Carmen Johnson
44-01 3/20/12

RESPONSE TO REVIEW COMMENTS

LANDFILL NO. 6, AREA A

CHAMPION INTERNATIONAL CORPORATION

CANTON, NORTH CAROLINA

SEPTEMBER 1990

PREPARED BY:

SIRRINE ENVIRONMENTAL CONSULTANTS
GREENVILLE, SOUTH CAROLINA

TABLE OF CONTENTS

REVIEW COMMENTS	PAGE NO.
REVIEW COMMENT #1	1
REVIEW COMMENT #2	5
REVIEW COMMENT #3	7
REVIEW COMMENT #4	9
REVIEW COMMENT #5	12
REVIEW COMMENT #6	16
REVIEW COMMENT #7	19

FIGURES

PRIOR TO DEVELOPMENT	13
CELL I DEVELOPMENT	14
CELL II DEVELOPMENT TYPICAL FOR CELLS III AND IV	15
CONSTRUCTION PHASE RUNOFF COLLECTION	17
UNCONTAMINATED RUNOFF DRAINAGE DETAIL	18

APPENDICES

APPENDIX A - CHEMICAL RESISTANCE

APPENDIX B - DESIGN CALCULATIONS

APPENDIX C - SPECIFICATIONS

1) Selection of materials for the liner system, leachate collection and removal system, underdrain, etc., is based upon an engineering evaluation of required material properties. Criteria and justification for material selection of system components shall be described in the application.

The materials selected for each component of the liner, leachate collection, and underdrain systems were based on several criteria which included strength, flexibility, and chemical resistance. High density polyethylene (HDPE) is the material of choice for the synthetic membrane liner, the drainage net, the leachate collection system piping, the underdrain system piping, and the storm drain piping. HDPE is resistance to a wide range of different chemicals including acids, bases, heavy metals, hydrocarbons, inorganic salts, detergents, natural fats and oils, chlorinated hydrocarbons and others. HDPE is the most commonly used material for various components in landfills and has become standard practice due to its proven performance in landfill applications.

HDPE was selected as the liner material over other materials because of superior chemical resistance and high tensile strength. Table 1 provides a comparison of chemical resistance for commonly used liner materials. Table 2 provides a relative comparison of both natural and synthetic liner materials along with the potential advantages and disadvantages of each. HDPE is available in a variety of thicknesses and can be manufactured with a textured surface which increases the level of friction to provide additional stability. Additional chemical resistance information is provided in Appendix A.

HDPE was selected for use as the appropriate piping material for the leachate collection, underdrain, and storm drain piping. This material offers superior chemical resistance, as discussed above, and is relatively flexible when compared to other materials such as PVC. The pipe conforms to differential settlement without failure and provides a smooth interior surface which resists clogging due to the collection of solids. The pipe is easily fused in

the field to conform to various configurations and can bear the overburden loads which will be encountered in this design.

An HDPE drainage net was selected as the appropriate drainage media to convey leachate to the leachate collection system piping for several reasons. The drainage net is easily installed when compared to sand or gravel as a drainage media, especially on the steep side slopes. The drainage net requires less vertical space resulting in additional volume available for fill. HDPE was the material selected due to its chemical resistance and strength properties. The drainage net provides high permeability values of approximately 0.1 to 1 cm/s which is equivalent to permeabilities provided by gravel and at least 10 times higher than the permeability of sand. The use of drainage nets on the side slopes provides a more stable drainage layer requiring little maintenance.

The geotextile selected for this application is a nonwoven continuous filament polypropylene material. The geotextile will cover the drainage net to prevent the intrusion of fill material into the net resulting in clogging. A nonwoven fabric was selected over a woven fabric to minimize the migration of fill material through the spaces between filaments of a woven material under extreme overburden loads. Polypropylene was the material selected for the geotextile because of its chemical resistance. At ambient temperatures it is essentially insoluble in common solvents and resists acids, alkalies, moisture and salt solutions. Chemical resistance data for polypropylene is provided in Appendix A.

TABLE 1 - COMPARATIVE RESISTANCE TO SOME COMMONLY ENCOUNTERED SOLUTIONS

SOLUTION	HYPALON* (CPSE)	PVC*	CPE*	HDPE**
Water	E	E	E	E
Hydrochloric Acid	F	F	G	E
Sulfuric Acid	E	G	E	E
Acetic Acid	F	P	F	E
Ferric Chloride	F	G	G	E
Sodium Hydroxide	E	P	E	E
ASTM Oil #1	F	P	G	E
ASTM Oil #3	P	P	F	E
ASTM Fuel A	F	P	F	E
ASTM Fuel B	P	P	F	E
Kerosene	P	P	F	E

* From Dow Literature
** From Gundle Literature

E = Excellent
G = Good
F = Fair
P = Poor

Table 2 - Comparison of Manufactured Liner Materials

Material	Available	Cost	Installation Difficulty	Seaming	Chemical Resistance	Permeability (magnitude) cm/sec	Advantages	Disadvantages	Remarks
HDPE	30-140 mil	Low	Medium	Heat Seamed Extrusion Weld	Excellent	1E-13	Standard practice. High tensile strength can be exposed. Good puncture resistance.	Seam quality. More seams required. Relatively Rigid. Low biaxial strength.	Recommended for bottom composite liner per chemical resistance and strength.
VLDPE	20-40 mil	Low	Medium	Heat Seamed Extrusion Weld	Good	1E-11	Flexible. Conforms to surface high tensile strength. Can be exposed. Good puncture resistance.	Seam quality. More seams required. Relatively new product.	Have been used for cover liners due to flexibility.
PVC	20-60 mil	Low	Low	Solvent Weld	Fair	1E-10	Flexible. Large sheet available requiring less field seaming. Good biaxial strength.	Cover required. Loss of plasticizier causes material to be brittle. Poor chemical resistance to oils.	Currently used as cover liner due to biaxial strength and flexibility. Have been used for bottom liners for given conditions.
CPE	36 mil	Medium	Low	Solvent Weld	Fair	1E-11	Large sheet available.	Low strength. Fair resistance to oil. Low tear resistance. May require reinforcing.	Not commonly used.
CSPE (Hypalon)	36-60 mil	Medium	Low	Solvent Weld	Fair	1E-11	Can be exposed. Large sheet available.	Low strength. May required reinforcing.	Used for linining ponds and lagoons with exposed liners which do not require high chemical resistance.
CLAYMAX	.25 in.	High	Low	Overlapped	Good	1E-9 to 1E-10	No seaming required easy installation. Good attenuation capacity.	Must be covered. Cannot be allowed to dehydrate. Permeability can be increased by some chemicals. Relatively permeable compare to FMLs.	Often used as a substitute for thicker clay liners. Has been used as a bottom liner.
Compacted Soil (Clay)	N/A	High	High	N/A	Good	1E-5 to 1E-8	Good attenuation capacity.	Quality control critical to insure compaction. Construction cost high. Relatively permeable.	Most common lining material. Recommend as alternative to compacted soil material for use in composite bottom liner.

2) All design calculations must be provided and must substantiate that the systems will perform as intended, including mechanical and hydraulic performance of the components under maximum loads, slope stability, etc.

Design calculations are included for the system performance as a function of hydraulic capacity, mechanical strength, and slope stability. Each function is discussed below and the associated calculations are included in Appendix B.

Hydraulic Capacity - The principal drainage systems are the leachate control system, the uncontaminated runoff control system, and the underdrain system. All systems are designed to utilize gravity flow and thereby limit the number of pumping stations. One existing pump station is utilized in the handling of leachate; no pumping stations will be required to control uncontaminated runoff or underdrainage.

Leachate will be generated from water which drains from the dewatered sludge, stormwater which comes in contact with sludge during filling operations, and storm water contacting intermediate dikes constructed of waste lime. The leachate control system is designed to allow gravity flow of leachate from the landfill area to an existing lined leachate holding pond that has a capacity to hold 100 percent of the runoff from a 25-year 24-hour storm event (7.0 inches) over an 8 acre active cell area. The leachate collection system can accommodate flows of 2079 gallons per minute which will drain the leachate generated by the design storm to the holding pond in approximately 12 hours. This represents the worst case condition with no fill in an opened cell which allows runoff to directly enter the leachate system. As fill is placed stormwater must leach through the fill or enter the drainage net to reach the leachate system which drastically reduces the peak flow. All existing lines are provided with shutoff valves to allow cut-off of leachate drainage into the pond in case of an emergency. From the holding pond leachate is pumped through an existing pump station and force main to a city sewer line which ties into Champion's wastewater treatment facilities.

The uncontaminated runoff control system is designed to collect storm runoff from areas upslope of active landfilling operations and convey the uncontaminated runoff out of the landfill area through sealed pipes under the landfill. The uncontaminated storm drainage piping is designed to limit flow to 3352 gallons per minute. All excess flow will be ponded in the unopened cells. Calculations show a drainage time for the 25-year 24-hour storm of 30.2 hours which is adequate.

The underdrain system will not be subject to any stormwater runoff, only drainage occurring from natural springs. Field flow measurements recorded a total of ten gallons per minute from all the springs in the area. The capacity of the underdrain system is significantly greater than this amount, at 5091 gallons per minute.

Mechanical Strength - The principal components that were evaluated for structural strength to prevent collapse are the leachate collection pipes, uncontaminated storm drains, and underdrain pipes. Calculations show that the maximum earth loading on the pipe is 780 pounds per linear foot and the allowable loading for 12 inch SDR-11 pipe is 2590 pounds per linear foot. Calculations are provided in Appendix B.

The other item that must be evaluated for mechanical strength is the ability of the liner to resist yield due to shear stress on side slopes. Shear box studies were performed by Gundle Lining Systems Inc. on material from the site. Results of the tests indicate that the friction angle is in excess of 35 degrees between the textured liner and site soils. Since the slope angle is 26 degrees, there is an adequate safety factor against slope failure. Test results are provided in Appendix B.

Slope Stability - Slope stability analysis was included as Appendix G of the Geotechnical Report. Analysis shows the exterior dikes with slopes of 2:1 to be stable with a factor of safety of at least 1.5. The interior dikes constructed of earth or lime have a stable slope of 1.5:1 using appropriate construction techniques.

3) Erosion control calculations must be included in the permit application. The section will forward one copy of the application to the Land Quality Section for their review and comments.

The Erosion Control Plan for Landfill 6 Area A is included as a separate document for submittal to the Land Quality Section. The Erosion Control Plan addresses all measures necessary to prevent erosion during construction and after the landfill cells are completed.

The erosion control measures required during the construction of Area A were divided into three areas. The areas are 1) inside the landfill area, 2) outside the landfill area, and 3) the excess material spoil area. During initial construction, the construction phase riser will control runoff from the landfill area and form a sediment pond. The sediment pond will capture eroded material and will be cleaned out as necessary. After the HDPE liner is installed, erosion in the landfill area will be eliminated. The construction phase riser will be replaced with uncontaminated runoff drainage structure which will drain uncontaminated runoff from the area at a controlled rate of approximately 7.5 cubic feet per second. Since the peak flow from the area is estimated to be 150 cubic feet per second, the excess runoff will pond in the cell and will gradually drain to Bowen Branch in approximately 30.2 hours. As additional cells are developed, the stormwater pipe will be extended upslope beyond the divider dikes to collect runoff from the lined area where waste is not being placed. This progression of divider dikes and line extensions will continue until the final 8 acre cell is ready for filling at which time the stormwater pipe will be capped. The runoff from the uncontaminated areas will remain separate from the contaminated runoff at all times.

Erosion control measures outside the landfill area will consist of silt fencing around the entire diked area. The side slopes will be seeded and mulched upon completion of dike construction. Appropriate grass cover will be maintained on the side slopes and additional

seeding will be performed as necessary. The silt fencing will be periodically inspected and maintained as necessary to insure proper performance.

The excess spoil area located west of Area A will require silt fencing. Since the volume of spoil material is uncertain, the length and location of the fencing will be determined in the field by the owner/engineer. Silt fencing will be installed and the slopes will be seeded as necessary to control erosion. When spoil operations are completed, the spoil area will be graded to a 1 percent slope to promote drainage and prevent erosion.

As the landfill cells are completed, final cover will be placed and vegetation will be established. The final cover will have relatively flat slopes to prevent erosion of the top cover. Each cell will drain to ditches located on each side of the cell. The culverts and ditches have been sized to accommodate the 25-year 24-hour storm event as they accumulate from each cell. The ditches will be rip-rapped to prevent erosion since the velocities are greater than 5 fps.

4) A construction Quality (CQA) Report, including as-built drawings, is now required upon completion of construction.

The CQA Report must summarize the following:

1) Construction of the subgrade, liner system, leachate collection, removal and storage system as specified in the construction plan;

2) Modification to the approved plans;

3) Documentation of all destructive and non-destructive tests, methods and results, an repairs;

4) Geomembrane panel layout with test locations and repairs illustrated; and

5) Any other pertinent documentation.

A comprehensive CQA plan outlining quality assurance measures, along with plans for developing the CQA report must be included in the construction plan application.

A CQA Report will be compiled and submitted upon completion of landfill construction. The report will include items in the following outline. The CQA Report will be developed by the owner/engineer and will consist basically of documentation confirming the landfill was constructed according to specifications. The CQA report will include as built drawings, documentation of where unsuitable soils were encountered, test results of compaction testing, and other information pertinent to the landfill construction. The liner installation will require an extensive CQA effort to insure proper performance. The CQA for the liner will include certification of the liner material by the manufacturer that it meets specifications, documentation of destructive and nondestructive testing, a panel layout drawing, written acceptance of the subgrade, as built drawings showing repair locations, certification of installers, and other information pertinent to liner installation. Sections 02201 and 03000 of the specifications, attached in Appendix C, provide the installation criteria for the earthwork and liner.

QUALITY CONTROL ASSURANCE (CQA) REPORT
PROPOSED REPORT OUTLINE & REQUIREMENTS

I. Introduction

A. Project Background

B. Purpose and Scope

II. Site survey and Construction Control

A. Topographic Survey - Hampton, Hintz and Associates

B. Resident inspection - continuous inspection

1. Champion - Project Manager
2. Champion - Project Superintendent
3. Sirrine Environmental Consultants - Project Engineer
4. Soils Testing Data

III. Landfill construction Control - Earthwork

A. Stripping - Minimum of 6'; Plus all Other Organic Matter as Determined by Project Superintendent

B. Unsuitable Materials Excavation - Removal of all Unsuitable Soils as Determined by Project Engineer.

C. Earth Fill for berms, Subgrade, Structures (Reference Attached Specification)

1. Material Approval - Project Engineer
2. Lift Thickness - 9 inches
3. Moisture Control - 1 percent below to 4 percent above Optimum
4. Compaction Requirements - 95 percent of Maximum, Standard Procter

D. Quality Assurance - Compaction Testing

1. Performed by Soils Consultant
2. Test for Each Lift

IV. Landfill construction Control - Liner (Reference Attached Specification)

A. Subgrade Preparation - Approval by liner/manufacturer; unsuitable areas provided with 8 oz-geotextile

NO. Wait good contact w/ subgrade add soil instead

B. Liner Requirements

1. Manufacturer Certification of Physical Properties
2. Test Methods per ASTM D 638 of the Actual Production Run

C. Installation Requirements

1. Subgrade Preparation - Written Acceptance by Liner installer
2. Layout Drawing Provided by Manufacturer/Installer
3. Modifications Must be Noted and Approved by Project ENgineer

D. Field Seaming

1. Extrusion Weld - 4 inch Overlap
2. Hot Wedge Weld - 5 inch Overlap (Recommended)

D. Field Seam Testing

1. Non-Destructive Tests; All Welds
2. Test Weld; Start of Each Day
3. Destructive Tests; One per 1000' of Weld
4. Miscellaneous Tests

V. Miscellaneous Site construction

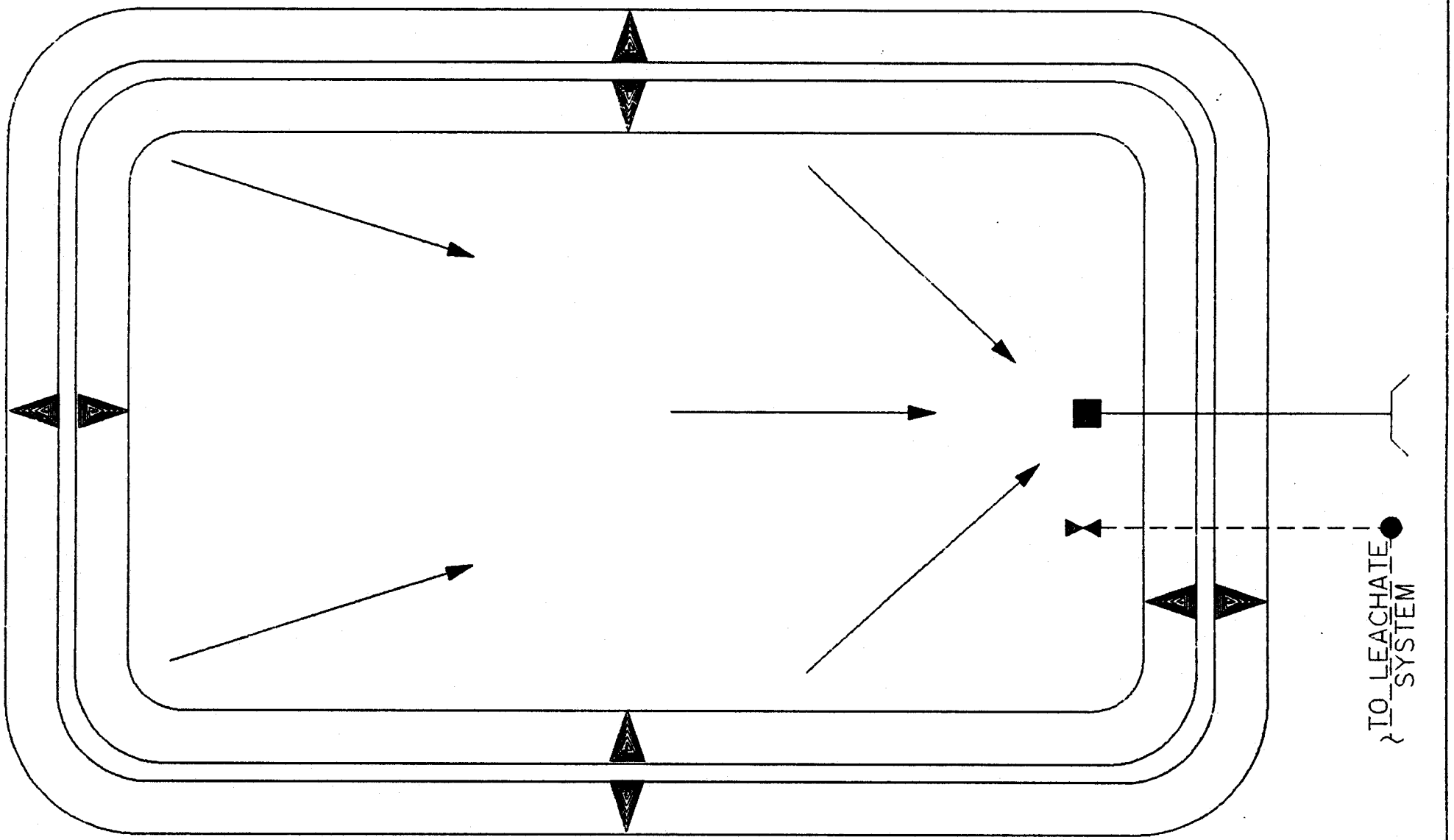
A. Leachate Collection System
B. Uncontaminated Storm Drainage
C. Underdrains
D. Roadways
E. Grassing
F. Erosion Control

Appendices

Appendix A - Construction Documentation Photographs
Appendix B - Earth Fill Compaction Test Results
Appendix C - Liner Testing Results
Appendix D - Field Inspection Reports
Appendix E - As-Built Drawings

5) More detailed information is requested on the storm water and leachate collection lines as the landfill development progresses.

The development of each cell and the extension of the stormwater and leachate collection is illustrated in the following schematic drawings. Initially when landfill construction is complete and the liner has been installed prior to the development of the first cell, the stormwater will exit through the stormwater pipe stubbed up near the outlet box. The leachate line will be valved off prior to the placement of any fill material. When the first lime divider dike is constructed, the leachate collection line and stormwater line will be extended to just beyond the divider dike. An earth berm will be constructed upslope from the divider dike to separate contaminated runoff from the dike slope and the uncontaminated runoff from the remaining landfill area. The leachate line will end at the upslope toe of the divider dike and receive leachate and contaminated runoff from the cell and the lime dike slope. The stormwater will only receive runoff from the upslope liner area. This progression of divider dike, leachate line extension, stormwater line extension, and earth berm construction will continue until the final cell is completed. Drawings G-9083-2 and G-9083-3, previously submitted, provide a layout and sections of the proposed system.



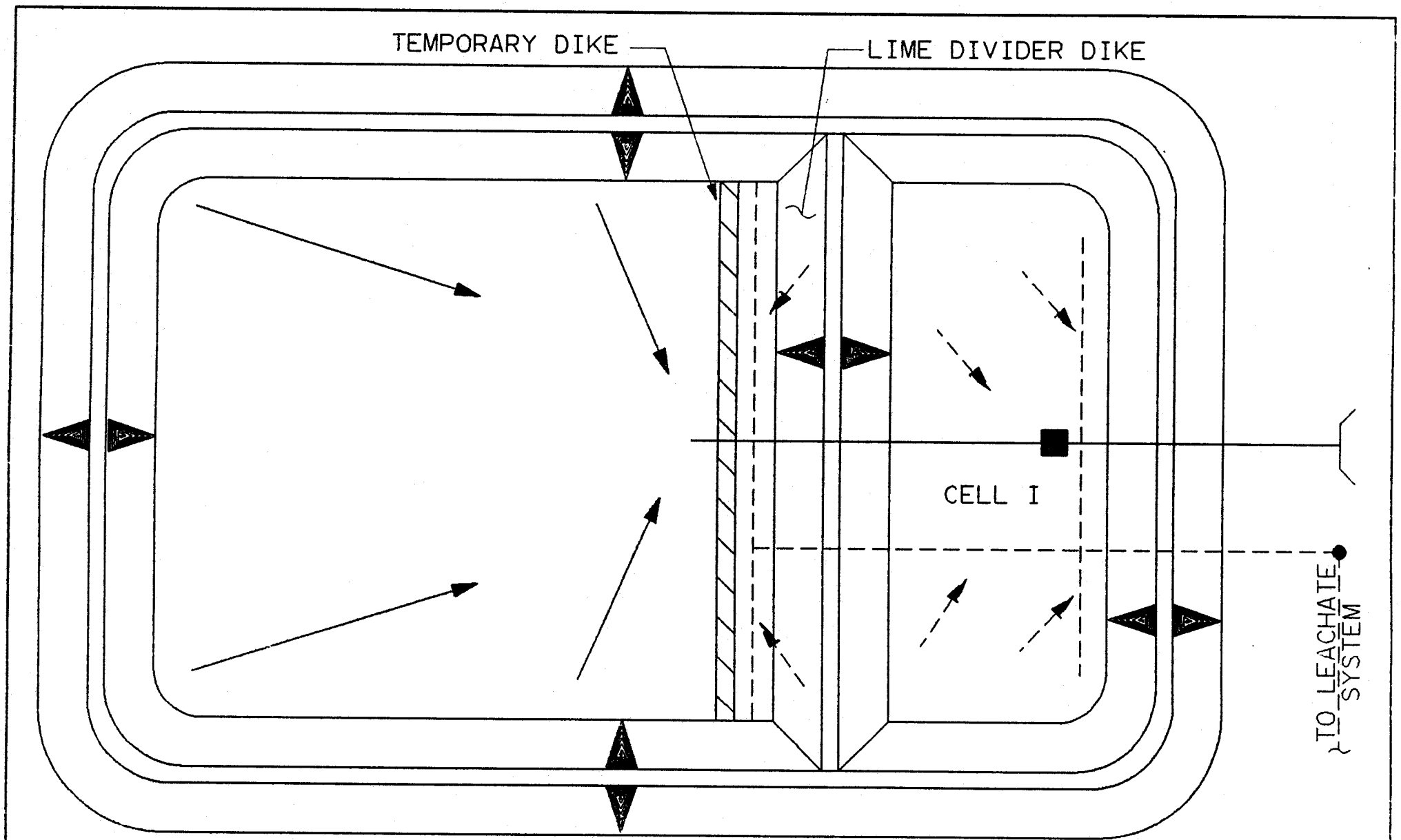
UNCONTAMINATED STORM DRAINAGE

CONTAMINATED LEACHATE DRAINAGE

SIRRINE ENVIRONMENTAL CONSULTANTS

Greenville, South Carolina

PRIOR TO DEVELOPMENT

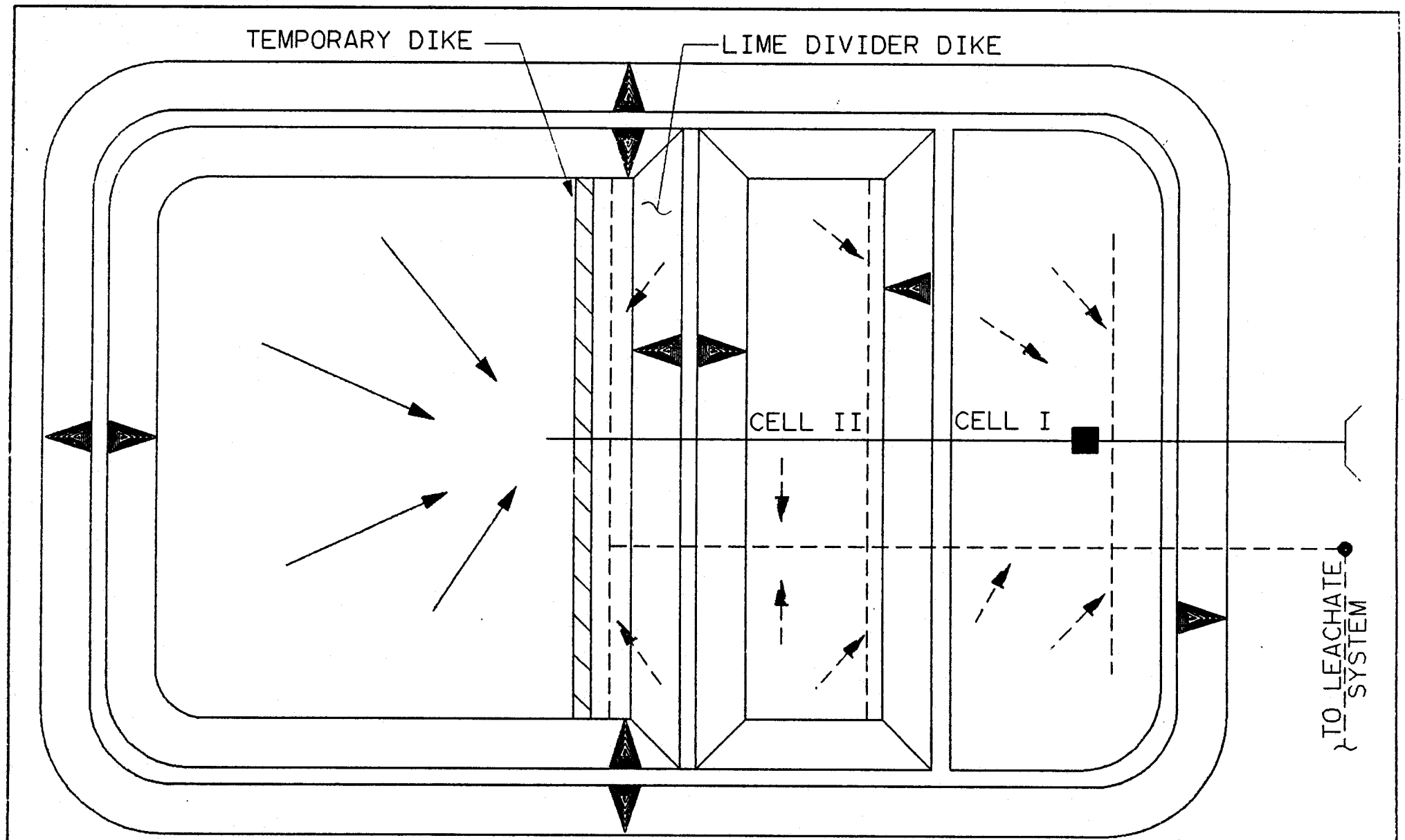


UNCONTAMINATED STORM DRAINAGE

CONTAMINATED LEACHATE DRAINAGE

SIRRINE ENVIRONMENTAL CONSULTANTS
Greenville, South Carolina

CELL I DEVELOPMENT



UNCONTAMINATED STORM DRAINAGE

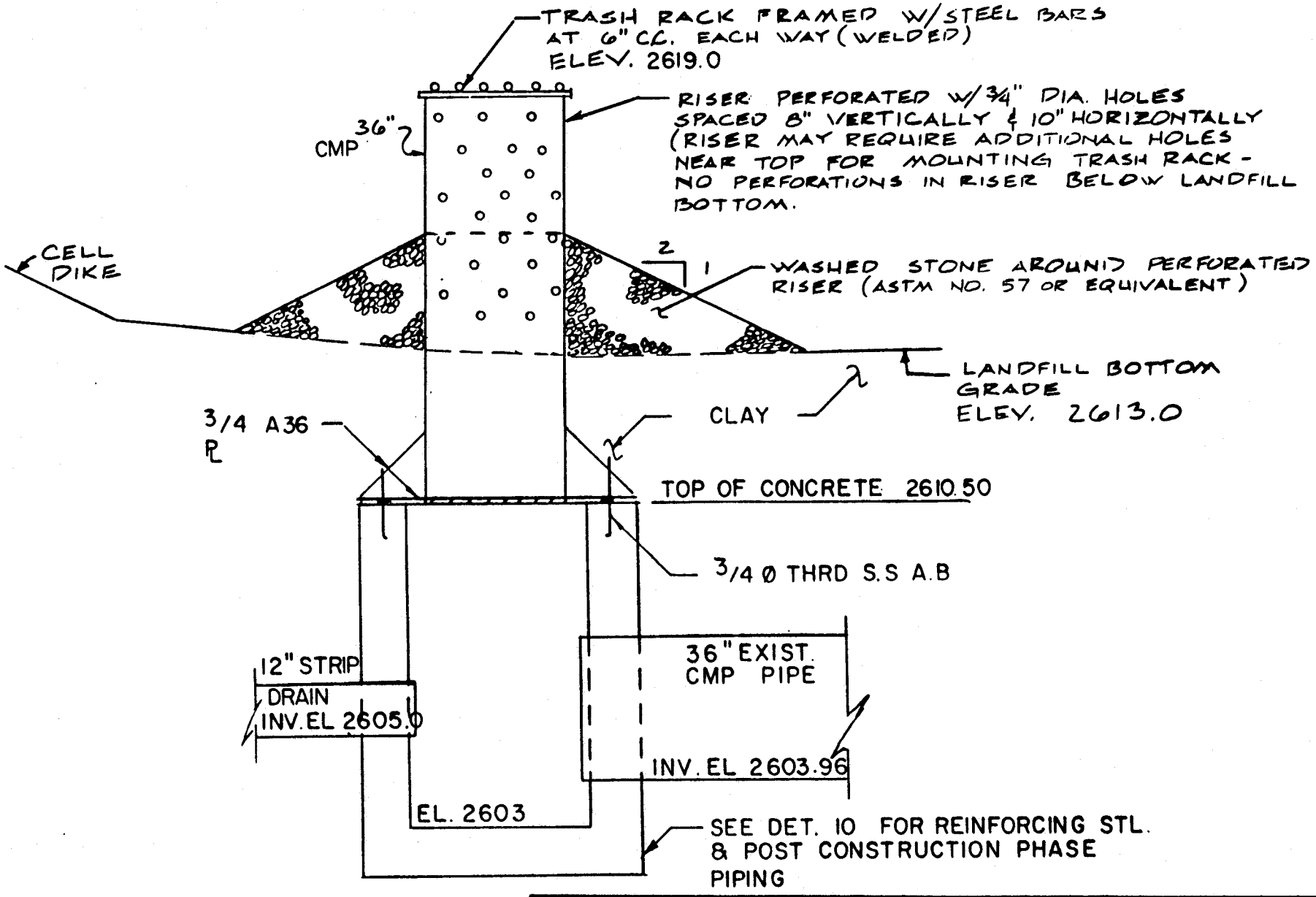
CONTAMINATED LEACHATE COLLECTION

SIRRINE ENVIRONMENTAL CONSULTANTS
Greenville, South Carolina

CELL II DEVELOPMENT TYPICAL FOR CELLS III & IV

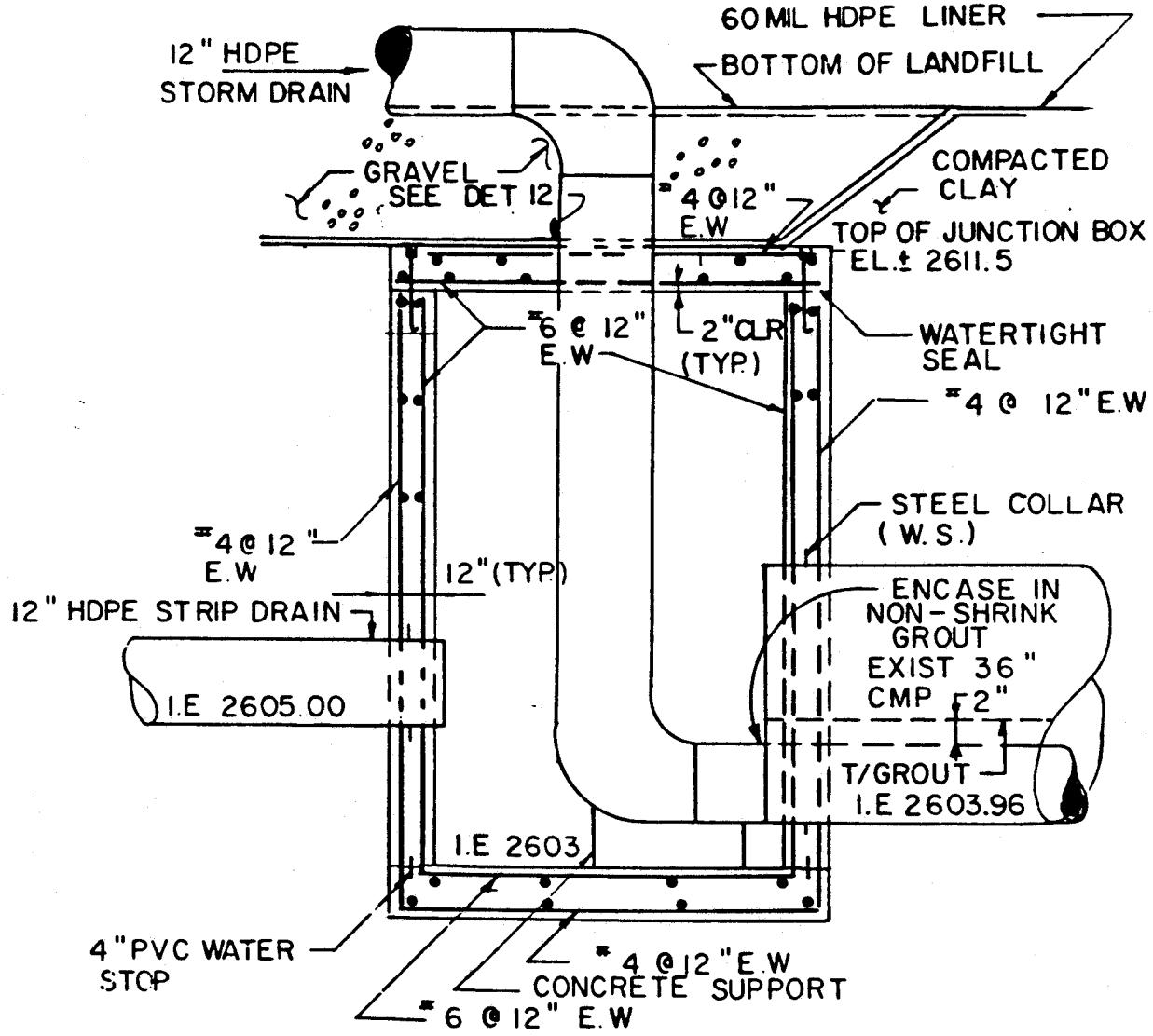
6) A detail drawing of the storm water drainage inlet must be presented. Also, the inlets must be located on the section drawing.

A detail drawing of the stormwater inlet is provided on the following details. The Construction Phase Runoff Collection detail will be installed during initial construction and serve as the outlet for the sediment pond. When liner installation is nearly complete, the construction phase riser is removed and replaced with the Uncontaminated Runoff Drainage detail using the same outlet box. The outlet will be located near the inside toe of the east dike in the lowest area of the landfill at the end of the existing 36 inch pipe. Due to the small scale on the section drawing (1"=50'), it can not be accurately shown on the section. The box on Site Plan, G-9083-2, is the location of the outlet structure.



SIRRINE ENVIRONMENTAL CONSULTANTS
Greenville, South Carolina

CONSTRUCTION PHASE RUNOFF COLLECTION



SIRRINE ENVIRONMENTAL CONSULTANTS

Greenville, South Carolina

UNCONTAMINATED RUNOFF DRAINAGE DET.

DUNCAN-PARNELL, INC., CHARLOTTE 888 888-482-8822

7) Any water which comes into contact with the proposed lime mud dikes will be considered leachate. A stabilized intermediate compacted soil cover for the exterior dike slope is suggested.

Installation of the earth berm, previously discussed, will separate contaminated runoff from the dike slope from the uncontaminated runoff upslope of the berm. Runoff from the dike slope is directed into the leachate collection system and runoff from the upslope uncontaminated cell enters the stormwater system. A compacted soil cover on the upslope side of the dike was considered but due to instability and construction on the steep slopes, this was not considered feasible.

APPENDIX

APPENDIX A
CHEMICAL RESISTANCE

THE CHEMICAL RESISTANCE

OF

POLYETHYLENE AND POLYPROPYLENE POLYOLEFINS

TTN:PT2.0
4/18/86

T-055

SUMMARY

Based on research performed by our polypropylene suppliers (Himont, Shell, Soltex), the chemical resistivity of polypropylene is outstanding. At room temperature it is essentially insoluble in common solvents. When it is removed from the solvent, its swelling is reversible. It resists acids, alkalies, moisture, and salt solutions. It is attacked by strong oxidizing agents such as concentrated nitric acid, hydrogen peroxide, and wet chlorine, especially at temperatures approaching 60°C. Except in oxidizing environments, polypropylene is immune to stress cracking, as determined by accepted testing procedures.

Based on research performed by our suppliers of high density polyethylene (Soltex and British Petroleum), due to its molecular structure, HDPE is resistant to attack by all chemicals which may be reasonably considered to be present in soil. Soltex studies find no known solvent for their high molecular weight, high density polyethylene below 60°C (140°F). The higher the molecular weight, the more HDPE is resistant to chemical attack. The Tensar Corporation employs high molecular weight fractional melt polyethylenes in the manufacture of geogrids and geonets.

Attached to this Tensar Technical Note is support documentation on the resistance to chemical attack of TENSAR® Geogrids. Specifically, The Tensar Corporation uses Himont, Shell, and Soltex polypropylenes for all biaxial products and Soltex XF 409 and BP HDPE for the uniaxial soil reinforcement products. Enclosed are Himont and Soltex Polypropylene and Soltex XF409 and BP High Density Polyethylene chemical resistance data. Also included in this technical note are two exerpts from research done by Dr. J. P. Giroud on the chemical resistivity of TENSAR Geogrid and Geonets and from research done by G. H. Burke of BP Chemicals on aging of HDPE in buried situations.

Requests for information on specific chemicals or their concentrations not included in the enclosed data tables can be requested from The Tensar Corporation, Director of Production Technology.

® Registered Trademark

TABLE OF CONTENTS

	Page(s)
Himont Polypropylene Chemical Resistance Product Data	4-7
Chemical Resistance of Fortilene Polypropylene (as supplied by Soltex)	8-10
Chemical Resistance of Fortiflex HDPE (as supplied by Soltex)	11-14
Chemical Resistance of BP Rigidex HDPE (as supplied by BP)	15-21
Polypropylene Biaxial Geogrid Resistance to Chemical Attack in Soil Burial by J. P. Giroud	22
Evaluation of Chemical Resistance of Tensar Drainage Nets.... by J. P. Giroud	23-24
Ageing of HDPE in Buried Situations... by G. H. Burke	25-26

HIMONT U.S.A., Inc.
1313 N. Market Street
Wilmington, DE 19894
(302) 594-5500

Product Data

NUMBER 511
(Supersedes PPD-32F)

PRO-FAX[1] Polypropylene
Chemical Resistance

PRO-FAX polypropylene, like most of the polyolefins, is highly resistant to solvents and chemicals.

The results of extensive laboratory and actual field installation tests of polypropylene's chemical resistance are reported in this data sheet, which is updated at intervals.

The corrosion resistance data presented here are based on unstressed specimens of Pro-fax, 3 in. long by 0.025 in. thick, in the shape of dumbbells. Results are reported after 1-month immersion. As it is difficult to create actual service conditions in the laboratory, the results of many of the environments should be taken only as an indication of behavior in service.

Pro-fax polypropylene has outstanding resistance to water and other inorganic environments. In most aqueous environments, its weight increase is less than 0.2% when it has been stored for 6 months at ambient temperatures. When the temperature is increased to 60°C (140°F), the weight increase is less than 0.5% for a similar period. According to ASTM D 570-63T, its 24-hr water absorption rate is 0.03%. It resists most strong mineral acids and bases, but, like the other polyolefins, it is subject to attack by oxidizing agents.

Pro-fax polypropylene is appreciably affected by chlorosulfonic acid and oleum at room temperature, 98% sulfuric acid, 30% hydrochloric acid, and 30% hydrogen peroxide at 100°C (212°F). It is also affected by 98% sulfuric acid at 60°C (140°F) and fuming nitric acid and liquid bromine at room temperatures. Under strain, failure could occur with strong oxidizing acids at temperatures lower than those mentioned. With few exceptions, however, inorganic chemicals produce little or no effect on Pro-fax over a period of 6 months at temperatures up to 120°C (248°F).

The permeation resistance of Pro-fax polypropylene to organic chemicals depends on the rate and extent to which absorption occurs. This, in turn, will govern the suitability of the resin to serve in a particular environment. When the plastic is removed from the environment, evaporation will take place and cause it to return almost to its original dimensions. Property changes resulting from the absorption will be reversed if evaporation is complete.

Temperature and polarity of the organic medium are the foremost factors determining the extent of absorption by polypropylene. Absorption becomes greater as temperatures are increased and polarity of the medium is decreased. Copolymers swell more than homopolymers, indicating greater absorption. Such non-polar liquids as benzene, carbon tetrachloride, and petroleum ether have a higher absorption rate by polypropylene than polar media such as ethanol and acetone. Some reduction in tensile strength and an increase in flexibility and elongation to break in tension can be expected, depending on the nature and amount of the organic medium absorbed.

Pro-fax polypropylene has excellent resistance to environmental stress-cracking. When it is tested according to ASTM D 1693-60T, the brittle fractures that occur with certain polyethylenes in contact with polar organic liquids, detergents, and silicone fluids are not observed. Failure of this type with polypropylene is rare. Those environments known to cause such cracking to polypropylene are 98% sulfuric acid, concentrated chromic/sulfuric acid mixtures, and concentrated hydrochloric acid/chlorine mixtures.

The useful life of Pro-fax polypropylene at elevated temperatures is limited by oxidative degradation. The expected life of polypropylene at any given temperature is also determined by the nature of the environment, and by the extraction of some of the antioxidant system. Any environment that tends to extract the antioxidants may lead to more rapid breakdown of the polypropylene, especially at elevated temperatures.

[1]Registered trademark of HIMONT Incorporated.

We cannot anticipate all conditions under which this information and our products, or the products of other manufacturers in combination with our products, may be used. We accept no responsibility for results obtained by the application of this information or the safety and suitability of our products, either alone or in combination with other products. Users are advised to make their own tests to determine the safety and suitability of each such product or product combination for their own purposes. Unless otherwise agreed in writing, we sell the products without warranty, and buyers and users assume all responsibility and liability for loss or damage arising from the handling and use of our products, whether used alone or in combination with other products.

RATING SYSTEM

This chart rates the chemical resistance of Pro-fax polypropylene according to the following code:

A = NEGLIGIBLE EFFECT — Should be suitable for all applications where these environmental conditions exist.

B = LIMITED ABSORPTION OR ATTACK — Should be suitable for most applications, but the user is advised to make his own tests to determine the suitability of polypropylene in the particular environment.

C = EXTENSIVE ABSORPTION AND/OR RAPID PERMEATION — Should be suitable for applications where only intermittent service is involved, or where the swelling produced has no detrimental effect on the part. The user should make his own tests to determine the suitability of polypropylene in the particular environment.

D = EXTENSIVE ATTACK — The specimen dissolves or disintegrates. Polypropylene is not recommended.

Environment	Conc., %	Temperature, °C		
		20	60	100
Acetic acid (glacial)	97	A	B (80°C)	—
Acetic acid	50	A	A (80°C)	—
Acetic acid	40	A	—	—
Acetic acid	10	A	A	—
Acetone	100	A	A	—
Acetophenone	100	B	B	—
Acriflavine (2% solution in H_2O)	2	A	A (80°C)	—
Acrylic emulsions		A	A	—
Aluminum chloride		A	A	—
Aluminum fluoride		A	A	—
Aluminum sulfate		A	A	—
Alums (all types)		A	A	—
Ammonia (aqueous)	30	A	—	—
Ammonia gas (dry)		A	A	—
Ammonium carbonate	Satd.	A	A	—
Ammonium chloride	Satd.	A	A	—
Ammonium fluoride	20	A	A	—
Ammonium hydroxide	10	A	A	—
Ammonium metaphosphate	Satd.	A	A	—
Ammonium nitrate	Satd.	A	A	—
Ammonium persulfate	Satd.	A	A	—
Ammonium sulfate	Satd.	A	A	—
Ammonium sulfide	Satd.	A	A	—
Ammonium thiocyanate	Satd.	A	A	—
Amyl acetate	100	B	C	—
Amyl alcohol	100	A	B	—
Amyl chloride	100	C	C	—
Aniline	100	A	A	—
Anisole	100	B	B	—
Antimony chloride		A	A	—
Aqua regia	(a)	B	B	—
Aviation fuel (115/145 octane)	100	B	C	—
Aviation turbine fuel	100	B	C	—
Barium carbonate	Satd.	A	A	—
Barium chloride	Satd.	A	A	—
Barium hydroxide		A	A	—
Barium sulfate	Satd.	A	A	—
Barium sulfide	Satd.	A	A	—
Beer		A	A	—
Benzene	100	B	C	C
Benzoic acid		A	A	—
Benzyl alcohol		A	A (80°C)	—
Bismuth carbonate	Satd.	A	A	—
Borax		A	A	—
Boric acid		A	A	—
Brine	Satd.	A	A	—
Bromine liquid	100	D	—	—
Bromine water	(a)	C	—	—
Butyl acetate	100	—	C	C
Butyl alcohol	A	—	—	100

Environment	Conc., %	Temperature, °C		
		20	60	100
Calcium carbonate	Satd.	A	A	—
Calcium chlorate	Satd.	A	A	—
Calcium chloride	50	A	A	—
Calcium hydroxide		A	A	—
Calcium hypochlorite bleach	20	A	B	—
Calcium nitrate		A	A	—
Calcium phosphate	50	A	—	—
Calcium sulfate		A	A	—
Calcium sulfite		A	A	—
Carbon dioxide (dry)		A	A	—
Carbon dioxide (wet)		A	A	—
Carbon disulfide	100	B	C	—
Carbon monoxide		A	A	—
Carbon tetrachloride	100	C	C	C
Carbonic acid		A	A	—
Castor oil		A	—	—
Cetyl alcohol	100	A	—	—
Chlorine (gas)	100	D	D	—
Chlorobenzene	100	C	C	—
Chloroform	100	C	D	D
Chlorosulfonic acid	100	D	D	D
Chrome alum		A	A	—
Chromic acid	80(a)	A	—	—
Chromic acid	50(a)	A	A	—
Chromic acid	10(a)	A	A	—
Chromic/sulfuric acid		D	D	—
Cider		A	A	—
Citric acid	10	A	A	—
Copper chloride	Satd.	A	A	—
Copper cyanide	Satd.	A	A	—
Copper fluoride	Satd.	A	A	—
Copper nitrate	Satd.	A	A	—
Copper sulfate	Satd.	A	A	—
Cottonseed oil		A	A	—
Cuprous chloride	Satd.	A	A	—
Cyclohexanol	100	A	B	—
Cyclohexanone	100	B	C	—
Decalin	100	C	C	C
Detergents	2	A	A	A
Developers (photographic)		A	A	—
Dibutyl phthalate	100	A	B	D
Dichloroethylene	100	A	—	—
Diethanolamine	100	A	A	—
Diisooctyl phthalate	100	A	A	—
Emulsifiers		A	A	—
Ethanolamine	100	A	A	—
Ethyl acetate	100	B	B	—
Ethyl alcohol	96	A	A	A (80°C)
Ethyl chloride	100	C	C	—
Ethylene dichloride	100	B	—	—
Ethylene glycol		A	A	—
Ethylene oxide	100	B (10°C)	—	—
Ethyl ether	100	B	—	—

Environment	Conc., %	Temperature, °C		
		20	60	100
Fatty acids (C_4)	100	A	A	—
Ferric chloride	Satd.	A	A	—
Ferric nitrate	Satd.	A	A	—
Ferric sulfate	Satd.	A	A	—
Ferrous chloride	Satd.	A	A	—
Ferrous sulfate	Satd.	A	A	—
Fluosilicic acid		A	A	—
Formaldehyde	40	A	A	—
Formic acid	100	A	—	—
Formic acid	10	A	A	—
Fructose		A	A	—
Fruit juices		A	A	—
Furfural	100	C	C	—
Gas liquor		C	—	—
Gasoline	100	B	C	C
Gearbox oil	100	A	B	—
Gelatin		A	A	—
Glucose	20	A	A	—
Glycerin	100	A	A	A
Glycol		A	A	—
Hexane	100	A	B	—
Hydrobromic acid	50(a)	A	A	—
Hydrochloric acid	30(a)	A	B	D
Hydrochloric acid	20	A	A (80°C)	—
Hydrochloric acid	10	A	A (80°C)	B
Hydrochloric acid	2	A	A	A
50-50 HCl-HNO_3	(a)	B	D (80°C)	—
Hydrofluoric acid	40	A	—	—
Hydrofluoric acid	60(a)	A	A (40°C)	—
Hydrogen chloride gas (dry)	100	A	A	—
Hydrogen peroxide	30	A	—	D
Hydrogen peroxide	10	A	B	—
Hydrogen peroxide	3	A	—	—
Hydrogen sulfide		A	A	—
Hydroquinone		A	A	—
Inks		A	A	—
Iodine tincture		A	—	—
Isooctane	100	C	C	—
Isopropyl alcohol	100	A	A	—
Ketones		A	—	—
Lactic acid	20	A	A	—
Lanolin	100	A	A	—
Lead acetate	Satd.	A	A	—
Linseed oil	100	A	A	—
Lubricating oil	100	A	B	—
Magenta dye (aqueous solution)	2	A	A Some staining	—
Magnesium carbonate	Satd.	A	A	—
Magnesium chloride	Satd.	A	A	—
Magnesium hydroxide	Satd.	A	A	—
Magnesium nitrate	Satd.	A	A	—
Magnesium sulfate	Satd.	A	A	—
Magnesium sulfite	Satd.	A	A	—
Meat juices		A	A	—
Mercuric chloride	40	A	A	—
Mercuric cyanide	Satd.	A	A	—
Mercurous nitrate	Satd.	A	A	—
Mercury	100	A	A	—

Environment	Conc., %	Temperature, °C		
		20	60	100
Methyl alcohol	100	A	A	—
Methylene chloride	100	A	—	—
Methyl ethyl ketone	100	A	B	—
Milk and its products		A	A	A
Mineral oil	100	A	B	—
Molasses		A	A	—
Motor oil	100	A	B	—
Naphthalene	100	A	A	A
Nickel chloride	Satd.	A	A	—
Nickel nitrate	Satd.	A	A	—
Nickel sulfate	Satd.	A	A	—
Nitric acid	fuming	D	D	D
Nitric acid	70(a)	C	D	—
Nitric acid	60	A	D (80°C)	—
Nitric acid	10	A	A	A
50-50 HNO_3-HCl	(a)	A	D (80°C)	—
50-50 HNO_3-H_2SO_4	(a)	C	D (80°C)	—
Nitrobenzene	100	A	A	—
Oleic acid		A	B	—
Oleum		—	—	D
Olive oil	100	A	A	—
Oxalic acid (aqueous)	50	A	B	—
Paraffin	100	A	B	—
Paraffin wax	100	A	A	—
Petrol	100	B	C	—
Petroleum ether (boiling point 100-140°C)	100	C	C	—
Phenol	100	A	A	—
Phosphoric acid	95	A	A	—
Plating solutions, brass		A	A	—
Plating solutions, cadmium		A	A	—
Plating solutions, chromium		A	A	—
Plating solutions, copper		A	A	—
Plating solutions, gold		A	A	—
Plating solutions, indium		A	A	—
Plating solutions, lead		A	A	—
Plating solutions, nickel		A	A	—
Plating solutions, rhodium		A	A	—
Plating solutions, silver		A	A	—
Plating solutions, tin		A	A	—
Plating solutions, zinc		A	A	—
Potassium bicarbonate	Satd.	A	A	—
Potassium borate	1	A	A	—
Potassium bromate	10	A	A	—
Potassium bromide	Satd.	A	A	—
Potassium carbonate	Satd.	A	A	—
Potassium chlorate	Satd.	A	A	—
Potassium chloride	Satd.	A	A	—
Potassium chromate	40	A	A	—
Potassium cyanide	Satd.	A	A	—
Potassium dichromate	40	A	A	—
Potassium ferri-/ferrocyanide		A	A	—
Potassium fluoride		A	A	—
Potassium hydroxide	50	A	A	—
Potassium hydroxide	10	A	A	A
Potassium nitrate	Satd.	A	A	—
Potassium perborate	Satd.	A	A	—
Potassium perchlorate	10	A	A	—
Potassium permanganate	20	A	A	—
Potassium sulfate		A	A	—
Potassium sulfide		A	A	—
Potassium sulfite		A	A	—
Propyl alcohol	100	A	A	—
Pyridine	100	A	—	—
Silicone oil	100	A	A	—
Soap solution (concentrated)		A	A	—

Environment	Conc., %	Temperature, °C		
		20	60	100
Sodium acetate		A	A	—
Sodium bicarbonate	Satd.	A	A	—
Sodium bisulfate	Satd.	A	A	—
Sodium bisulfite	Satd.	A	A	—
Sodium borate		A	A	—
Sodium bromide oil solution		A	A	—
Sodium carbonate	Satd.	A	A	—
Sodium chlorate	Satd.	A	A	—
Sodium chloride	Satd.	A	A	A
Sodium chlorite	2	A	A (80°C)	—
Sodium chlorite	5	A	A (80°C)	—
Sodium chlorite	10	A	A (80°C)	—
Sodium chlorite	20	A	A (80°C)	—
Sodium cyanide	Satd.	A	A	—
Sodium dichromate	Satd.	A	A	—
Sodium ferricyanide	Satd.	A	A	—
Sodium ferrocyanide	Satd.	A	A	—
Sodium fluoride	Satd.	A	A	—
Sodium hydroxide	50	A	A	—
Sodium hydroxide	10	A	A	A
Sodium hypochlorite	20	A	B	B
Sodium nitrate		A	A	—
Sodium nitrite		A	A	—
Sodium silicate		A	A	—
Sodium sulfate	Satd.	A	A	—
Sodium sulfide	25	A	A	—
Sodium sulfite	Satd.	A	A	—
Stannic chloride	Satd.	A	A	—
Stannous chloride	Satd.	A	A	—
Starch		A	A	—
Sugars and syrups		A	A	—
Sulfamic acid		A	A (80°C)	—
Sulfates of calcium and magnesium	Satd.	A	A	—
Sulfites of potassium and sodium	Satd.	A	A	—
Sulfur		A	A	—
Sulfuric acid	98(a)	C	—	D

(a) May produce cracking in material under stress.
(b) Registered trademark of Chesebrough-Ponds, Inc.

Environment	Conc., %	Temperature, °C		
		20	60	100
Sulfuric acid	60	A	B (80°C)	—
Sulfuric acid	50	A	B	—
Sulfuric acid	10	A	A	A
50-50 H_2SO_4/HNO_3	(a)	C	D (80°C)	—
Tallow		A	A	—
Tannic acid	10	A	A	—
Tartaric acid		A	A	—
Tetrahydrofuran	100	C	C	C
Tetralin	100	C	C	C
Toluene	100	C	C	—
Transformer oil	100	A	C	—
Trichloroacetic acid	10	A	A	—
Trichloroethylene	100	C	C	C
Triethanolamine	100	A	A (80°C)	—
Turpentine	100	C	C	C
Urea		A	A	—
Urine		A	A	—
Vaseline(b)		A	A	—
Vinegar		A	A	—
Water (distilled, soft, hard, and vapor)		A	A	A
Wet chlorine gas		—	D (70°C)	—
Whisky		A	A	A
White paraffin	100	A	B (80°C)	—
White spirit	100	B	C	—
Wines		A	A	—
Xylene	100	C	C	C
Yeast		A	A	—
Zinc chloride	Satd.	A	A	—
Zinc oxide		A	A	—
Zinc sulfate	Satd.	A	A	—

SALES OFFICES

AKRON, OH 44313
Suite 201
3200 West Market Street
(216) 867-3788

ATLANTA
Norcross, GA 30071
Suite 700
3169 Holcomb Bridge Road
(404) 447-9976

CHICAGO
Naperville, IL 60566
Suite 260
One Energy Center
300 East Shuman Boulevard
(312) 961-4025

CINCINNATI, OH 45241
Suite 122-124
4050 Executive Park Drive
(513) 769-4115

DALLAS, TX 75243
Suite 518
9441 LBJ Freeway and Abrams
(214) 231-9338

DETROIT
Southfield, MI 48075
Suite 400
3000 Town Center
(313) 358-1505

LAGUNA HILLS, CA 92653
Suite 215-216
25301 Cabot Road
(714) 770-8844

WILMINGTON, DE 19894
Hercules Marketing Center
Northeastern Region
1313 N. Market Street
(302) 994-3569

HIMONT

HIMONT U.S.A., Inc.
Wilmington, DE 19894, U.S.A.

10-84

PRINTED IN U.S.A.

Table 4

CHEMICAL RESISTANCE OF FORTILENE POLYPROPYLENE

Legend: S = Satisfactory, O = Some Attack, U = Unsatisfactory

Reagent	70°F (21°C)	140°F (60°C)	212°F (100°C)
Acetic Acid (10%)	S	S	
Acetic Acid (50%)	S	S	O
Acetic Acid (100%)	S	S	
Acetic Anhydride	S	S	
Acetone	S	S	
Acetonitrile	S		
Acetophenone	O	O	U
Aluminum Ammonium Sulfate	S	S	
Aluminum Chloride	S	S	O
Aluminum Fluoride	S	S	
Aluminum Hydroxide	S	S	
Aluminum Nitrate	S	S	S
Aluminum Potassium Sulfate	S	S	
Alums (all types)	S	S	
Ammonia (anhydrous)	S	S	
Ammonia (30% aqueous)	S	S	
Ammonium Bifluoride	S	S	
Ammonium Carbonate	S	S	S
Ammonium Chloride	S	S	O
Ammonium Fluoride (25%)	S	S	
Ammonium Hydroxide	S	S	
Ammonium Nitrate	S	S	S
Ammonium Sulfate	S	S	S
Ammonium Sulfide	S	S	
Ammonium Thiocyanate	S	S	
Amyl Acetate	O	U	
Amyl Alcohol	S	O	U
Amyl Chloride	U	U	
Aniline	S	S	O
Anisole	O	O	U
Antimony Trichloride	S	S	
Aqua Regia	O	O	
Arsenic Acid	S	S	
Aviation Fuel	O	O	
Barium Carbonate	S	S	
Barium Chloride	S	S	O
Barium Hydroxide	S	S	
Barium Soap Grease	S	O	
Barium Sulfate	S	S	
Barium Sulfide	S	S	S
Beer	S	S	
Benzaldehyde	S	S	
Benzyl Alcohol	S	S	
Benzyl Chloride	S	S	
Bismuth Carbonate	S	S	
Borax	S	S	S
Boric Acid	S	S	
Brake Fluid	S	O	
Brine	S	S	S
Bromic Acid	U	U	
Bromine	U	U	
Bromine Water	U	U	
Butyl Acetate	U	U	
Butyl Acrylate	U	U	
Butyl Alcohol	S	S	
Calcium Bisulfate	S	S	
Calcium Carbonate	S	S	S
Calcium Chlorate	S	S	
Calcium Chloride	S	S	O
Calcium Hydroxide	S	S	S
Calcium Hypochlorite	S	S	
Calcium Nitrate	S	S	
Calcium Soap Grease	S	O	
Calcium Sulfate	S	S	
Calgonite (1%)	S	S	
Carbon Dioxide (dry)	S	S	
Carbon Dioxide (wet)	S	S	
Carbon Disulfide	O	U	
Carbon Monoxide	S	S	
Carbon Tetrachloride	U	U	
Carbonic Acid	S	S	
Castor Oil	S	S	
Cellusolve	S	S	
Cetyl Alcohol	S		
Chlorine (dry)	U	U	
Chlorine (wet)	O	U	
Chloroacetic Acid	S		
Chlorobenzene	U	U	
Chloroform	O	U	
Chlorosulfonic Acid	U	U	
Chromic Acid (10%)	S	S	
Chromic Acid (50%)	S	S	
Chromic Acid (80%)	S		
Cider	S	S	
Citric Acid	S	S	
Clorox	S	S	S
Copper Chloride	S	S	
Copper Cyanide	S	S	
Copper Fluoride	S	S	
Copper Nitrate	S	S	
Copper Sulfate	S	S	
Corn Oil	S	S	
Cottonseed Oil	S	S	
Cresol	S	S	
Cuprous Chloride	S	S	
Cyclohexane	S	O	
Cyclohexanol	S	O	
Cyclohexanone	O	U	
Decalin	U	U	
Developers (photographic)	S	S	
Dextrin	S	S	
Dibutyl Phthalate	S	S	U
Dichloroethylene	S		
Diethanolamine	S	S	
Diethyl Ether	O	O	
Diglycolic Acid	S	S	
Diisooctyl Phthalate	S	S	
Dimethyl Phthalate	S	S	
p-Dioxane	S	O	
Ethyl Acetate	S	S	
Ethyl Alcohol	S	S	S
Ethylamine	S	S	
Ethylene Chloride	U	U	
Ethylene Chlorohydrin	S	S	

CHEMICAL RESISTANCE OF FORTILENE POLYPROPYLENE

Legend: S=Satisfactory. O=Some Attack. U=Unsatisfactory

Reagent	70°F (21°C)	140°F (60°C)	212°F (100°C)
Ethylene Glycol	S	S	
Ethanolamine	S	S	
Ethyl Ether	O	O	
Ethyl Chloride	O	O	
Ethylene Dichloride	S		
Ethylene Oxide	S		
Ferric Chloride	S	S	
Ferric Nitrate	S	S	
Ferric Sulfate	S	S	
Ferrous Chloride	S	S	
Ferrous Nitrate	S	S	O
Ferrous Sulfate	S	S	
Fluorine	U	U	
Fluorosilicic	S	S	
Formaldehyde	S	S	O
Formic Acid (10%)	S	S	
Formic Acid (100%)	S		
Fructose	S	S	
Fruit Juice	S	S	
Fuel Oil	S	O	
Furfural	U	U	
Gasoline	O	U	
Gelatin	S	S	
Glucose	S	S	
Glycerol	S	S	S
Glycol	S	S	O
Glycolic Acid	S	S	
Heptane	U	U	
Hexadecyl Alcohol	S	S	
Hexane	S	S	
Hydroiodic Acid	U	U	
Hydrobromic Acid(50%)	S	S	
Hydrochloric Acid(20%)	S	S	O
Hydrochloric Acid(100%)	S	S	
Hydrofluoric Acid(35%)	S	S	
Hydrogen Peroxide(30%)	S	O	
Hydrogen Peroxide(90%)	O	O	
Hydrogen Chloride Gas(dry)	S	S	
Hydrogen Sulfide	S	S	
Hydroquinone	S	S	
Igepal	S	S	
Iodine(dry)	S	S	
Iodine(wet)	U		
Isopropyl Alcohol	S	S	
Isooctane	U		
Jet Fuel(JP 4 & 5)	O	U	
Lactic Acid	S	S	
Lanolin	S	S	
Lauric Acid	S	S	
Lead Acetate	S	S	S
Lemon Oil	O		
Linseed Oil	S	S	
Lubricating Oil	S	O	

Reagent	70°F (21°C)	140°F (60°C)	212°F (100°C
Magnesium Sulfite	S	S	
Malic Acid	S	O	
Mercuric Chloride	S	S	
Mercuric Cyanide	S	S	
Mercuric Nitrate	S	S	
Mercury	S	S	
Merthiolate (Tincture)	S	S	
Methane	S	S	
Methanol	S	S	
Methyl Cellusolve	S		
Methyl Chloride	U		
Methylene Chloride	S	O	
Methyl Ethyl Ketone	S	S	
Methyl Isobutyl Ketone	S	S	
Methyl Sulfuric Acid	S	S	
Milk	S	S	
Mineral Oil	S	U	
Mineral Spirits	S	S	
Motor Oil	S	S	
Naphtha	S	S	
Naphthalene	S	S	S
Nickel Chloride	S	S	
Nickel Nitrate	S	S	(
Nickel Sulfate	S	S	S
Nitric Acid (10%)	S	S	S
Nitric Acid (concentrate)	O	U	
Nitric Acid (fuming)	U		
Nitric/Sulfuric Acid 50/50%	U		
Nitrobenzene	S	O	
Nitrous Acid	O		
Oleic Acid	S	S	
Oleum	U		
Olive Oil	S	S	
Oxalic Acid	S	S	
Oxygen	U	U	
Ozone	U	U	
Paradichlorobenzene	S	S	
Paraffin	S	S	
Peanut Oil	S	S	
Perchloroethylene	U	U	
Phenoil (10%)	S	S	O
Phosgene (gas)	U	U	
Phosgene (liquid)	U	U	
Phosphoric Acid (30%)	S	S	O
Phosphoric Acid (85%)	S	S	O
Phosphorus	S		
Phathalic Acid	S		
Polyvinyl Acetate	S		
Potassium Bromide	S	S	S
Potassium Carbonate	S	S	S
Potassium Chlorate	S	S	O
Potassium Chloride	S	S	O
Potassium Cyanide	S	S	
Potassium Dichromate	S	S	S
Potassium Ferrocyanide	S	S	
Potassium Hydroxide	S	S	S
Potassium Nitrate	S	S	

Table 4 (continued)

CHEMICAL RESISTANCE OF FORTILENE POLYPROPYLENE

Legend: S = Satisfactory, O = Some Attack, U = Unsatisfactory

Reagent	70°F (21°C)	140°F (60°C)	212°F (100°C)
Magnesium Carbonate	S	S	S
Magnesium Chloride	S	S	O
Magnesium Hydroxide	S	S	S
Magnesium Nitrate	S	S	
Magnesium Sulfate	S	S	
Potassium Permanganate	S	O	
Potassium Sulfate	S	S	S
Potassium Sulfide	S	S	S
Propanol	S	S	
Pyridine	S		
Silicone Oil	S	S	
Silver Cyanide	S	S	
Silver Nitrate	S	S	S
Sodium Acetate	S	S	
Sodium Benzoate	S	S	S
Sodium Bicarbonate	S	S	
Sodium Bisulfate	S	S	
Sodium Bisulfite	S	S	
Sodium Bromide	S	S	
Sodium Carbonate	S	S	S
Sodium Chlorate	S	S	O
Sodium Chloride	S	S	O
Sodium Cyanide	S	S	
Sodium Fluoride	S	S	
Sodium Hydroxide (concentrated)	S	S	S
Sodium Sulfate	S	S	
Sodium Sulfite	S	S	
Starch	S	S	
Stannic Chloride	S	S	
Stannous Chloride	S	S	

Reagent	70°F (21°C)	140°F (60°C)	212°F (100°C)
Sucrose (20%)	S	S	
Sulfuric Acid (10%)	S	S	S
Sulfuric Acid (50%)	S	S	
Sulfuric Acid (concentrated)	S	O	U
Sulfuric Acid (fuming)	U	U	
Sulfamic Acid	S	S	
Tannic Acid (10%)	S	S	
Tetrahydrofuran	S	O	O
Tetralin	O	O	O
Toluene	U	U	
Tributyl Phosphate	S	O	
Trichloroacetic Acid	S	S	
Trichloroethylene	U	U	
Tricresyl Phosphate	S	S	
Triethanolamine	O	O	
Trisodium Phosphate	S	S	
Turpentine	S	O	O
Urea	S	S	
Urine	S	S	
Water	S	S	O
Whiskey	S	S	S
Wines	S	S	
Xylene	O	U	
Xylol	S		
Yeast	S	S	
Zinc Chloride	S	S	
Zinc Oxide	S	S	
Zinc Sulfate	S	S	

Table II
Chemical Resistance of Fortiflex HDPE

Legend: S = Satisfactory, O = Some Attack, U = Unsatisfactory

Reagent	21°C (70°F)	60°C (140°F)
Acetaldehyde	S	O
Acetic Acid 1-10%	S	S
Acetic Acid 10-60%	S	O
Acetic Acid 80-100%	S	O
Acetic Anhydride	S	S
Acetone	S	S
Acids, Aromatic	S	S
Acrylic Emulsions	S	S
Adipic Acid	S	S
Aluminum Chloride Dilute	S	S
Aluminum Chloride Conc.	S	S
Aluminum Fluoride Conc.	S	S
Aluminum Sulfate Conc.	S	S
Alums (all types) Conc.	S	S
Amino Acetic Acid	S	S
Ammonia 100% Dry Gas	S	S
Ammonium Acetate	S	S
Ammonium Bromide	S	S
Ammonium Carbonate	S	S
Ammonium Chloride Sat'd	S	S
Ammonium Fluoride 20%	S	S
Ammonium Hydroxide	S	S
Ammonium Metaphosphate Sat'd	S	S
Ammonium Nitrate Sat'd	S	S
Ammonium Persulfate Sat'd	S	S
Ammonium Phosphate	S	S
Ammonium Sulfate Sat'd	S	S
Ammonium Sulfide Sat'd	S	S
Ammonium Thiocyanate Sat'd	S	S
Amyl Acetate 100%	O	U
Amyl Alcohol 100%	S	S
Amyl Chloride 100%	O	U
Aniline 100%	S	U
Anise Seed Oil	O	U
Antimony Chloride	S	S
Aqua Regia	O	U
Aromatic Hydrocarbons	U	U
Arsenic	S	S
Aspirin	S	S
Barium Carbonate Sat'd	S	S
Barium Chloride Sat'd	S	S
Barium Hydroxide	S	S
Barium Sulfate Sat'd	S	S
Barium Sulfide Sat'd	S	S
Beer	S	S
Benzaldehyde	S	O
Benzene	O	U
Benzene Sulfonic Acid	S	S
Benzoic Acid		
Crystals	S	S
Saturated	S	S
Bismuth Carbonate Sat'd	S	S
Black Liquor	S	S
Bleach Lye 10%	S	S
Borax Cold Sat'd	S	S

Reagent	21°C (70°F)	60°F (140°F)
Boric Acid Dilute	S	S
Boric Acid Conc.	S	S
Brine	S	S
Bromic Acid 10%	S	S
Bromine Liquid 100%	O	U
Bromochloromethane	U	U
Butadiene	U	U
Butanediol 10%	S	S
Butanediol 60%	S	S
Butanediol 100%	S	S
Butter	S	S
Butyl Acetate 100%	O	U
Butyl Alcohol 100%	S	S
Butylene Glycol	S	S
Butyric Acid 100%	S	S
Caffeine Citrate Sat'd	S	S
Calcium Bisulfide	S	S
Calcium Bromide	S	S
Calcium Carbonate Sat'd	S	S
Calcium Chlorate Sat'd	S	S
Calcium Chloride Sat'd	S	S
Calcium Hydroxide	S	S
Calcium Hypochlorite Bleach Sat'd	S	S
Calcium Nitrate 50%	S	S
Calcium Sulfate	S	S
Camphor Crystals	S	S
Camphor Oil	U	U
Carbon Dioxide 100% Dry	S	S
Carbon Dioxide 100% Wet	S	S
Carbon Dioxide Cold Sat'd	S	S
Carbon Disulphide	O	U
Carbon Monoxide	S	S
Carbon Tetrachloride	U	U
Carbonic Acid	S	S
Carnauba Wax	S	S
Carrot Juice	S	S
Castor Oil Conc.	S	S
Catsup	S	S
Caustic Soda	S	O
Cedar Leaf Oil	U	U
Cedar Wood Oil	U	U
Chlorine Liquid	O	U
Chlorobenzene	O	U
Chloroform	U	U
Chlorosulfonic Acid 100%	U	U
Chrome Alum Sat'd	S	S
Chromic Acid 10-20%	S	O
Chromic Acid 50%	S	O
Cider	S	S
Cinnamon	S	S
Cinnamon Oil	U	U
Citric Acid Sat'd	S	S
Citronella Oil	O	U
Cloves (Ground)	S	S
Coconut Oil Alcohols	S	S
Cod Liver Oil	S	S
Coffee	S	S

Table II
Chemical Resistance of Fortiflex HDPE

Legend: S = Satisfactory, O = Some Attack, U = Unsatisfactory

Reagent	21°C (70°F)	60°C (140°F)
Copper Chloride Sat'd	S	S
Copper Cyanide Sat'd	S	S
Copper Fluoride 2%	S	S
Copper Nitrate Sat'd	S	S
Copper Sulfate Dilute	S	S
Copper Sulfate Sat'd	S	S
Corn Oil	S	S
Cottonseed Oil	S	S
Cranberry Sauce	S	S
Cresols	S	O
Cuprous Chloride Sat'd	S	S
Cuprous Oxide	S	S
Cyclohexane	U	U
Cyclohexanone	U	U
Decalin	U	U
Detergents Synthetic	S	S
Developers Photographic	S	S
Dextrin Sat'd	S	S
Dextrose Sat'd	S	S
Dibutyl Ether	O	U
Dichlorobenzene (O&P)	U	U
Diethylene Glycol	S	S
Disodium Phosphate	S	S
Dioxane	O	O
Emulsions Photographic	S	S
Ether	O	O
Ethyl Acetate 100%	O	O
Ethyl Alcohol 100%	S	S
Ethyl Alcohol 35%	S	S
Ethylbenzene	O	U
Ethylene Glycol	S	S
Ferric Chloride Sat'd	S	S
Ferric Nitrate Sat'd	S	S
Ferrous Ammonium Citrate	S	S
Ferrous Chloride Sat'd	S	S
Ferrous Sulfate	S	S
Fluoboric Acid	S	S
Fluorine	S	U
Fluosilicic Acid 32%	S	S
Fluosilicic Acid Conc.	S	S
Formaldehyde		
10-30%	S	S
30-40%	S	O
Formic Acid 20%	S	S
Formic Acid 50%	S	S
Formic Acid 100%	S	S
Fructose Sat'd	S	S
Fuel Oil	S	U
Furfural 100%	O	U
Furfuryl Alcohol	S	O
Gallic Acid Sat'd	S	S
Gasoline	S	U
Glucose	S	S
Glycerine	S	S
Glycol	S	S

Reagent	21°C (70°F)	60°F (140°F)
Glycolic Acid 30%	S	S
Grape Juice	S	S
Grapefruit Juice	S	S
Heptane	O	U
Hexachlorobenzene	S	S
Hexane	U	U
Hydrobromic Acid 50%	S	S
Hydrocyanic Acid Sat'd	S	S
Hydrochloric Acid 10%	S	S
Hydrochloric Acid 30%	S	S
Hydrochloric Acid 35%	S	S
Hydrocyanic Acid	S	S
Hydrofluoric Acid 40%	S	S
Hydrofluoric Acid 60%	S	S
Hydrofluoric Acid 75%	S	S
Hydrogen 100%	S	S
Hydrogen Bromide 10%	S	S
Hydrogen Chloride Gas Dry	S	S
Hydrogen Peroxide 30%	S	S
Hydrogen Peroxide 90%	S	S
Hydroquinone	S	S
Hydrogen Sulfide	S	S
Hypochlorous Acid Conc	S	S
Inks	S	S
Iodine Crystals	O	O
Isobutyl Alcohol	S	S
Isopropyl Alcohol	S	S
Isopropyl Ether	O	U
Kerosene	O	U
Lactic Acid 10%	S	S
Lactic Acid 90%	S	S
Lanolin	S	S
Lard	S	S
Lead Acetate Sat'd	S	S
Lead Nitrate	S	S
Lemon Juice	S	S
Lemon Oil	O	U
Lime Juice	S	S
Linseed Oil	S	S
Magnesium Carbonate Sat'd	S	S
Magnesium Chloride Sat'd	S	S
Magnesium Hydroxide Sat'd	S	S
Magnesium Nitrate Sat'd	S	S
Magnesium Sulfate Sat'd	S	S
Margarine	S	S
Mercuric Chloride	S	S
Mercuric Cyanide Sat'd	S	S
Mercurous Nitrate Sat'd	S	S
Mercury	S	S
Methyl Alcohol 100%	S	S
Methyl Ethyl Ketone 100%	U	U
Methylsulfuric Acid	S	U
Methylene Chloride 100%	U	U

Table II
Chemical Resistance of Fortiflex HDPE

Legend: S = Satisfactory, O = Some Attack, U = Unsatisfactory

Reagent	21°C (70°F)	60°C (140°F)
Milk	S	S
Mineral Oils	S	U
Molasses	S	S
Mustard (Prepared)	S	S
Naphtha	O	U
Napthalene	S	U
Natural Gas (Wet)	S	S
Nickel Chloride Sat'd	S	S
Nickel Nitrate Conc.	S	S
Nickel Sulfate	S	S
Nicotinic Acid	S	S
Nitric Acid 0-30%	S	S
Nitric Acid 30-50%	S	O
Nitric Acid 70%	S	O
Nitric Acid 95-98%	U	U
Nitrobenzene 100%	U	U
Nitroglycerine	O	U
Octane	S	U
Oleum Conc.	U	U
Olive Oil	S	S
Orange Juice	S	S
Oxalic Acid Dilute	S	S
Oxalic Acid Sat'd	S	S
Ozone	O	O
Palm Oil	S	S
Paraffin Oil	S	O
Peanut Butter	S	S
Perchloroethylene	U	U
Pepper (Fresh Ground	S	S
Peppermint Oil	O	U
Perchloric Acid 50%	S	O
Petroleum Ether	U	U
Petroleum Jelly	S	S
Phenol	S	S
Phosphoric Acid 0-30%	S	S
Phosphoric Acid 30-90%	S	S
Phosphoric Acid Over 90%	S	S
Photographic Solutions	S	S
Phthalic Anhydride	S	S
Pickling Baths		
Sulfuric Acid	S	S
Hydrochloric Acid	S	S
Sulfuric-Nitric	S	U
Pine Oil	O	U
Plating Solutions		
Brass	S	S
Cadmium	S	S
Chromium	S	S
Copper	S	S
Gold	S	S
Indium	S	S
Lead	S	S
Nickel	S	S
Rhodium	S	S
Silver	S	S
Tin	S	S
Zinc	S	S
Potassium Bicarbonate Sat'd	S	S
Potassium Borate 1%	S	S
Potassium Bromate 10%	S	S
Potassium Bromide Sat'd	S	S
Potassium Carbonate	S	S
Potassium Chlorate Sat'd	S	S
Potassium Chloride Sat'd	S	S
Potassium Chromate 40%	S	S
Potassium Cyanide Sat'd	S	S
Potassium Dichromate 40%	S	S
Potassium Ferri/Ferro Cyanide	S	S
Potassium Fluoride	S	S
Potassium Hydroxide 20% Conc	S	S
Potassium Nitrate Sat'd	S	S
Potassium Perborate Sat'd	S	S
Potassium Perchlorate 10%	S	S
Potassium Permanganate 20%	S	S
Potassium Sulfate Conc	S	S
Potassium Sulfide Conc.	S	S
Potassium Sulfite Conc	S	S
Potassium Persulfate Sat'd	S	S
Propane Gas	S	S
Propargyl Alcohol	S	S
Propyl Alcohol	S	S
Propylene Glycol	S	S
Pyridine	S	O
Rayon Coagulating Bath	S	S
Resorcinol	S	S
Salicylic Acid	S	S
Sea Water	S	S
Shortening	S	S
Silicic Acid		
Silver Nitrate Sol'n	S	S
Soap Solution Conc.	S	S
Sodium Acetate Sat'd	S	S
Sodium Benzoate 35%	S	S
Sodium Bicarbonate Sat'd	S	S
Sodium Bisulfate Sat'd	S	S
Sodium Bisulfite Sat'd	S	S
Sodium Borate	S	S
Sodium Carbonate Conc.	S	S
Sodium Chlorate Sat'd	S	S
Sodium Chloride Sat'd	S	S
Sodium Cyanide	S	S
Sodium Dichromate Sat'd	S	S
Sodium Ferricyanide Sat'd	S	S
Sodium Ferricyanide	S	S
Sodium Fluoride Sat'd	S	S
Sodium Hydroxide Conc.	S	S

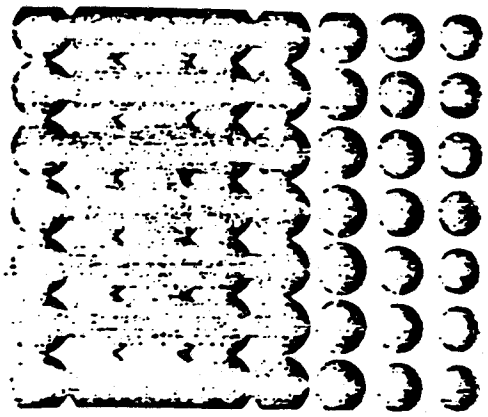
Table II
Chemical Resistance of Fortiflex HDPE

Legend: S = Satisfactory, O = Some Attack, U = Unsatisfactory

Reagent	21°C (70°F)	60°C (140°F)
Sodium Hypochlorite	S	S
Sodium Nitrate	S	S
Sodium Nitrite	S	S
Sodium Perborate	S	S
Sodium Phosphate	S	S
Sodium Sulfide 25% to Sat'd	S	S
Sodium Sulfite Sat'd	S	S
Sodium Thiosulphate	S	S
Soybean Oil	S	S
Stannous Chloride Sat'd	S	S
Stannic Chloride Sat'd	S	S
Starch Solution Sat'd	S	S
Stearic Acid 100%	S	S
Sulfuric Acid 0-50%	S	S
Sulfuric Acid 70%	S	O
Sulfuric Acid 80%	S	U
Sulfuric Acid 96%	O	U
Sulfuric Acid 98% Conc	O	U
Sulfuric Acid Fuming	U	U
Sulfurous Acid	S	S
Tartaric Acid	S	S
Tannic Acid 10%	S	S
Tea	S	S
Tetrahydrofurane	O	O

Reagent	21°C (70°F)	60°F (140°F)
Toluene	U	U
Tomato Juice	S	S
Transformer Oil	S	O
Trisodium Phosphate Sat'd	S	S
Trichloroethylene	U	U
Turpentine	O	U
Urea	S	S
Urine	S	S
Vanilla Extract	S	S
Vaseline	S	S
Vinegar Comm.	S	S
Wetting Agents	S	S
Whiskey	S	S
Wines	S	S
Xylene	U	U
Yeast	S	S
Zinc Chloride Sat'd	S	S
Zinc Oxide	S	S
Zinc Sulfate Sat'd	S	S

Rigidex
high density
polyethylene



Technigram T800/1

Chemical resistance of Rigidex

Introduction

A guide to the effect that a variety of chemicals has on high density polyethylene (HDPE) is given in the following Table which is a compendium of BP Chemicals Limited information and other published literature sources.

Polyethylene materials as a class have a high resistance to chemical attack and are insoluble in all known solvents at room temperature. However, when considering the suitability of Rigidex HDPE for a particular application, certain other factors should be taken into account.

Permeation effects

HDPE has a closely packed molecular structure and as a result provides an effective barrier to many liquids, gases and vapours. Consequently, Rigidex grades are used extensively to package and transport a wide range of household and industrial products, foodstuffs, pharmaceuticals, agrochemicals and cosmetics. However, HDPE, in common with all thermoplastics is incapable of providing a complete barrier to all substances and loss by relatively low permeation rates can sometimes be accompanied by partial collapse of the container (panelling). In some instances, this can influence the stacking performance of the container in addition to detracting from the aesthetic appeal.

If panelling cannot be overcome by improving bottle rigidity, then it might sometimes be possible to camouflage the effect by using an oval cross section bottle or incorporating concave surfaces.

Photo-degradation effects

Panelling can also occur with products that are either photo-degradable or result in the absorption of oxygen from the ullage space. However, the use of opaque pigmentation and/or flushing the head space with nitrogen immediately prior to capping, will often eliminate panelling.

Absorption

This phenomenon is similar to permeation and in general the two effects tend to present problems with the same liquids. One notable exception is motor oil, which often exhibits quite high absorption levels yet negligible permeation.

When HDPE absorbs a liquid, there may be a change of dimensions and swelling. In severe cases, buckling of the container walls and panelling effects similar to those observed by permeation can occur. The swelling is usually accompanied by some loss of mechanical properties, notably tensile strength and softening of the polymer.

Environmental stress crack resistance

Products made from HDPE sometimes fail prematurely in service in the presence of certain surface active environments. Examples of these are detergents, chlorinated hydrocarbons, alcohols and some silicone products.

The brittle type of failure which occurs is always associated with a combination of the active environment and mechanical stresses in the moulded product. In any moulding there will always be regions of moulded-in stress in addition to stresses which result from externally applied loads. Also, some features of container design such as sharp corners or notches will produce areas of stress concentration which intensify the effects of applied loads. These stresses can result in brittle failure in the presence of active environments, even though the stresses involved would normally be within the mechanical limits of the polymer. In addition, these effects can be accelerated by elevated temperatures.

The activity of a liquid as a stress cracking environment and the resistance to stress cracking provided by the polymer may be assessed by a range of test methods. Generally, polyethylene materials of lower density and melt flow rate have better resistance to environmental stress cracking.

Packaging suitability

The use of small scale accelerated tests should be used only as an indication of the suitability of HDPE as a packaging material for a particular product. Information inferred from these tables for a single product may not, of course, be relevant when it is used as a component in a mixture of chemicals. Consequently, potential users of HDPE containers should always satisfy themselves that the containers are suitable for their particular product, taking into account the conditions of storage and distribution.

Guide to chemical resistance

Key

S. Satisfactory. This chemical is only absorbed to a low level and thus has little or no measurable effect on physical properties.

L. Limited resistance. A higher level of absorption occurs resulting in definite loss of physical properties. The question of the suitability of high density polyethylene would have to be considered with respect to the particular environment.

E. Environmental stress cracking may occur.

NS. Not satisfactory. Chemical attack or a high level of absorption occurs. In both cases the loss of physical properties is such that high density polyethylene is not suitable where prolonged contact is likely.

Substance	Conc.%	20°C	60°C
General chemical products			
Acetaldehyde	100	S	L
Acetic acid	10	S/E	S/E
Acetic acid	100	S/E	L/E
Acetic anhydride	100	S	L
Acetone	100	S	S
Acetophenetidin		S	S
Acetophenone	100	S	S
Acetylene	All	S	S
Acrylic emulsions	All	S/E	S/E
Acrylonitrile	100	S	S
Adipic acid		S	S
Aliphatic alcohols	100	S	S
Allyl chloride	100	S	S
Allyl alcohol	96	S	S
Allyl chloride	100	L	L
Aluminium acetate	All	S	S
Aluminium carbonate	All	S	S
Aluminium chloride		S	S
Aluminium fluoride		S	S
Aluminium hydroxide		S	S
Aluminium nitrate		S	S
Aluminium oxalate		S	S
Aluminium oxychloride		S	S
Aluminium sulphate		S	S
Alums	All	S	S
Amino acetic acid	All	S	S
Ammonia (gaseous)	100	S	S
Ammonium acetate	All	S	S
Ammonium bicarbonate	All	S	S
Ammonium carbonate		S	S
Ammonium chloride		S	S
Ammonium fluoride		S	S
Ammonium hydroxide		S	S
Ammonium metaphosphate		S	S
Ammonium nitrate		S	S
Ammonium oxalate		S	S
Ammonium persulphate		S	S
Ammonium phosphate		S	S
Ammonium sulphate		S	S
Ammonium sulphide		S	S
Ammonium thiocyanate		S	S
Amyl acetate	100	L	L

Substance	Conc.%	20°C	60°C
Amyl alcohol	10	L	L
Amyl chloride	All	L	L
Aniline	100	L	L
Antimony	100	S	S
Antimony trichloride	100	S	S
Aqua regia	100	NS	NS
Arsenic	100	S	S
Arsenic acid		S	S
Aryl sulphonic acid	100	S	S
Benzaldehyde	100	S	L
Benzaldehyde (AQ)	Sat.	S	—
Benzene	100	L	NS
Benzene sulphonic acid	100	S/E	S/E
Benzoic acid	Sat.	S	S
Benzophenone	100	S	S
Benzoyl cloride	100	L	L
Bismuth carbonate		S	S
Boric acid		S	S
Boron trifluoride	100	S	
Bromic acid	10	S	S
Bromine (liquid)	100	NS	NS
Bromine (vapour)	High	NS	NS
Bromine water	Sat.	NS	NS
Bromochloromethane	100	NS	NS
Butadiene	100	NS	NS
Butanediol	100	S/E	
Butane (gaseous)	100	S	S
Butane (liquid)	100	L	—
Butanol	100	S	S
Butoxyl (methoxy butyl acetate)	100	S	L
Butyl acetate	100	L	NS
Butyl alcohol	100	S/E	S/E
Butylene glycol	100	S	S
Butyric acid	100	S	L
Carbon dioxide (dry)	100	S	S
Carbon dioxide (wet)	100	S	S
Carbon disulphide	100	L	—
Carbon monoxide	100	S	S
Carbon tetrachloride	100	NS	NS
Caustic potash (soln.)	50	S	S
Caustic potash (soln.)	10	S	S
Caustic soda	50	S	S
Caustic soda	10	S	S
Chloral hydrate	100	S	S
Chlorine gas (moist)		L	NS
Chlorine liquid		NS	NS
Chlorine water		L	NS
Chloroacetic acid	100	S	S
Chlorobenzene	100	L	NS

Substance	Conc.%	20°C	60°C
Chloroethanol	100	S	S
Chloroform	100	NS	NS
Chloromethane	100	L	—
Chlorosulphonic acid	100	NS	NS
Chrome alum		S	S
Chromic acid	Sat.	S/L	NS
Chromium salts	Sat.	S	S
Citric acid		S/E	S/E
Copper salts (aqueous)	Sat.	S	S
Cresols	100	S	S
Cresylic acid	100	L	—
Cresylic acid	50	S	S
Cyclohexane	100	L	L
Cyclohexanol	100	S/E	S/E
Cyclohexanone	100	S	L
Decahydronaphthalene	100	L	NS
Dibutyl ether	100	L	NS
Dibutyl phthalate	100	L	L
Dibutyl sebacate	100	S	—
Dichloroacetic acid	100	S	L
Dichloroacetic acid	50	S	S
Dichloroacetic acid/methyl ester		S	S
o-dichlorobenzene		L	NS
p-dichlorobenzene		L	NS
Dichloroethane	100	L	L
Dichloroethylene	100	NS	NS
Diethyl ether	100	L	L
Diethylene glycol	100	S/E	S/E
Diglycolic acid	100	S/E	S/E
Dihexyl phthalate	100	S	S
Diisobutyl ketone	100	S	NS
Dimethyl carbinol	100	S	—
Dimethyl formamide	100	S	L
Dimethyl sulphoxide	100	S	S
Dinonyl adipate	100	S	—
Dinonyl phthalate	100	S	L
Dioctyl adipate	100	S	—
Dioctyl phthalate	100	S	L
1,4-Dioxane	100	S	S
Diphenyl ether	100	L	L
Disodium phosphate	100	S	S
Epichlorhydrin	100	S	S
Epoxy resins	100	S	S
Ethanediol	100	S	S
Ether	100	S/E	L
Ethyl acetate	100	S	L
Ethyl acrylate	100	L	L
Ethyl alcohol	100	S/E	S/E
Ethylbenzene	100	L	NS

Substance	Conc.%	20°C	60°C
Ethyl butyrate	100	L	NS
Ethyl chloride	100	L	NS
Ethylene chloride	100	L	NS
Ethylenediaminetetra-acetic acid	100	S	S
Ethylene dichloride	100	L	NS
Ethylene glycol	100	S/E	S/E
2-Ethylhexanol	100	S	—
Fatty acids (>6)		S/E	S/E
Ferric chloride		S	S
Ferric nitrate		S	S
Ferric sulphate		S	S
Ferrous ammonium citrate chloride	Sat.	S	S
Ferrous sulphate		S	S
Fluoboric acid	100	S	S
Fluoric acid	40	S	S
Fluorine	100	NS	NS
Fluorosilicic acid		S	S
Formaldehyde (aqueous)	40	S/E	S/E
Formalin		S	S
Formic acid		S/E	S/E
Furfural	100	L	NS
Furfuryl alcohol	100	S	L
Gallic acid		S/E	S/E
Glycolic acid	30	S/E	S/E
Glycolic acid butyl ester	100	S	S
Heptane	100	S	NS
Hexachlorobenzene	100	S	S
Hexamine	100	S/E	S/E
Hexane	100	NS	NS
Hydrazine	100	S/E	S
Hydrazine hydrate	100	S/E	S
Hydrobromic acid	50	S	S
Hydrochloric acid	Conc.	S	S
Hydrocyanic acid	100	S	S
Hydrocyanic acid	Sat.	S	S
Hydrocyanic acid	10	S	S
Hydrofluoric acid	40	S	S
Hydrofluoric acid	70	S	S
Hydrogen	100	S	S
Hydrogen bromide	10	S	S
Hydrogen peroxide	30	S	S
Hydrogen peroxide	90	S	NS
Hydrogen phosphite	100	S	S
Hydrogen sulphide	Low	S	S
Hydroquinone		S	S
Hypochlorites	100	S	S
Hypochlorous acid	All	S	S

Substance	Conc.%	20°C	60°C
Iron salts (aqueous)	Sat.	S	S
Isobutyl alcohol	100	S	—
Isooctane	100	S	L
Isopropanol	100	S	S
Isopropyl ether	100	L	NS
Lactic acid	100	S/E	S/E
Lead acetate	Sat.	S	S
Lead tetraethyl		S	
Magnesium carbonate		S	S
Magnesium chloride		S	S
Magnesium hydroxide		S	S
Magnesium nitrate		S	S
Magnesium sulphate		S	S
Maleic acid	50	S	S
Manganese sulphate		S	S
Mercuric chloride		S	S
Mercuric cyanide		S	S
Mercurous nitrate		S	S
Mercury	100	S	S
Methoxybutanol	100	S	L
Methyl acrylate		NS	NS
Methyl alcohol		S/E	S/E
Methyl bromide		L	NS
Methyl cyclohexane		L	NS
Methylene chloride		NS	NS
Methyl ethyl ketone	100	S	L
Methyl glycol		S	S
4-Methyl-2-pentanol		S	L
Methyl sulphuric acid		S/E	S/E
Monochloroacetic acid		S	S
Monochlorobenzene		S	S
Naphthalene	100	S	
Natural gas		S	S
Nickel salts (aqueous)	Sat.	S	S
Nicotine	Dil.	S/E	S/E
Nicotinic acid		S/E	S/E
Nitric acid	50	L	NS
Nitric acid	98	NS	NS
Nitrobenzene	100	NS	NS
Nitroglycerine	100	NS	NS
Nitropropane		L	L
o-nitrotoluene	100	S	L
Nitrous gases	100	S	S
Nonyl alcohol	100	S	—
Oleic acid	100	S/E	L/E
Oleum		NS	NS
Oxalic acid		S/E	S/E

Substance	Conc.%	20°C	60°C
Oxygen	100	S	S
Ozone		NS	NS
Palmitic acid		S/E	S/E
Pentane		NS	—
Perchloric acid	20	S	S
Perchloric acid	50	S	S
Perchloric acid	70	S	NS
Petroleum ether	100	S	L
Phenol (aqueous phase)		S	S
Phenol (solid phase)	100	S	S
Phenyl sulphonate		S	S
Phosgene		S	—
Phosphoric acid	25	S	S
Phosphoric acid	50	S	S
Phosphoric acid	Conc.	S/L	NS
Phosphoric anhydride		S	S
Phosphorous		S	S
Phosphorous oxychloride		S	L
Phosphorous pentoxide		S	S
Phosphorous trichloride		S	L
Phthalic acid	50	S	S
Phthalic anhydride		S	S
Picric acid		S	S
Polyglycol ethers		S	S
Potassium antimonate		S	S
Potassium bicarbonate		S	S
Potassium bichromate		S	S
Potassium bisulphate		S	S
Potassium borate		S	S
Potassium bromate		S	S
Potassium bromide		S	S
Potassium carbonate		S	S
Potassium chlorate		S	S
Potassium chloride		S	S
Potassium chromate		S	S
Potassium cuprocyanide		S	S
Potassium cyanide		S	S
Potassium dichromate		S	S
Potassium ferri/ ferrocyanide		S	S
Potassium fluoride		S	S
Potassium hydroxide		S	S
Potassium hypochlorite		S	S
Potassium iodide	Sat.	S	S
Potassium nitrate		S	S
Potassium orthophosphate		S	S

Substance	Conc.%	20°C	60°C
Potassium perborate		S	S
Potassium permanganate		S	S
Potassium persulphate		S	S
Potassium sulphate		S	S
Potassium sulphide		S	S
Potassium sulphite		S	S
Propane (gaseous)	100	S	S
Propane (liquid)	100	S	—
Propargyl alcohol		S/E	S/E
Propionic acid	50	S	S
Propionic acid	100	S	L
Propyl alcohol	100	S/E	S/E
Propylene dichloride	100	NS	NS
Propylene glycol		S/E	S/E
Pseudocumene		L	L
Pyridine	100	S	NS
Quinine		S	
Resorcinol	100	S	S
Salicylic acid		S	S
Selenic acid	100	S	S
Silicic acid		S	S
Silicone fluids		S/E	S/E
Silver nitrate		S	S
Silver salts (aqueous)	Sat.	S	S
Sodium acetate		S	S
Sodium benzoate		S	S
Sodium bicarbonate		S	S
Sodium bisulphate		S	S
Sodium borate		S	S
Sodium bromide		S	S
Sodium carbonate		S	S
Sodium chlorate		S	S
Sodium chloride		S	S
Sodium chlorite		S	S
Sodium cyanide		S	S
Sodium dichromate		S	S
Sodium dodecyl-benzenesulphonate		S	S
Sodium ferricyanide		S	S
Sodium ferrocyanide		S	S
Sodium fluoride		S	S
Sodium hydroxide		S	S
Sodium hypochlorite		S	S
Sodium hyposulphate		S	—
Sodium nitrate		S	S
Sodium nitrite		S	S

Substance	Conc.%	20°C	60°C
Sodium orthophosphate		S	S
Sodium perborate		S	S
Sodium peroxide	10	S	—
Sodium peroxide	Sat.	L	—
Sodium phosphate		S	S
Sodium silicate		S	S
Sodium sulphate		S	S
Sodium sulphide		S	S
Sodium sulphite		S	S
Sodium tetraborate		S	S
Sodium thiosulphate		S	S
Stannic chloride		S	S
Stannous chloride		S	S
Stearic acid	100	S/E	S/E
Succinic acid	Sat.	S	S
Sulphur		S	S
Sulphur dioxide (dry)		S	S
Sulphur dioxide (wet)		S	S
Sulphur trioxide		NS	NS
Sulphuric acid	10	S	S
Sulphuric acid	50	S	S
Sulphuric acid	95	S	L
Sulphurous acid	30	S	S
Sulphuryl chloride		NS	
Tannic acid		S/E	S/E
Tartaric acid	100	S	S
Tartaric acid (aqueous)	Sat.	S	S
Tetrabromomethane	100	NS	NS
Tetrachloroethane	100	NS	NS
Tetrahydrofuran	100	L	NS
Tetralin	100	S	L
Thioglycolic acid	100	S	S
Thionyl chloride		NS	
Thiophene	100	L	L
Toluene	100	L	NS
Trichloroacetic acid	50	S	S
Trichloroacetic acid	100	L	NS
Trichloroethylene	100	L	NS
Tri ß chloroethylene phosphate	100	S	S
Tricresyl phosphate	100	L	L
Triethanolamine		L	L
Urea		S/E	S/E
Xylene	100	L	NS
Zinc ammonium carbonate		S	S
Zinc carbonate		S	S
Zinc chloride		S	S
Zinc oxide		S	S
Zinc sulphate		S	S
Oils and Waxes			
Aniseed oil	100	L	NS
Beeswax	100	S	S
Carnauba wax		S	S
Castor oil	100	S/E	S/E
Cedar leaf oil		NS	NS
Cedar wood oil		NS	NS
Cinnamon oil		NS	NS
Citronella oil		NS	NS
Clove oil		S	S
Coconut oil		S	NS
Coconut oil alcohols		S/E	S/E
Cod liver oil	100	S	—
Corn seed oil		S	L
Cotton seed oil		S/E	S/E
Diesel oil		S	S
Fuel oil	100	S	L
Kerosene		L	L
Lanolin	100	S	—
Lemon peel oil		S	L
Linseed oil	100	S	S
Menthol	100	S	S
Mineral oil		L	L
Motor oil	100	S	L
Olive oil	100	S	S
Orange peel oil	100	S	—
Palm oil	100	S	—
Paraffin oil	100	S	L
Paraffin wax	100	S	S
Peanut oil	100	S	S
Peppermint oil		L	NS
Petrol		S/L	S/L
Pine needle oil	100	S	S
Pine oil	100	L	NS
Salad oils	100	S	L
Silicone oil	100	S/E	L/E

Substance	Conc.%	20°C	60°C
Soya bean oil	100	S	S
Tallow	100	S	—
Transformer oil	100	S	L
Turpentine oil	100	L	NS
White spirit		S/L	L
Foods etc.			
Beer		S	S
Brandy		S	—
Butter		S	—
Buttermilk		S	—
Cider		S/E	S/E
Cinnamon		S	—
Cloves		S	—
Coca Cola		S	S
Cocoa		S	—
Coffee		S	—
Cream		S	—
Curds		S	—
Dextrose		S	S
Fructose		S	S
Fruit juices		S	S
Gelatine		S	S
Gin	40	S	L
Glucose		S	S
Glycerine	100	S/E	S/E
Glycerine (aqueous)	High	S	S/E
Glycerine (aqueous)	Low	S	S
Grapefruit juice		S	S
Honey		S	S
Horse radish		S	—
Jam	100	S	S
Jelly	100	S	S
Lard		S	
Lemon juice		S	S
Lime juice		S	S
Margarine	100	S	S
Mayonnaise	100	S	—
Milk		S	S
Molasses		S	S
Mustard		S	S
Orange juice		S	S
Paprika	100	S	S

Substance	Conc.%	20°C	60°C
Pectin	Sat	S	S
Pepper		S	S
Pineapple juice		S	S
Rum		S	S
Saccharose	100	S	S
Soda water		S	—
Starch		S	S
Sugar beet syrup	100	S	S
Tea (leaves)		S	S
Tomato juice	100	S	S
Tomato ketchup	100	S	S
Vanilla	100	S	S
Vinegar	All	S	S
Whisky	40	S/E	
Wine (mulled claret)	100	S	S
Wine spirit	100	S	S
Yeast	100	S	S
Car, garden, household products			
Antifreeze		S	S
Bleach		L	L
Borax		S	S
Brake fluid	100	S/E	S/E
Brine		S	S
Creosote	100	S	S
Cresol (aqueous)		S	S
Detergents		S/E	S/E
Dextron		S	S
Emulsions (photographic)	100	S/E	S/E
Floor wax	100	S	L
Furniture polish	100	S/E	L
Hair shampoo		S	S
Hydraulic fluid	100	S	L
Ink	100	S	S
Methylated spirit		S/E	S/E
Nail polish and remover	100	S	L
Petroleum jelly	100	S	S
Shoe polish	100	S	L
Talc		S	S
Tar	100	S	L

EVALUATION OF RESISTANCE OF TENSAR POLYPROPYLENE BIAXIAL GEOGRIDS TO CHEMICAL ATTACK AND SOIL BURIAL FROM AVAILABLE INFORMATION.

Technical Note
Prepared for The Tensar Corporation
by J. P. Giroud, GeoServices, Inc.

Tensar biaxial geogrids, SS1, SS2 and AR1, are made of polypropylene. This polymer is known for having a high chemical resistance. In addition, the molecular orientation, imparted to the polymer by the manufacutirng process of Tensar geogrids, decreases polypropylene permeability, which is considered likely to increase chemical resistance. A summary of data regarding chemical resistance of polypropylene is presented below, with conclusions on the use of geogrids in civil engineering.

Polypropylene is not affected by detergents, organic salts in aqueous solutions, and by almost all inorganic acids and alkalis, even at high concentration and high temperture (60°C or more). Due to the resistance of polypropylene to alkalis, polypropylene Tensar geogrids are not affected by cement and concrete.

Polypropylene is attacked by strong oxidizing agents, such as fuming sulphuric acid, concentrated nitric acids and halogens. Such chemicals are not normally encountered in civil engineering but they can be present in a waste disposal cell. To decide if a Tensar polypropylene geogrid can be put in contact with such chemicals, the attached table can be used as a first guide and tests should be conducted.

Polypropylene has some sensitivity to certain solvents, oils, and hydrocarbons, such as asphalt. Polypropylene geogrids could be slowly affected if they were exposed during a long period of time to diesel fuel. Also, polypropylene geogrids could be slowly affected if they were placed below a thin layer of asphalt exposed to the sun in a very hot climate (where the surface of asphalt can reach 140°F during several hours every summer day). Polypropylene is inert to sulphur included in some asphalt pavements.

Polypropylene is not a nutrient medium for micro-organisms, and is therefore not attacked by them. Consequently, polypropylene Tensar geogrids can be used safely in the ground, even in highly organic soils. In fact, polypropylene geotextiles have been extensively used in the past two decades, and experience has shown that they can be expected to have a service life of several dozens of years when placed in most naturally occurring soil environments. Since geogrid rib thickness is at least 20 times the diameter of typical geotextile fibers, the durability of polypropylene geogrids is expected to be greater than the durability of polypropylene geotextiles.

J. P. Giroud
1984 August

EVALUATION OF CHEMICAL RESISTANCE OF TENSAR DRAINAGE NETS FROM AVAILABLE INFORMATION

Technical Note
Prepared for The Tensar Corporation
by J.P. Giroud, GeoServices, Inc.

Tensar drainage nets are made from polyethylene. This polymer is known for having a high resistance to chemical attack and being insoluble in all known solvents at room temperature.

The chemical resistance of polyethylene materials increases in general with increasing density. As shown in the attached Table, the resistance of polyethylene to aromatic solvents is affected by density. However, the effect is known to be small and, as shown in the Table, the resistance of polyethylene to acids and alkalis is not noticeably affected by density.

The influence of density on the chemical behavior of polyethylene is linked to the structure of the polymer. A high density polyethylene macromolecule is a linear chain of CH_2 elements, while low density polyethylene macromolecules are usually a complex arrangement of branches of CH, CH_2, and CH_3. Because of its many branches, a low density polyethylene is more prone to react with chemials than a high density polyethylene, while a high density polyethylene is more likely to crack in certain environments (stress cracking) because it is made of parallel chains.

Tensar drainage nets (with a specific gravity of 0.925 to 0.930) and high density polyethylene geomembranes (0.935 to 0.945) are in the middle of the range of existing polyethylenes (0.91 to 0.97). It may therefore be concluded that there should be no significant difference in chemical behavior between the polyethylene used for Tensar drainage nets and the polyethylene used for high density polyethylene geomembranes.

High density polyethylene geomembranes have been subjected to extensive chemical compatibility testing in the past five years in view of their utilization in waste management facilities. Test results have shown that high density polyethylene geomembranes have a better compatibility with most chemicals than other available geomembranes. As a result, they are now used routinely to line hazardous waste disposal facilities.

The thickness of materials exposed to chemcials is also believed to have some influence on their durability. The thickness of Tensar net strands is typically two or three times the thickness of a 60mil-thick geomembrane. However, geomembranes are exposed on only one side and one may conclude that Tensar nets and 60mil-thick geomembranes are equivalent regarding thickness.

Some of the Tensar drainage nets are made of a foamed polyethylene. The foam structure results from the inclusion of bubbles that do not communicate. Therefore, foaming should not increase exposure to chemicals. Also, according to the manufacturer of the net, the foaming agent used in the manufacturing process has no effect on the chemical resistance of the polymer.

From our present knowledge on chemical compatibility, and considerations on density and thickness, it may be concluded that Tensar drainage nets can be used in waste disposal facilities where the use of currently available high density polyethylene geomembranes has been approved.

J.P. Giroud
1984.08.01

'AGEING' OF HIGH DENSITY POLYETHYLENE IN BURIED SITUATIONS

Publications such as BSI CP312 and manufacturers' data sheets which refer to ageing tests relate to the effects of ultraviolet or near visible radiation attack on the polymer which can result in oxidative degradation and embrittlement. Although buried PE does not suffer from this problem changes in free volume, crystallinity, and the possible effect of chemical and microbiological attack need to be considered with respect to any potential long term effect on properties.

Work initiated by RAPRA (Reference 1) some 16 years ago has involved a storage and examination of HDPE. Samples of polymer were stored, in Aluminium boxes with free air circulation, in temperate, hot wet and hot dry climates in the absence of radiation. No significant changes occurred in the basic properties of the HDPE after this period. This leads to the conclusion that any crystallinity changes, had an insignificant effect.

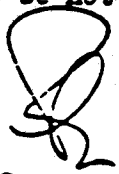
HDPE has been used in buried pipe applications for agricultural drainage, potable water, effluent and gas distribution for up to 30 years. A major reason is its corrosion resistance to acid soils and its generally excellent chemical resistance - HDPE is generally inert to chemicals other than strongly oxidising acids because of its chemical structure (2) HDPE has also been used to sheathed metal pipes in buried soil conditions in order to eliminate corrosion. Rigidex is an approved grade in the U.K.

HDPE sheathed Transatlantic telephone cables have also been used in a salt water environment for nearly 20 years without problems of chemical attack.

Certain types of chemicals such as detergents cause stress cracking of unoriented HDPE test pieces but creep rupture tests carried out in water and 2% detergent solutions at 23°C on samples of Tensar to compare the environments, have shown no deleterious effects. These data compare well with tests normally carried out on pressure pipe grades which are required to possess a high resistance to stress cracking in order to fulfill their 50 year design life requirement.

HDPE also has excellent resistance to microbiological attack and will not rot away when buried (3).

Field service evidence to date on the use of HDPE in civil engineering applications is based on non-annealed products. Orientation is known to reduce the permeability of HDPE and this enhancement coupled with the evidence of improved stress crack resistance lends support to the deduction that oriented grid structures will have no less a permanence in buried soil conditions than that of the established uses of non-oriented products. For example, HDPE gas pipe is supplied on a prognosis of a 50 year minimum life - the critical element is the risk of internal wall softening due to occluded gas condensate - the risk of attack resulting from the buried soil environment is considered to be not critical.



G. H. BURKE

30th October, 1981

REFERENCES

1. RAPRA Members Journal, July/August 1975, P53 and March/April 1976, P19 by R. C. Moakes.

2. Vinyl and Allied Polymers, Volume 1, Iliffe Books P148 (1968).

3. British Plastics, October 1967, P105, B. Dolezal, Micro-organisms and Plastics.

30th October, 1981

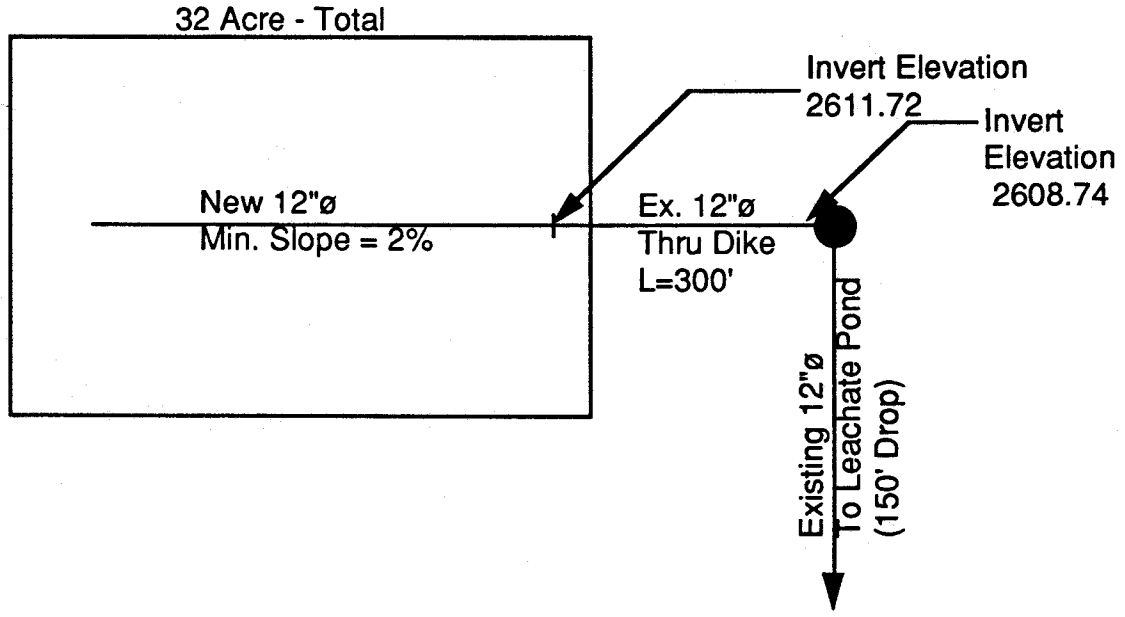
DESIGN CALCULATIONS

SYSTEM HYDRAULIC CALCULATIONS
CHAMPION
CANTON, NC
SEC JOB NO. G-9083

Required: Perform hydraulic calculations to evaluate the hydraulic capacity and adequacy of the proposed leachate, uncontaminated stormwater, and underdrain collection systems

I. Leachate Collection System

System Sketch



1. Check the hydraulic capacity of the drainage system

Note: The existing 12"ø thru the dike will be the limiting segment

$$\text{Slope} = \frac{2611.72 - 2608.74}{300'} = .0099 \text{ ft/ft}$$

N = .010 (HDPE Pipe)

Utilizing Manning's Eqtation

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

n = Manning's Coefficient

A = Area

R = Hydraulic Radius, S = Slope

$$Q = \frac{1.486}{.010}\left(\frac{.5'}{2}\right)^{2/3}(.010)^{1/2}(\pi(.5)^2) = 4.63 \text{ cfs} = 2079 \text{ gpm}$$

2. Check the adequacy of this system to drain the leachate

Note: 1. Cell development is limited to 8 acres at one time since that is the limit of storage available in the Leachate Collection Pond

2. Leachate Volume is from two sources; rainwater & water from the sludge. Stormwater will be the major portion.

3. Ensure the system is adequate to drain the cell in 24 hours.

25 yr. - 24 hr. rainfall = 7.0"

Assume all runs off

Runoff Volume/24 hrs

$$= 7.0" \times \frac{1'}{12"} \times 84 \text{ acres} \times 43{,}500 \text{ ft}^2/\text{acre}$$

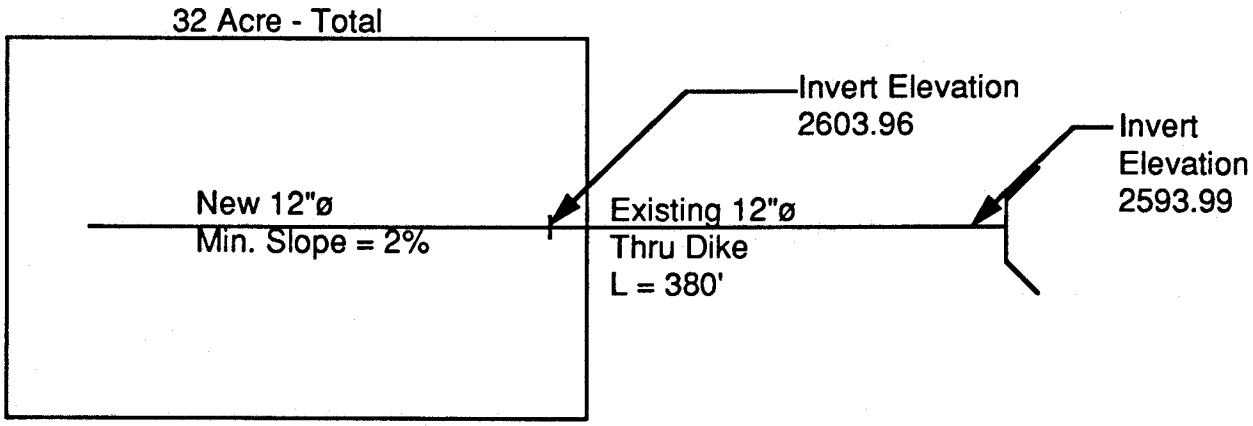
$$= 203{,}280 \text{ ft}^3 = 1{,}520{,}534 \text{ gal/24 hrs}$$

$$1{,}520{,}534 \text{ gal/24hr} \times \frac{1\text{hr}}{60 \text{ min}} = -1056 \text{ gpm}$$

=> This existing system has adequate capacity and will drain leachate in approximately 12 hours.

II. Uncontaminated Stormwater Collection

System Sketch



1. Check the hydraulic capacity of the drainage system

   Note: The existing 12"ø must drain the entire 32 acres. The new 12" will only be required to drain 24 acres since it will only be used after cell development begins and the initial 8 acres will discharge to the leachate collection system.

   A. Existing 12"ø

   $$\text{Slope} = \frac{2603.96 - 2593.99}{380'} = .026 \text{ ft/ft}$$

   $N = .010$

   $$\therefore Q = \frac{1.486}{.010}\left(\frac{.5'}{2}\right)^{2/3}(.026)^{1/2}(\pi(.5)^2) = 7.47 \text{ cfs} = 3352 \text{ gpm}$$

   B. New 12"ø

   $$Q = \frac{1.486}{.010}\frac{.5'}{2}{}^{2/3}(.02)^{1/2}(\pi(.5)^2) = 6.55 \text{ cfs} = 2934 \text{ gpm}$$

2. Check drainage times

   A. 32 acre cell
   Runoff Volume/24 hr

   $$= 7.0\text{"} \times \frac{1'}{12"} \times 32 \text{ acres} \times 43{,}560 \text{ ft}^2/\text{acre}$$

   $$= 813{,}120 \text{ ft}^3/24 \text{ hr} = 6{,}082{,}138 \text{ gal}/24\text{hr}$$

   At a drainage rate of 3352 gpm

$$= 6{,}082{,}138 \times \frac{1 \text{ min}}{3352 \text{ gal}} \times \frac{1 \text{ hr}}{60 \text{ min}} = 30.2 \text{ hrs}$$

B. 24 Acre Cell

Runoff Volume/24hr

$$= 6{,}082{,}138 \text{ gal/24hr} \times \frac{24 \text{ acres}}{32 \text{ acres}} = 4{,}561{,}603 \text{ gal/24hr}$$

At a drainage rate of 2934 gpm

$$= 4{,}561{,}603 \text{ gal/24 hr} \times \frac{1 \text{ min}}{2934 \text{ gal}} \times \frac{1 \text{ hr}}{60 \text{ min}} = 26 \text{ hrs}$$

III. Underdrain System

1. Measured flow in field = 10 gal/min

2. Capacity @ 6% slope (Per Geotechnical Report)
12"ø HDPE

$$Q = \frac{1.486}{.010} \left(\frac{.5'}{2}\right)^{2/3} (.06)^{1/2} (\pi(.5)^2) = 11.34 \text{ cfs} = 5091 \text{ gpm}$$

EROSION CONTROL MEASURES
CHAMPION
CANTON, NC
SEC JOB NO. G-9083

Required: Estimate the stormwater runoff discharge during development of the 32 acre landfill Cell A at landfill No. 6

Given:

Utilize SCS methodology (TR-55 Chart Method)

From attached calculation (For 25 year storm)

Q_{p2} = 150 cfs

From attached calculation (For 10 year storm)

Q_{p10} = 120 cfs

* Check the retention time in the Sedimentation Control Pond when the peak flows occur; See Attached Drawings

1. Calculate Approximate Storage Volume:

Elevation	Surface Area	Storage Volume
2613	0	22,000 ft^3
2615	22,000 ft^2	130,800 ft^3
2619	43,400 ft^2	130,800 ft^3
	Vol =	152,800 ft^3

2. Check retention times at peak flows

$$\text{10 yr. storm} = 152{,}800\ ft^3 \times \frac{1\ sec}{120\ ft^3} \times \frac{1\ min}{60\ sec} = 21.2\ min$$

$$\text{25 yr. storm} = 152{,}800\ ft^3 \times \frac{1\ sec}{150\ ft^3} \times \frac{1\ min}{60\ sec} = 17.0\ min$$

Summary: During peak discharge from the 25 year storm, the retention pond has greater than 15 minute retention. Normal operation will provide substantially greater retention. This should provide adequate retention time for settling of the sediments during the landfill cell development.

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Chapin - Conlon, NC Computed By YIC Date _____
Checked By _____ Date _____

1. Required Input

A = 32 Acres : Drainage Area
10 T = 25 Years : Design Frequency (return period)
6.0 P = 9.0 Inches: Rainfall depth for 24-hour, T-year event (See TP-40)
Y = 5 % : Average watershed slope
CN = 80 : Runoff Curve Number

2. Compute Volume of Runoff, Q

3.8 Q = 4.75 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = _____ feet : Hydraulic Length
EA = 32 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1.0 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 30 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.05 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)
Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___
PF = 1.0 : Use PPS and T with Table 6-a, 6-b, or 6-c.

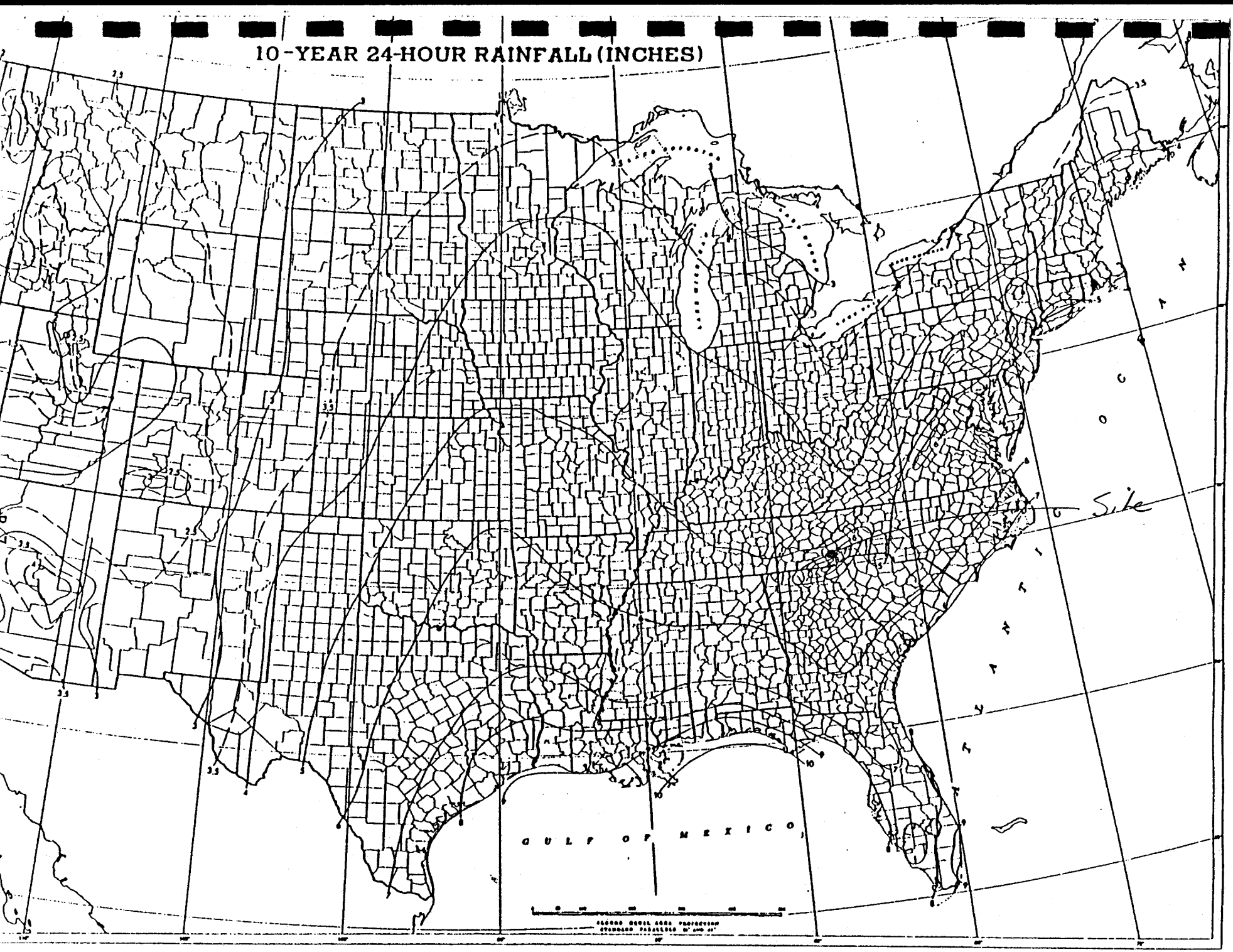
7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 30 x 4.75 x 1.0 x 1.05 x 1.0
25 = 150 cfs
10 = 120 cfs

8. Modifications for Urbanization (N/A)

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs


10-YEAR 24-HOUR RAINFALL (INCHES)
GULF OF MEXICO
Site

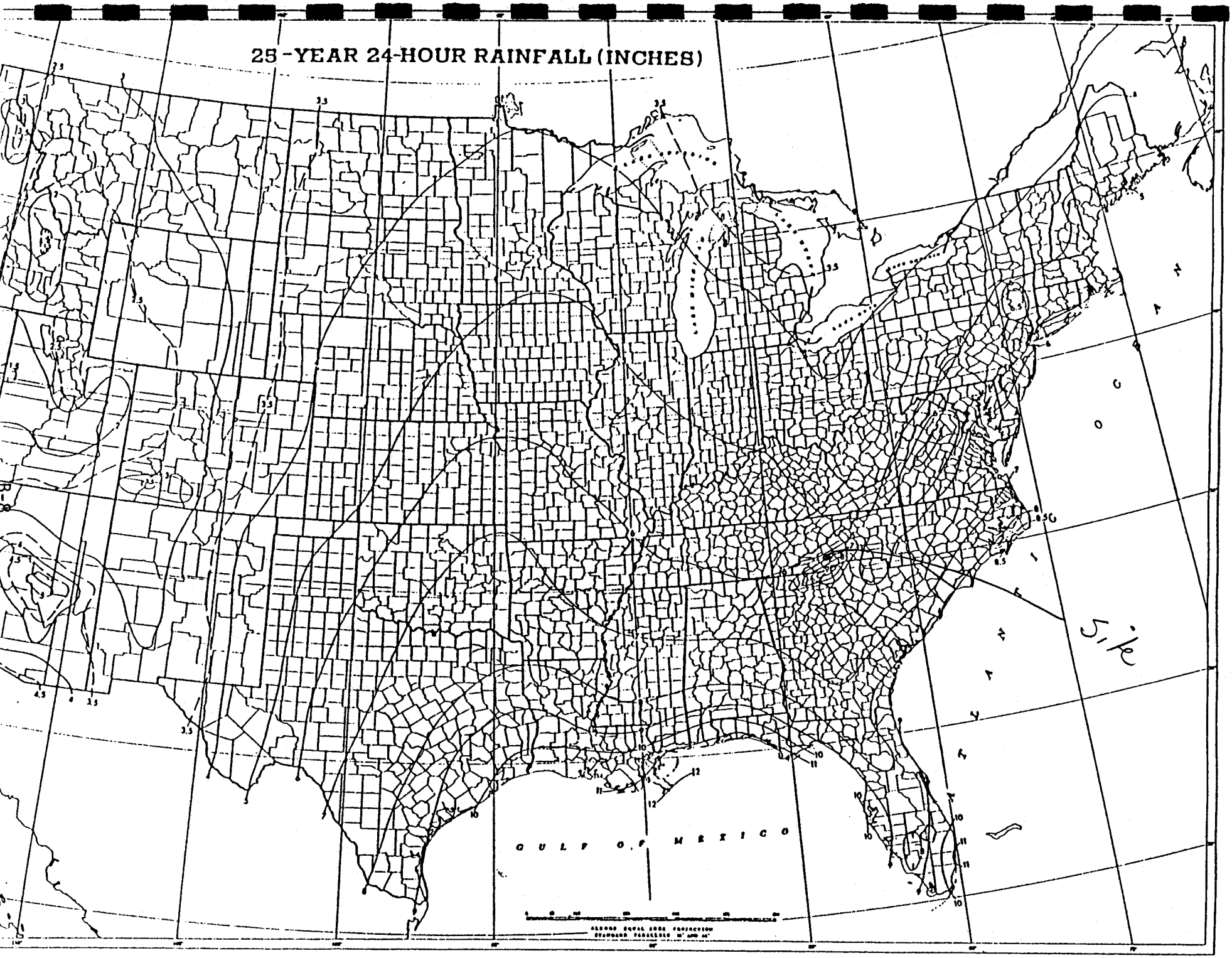

25-YEAR 24-HOUR RAINFALL (INCHES)
GULF OF MEXICO
Site

TABLE 2. Runoff Curve Numbers for Hydrologic Soil-Cover Complexes
(Antecedent Moisture Condition II, and $I_a = 0.2\ S$)

Land Use Description/Treatment/Hydrologic Condition			Hydrologic Soil Group			
			A	B	C	D
Residential:[1]						
Average lot size	Average % Impervious[2]					
1/8 acre or less	65		77	85	90	92
1/4 acre	38		61	75	83	87
1/3 acre	30		57	72	81	86
1/2 acre	25		54	70	80	85
1 acre	20		51	68	79	84
Paved parking lots, roofs, driveways, etc.[3]			98	98	98	98
Streets and roads:						
paved with curbs and storm sewers[3]			98	98	98	98
gravel			76	85	89	91
dirt			72	82	87	89
Commercial and business areas (85% impervious)			89	92	94	95
Industrial districts (72% impervious)			81	88	91	93
Open Spaces, lawns, parks, golf courses, cemeteries,etc.						
good condition: grass cover on 75% or more of the area			39	61	74	80
fair condition: grass cover on 50% to 75% of the area			49	69	79	84
Fallow	Straight row	---	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Contoured & terraced	Poor	66	74	80	82
	Contoured & terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close -seeded	Straight row	Poor	66	77	85	89
legumes[4]	Straight row	Good	58	72	81	85
or	Contoured	Poor	64	75	83	85
rotation	Contoured	Good	55	69	78	83
meadow	Contoured & terraced	Poor	63	73	80	83
	Contoured & terraced	Good	51	67	76	80
Pasture		Poor	68	79	86	89
or range		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods or		Poor	45	66	77	83
Forest land		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		---	59	74	82	86

Use CN = 80

[1] Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.

[2] The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

[3] In some warmer climates of the country a curve number of 95 may be used.

[4] Close -drilled or broadcast.

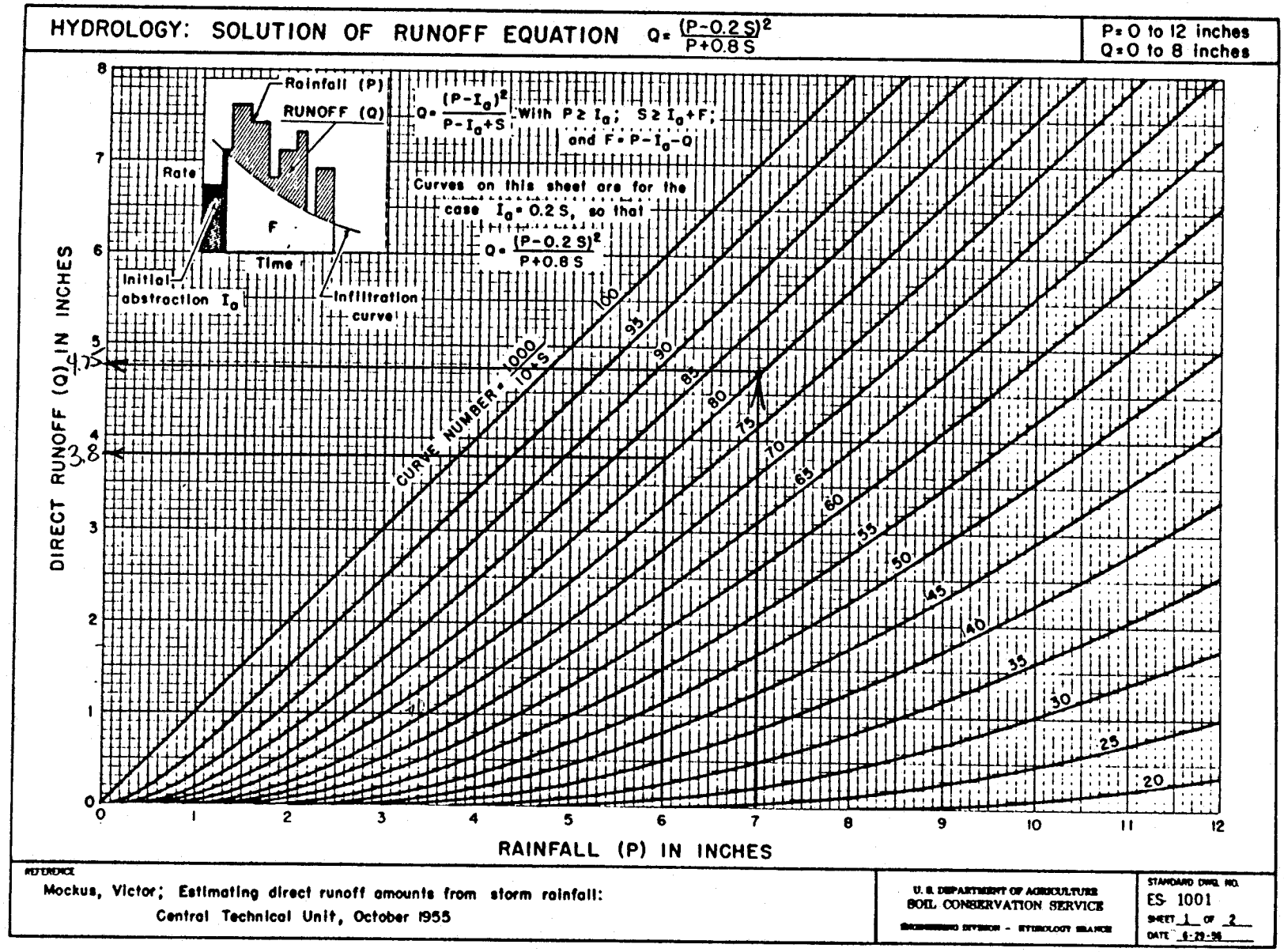


FIGURE 5. Graphical Solution of Rainfall-Runoff Equation

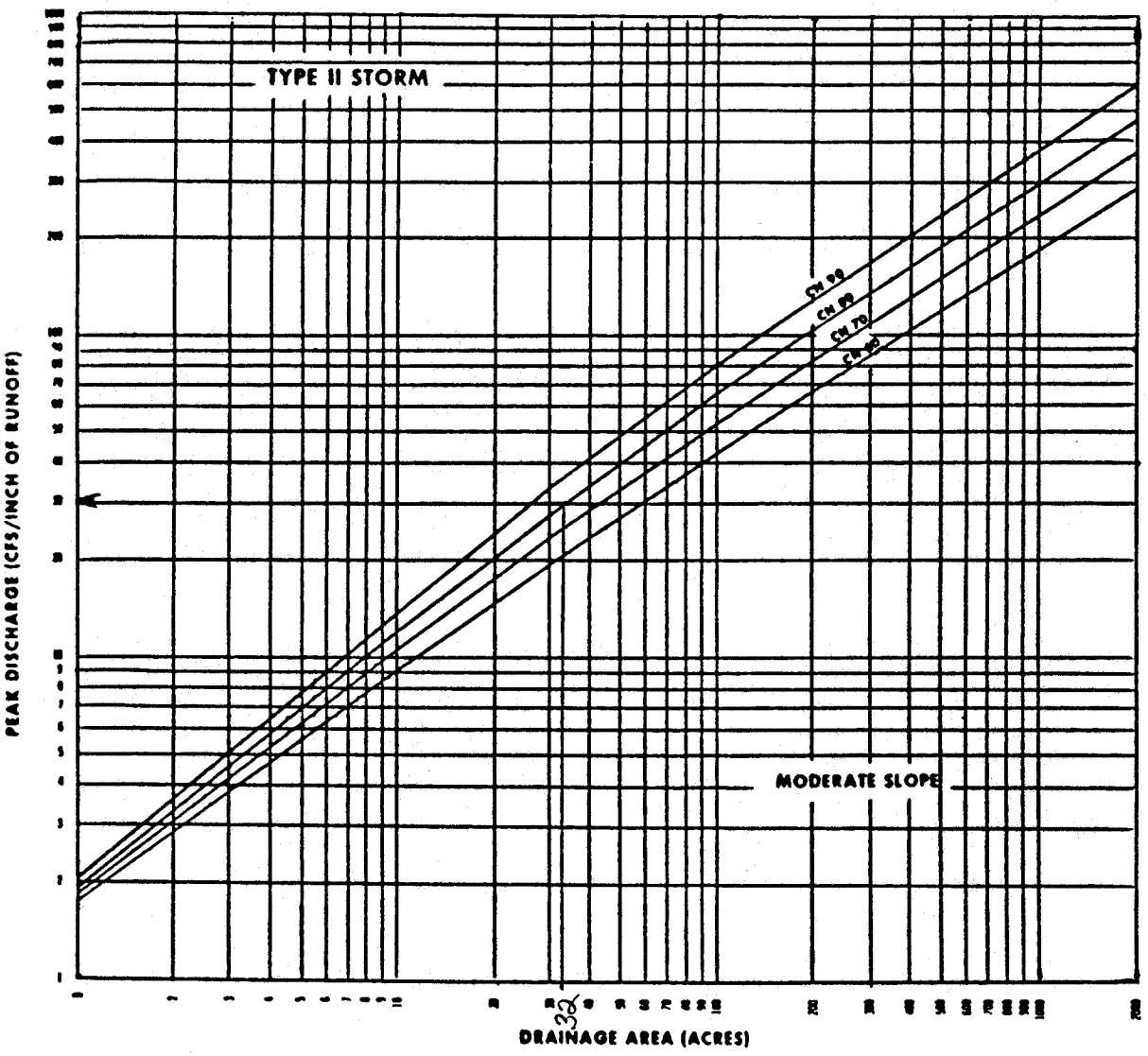


Figure 11.--Peak rates of discharge for small watersheds (24-hour, type-II storm distribution). Sheet 2 of 3

Table 7 .--Slope adjustment factors by drainage areas

Slope (percent)	10 acres	20 acres	50 acres	100 acres	200 acres	500 acres	1,000 acres	2,000 acres
FLAT SLOPES								
0.1	0.49	0.47	0.44	0.43	0.42	0.41	0.41	0.40
0.2	.61	.59	.56	.55	.54	.53	.53	.52
0.3	.69	.67	.65	.64	.63	.62	.62	.61
0.4	.76	.74	.72	.71	.70	.69	.69	.69
0.5	.82	.80	.78	.77	.77	.76	.76	.76
0.7	.90	.89	.88	.87	.87	.87	.87	.87
1.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.5	1.13	1.14	1.14	1.15	1.16	1.17	1.17	1.17
2.0	1.21	1.24	1.26	1.28	1.29	1.30	1.31	1.31
MODERATE SLOPES								
3	.93	.92	.91	.90	.90	.90	.89	.89
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.04	1.05	1.07	1.08	1.08	1.08	1.09	1.09
6	1.07	1.10	1.12	1.14	1.15	1.16	1.17	1.17
7	1.09	1.13	1.18	1.21	1.22	1.23	1.23	1.24
STEEP SLOPES								
8	.92	.88	.84	.81	.80	.78	.78	.77
9	.94	.90	.86	.84	.83	.82	.81	.81
10	.96	.92	.88	.87	.86	.85	.84	.84
11	.96	.94	.91	.90	.89	.88	.87	.87
12	.97	.95	.93	.92	.91	.90	.90	.90
13	.97	.97	.95	.94	.94	.93	.93	.92
14	.98	.98	.97	.96	.96	.96	.95	.95
15	.99	.99	.99	.98	.98	.98	.98	.98
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10
25	1.06	1.08	1.12	1.14	1.15	1.16	1.17	1.19
30	1.09	1.11	1.14	1.17	1.20	1.22	1.23	1.24
40	1.12	1.16	1.20	1.24	1.29	1.31	1.33	1.35
50	1.17	1.21	1.25	1.29	1.34	1.37	1.40	1.43

PIPE MATERIAL STRENGTH
CHAMPION
CANTON, NC
SEC JOB NO. G-9083

Required: Verify the adequacy of the underdrain, stormwater, and leachate collection pipes to handle the fill above the pipes with no structural deflection.

Note: The manufacturer of Phillips Drisco Pipe reported SDR-11 would be adequate for up to 150' of burial. I will check another pipe manufacturer to verify this assessment

Given:

1. 12"ø Pipe
2. SDR-11 Wall Thickness
3. Maximum Burial = 85' (This occurs under the cell divide dikes)

Calculate Earth Load:

$$W = C_D \times W \times B_D \times D$$

W = Soil density = 120 lbs/ft^3
B_D = Trench Width (Assume 5' - Conservative)
D = Pipe Diameter = 1'
C_D = From Fig 16 = 3.3

Earth Load (W) = 3.3 x 120 x 5 x 1' = 1980

From Fig.13 => 750 pounds/ft

Note: This just confirms the conservatism of the previous calculation

From Fig. 14, 12"ø with soil modules = 700 psi
Allowable loading > 2590 lbs/ft

EARTHLOADING

POLY PIPE, due to its flexibility, will deflect when it is buried and is subjected to loads caused by the compressive forces of the compacted soil. The degree of deflection will depend upon the soil conditions, trench width, and the depth of burial. The degree of deflection of the pipe is limited by the soil around its periphery especially in the lateral direction. When the soil compacts around the pipe there is a supportive effect from the soil itself, and as compaction occurs there is a soil arch formed over the pipe which reduces the direct load on the pipe.

POLY PIPE, as do other flexible conduits, depends on the surrounding soil for support and has to be considered as one component in a pipe/soil system. Therefore, performance of **POLY PIPE** is determined as much by the quality and density of the soil underneath the pipe haunches and at its sides as by the properties of the pipe itself.

The presence of the soil arch and the support derived from the lateral movement limitations are highly beneficial to the efficiency of the system. The flexibility of **POLY PIPE** is the major reason for these advantages. As has been stated the durability of polyethylene is the reason for its resistance to high levels of mechanical abuse and this is no less true for buried systems where forced deflections may occur due to subsidence, washout and settlement and to surface traffic.

The earth load being applied to a buried system can be determined by the use of the modified Marston formula.

$$W = C_d \times w \times B_d \times D \qquad \textbf{(10)}$$

Where W = earth load in pounds per linear feet of pipe, lb./ft.
C_d = coefficient dependent on soil type and height of backfill to width of trench ratio. (see Fig. 16 for C_d)
w = density of soil, lbs./cu.ft.
D = outside diameter of pipe, ft.
B_d = trench width at top of pipe, ft.

In general practice the trench width can be kept to a minimum of 6 inches per side greater than the pipe diameter itself. Although this may seem narrow in comparison to trenching of conventional materials it must be noted that **POLY PIPE** can be preassembled above ground and later placed into the trench. The trench width should be maintained as narrow as possible as the soil loading on the pipe is a relationship of the trench width

The loads applied to the pipe as a result of the backfill are given in Fig. 13.

In situations where the pipe is buried below the water table the effect is to relieve the load on the pipe to some extent due to buoyancy of the pipe. Although this can be a considerable effect, it should not be taken into account when designing a system as the water table can change to a position below the pipe. In the event the water level does not change, the reduction in stress will serve as an additional safety factor.

In calculating the soil load placed on a buried pipe, the designer must be able to calculate to some degree of accuracy the type and condition of the backfill material. Saturated clay would be more difficult to place and adequately compact than would coarse granular material that would not stick together. It is important in the pipe/soil system that the backfill material utilized for haunching and initial backfill (see Fig. 18 for explanation of terminology) be granular and non-cohesive, free of debris, organic matter, frozen earth and rocks larger than 1½ inch in diameter. This material can best be described as Class I or II of ASTM D2321 "angular ¼ to 1½ inch graded stone, slag, cinders, crushed shells and stone or sands and gravels containing small percentages of fines, generally granular and non-cohesive, wet or dry." This material can easily be worked into the pipe haunch, compacted in approximately 4 to 6 inch lifts to above the pipe.

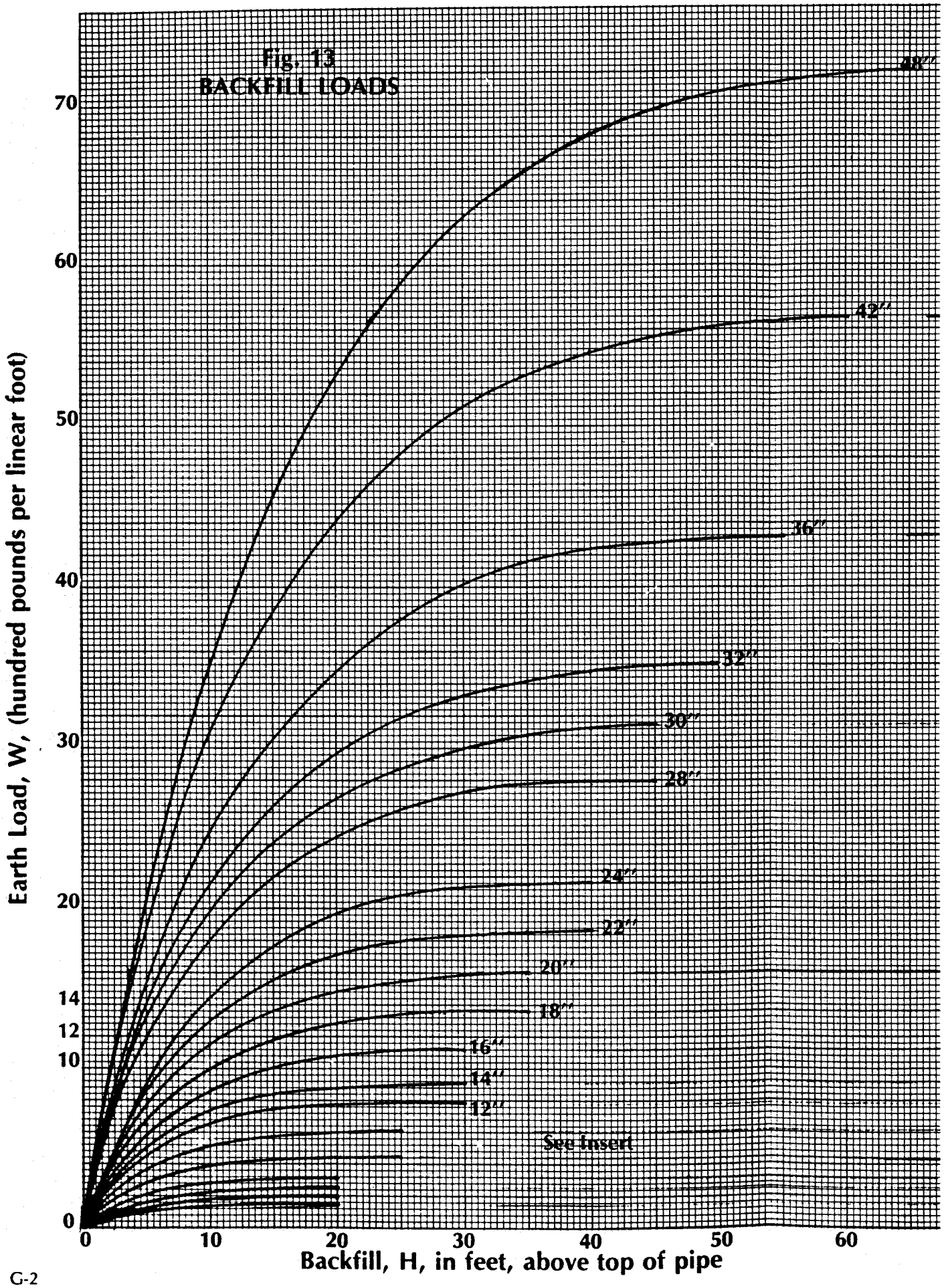


Fig. 13
BACKFILL LOADS
Earth Load, W, (hundred pounds per linear foot)
Backfill, H, in feet, above top of pipe
0
10
20
30
40
50
60
70
14
12
10
48″
42″
36″
32″
30″
28″
24″
22″
20″
18″
16″
14″
12″
See Insert
0
1
2
3
4
5
6

Fig. 14

Maximum recommended external loading with 5% deflection, pounds per linear foot of pipe.

Nominal Pipe Size, in.	Soil Modulus, psi	SDR 32.5	26	21	17	13.5
3	300			285	315	370
	700			630	655	710
4	300		350	370	405	475
	700		790	810	840	915
5	300	420	435	455	500	590
	700	965	975	1000	1040	1130
6	300	500	515	540	595	700
	700	1145	1160	1190	1240	1345
8	300	650	670	705	770	910
	700	1495	1510	1550	1615	1755
10	300	810	835	880	960	1135
	700	1860	1885	1930	2010	2185
12	300	965	990	1045	1140	1350
	700	2205	2235	2290	2385	2590
14	300	1055	1090	1145	1255	1480
	700	2425	2455	2510	2620	2845
16	300	1210	1245	1310	1430	1690
	700	2770	2805	2870	2995	3255
18	300	1360	1400	1475	1610	1905
	700	3115	3155	3230	3370	3660
20	300	1510	1555	1635	1790	2115
	700	3465	3505	3590	3740	4065
22	300	1660	1710	1800	1970	2325
	700	3810	3855	3950	4115	4475
24	300	1815	1865	1965	2150	2535
	700	4155	4210	4305	4490	4880
28	300	2115	2175	2290	2505	2960
	700	4845	4910	5025	5240	5695
30	300	2265	2335	2455	2685	3170
	700	5195	5260	5385	5615	6100
32	300	2415	2490	2620	2865	3385
	700	5540	5610	5740	2990	6505
36	300	2720	2780	2945	3220	
	700	6235	6310	6460	6735	
42	300	3170	3265	3435		
	700	7270	7365	7535		
48	300	3625	3730			
	700	8310	8415			

Listed below are the recommended maximum allowable design limits for deflection of polyethylene pipe for the different available standard dimension ratios.

Dimension Ratio	Safe Deflection (% of diameter)
32.5	8.0
26	7.0
21	6.0
17	5.0
13.5	4.0
11	3.0

Fig. 14 depicts the load imposed on a pipe when recommended installation practices are followed. In this Fig. a value of 120 #/ft³ soil and for Class II soils a ratio of lateral to vertical pressures of 0.17. For other classes of soil as noted in Fig. 16, Class I = 0.19, Class III = 0.15, Class IV = 0.13, and Class V = 0.11. As can be seen from Fig. 13, there is a depth at which increased loading on the pipe ceases and the load level remains constant, regardless of the height of backfill.

POLY PIPE through its inherent physical properties of flexibility, resilience, and toughness can withstand significant deflection without failure. It can be flattened without causing a fracture of the pipe wall. However, this condition is unacceptable as far as service is concerned. A deflection of 15% would be acceptable for a butt fused polyethylene system although a reduction in flow would be noted. It would also be difficult to utilize conventional cleaning equipment with this severe a deflection. For these reasons, **POLY PIPE** recommends maximum deflections of 5 to 7½%. Calculations in this guide have been based on 5%.

Compaction or quality of backfill above the pipe zone, while important for many reasons, does not effect the predicted deflection of the pipe. The designer may wish to review Sec. H, Underground Installations, for further considerations.

Some design considerations to be recognized in the installation of buried pipelines is the exercise of caution in the tamping of the side-fill so as to not force granular, free flowing, non-cohesive Class I & II bedding materials under the haunch in sufficient force to "float" the pipe. It is imperative that buried pipe be on a firm, continuous support. Final backfill material, while unimportant to the pipe zone, should be free of large rocks, boulders or other similar materials that could project down into the pipe.

The designer may wish to review Sec. C, Critical Buckling, of this design guide in conjunction with this section.

For a full discussion of the formula and the derivative work involved the reader is referred to Bulletin 153 of the Iowa State College Bulletin "The Structural Design of Flexible Pipe Culverts" by M.G. Spangler.

Fig. 15

Classification of Backfill Material

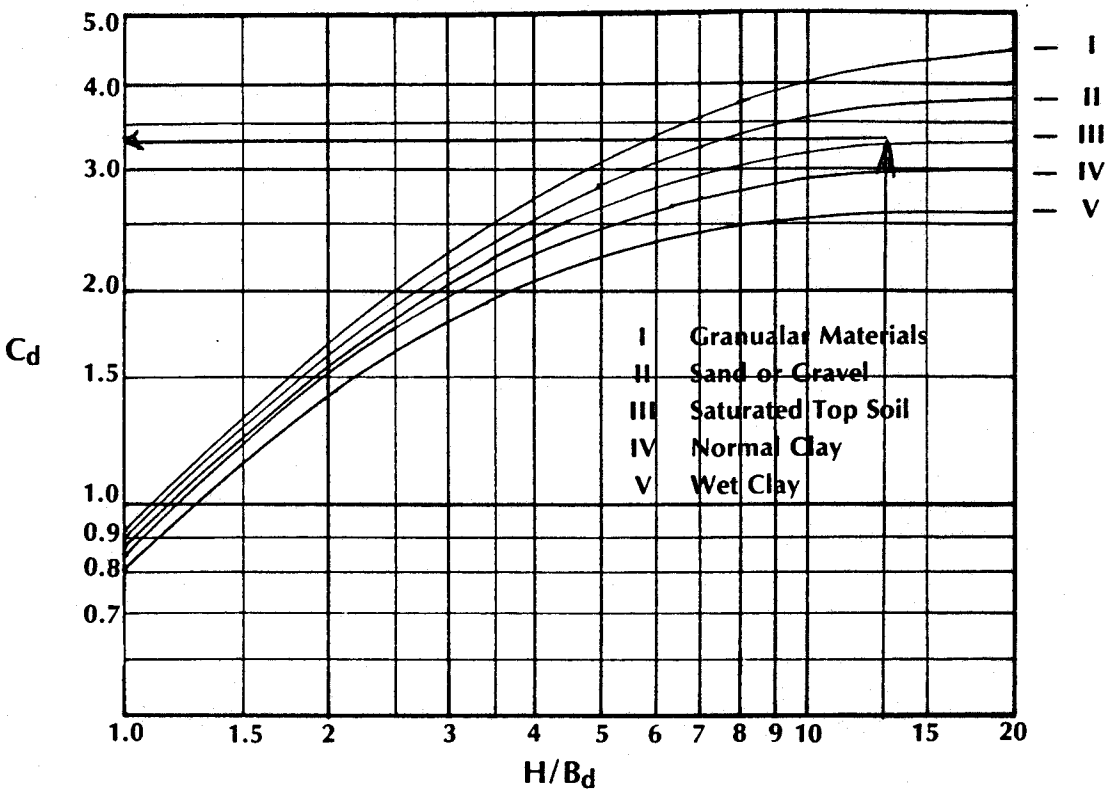
per ASTM D2321*

Class	Comments
Class I — Angular graded stone, ¼ to 1½ in., including a number of fill materials that have regional significance such as coral, slag, cinders, crushed stone, crushed gravel, and crushed shells.	100 - 120 pounds per cubic foot. Pipe sizes less than 10-inch should limit maximum particle size to ½ to ¾-inch for ease of placement.
Class II — Coarse sands and gravels with maximum particle size of 1½ in., including variously graded sands and gravels containing small percentages of fines, generally granular and non-cohesive, either wet or dry.	110 - 130 pounds per cubic foot. Pipe sizes less than 10-inch should limit maximum particle size to ½ to ¾-inch for ease of placement.
Class III — Fine sand and clayey gravels, including fine sands, sand-clay mixtures, and gravel-clay mixtures.	140 - 150 pounds per cubic foot.
Class IV — Silt, silty clays, and clays, including inorganic clays and silts of medium to high plasticity and liquid limits.	150 - 180 pounds per cubic foot.
Class V — Includes organic soils as well as soils containing frozen earth, debris, rocks larger than 1½ in. in diameter and other foreign materials.	Not recommended for backfill except in the final backfill zone.

*For further classification of soils the designer may want to review ASTM D2487, Standard Test Method for Classification of Soils for Engineering Purposes.

Fig. 16

Coefficient, C_d, dependent on soil type and ditch configuration.



$H/B_d = \frac{85'}{5'} = 13$

Assum Type III

Gundle Lining Systems Inc
Gundle®

19103 Gundle Rd.
Houston, Texas 77073
U.S.A.

Phone: (713) 443-8564
Toll Free: (800) 435-2008
Telex: 4620281 GUNDLE HOU
Fax: (713) 875-6010

July 12, 1990

Mr. Clark
Sirrine Environmental
P.O. Box 24000
Greenville, SC 29616

Dear Mr. Clark:

Please find the attached test results from J & L Testing indicating a friction angle in excess of 35° between Gundline HDT and Champion Paper site soils. With that level of friction, we can warrant Gundline HDT against slope failure on your 2:1 (26°) slope. The test data reported excellent friction with your site soil.

Please call if you have any questions.

Very truly yours,

Mark Cadwallader

Mark Cadwallader
Director of Research
and Technical Development

MC:jg

Attachments

DIRECT SHEAR TEST RESULT

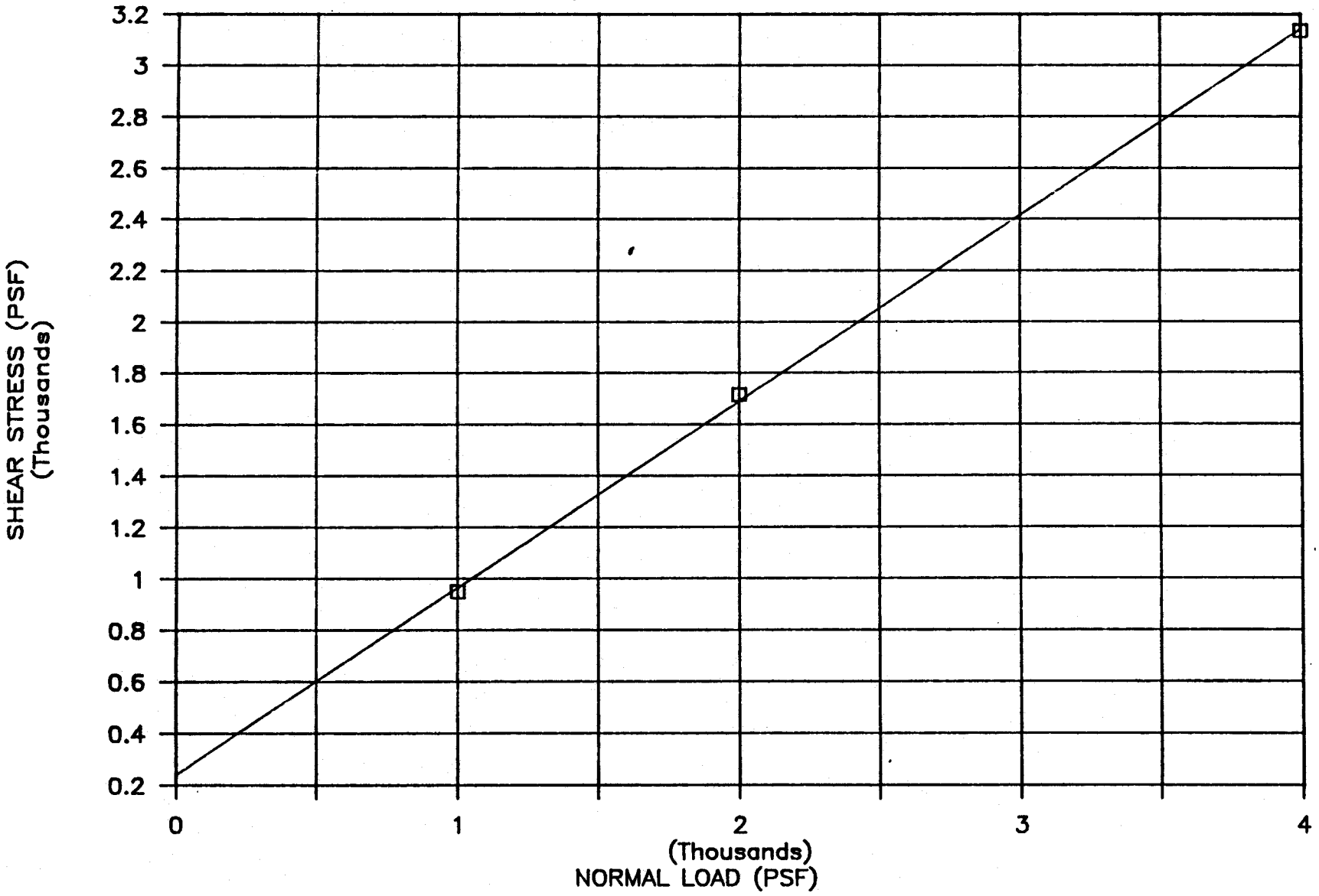
CONFIGURATION		PROJECT:		JOB NO.:	90S853-01
TOP:	LINER 60 MIL GUNDLE	SOIL:	YEL.BRO.SAND,SILT	SAMPLE NO.:	
BOTTOM:	YEL.BRO.SAND,SILT	WATER CONTENT(%):	16.7	DATE OF TESTING:	7-3-90
SATURATED	NO	DRY DENSITY(pcf):	106.7	TESTED BY:	JB

		1	2	3		1	2	3
HORIZ. DIAL READING	HORIZ. DISP'T (IN)	LOAD DIAL READING	LOAD DIAL READING	LOAD DIAL READING	CORR. AREA (FT^2)	SHEAR STRESS (PSF)	SHEAR STRESS (PSF)	SHEAR STRESS (PSF)
0.0	0.000	0.0	0.0	0.0	0.11	0.00	0.00	0.00
20.0	0.020	31.0	81.0	97.0	0.11	221.45	578.63	692.93
40.0	0.040	55.0	114.0	148.0	0.11	392.90	814.37	1057.25
60.0	0.060	79.0	147.0	203.0	0.11	564.34	1050.10	1450.14
80.0	0.080	97.0	177.0	237.0	0.11	692.93	1264.41	1693.03
100.0	0.100	109.0	193.0	280.0	0.11	778.65	1378.71	2000.20
120.0	0.120	118.0	210.0	311.0	0.11	842.94	1500.15	2221.65
140.0	0.140	123.0	222.0	342.0	0.11	878.66	1585.87	2443.10
160.0	0.160	127.0	231.0	361.0	0.11	907.23	1650.16	2578.83
180.0	0.180	131.0	236.0	381.0	0.11	935.81	1685.88	2721.70
200.0	0.200	133.0	240.0	396.0	0.11	950.09	1714.46	2828.85
220.0	0.220	132.5	240.0	408.0	0.11	946.52	1714.46	2914.58
240.0	0.240	132.0	240.0	419.0	0.11	942.95	1714.46	2993.16
260.0	0.260	132.0	240.0	427.0	0.11	942.95	1714.46	3050.30
280.0	0.280	132.0	240.0	432.0	0.11	942.95	1714.46	3086.02
300.0	0.300	132.0	240.0	435.0	0.11	942.95	1714.46	3107.45
320.0	0.320	132.0	240.0	436.0	0.11	942.95	1714.46	3114.60
340.0	0.340	132.0	240.0	439.0	0.11	942.95	1714.46	3136.03
360.0	0.360	132.0	240.0	437.5	0.11	942.95	1714.46	3125.31
380.0	0.380	132.0	240.0	435.5	0.11	942.95	1714.46	3111.03
400.0	0.400	132.0	240.0	431.8	0.11	942.95	1714.46	3084.59

RESULTS: C = 239.3 PSF PHI = 35.98 DEG

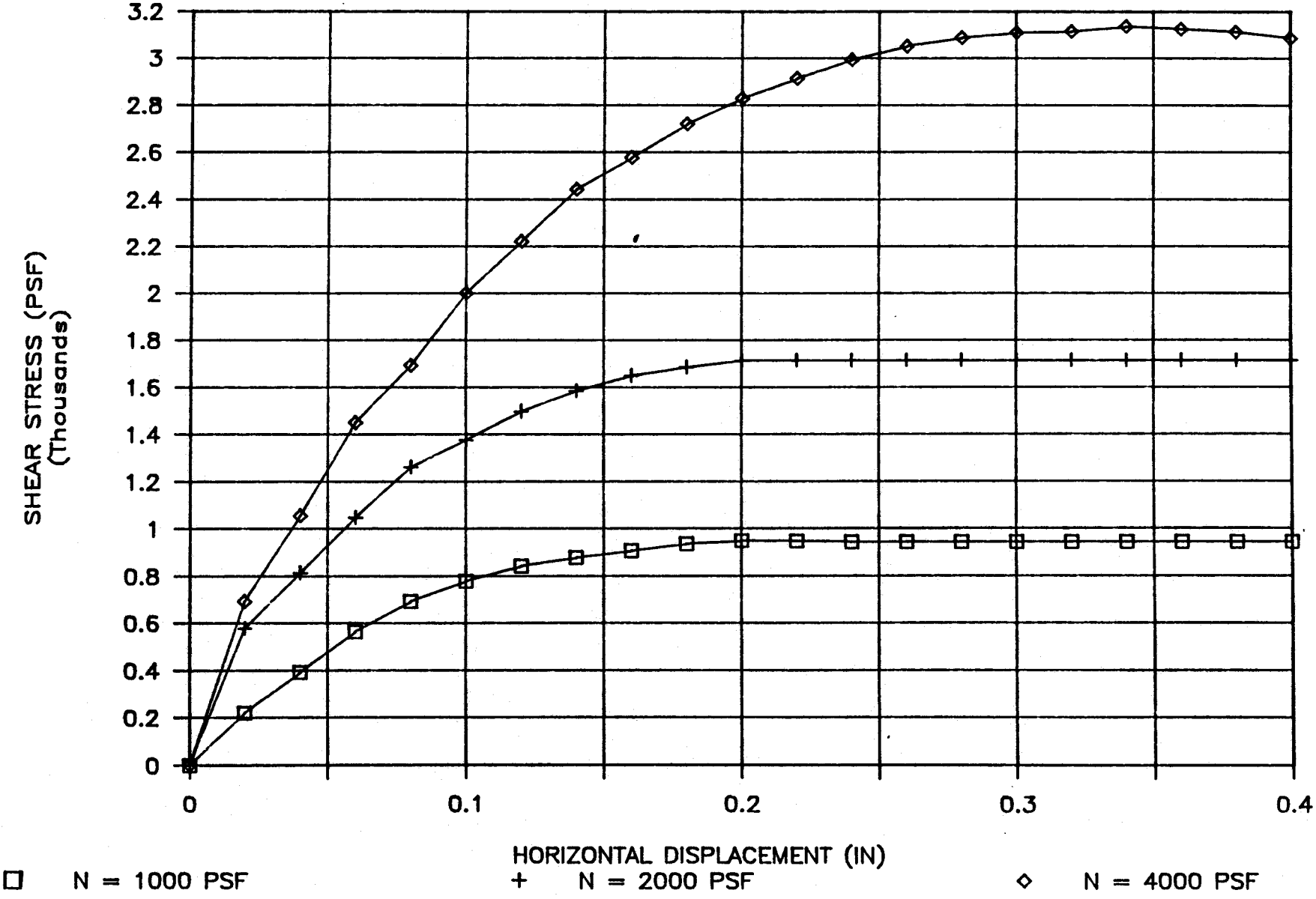
DIRECT SHEAR TEST RESULTS

90S853-01, LINER 60 MIL GUNDLE vs. SOIL



DIRECT SHEAR TEST RESULTS

90S853-01, LINER 60 MIL GUNDLE vs. SOIL



SPECIFICATIONS

SECTION 02201

EXCAVATION, FILLING, AND BACKFILLING

1.0 DEFINITIONS

1.1 Excavation: Excavation consists of the removal of materials encountered to subgrade elevations indicated and subsequent fill of materials removed.

1.2 Satisfactory Soils Materials: Materials consisting of in-place soils, fill, and backfill material, are defined as those complying with ASTM D 2487 soil classification groups GW, GP, GM, SW, SM, SP, SC, ML, CL free of organics, rocks greater than 6" in diameter, and other deleterious material.

1.3 Unsatisfactory Soil Materials: Materials classified in ASTM D 2487 soil classification groups GC, MH, CH, OL, OH, and PT.

1.4 Degree of Compaction: Degree of compaction required is expressed as a percentage of the maximum density obtained by the Laboratory Tests (ASTM D 698) for the material in question.

2.0 SCOPE OF WORK

2.1 Work included as part of the excavation and backfill includes:

a. Excavation of material from the entire area of Area A at Landfill No. 6 to achieve the final grades as indicated on the Drawings.

b. Excavation of material from a borrow area designated by the Engineer if the area of excavation at Area A is insufficient in quantity for fill material requirements.

c. Preparation of the foundation for the earth fill areas including any drainage or dewatering that may be required to control surface water or groundwater in the dike and roadway fill areas.

d. Construction of the compacted fill including placement, spreading, and compaction of the fill to the lines and grade indicated on the Drawings.

e. Disposal of any excess excavated materials to a disposal area designated by the Engineer. Disposal areas shall be compacted and maintained in sufficient drainage condition to minimize erosion prior to seeding operations.

f. Any other work necessary to the proper construction and completion of the earth fill.

3.0 MEASUREMENT

3.1 The quantity of compacted earth fill will be determined by measurement of the volume between the final surface of the fill foundation as determined by surveys made after the completion of stripping (and excavation of any unsatisfactory material) and the final surface of the compacted earth fill determined by surveys made after the completion of slope dressing. In addition, estimates will be made of small volumes of fill if any minor excavations, depressions or cavities that were filled in and the volume was not measured by survey.

4.0 PAYMENT

4.1 Payments will be made at the contract price per cubic yard for Compacted Earth Fill. This price is to cover everything required to perform, to completion and final acceptance, the work outlined in the Scope of Work in accordance with these Specifications.

5.0 FINAL CONTOURS

5.1 Excavation shall be to the best extent possible to the lines and grades shown on the Drawings. It is likely that rock may be encountered in several of the excavated areas. Should rock removal be selected to obtain the lines and grades shown on the Drawings, this excavation will be covered in Specification Section 02202, Rock Removal.

5.2 The earth fill shall be constructed to the elevations, lines, grades, and cross sections indicated on the Cotnract Drawings or revisions thereto. Increased heights and widths may be required to compensate for later shrinkage and settlement.

5.3 The Owner or Engineer reserves the right to vary the foundation widths and the fill slopes, and to make other changes in the sections of the compacted fill. Changes in lines and grades which result in changed material quantities will not be cause for revision of unit prices.

6.0 FILL MATERIAL

6.1 Materials for the earth fill shall be obtained from areas of excavation to reach final grades as shown on the Drawings. If the area of excavation is insufficient in quantity, the Engineer will designate an alternative borrow area.

6.2 Fill material shall be satisfactory soil materials as classified in ASTM D 2487.

6.3 Unsatisfactory soil materials as classified in ASTM D 2487 shall not be permitted in the fill. Unsatisfactory materials shall be placed in a spoil area designated by the Engineer.

6.4 Frozen material can not be used as backfill or fill. Fill shall not be placed upon a frozen surface.

7.0 FILL PREPARATION

7.1 Drainage of the dike foundation area shall be provided by the Contractor. The contractor shall install such ditches, trenches, pits or sumps as may be required to control both surface water and high ground water. Ground water shall be maintained at least 2 feet below the stripped foundation surface or undercut surface until the compacted earth fill dike is constructed to a height of at least 3 feet above the original water level, to original ground level, or until such time as determined by the Engineer.

7.2 After establishing drainage and after stripping of foundation and removal of weak or unsuitable materials has been completed, and before start of material placement, clean soil shall be used to fill all test pits, stump holes, minor excavations and depressions or cavities inside the earth fill limits. These fillings shall be placed in layers over areas of practical size, and shall be moistened or dried to obtain the moisture requirements of the fill. In small areas where roller equipment cannot be employed, material shall be compacted by hand tampers. Layer thickness, moisture content and compaction requirements are detailed below.

7.3 After the filling of depressions and prior to the placement of compacted fill, the earth fill foundation shall be proofrolled to detect any soft surface zones. Proofrolling shall be done with a 50-ton rubber-tired roller or a fully loaded 20 yard pan. A total of four passes of the roller or pan shall be made over each spot of the foundation, two in mutually perpendicular directions. Areas that continue to deflect more than two inches after two or three repeated passes of the roller or pan shall be excavated and replaced with fill. Proofrolling shall not be undertaken on areas of the foundation saturated due to the presence of the water table or other critical areas if, in the opinion of the Engineer, such proofrolling, will cause deterioration of the foundation. In lieu of such proofrolling, visual inspection of the foundation, supplemented by dynamic cone penetrometer tests, standard penetration tests, auger borings, or such other means as the Soils Engineer may employ will be used to ascertain the presence of an acceptable foundation.

7.4 After acceptance of the foundation, the entire surface shall be thoroughly loosened to a depth of three to six inches by scarifying, plowing, disc harrowing or other approved method. After scarifying, the loosened area shall be covered by a layer of fill material having proper moisture content and being placed to a depth of not more than six inches loose measurement. The scarified and deposited soils shall then be thoroughly mixed with a disc harrow or other approved equipment. The area so treated shall then be compacted to the density specified for Compaction of Fill Material.

7.5 No separate payment will be made for any of the above processes, as the entire costs thereof shall be included in the contract unit price for Compacted Earth Fill.

8.0 BERM FILLS

8.1 Placement of a bonding layer shall, except for its thickness, be in accord with the provisions of this section. Materials shall, as far as practicable, be spread during dumping.

Further spreading shall be accomplished by bulldozers or graders or other approved means. Layers shall be approximately horizontal with the thickness of each not greater than 9 inches, loose measure. Harrowing of the layer may be required to break up and blend the fill materials, or to obtain uniform moisture conditions.

8.2 The distribution and gradation of materials shall be such that there will be no lumps, pockets or layers of material differing substantially in texture and gradation from surrounding materials. Small stones and gravel shall not be allowed to accumulate at any point. Rock fragments larger than 6 inches in size will not be allowed to be placed in the compacted fill.

8.3 As soon as feasible after starting construction of the fill, the central portion thereof shall be built and maintained slightly higher than the sides so that the top of the fill will drain freely toward the side slopes. The fill surfaces shall be maintained in a free draining condition throughout construction.

8.4 Equipment shall not travel continuously over the same routes. All traveling shall be along the length of the fill insofar as possible, except for turning movements. Ruts shall be continuously broken up to facilitate proper bonding. When the fill has been otherwise completed, the Contractor shall dress the slope surfaces to the required limits of fill as directed by the Engineer. Any slopes which are not grassed immediately upon completion shall be "tracked" by movement of a cleated dozer up and down the slope to impede surface runoff during rainfall.

8.5 Rock encountered within the landfill area and, at the direction of the Engineer, is left in-place, shall be covered by at least a 2 feet thick layer of compacted soil fill as directed by the Engineer.

9.0 MOISTURE CONTROL

9.1 Compaction shall be done at moisture contents within the limits of 1 percent below to 4 percent above laboratory optimum. Regardless of source, materials that are too wet to permit proper compaction shall not be spread on the fill until the moisture content is satisfactorily reduced. When material is too dry, each layer of the fill shall be sprinkled prior to its compaction. This water shall be blended into the material, by harrowing or otherwise, until a uniform distribution of moisture has been obtained. The amount of water so applied shall be sufficient to dampen the material to the required moisture content, and its application shall be so controlled that no free water will appear on the surface during compaction or afterwards. Should too much water be added to any part of the embankment so that material is too wet to obtain the desired density, the compaction and all work on that section of the embankment shall be delayed until the moisture content of the material is reduced to within the specified limits. Water jets shall not be directed at the embankment with enough force to cause separation of materials. If it is found impractical to add sufficient moisture to materials on the fill, the materials shall be prewetted at the source of excavation. The Contractor shall have an adequate supply of water available at all times.

10.0 FILL COMPACTION

10.1 When the moisture content and other conditions in any layer are satisfactory, that layer shall be compacted as required to attain a density not less than the 95 percent of Standard Proctor maximum density as determined by Laboratory Tests (ASTM D 698) for the soil type in question. The entire fill area shall be covered by the number of passes necessary to produce a uniform compaction. When there is sufficient area, separate dumping, spreading, sprinkling and compacting operations may be carried on at the same time at different places on the fill.

10.2 The fill shall be compacted to create low permeability. Tamping type rollers, either sheepsfoot, or other approved type, shall be used. Weights of these rollers and arrangement of tamping feet shall be such that rollers will not completely "walk out" of a fill layer. Rollers shall leave a roughened surface for placement of the succeeding fill layer. Rubber tired equipment may be used for towing rollers on the fill provided excessive rutting does not occur. If such rutting occurs the Engineer may require that the Contractor substitute crawler type equipment for towing rollers.

10.3 The fill shall be compacted to the full extent of the design slopes. It may be necessary to overbuild the slopes in order to obtain the required degree of compaction and then cut the slopes back to design grade.

SECTION 03000

HDPE LINER INSTALLATION

1.0 DEFINITIONS

1.1 HDPE Liner Installation includes furnishing an effective liner system to control migration of leachate from the landfill.

2.0 SCOPE OF WORK

2.1 This item includes furnishing and installing a 60 mil high density textured polyethylene (HDPE) liner for Landfill #6 - Area A as shown on drawing No. 2. The liner will cover the entire bottom surface of the landfill and extend up the side slopes to the anchor trench adjacent to the access road.

3.0 MEASUREMENT

3.1 Measurement of HDPE liner will be in actual square feet installed.

4.0 PAYMENT

4.1 The HDPE liner will be paid for at the contract price per square foot. This price shall include furnishing and complete installation of the liner including appropriate seam testing, quality control procedures, and subgrade preparation.

5.0 LINING MATERIAL

5.1 The HDPE liner shall have a minimum thickness of 60 mils and have a textured surface on both sides. The textured liner provides an acceptable factor of safety against sliding for the construction of intermediate dikes.

5.2 The new membrane liner shall be comprised of HDPE material manufactured specifically for the purpose of liquid containment in hydraulic structures.

5.3 The Contractor shall, at the time of bidding, submit a certification from the manufacturer of the sheeting, stating that the sheeting meets physical property requirements for the intended application.

5.4 The liner material shall be so produced as to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter. Any such defect shall be repaired using the extrusion fusion welding technique in accordance with the manufacturer's recommendations.

5.5 Labels on the roll shall identify the thickness, length, and manufacturer's roll number. There shall be no factory seams.

5.6 All compound ingredients of the HDPE materials shall be randomly sampled on delivery to the HDPE manufacturing plant to ensure compliance with specifications. Tests to be carried out shall include Density ASTM D1505 and Melt Index ASTM D1238, Conditions E&P.

5.7 Samples of the production run shall be taken and tested according to ASTM D638 to ensure that tensile strength at yield and break, elongation at yield and break meet the minimum specifications. A quality control certificate shall be issued with the material.

5.8 All welding material shall be of a type supplied by the manufacturer.

6.0 LINER INSTALLATION

6.1 The contractor shall be responsible for preparing and maintaining the subgrade in a condition suitable for installation of the liner unless specifically agreed otherwise.

6.2 Surfaces to be lined shall be smooth and free of debris, roots, and angular or sharp rocks larger than three quarter (3/4) inches in diameter to a depth of four (4) inches. All fill shall consist of well-graded material free of organics, trash, clayballs, sharp stones or any other deleterious material that may cause damage to the liner. The subgrade shall be compacted to provide a firm unyielding foundation sufficient to permit the movement of vehicles and welding equipment over the subgrade without causing rutting or other deleterious effects. The subgrade shall have no sudden sharp or abrupt changes in grade. The subgrade shall be inspected and approved by the liner manufacturer.

6.3 The anchor trench shall be excavated by the contractor to lines and widths shown on the design drawings prior to liner placement.

6.4 Corners in the anchor trench shall be slightly rounded where the liner adjoins the trench to minimize sharp bends in the liner.

6.5 Prior to commencement of liner deployment, layout drawings shall be produced to indicate the panel configuration and location of seams for the project by the Contractor.

6.6 Each panel used for the installation shall be given an numeric identifier consistent with the layout drawing. This identification number shall be related to a manufacturing roll number that identifies the resin type, batch number, and date of manufacture.

6.7 The Contractor will install field panels at the location indicated on the layout drawing. If the panels are deployed in a location other than that indicated on the layout drawings, the revised location shall be noted in the field on a layout drawing which will be modified at the completion of the project to reflect actual panel locations.

6.8 The liner shall not be installed during any precipitation, in the presence of excessive moisture (i.e. fog, dew), in an area of standing water, or during high winds.

6.9 The method and equipment used to deploy the panels must not damage the liner or the supporting subgrade surface. No personnel working on the liner will smoke, wear shoes that can damage the geomembrane, or engage in actions which could result in damage to the liner.

6.10 Adequate temporary loading and/or anchoring, (i.e. sandbags, tires), which will not damage the liner, will be placed to prevent uplift of the liner by wind.

6.11 Any area of a panel seriously damaged (torn, twisted, or crimped) will be marked, cut out, and removed from the work area with resulting seaming and/or repairs performed in accordance with Paragraph 9.2 of this specification.

7.0 FIELD SEAMING

7.1 In general seams shall be oriented parallel to the slope. Whenever possible, horizontal seams should be located not less than five (5) feet from the toe of the slope. Each seam made in the field shall be numbered in a manner that is compatible with the panel layout drawing for documentation of seam testing results.

7.2 All personnel performing seaming operations shall be trained in the operation of the specific seaming equipment being used, have sufficient experience, and will qualify by successfully welding a test seam. The project foreman will provide direct supervision of all personnel seaming to verify proper welding procedures are followed.

7.3 Individual panels of liner material shall be laid out and overlapped by a maximum of four inches (101 millimeters) for extrusion weld prior to welding or five inches (127 millimeters) for hot wedge weld prior to welding. Extreme care shall be taken by the installer in the preparation of the areas to be welded. The area to be welded shall be cleaned and prepared according to the procedures laid down by the material manufacturer. All sheeting shall be welded together by means of integration of the extrudate bead with the lining material. The composition of the extrudate shall be identical to the lining material or all sheeting shall be welded together using the hot wedge welding system.

7.4 The welding equipment used shall be capable of continuously monitoring and controlling the temperatures in the zone of contact where the machine is actually fusing the lining material so as to ensure that changes in environmental conditions will not affect the integrity of the weld.

7.5 No "fish mouths" shall be allowed within the seam area. Where "fish mouths" occur, the material shall be cut, overlapped, and an overlap extrusion weld shall be applied.

8.0 FIELD SEAM TESTING/QUALITY CONTROL

8.1 The installer shall employ on-site physical non-destructive testing on all welds. Non-Destructive testing shall be done by either air pressure testing or vacuum testing using recognized test procedures.

8.2 A quality-control technician shall inspect each seam. Any area showing a defect shall be marked and repaired in accordance with HDPE repair procedures.

8.3 A test weld three (3) feet long from each welding machine shall be run each day prior to liner welding and under the same conditions as exist for the liner welding. The test weld shall be marked with date, ambient temperature, and welding machine number. Samples of weld 1/4" to 1/2" (10 mm to 20 mm) wide shall be cut from the test weld and pulled by hand in peel. The weld should not peel. Seams should exhibit a film tear bond. The weld sample shall be kept for subsequent testing on laboratory tensiometer equipment in accordance with the applicable ASTM standards. Random weld samples for destructive testing may be removed from the installed welded liner at a frequency of one per 1000' of weld.

9.0 DEFECTS AND REPAIRS

9.1 The Contractor's Project Superintendent shall conduct a detailed walk through and visually check all seams and non-seam areas of the liner for defects, holes, blisters, and signs of damage during installation.

9.2 Repair Procedures. Any portion of the geomembrane showing a flaw, or failing a destructive or non-destructive test shall be repaired. Several procedures exist for repair and the decision as to the appropriate repair procedure shall be made by the Project Superintendent. Procedures available for repair:

A. Patching - used to repair large holes, tears and destructive sample locations. All patches shall extend at least six (6) inches beyond the edges of the defect and all corners of patches shall be rounded.

B. Grinding and welding - used to repair sections of extruded seams.

C. Spot welding or seaming - used to repair small tears, pinholes or other minor localized flaws.

D. Capping - used to repair lengths of failed extruded seams.

E. Removal of a bade seam and replacement with a strip of new material seamed into place.

9.3 Verification of Repairs. Every repair shall be non-destructively tested. Repairs which pass the non-destructive test shall be deemed adequate. Large repairs may require a destructive test. Repair test results shall be recorded. The repair location shall be recorded on an as-built drawing.

10.0 WARRANTY AND GUARANTEE

The manufacturer/installer shall provide a written warranty. This warranty shall be directly with Champion International Paper Co., in addition to any project guarantees provided by the Contractor.

11.0 SUGGESTED LINER MANUFACTURES

1. Gundle Lining Systems
   19103 Gundle Road
   Houston, TX 77073

   Phone: 1-800-435-2008
   Contact: Rick Cannon

2. National Seal Company
   P.O. Box 1448
   Galesburg, IL 61401

   Phone: 1-800-323-3820
   Contact: Chris Hult

3. SLT-North America
   Four Greenspoint Plaza
   16945 Northchase, Suite 1750
   Houston, TX 77060

   Phone: (713) 874-2150
   Contact: Wendy Freund