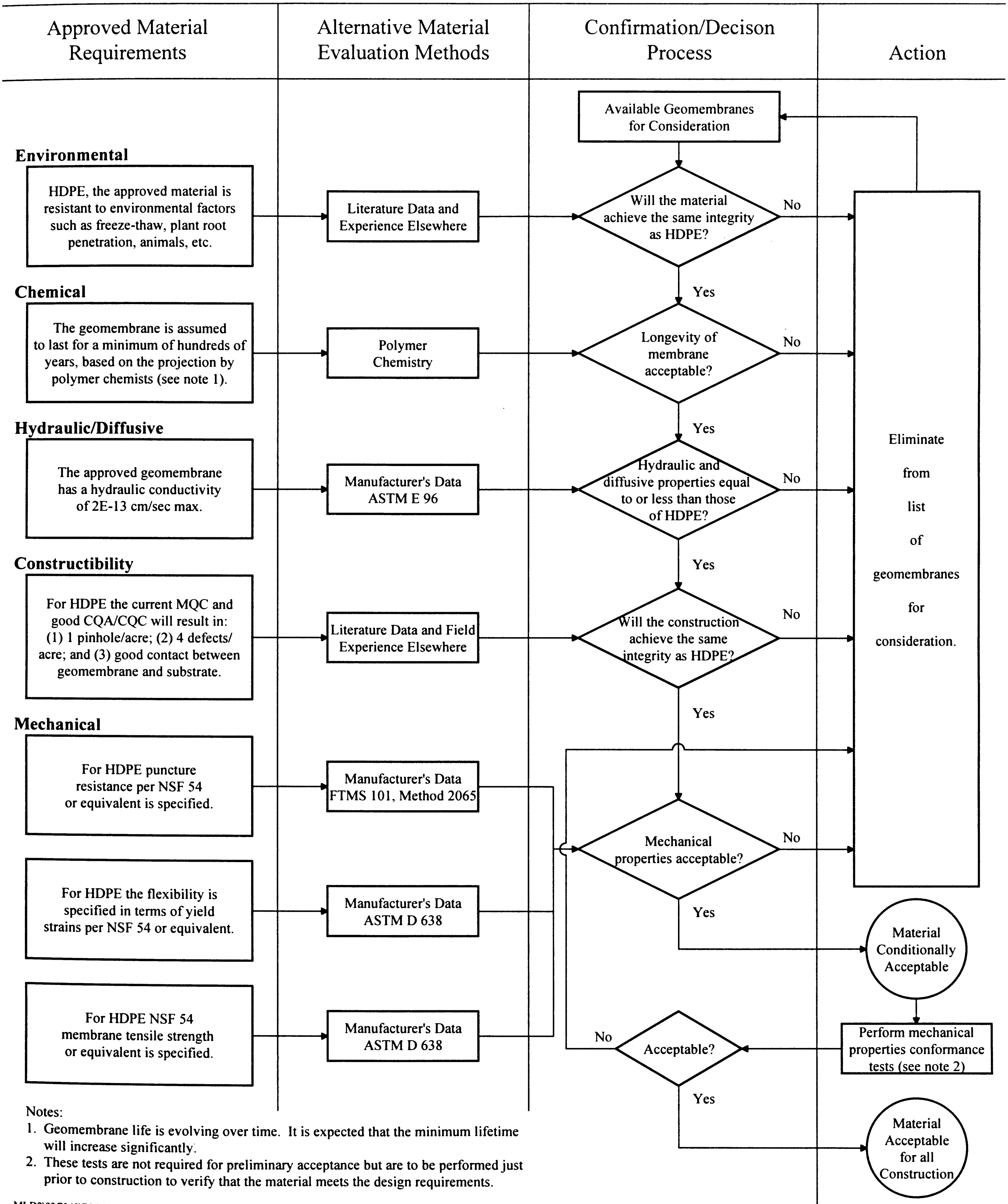
These factors have been accounted for in the TMA design by providing a thick soil cover over the geomembrane. Since HDPE is the selected membrane for the cover, any alternative geomembrane should have equal or better performance under the environmental conditions cited.

4.2 Chemical Compatibility

When disposed of as a waste material in landfills, plastics are considered indestructible and permanent without the possibility of deterioration. When plastics are used as liners for containment purposes, their longevity is at times questioned. Based on the December 1996 report prepared by GeoSyntec Consultants of Boca Raton, Florida, titled *Assessment of Long-Term Performance of the Proposed HDPE Geomembrane Liner and Cap at the Crandon Project TMA Facility* (GeoSyntec, 1996), ". . . the HDPE geomembrane liner and cap at the TMA facility should function as designed for a very long time (e.g., hundreds of years) without deterioration in performance."

If an alternative geomembrane is considered in the future as a substitute for the currently specified material (HDPE) and polymer chemists estimate its lifespan will meet the lifespans for materials available at the time of evaluation, it will be deemed to meet the longevity design/performance requirements.

Figure 2
Crandon Project
Decision Matrix for Geomembrane Application for Final Covers



Notes:
1. Geomembrane life is evolving over time. It is expected that the minimum lifetime will increase significantly.
2. These tests are not required for preliminary acceptance but are to be performed just prior to construction to verify that the material meets the design requirements.

MLD2\93C049\DM-FIG-2.FLO 4/23/97

4.3 Hydraulic Conductivity and Diffusion Coefficient

In the water balance computations discussed in the TMA Feasibility Report, the geomembrane hydraulic conductivity used corresponds to that of HDPE. Even though minor changes in the hydraulic conductivity of the geomembrane, normally estimated from water vapor transmission tests (ASTM E 96), will not change the computed percolation from the site significantly, the decision matrix specifies that the maximum allowable hydraulic conductivity for alternative geomembranes will be 2×10^{-13} cm/sec as estimated based on the ASTM E 96 water vapor transmission test, or equivalent.

An oxygen transport model (SRK, 1997) was used to evaluate the potential for oxygen movement through the final cover and into the tailings. In this study, a diffusion coefficient corresponding to that of HDPE was used. Therefore, any alternative material being considered should have a diffusion coefficient equal to or less than that of HDPE.

4.4 Constructibility

Constructibility issues are important to geomembrane performance, but are critical only if the construction practices impact the quantitative results used in the design and evaluation of the system containing the geomembranes. Therefore a substitute geomembrane would be acceptable from a constructibility standpoint if it can be installed to the same degree of integrity as HDPE. This qualitative comparison will be largely based on experience in the field elsewhere. Other issues to be considered in this regard are ease of installation and ability to weld, including to previously placed HDPE, in a timely fashion.

4.5 Mechanical Properties

4.5.1 Required Properties for an Alternative Geomembrane

Even though the mechanical properties of the geomembrane in the final cover system are not required to resist any anticipated mechanical stresses or strains, CMC has specified the same puncture resistance as the HDPE geomembrane currently proposed. The same logic has been used for the tensile properties namely tensile strength and yield strain. Therefore, the alternative material must meet the mechanical properties listed in the NSF 54 specifications (NSF, 1993) corresponding to HDPE.

4.5.2 Verification of Properties for an Alternative Geomembrane

The acceptability of an alternative geomembrane will be evaluated as follows. For tensile properties and puncture resistance, manufacturers' data will be used to determine preliminary acceptance of the alternative material. Standardization of testing methods and the awareness of the strict QA/QC procedures which occur during construction, plus efforts by geosynthetic societies and trade organizations have established the credibility of material properties published by manufacturers. Therefore, manufacturers' data are sufficient and appropriate for preliminary acceptance of an alternative geomembrane. However, during the construction stage, the QA/QC procedures outlined in Appendix A of Addendum No. 3 to the Feasibility Report (Foth & Van Dyke, 1997) require that manufacturers' QC test data be obtained for each roll of material. In addition, the procedures outlined in Appendix A also require conformance testing (ASTM D 638 as modified by NSF 54 Appendix A for tensile properties and FTMS 101C, Method 2065 for puncture resistance) on a specified number of rolls. These procedures will assist in verifying that the material in the field meets the design requirements. Normally, geomembranes which are more flexible than HDPE are characterized by lower break strength. Since for the final cover flexibility is more important, the break strength of an alternative material may be less than that of HDPE by up to 20 percent.

4.6 Summary

In summary, the decision matrix in Figure 2 illustrates how CMC would proceed to evaluate a material other than HDPE as an alternative geomembrane for the final cover application. Environmental, chemical, hydraulic/diffusive, and mechanical requirements of the geomembrane design will be evaluated for the proposed alternative material against the criteria established above. Installation requirements the alternative material will need to meet include compatibility with the previously installed geomembrane to which the alternative material may have to be welded, potential installation defects, etc. Unquantifiable features which facilitate an easier installation may be considered acceptable based on engineering judgement, but only if the other requirements as shown on the decision matrix are met first.

5 Geotextiles for Cushioning and Separation

The Feasibility Report discusses both design principles and methods for geotextiles used for cushioning and for separation. Geotextiles for cushioning are proposed for the base of all TMA cells, and the sideslopes of Stages II, IV, VI, and VIII. Geotextiles for separation are proposed between the granular drainage layer and the soil above, for the liner system at the base of the TMA.

For cushioning geotextiles, a 12 oz/sy non-woven needle punched geotextile will be used, unless field testing to document the acceptability of a lesser weight material is completed. A class 2 geotextile per AASHTO M 288-96 (AASHTO, 1995) is considered appropriate. For separation, a class 2 geotextile meeting the requirements of Table 3 of AASHTO M 288-96 is specified.

Figure 3 presents a decision matrix that can be employed at any future date to evaluate and select an alternative geotextile(s) for use as a cushioning geotextile or for separation.

5.1 Durability of Polymers

Polypropylene geotextiles are considered as the primary geotextile for application at the TMA site although polyester is also acceptable. The durability of the geotextile in the liner system is a desirable feature at least until the time when the percolation from the TMA becomes insignificant and equal to that through the cap. This time is less than the 40-year post-closure monitoring period. Because experience has shown that geotextiles will last for longer than such a design life, no quantitative estimates are deemed necessary. However, any alternative material will be acceptable only if the durability of the geotextile is comparable to that of polypropylene or polyester.

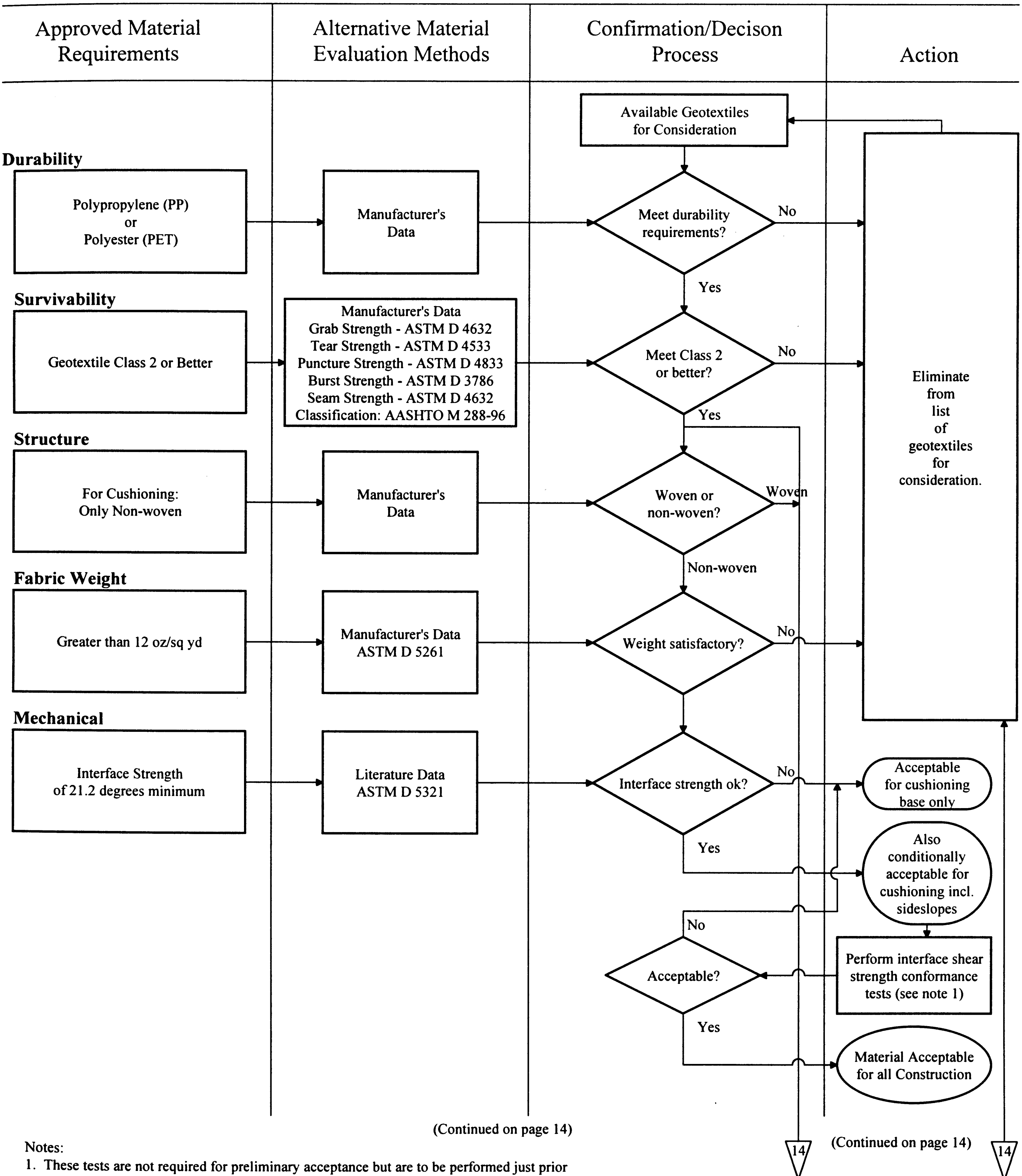
5.2 Survivability

All geotextiles, regardless of their application need to be specified with survivability requirements. AASHTO M 288-96 (1995) has provided geotextile classes depending on the severity of installation conditions. For TMA applications, the installation conditions are not considered harsh and a Class 2 classification is considered appropriate. Any alternative geotextile used for either cushioning or for separation at the TMA will have to meet AASHTO 288-96, Class 2 requirements or equivalent.

5.3 Structure and Fabric Weight

Geotextiles are produced as either woven or non-woven products. For cushioning purposes only, woven geotextiles will be acceptable. For filtration and separation, either woven or non-woven geotextiles will be acceptable.

Figure 3
Crandon Project
Decision Matrix for Geotextile Applications



(Continued on page 14)

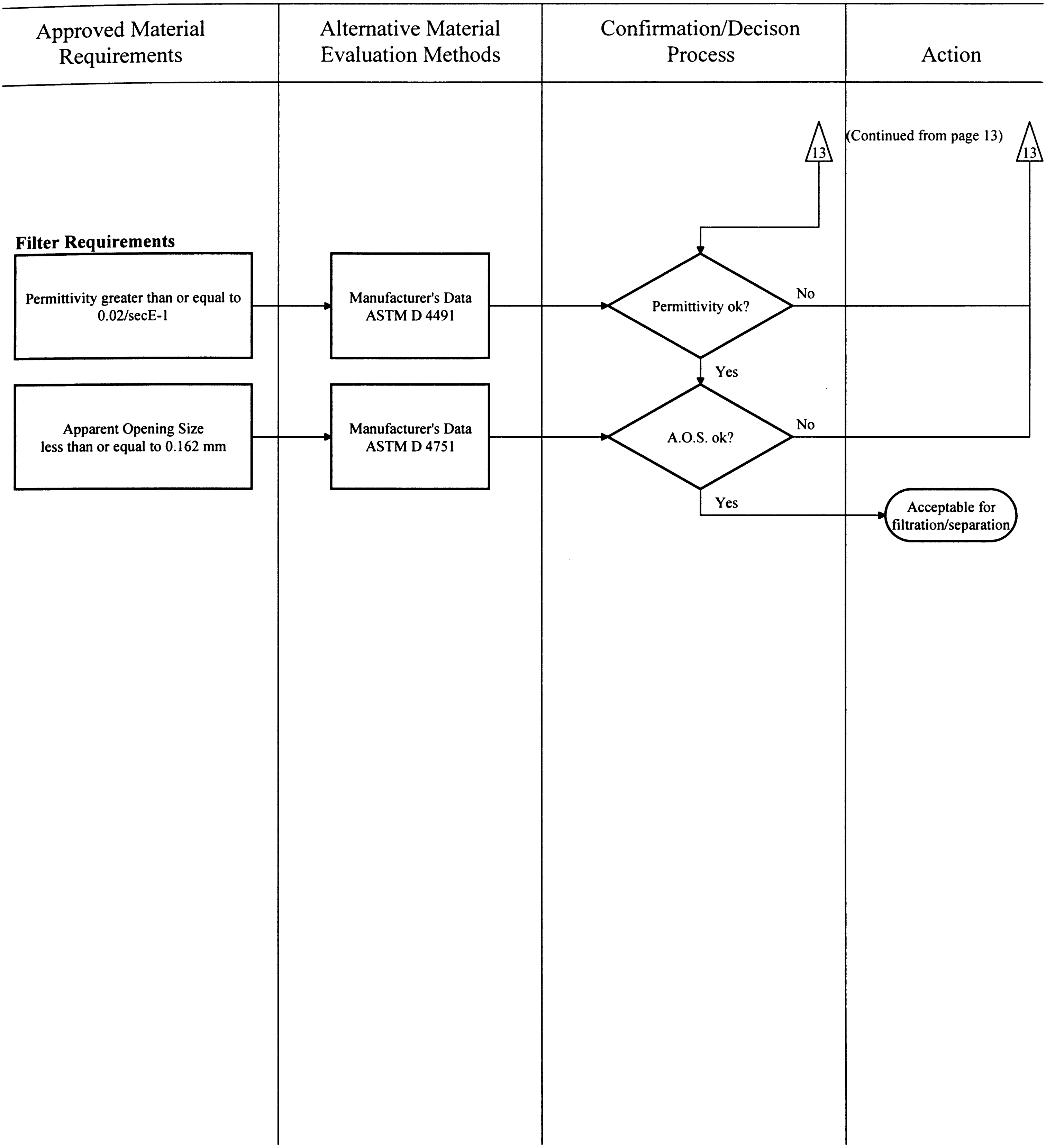
(Continued on page 14)

Notes:

1. These tests are not required for preliminary acceptance but are to be performed just prior to construction to verify that the material meets the design requirements.

MLD2\93C049\DM-FIG-3.FLO 4/23/97

Figure 3 *(Continued)*



MLD2\93C049\DM-FIG-3.FLO 4/23/97

For cushioning geotextiles a minimum mass per unit area of 12 oz/sy will be used unless field testing to document the acceptability of a lesser weight material is completed. For such a field test, geomembrane overlain with the 6 oz/sy cushioning geotextile and the protective cover soils would be subjected to loads from actual construction equipment to simulate construction stresses. The geomembrane would then be exhumed and tested to see if the break strength is reduced by more than 10% (ASTM D 638 as modified by NSF 54 Appendix A, or equivalent). If the reduction is less than 10% the 6 oz/sy geotextile would be considered acceptable. If the reduction exceeds 10%, additional geotextile cushioning (e.g., 8 oz/sy or 10 oz/sy) would be used and a second field test would be conducted.

5.4 Mechanical Properties

The cushioning geotextile used in the second stages of the TMA will create potential planes of failure along the interfaces both above and below the geotextile. The interface below is with the geomembrane and that above is with the till layer. Since the stability of the cover soils on the sideslopes is predicated upon the weakest plane and since the design of the TMA components is based on a desired factor of safety, it is necessary that both interfaces discussed above have a minimum friction angle of 21.2°. If this value cannot be met by an alternate geotextile, the alternative material cannot be used for the sideslopes and its consideration will be limited to the TMA base application.

5.5 Filter Requirements

Geotextiles used for separation must have permittivity greater than that of the soil or a minimum value equal to a default value of 0.02 sec^{-1}. The permittivity of the 2-ft thick drainage layers of the TMA liner equals 0.005 sec^{-1}. The permittivity of the drainage layer in the cap is equal to 0.01 sec^{-1}. Therefore, the specification adopted from AASHTO M 288-96 (1995) is a minimum permittivity of 0.02 sec^{-1}. Any alternative material being considered should meet the two above criteria. If AASHTO M 288-96 is revised or an equivalent specification is made available, the revised or new specification will govern.

The required apparent opening size (AOS) for geotextiles used for separation is obtained based on filter criteria applied to the base soil (the till overlying the drainage layer). This value has been preliminarily determined for the base liner application as 0.162 mm. The preliminary value for the final cover application is also similar. AASHTO M 288-96 (1995) specifies AOS to be less than 0.60 mm. Therefore, 0.162 mm (maximum) will govern.

5.6 Verification of Properties

To verify the needed properties of the geotextiles, i.e., survivability, the interface shear strength characteristics and the filter requirements, the standard test methods and the minimum acceptable factors of safety to be used by the manufacturer, engineer, and CQA personnel are presented in Table 5-1.

Table 5-1

Geotextile Test Methods and Required Values

		Measured Elongation <50%	Measured Elongation ≥50%
Grab Strength	ASTM D 4632	1100 N (247 lb)	700 N (158 lb)
Sewn Seam Strength	ASTM D 4632	990 N (223 lb)	630 N (142 lb)
Tear Strength	ASTM D 4533	400 N (90 lb)	250 N (56 lb)
Puncture Strength	ASTM D 4833	400 N (90 lb)	250 N (56 lb)
Burst Strength	ASTM D 3786	2700 N (608 lb)	1300 N (293 lb)
Cushioning Geotextile			
Mass per unit area	ASTM D 5261	12 oz/sy	
Interface shear strength	ASTM D 5321	21.2° min	
Separation Geotextile			
Permittivity	ASTM D 4491	0.02 sec^{-1} min	
Apparent opening size	ASTM D 4751	0.162 mm max	

Prepared by: NXP
Checked by: REM

6 Geocomposites for Stage I Sideslopes

The Feasibility Report discusses both design principles and methods for the geocomposite used for sideslope drainage in the first stages of the TMA. The proposed geocomposite consists of a geonet with geotextiles laminated to it on both sides.

The geotextiles used for the geocomposite do not need to meet the survivability requirements for geotextiles proposed for other uses (see Section 5.2) since the lamination takes place in the factory and the geotextiles are not subjected to severe stresses. The geotextiles used for the geocomposites need to meet the interface strength requirements and the permittivity requirements outlined in Sections 5.4 and 5.5, respectively. The permittivity requirements are important for the upper geotextile only. The geonet in almost all available geocomposites is made of polyethylene polymer. The geocomposite must meet the transmissivity (in-plane flow rate) requirements for the proposed design which is a minimum 0.97 gal/min/ft at a hydraulic gradient of 0.1 and a pressure of 14.5 psi.

Figure 4 presents a decision matrix that can be employed at any future date to evaluate the selection of an alternative geocomposite for sideslope drainage of the first phases of the TMA.

6.1 Geocomposite Construction

The geonet of the geocomposite will be HDPE and the geotextiles laminated to it either polypropylene or polyester. These materials are believed to possess a design life far exceeding the design requirements of the sideslope drainage system of the TMA. Note that HELP model analyses (Foth & Van Dyke, 1997) show that the drainage in the geocomposite layer drops off to insignificant values within 10 years after TMA cell closure. Any alternative geocomposite being considered for use should have similar life expectancy.

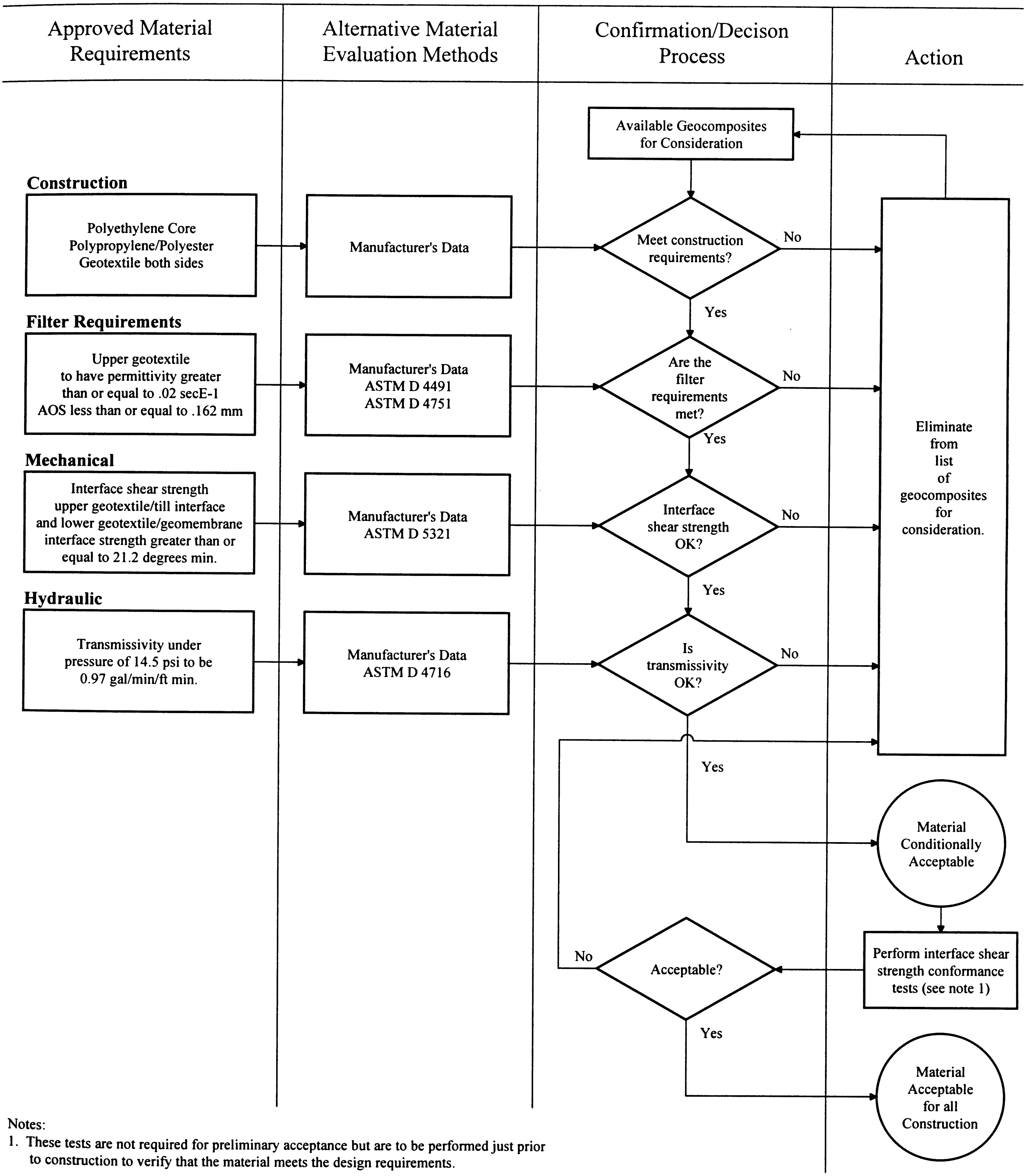
6.2 Filter Requirements

Since the upper geotextile of the geocomposite will act as a separation layer between the till and the geonet, the required properties and the methods of verification for any alternative material being considered should meet the conditions listed in Section 5.5 for the geotextile decision matrix.

6.3 Mechanical Properties

The geocomposite used on the sideslopes of the first stages of the TMA will create potential planes of failure along the interfaces both above and below the geocomposite. The interface below will be with the geomembrane and that above is with the till layer. Since the stability of the cover soils on the sideslopes is predicated on the weakest plane and since the design of the TMA components is based on a desired factor of safety, it is necessary that both interfaces discussed above possess a minimum friction angle of 21.2°.

Figure 4
Crandon Project
Decision Matrix for Geocomposite Applications



Notes:
1. These tests are not required for preliminary acceptance but are to be performed just prior to construction to verify that the material meets the design requirements.

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6.4 Hydraulic Properties

The in-plane flow rate or transmissivity of the geocomposite as proposed for the TMA is a minimum 0.97 gal/min/ft at a hydraulic gradient of 0.1 and a pressure of 14.5 psi. Any alternative geocomposite under consideration must possess similar or larger transmissivity.

6.5 Verification of Properties

To verify the needed properties of the geocomposite, i.e., permittivity and apparent opening size of the upper geotextile, the interface shear strength characteristics and the transmissivity of the geocomposite, the standard test methods and the minimum acceptable factors of safety to be used by the manufacturer, engineer, and CQA personnel are presented in Table 6-1.

Table 6-1

Geocomposite Test Methods and Required Values

Upper Geotextile		
Permittivity	ASTM D 4491	0.02 sec^{-1} min
Apparent Opening Size	ASTM D 4751	0.162 mm max
Interface Shear Strength with Till	ASTM D 5321	21.2° min
Lower Geotextile		
Interface Shear Strength with Geomembrane	ASTM D 5321	21.2° min
Transmissivity of Geocomposite	ASTM D 4716	min 0.97 gal/min/ft at a hydraulic gradient of 0.1 and at a pressure of 14.5 psi

Prepared by: NXP
Checked by: REM

7 Geosynthetic Clay Liner

The Feasibility Report discusses both design principles and methods and identifies a geosynthetic clay liner (GCL) as the soil component of the composite hydraulic barriers of both the liner and final cover systems of the TMA. The GCL identified will have sodium bentonite sandwiched between a woven or non-woven lower geotextile and non-woven upper geotextile and needle punched such that the internal shear strengths are high. As a natural mineral, bentonite is considered to have unlimited durability if it is chemically compatible with the leachate expected to be produced in the TMA. The geotextiles do not play a role in the performance of the GCL after the TMAs are filled with the tailings.

Figure 5 presents a decision matrix that can be employed at any future date to evaluate and select an alternative geosynthetic clay liner for use at the site.

7.1 Structure

The GCL chosen consists of bentonite sandwiched between non-woven geotextiles and subsequently needle punched. Needle punching increases the internal shear strength of the GCL. The non-woven geotextiles also result in increased interface shear strength. Because of these features, any alternative GCLs considered should also have the same structure.

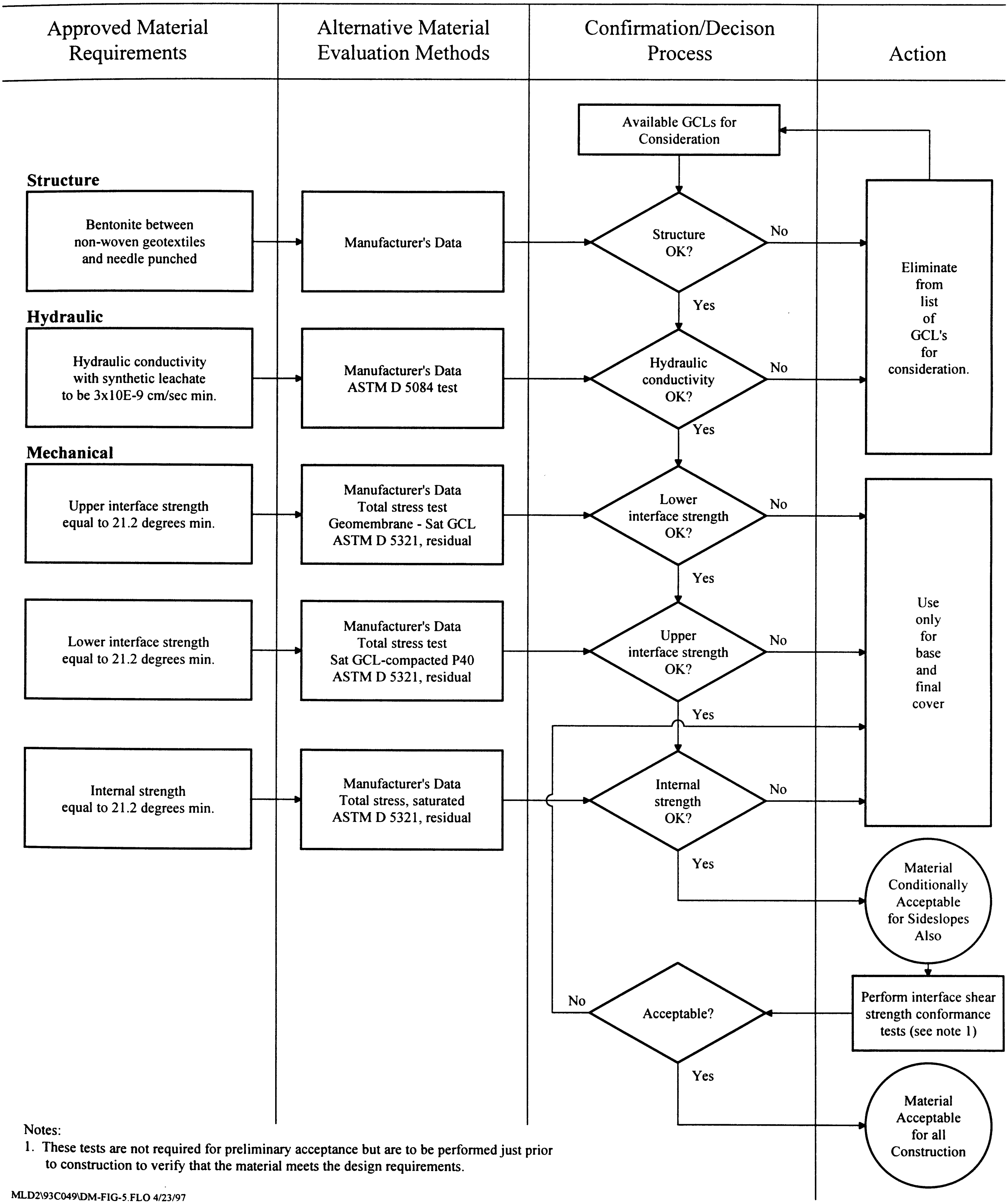
7.2 Hydraulic Conductivity

The most important property of the GCL for the TMA application is its low hydraulic conductivity. A GCL with a maximum design hydraulic conductivity of $3x10^{-9}$ cm/sec was specified in the Feasibility Report. As tested using methods in ASTM D 5084, the resulting hydraulic conductivity of an alternate GCL should not be more than $3x10^{-9}$ cm/sec at a confirming stress of 5 psi and a head pressure of 2 psi. The hydraulic conductivity is normally predicated upon the GCL being initially hydrated by water unless the permeant and the bentonite are incompatible. Therefore, one of the design requirements for the GCL to be used for the TMA is that the bentonite be compatible with the leachate expected to be produced in the TMA. The permeant used in the test should therefore be a synthetic leachate specifically prepared to represent the leachate likely to be produced at the site. Characteristics of the site's anticipated leachate are provided in the Feasibility Report.

7.3 Mechanical Properties

The GCL creates two interfaces, one between the lower geotextile of the GCL and the underlying P40 till layer, and the second between the upper geotextile and the geomembrane overlying it. These interfaces need to have shear strengths (residual) equal to or higher than 21.2°, the value determined to be required to obtain the design factor of safety of the cover soils over the sideslopes of the TMA. For the interface between the lower geotextile of the GCL and the underlying P40 till material, the total stress strength parameter is to be obtained from a direct shear test (ASTM D 5321) with the P40 till material compacted wet of optimum but not saturated

Figure 5
Crandon Project
Decision Matrix for GCL Applications



Notes:

1. These tests are not required for preliminary acceptance but are to be performed just prior to construction to verify that the material meets the design requirements.

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prior to the slow rate of shear displacement. The second interface, i.e., between the GCL and the geomembrane, is discussed in Section 3.4.2 for the base liner geomembrane decision matrix.

The internal shear strength of the GCL is also an important parameter. Since the GCL will be forming a plane surface, a potential failure plane could be created. Since the currently available research data appear to show that in the range of normal stresses expected to be present along the TMA sideslopes, the total stress strength parameter can be represented by a friction parameter. Therefore, the internal shear strength (residual) of the GCL has also been specified as a minimum of 21.2°.

7.4 Verification of Properties

The hydraulic conductivity of an alternative GCL should be determined using the hydraulic conductivity test specified in ASTM D 5084 using the synthetic leachate representing the site leachate as the permeant. The site interface shear characteristics must be determined using a slow direct shear test machine. Details relating to the tests for the GCL geomembrane interface are discussed in Section 3.4.2 for the base liner geomembrane decision matrix.

For the interface between the P40 till soil and the lower geotextile of the GCL, the till should be compacted to the field density specifications (wettest permissible moisture content and lowest permissible densities) and the test run at a very slow rate of displacement to represent field conditions. The total strength should be represented as a friction parameter since the failure surface is pre-determined in the field. If a GCL does not pass the interface shear test, its application will be limited to the base and final cover.

8 References

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