FINAL AMENDED REMEDIAL DESIGN PROJECT PLAN

VOLUME 1
DESIGN REPORT AND SPECIFICATIONS

PREPARED ON BEHALF OF
THE BUTTERWORTH SITE GROUP

PREPARED BY:
RMT, INC.

JUNE 1999

RMT, INC.
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May 28, 1999

Mr. Dion Novak
Remedial Project Manager
USEPA Region 5
77 West Jackson Boulevard
Chicago, IL 60604-3590

RE: Butterworth Landfill Remedial Action
Grand Rapids, Michigan

Dear Dion,

On behalf of the Butterworth Site Group (BSG), RMT, Inc., is submitting the attached responses to the USEPA's May 12, 1999, comments on the Amended Remedial Design Project Plan (Amended RDPP). It is the BSG's understanding that these responses are acceptable to the agencies, as they were discussed orally with the you and the MDEQ during the meeting on May 26. We further understand that you are not planning to respond to this submittal in writing since your May 12 letter provided approval of the Amended RDPP. Additionally, while your May 12 letter stated that responses were due by May 26, you approved the BSG's request during the May 26 meeting to extend the due date to today.

Please call either Phill Mazor, at 616-688-5777, or me if you have any questions.

Sincerely,

RMT, Inc.

Linda E. Hicken

Linda E. Hicken, P.E.
Senior Project Manager

Attachment

cc: Brian vonGunten, MDEQ
BSG Technical Committee
Donna Brunner, Tetra Tech EM
Ray Mastrolonardo, Tetra Tech EM
Bhupen Gandhi, Tetra Tech EM

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RESPONSES TO THE USEPA'S MAY 12, 1999, COMMENTS CONCERNING THE AMENDED REMEDIAL DESIGN PROJECT PLAN FOR THE BUTTERWORTH LANDFILL, GRAND RAPIDS, MICHIGAN

1. *Response to comment 11. Attachment 3 to Appendix A of the Soil Cover proposal presents engineering testing results for the imported soil. The comment was referring to any contaminant testing done on these soils that is typical when importing soil to a Superfund site, to ensure that the soil is contaminant free. Please provide this information to the Agencies.*

   No contaminant testing has been performed on the material to be used for the soil cover because the source of the material is a greenfield. The soil will be imported from previously undeveloped land at the Waste Management, Inc., Autumn Hills Recycling and Disposal Facility near Zeeland, Michigan. This material was excavated from the area of the Autumn Hills facility where the landfill was constructed. The land use in this area was formerly agricultural.

   Prior to importing the proposed soil cover material from the Autumn Hills facility, the BSG will collect and analyze two samples of this material for the TCL and TAL parameters.

2. *Response to comment 13. The condition to trigger increased monitoring should be revised to include comparing the pressure in the probe during a monitoring event with the pressure recorded immediately after completion of the cap. This method would more accurately account for LFG accumulation after the cap is installed, rather than from one sampling event to another, and would measure gas buildup under the cap over time as well. This method will also help the proposed monitoring probes provide accurate information on gas conditions at the site.*

   As requested, the pressure recorded in a probe during a monitoring event will also be compared with the pressure recorded in that probe immediately after completion of the cap.

3. *Response to comment 19. Specification 02230 should state that large clumps "will be" broken down rather than as stated "capable of being broken down." This eliminates pathways for vertical migration of water.*

   The text in Specification 02230, Subpart 2.05 B, will be changed as requested.

4. *Response to comment 20. The specifications for Folkertsma required the rock size to be 2 inches or less, not 6 inches as referenced here.*

   The BSG acknowledges that the technical specifications for the Forkertsma Landfill call for a rock size of 2 inches. The increase to a maximum of 6 inches was approved by the MDEQ as a field modification.

   In addition to the other supporting information previously provided on this issue, the BSG notes that the Michigan Solid Waste Rules in effect when the ROD was signed do not address the size of the rocks that can be used. Moreover, the proposed material from the

Autumn Hills RDF has previously been approved by the MDEQ for similar use at other landfills in Michigan.

5. *Response to comment 22. Have the specifications been revised to include the new seed mixtures as they are presented to the contractors?*

   The BSG purchased the seed mixtures directly from the supplier to save contractor mark-up and to take advantage of a limited opportunity to purchase the seed before a significant price increase was expected to occur. The seed mixtures presented in Appendix C of the RA Work Plan were ordered.

6. *Response to comment 28. Signage should also include signs that identify the site as a Superfund site.*

   The signs will also identify the landfill as a Superfund site.

April 14, 1999

Mr. Dion Novak
Remedial Project Manager
USEPA Region V
77 West Jackson Boulevard
Chicago, IL 60604-3590

RE: Response to Comments - Amended Remedial Design Project Plan
Butterworth Landfill, Grand Rapids, Michigan

Dear Dion:

On behalf of the Butterworth Site Group (BSG), RMT has prepared the attached responses to the April 6, 1999, consolidated comments from the USEPA, the MDEQ, and Tetra Tech EM's review of the Amended Remedial Design Project Plan (RDPP).

While we appreciate the timely response to this latest submittal of the design document for this Site, we were somewhat disappointed at what appears to have been limited consideration of the BSG's previous responses to agency review comments that were documented in the Pre-Final RDPP, the Final RDPP, and the Revised Final RDPP. Agency concerns involving the limits of capping, soil sampling, landfill gas (LFG) management, and the construction of the clay cap that are raised in the current comments were previously reviewed by the USEPA, the USEPA's oversight consultant at the time (E&E), and the MDEQ. These issues were resolved as part of the Pre-Final RDPP, which was approved by USEPA on July 13, 1997, and on September 16, 1997 (regarding LFG issues). Moreover, with the exception of details related to the soil cover to be constructed over the Radio Tower and Station Building (RTSB) Area, the concepts and components questioned by these comments were included in the Revised Final RDPP, which was approved by the USEPA.

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We have also attached pages and a drawing, revised as a result of the April 6, 1999, comments, for insertion into the Amended RDPP. The BSG requests approval of the Amended RDPP on the basis of the attached responses and the revised pages and design drawing. Please call either Phill Mazor at (616) 688-5777, or me, if you have any questions.

Sincerely,

RMT, Inc.

Linda Hicken

Linda E. Hicken, P.E.
Senior Project Manager

cc: Rob Franks, MDEQ
Leslie Kirby, EPA ORC
Donna Brunner, Tetra Tech EM (2 copies)
BSG Technical Committee
Gary Connor, RMT
Wally Kurzeja, RMT
Frank Griffin, Enterprise Environmental & Earthworks

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RESPONSES TO THE USEPA'S APRIL 6 , 1999, COMMENTS ON THE MARCH 1999 AMENDED REMEDIAL DESIGN PROJECT PLAN

1. *Page 5. Please delete the summary history of the plan development as outlined on this page. This information is unnecessary as the soil cover request has been memorialized in an ESD for the radio tower area.*

   Response: The summary is justifiably included in the section entitled "Background" because it documents the process and the effort expended by the Butterworth Landfill Cooperating Parties (BLCP, the PRPs who conducted the Remedial Design) and the BSG to comply with the consent decrees for both the Remedial Design and the Remedial Action.

2. *Page 9, RTSB investigations. The information presented here should be revised to reflect the findings of the ESD.*

   Response: The discussion in this section has been updated by adding a reference to the Group's "Proposal to Place a Soil Cover over the RTSB Area," (RMT, June 1, 1998), and by inserting text from the relevant portion of the ESD.

3. *Page 14, Section 2.4. As discussed recently, conversations about site reuse should happen shortly. If there are any Agency concerns regarding reuse plans, they are addressed more easily when construction is active. I would encourage the BLCP to organize their ideas and present them to the Agencies as soon as possible.*

   Response: Acknowledged. No modification to the Amended RDPP appears to be necessary.

4. *Page 15, Section 3.1. It is stated here that the cover will extend over an area of waste on the Consumers Energy property. Has this waste been characterized as part of the Butterworth investigations? Was this waste from Butterworth operations? What is the purpose of covering this area? Is it for slope stability? Please address.*

   Response: The Butterworth Landfill "Site" is comprised of multiple parcels of property that are owned by a number of private parties, in addition to the City of Grand Rapids. The particular area of concern (*i.e.*, the rubble berm) that lies within the Consumers Energy parcel bordering the eastern side of the Site has not been characterized beyond identifying it as one of several contiguous areas of municipal waste and/or rubble debris that lie outside the City's property. All such areas were assumed to have been affected by the former filling operations at the Site.

   Furthermore, reviewers should note that the extent of waste indicated on the grading plans is approximate and will be verified in the field prior to placement of the cap. If grading activities at the edges of the landfill in areas like the eastern edge (*i.e.*, the Consumers Energy parcel) uncover thin waste fills, then the BSG may decide to excavate and reconsolidate these wastes in areas to be covered by the clay cap. As for the purpose of the cover, the ROD requires that these wastes be covered.

5. *Page 16, last two paragraphs. Do the agreements with the station owners contain assurances that construction in the radio tower area will not be delayed by denying access over disagreements? How are future repairs of the ground plane system going to impact the integrity of the soil cover if the existing system is under the soil? How will the placement of a new ground plane system impact the minimum 12 inch cover thickness in the RTSB area?*

   Response: In accordance with Section IX, Paragraph 26, of the RA Consent Decree, the BSG will pursue an access agreement that is not anticipated to be jeopardized by any future disagreements, However, should the BSG's efforts fail, USEPA assistance will be sought (in accordance with Par. 27 of the Consent Decree).

   Future repairs are limited to the replacement of part of or all of the ground plane system(s) when corrosion eventually degrades the effectiveness of the systems. Although the life of these systems varies, it is unlikely that a new ground plane system (which may be installed after the soil cover is constructed) will require replacement during the 30 years of O&M required by the Consent Decree for the RA.

   In any event, installation of a ground plane system, or repairs, will not affect the performance of the soil cover. A new or repair installation would likely involve plowing No. 8 to No. 10 bare strands of copper wire into the soil at approximately 6 inches of depth. The disturbed ground would be covered or regraded immediately. However, based on the installation methods, no disturbance of vegetation is anticipated.

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6. *Page 19, 1st full paragraph. What is the basis for the 20 times the GSI criteria? What is the significance of the results? Will further excavation take place if levels are significant? What about placement of clay east of the CSO ditch?*

   Response: The 20 times the GSI criteria is the state default (generic) soil cleanup criteria that is protective of groundwater quality, as established in the MDEQ-ERD Interim Operational Memorandum #18: Part 201 Generic Cleanup Criteria Tables. If levels of contaminants in the soils exceed the default values, then additional excavation may be conducted. Alternately, the BSG may choose to cover the area of concern.

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7. *Page 19, 3rd full paragraph. This paragraph is factually incorrect and must be deleted.*

   Response: According to the record established for these sites, the content of this paragraph is factual and was previously presented in the Revised Final RDPP, which was approved by the USEPA.

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8. *Page 19, last two lines. This sentence is incorrect as there is waste on at least two other properties owned by Consumers Energy.*

   Response: Please refer to the response to Comment 4. Specific to this comment, according to CERCLA, the sentence and its reference to "site property" is correct. The site property is defined by the extent of the release and is not defined by legal boundaries. Additionally, Consumers Energy is a Respondent to the RA Consent Decree.

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9. *Page 20, 1st full paragraph. What was the result of this review by Consumers Energy? Is the cap construction acceptable for their operation and maintenance activities?*

   Response: Consumers Energy, an active PRP throughout the remedial design effort, has found the final design acceptable with respect to issues specific to their operations.

10. *Page 21, 4th full paragraph. How will the seeding be accomplished? How will bare spots after initial seeding be addressed?*

Response: Seeding requirements are described in the specifications. For example, Section(s) 02931-3, 3.04 and 3.05 identify Brillion and Hydroseeding. Bare spots will be reseeded by either the construction contractor (see 02931-3.10) or the O&M contractor (Volume 2 - Operation and Maintenance Plan - Section 4.14).

11. *Page 22, Section 3.1.3 bullets. How will the imported soil be tested before placement?*

Response: The "imported soil" referenced in the comment has previously been tested. The results were reported in Attachment 3 of Appendix A of the "Proposal to Place a Soil Cover over the RTSB Area," (RMT, June 1, 1998). Further, Terry Hartman of the MDEQ Grand Rapids District Office, performed a visual inspection of the stockpile to confirm that the material was homogeneous and that the samples collected were representative of the stockpile. No additional testing is proposed prior to placement.

12. *Page 22, Section 3.1.3 paragraph 2. There is no information presented here to justify the 4-inch depth for grass rooting. The phrase "majority of the rooting system" implies that some roots will extend into the 6-inch clay cover. As was discussed at previous meetings, this is not acceptable and the prevention of deeper rooting was one of the key factors in modifying the ROD cap remedy in this area. The Agencies expect to see some type of documentation indicating that the lower portion of the cap in this area will be protected. Installation of a geomembrane such as a high density polyethylene liner placed over the clay layer should be considered to improve performance of the cover in the RTSB area, prevent roots from extending into the clay layer, and to protect the clay layer from freeze and thaw cycles.*

Response: The BSG surveyed professional and academic opinions regarding root penetration of turf grasses and documented our findings in a letter of September 8, 1998, to Dion Novak. The consensus was that rooting depths vary depending on the type of grasses, soil conditions, and climate. A site-specific habitat planting plan was subsequently developed by Resource Management Group, Inc., (RMG) of Grand Haven, Michigan, to identify appropriate grass and plant species for use at the Butterworth Landfill. Shallow rooting depth was one of the primary criteria for selection of the grasses. RMG's recommendations of specific grass and plant species that would be appropriate for the Butterworth Landfill was documented in Appendix C of the Draft RA Work Plan, which was submitted to the agencies on April 1, 1999.

The term "majority" refers to the more dense and massive root system that occupies 30 to 40 percent (by volume) of the ground, as compared to the 60 to 70 percent of the ground that is occupied by soil. This zone of massive rooting generally occupies the upper 4 inches of the ground. This is evident when taking a shovel and overturning a piece of ground with turf grasses present. The smaller and less dense rooting system generally extends further into the soil. However, in environments such as landfills with clay or less permeable soil covers, root penetration is also limited by the periodic saturated conditions in the soil above the barrier, or less permeable, cover layer. This phenomena is documented in "Evaluating Soil Covers For Solid and Hazardous Waste" published by USEPA.

With regard to the part of the comment concerning consideration of a geomembrane over the lower 6 inches of the soil cover, a geomembrane would be inconsistent with the intent of the ESD because it would reduce infiltration of precipitation even more than the Act 641 cap over the other areas of waste. The ESD provides for a soil cover in recognition that infiltration and leaching of landfill constituents are of less concern in the RTSB Area than in other areas of the landfill.

Finally, a geomembrane over the compacted clay comprising the lower 6 inches of the soil cover in the RTSB Area would be covered by only 6 inches of topsoil, and thus would not protect the lower 6 inches from freeze/thaw cycles.

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13. *(a) Page 22-23, Section 3.1.4. It is stated in this section that landfill gas production has declined and that "minimal to no LFG pressure precludes the need for direct venting of LFG through the cover." It is also stated that the LFG production is only occurring in the northwest corner of the landfill.*

The monitoring results included in this plan indicate that LFG production is occurring across most of the landfill, and that a high percentage of methane was detected during all monitoring events. Also, because the clay cover will be placed over the landfill, LFG will not be able to naturally vent through the soil cover and pressures will increase. Installation of a positive venting system should be considered to relieve the LFG buildup under the cap.

The second bullet states that most of the LFG production occurs west of the CSO ditch in areas 2 and 3. This contradicts the monitoring results presented in Appendix A-2, which shows that gas wells GW-8, located near east, and GW-9, located far east of the CSO ditch, contained higher percentages of methane than gas wells on the far west side of the CSO ditch during all monitoring events. Also, the percentage of methane at GW-9 increased from 69 percent in 1995 to 75.3 percent in 1997. In addition, the third bullet states that "during November 1995, LFG was measured at 100 percent of the LEL at the narrow strip of more permeable fill in the NW corner of the site." During November 1995, LEL percentages were not measured at gas wells GW-1 through GW-9. However, during August 1996, LEL percentages were measured at 100 percent at all gas wells except GW-5, GW-6, and GW-7, which are on the near west side of the CSO ditch, indicating that LFG production is occurring on the east and west sides of the CSO ditch.

For these reasons, the LFG management plan should be reviewed and updated as necessary.

Response: These comments were previously addressed and resolved with the MDEQ. The BLCP addressed all of these issues in the Pre-Final RDPP response to comments, which were approved by USEPA. Point by point:

- This comment is incorrect. The document does not state that LFG production is only occurring in the northwest corner, but rather that migration has been limited to that area.
- The conclusion that LFG production is declining is based on modeling results (please refer to Section 6 of the Pre-Design Studies Report, which is Appendix C of the Preliminary RDPP [RMT, April 1996]) and is supported by the absence of positive pressure in the gas monitoring probes, not on the fact that methane is present at any particular point.
- Some landfill gas production is occurring over most of the landfill. However, trying to estimate or speculate on production levels based on methane levels and 5 percent variations in methane readings is an incorrect interpretation of the data.

- LEL measurements in the narrow strip in the NW corner were made in barholes or temporary probes in November 1995. LEL measurements in wells constructed in the waste do not produce useful data for production and migration estimates.
- Comparisons of production levels for the eastern and western sides of the landfill cannot be made on the basis of the levels of methane measured at so few monitoring points. For landfills that have been inactive as long as the Butterworth Landfill, the time of placement, disposal method, moisture conditions, and volume are more reliable indicators (and model input parameters) of landfill gas production.
- In a probe constructed in waste, an LEL measurement of 100 percent is common and is not an indication of more or less gas production; however, the absence of pressure is an indicator.

Please refer to the Preliminary RDPP (Volume 2) for the results of the LFG modeling and to the responses to comments provided in the Pre-Final RDPP. Additionally, please note that the LFG Management Plan in the Amended RDPP includes installation of six additional soil gas probes along the northern property boundary along with monthly monitoring during construction and for at least one year after construction to verify that placement of the clay cap does not cause off-site migration of LFG. Moreover, the contingency response plan (Subsection 8.3.2 of the O&M Plan) describes the trigger levels and response actions that will be taken by the BSG in case LFG conditions are other than anticipated.

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13. *(b) Page 27, 1st incomplete paragraph. Is the area for the institutional controls for well installation included in the RA Work plan, as outlined in the RA SOW?*

Response: Yes.

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14. *Page 29, Section 4.1. LFG probes must be monitored for more than one year. Is the intent to submit a proposal to reduce monitoring frequency after one year of monitoring data? If so, the text should be modified.*

Response: As stated in Subsection 4.1, LFG levels will be monitored monthly during construction (a period currently estimated to extend over approximately 18 months) and for a minimum of one year after construction. If, after the post-construction monitoring period, the data support the design basis that LFG migration is not a potential exposure pathway at this site, then the BSG will likely petition the USEPA to either reduce the frequency of monitoring (for example, from monthly to quarterly) or may propose to discontinue this activity. Any proposed change in the monitoring program will be presented to the agencies with the supporting data. The complete monitoring plan is presented in Volume 2, Section A, Section 6.

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15. *Page 29, Section 4.2. The Draft RA Work plan is due 45 days after lodging of the consent decree-please modify text.*

Response: The text has been modified as requested.

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16. *Page 31, 1st paragraph. Should state here that the schedule must be included in the RA work plan submittal.*

Response: Agreed.

17. *Appendix C, page 1. Who is responsible for monitoring fugitive dust and VOC emissions from the landfill during construction activities? What is the document that memorializes this agreement?*

    Response: The Construction Manager (Enterprise Environmental & Earthworks, Inc.) is responsible for implementing the Fugitive Dust Control and VOC Monitoring Plan. This is stated in Section 5.6 of Volume 2, Section C of the Amended RDPP.

18. *Appendix D, page 6. Why are the topsoil and low perm quantities different for area 2, when the thicknesses are the same?*

    Response: The thicknesses are presented solely to indicate the minimum allowable thickness. The larger volume reflects the amount of soil that is required to meet the minimum slope requirements and the transition between the soil cover and the clay cap.

19. *Appendix F, Spec 02230, page 02230-2 and Section 3.06, page 02230-4. Why is it not specified that clumps are required to be broken down into a smaller size? Because placement and compaction of clay fill is covered under specification 3.06, breakdown of clumps to a smaller size of 2-3 inches should be specified here.*

    Response: Specification Sections 02230-2.05 address "clumps".

20. *Appendix F, Spec 02230, page 02230-2. It is stated here that the maximum rock size is 6 inches in the longest direction. However landfill cap guidance (EPA/625/4-89/022, August 1989) requires the maximum rock size as 2 inches in any direction. Please correct this discrepancy.*

    Response: Based on professional judgment and experience, irregularly shaped rocks that are six inches and less in the longest dimension do not create voids and do maintain the cap performance and integrity. Rounded rocks 6 inches and larger in diameter generally surface during clay placement (grading) and are picked up. The USEPA has allowed similar standards at several CERCLA landfills such as the Muskego Landfill in Wisconsin, and the Folkertsma Landfill in Michigan.

21. *Appendix F, Spec 02230, page 02230-4. Moisture content is reported here as between 2 and 5 percent. Ideally, this should be between 1 and 5 percent because the clay may dry and crack from desiccation, thereby impacting the integrity of the clay layer.*

    Response: The specified range refers to the allowable range surrounding the optimum moisture content. The cited range of 2 points under and 5 points over optimum moisture is specified by rule (Michigan PA 641) in affect at the time the ROD was signed).

22. *Appendix F, Spec 02931. RMT has indicated in previous meetings that a variety of seed mixtures would be used in different areas of the landfill after construction of the soil cover. However, it is stated here that only one mixture will be used. This section needs to be revised and updated to include this additional information.*

    Response: It is further stated in Item C of the same specification, Section 2.02 (b) (1), that the mixture may be modified per the contractor's recommendations. Subsequent to submittal of the Amended RDPP, seed mixes have been selected for use at this site. These seed mixes were chosen on the basis of site-specific criteria, including shallow root structures. The seed mixes are presented in Appendix C of the Draft RA Work Plan, which is currently under review by the USEPA.

23. *Appendix G. It is the understanding that all topsoil was imported from Autumn Hills at no cost. Why are material costs of over $556,000 included in the RA cost estimate?*

Response: Only a small portion of the topsoil staged at the site came from the Autumn Hills facility. There were costs associated with all of the cover materials, which include at a minimum, loading, transportation, stockpiling, and general coordination. Specific to the comment, the cost estimate provides a reasonable estimate of what the remedy will cost regardless of any possible discounts and work completed prior to developing the estimate.

24. *Drawings Sheet 7 of 10, note 6. This note states "Terminate GCL in anchor trench as close to the existing structure as possible." However, the drawings and specifications do not indicate the use of a GCL. Please revise the document to include this information.*

Response: The GCL reference was inadvertently left in from a previous submittal of the RDPP and has now been removed. The revised drawing is attached.

25. *Drawings Sheet 8 of 10, note 1. This note states "Excavate soft sediments and sludge to establish a foundation for dam on competent ground or establish foundation with engineered fill." However, the term 'competent ground" is not defined. Please revise the document to include this information.*

Response: The determination of competent ground is made on the basis of professional judgment and will be a field determination made collectively with input from the contractor, the design engineer, agency oversight personnel, the CQA Officer, and as necessary, other appropriate engineering professionals. In the event that saturated or spongy soils are present, structural (or engineered) fill will be used to establish a foundation. Competent is generally defined according to specific field conditions and by one or more professionals.

26. *Volume 2, O & M Plan page 5 Section 4.1.3 and 4.1.4. What steps will be taken to repair the topsoil layer if required? What steps will be taken to minimize impacts to these areas? How will the seed be applied during cover repairs?*

Response: Amended RDPP - Volume 2, Section A, Sections 4.1.2 and 4.2 address topsoil, cover soil repair, and reseeding; including steps to minimize impacts by stockpiling soil, erosion control, and surface water control. Repair of the topsoil layer is also a component in the repairs cited in 4.1.1, 4.1.3, and 4.1.4. Section 4.1.4 states that reseeding will be done in accordance with the specifications.

27. *Page 6, Mowing. Where are the requirements for more frequent mowing to limit the root depth of the cover grasses, as was agreed to at previous meetings between the Agencies and the BLCP?*

Response: Mowing is specified as periodic based on the need to control volunteer grasses and weeds, and the grasses with deeper rooting systems. The grasses selected for the RTSB Area are shallow-rooted species and do not require frequent mowing. Care will also be taken to ensure that inappropriate mowing (either too frequent or too short in length) does not cause the rooting systems to be driven deeper into the soil or eventually kill the grasses.

28. *Page 6, Section 4.2.2. What types of signs will be placed at the site?*

Response: At a minimum, signs will prohibit open flames, excavation, and motorized vehicles.

29. *Page 7, Section 4.5. What provisions will be taken for sampling if the well is not accessible?*

Response: The only way the wells would be inaccessible would be as a result of high river stage, in which case sampling will not occur at that time, as stated in the ACL Performance Monitoring Plan, which is Appendix A of the Draft RA Work Plan.

30. *Page 8, Section 5.4. What about damage to dedicated pumps and sampling equipment, such as bailers and damage to wells from vehicles? How will these problems be addressed?*

Response: Spare equipment will be available and ready for use. Damage from vehicles will require repair or replacement of wells as noted in the Amended RDPP - Volume 2A Section 4.5 on page 7.

31. *Page 9, last paragraph. A written petition to EPA for approval must precede any modifications.*

Response: Agreed, as intended by "review potential changes with the USEPA," in the referenced paragraph.

32. *Page 10, paragraph 1. Why is this data not included in this plan as it has already been collected?*

Response: It is included with the other LFG data in Appendix A-2 of the Amended RDPP.

33. *Page 10, paragraph 4. What will probes be replaced with if they are not "valuable?" What does "valuable" mean?*

Response: The wells, which are functionally probes, within the fill areas (GW-1 through GW-9) will not be replaced if they do not provide data that are useful in evaluating potential off-site gas migration. The probes (GP-1 through GP-6) would be repaired or replaced as needed to comply with the monitoring program.

34. *Page 11, Section 7.1. "May" be removed? More definition should be provided here.*

Response: "May" provides flexibility to be cost-effective and still maintain the intended performance of the clay cap. An alternative may include leaving the section of geomembrane and filling with general fill and topsoil.

35. *Page 11, Section 7.4. What if the well is not sampleable?*

Response: This is addressed in the Amended RDPP, Volume 2A, Section 4.5; replacement or repairs will be made to accommodate sampling.

36. *Page 12, Section 8.3. How will it be determined if the stressed vegetation is a result of landfill gas?*

Response: At a minimum, by a qualified inspector using professional judgment. Isolated and reoccurring spots of dead grass accompanied by a landfill odor can be an indication.

37. *Page 12, Section 8.3.1. When will new probes be necessary?*

Response: The criteria for installing new probes is provided in Volume 2, Section A, Subsection 8.3.2. If, after construction of the LFG barrier/outlet, methane levels at the property boundary exceed 25 percent of the LEL (the performance criteria for LFG), then appropriate response actions will be taken until the compliance criteria is achieved, including, as appropriate, installing new probes to demonstrate compliance. The need for, as well as the number and location(s) of new probes, will be determined on the basis of all information available at the time. The USEPA will be consulted prior to installing additional probes, if they are needed.

38. *Page 12, Section 8.3.2. Change "may be" to "will be" on last line of page.*

Response: The referenced frequency is only an example. If conditions warrant monitoring daily, then twice weekly is insufficient. The actual frequency will be reviewed and discussed with the agency (as the text states) if implementation of this contingency is necessary.

39. *Page 13, 2nd bullet. See previous comment.*

Response: See response 38.

40. *Page 15, paragraph 1. Update the reporting frequency as already outlined in the RA SOW.*

Response: The paragraph has been updated.

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List of Drawings

Section 1
INTRODUCTION

1.1 Purpose of the Amended Remedial Design Project Plan

This Amended Remedial Design (RD) Project Plan for the Butterworth Landfill in Grand Rapids, Michigan, has been prepared by RMT, Inc. (RMT), on behalf of the Butterworth Site Group (BSG). This document was prepared in accordance with the approved RD Work Plan; the RD Scope of Work (SOW), Explanation of Significant Differences (ESD), and an Amendment to the ESD. The RD SOW is attached to the Administrative Order on Consent (AOC) for the RD between the Butterworth Landfill Cooperating Parties (BLCP) and the United States Environmental Protection Agency (USEPA) Region V. The ESD was issued by the USEPA on October 23, 1998, to modify the Record of Decision. The Amendment to the ESD was issued December 23, 1998. The Amended RD Project Plan is presented into two volumes as follows:

- Volume 1 — Design Report and Specifications
- Volume 2 — Section A — Operation and Maintenance Plan
  - Section B — Site Health and Safety Plan
  - Section C — Construction Quality Assurance Objectives Plan

The purpose of the Amended RD Project Plan is to finalize the plans and specifications for the remedy and to provide a basis for obtaining bids for construction.

1.2 Background

1.2.1 Site Setting

The Butterworth Landfill (Site) is located on a 180-acre parcel on the northern bank of the Grand River, approximately 1 mile southwest of downtown Grand Rapids, as shown on Sheet 1 of the RD Drawing Set. The site is bounded on the north by Butterworth Street, on the east by a Consumers Energy Company substation, on the south by the Grand River, and on the west by a drainage swale locally known as "Western Creek," which is just east of Interstate Highway I-196. The landfill accepted residential, demolition, and industrial wastes from sometime prior to 1938 (the start of operation is undocumented) until 1973. The site is composed of the following five general areas (shown on Sheet 2 of the RD Drawing Set):

- Butterworth No. 1 (the Old Butterworth Dump)
- Butterworth No. 2
- Butterworth No. 3
- The Northeast Study Area (NESA)
- The RT&SB Area (the RT&SB Area is directly west of the combined sewer overflow [CSO] ditch)

The NESA and the RT&SB Area were not identified as waste disposal areas in the Record of Decision (ROD). The areal extent of these previously unconfirmed waste disposal areas was determined during the field investigation phase of the Pre-Design Studies (PDS) (RMT, 1996).

The ground surface topography at the site is generally flat, sloping to the south (toward the Grand River). A large part of the site lies within the 100-year floodplain of the Grand River, with uplands rising to the west. Low-lying drainage areas are present to the north and west of the site.

The CSO ditch is an unlined drainage ditch that can be used by the City of Grand Rapids for permitted discharges of combined storm water and sanitary wastewater if the City's wastewater treatment plant cannot meet the system demands. Use of the CSO ditch has been largely reduced by the recent construction of a storm water holding facility and the installation of new CSO piping. However, the CSO ditch may still receive permitted discharges during severe storm conditions.

Other significant site surface features are the Consumers Energy Company transmission tower structures that support high voltage powerlines that traverse the center and northern portions of the site from west to east.

1.2.2 Site Geology and Hydrogeology

The regional and site geology and hydrogeology were described in detail in the Remedial Investigation (RI) Report (Fred C. Hart Associates, Inc., 1989). In general, the site geology consists of a layer of unconsolidated glacial outwash and fluvial deposits (mostly sand and gravel), having an observed thickness of 10 to 30 feet, which overlies a 75- to 116-foot–thick layer of gypsum and shale (the Michigan Formation), which in turn overlies a 300-foot–thick layer of sandstone and shale (the Marshall Formation). The thickness of the waste at the site ranges from 0 to approximately 40 feet.

The water table is present between approximately 5 and 30 feet below ground surface and generally occurs in the unconsolidated deposits. In some areas, the wastes are saturated. Shallow groundwater in the outwash aquifer, the uppermost aquifer at the site, is affected by landfill leachate. Based on water level measurements made during the RI and during the first and second RD groundwater monitoring events (RMT, 1997a and 1998a), shallow groundwater under the landfill vents to the Grand River. There are no known users of the shallow aquifer within the site boundaries (McLaren/Hart Environmental Engineering, 1991a). The City of Grand Rapids draws its municipal water supply from Lake Michigan.

The Marshall Formation, the next uppermost aquifer, is hydraulically separated from the outwash aquifer by the Michigan Formation, which has a very low vertical hydraulic conductivity. Because the hydraulic heads in the Marshall Formation are approximately 5 to 15 feet greater than the hydraulic heads in the outwash aquifer, and because the Michigan Formation is an effective confining layer, water in the outwash aquifer is unlikely to migrate into the Marshall Formation in the area of the landfill. This conceptual model of groundwater flow is also supported by the absence of leachate constituents in monitoring wells in the Marshall Formation near the site.

1.2.3 Regulatory History

The Butterworth Landfill was placed on the USEPA's National Priority List (NPL) in December 1982. A Consent Decree for the performance of a Remedial Investigation/ Feasibility Study (RI/FS) was signed by the USEPA and members of the Butterworth Landfill Steering Committee in April 1987. An RI and three phases of RI addenda studies were conducted (Fred C. Hart Associates, Inc., 1989; McLaren/Hart Environmental

Engineering, 1989; McLaren/Hart Environmental Engineering, 1991b; and McLaren/Hart Environmental Engineering, 1991c).

A removal action was conducted in 1990 to remove surface soil containing unacceptable levels of PCBs and chromium that had been detected during the RI. Approximately 1,100 tons of surface soil were excavated and disposed off-site. Other constituents of concern in the soil at the site included arsenic, beryllium, polynuclear aromatic hydrocarbons (PAHs), and dieldrin. The constituents of concern in groundwater that were identified in the RI included antimony, arsenic, 1,1-dichloroethane, vinyl chloride, and bis(2-ethylhexyl)phthalate.

The baseline risk assessment (McLaren/Hart Environmental Engineering, 1991a) identified the primary route of residential exposure to site contaminants as inhalation of airborne contaminants and dusts. Other potentially significant routes of exposure included dermal contact and ingestion of surface soil.

The FS was completed in 1991 (McLaren/Hart Environmental Engineering, 1991d). The ROD for this site was signed on September 29, 1992, by the USEPA Region V Administrator (USEPA, 1992). The selected remedy includes the following components:

- The establishment of institutional controls
- The capping of the site to meet the requirements of the Michigan Solid Waste Management Act (former Act 641) in effect at the time the ROD was signed, with the inclusion of a freeze-thaw layer
- The establishment of Alternate Concentration Limits (ACLs) for groundwater
- The monitoring of groundwater, and of river water, river sediment, and river biota

The AOC to conduct the RD was signed in February 1993 by the members of the Butterworth Landfill Cooperating Parties (BLCP) and the USEPA Region V (USEPA, 1993). The BLCP included the City of Grand Rapids, Consumers Energy Company; General Motors Corporation; Michigan Waste Systems, Inc.; and Wickes Manufacturing Company.

The USEPA provided conditional approval of Revision #2 of the RD Work Plan (Woodward-Clyde, 1995a) in a letter dated July 18, 1995. The BLCP made the requested modifications and submitted the final RD Work Plan to the USEPA and the

MDEQ on October 14, 1995 (Woodward-Clyde, 1995b). The USEPA Remedial Project Manager verbally approved the RD Work Plan (with the exception of the groundwater, surface water, sediment, and biological monitoring plans and the methodology for establishing the ACLs) on October 20, 1995.

The BLCP submitted the Preliminary RD Project Plan on April 16, 1996. The USEPA's comments on the Preliminary RD Project Plan were provided to the BLCP in a letter dated July 12, 1996. The final set of the MDEQ's comments was provided in a letter dated September 16, 1996. Responses to the USEPA's and the MDEQ's comments on the Preliminary RD Project Plan were incorporated in the Pre-Final RD Project Plan submitted in February 1997. The Pre-Final RD Project Plan included a soil cover over the RT&SB Area (as did the Preliminary RD submittal). The USEPA disapproved the Pre-Final submittal without review because it included the soil cover over the RTSB area as part of the design and required the BLCP to submit a second Pre-Final design document that included a low-permeability clay cap over the RT&SB Area.

The BLCP submitted a second version of that document, the Alternative Pre-Final RD Project Plan on March 7, 1997. The second submittal was labeled "Alternative" to distinguish that submittal from the first Pre-Final submittal. Agency (USEPA and MDEQ) comments on the Alternative Pre-Final RD Project Plan were contained in a letter from the USEPA, dated July 13, 1997. However, the comments relating to landfill gas (LFG) were incomplete. Subsequently, the LFG issues were resolved as confirmed in a letter from the USEPA dated September 16, 1997. The Final RD Project Plan, which included an Act 641 cap over all landfilled areas, was submitted on October 16, 1997.

The BLCP received comments on the Final RD Project Plan from the USEPA in a letter dated December 22, 1997. Responses to each of these comments were incorporated in the Revised Final RD Project Plan and were submitted to the USEPA on January 30, 1998. The Revised Final RD Project Plan was approved by the USEPA on February 3, 1998.

On June 1, 1998, subsequent to approval of the Revised Final RD Project Plan, comprehensive proposals for the construction of a 1-foot-thick soil cover over the RT&SB Area and the use of mixing zone-based GSI criteria as the ACLs were submitted to USEPA. Also, subsequent to the approval of the Revised Final RD Project Plan, additional PRPs agreed to join the original BLCP to form the Butterworth Site Group (BSG).

On October 23, 1998, the USEPA issued an Explanation of Significant Differences (ESD), documenting the changes to the ROD relating to the soil cover and the ACLs. Lastly, on December 23, 1998, the USEPA issued an Amendment to the ESD, which modified some of the ACLs in the ESD. The Amended RD Project Plan incorporates the soil cover over the RT&SB Area as provided by the ESD.

1.2.4 Related Studies

Several studies associated with the RD have been conducted since the completion of the RI. The results of these studies were presented in separate reports that were previously submitted to the USEPA and the MDEQ. The objectives, scope, and results of these related studies are summarized below:

Predesign Studies (PDS)

In accordance with the RD Work plan, a set of predesign studies was conducted to obtain additional information necessary for designing the landfill cover. The PDS were developed to address the following objectives:

- To assess the presence, type, and extent of waste in the NESA, the Powerline Corridor, and the RT&SB Area
- To delineate the thickness and lateral extent of the general fill and rubble in the berm that extends around the perimeter of most of the landfill
- To estimate present landfill gas generation rates and to evaluate potential ambient air impacts
- To evaluate potential subsurface gas migration pathways

The results and conclusions of the Predesign Studies were presented in the Preliminary RD Project Plan (RMT, 1996). The most significant findings of the PDS are summarized as follows:

- Certain areas of the landfill contain predominately municipal/industrial solid waste (Butterworth No. 1, No. 2, and No. 3, and the NESA), while others contain general fill and rubble (the perimeter berm), or highly decomposed waste (RT&SB Area). In two areas, the highly decomposed waste is interbedded with foundry sand. The extent of fill in each area is shown on Figure 4 of the PDS Report.

- The fill materials in the RT&SB Area have been so highly decomposed and weathered by the passage of time that they appear to have limited potential to leach contaminants into the groundwater flow system at levels that would adversely affect the Grand River. The data supporting the conclusions regarding the RT&SB Area are contained in Subsections 4.6, 5.1, and 5.3 of Volume 2.C of the Preliminary RD Project Plan. The BLCP's conclusions and recommendations concerning the waste in the RT&SB Area were presented in the PDS Report for completeness in documenting the RD activities. This information was not submitted for approval by the agencies.

- The results of the landfill gas generation model showed that peak landfill gas generation occurred in the late 1970s, and that current landfill gas generation may be on the order of 50 cubic feet per minute. Furthermore, an evaluation of potential ambient air quality impacts as a result of landfill gas emissions showed that, even using conservative assumptions, the predicted impacts are well below the MDEQ's acceptable ambient concentrations.

- Landfill gas was detected in the northwestern corner of the site outside the limits of waste at concentrations above 100 percent of the Lower Explosive Limit of methane. These elevated levels were measured in permeable engineered fill materials (soil, sand, and gravel). The permeable engineered fill materials may provide a conduit for methane to migrate from the landfill to the former railroad bed along the northern site boundary.

Routine Wetland Delineation

A wetland delineation was conducted by Resource Management Group, Inc., of Grand Haven, Michigan, as a subconsultant to RMT. The wetland delineation study concluded that there are approximately 7 acres of wetlands on the site. The wetland delineation report was submitted to, and approved by, the MDEQ Land and Water Management Division. Through a subsequent investigation of the soil beneath the wetland that was conducted in response to a comment by the MDEQ on the Preliminary RD Project Plan, the BLCP determined that the wetlands at the site are not regulated under Part 303 of PA 451. This determination is based on the size (less than 5 contiguous acres) and hydrologic independence of the wetlands from the groundwater and nearby surface water bodies. Wetland issues are discussed in additional detail in Appendix B. While wetland compensatory mitigation requirements do not apply, the BSG intend to restore and maintain the wetlands on the site such that no net loss of wetlands occurs.

Western Creek

As documented in a letter from the MDEQ to the USEPA, dated March 7, 1997, the MDEQ Surface Water Quality Division determined that Western Creek is not a water of the state, as defined in Rule R 323.1044(o) of the Part 4 Water Quality Standards.

Flood Protection

In early 1996, the City of Grand Rapids submitted a permit application to raise the flood wall upstream of the site and in the city as part of a project that is separate from the Butterworth Landfill RD. The City's consultant for the flood wall project, Fishbeck, Thompson, Carr & Huber, Inc. (FTC&H), of Grand Rapids, also evaluated the effects of capping the landfill and/or building a flood protection structure for the landfill (essentially by removing the entire landfill area from the available floodplain) on flood stage elevations upstream of the site.

At the time this flood analysis was conducted, the design approach for protecting the landfill cover from erosion due to flooding had not been determined. Therefore, FTC&H modeled a hypothetical worst-case scenario for providing flood protection for the landfill cover with regard to the potential effect on upstream flood stage elevations. The hypothetical worst-case scenario consisted of a flood wall built along the river front bordering the landfill. This would represent the greatest potential impact to both the floodway and the upstream flood stage elevations. The U.S. Army Corps of Engineers HEC-2 computer model was used for the analysis.

The results of the study concluded that, even under this hypothetical worst-case scenario, the average upstream 100-year flood stage elevation would increase by approximately 0.05 foot (RMT, 1996). This increase is within the allowable range mandated by the Federal Emergency Management Agency (FEMA) and the recommended MDNR water surface increase specified in Part 315 of Michigan Act 451 (formerly Act 245). Current FEMA regulations permit construction in a floodplain as long as the resulting water surface elevation is not increased by 1 or more feet. Current MDNR regulations generally permit construction in the floodplain as long as the resulting water surface elevation is not increased by 0.10 foot or more, and no increase in the risk of potential flooding results.

The MDEQ Land and Water Management Division reviewed the flood study report and have concurred with FTC&H that the hypothetical flood wall would not create an appreciable effect upstream of the site. Because a hypothetical flood wall (*i.e.*, the worst-case scenario) along the river front would not create an appreciable effect on flood stage elevations upstream, it was also concluded that the proposed increased landfill surface elevations due to the new cap will not impact areas upstream of the site.

RT&SB Area Investigations

As part of the Predesign Studies (RMT, 1996), four samples of the native soil beneath the highly decomposed waste in this area were collected and analyzed for total metals. The laboratory results indicated potentially limited migration of metals from the waste to the underlying soil.

Subsequent to the Predesign Studies, an initial study of the leaching potential of waste samples from the RT&SB Area was performed to collect physical and chemical data on the waste in this portion of the landfill (RMT, 1997b). The data from the leaching study were intended to be used as a part of a larger scale assessment of the appropriateness of a soil cover over the waste in the RT&SB Area. The observed waste thickness in the 10 borings in the RT&SB Area varied from 15 to 17 feet. The visual state of the waste was consistent with the results of the Predesign Studies—the samples contained no putrescible waste, and consisted primarily of clay, silt, sand, gravel, ash, cinders, bricks, wood, glass, and metal fragments. The water table occurred within the bottom several feet of the waste. There was no evidence of significant mounding of the water table in the RT&SB Area.

Composite waste samples from the 10 borings that fully penetrated the waste were leached using the Synthetic Precipitation Leaching Procedure (SPLP), and the leachates were analyzed for VOCs and metals. The chemical compositions of the leachates were compared to the Part 201 generic groundwater–surface water interface (GSI) values (ERD Operational Memorandum #8, Revision 4) to evaluate whether significant concentrations of constituents of concern could leach from the waste to the groundwater flow system, and ultimately to surface water. Compositing the samples did not result in appreciable loss of VOCs, based on a comparison of the compositional analyses for VOCs for composited and uncomposited waste samples.

Aromatic hydrocarbons and chlorinated ethenes were detected in several of the leachate samples, but none of the samples leached VOCs at levels exceeding the generic GSI values, except for naphthalene, which was detected above the limits of quantitation in one of the ten composite waste samples. Among metals, lead and copper were detected in six of the ten waste leachates, and exceeded the generic GSI criteria in only one of the leachates. Based on the results of this initial leaching study, the waste in the RT&SB Area does not appear to contribute appreciably to the concentrations of constituents of concern in groundwater beneath the Butterworth Landfill.

On June 1, 1998, the Respondents to the Special Notice Letters for the Remedial Action (including BLCP members) submitted a formal proposal supporting the design and construction of a 12-inch-thick soil cover over the RT&SB area. The proposal was entitled "Proposal To Place A Soil Cover Over The Radio Tower And Station Building Area At The Butterworth Landfill, Grand Rapids, Michigan." USEPA reviewed the proposal and on October 23, 1998, issued an Explanation of Significant Differences which modified the ROD for the Butterworth Landfill Site by incorporating the soil cover over the RT&SB area.

ESD Findings

- Historical groundwater monitoring results from the RI, the first mixing zone determination sampling event, and the first round of remedial design groundwater monitoring, show that the groundwater quality between the RTSB area and the Grand River currently meets the mixing zone GSI criteria.

- The wastes present in the RTSB area have been reported to be older and more highly weathered than other areas of the landfill and would be more likely to leach lower amounts of contamination than the other areas of the landfill. As reported in the RI report, the waste in this area lacks significant amounts of putrescible organic material or decomposing waste odor, and lacks significant subsurface landfill gas pressure.

- Because a portion of the land filled waste lies below the water table, the reduction in contaminant flux from the landfill to the river would be minimal, even with placement of an Act 641 clay cover over the RTSB area.

- The groundwater monitoring performed to determine compliance with the mixing zone GSI criteria, will be used in assessing the effectiveness of the soil cover during planned five year reviews at the site. If the five year review(s) indicate that the groundwater contamination exceeds the ACL values established for the site, a contingency plan is in place that requires the replacement of the soil cover with a clay cover over the RTSB area.

- A soil cover over the RTSB area is protective of human health and the environment, because it will prevent direct contact with the landfill contents and will prevent inhalation of airborne particles affected by the landfill (exposure pathways of concern identified in the ROD).

1.3 Scope of the Amended Remedial Design Project Plan

This RD Project Plan provides the basis for the final design of the landfill cover and landfill gas-related response actions that are required by the ROD and the October 23, 1998, ESD. The design details for the landfill cover, institutional controls, and wetland restoration activities are presented in Section 3. The Amended RD Project Plan was developed by modifying the approved Revised Final RD Project Plan (RMT, 1998a) to incorporate the soil cover over the RT&SB Area that was described in the proposal submitted to the USEPA on June 1, 1998, and which was incorporated by the USEPA in the ESD.

All groundwater and leachate monitoring activities are described in the ACL Performance Monitoring Plan, which will be submitted as part of the RA Work Plan.

Section 2

REMEDIAL DESIGN STRATEGY AND BASIS

2.1 Compliance with Applicable, or Relevant and Appropriate Requirements (ARARs)

The ARARs identified in the ROD include federal and state requirements that are chemical, location, and action-specific. The remedial action presented in this project plan was designed to meet the ARARs for the site and to protect human health and the environment.

Because the Butterworth Landfill is a federal Superfund site, the PRPs are not required to obtain state, local, and federal permits for certain types of on-site activities, but rather to meet the substantive requirements of the ordinance or rules that required a permit.

2.1.1 Chemical-Specific ARARs

The ROD specified the establishment and use of Alternate Concentration Limits (ACLs) for groundwater in lieu of the federal Maximum Contaminant Levels (MCLs), or Maximum Contaminant Level Goals (MCLGs). Subsequently, on October 23, 1998, the USEPA issued an ESD allowing the use of State of Michigan mixing zone–based GSI criteria, as allowed under Parts 201 and 31 of P.A. Act 451, as amended, as the ACLs for groundwater. The mixing zone-based ACLs replaced the surface water/sediment/biological monitoring program that is specified in the ROD (refer to the discussion in Subsection 1.2.3). In accordance with the SOW for the RA, an ACL performance monitoring program will be developed as part of the RA Work Plan.

2.1.2 Location-Specific ARARs

Executive Order 11988 - Protection of floodplains

As described in Subsection 1.2.4 and in Appendix B, the cover over the portions of the site within the 100-year floodplain of the Grand River will meet the requirements of Executive Order 11988.

Section 404 - Clean Water Act

As discussed in Subsection 1.2.4 and in Appendix B, filling and grading activities associated with landfill cover construction will not impact "waters of the United States" as defined by Section 404 of the Clean Water Act (CWA).

Inland Lakes and Streams Act 346/Soil and Sedimentation Control Act 347

As provided in Appendix B, the remedial action has been designed so that all construction activities take place above the "ordinary high water mark" of the Grand River. Landfill cover activities, primarily grading and construction of storm water controls, were designed to meet the substantive requirements of the Inland Lakes and Streams Act 346 and the Soil and Sedimentation Control Act 347.

Executive Order 11990 - Protection of Wetlands, the Goemaere-Anderson Wetland Protection Act 203, and Section 404 - Clean Water Act

The landfill cover has been designed so that there is no net loss or degradation of the delineated wetlands at the site. After further evaluation of the wetlands delineated on the site, the BLCP concluded that the wetlands are not regulated by the MDEQ or Section 404 of the Clean Water Act. The site wetlands comprise less than 5 contiguous acres and are hydrologically independent of the groundwater system and nearby surface water, primarily the Grand River.

Excavation of wastes in fill areas where the thickness of waste is roughly 5 feet or less is expected to occur where these areas encroach upon the wetlands in the NESA, in the Powerline Corridor west of the CSO ditch, and in the wetlands in the north Powerline Corridor. While not regulated as wetlands, grading, filling, and restoration in wetlands will meet the substantive requirements of Executive Order 11990-Protection of Wetlands, the Goemaere-Anderson Wetland Protection Act 203, and Section 404 - Clean Water Act. Wetland issues are further discussed in Appendix B.

2.1.3 Action-Specific ARARs

Act 641 (now Part 115 of Act 451) - Michigan Solid Waste Management Act

A multi-layer landfill cover will be constructed over the areas known as Butterworth No. 1, 2, 3, and the NESA. The multi-layer cover meets the substantive requirements of rules promulgated under Act 641 that were in effect when the ROD was signed. An ESD was issued by USEPA on October 23, 1998, to allow the installation of a 1-foot-thick soil cover over the RT&SB Area.

40 CFR Part 262 - RCRA Act 64 (now Part 11 of Act 451) of the 1979, Michigan Hazardous Waste Management Act

Based on the findings of the RI and the Predesign Studies, the need for the treatment or storage of hazardous landfill components, such as drums, is not anticipated. The approved Drum Contingency Plan will be followed, as necessary.

2.2 Minimization of Environmental and Public Health Impacts

The remedial action was designed to minimize short-term (construction) and long-term impacts to public health and the environment.

Temporary controls designed to protect public health and the environment during construction include the following:

- A fugitive dust control and monitoring plan, to prevent nuisance levels of fugitive dust at the site boundaries and at the radio station building
- An ambient VOC monitoring plan to ensure the health and safety of workers at the site and nearby residents
- Sedimentation and erosion controls during grading and cap construction and CSO ditch dredging, which may include silt fences, straw bale dikes, stone filtering, or silt curtains
- Site security during construction that will limit Site access to radio station personnel, BSG representatives and their consultants and contractors, USEPA and MDEQ personnel, and other authorized agency representatives

Permanent controls designed to provide long-term protection of public health and the environment include the following:

- Land use restrictions on the landfill properties (the site is owned by multiple parties) prohibiting construction of water supply wells and the disturbance of cover materials
- Permanent vegetation to minimize soil erosion and sediment transport to wetlands or the Grand River during major storm events
- An upgraded landfill cover to minimize the risk of direct contact with the landfill contents and to reduce infiltration of precipitation
- Erosion matting for floodway and river bank protection
- Control of potential off-site landfill gas migration using natural features and artificial barriers/outlets in the northwestern corner of Butterworth No. 3

2.3 Design and Construction Practices

The landfill cover, the landfill gas management plan, the flood erosion protection plan, and the storm water management plan were designed in accordance with accepted industry practices. Material specifications, construction requirements, and performance criteria for the clay cap were developed in accordance with Michigan Act 641 rules for landfill finals covers in effect in 1992. Temporary and permanent erosion and sedimentation controls were designed in accordance with the Guidebook of Best Management Practices for Michigan Watersheds, issued by the Michigan Department of Natural Resources (MDNR, 1995). Similar landfill covers and remedial components have been approved by the USEPA and the MDEQ for numerous other landfill sites (CERCLA and non-CERCLA sites).

As necessary, the procedures established in the approved Drum Contingency Plan (attached to the Site Health and Safety Plan) and in the approved Cover Materials Stockpiling Plan may also be used.

2.4 Current and Potential Future Land Use

Although a variety of potential future land uses were considered during the development of this design, the only certain future land uses are the continued operation of the two radio towers and the WFUR radio station, the availability of the CSO ditch for emergency backup use by the City, and the continued use of the concrete boat ramp by the City Fire Department and Rescue Squad. Other potential future land uses will be reviewed with the USEPA and the MDEQ to determine appropriate requirements to protect human health and the environment. Other potential future land uses are expected to be recreational in nature. Potential future recreational uses will be presented to the agencies when appropriate.

Section 3
REMEDIAL DESIGN

3.1 Landfill Cover

A landfill cover has been designed for approximately 160 acres of municipal and industrial waste, general fill, and highly decomposed waste (and foundry sand). The limits of the landfill cover are shown on the final grading plans of the RD Drawing Set (Sheets 5 and 6). The cover will also extend over an area of waste on the Consumers Energy Company property east of the NESA. Easements will be obtained as necessary for this property, as well as for any other properties requiring easements. The following components of the landfill cover are described in detail in the subsections that follow:

- Preparation grading and site work
- Landfill cover design and material specifications
- Landfill gas management
- Floodway/ Floodplain protection
- Permanent erosion and sedimentation controls
- Surface water management

The technical specifications are included in Appendix F.

3.1.1 Preparation Grading and Site Work

The existing site topography is generally flat, although it is irregularly sloped in some places, and heavily vegetated with mature trees. Prior to the start of construction, the site will be cleared and grubbed of brush and trees, except along the banks of the river and the CSO ditch. In these areas, the vegetation is incorporated into the design to prevent soil erosion.

Preparation grading and associated site work will be performed prior to construction of the final cover system to provide for the runoff of storm water. The preparation grades were developed using a 1993 topographic (aerial) map. The actual preparatory grades and slope configuration may be adjusted after a preconstruction survey is performed to set control points and to identify random settlement that may have changed some of the existing ground surface elevations.

Site grading will include making some shallow cuts of existing knolls and subsequently filling in depressions. In the unlikely event that any fill material is unearthed (including drums) during site grading activities, the Drum Contingency and Health and Safety Plans will be followed to dispose of, or cover, the subject area. Imported fill soil and/or construction and demolition material will be placed where necessary to meet minimum slope requirements. The cut and fill volumes for the preparatory grades are presented in Appendix D. The preparatory grades are shown on Sheets 3 and 4 of the RD Drawing Set.

The abandoned radio tower and miscellaneous concrete structures on the eastern side of the CSO ditch will be demolished and either sold for scrap or placed in areas requiring fill prior to cap construction.

Parts of the RT&SB Area are occupied by two radio broadcasting companies. One company is WFUR, whose entire operation is at the site. WFUR owns and operates the station buildings and the two northernmost radio towers. The other company, WBBL/WLAV, operates the southernmost tower and satellite dishes. Two of the three towers, the northernmost (WFUR) and southernmost (WBBL) towers, are AM broadcast towers and consequently have buried ground plane systems, which are essential for transmission. The exact locations of the ground plane systems are not documented. Typical installations consist of individual copper wires buried approximately 6 inches below ground surface that extend radially (approximately 3 degrees apart) from the tower base at a distance equal to one-fourth of the AM frequency (1200 AM = 300 feet, *etc.*). Preparation grading will remove or add soil over some of each ground plane system.

Preparatory grading, which includes cuts and fills in the RT&SB Area, has been discussed with both station operators. The stations will either keep operating or will establish other means of transmitting during the remedial action construction to maintain their broadcasts.

Maintaining the existing ground plane systems or installing new systems (after construction) will not reduce the integrity of the cover system. The existing ground plane systems will remain below the cover system, and a new ground plane system may be plowed into the topsoil layer.

The existing concrete boat ramp along the river front and along the eastern side of the site will be left intact for continued use by the City of Grand Rapids Fire Department and Emergency Rescue Squad who use the ramp for river access. The existing abandoned dock structure will be removed.

The preparatory and final grades will require filling around and beneath the Consumers Energy Company electrical transmission towers to manage storm water. Flowable fill material with a permeability of 1×10^{-7} cm/s or less will be used to eliminate the need for equipment to work within the structures. Contractors will be required to submit design mixes for flowable fill meeting the specifications. Based on historical aerial photographs, the installation of the tower structures on the western part of the site pre-date landfilling at the site. Information on the type of material beneath the tower structures on the eastern part of the site is not available. However, it has been a long-standing Consumers Energy Company policy to erect towers only on competent fill.

Additional site work required to develop preparatory grades includes the following:

- Installing temporary erosion and sedimentation controls
- Removing any surface debris from areas that will not be covered (in the wetlands, for example)
- Excavating and reconsolidating waste in certain areas

Fugitive Dust Control

Fugitive dust may be generated during the remedial action by construction equipment traveling over unpaved surfaces, by unloading soil, or as a result of cover placement/grading activities. A fugitive dust control plan was developed to prevent the transport of nuisance levels of dust across the landfill property lines or around the radio station building. The primary method for controlling for fugitive dust will be to water frequently traveled, unpaved roads or soil working surfaces. The plan to control and monitor fugitive dust, as well as to monitor ambient concentrations of VOCs, is described in Appendix C.

Temporary Erosion-Sedimentation Control

Temporary erosion and sedimentation controls will be installed prior to establishing preparatory grades and will be maintained until permanent erosion controls are in place. Temporary erosion and sedimentation controls will consist of silt fencing and straw bale dikes. Silt fences will be installed around active grading areas to collect sedimentation carried by surface water runoff. Sediment carried by surface water runoff in areas of more concentrated flows will be trapped by straw bale dikes. Trapped sediment will be excavated and replaced on the eroded slopes as needed to re-establish a smooth, stable surface. Silt fences will also be installed around wetland areas that may be impacted by the construction.

A single-tiered or a two-tiered silt curtain, or similar means of sediment control, will be used immediately downstream of CSO ditch–related construction activities to capture and control disturbed sediment. Sediment controls will be installed in accordance with the Guidebook of Best Management Practices for Michigan Watersheds (MDNR-SWQD).

Waste Excavation/Reconsolidation

The following areas in which the waste is on the order of 2 to 5 feet thick will be excavated and reconsolidated to areas that will be capped with clay:

- The Powerline Corridor west of the RT&SB Area
- The edges of wetlands along the northern edge of the site, primarily in the northern Powerline Corridor
- The northwestern corner of the site near the former railroad bed and site entrance

These areas are shown on Sheets 3 and 4 of the RD Drawing Set. Estimates of waste volumes for excavation and reconsolidation are provided in Appendix D. Excavated wastes will only be relocated to areas where the existing waste will be covered with the clay cap. Relocation areas shown on the RD drawings were selected to best fit the grading plans and to minimize relocation distances.

The removal of thin waste layers (on the order of 2 to 5 feet thick) in the Powerline Corridor will enhance wetland quality, and will accommodate drainage for the final cover grades. The removal of waste at the northwestern corner of the site will accommodate the proposed landfill gas controls.

In addition, during site preparation, the narrow strip of waste north of the NESA may be removed to provide storm water drainage relief for the wetland north of the NESA. This wetland is located on the unfilled property owned by Consumers Energy Company. If removed, the waste will be placed on designated reconsolidation areas that will be capped with clay.

Samples of underlying native soil from areas in which waste is excavated will be collected and analyzed to assess whether residual levels of constituents exceed 20 times the state groundwater–surface water interface (GSI) criteria. The samples will be collected in accordance with SOP-10 of the RD Work Plan and analyzed for the TCL and TAL parameters. The number of samples will be determined in the field and will consider the guidelines contained in the state's guidance document "Verification of Soil Remediation, " (MDNR, 1994). Because the sampling strategy that is described in this document is dependent on the size of the excavation(s), which cannot be determined at this time, best professional judgment and site-specific knowledge will be used to select the number and locations of soil verification samples. The BSG will consult with the USEPA and the MDEQ about the number and location of the samples prior to collecting them. If the underlying native soil in an area of waste excavation is visibly stained or odorous, the clay cap may be extended to cover this area(s) in lieu of testing the soil.

In areas where waste is excavated (reconsolidated), a minimum of 24 inches of Type A general fill will be placed over the exposed native soil and graded to match excavated areas. Topsoil will be placed over the general fill and then seeded.

This sampling plan is more conservative than the sampling required by the agencies for areas of waste excavation at least two other closed landfill remediation projects in Michigan. The USPEA Region V did not require any sampling in areas of waste excavation at the Folkertsma Landfill NPL site in the City of Walker, which is about 4-5 miles from the Butterworth Landfill. Additionally, sampling was not required in the approximately 5-acre area in which waste was removed at the former Jacobusse Landfill in Holland Township. The Jacobusse Landfill remediation was conducted as a voluntary cleanup with oversight by the MDEQ. Furthermore, the area of waste removal at the former Jacobusse Landfill was subsequently redeveloped as a residential neighborhood.

The proposed sampling plan is also justified considering that all areas of potential waste excavation at the Butterworth Landfill are within the site property boundaries and that institutional controls on the property will prohibit unauthorized access and construction of water supply wells.

Grading and filling around the Powerline support structures have been minimized to the extent possible. The Consumers Energy Company Engineering Office reviewed the Preliminary RD Project Plan to evaluate how the proposed grading may impact the required ground clearance between the high voltage transmission lines and the final grades after cap construction.

3.1.2 Landfill Cover Design and Material Specifications

Landfill Cover Design for Butterworth No. 1, No. 2, and No. 3; and the Northeast Study Area - A multi-layer landfill cover system will be constructed over Butterworth No. 1, No. 2, and No. 3; and the NESA. The cover system includes 24 inches of soil on top of the clay layer to protect the clay from freeze-thaw cycle degradation and desiccation. This thickness of soil on top of the clay layer is greater than the typical depth of frost penetration in the Kent County area, which is 22 inches (Michigan Department of Labor, 1977).

From the base to the top, the cover system for the above areas consists of the following layers:

- A 24-inch–thick low-permeability clay cap
- An 18-inch–thick frost protection layer
- A 6-inch–thick vegetated topsoil cover

These layers are described in detail in the paragraphs that follow:

Low-Permeability Clay Cap - A low-permeability clay cap will be constructed over the preparation grades and will consist of a minimum 24 inches of clay soil. Clay soil from the Autumn Hills Landfill (a permitted Type II landfill near Zeeland, Michigan) was imported and stockpiled at the Butterworth Landfill in 1995 and 1996 as part of an agency-approved Cover Material Stockpiling Plan. The BLCP requested written approval for using this borrow source in a letter dated December 14, 1994, to the MDEQ Waste Management Division, Grand Rapids District Office. The MDEQ Waste Management Division approved the Autumn Hills clay for use at the Butterworth site in a letter dated

December 21, 1994, and conveyed that approval to the USEPA in a letter dated January 12, 1995. These letters are provided in Appendix D. This material was tested as part of the stockpiling project and has been classified as CL in accordance with the Unified Soil Classification System.

The clay cap will be compacted to 90 percent of the maximum dry density as determined by the Modified Proctor Test. The appropriate soil moisture during placement will be maintained on the wet side of optimum, which should result in an acceptable compaction. The appropriate range of moisture content will be determined by the construction testing of clay samples during placement.

Frost Protection Layer - A frost protection layer consisting of a minimum of 18 inches of soil will be placed over the clay cap to preserve the integrity of the clay cap against frost penetration. The frost protection layer will consist of natural soil material that is generally free of large organic material and woody vegetation, rocks greater than approximately 8 inches in diameter, and other deleterious material. Composted material may be mixed with natural soil for frost protection layer material.

Vegetated Topsoil Cover - A 6-inch–thick layer of vegetated topsoil will be placed over the frost protection layer. Approximately 112,950 cubic yards of topsoil have already been stockpiled at the site. The topsoil will be tested to determine the nutrient requirements to sustain vegetation. Fertilizer, agricultural lime, and mulch application rates will be determined from the topsoil testing program.

The topsoil will be vegetated to prevent erosion. A seed mixture that is appropriate for the climatic conditions of Grand Rapids has been preliminarily selected and is provided in the RD specifications. The final mixture may be revised to better fit site conditions. Additional final seeding and maintenance to control volunteer deep-rooted vegetation are discussed in the Operation and Maintenance Plan (Volume 2).

A summary of the estimated quantities (in-place) of materials needed to construct the multi-layer cover system are included in Appendix D.

3.1.3 Landfill Cover Design for the Radio Tower and Station Building Area

The RT&SB area is approximately 32 acres and will be covered with a 1-foot-thick low-permeability "soil" cover constructed as follows:

- The lower 6 inches will consist of lean clay and silty-clay from the Waste Management, Inc., Autumn Hill Recycling and Disposal Facility near Zeeland, Michigan or another suitable source. The laboratory permeabilities for four samples of this material ranged from 8.7×10^{-6} to 1.1×10^{-7} cm/s, with a geometric mean of 4.0×10^{-7} cm/s.
- The upper 6 inches will be a topsoil layer that will consist of either the lean clay and silty-clay from the Autumn Hills facility or another suitable topsoil borrow source. The permeability of the topsoil layer is anticipated to be in the general range of 7.2×10^{-4} cm/s, which is the default value for topsoil used by the U.S. Army Corps of Engineers in the Hydrologic Evaluation of Landfill Performance (HELP) model developed for the USEPA.
- Prior to importing the proposed soil cover material from the Autumn Hills facility, two samples of this material will be collected and analyzed for the TCL and TAL parameters.

The final grades of the soil cover will be constructed to an average slope of 1 percent in order to minimize disturbance to the current radio station operations, while also maintaining positive drainage. The RT&SB Area will be seeded with a turf grass that maintains the majority of the rooting system in the upper 4 inches of the soil cover.

3.1.4 Landfill Gas Management

Landfill gas (LFG) generation rates and quality (pressure, methane, and oxygen, *etc.*) were evaluated as part of the Predesign Studies and in subsequent gas monitoring events. The results are summarized as follows:

- Rapidly declining LFG production (current production is estimated at 50 cubic feet per minute [the model result of 42 cfm was rounded to one significant digit] down from an estimated peak production rate of 1,400 cubic feet in the late 1970s) and minimal to no LFG pressure preclude the need for direct venting of landfill gas through the cover. The minimal amount of remaining LFG will be allowed to naturally vent through final cover soil utilizing the aerobic soil conditions to minimize potential odor impacts.
- Most of the remaining LFG production occurs west of the CSO ditch in Butterworth No. 2 and No. 3, where approximately 70 percent of the waste volume was placed during the last 6 years of operation (1967-1973).
- The natural features, including wetlands, drains, or ditches, and the Grand River limit potential migration pathways south, east, and west of the site. The northern

perimeter of the site consists primarily of wetlands with the exception of the northwestern corner of the site. During November of 1995, LFG was measured at 100 percent of the LEL at the narrow strip of more permeable fill in the northwestern corner of the site.

Since the Preliminary RD Project Plan was submitted, additional LFG monitoring data were obtained on August 14, 1996, and February 13, 1997. The pressure, methane, and oxygen levels were measured in the nine gas probes (labeled GW-1 through GW-9) installed during the Predesign Studies. The results of all of the LFG monitoring activities were reported to the agencies in the monthly progress reports.

The November 1995, August 1996, and February 1997, LFG pressure readings consistently showed very low levels of LFG generation. The readings showed that Probes GW-1 through GW-4, and GW-8 and GW-9 maintain consistent levels of methane and Probes GW-5 through GW-7 consistently show little evidence of LFG production. A summary of LFG monitoring data is provided in Appendix A-2.

As an additional measure (reported in Progress Report No. 42 for September 1996), the BLCP installed a natural gas detector in the WFUR radio station building, which is on the landfill. The gas detector is designed to alarm if the concentration of methane exceeds 25 percent of the LEL. The detector has not alarmed since it was installed.

Potential LFG migration to the north of the site will be controlled and monitored as follows:

- Constructing a barrier/outlet between the adjacent wetland and Western Creek, as shown on Sheet 9 of the RD Drawing Set. This will extend the natural benefits already provided by wetlands and surface water, and will eliminate the more permeable strip of ground.
- Installing (in natural soil) and monitoring six new LFG probes (GP-1 through GP-6) along the northern perimeter of the site as shown on sheets 5 and 6 of the RD Drawing set.
- Monitoring the existing LFG probes (GW-1 through GW-9) installed during the Predesign Studies.

The LFG monitoring program is described in detail in the Operation and Maintenance Plan.

3.1.5 Floodway/Floodplain Protection

The final cover along the southern limits of the landfill will be protected to minimize the potential impact of a 100-year flood of the Grand River. The mature trees along the river front and selected embankments of the rubble berm will be left in place for added protection of the landfill embankment against flood shear forces, ice flow damage, or damage from large floating objects. Selected trees may be removed to accommodate placement of flood protection measures.

The flood analysis (*"Grand River Floodwall and Embankment Improvements, Butterworth Landfill Embankment, Flood Stage Impact Evaluation,"* FTC&H, December 1995, refer to Volume 2 of the Preliminary RD Project Plan submittal) contains an estimate of the Grand River's potential surface elevation and flow velocities associated with a 100-year flood event. The peak surface elevation expected for the 100-year flood event in the section of the Grand River adjacent to the landfill is approximately 609 feet mean sea level (M.S.L.). Typical surface water elevation (as of the date of the aerial topographic map that was used as the basis for the cover design) is approximately 590 feet. The estimated maximum average channel flow velocity for the Grand River at the 100-year flood event is approximately 6.2 feet per second.

The flood analysis by FTC&H was based on a hypothetical scenario that assumed the installation of a vertical wall with a top elevation of 610 feet M.S.L. as the method of landfill embankment protection. A flood wall was modeled because, at the time the flood analysis was conducted, the design for landfill embankment protection had not been determined and a flood wall represented a simple, worst-case scenario for evaluating floodway velocities and potential impacts on upstream flood stage elevations. The actual proposed method of landfill embankment protection is the installation of UV-resistant, nylon mesh erosion control matting in the vegetated topsoil layer. The erosion control matting will be installed over areas of the landfill cap that will remain within the 100-year floodplain of the Grand River (to elevation 610 feet M.S.L.). The erosion control matting will be rated for the estimated flow velocities and resultant shear forces along the embankment that were calculated by FTC&H for a vertical flood wall (Appendix E). This is a conservative design basis because the proposed method of embankment protection will not encroach on the floodway as much as a vertical wall would, and will therefore result in lower flow velocities and shear forces along the embankment.

The erosion control matting will provide a stable anchor for the topsoil and the cover vegetation's rooting system. The matting will be installed in conformance with the manufacturer's specifications and recommendations. The final grades and the slope of the matting will conform to existing slopes wherever possible. Where the embankment is treeless, embankment slopes steeper than 25 percent (4 horizontal to 1 vertical) will be regraded to provide a stable preparatory grade for construction of the final cover system and installation of the erosion control matting. The erosion control matting will be cut to the extent necessary to abut the mature trees left in place.

3.1.6 Permanent Erosion and Sedimentation Controls

In addition to the river embankment protection described above, erosion caused by surface water runoff from the rest of the landfill will be minimized by revegetating the final grades and, if necessary, using erosion control matting or riprap in existing or new drainage ways. Estimates of erosion from the site, using the Universal Soil Loss Equation are presented in Appendix E.

3.1.7 Surface Water Management

The final cover has been designed to direct surface water off-site primarily via sheet flow. The slopes of the final grade are generally 2 percent, over Butterworth No.1, No.2, and No.3 Fill areas, and the NESA. Slopes of the final grade are generally 1 percent over the Radio Tower and Station Building Area. These small slopes minimize the need for diversion ditches or channelized flows. However, diversion ditches or berms will be constructed to control surface water around the radio station structures, and to control runoff to the adjacent Consumers Energy Company property. Diverted runoff will be conveyed to the Grand River, Western Creek, the wetland in the NESA, the CSO ditch, and the adjacent properties north and east of the site.

Stormwater runoff will be managed in 12 subareas (see Sheets 5 and 6 of the RD Drawing Set and Appendix E).

Subareas #1, #2, and #3 border Western Creek, a tributary of the Grand River. Subareas #1 and #3 drain into Western Creek via sheet flow runoff. Subarea #2 drains to Western Creek via culvert drain. The culvert drain will be equipped with a check valve to prevent back-flow of river floodwaters. Culvert design calculations are provided in Appendix E.

Subareas #4 and #9 drain to the Grand River via sheet flow runoff. Subareas #5 and #8 drain to the West Side ditch (combined sewer overflow) via sheet flow runoff. Subareas #6 and #7 drain to the lower elevations at the powerline corridor north of the west side at the Butterworth Landfill. A portion of the corridor is a wetland. Culvert drains were designed to convey excess storm water out of the wetlands and into Western Creek (#7), and the West Side Ditch (#6). Invert elevations of these culverts were designed to hold standing water to levels which benefit wetlands growth. Culvert invert calculations are provided in Appendix B.

Subarea #10 drains via sheet flow toward the lower elevation at the Consumers Power property bordering the east side of the Butterworth Landfill. The City of Grand Rapids is constructing a floodwall which will meet the 610 Ft. elevation of the landfill cover. A diversion berm constructed along the landfill slope will convey approximately 70% of the runoff to the Grand River. The remaining 30% will be diverted to the lower elevation of the Powerline Corridor north of the east side of the Butterworth Landfill.

Subarea #11 drains via sheet flow into the lower elevation of the Powerline Corridor north of the east side of the Butterworth Landfill. Standing storm water will be allowed to accumulate to a level designed to enhance wetland growth. Excess stormwater will be conveyed via culvert to the NESA wetland.

Subarea #12 drains via sheet flow into the NESA wetland. Like the other stormwater accumulation points in the wetlands, levels will be controlled by a culvert which drains from the NESA wetland to the West Side Ditch. The culvert will be equipped with a check valve to prevent back flow during significant flooding periods when Grand River water levels exceed elevations of wetlands and tributaries.

The proposed surface water drainage plan was evaluated to assess potential impacts to on-site wetlands during a 25-year, 24-hour storm event. Peak surface water runoff was calculated using the Quick TR-55 (QTR55) software program by Haestad Methods. This program is based on the methodology of *"Urban Hydrology for Small Watersheds" (Soil Conservation Service, 1986).* The peak flows and the total runoff (in inches) are provided in Appendix E.

3.2 Institutional Controls

Institutional controls will be imposed to restrict site use to nonspecific, potential future recreational use of all areas of the landfill except for the Radio Tower and Station Building Area and the powerline corridor that traverses the site. The Radio Tower and Station Building Area and the powerline corridor will continue to be used for commercial and industrial purposes, respectively. The institutional controls will prohibit any future use that would impair the integrity of the cap or result in unacceptable exposures. The institutional controls will also include a prohibition on the installation of water supply wells. The institutional controls will be implemented through restrictive covenants or municipal ordinances.

3.3 Wetland Restoration

Waste removal, filling, and grading are expected to impact less than 1 acre of site wetlands. Overall wetland quality is generally expected to improve after waste is removed. Although unregulated, the site wetlands will be restored so that there is no net loss of wetlands at the site. Surface water controls have been designed to enhance the existing wetland quality by better controlling the wetland hydrology. Surface water calculations and supporting discussion are provided in Appendix B.

3.4 Miscellaneous Design

3.4.1 Access Roads and Gates

There will be three major access roads on the site that will be accessible from Butterworth Road. The existing road to the WFUR radio station building will be restored after site construction activities are completed. Gated access to this road will be used to provide security for radio station operations. Two other paved roads will be constructed to provide general access to the site. The existing gravel road along the eastern side of the CSO ditch will be widened and resurfaced with asphalt (see Sheet 6 of the RD Drawing Set). A new asphalt road along the western boundary of the site (see Sheet 5 of the RD Drawing Set) will be constructed to provide access to the Powerline Corridor and to monitoring well locations on the western side of the site. Gates, designed to prevent vehicle access, will be installed at all of the roadway entrances to the site. A gravel road will be constructed along the southern perimeter of the site to provide access for monitoring and inspection, as well as for city fire and rescue vehicles.

3.4.2 CSO Ditch

The City must maintain the CSO ditch until the year 2000 and possibly longer, pending the completion of Section W-5 of the City's CSO improvement project. Based on aerial photographs taken in 1938, 1950, 1955, 1960, 1963, 1965, 1967, and 1972, the CSO ditch had been used as a drainage conveyance before and throughout active landfilling. Available plans indicate that the CSO ditch was dredged in 1980 (landfill activities ceased in 1973). Based on this time line, the sediment currently present in the ditch are unlikely to be related to the landfill. Additionally, sediment and surface water sample results are included in Table 3-15 of the RI report (Fred C. Hart Associates, Inc., 1989). These results indicate impacts to the sediment in the ditch.

The CSO ditch will be dredged during the remedial action construction. The dredged sediment will be placed in an area designated for waste reconsolidation prior to capping. Clay will be recompacted along the dredged CSO bottom and lower sides to accommodate surface water runoff via sheet flow from the site and other storm water discharges. A new earthen bridge (over culvert drains) will be constructed across the CSO ditch, just north of the existing bridge. Geotechnical calculations (slope stability) are provided in Appendix D. The new culvert drains will be installed with flapgates or valves that are designed to open under minimal head and to prevent backflow into the CSO ditch during normal fluctuations of the Grand River. A chain-link fence will be constructed around the CSO ditch to prevent unauthorized access.

Section 4

REMEDIAL ACTION MONITORING

4.1 Landfill Gas Monitoring

Additional LFG probes (GP-1 through GP-6 shown on Sheets 5 and 6 of the RD drawing set) will be installed outside of the landfill along the northern perimeter. The new LFG probes (GP-1 through GP-6) and the existing LFG probes (GW-1 through GW-9) will be monitored monthly during construction and for a period of at least 1 year after construction. A reduction in the monitoring frequency may be proposed to the USEPA after evaluating the monthly data if off-site migration is not evident. The LFG monitoring and contingency plans are included in the Operation and Maintenance Plan (Volume 2).

Existing LFG probes (GW-1 through GW-9) are in fill areas that will be covered. These probes will be maintained (if possible) through construction and for at least 2 years thereafter. If probes GW-1 through GW-9 are accidentally destroyed during cover construction, they may be replaced after cover placement is complete. The need to replace these monitoring points will be reviewed with the agencies on a probe-specific basis. Note that GW-1 through GW-9 are not compliance monitoring points.

4.2 Groundwater Monitoring

An ACL Performance Monitoring Plan will be developed and submitted as a component of the RA Work Plan, the second submittal required by the RA SOW. The Draft RA Work Plan will be submitted within 45 days after the lodging of the consent order.

4.3 Landfill Gas Probe Abandonment

LFG probes damaged during construction or approved by the USEPA as no longer providing useful information will be abandoned. The LFG probes will be abandoned by overdrilling the casing through the base of the screen, and then pressure-grouting the hole with a cement-bentonite slurry as the drill rod is pulled from the ground.

Section 5

REMEDIAL ACTION SCHEDULE

A summary of the construction schedule and reporting requirements contained in the SOW is presented below:

	Activity	Due Date
1.	Draft Amended Remedial Design Project Plan (ARDPP)	10 days after lodging of the Consent Decree
2.	Final ARDPP	20 days after receipt of the EPA's comments on the Draft ARDPP
3.	Draft RA Work Plan	45 days after lodging of the Consent Decree
4.	Final RA Work Plan	20 days after receipt of the EPA's comments on Draft RA Work Plan
5.	Award RA contract(s)	Thirty (30) days after EPA approval of Final RA Work Plan
6.	Pre-construction inspection	Fifteen (15) days after award of RA and meeting contract(s)
7.	Initiate construction of RA	Fifteen (15) days after the pre-construction inspection and meeting, or upon entry of the Consent Decree, whichever is later
8.	Completion of Construction	In accordance with the EPA's approved RA construction schedule
9.	Pre-Final Inspection	No later than fifteen (15) days after completion of construction
10.	Pre-Final Inspection Report	Fifteen (15) days after completion of pre-final inspection
11.	Final Inspection	Fifteen (15) days after completion of work identified in pre-final inspection report
12.	Final Inspection Report	15 days after completion of final inspection
13.	O & M Plan Addendum	60 days after completion of final inspection

14. Completion of Construction Report — 60 days after completion of final inspection

The complete RA schedule will be provided in the RA Work Plan. The construction phase of the schedule may be modified to reflect contractor availability. Seasonal factors affecting certain components of the RA (for example, clearing and grubbing of vegetation should be done when the leaves are off the trees, and at least one of the pre-cover placement landfill gas monitoring events should be conducted when the ground is frozen) will also need to be considered in finalizing the RA schedule.

Section 6

CONSTRUCTION, AND OPERATION AND MAINTENANCE COST ESTIMATE

Capital construction cost estimates are provided in Appendix G. Costs for groundwater monitoring and institutional controls are not included in the capital or O&M estimate. The scope of institutional controls and groundwater monitoring are not fully defined as of this submittal. The costs for groundwater monitoring will be provided in the ACL Performance Monitoring Plan, an appendix of the RA Work Plan.

Two options were used to calculate present worth of operation and maintenance costs incurred in future years.

Option #1 uses a 7 percent discount rate. Seven percent is used in accordance with OMB Circular A-94 (Revised 1993) on Guidelines and Discount Rates for Benefit-Cost Analysis.

Option #2 uses 7 percent interest and a 3.8 percent inflation factor. Total present worth and cost estimate details are provided in Appendix G.

Section 7

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USEPA 1998. Amendment to ESD, Butterworth Landfill Site.

Woodward-Clyde. 1995a. Remedial design work plan (Revision 2, dated May 11, 1995).

Woodward-Clyde. 1995b. Final remedial design work plan (Revision 3, dated October 1995, with minor modifications by RMT, Inc.).

APPENDIX A

REGULATORY AGENCY–RELATED DOCUMENTS

- Appendix A-1 ESD for soil cover over RT&SB Area and Mixing Zone-Based ACLs
- Appendix A-2 Landfill Gas Monitoring Summary (Submitted to the USEPA in Progress Reports)

APPENDIX A - 1
ESD FOR SOIL COVER OVER THE RT&SB AREA AND MIXING ZONE-BASED ACLS

EXPLANATION OF SIGNIFICANT DIFFERENCES

BUTTERWORTH LANDFILL SUPERFUND SITE
GRAND RAPIDS, MICHIGAN

I. Introduction

The purpose of this document is to provide a brief background of the Butterworth Landfill Superfund site (Butterworth) and to explain which remedial activities will differ from the Remedial Action (RA) selected by the United States Environmental Protection Agency (EPA) in the Record of Decision (ROD) signed on September 29, 1992. The Butterworth site is located in Grand Rapids, Kent County, Michigan, about one mile southwest of the Grand Rapids downtown area. The site is approximately 180 acres and its approximate boundaries are the Grand River on the south, Interstate 196 on the west, Butterworth Street on the north, and a Consumers Power substation on the east (See Figure 1). A combined storm water outfall crosses the site (See Figure 2). The site is within the hundred year floodplain of the Grand River.

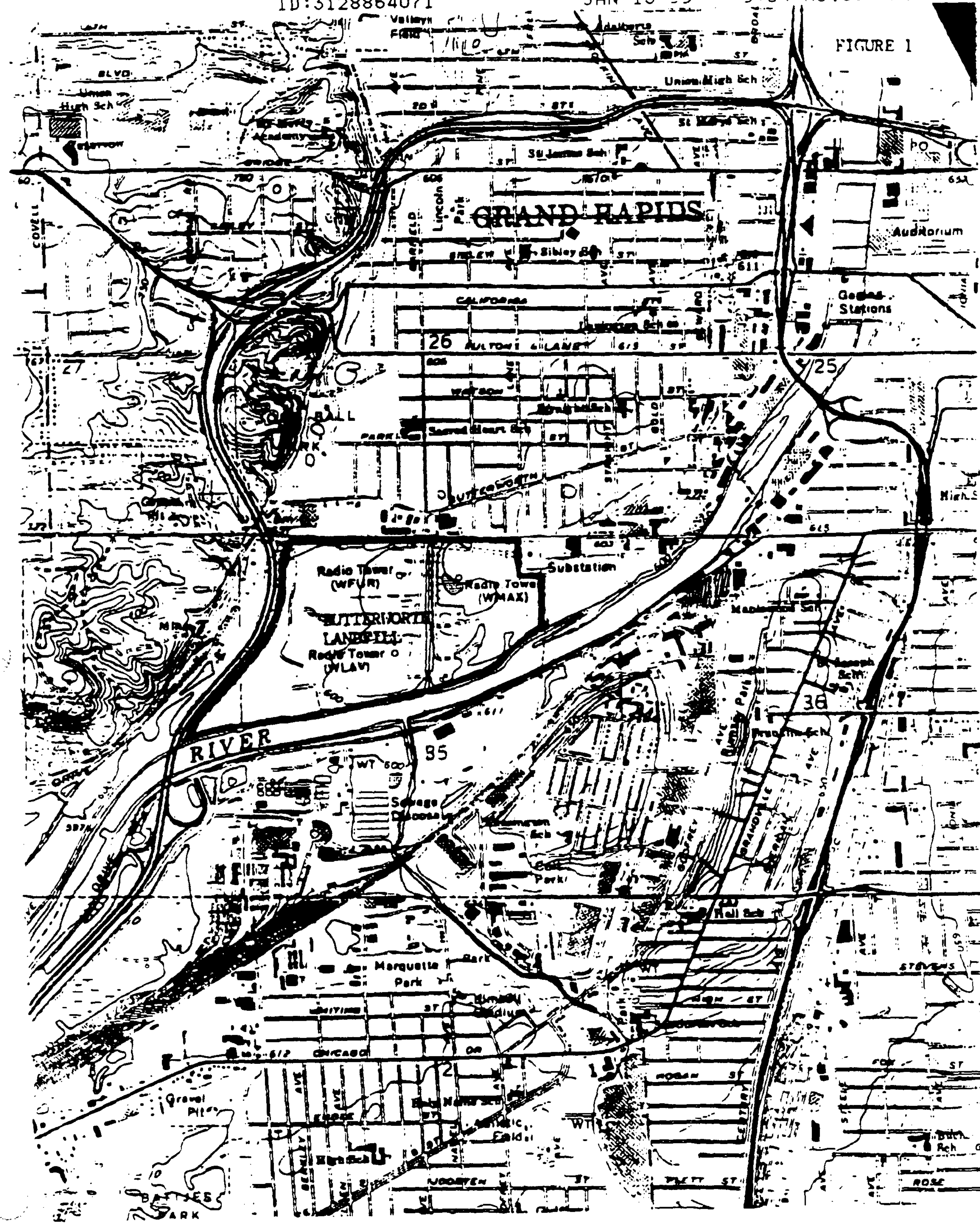
The area immediately surrounding the Butterworth site is predominantly industrial (See Figure 1). To the west of Interstate 196 are gypsum mining and processing facilities. Metal recycling facilities and the Consumers Power substation are located to the east. Across the Grand River is the Grand Rapids sewage treatment plant, which is permitted by the State of Michigan to discharge to the river just south of the site. Between Butterworth Street and the Butterworth Landfill are several light industrial facilities. To the north of Butterworth Street is a residential area, ball park, and a zoo.

The EPA and the Michigan Department of Environmental Quality (MDEQ) have jointly overseen remedial design activities at the Butterworth site under the authority of the Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended (CERCLA), 42 U.S.C. Section 9601, et seq. U.S. EPA and the Butterworth Landfill Cooperating Parties (BLCP) entered into a consent decree for remedial design of the remedial action, described in a ROD dated September 29, 1992.

The BLCP has designed the remedy for the site under U.S. EPA and MDEQ oversight. During negotiations for the consent decree, new information provided by the BLCP has persuaded U.S. EPA and the MDEQ that certain technical modifications and improvements to the selected remedy are appropriate.

Section 117© of CERCLA and Section 300.435(c)(2)(I) of the National Oil and Hazardous Substances Contingency Plan establish procedures for explaining, documenting, and informing the public of significant changes to the remedy that occur after the ROD is signed. An ESD is required when the remedial action to be taken differs significantly from the remedy selected in the ROD but does not fundamentally alter that remedy with respect to scope, performance or

FIGURE 1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St Marys Sch
St James Sch
Sibley Sch
Auditorium
Stations
26
25
Sacred Heart Sch
BUTTERWORTH
Substation
Radio Tower (WFUR)
Radio Tower (WMAX)
BUTTERWORTH LANDFILL
Radio Tower (WLAV)
RIVER
35
36
Sewage Disposal
Marquette Park
CHICAGO
High Sch
Gravel Pit
Athletic Field
ROSE
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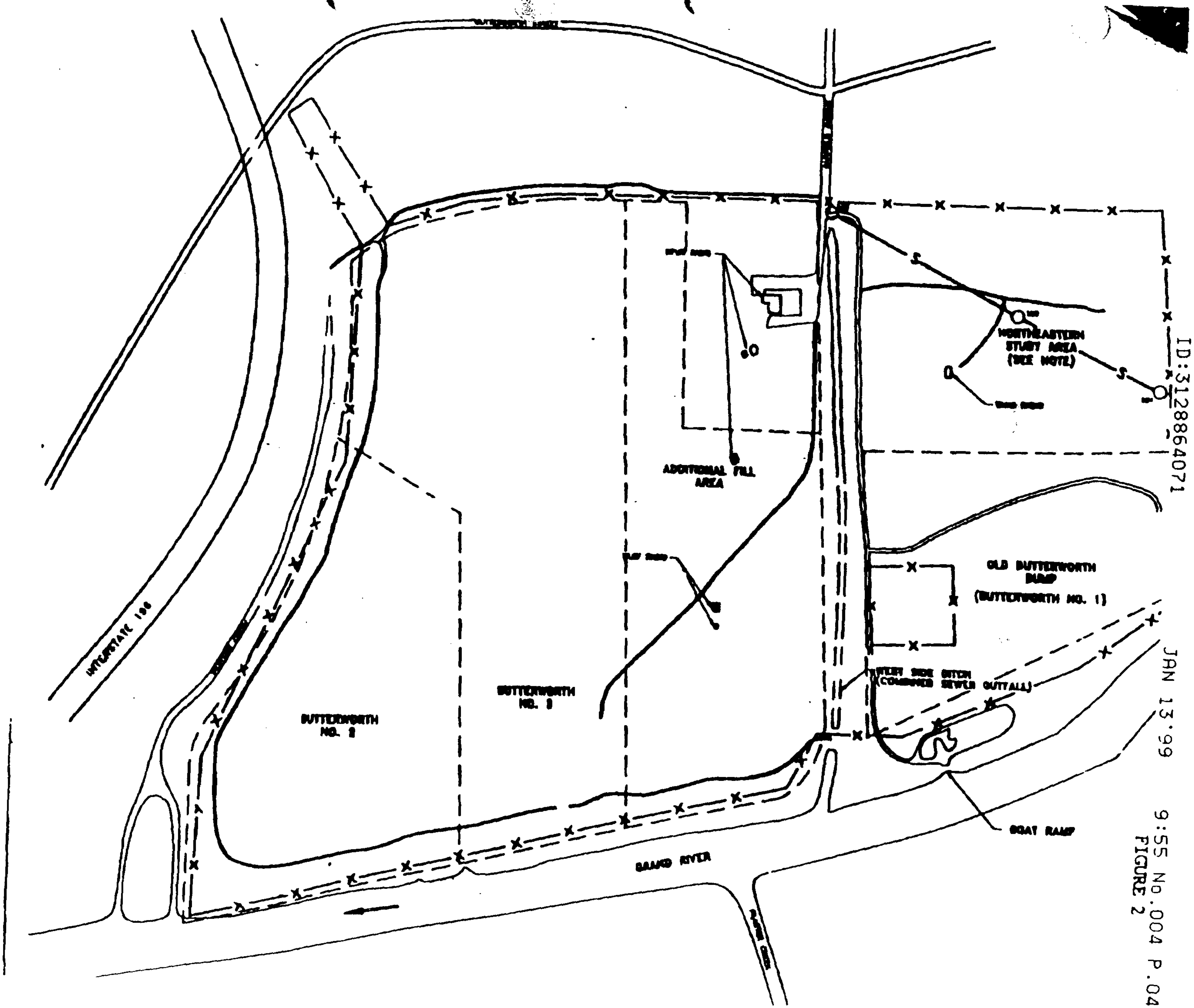

INTERSTATE 196
BUTTERWORTH NO. 2
BUTTERWORTH NO. 3
ADDITIONAL FILL AREA
NORTHEASTERN STUDY AREA (SEE NOTE)
OLD BUTTERWORTH DUMP
(BUTTERWORTH NO. 1)
WEST SIDE DITCH (COMBINED SEWER OUTFALL)
BOAT RAMP
GRAND RIVER

FIGURE 2

cost. This Explanation of Significant Differences (ESD) and supporting documentation shall become part of the administrative record file which is available at the Main Branch of the Grand Rapids Public Library, the West Branch of the Grand Rapids Public Library and at the U.S. EPA regional office in Chicago, Illinois (77 W. Jackson Blvd, 7th Floor) during normal business hours.

II. Summary of Site History, Contamination Problems, and Selected Remedy

A. Site History

The Butterworth Landfill site (See Figure 1) was operated by the City of Grand Rapids, Michigan, and was used for both residential and industrial waste. Land filling was performed in three general areas at the site. The limited information available indicates that, prior to 1967, the area to the east of the storm sewer outfall was used as a municipal landfill. This area is referred to as the Old Butterworth Dump, or Butterworth #1. This portion of the site was operated as an open landfill where daily cover of refuse was not provided. The refuse was often burned to reduce its volume.

After the enactment of Michigan Act 87 in 1965, and consistent with the federal goal of eliminating open dumping, the Old Butterworth Dump was closed sometime around 1967 and a new site, Butterworth Landfill #2, was opened. This new site occupied an area in the southwest corner of the site.

Later, an additional area, Butterworth Landfill #3, was opened. The combined size of Landfills #2 and #3 was about 80 acres. These areas were used by local residents and industries to dispose of wastes. In addition, this area was allegedly used to dispose of liquid wastes such as solvents and paint sludges.

The landfill reportedly received municipal solid waste and industrial wastes. Industrial wastes disposed of at the landfill were allegedly in drums, which were buried, or simply dumped in liquid form on a working surface. Records indicate that from 1967-1971, about 3000 to 4000 yards of waste per day were received at the landfill.

Butterworth was nominated for the NPL and was placed on the NPL in December, 1982. In 1988, the surface soil/test pit assay conducted during the RI located a hot spot of polychlorinated biphenols (PCBs) at levels of 800 mg/kg and chromium (total) at levels of 43,000 mg/kg. An removal action was initiated to address this contamination and was completed in June 1990.

In September, 1992, a Record of Decision was signed by the Regional Administrator for the site calling for the installation of a State of Michigan Act 641 solid waste cap, the establishment of Alternate Concentration Levels (ACLs) for contaminated groundwater, and groundwater, surface water, and river sediments monitoring.

B. **Contamination Problems**

Surface soil sampling conducted during the Remedial Investigation discovered arsenic contamination as high as 34 parts per million (ppm), beryllium to 8.5 ppm, chromium to 43,000 ppm, polynuclear aromatic hydrocarbons (PAHs) to 121 ppm, polychlorinated biphenols (PCBs) to 800 ppm and dieldrin to 0.29 ppm. Groundwater sampling discovered antimony to levels of 193 parts per billion (ppb), arsenic to 58 ppb, 1,1-dichloroethane to 47 ppb, vinyl chloride to 61 ppb, and bis (2-ethylhexyl) phthalate to 310 ppb.

C. **Selected Remedy**

The ROD for the site (September 1992) required:

- Institutional controls;
- Grading and leveling of the site;
- Removal of exposed drums containing hazardous material, substance or waste, and disposal off-site at a permitted RCRA Subtitle C disposal facility;
- Improvement of the site capping to meet the Michigan solid waste cap (MI Act 641) requirements with inclusion of a frost protection layer;
- Establishment of Alternate Concentration Limits (ACLs) for groundwater;
- Groundwater, surface water and river sediments monitoring;

III. **Description of the Significant Differences and the Basis for those Differences**

Determination of Alternate Concentration Levels

The ROD for the site required the development of Alternate Concentration Limits (ACLs) for shallow groundwater and the implementation of surface water, river sediment, and biological monitoring programs. These actions were required to monitor for any potential adverse effects of groundwater venting to the Grand River. Subsequent changes to Michigan regulations allow for a different approach to the ACL determination for the site.

The regulations identify criteria for measuring the impact of contaminated groundwater on surface waters. These regulations evaluate the significance of contaminated groundwater venting to surface water by comparing the onsite groundwater contaminant concentrations to the Groundwater/Surface Water Interface (GSI) criteria that are established by the MDEQ Surface Water Quality Division (SWQD). As provided under Part 201 of the Natural Resources and Environmental Protection Act, 1994 PA 451, the GSI values are developed in accordance with Rule 323.1057 (Rule 57) of Part 4 of Part 31 of Act 451 (formerly known as Act 245), and the National Toxics Rule (NTR; Federal Register, 12/22/92).

The generic GSI criteria are established and updated periodically based on available toxicological and exposure data for human health and aquatic life. The generic GSI values are, with the exception of arsenic, the more restrictive of the Rule 57 values and the NTR values, where both values are available.

The MDEQ Environmental Response Division (ERD) uses GSI criteria to provide protection of human health and aquatic life in surface waters of the State. The MDEQ published generic GSI criteria in ERD Operational Memoranda #8 and #14 (the values are the same in both documents), which are periodically updated. The published GSI values are used for surface water that is not used as a drinking water source. These GSI criteria may either be "generic" or site-specific, mixing zone based GSI criteria. The portion of the Grand River located near the site is not used as a drinking water source. The City of Grand Rapids obtains their drinking water directly from Lake Michigan.

The ERD guidance at the time the ROD was signed stated that the GSI criteria were used to judge compliance with Rule 299.5713 but did not allow for a mixing zone for discharges of venting groundwater.

At the time the ROD was signed, the relevant groundwater data exceeded a limited number of the published GSI values; and, because a mixing zone was not allowed, a range of alternatives to protect surface water were considered in the ROD. Despite the exceedance of the generic GSI values, the surface water and sediment samples that were collected during the RI did not show a statistically significant impact on surface water or sediment attributable to the site.

The ROD evaluated this information and concluded that ACLs were appropriate for the site due to the absence of site impact on the Grand River.

The promulgation of the Part 201 amendments and related amendments in June 1995, changed the GSI methodology for remedial sites in Michigan, by specifically allowing for a mixing zone for discharges of venting groundwater.

ERD Operational Memorandum #14, Revision 2, dated June 6, 1995, states that the GSI values define the maximum allowable hazardous substance concentration at the GSI, or at the edge of a mixing zone, whichever is applicable to a specific site. This memorandum also states that a mixing zone is allowed at those sites where an additional load to the receiving stream of site-specific contaminants is allowable and where a mixing zone is appropriate for the receiving stream.

The mixing zone based GSI criteria, which are site specific criteria, are the final acute values (FAVs) for toxicity to aquatic life. Mixing zone based GSI criteria have been developed for the Butterworth Landfill. Since mixing zone based GSI criteria are risk based criteria that were developed to protect human health and aquatic life in surface water, it is acceptable to utilize these criteria to establish the ACLs for the site.

The mixing zone based GSI criteria developed under the State of Michigan's Part 201 program will be substituted for the ROD recommended methodology for developing the ACLs for groundwater and will become the ACLs for the Butterworth site. The monitoring program used to measure compliance for the GSI numerical criteria would also replace the ROD requirement for surface water, river sediment, and biological monitoring.

The implementation of the GSI criteria will replace the ROD requirements for surface water, river sediment, and biological monitoring and use of the GSI criteria will protect human health and aquatic life and will provide a mechanism for measuring the effects of groundwater venting to the Grand River.

The mixing zone approach for establishing ACLs will allow for faster implementation of the remedy than the schedule outlined in the ROD. The criteria used to establish the GSI values have already been established for this site; the ROD called for a minimum of two years after the cap installation is completed for ACLs to be established.

For the reasons mentioned above, U.S. EPA believes that substitution of GSI criteria for the methodology outlined in the ROD is as protective as the ROD remedy of human health and the environment.

Original Remedy	Modified Remedy
Establishment of Alternate Concentration Limits (collection of a minimum of eight quarterly rounds of groundwater data and statistical analysis to determine ACLs)	Alternate Concentration Limits (ACLs) (Groundwater/surface water interface numeric criteria developed by the State of Michigan exclusively for the Butterworth site (See Table 1)
Surface water, river sediments and biological monitoring program	GSI performance monitoring program

Soil Cover over the Radio Tower and Station Building (RTSB) Area

The ROD for the site calls for the upgrade of the existing landfill cap to meet the requirements of Solid Waste Management Act 641 (1978), as amended, Michigan Code of Laws (MCL) Sections 299.401 through 299.436. This upgraded cap would include a vegetative soil layer consisting of a minimum of six inches of topsoil, an 18 inch thick rooting zone layer, and a low permeability clay layer, with a minimum thickness of 24 inches. In the vicinity of the RTSB area, this cap upgrade would be modified to incorporate a soil cover, consisting of 6 inches of topsoil (permeability of 4 x 10(-7) cm/sec) and 6 inches of lean clay and silty clay (permeability of 7.2 x 10(-4) cm/sec).

Table 1

Alternate Concentration Limits for the Performance Monitoring Wells

CONSTITUENT	ALTERNATE CONCENTRATION LIMIT(1) µg/L	CONSTITUENT	ALTERNATE CONCENTRATION LIMIT(1) µg/L
Acenaphthene	95	1,4-Dichlorobenzene	160
Antimony*	1,400 {A}[2]	Dieldrin*	0.48
Arsenic*	680	Ethylbenzene	320
Barium*	2,300	Iron*	NL
Benzene*	1,800	Lead*	2,300
Beta-BHC*	1.9	Manganese*	NA
Bis(2-ethylhexyl)phthalate*	285	Nickel*	4,200 {A}
Biological oxygen demand	10,000[3]	Nitrogen, ammonia	2,000[3]
Cadmium	52 {A}	PCBs*[5]	MDL
Chlorobenzene	850	Selenium	120
Chloroethane*	NA	Silver*	22
Chromium, total*	3,800 {A}	Toluene	1,700
Chromium, VI	32	Total dissolved solids	1,650,000,000[7]
Cobalt	740	Trichloroethene*	3,500
Copper	100 {A}	Vanadium*	220
Cyanide, amenable*	44	Vinyl chloride*	15[6]
1,1-Dichloroethane*	NA	Xylenes, total*	630
1,2-Dichloroethene*	7,200[4]	Zinc*	1,100 {A}

NOTES:

1. The Alternate Concentration Limits are State of Michigan mixing zone-based groundwater–surface water interface (GSI) criteria. With the exceptions of BOD, ammonia, silver, and TDS, these criteria are the Final Acute Values developed by the SWQD. The criteria for BOD, ammonia, silver, and TDS were also developed by the SWQD in accordance with the administrative rules for Part 8 of Part 31 of Act 451.
2. A mixing zone-based GSI criteria for antimony is not available yet from the MDEQ. The SWQD is evaluating criteria for antimony. The value shown is a screening-level GSI criteria to be used until a mixing zone-based GSI criteria is established. The screening-level GSI criteria is the pre-Great Lakes Initiative (GLI) "generic" GSI criteria listed in ERD Operational Memorandum #14, Revision 2 (June 6, 1995). A <u>post</u>-GLI "generic" GSI criteria has not yet been established by the MDEQ.
3. This is a daily maximum water quality-based effluent limit (WQBEL) that applies only in August and September (November 13, 1996, letter from the SWQD)
4. Same value for cis- and trans-
5. Includes Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260.
6. Mixing zone-based GSI criteria for vinyl chloride is not available yet from the MDEQ. The SWQD is evaluating criteria for vinyl chloride. The value shown is a screening-level GSI criteria to be used until a mixing zone-based GSI criteria is established. The screening-level GSI criteria is the <u>post</u>-GLI "generic" GSI criteria from the ERD Groundwater: Residential and Industrial-Commercial Part 201 Cleanup Criteria and Screening Levels (Page 6 1, February 1998).
7. Daily maximum concentration. Applied at the edge of the mixing zone, based on dilution with 100 percent of the stream design flow (e-mail from Jack Wuycheck to Rob Franks, dated November 10, 1997). The average limit would be 470,000,000 µg/L (based on river background TDS = 400 mg/L, Qriver = 800 cfs, and Qgroundwater = 0.17 cfs.)

*	Contaminant of Concern in Groundwater, as listed in Table 3-2 of the Remedial Design Work Plan
MDL	Method detection limit
NA	Not available from the MDEQ. The SWQD is evaluating criteria for these constituents. Final values will be inserted into this table and become enforceable when available from the MDEQ.
ND	Not detected
NL	No limit. The MDEQ has determined that a mixing zone-based GSI criteria is not needed for iron.
{A}	Background may be substituted if higher than the cleanup criteria.

Historical groundwater monitoring results from the RI, the first mixing zone determination sampling event, and the first round of remedial design groundwater monitoring, indicate that the groundwater quality between the RTSB area and the Grand River meets the mixing zone GSI criteria outlined above at the present time.

The wastes present in the RTSB area have been reported to be older and more highly weathered than other areas of the landfill and would be more likely to leach lower amounts of contamination than the other areas of the landfill. As reported in the RI report, the waste in this area lacks significant amounts of putrescible organic material or decomposing waste odor, and lacks significant subsurface landfill gas pressure.

Because a portion of the land filled waste lies below the water table, the reduction in contaminant flux from the landfill to the river would be minimal, even with placement of an Act 641 clay cover over the RTSB area.

The ROD requirement entailing the placement of a clay cap over the site will be modified to incorporate the placement of a soil cover over the RTSB area (See Figure 3). The soil cover also addresses the ROD concerns by providing protection from direct contact with landfill contents. The groundwater monitoring performed to determine compliance with the mixing zone GSI criteria, will be used in assessing the effectiveness of the soil cover during planned five year reviews at the site. If the five year review(s) indicate that the groundwater contamination exceeds the ACL values established for the site, a contingency plan is in place that requires the replacement of the soil cover with a clay cover over the RTSB area. The clay cover would meet the requirements of Solid Waste Management Act 641 (1978) as amended, Michigan Code of Laws (MCL) Sections 299.401 through 299.436.

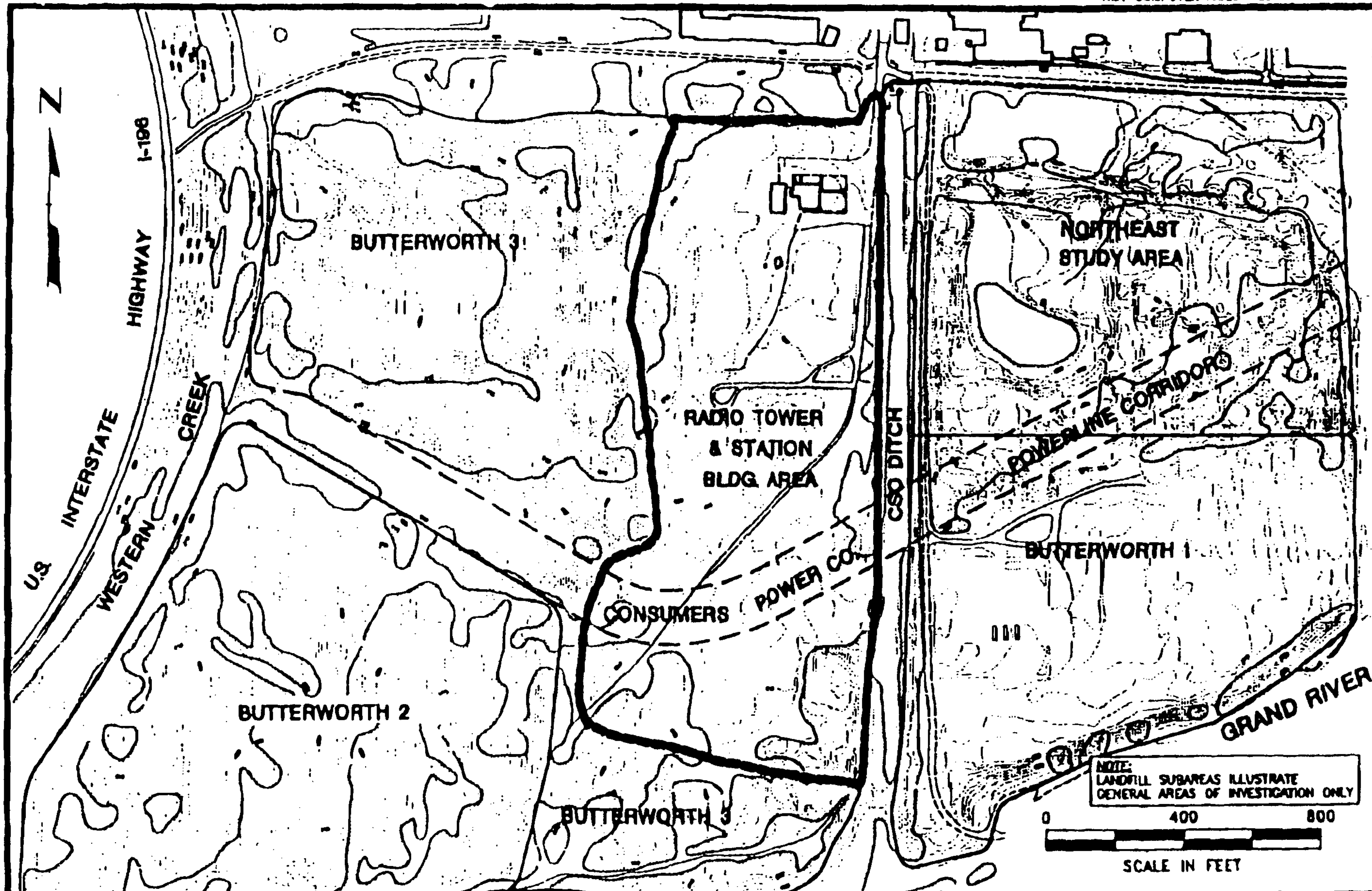
Furthermore, there are no water supply wells within the portion of the aquifer affected by the landfill and deed restrictions will prohibit the future installation of water supply wells in affected portions of the aquifer, limiting the potential exposure to human health.

A soil cover over the RTSB area is protective of human health and the environment, because it will prevent direct contact with the landfill contents and will prevent inhalation of airborne particles affected by the landfill (exposure pathways of concern identified in the ROD). Groundwater affected by leachate from the RTSB area will be monitored to ensure compliance with mixing zone GSI criteria that were developed to address potential human health and aquatic life exposure at the groundwater/surface water interface.

Increased groundwater contaminant loading, although a potential problem, will be monitored closely to ensure no adverse impact to groundwater from the installation of the soil cover.

Drawing Name: J:\03538\20\39382001.DWG Dwg Size: Plot Date: Thursday, August 1, 1996
Operator Name: MDO Plot Time: 10:24.4368 AM
Scale 1"=400' Attached Xref's: No xref's Attached

RMT COMPUTER AIDED DESIGN & DRAFTING



LOCATION OF THE RADIO TOWER & STATION BUILDING AREA WITHIN THE BUTTERWORTH LANDFILL GRAND RAPIDS, MICHIGAN

RMT, INC.

DWN. BY:	MDD
APPROVED BY:	
DATE:	AUGUST 1996
PROJ. #	3938.20
FILE #	39382001.DWG

FIGURE 1

ID:3128864071 JAN 13'99 10:00 No.004 P.11

Original Remedy	**Modified Remedy**
Improvement of the site capping to meet the requirements of a solid waste cap (Solid Waste Management Act 641 (1978), as amended, Michigan Code of Laws (MCL) Sections 299.401 through 299.436)	Inclusion of a requirement for placement of a soil cover (minimum 12 inches) over the RTSB area, while maintaining the requirement for the solid waste cap specified in the ROD for the other areas of the landfill

It is estimated that approximately $700,000 in cost savings can be realized by utilizing the GSI criteria as the ACLs, eliminating the need to conduct the surface water, river sediment, and biological sampling and also eliminating the number of monitoring events needed to establish the ACLs. Because additional evaluation to distinguish site related impacts to the river from other potential sources is unnecessary by using the GSI criteria as the ACLs, additional cost savings may be realized.

It is also estimated that approximately $2,000,000 in cost savings can be realized by constructing a soil cover over the RTSB area instead of an Act 641 clay cover, mainly from reduction in material and transportation costs.

IV. Support Agency Comments

MDEQ concurs with this ESD.

V. Affirmation of the Statutory Determinations

Considering the new information that has been developed and the changes that have been made to the selected remedy, U.S. EPA and MDEQ believe that the remedy remains protective of human health and the environment, complies with federal and state requirements that were identified in the September 1992 ROD as applicable or relevant and appropriate to this remedial action at the time of the original ROD, and is cost effective. In addition, the revised remedy utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable for this site.

VI. Public Participation Activities

U.S. EPA will publish a notice of this ESD in the Grand Rapids Press and The West Side Advance newspapers, informing interested parties that a copy of the ESD, and supporting documentation is available at the Grand Rapids Public Library - Main Branch, 60 Library Plaza, NE, and Grand Rapids Library - West Side Branch 713 Bridge Street, NW, and at the U.S. EPA regional offices in Chicago, Illinois, 77 W. Jackson-7th Floor, during normal business hours.

VII. **Concurrence**

William E. Muno, Director
Superfund Division

Date 10/23/98

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

REPLY TO THE ATTENTION OF

DATE: DEC 2 ? 1998

SUBJECT: Amendment to Explanation of Significant Differences-Butterworth Landfill Site, Grand Rapids, Michigan

FROM: William E. Muno, Director
Superfund Division

TO: File

On October 23, 1998, the United States Environmental Protection Agency (EPA) signed an Explanation of Significant Differences (ESD) for the Butterworth Landfill Superfund site in Grand Rapids, Michigan. This ESD included justification for several changes to the original Record of Decision (ROD), dated September 29, 1992.

One of the changes to the original ROD remedy was the substitution of groundwater/surface water interface (GSI) criteria for the Alternate Concentration Limit (ACL) determination methodology outlined in the ROD. These GSI criteria were developed by the Michigan Department of Environmental Quality (MDEQ) for the Butterworth Landfill site. These GSI criteria were listed in Table 1 of the ROD.

Since the issuance of the October 23, 1998 ESD, the criteria for determining GSI values for several constituents has changed, necessitating this amendment to the ESD.

Specifically, preliminary ACLs have been developed for chloroethane and 1,1-Dichloroethane. The methodology for establishing screening level criteria for these criteria was based on analytical results from the Remedial Investigation.

The maximum detected RI concentration for these two constituents was doubled and will serve as a preliminary ACL until a mixing zone based GSI criteria is established for these constituents by the MDEQ.

EPA determined that using a value of twice the maximum detected RI concentration would provide adequate protection of surface water quality until a mixing zone based GSI criteria was developed by the MDEQ. This was because it is difficult to discern site related impacts from these constituents on Grand River water quality.

Additional changes to Table 1 include clarifications to the footnotes, to provide more clarification of the basis for developing the screening level GSI criteria and preliminary ACLs presented in the table.

Table 1

Alternate Concentration Limits for the Performance Monitoring Wells

CONSTITUENT	ALTERNATE CONCENTRATION LIMIT(1) µg/L	CONSTITUENT	ALTERNATE CONCENTRATION LIMIT(1) µg/L
Acenaphthene	95	1,4-Dichlorobenzene	160
Antimony*	1,400 {A}[2]	Dieldrin*	0.48
Arsenic*	680	Ethylbenzene	320
Barium*	2,300	Iron*	NL
Benzene*	1,800	Lead*	2,300 [4]
Beta-BHC*	1.9	Manganese*	4600 [6]
Bis(2-ethylhexyl)phthalate*	285	Nickel*	4,200 {A}
Biological oxygen demand	10,000	Nitrogen, ammonia	2,000[3]
Cadmium	52 {A}	PCBs*[7]	MDL
Chlorobenzene	850	Selenium	120
Chloroethane*	164	Silver*	22
Chromium, total*	3,800 {A}	Toluene	1,700
Chromium, VI	32	Total dissolved solids	1,650,000,000[8]
Cobalt	740	Trichloroethene*	3,500
Copper	100 {A}	Vanadium*	220
Cyanide, amenable*	44	Vinyl chloride*	15[7]
1,1-Dichloroethane*	94 [4]	Xylenes, total*	630
1,2-Dichloroethene*	7,200[4,5]	Zinc*	1,100 {A}

NOTES:

1. Except as described in note 2, the Alternate Concentration Limits are State of Michigan mixing zone-based groundwater-surface water interface (GSI) criteria. With the exceptions of BOD, ammonia, silver, and TDS, these criteria are the Final Acute Values (FAV) developed by the MDEQ. The criteria for BOD, ammonia, silver, and TDS were also developed by the MDEQ in accordance with the administrative rules for Part 8 of Part 31 of Act 451.

2. The MDEQ has determined that the currently available toxicity data for antimony and vinyl chloride are not adequate to establish FAVs. The screening level GSI criteria shown in this table for vinyl chloride is the generic GSI criteria that was established by the MDEQ. The generic GSI criteria for vinyl chloride is the human cancer value (HCV) for non-drinking water supplies. The screening level criteria shown in this table for antimony was provided by the MDEQ.

3. This is a daily maximum water quality-based effluent limit (WQBEL) that applies only in August and September (November 13, 1996, letter from the SWQD).

4. The MDEQ has determined that the projected discharge concentrations for chloroethane, 1,1-dichloroethane, 1,2-dichloroethene, lead, and selenium do not indicate a reasonable potential to exceed surface water quality standards. Preliminary ACLs will be used for these criteria until such time as mixing zone based GSI criteria are established. *The preliminary ACLs for these five constituents represent the following:*

- chloroethane-two times the previously detected maximum concentration in the existing monitoring wells along the riverfront at the Butterworth Landfill
- 1,1-dichloroethane-two times the previously detected maximum concentration in the existing monitoring wells along the riverfront at the Butterworth Landfill
- 1,2-dichloroethene-developed in consultation with the MDEQ
- lead-FAV
- selenium-FAV

5. Same value for cis- and trans-

6. The criteria for manganese shown in this table will be used as the preliminary ACL for the Butterworth Landfill until a FAV is established by the MDEQ. *The preliminary ACL is two times the previously detected maximum concentration in the existing monitoring wells along the riverfront at the Butterworth Landfill.*

7. Includes Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

8. Daily maximum concentration. Applied at the edge of the mixing zone, based on dilution with 100 percent of the stream design flow (e-mail from Jack Wuycheck to Rob Franks, dated November 10, 1997). The average limit would be 470,000,000 Fg/L (based on river background TDS = 400 mg/L, Qriver = 800 cfs, and Qgroundwater = 0.17 cfs.)

*	Contaminant of Concern in Groundwater, as listed in Table 3-2 of the Remedial Design Work Plan.
MDL	Method detection limit
NA	Not available from the MDEQ. The SWQD is evaluating criteria for these constituents. Final values will be inserted into this table and become enforceable when available from the MDEQ.
ND	Not detected
NL	No limit. The MDEQ has determined that a mixing zone-based GSI criteria is not needed for iron.
(A)	*Background may be substituted if higher than the cleanup criteria.*

APPENDIX A - 2
LANDFILL GAS MONITORING SUMMARY
(SUBMITTED TO THE USEPA IN PROGRESS REPORTS)

APPENDIX A-2

LANDFILL GAS MONITORING SUMMARY (SUBMITTED TO THE USEPA IN PROGRESS REPORTS)

November 1995 through February 1997

Field Pressure Measurements (inches of water)

Gas Probe	Nov. 13/14, 1995 (field instrument)	Nov. 13/14, 1995 (Summa canisters)	August 14, 1996 (field instrument)	Feb. 13, 1997 (field instrument)
GW-1	0.01	This type of data was not collected during this monitoring event.	0.01	<0.01
GW-2	<0.01		0.01	-0.01
GW-3	<0.01		0.05	-0.01
GW-4	<0.01		0.02	-0.01
GW-5	<0.01		<0.01	-0.02
GW-6	<0.01		<0.01	-0.03
GW-7	<0.01		<0.01	-0.02
GW-8	<0.01		0.01	<0.01
GW-9	<0.01		0.025	<0.01

Combustible Gas Concentrations (percent LEL)

Gas Probe	Nov. 13/14, 1995 (field instrument)	Nov. 13/14, 1995 (Summa canisters)	August 14, 1996 (field instrument)	Feb. 13, 1997 (field instrument)
GW-1	This type of data was not collected during this monitoring event.	This type of data was not collected during this monitoring event.	100	This type of data was not collected during this monitoring event.
GW-2			100	
GW-3			100	
GW-4			100	
GW-5			1	
GW-6			17	
GW-7			0	
GW-8			100	
GW-9			100	

Combustible Gas Concentrations (percent methane)

Gas Probe	Nov. 13/14, 1995 (field instrument)	Nov. 13/14, 1995 (Summa canisters)	August 14, 1996 (field instrument)	Feb. 13, 1997 (field instrument)
GW-1	57	42	This type of data was not collected during this monitoring event.	40.4
GW-2	28	26		21.6
GW-3	69	53 (Dup.=52)		56.1
GW-4	60	56		66.8
GW-5	1.0	0.014		0.0
GW-6	8	0.31		0.0
GW-7	uncertain	<0.002		0.0
GW-8	36	36		54.0
GW-9	69	58		75.3

Oxygen Concentrations (percent)

Gas Probe	Nov. 13/14, 1995 (field instrument)	Nov. 13/14, 1995 (Summa canisters)	August 14, 1996 (field instrument)	Feb. 13, 1997 (field instrument)
GW-1	0.0	4.6	0.2	0.9
GW-2	0.0	3.3	0.2	0.0
GW-3	0.0	4.4 (Dup.=2.5)	0.2	0.0
GW-4	0.0	1.9	0.1	0.0
GW-5	0.0	3.9	0.3	0.0
GW-6	0.7	3.1	0.2	0.0
GW-7	14.2	14	18.4	13.3
GW-8	0.0	7.7	0.1	0.0
GW-9	0.0	3.2	0.2	0.0

Hydrogen Sulfide Concentrations (ppm)

Gas Probe	Nov. 13/14, 1995 (field instrument)	Nov. 13/14, 1995 (Summa canisters)	August 14, 1996 (field instrument)	Feb. 13, 1997 (field instrument)
GW-1	This type of data was not collected during this monitoring event.	This type of data was not collected during this monitoring event.	4	This type of data was not collected during this monitoring event.
GW-2			3	
GW-3			5	
GW-4			4	
GW-5			3	
GW-6			1	
GW-7			1	
GW-8			2	
GW-9			3	

Carbon Monoxide Concentrations

Gas Probe	Nov. 13/14, 1995 (field instrument)	Nov. 13/14, 1995 (Summa canisters) (percent)	August 14, 1996 (field instrument) (ppm)	Feb. 13, 1997 (field instrument)
GW-1	This type of data was not collected during this monitoring event.	<0.002	12	This type of data was not collected during this monitoring event.
GW-2		<0.002	16	
GW-3		<0.002 (Dup.<0.002)	16	
GW-4		<0.001	18	
GW-5		<0.002	6	
GW-6		<0.002	6	
GW-7		<0.002	2	
GW-8		<0.002	8	
GW-9		<0.001	20	

Carbon Dioxide Concentrations

Gas Probe	Nov. 13/14, 1995 (field instrument)	Nov. 13/14, 1995 (Summa canisters)	August 14, 1996 (field instrument)	Feb. 13, 1997 (field instrument) (ppm)
GW-1	This type of data was not collected during this monitoring event.	This type of data was not collected during this monitoring event.	This type of data was not collected during this monitoring event.	32.1
GW-2				29.3
GW-3				30.6
GW-4				35.4
GW-5				10.0
GW-6				8.5
GW-7				4.4
GW-8				23.7
GW-9				26.1

Notes:

- The field measurements recorded for November 13 and 14, 1995, were made using a Digiflam meter.
- The Summa canister samples were collected on November 13 and 14,1995, after the field measurements were made.
- The field measurements recorded for August 14, 1996, were made with a Bacharach Sentinel 44 quad gas meter.
- The field measurements recorded for February 13, 1997, were made using a GA-90L gas meter.
- Pressure measurements were made using a magnahelic pressure gauge.

APPENDIX B

WETLANDS AND FLOODPLAIN–RELATED DOCUMENTS

- Appendix B-1 Resource Management Group, Incorporated's Lake and Stream, Floodplain, and Wetlands Analysis Report
- Appendix B-2 Wetland Hydrology Calculations

APPENDIX B-1

RESOURCE MANAGEMENT GROUP, INCORPORATED'S LAKE AND STREAM, FLOODPLAINS, AND WETLAND ANALYSIS REPORT

LAKES & STREAMS, FLOODPLAINS, AND WETLANDS ANALYSIS

PREPARED FOR THE BUTTERWORTH LANDFILL

Prepared by:

RESOURCE MANAGEMENT GROUP, INC.
Environmental Planners and Consultants

Grand Haven ↔ Reed City ↔ Escanaba ↔ Green Bay

Lakes & Streams

The site is bounded on the south by the Grand River, a Section 10 navigable waterway. There are no other lakes or streams adjacent to or on the property. There is a CSO discharge ditch which bisects the parcel and flows north to south to the Grand River during times of discharge. The Environmental Response Division of MDEQ has determined the CSO ditch is not a stream and is not considered a water of the United States.

The Grand River is regulated by both state and federal statutes. Part 301 of PA 451 of 1994, the Natural Resources and Environmental Protection Act, is the basis of state regulatory authority. Part 301 is commonly and historically referred to as the Inland Lakes & Streams Act. This law regulates any activity below the Ordinary High Water Mark (OHWM) of the Grand River. The Federal regulatory authority is based on Section 10 of the Rivers and Harbors Act of 1899, which also requires a permit for any activity below the OHWM.

Because there is no activity associated with the landfill closure and remediation plan proposed below the OHWM of the Grand River, there is no regulatory approval, authority, or review under either referenced state or federal statute relating to lakes, streams, and navigable waterways required for this project. The remedial design plan complies with State & Federal Lake and Stream Regulation.

Floodplains

A portion of the site lies within the 100-year floodplain of the Grand River. As there is no federal floodplain regulatory permit required (only compliance with Executive Order). the project must comply with the State of Michigan Floodplain Regulatory Authority. as contained in Part 31 of PA 451, supra. This regulation states that any grade change, structure placement. or materials stockpiling within the designated floodplain requires authorization from MDEQ.

As part of the initial effort to determine floodplain regulatory interaction associated with the remedial design closure and capping effort, Fishbeck. Thompson. Carr & Huber Engineers were retained to conduct a HEC-2 hydraulic analysis to determine if any proposed activity associated with the landfill remediation plan would interfere or create an additional backwater during times of flooding. The HEC-2 analysis was conducted based on a hypothetical placement of a flood wall along the banks of the Grand River. Because final planning was not completed. this hypothetical condition was used to ensure any actual activity would be less an encroachment and confinement to the floodplain than a flood wall. Note. a flood wall is not proposed. it was used simply to demonstrate that no harmful effect on flood flows would result from any proposed capping endeavor. The HEC-2 analysis was previously provided to the department.

The HEC-2 hydraulic analysis revealed even a flood wall would not raise the flood stage of the Grand River. This analysis was evaluated. confirmed. and approved by Land and Water Management Division of MDEQ in an interoffice communication to ERD dated May 17. 1996 (see following documentation). Therefore. the proposed remedial capping effort and plan. which results in significantly less encroachment and fill within the floodplain than the postulated flood wall. will not interfere with or harmfully alter the flood stages of the Grand River. and is therefore permittable under the floodplain regulatory authority cited above.

Please note the Land and Water Management Division has requested a set of final capping plans to confirm no impact to the floodplain. An additional set of grading plans has been provided for forwarding to that Division. The remedial design plan complies with State Floodplain Regulation & Federal Executive Order.

Wetlands

A wetland regulatory determination and delineation was conducted by Resource Management Group. The determination report and wetland mapping have been submitted to ERD and were accepted and approved by the Land and Water Management Division in the interoffice communication dated May 17, 1996 (see following documentation).

State Regulation

However, based on additional information not available at the time the wetland delineation was conducted, the conclusion of State regulatory authority under Part 303 of PA 451, needs to be revised to reflect the new information. Groundwater elevations have been identified and permeability testing has been conducted on the site to ascertain whether the wetlands are groundwater dependent. The findings of permeability testing and groundwater elevations (see following documentation) revealed that several of the subject wetlands are perched well above the water table and there is no interaction of hydrology between the surface and groundwater. Based on the state wetland regulations and unpromulgated rules involving the contiguous finding in relation to hydrologic interdependence of wetlands and nearby waterbodies, the site wetlands which are perched above the water table are not regulated by Part 303, contrary to the wetland delineation preliminary findings.

Because there is no hydrologic connection between the wetlands and the Grand River and, based upon the ERD finding that the CSO ditch is not considered a water of the U.S., all the wetlands proposed to be altered by the landfill capping project are not regulated. Please note that none of the subject wetlands is greater than 5 acres in size.

For example, wetland E-2B (see wetland delineation) is at elevation 598.8 and wetland E-1B is above 600.0, while the groundwater elevation is 588.4, providing at least 10 feet of separation between the perched wetland elevation and the groundwater elevation. Because the soils are highly impermeable, there is no hydrologic connection, either surface or groundwater, of either of these two wetlands to any waterbody. Therefore, neither of these two wetlands are regulated under Part 303.

Wetlands W-1B and W-2B are both above elevation 598. Because they are clearly perched above the groundwater elevation in that area of 592.8, the soils are highly impermeable, and there is no hydrologic connection to a waterbody, neither of these two wetlands is regulated by Part 303.

SHJ 1-6-97
DEO 12-31-96

RMT, Inc.
Falling Head Permeability Test
(Version 1.02)

Project:BUTTERWORTH LANDFILL
Project #:3938.07
Sample:Wetland #2, 1-2'
:
Visual Descript:

Date: 31-Dec-96
Tech: HJW
File: 393802
Cell #: 5

INPUT VALUES

	INIT.	FINAL
Sample Dia. (in)	1.38	1.38
Sample Ht. (in)	2.00	1.98
Tare & Wet (g)	99.68	184.86
Tare & Dry (g)	85.17	168.74
Tare (g)	0.00	83.57
Sample Wt. (g)	99.68	101.29

Permeant:	WATER	
Permeant Specific Gravity:	1.00	
Sample Specific Gravity:	2.70	EST.
Confining Pressure (psi):	100.0	
Burette Diameter (in):	0.250	
Burette Zero (cm):	100.0	

CALCULATED VALUES

MOISTURE (%)	17.0	18.9
WET DENS. (pcf)	126.9	130.3
DRY DENS. (pcf)	108.5	109.6
SATURATION (%)	83.1	95.0

MAXIMUM GRADIENT:	30.9
AVERAGE GRADIENT:	29.6
MAX. EFFECT. STRESS (psi):	4.3
MIN. EFFECT. STRESS (psi):	2.0
AVE. EFFECT. STRESS (psi):	2.7

Date YY	MM	DD	Time HH	MM	Temp Co*	Press.(psi) BOT	TOP	Readings (cm) CHAM	BOT	TOP	Flow Dif. %	Kv ** cm/sec	Ave. 0,1
96	12	20	13	24.00	0.0	97	97	51.15	3.20	100.70			
96	12	20	14	2.00	21.5	97	97	52.90	3.50	97.20	-84.2	1.4E-06	
96	12	20	14	29.00	21.5	97	97	53.90	3.65	96.20	-73.9	6.1E-07	
96	12	20	15	17.00	21.5	97	97	54.80	4.30	95.05	-27.8	5.5E-07	
96	12	20	15	45.00	21.5	97	97	55.45	4.60	94.35	-40.0	5.3E-07	
96	12	20	16	13.00	21.5	97	97	56.30	4.90	93.65	-40.0	5.4E-07	
96	12	23	7	23.00	22.0	97	97	82.92	14.35	65.80	-49.3	1.9E-07	
96	12	23	9	23.00	22.0	97	97	82.90	14.45	65.70	0.0	4.3E-08	
96	12	23	10	19.00	22.0	97	97	82.95	14.50	65.65	0.0	4.6E-08	
96	12	23	11	21.00	0.0	97	97	82.95	14.60	65.55			
96	12	23	12	27.00	22.0	97	97	82.95	14.65	65.50	0.0	3.9E-08	
96	12	23	13	53.00	0.0	98	97	5.70	14.65	100.20			
96	12	23	14	22.00	22.0	98	97	5.90	14.75	100.10	-0.0	5.8E-08	
96	12	23	14	54.00	22.0	98	97	5.85	14.80	100.05	0.0	2.6E-08	
96	12	23	15	23.00	22.0	98	97	5.90	14.90	99.95	0.0	5.8E-08	
96	12	23	15	53.00	22.0	98	97	5.90	14.95	99.90	0.0	2.8E-08	1
96	12	23	16	32.00	22.0	98	97	6.00	15.05	99.80	-0.0	4.3E-08	1
96	12	26	7	43.00	21.0	98	97	8.50	21.50	93.00	-2.6	3.2E-08	1

NOTES or COMMENTS :

Average Kv for those rows with a 1 in the Ave. column 3.4E-08 cm/
Termination determined by stable Kv and low flow differential 1.4E-08 in/[illegible]
* A zero in this column starts a series of measurements
** Kv adjusted for temperature

8

HBL 12/26/96

RMT, Inc.
Falling Head Permeability Test
(Version 1.02)

Project: BUTTERWORTH LANDFILL — Date: 26-Dec-96
Project #: 3938.07 — Tech: HJW
Sample: Wetland #1 — File: 393801 — Page: 1 of 1
: — Cell #: 4

Visual Descript:

INPUT VALUES

	INIT.	FINAL
Sample Dia. (in)	1.37	1.40
Sample Ht. (in)	2.09	1.89
Tare & Wet (g)	132.49	172.29
Tare & Dry (g)	127.51	153.18
Tare (g)	110.84	83.49
Sample Wt. (g)	92.14	88.80

Permeant:	WATER	
Permeant Specific Gravity:	1.00	
Sample Specific Gravity:	2.50	EST.
Confining Pressure (psi):	100.0	
Burette Diameter (in):	0.250	
Burette Zero (cm):	100.0	

CALCULATED VALUES

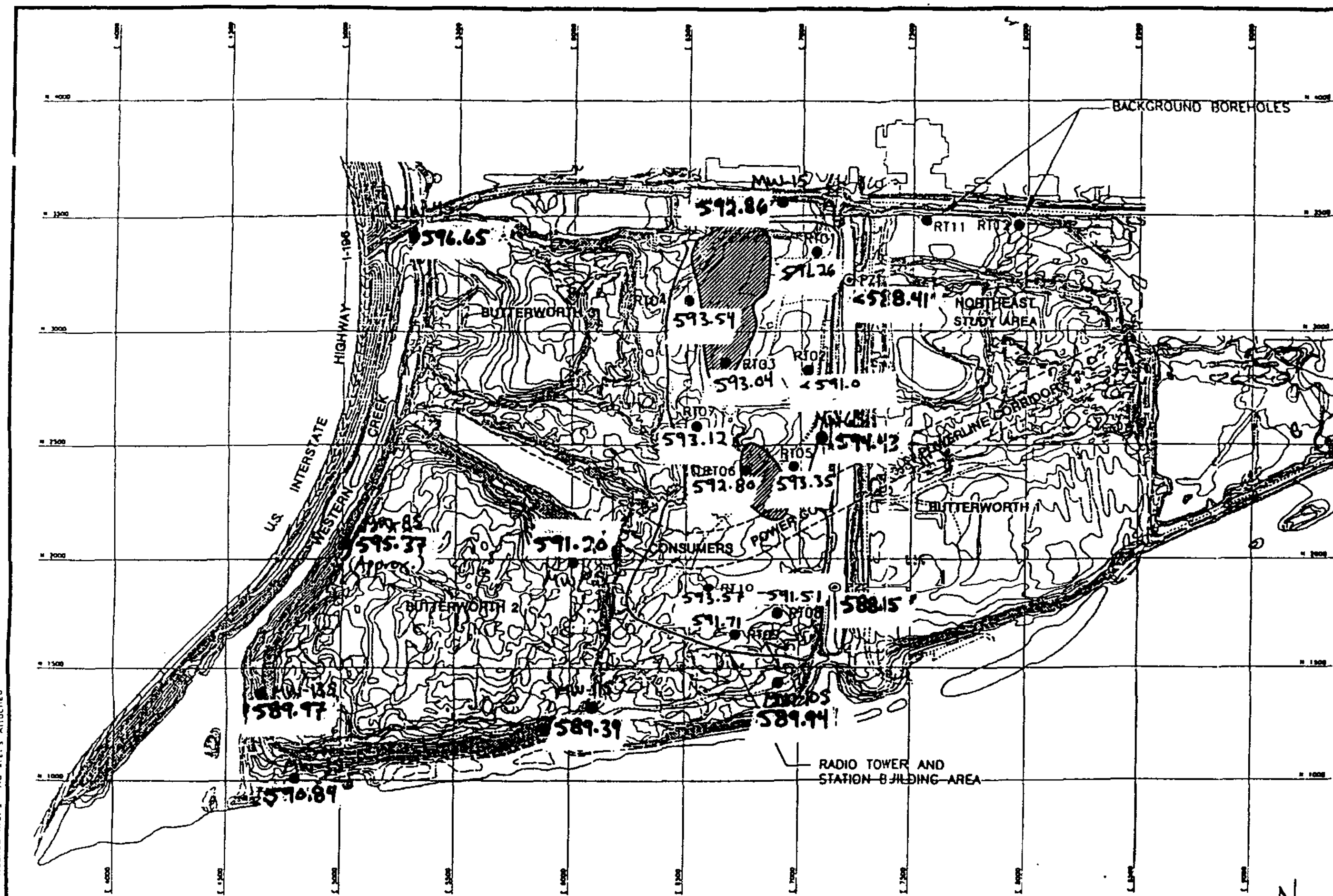
MOISTURE (%)	29.9	27.4
WET DENS. (pcf)	113.9	116.3
DRY DENS. (pcf)	87.7	91.3
SATURATION (%)	96.0	96.6

MAXIMUM GRADIENT:	16.4
AVERAGE GRADIENT:	16.4
MAX. EFFECT. STRESS (psi):	3.6
MIN. EFFECT. STRESS (psi):	2.2
AVE. EFFECT. STRESS (psi):	2.7

Date YY	MM	DD	Time HH	MM	Temp Co*	Press.(psi) BOT	TOP	Readings (cm) CHAN	BOT	TOP	Flow Dif. %	Kv ** cm/sec	Ave. 0,1
96	12	20	13	22.00	0.0	97	97	59.70	5.70	100.70			
96	12	20	14	3.00	21.5	97	97	60.85	5.55	99.50	-128.6	3.4E-07	
96	12	20	14	28.00	21.5	97	97	61.20	5.50	99.30	-166.7	8.0E-08	
96	12	20	15	16.00	21.5	97	97	61.70	5.90	99.35	128.6	9.7E-08	
96	12	20	15	46.00	21.5	97	97	61.95	6.00	99.30	33.3	6.7E-08	
96	12	20	16	12.00	21.5	97	97	62.30	6.05	99.25	0.0	5.1E-08	
96	12	23	7	22.00	22.0	97	97	70.40	13.05	92.35	0.7	5.2E-08	
96	12	23	9	22.00	22.0	97	97	70.40	13.25	92.20	14.3	4.5E-08	
96	12	23	10	19.00	22.0	97	97	70.40	13.35	92.10	-0.0	5.4E-08	1
96	12	23	11	20.00	0.0	97	97	70.40	13.40	92.05			
96	12	23	12	26.00	22.0	97	97	70.25	13.50	91.95	0.0	4.7E-08	1
96	12	23	12	59.00	22.0	97	97	70.25	13.55	91.90	0.0	4.7E-08	1

NOTES or COMMENTS :

Average Kv for those rows with a 1 in the Ave. column — 4.9E-08 cm/sec
Termination determined by stable Kv and low flow differential — 1.9E-08 in/sec
* A zero in this column starts a series of measurements
** Kv adjusted for temperature



LEGEND

- GRAVEL ROAD
- EXISTING 5-FOOT CONTOUR
- TREE LINE
- HIGHLY DECOMPOSED WASTE AND FOUNDRY SAND
- ● RT01 SOIL BORING LOCATION or WELL LOCATION
- ⊙ PZ1 PIEZOMETER LOCATION
- 591.26 Water level in augers
- 594.43 Water level in well or ditch

NOTES

1. BASE MAP DEVELOPED FROM AERIAL PHOTOGRAPHY PROVIDED BY ABRAMS AERIAL CORP. DATE OF FLIGHT WAS APRIL 30, 1993.
2. THE EXTENT OF WASTE SHOWN ON THIS FIGURE WAS DERIVED FROM ASSESSMENT OF HISTORICAL AERIAL PHOTOGRAPHS, GROUND SURFACE TOPOGRAPHY, SOIL BORINGS, TEST PITS, AND GEOPHYSICAL SURVEY RESULTS. WASTE CHARACTERISTICS IN VARIOUS PORTIONS OF THE LANDFILL ARE DESCRIBED MORE FULLY IN SECTION 4 OF THE PRE-DESIGN STUDIES REPORT.
3. BORING LOCATIONS ARE BASED ON OCTOBER 21, 1996 SURVEY PERFORMED BY HOLLAND ENGINEERING.

WATER LEVELS MAP

(11-4 to 11-6-96)

ACTUAL LOCATIONS OF SOIL BORINGS FOR THE SCALED-BACK WASTE LEACHING STUDY IN THE RADIO TOWER & STATION BUILDING AREA

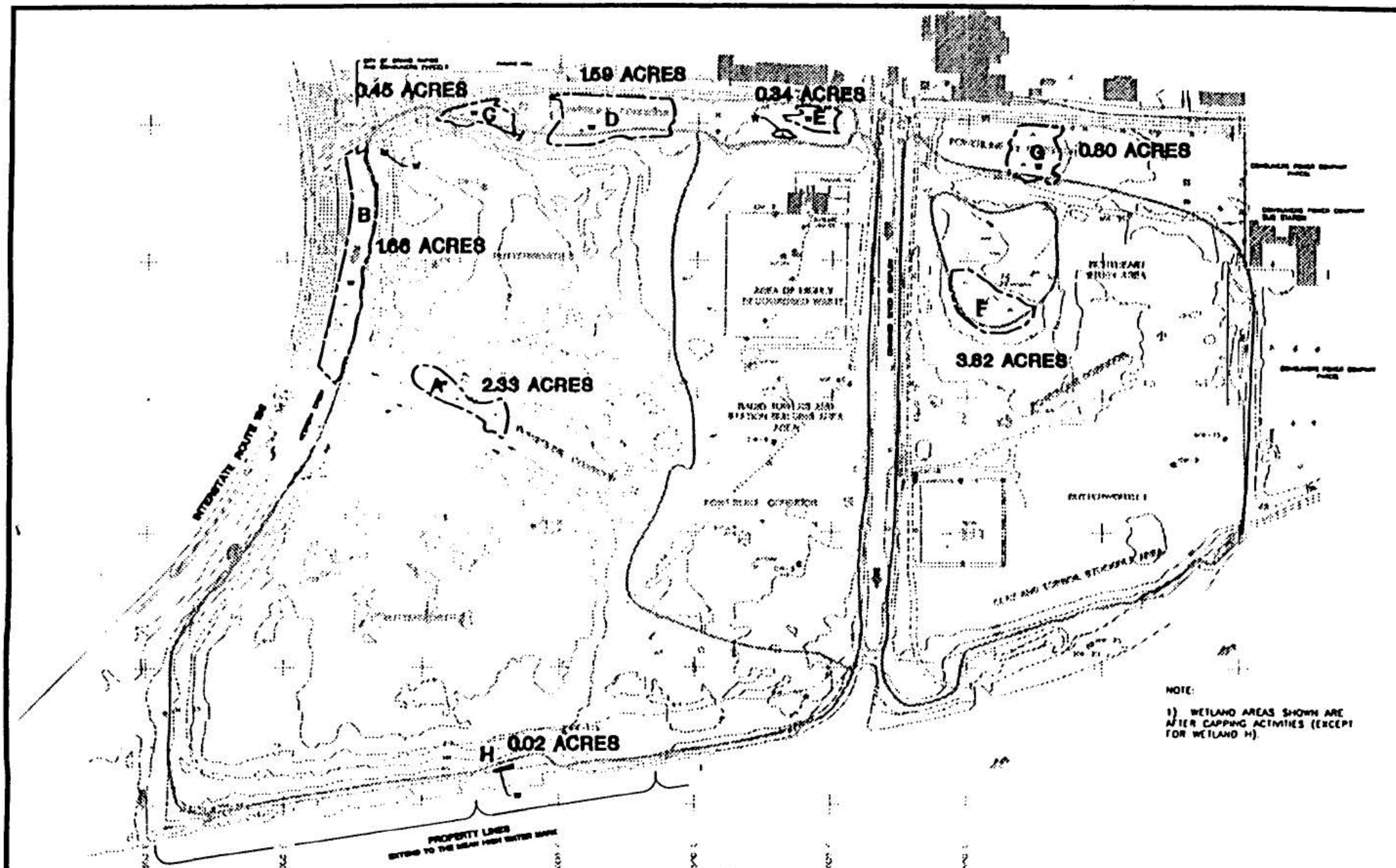
BUTTERWORTH LANDFILL
GRAND RAPIDS, MICHIGAN

0 500 1000
SCALE: 1" = 500'

RMT

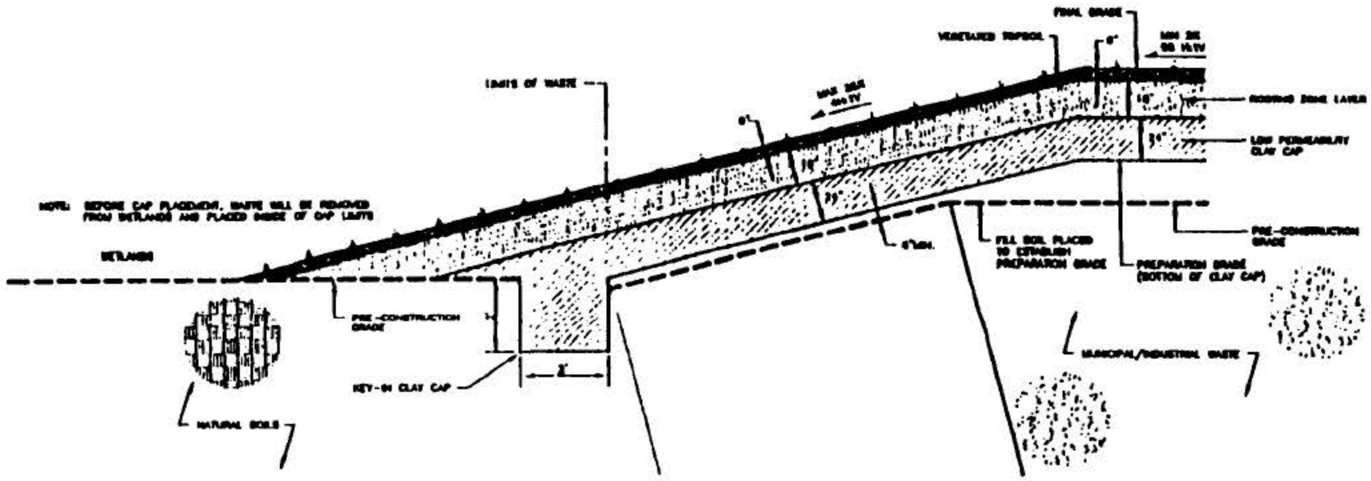
DWN. BY:	DSS
APPROVED BY:	
DATE:	DECEMBER 1996
PROJ. #	3938.20
FILE #	39382002.DWG

11



BUTTERWORTH LF REMEDIAL DESIGN	DRAWN BY: SGH	PROJ. NUMBER 3938.14	RMT INC.
13 **EXISTING WETLANDS**	CHECKED BY:	FILE NUMBER 39381409	1143 HIGHLAND DRIVE, SUITE B ANN ARBOR, MI 48108-2237
	APPROVED BY:	DATE:	P.O. BOX 991 48108-0991 PHONE [redacted]

1996 RMT COMPUTER AIDED DESIGN & DRAFTING



1/1 FINAL COVER TO WETLAND TRANSITION
(NOT TO SCALE)

RMT INC. 1143 HIGHLAND DRIVE, SUITE B ANN ARBOR, MI 48106-2237 P.O. BOX 991 48106-0991 PHONE: [redacted]	DRAWN BY: SGH	PROJ. NUMBER 3938.14	BUTTERWORTH LF REMEDIAL DESIGN
	CHECKED BY:	FILE NUMBER 39381417	WETLAND TRANSITION
	APPROVED BY:	DATE: FEBRUARY 1997	

15

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

May 17, 1996

TO: Carl Chavez
Environmental Response Division
Superfund Section, SMU 3, Lansing

FROM: Luis Saldivia, LWMD, Grand Rapids

RE: DEQ File 9605-09102
Butterworth Landfill Superfund Site
Section 35, T7N, R12W
City of Grand Rapids Kent County

The Land and Water Management Division has completed review of the Preliminary (30%) Remedial Design Project Plan, dated April 15, 1996 and have the following comments:

Floodplain Analysis

We have reviewed the Flood Analysis prepared by Fishbeck, Thompson, Carr and Huber entitled "Grand River Floodwall and Embankment Improvements, Butterworth Landfill Embankment, Flood Stage Impact Evaluation", dated December 1995.

We have determined that the proposed floodwall would not create an appreciable backwater increase upstream of the project site. It is important to note that the report indicates that the MDEQ would allow backwater increases of up to 0.1 foot, which is not necessarily true. If there is an existing or potential flooding problem, we may require no backwater increase. In this case we believe any increases would be contained within the City of Grand Rapids existing floodwall.

We are requesting that a larger scale topographic map of the site be provided to the LWMD to more accurately locate the proposed embankment along the Grand River.

<u>Wetland Delineation</u>

We have reviewed the Routine Wetland Delineation prepared by Resource Management Group, dated March 14, 1996 and concur with the report findings of approximately 7.5 acres of wetlands on the site.

According to the Preliminary Remedial Design Plan, waste removal, filling and grading are expected to impact less than 1 acre of the site's wetlands. The LWMD does not have an objection to the proposed activities provided the remedial plan protects, to the most feasible extent possible, any impacts to water or wetlands on site. Our Division recommends that a wetland mitigation plan be prepared for the site in which there will be no net loss to the wetland resources.

The LWMD also recommends during the filling and grading activities on the site that a siltation barrier be installed around the perimeter of the wetlands to protect them from soil erosion and sedimentation. The siltation barrier can also serve to prevent equipment and vehicles from impacting the wetlands. The siltation barrier should be inspected periodically and maintained in good working order throughout the duration of the project.

Wetlands W-3B and W-4B are above elevations 598 and 599 respectively, while groundwater in the area is between 593 and 596. Because there is no hydrologic connection to any waterbody, neither of these two wetlands is regulated by Part 303.

Wetland W-7B occurs at elevation 597.6, while groundwater is at 591.2. Again, this is obviously a perched situation, in highly impermeable soils, with no hydrologic connection to any waterbody. Therefore, as with the wetland areas outlined above, this wetland is not regulated by Part 303. In summary, based on the new hydrologic data and permeability testing, the only wetland areas shown on the subject wetland delineation which are regulated are wetlands W-6B and W-8B, which both have a direct surface water connection to the Grand River. Neither of these two State-Regulated Wetlands are within the project limit and no activity is proposed in these areas by the remedial plan.

Therefore, based on the above regulatory analysis, none of the wetland areas which may be altered or impacted by the proposed remedial capping project are regulated by MDEQ, and therefore wetland compensatory mitigation is not applicable under State Statute. Regardless of State Wetland Regulatory Authority, the proposed remedial plan provides for no wet loss of wetland area as discussed below under the heading Federal Regulation. The remedial plan complies with State Wetland Regulation.

Federal Regulation

The wetlands on the site would be regulated by Federal Statute under normal circumstances. The Federal Wetland Regulatory Authority lies within Section 404 of the Clean Water Act of 1977, P.L. 92-500. Although the State of Michigan has formally assumed Section 404 authority for interior waters of the state, the federal government retained authority over wetlands adjacent to Section 10 waters. This previously noted, the Grand River is a Section 10 navigable waterway in this location. The permeability and hydrological isolation data discussed previously may also delete regulation on those perch wetlands similar to the state. However, this determination is made on a case by case basis.

Federal Wetland Regulatory promulgation provides for goals of avoiding wetland loss, minimizing wetland impact, and compensating for unavoidable impacts such that there is no net loss of wetland on a project site.

In order to accomplish the basic project purpose of capping the landfill, some alteration of wetland is unavoidable. The following discussion is keyed to the enclosed wetland graphic and details what is proposed for each wetland area.

Wetland A (W7B). This wetland area is presently 0.69 acres in size. Within and adjacent to this wetland is shallow waste which is proposed to be removed and the wetland area regarded and expanded (see the typical drawing depicting wetland edge treatment). As a result of waste removal and regrading the wetland area is proposed to be expanded to at least 2.33 acres, resulting in net wetland creation of 1.64 acres and restoration/enhancement of the existing 0.69 acres. See Sheets 3 and 5 of the large-format 95% design plans. The water level in this expanded wetland will be partially controlled by placement of a culvert which will outlet to undisturbed wetlands to the west. See typical culvert inlet and outlet details on Sheet 10.

For all proposed wetland culvert outlets, a 25-year design storm event was utilized to size the pipes. This design storm event was chosen such that each of the wetlands will have fluctuating water levels to reflect hydrology of a natural system. Pulse inundation areas will exist slightly above the culvert inverts to provide additional elevational saturation during storms exceeding a 25-year event. Note all proposed wetland acreage is measured to the culvert inverts, while it is anticipated periodic pulse inundation will support wetland formation above the design grades.

Wetland A is proposed for a maximum water depth of 2.23 feet. The wetland will slope from east to west and provide a habitat range from saturated scrub-shrub to shallow-water emergent.

Wetland B (W6B). This wetland lies outside the landfill and proposed earth change limit. No impact to this wetland is anticipated or proposed. There is no degradation of the wetland due to historical waste placement.

Wetland C (W4B). This wetland is presently 0.45 acres in size and will remain at least the same size after remedial action completion. The south edge of the wetland is presently degraded by the presence of shallow waste. See typical wetland edge treatment cross-section for example of edge remediation. An overflow culvert will be placed outletting to Wetland B. The culvert size and pulse inundation scenario are the same as for Wetland A. Since most of this wetland will be left intact, habitat types are not expected to change.

Wetland D (W3B). This wetland will receive restorative edge treatment identical to Wetland C. The hydrological and habitat regimes are expected to remain unchanged.

Wetland E (W1B). This wetland will remain unchanged, with minor edge restoration per Wetland C. The hydrology will be controlled by a culvert outletting to the CSO ditch. Present hydrological and habitat regimes are expected to remain, with pulse inundation occurring per Wetland A.

Wetland F (E2B). This wetland is presently 1.01 acres in size. Upon completion of the proposed remedial plan, the wetland area will increase to 3.82 acres, for a net proposed wetland area increase of 2.81 acres. Existing degraded edges will be restored per previous wetland discussions. Expanded wetland area will be graded to provide similar habitat regimes as the existing area, that being primarily saturated scrub-shrub to shallow-water emergent. Maximum design water level is proposed to be 1.2 feet, with a culvert control having periodic pulse inundation as discussed previously, and outletting to the CSO ditch.

Wetland G (E1B). This wetland is currently 0.80 acres in size and will remain unchanged upon completion of the proposed remedial plan. Edge restoration activities will occur per previous discussion and a culvert with outlet to the CSO ditch will provide hydrological regimes as outlined for other areas.

Wetland H (W8B). This wetland lies exterior of the waste and earth-change limit and will remain unchanged. There is no degradation of the wetland due to hydrological waste placement.

Summary of wetland impact. Existing wetland on the site totals 6.57 acres. Within the earth change limits, wetland areas total approximately 4.9 acres. As a result of implementing the proposed remedial plan, a net wetland increase of 4.45 acres will result, nearly doubling the wetland acreage on site. In addition, the plan provides for remedial restoration of all wetland edges degraded by historical waste placement and provides level controls which result in fluctuating wetland water regimes.

Therefore the proposed remedial plan complies with both State and Federal wetland regulation by:

1) Totally avoiding any wetland take.
2) Restoring all degraded wetland edges.
3) Providing for no net loss of wetlands.
4) Providing for a net wetland area increase with varied hydrological and habitat regimes.

APPENDIX B-2

WETLAND HYDROLOGY CALCULATIONS

COMPUTATION SHEET

RMT INC.

1143 Highland Drive, Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Wetlands Calculations	By: SGH	Date: 02/27/97	GRC	10/1/98	3938.64

OBJECTIVE:

Determine the depth of standing water in each wetland after the 25-year, 24-hour storm event. Determine the invert elevations for the following culverts/channels:

- Wetland A to Western Creek (Culvert A)
- Wetland E to the CSO (Culvert B)
- Wetland G to Wetland F (Culvert C)
- Wetland F to the CSO (Culvert D)
- Wetland C to Wetland B (Culvert E)

METHODOLOGY:

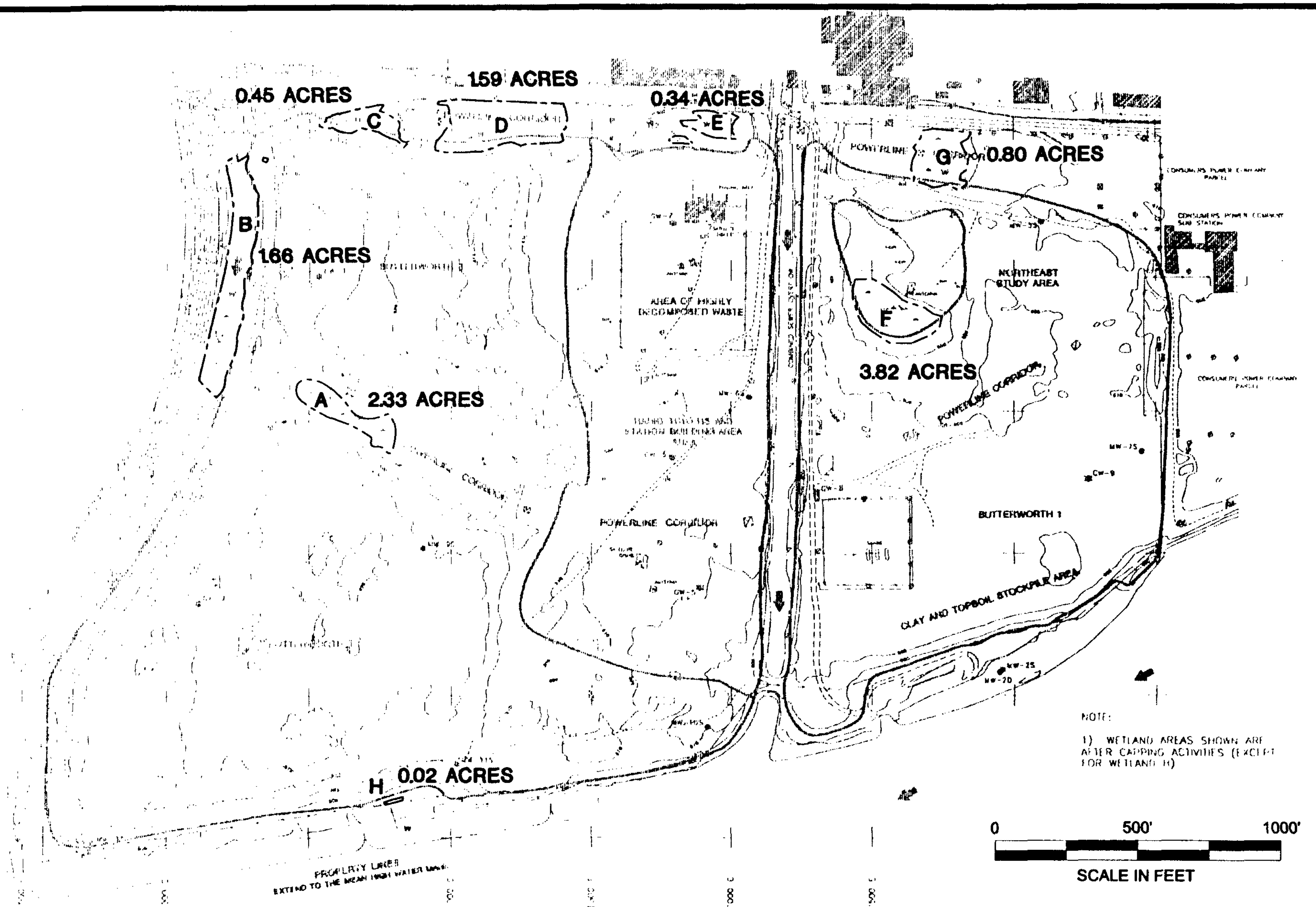
Use the depth in inches of runoff from the "Surface Water Calculations" package submitted as part of the Remedial Design. Multiply that depth by the drainage areas for each watershed and divide that volume by the surface area of each wetland to determine the depth of surface water in each wetland after the storm event. Each wetland will be designed to hold the 10-year, 24-hour storm event. Determine the water elevation after the 10-year, 24-hour storm event and set the invert elevation there.

Run-off from the 10-year event was calculated using the "Watershed Interconnected-Nodal Modeling Package (WIMP)" using methodology developed in "Urban Hydrology for Small Watersheds" (U.S. Dept. of Agriculture, 1986). While information regarding the model is included as sheets 12-20, a more detailed explanation of variables can be found in the "Surface Water Calculations".

CONCLUSION:

Wetland Designation (See sheet 10 of 31)	Area before Capping (acres)	Area after Capping (acres)	Depth of water in wetland (feet)
A	0.69	2.33	2.20
B	1.66	1.66	N/A
C	0.45	0.45	1.41
D	1.59	1.59	1.59
E	0.34	0.34	2.10
F	1.23	3.82	1.16
G	0.80	0.80	2.00
H	0.02	0.00	-

The invert elevation for Culvert A is 600.2 feet.
The invert elevation for Culvert B is 600.4 feet.
The invert elevation for Culvert C is 599.7 feet.
The invert elevation for Culvert D is 600.9 feet.
The invert elevation for Culvert E is 600.1 feet.



BUTTERWORTH LF REMEDIAL DESIGN	DRAWN BY: SGH	PROJ. NUMBER 3938.14
EXISTING WETLANDS	CHECKED BY:	FILE NUMBER 39381409
	APPROVED BY:	DATE:

RMT INC.

1143 HIGHLAND DRIVE, SUITE B
ANN ARBOR, MI 48108-2237
P.O. BOX 991 48106-0991
PHONE: 313-971-7080

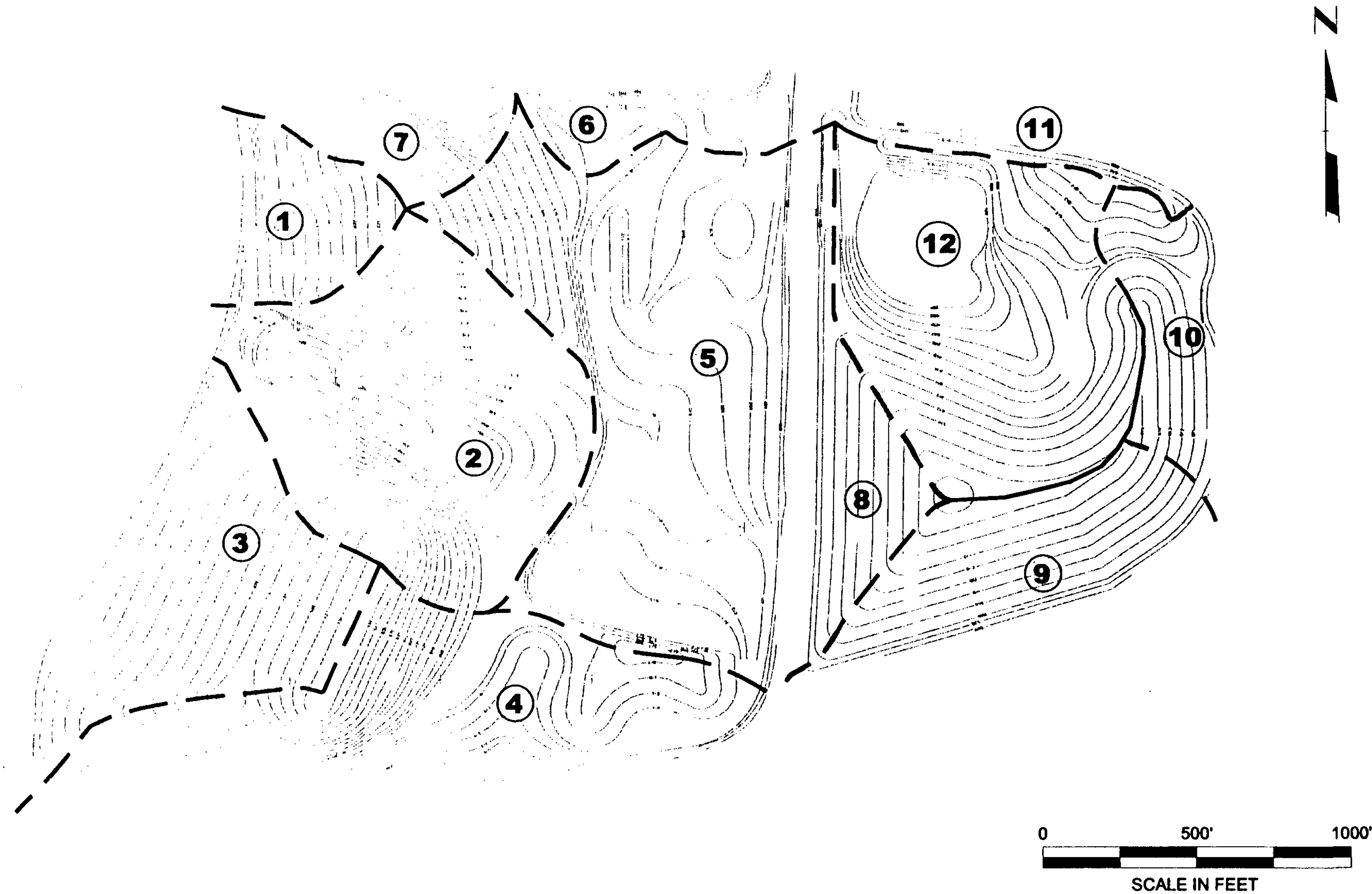
PLOT DATA

Drawing Name: J:\03938\64\39386410.DWG

Operator Name: lucidos
Scale: 1"=500'

Dwg Size: 149619 Bytes
Plot Date: Friday, October 2, 1998

Plot Time: 3:58.4973 PM
Attached Xref's: No xref's Attached.



RMT COMPUTER AIDED DESIGN AND DRAFTING

BUTTERWORTH LANDFILL
GRAND RAPIDS, MICHIGAN

WATERSHED AREAS

DRAWN BY:	SJL
APPROVED BY:	GRC
PROJECT NUMBER:	3938.64
FILE NUMBER:	39386410.DWG
DATE:	OCTOBER 1998

RMT INC. MICHIGAN

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Wetlands Calculations	By: SGH	Date: 02/27/97	GRC	10/1/98	3938.64

CALCULATIONS:

- Determine the standing water in each wetland after the 25-year, 24-hour storm

Direct runoff from the 25-year, 24-hour storm event is 2.46 inches.

Wetland A (see sheet 10) takes the runoff from watershed 2.

Watershed 2 Area (see sheet 11) = 25 acres
= 1,089,000 sq. ft

Volume = 1,163,052 * 2.46 / 12
= 223,245 cu. ft

Wetland A Area (after capping) = 2.33 acres
= 101,495 sq. ft

Depth of water in wetland = 238,426 / 101,495
= 2.20 feet

Wetland B (see sheet 10) takes the runoff from watershed 1.
However, wetland B immediately drains into Western Creek; depth of water in wetland does not need to be calculated

Wetland C takes half the runoff from Watershed 7.

1/2 of Watershed 7 = 3.1 acres
= 135,036 sq. ft

Volume = 135,036 * 2.46 / 12
= 27,682 cu. ft

Wetland C Area = 0.45 acres
= 19,602 sq. ft

Depth of water in wetland = 27,682 / 19,602
= 1.41 feet

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Wetlands Calculations	By: SGH	Date: 02/27/97	GRC	10/1/98	3938.64

CALCULATIONS (cont.,)

Wetland D takes half of the runoff from Watershed 7 & half of Watershed 6.

One half of Watershed 6 & 7 = 12.30 acres
= 535,788 sq. ft

Volume = 535,788 * 2.46 / 12
= 109,837 cu. ft

Wetland D Area = 1.59 acres
= 69,260 sq. ft

Depth of water in wetland = 109,837 / 69,260
= 1.59 feet

Wetland E takes 1/2 of the runoff from watershed 6

1/2 * Watershed 6 Area = 3.48 acres
= 151,371 sq. ft

Volume = 151,371 * 2.46 / 12
= 31,031 cu. ft

Wetland E Area = 0.34 acres
= 14,810 sq. ft

Depth of water in wetland = 31,031 / 14,810
= 2.10 feet

Wetland F takes the runoff from watershed 12

Watershed 12 area = 21.7 acres
= 945,252 sq. ft

Volume = 945,252 * 2.46 / 12
= 193,777 cu. ft

Wetland F Area (after capping) = 3.82 acres
= 166,399 sq. ft

Depth of water in wetland = 193,777 / 166,399
= 1.16 feet

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Wetlands Calculations	By: SGH	Date: 02/27/97	GRC	10/1/98	3938.64

CALCULATIONS (cont.,)

Wetland G takes the runoff from watershed 11. Multiply the watershed area by three to account for off-site drainage areas.

Watershed 11 area = 7.8 acres
= 339,768 sq. ft

Volume = 339,768 * 2.46 / 12
= 69,652 cu. ft

Wetland G Area = 0.8 acres
= 34,848 sq. ft

Depth of water in wetland = 69,652 / 34,848
= 2.00 feet

Wetland H will be eliminated during construction activities. The loss of 0.02 acres of wetland will be offset by the creation of an additional 2+ acres in Wetland F after construction of the remedial action.

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Wetlands Calculations	By: SGH	Date: 02/27/97	GRC	10/1/98	3938.64

CALCULATIONS (cont.,)

- Determine the invert elevation of Culvert A

Use WIMP, a surface-water modeling package, to determine the runoff from Watershed 2 for the 10-year, 24-hour storm.

Input variables:	Length of flow path:	645 feet
	Average slope:	4.40%
	2-year, 24-hour rainfall	2.7 inches
	10-year, 24-hour rainfall	3.9 inches

Direct runoff from 10-year, 24-hour storm event is 1.88 inches.

Wetland A takes the runoff from watershed 2

Watershed 2 Area = 25 acres
= 1,089,000 sq. ft

Volume = 1,163,052 * 1.88 / 12
= 170,610 cu. ft

Wetland A Area = 2.33 acres
= 101,495 sq. ft

Depth of water in wetland = 182,211 / 101,495
= 1.68 feet

The elevation of the wetland floor is 598.5 feet

Invert Elevation = 600.18 feet

COMPUTATION SHEET

1143 Highland Drive, Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Wetlands Calculations	By: SGH	Date: 02/27/97	GRC	10/1/98	3938.64

CALCULATIONS (cont.,)

- Determine the invert elevation Culvert E

Use WIMP, a surface-water modeling package, to determine the depth of runoff from Watershed 7A for the 10-year, 24-hour storm.

Input variables:	Length of flow path:	420 feet
	Average slope:	6.00%
	2-year, 24-hour rainfall	2.7 inches
	10-year, 24-hour rainfall	3.9 inches

Direct runoff from 10-year, 24-hour storm event is 1.88 inches.

Wetland C takes 1/2 the runoff from Watershed 7A

Watershed 7A Area = 3.1 acres
= 135,036 sq. ft

Volume = 135,036 * 1.88 / 12
= 21,156 cu. ft

Wetland C Area = 0.45 acres
= 19,602 sq. ft

Depth of water in wetland = 21,156 / 19,602
= 1.08 feet

The elevation of the wetland floor is 599 feet

Invert Elevation = 600.08 feet

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Wetlands Calculations	By: SGH	Date: 02/27/97	GRC	10/1/98	3938.64

CALCULATIONS (cont.,)

- Determine the invert elevation of Culvert B

Use WIMP, a surface-water modeling package, to determine the depth of runoff from Watershed 6 for the 10-year, 24-hour storm.

Input variables:	Length of flow path:	715 feet
	Average slope:	1.90%
	2-year, 24-hour rainfall	2.7 inches
	10-year, 24-hour rainfall	3.9 inches

Direct runoff from 10-year, 24-hour storm event is 1.88 inches.

Wetland E takes 1/4 the runoff from watershed 6

1/4 * Watershed 6 Area = 3.48 acres
= 151,371 sq. ft

Volume = 151,371 * 1.88 / 12
= 23,715 cu. ft

Wetland E Area = 0.34 acres
= 14,810 sq. ft

Depth of water in wetland = 23,715 / 14,810
= 1.60 feet

The elevation of the wetland floor is 598.8 feet

Invert Elevation = 600.40 feet

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Wetlands Calculations	By: SGH	Date: 02/27/97	GRC	10/1/98	3938.64

CALCULATIONS (cont.,)

- Determine the invert elevation of Culvert D

Use WIMP, a surface-water modeling package, to determine the depth of runoff in Watershed 11 for the 10-year, 24-hour storm.

Input variables:	Length of flow path:	80 feet
	Average slope:	17.80%
	2-year, 24-hour rainfall	2.7 inches
	10-year, 24-hour rainfall	3.9 inches

Direct runoff from 10-year, 24-hour storm event is 1.88 inches.

Wetland G takes the runoff from watershed 11. Multiply the watershed area by three to account for off-site drainage areas.

Watershed 11 Area = 7.8 acres
= 339,768 sq. ft

Volume = 339,768 * 1.88 / 12
= 53,230 cu. ft

Wetland G Area = 0.8 acres
= 34,848 sq. ft

Depth of water in wetland = 53,230 / 34,848
= 1.53 feet

The elevation of the wetland floor is 599.4 feet

Invert Elevation = 600.93 feet

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Wetlands Calculations	By: SGH	Date: 02/27/97	GRC	10/1/98	3938.64

CALCULATIONS (cont.,)

- Determine the invert elevation of Culvert C

Use WIMP, a surface-water modeling package, to determine the depth of runoff from Watershed 12 for the 10-year, 24-hour storm event.

Input variables:	Length of flow path:	685 feet
	Average slope:	2.50%
	2-year, 24-hour rainfall	2.7 inches
	10-year, 24-hour rainfall	3.9 inches

Direct runoff from 10-year, 24-hour storm event is 1.88 inches.

Wetland F takes the runoff from Watershed 12

Watershed 12 Area = 21.7 acres
= 945,252 sq. ft

Volume = 945,252 * 1.88 / 12
148,089 cu. ft

Wetland F Area = 3.82 acres
= 166,399 sq. ft

Depth of water in wetland = 148,089 / 166,399
= 0.89 feet

The elevation of the wetland floor is 598.8 feet

Invert Elevation = 599.69 feet

Appendix A: Hydrologic soil groups

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Soils are classified into hydrologic soil groups (HSG's) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSG's, which are A, B, C, and D, are one element used in determining runoff curve numbers (see chapter 2). For the convenience of TR-55 users, exhibit A-1 lists the HSG classification of United States soils.

The infiltration rate is the rate at which water enters the soil at the soil surface. It is controlled by surface conditions. HSG also indicates the transmission rate—the rate at which the water moves within the soil. This rate is controlled by the soil profile. Approximate numerical ranges for transmission rates shown in the HSG definitions were first published by Musgrave (USDA 1955). The four groups are defined by SCS soil scientists as follows:

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

In exhibit A-1, some of the listed soils have an added modifier; for example, "Abrazo, gravelly." This refers to a gravelly phase of the Abrazo series that is found in SCS soil map legends.

Disturbed soil profiles

As a result of urbanization, the soil profile may be considerably altered and the listed group classification may no longer apply. In these circumstances, use the following to determine HSG according to the texture of the new surface soil, provided that significant compaction has not occurred (Brakensiek and Rawls 1983):

HSG	*Soil textures*
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Drainage and group D soils

Some soils in the list are in group D because of a high water table that creates a drainage problem. Once these soils are effectively drained, they are placed in a different group. For example, Ackerman soil is classified as A/D. This indicates that the drained Ackerman soil is in group A and the undrained soil is in group D.

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)...........		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way).........................		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way).................................		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]...		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders).		96	96	96	96
Urban districts:					
Commercial and business..........................	85	89	92	94	95
Industrial..	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses).....................	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
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

"Urban Hydrology for Small Watersheds", Technical Release 55,
U.S. Dept. of Agriculture, June 1986

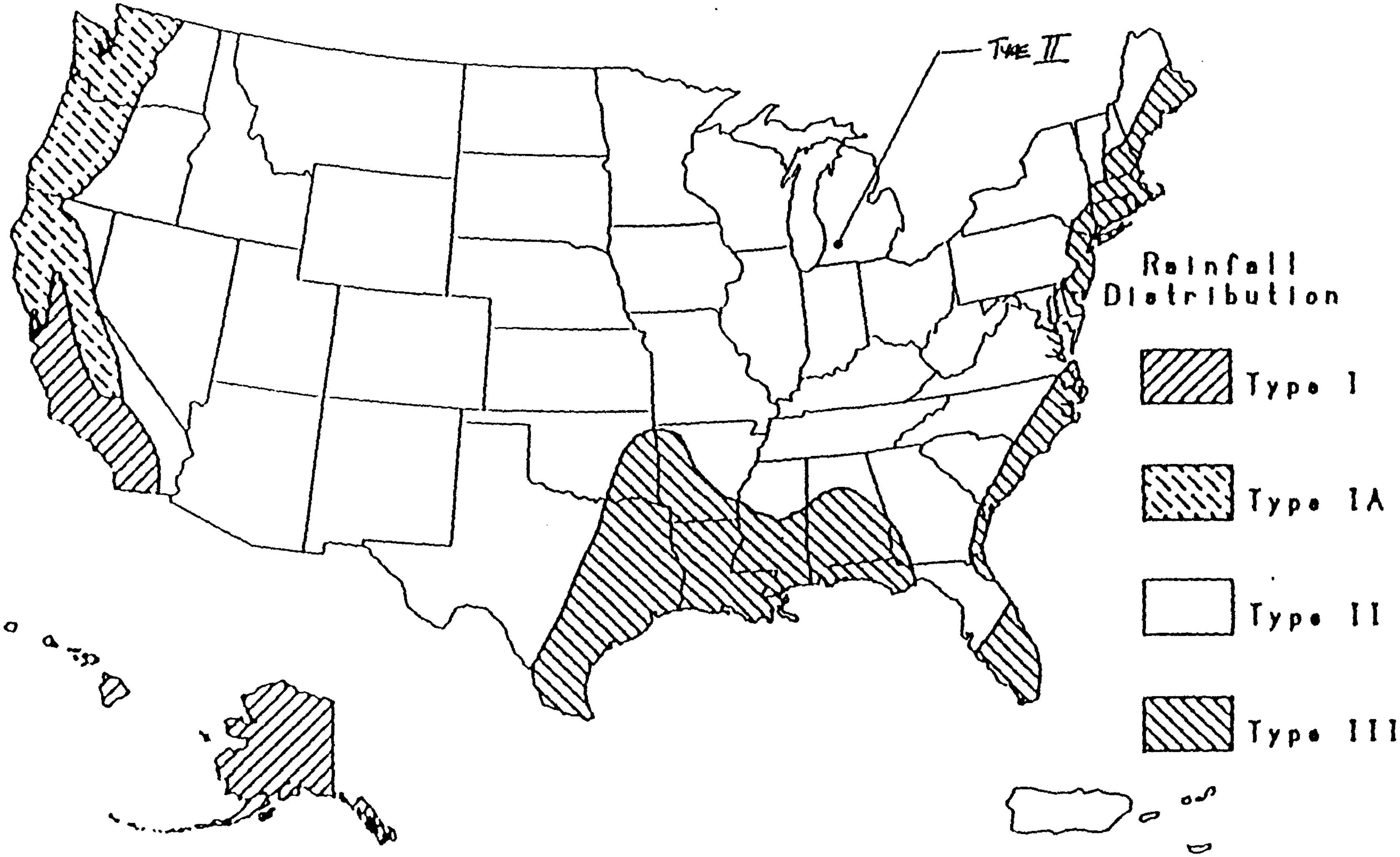
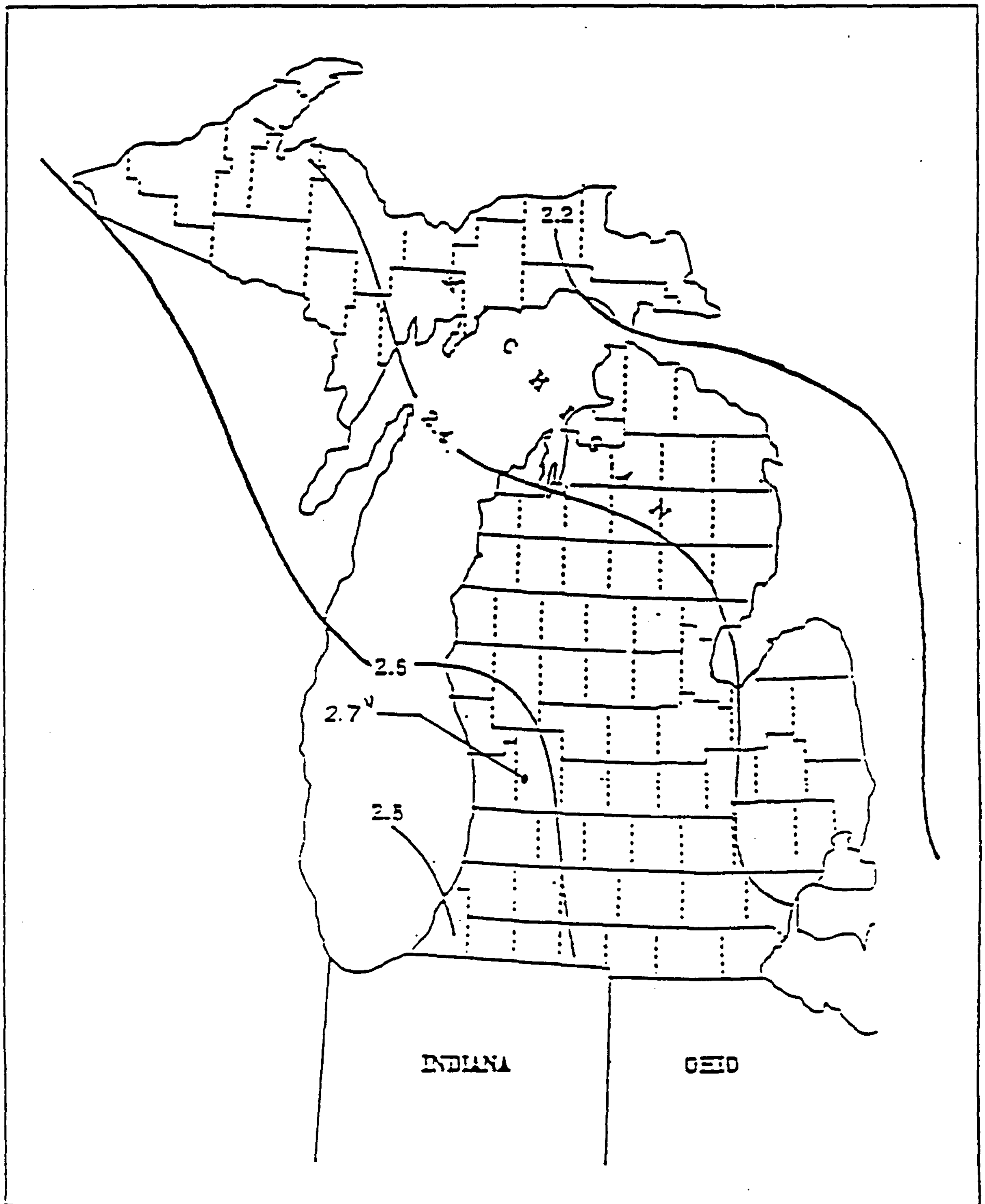


Figure B-2.—Approximate geographic boundaries for SCS rainfall distributions.

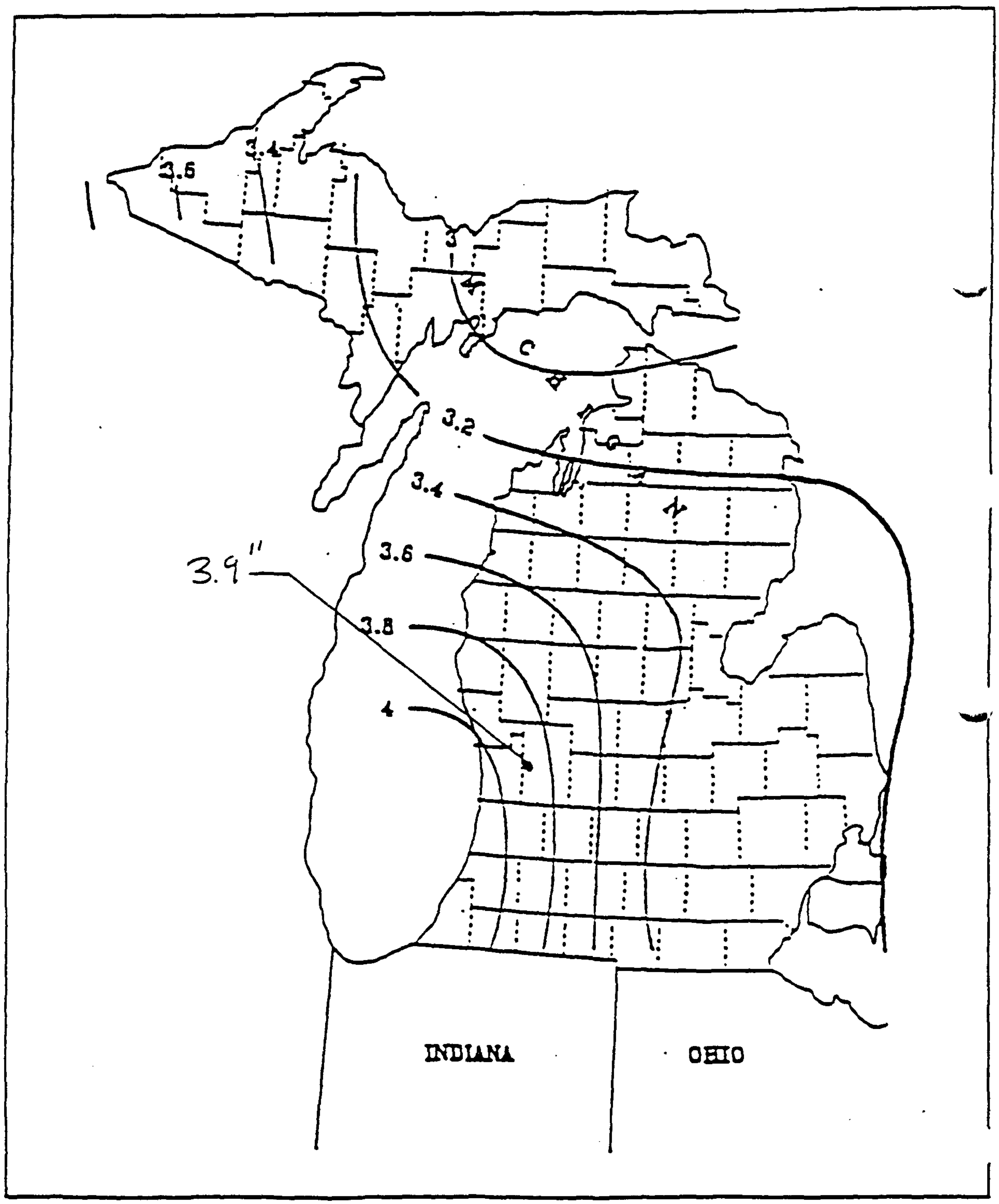
"Urban Hydrology for Small Watersheds", Technical Release 55,
U.S. Dept. of Agriculture, June 1986

Figure 3.1 2-year, 24-hour rainfall



"Guidebook of Best Management Practices for Michigan Watersheds",
Michigan Department of Natural Resources, Surface Water Quality Division, 1994

Figure 3.3 10-year, 24-hour rainfall



"Guidebook of Best Management Practices for Michigan Watersheds", Michigan Department of Natural Resources, Surface Water Quality Division, 1994

Hydrograph - SCS TR-55 Node

A SCS TR-55 node will generate a composite storm hydrograph for up to five watershed sub-areas using the SCS TR-55 tabular hydrograph method.

```
              WATERSHED INTERCONNECTED-NODAL MODELING PACKAGE
                      EDIT NODE - SCS TR55 HYDROGRAPH

Node: ONE, ACTIVE        Description:                      Outflow Node: END

             Tc          Tt          Area        CN      Description

    1    0.1000__    ___0.000    _____12.56    _90    _________Lower Area
    2    _{0.490}    ___0.000    ______13.8    _65    _______________
    3    ___0.000    ___0.000    _________0    _75    _______________
    4    ___0.000    ___0.000    _________0    _75    _______________
    5    ___0.000    ___0.000    _________0    _75    _______________

                                       SCS RAINFALL DISTRIBUTION
                                       ( )     Type I
  Rainfall Depth ___3.56               ( )     Type Ia
                                       ( )     Type II
                                       ( )     Type III

 Prompt:   Time of Concentration, in Hours, press F2 or Alt-C for calculator

 Settings            Help Alt-H            Quit-Esc            End-F10
```

Input — The input for this node type includes: 24 hour rainfall depth in inches, SCS storm distribution type (I, Ia, II, III) and for each watershed sub-area: Area in acres, Tc (time of concentration) in hours, Tt (time of travel) in hours, CN (SCS runoff curve number) and an optional description.

WIMP requires that at minimum; the 24 hour rainfall depth and one sub-area data line of Tc, CN, Area be entered.

To assist the user in calculating Tc and Tt, WIMP has been provided with built-in Tc and Tt calculators. A calculator is invoked by pressing the F2 key or the Alt-C key combination while a Tc or Tt field is highlighted. The Tc and Tt calculators provide a number of common techniques for the calculation of Tc and Tt. Refer to Appendix B for a listing of Tc and Tt equations used by WIMP. Once the user has supplied all desired information in the calculator screen, pressing F10 will transfer the calculated Tc or Tt into the hydrograph sub-area field. Calculated values of Tc and Tt are shown as being different from those directly entered by the user by having their values bracketed by { }. A Tc or Tt field computed by the calculator is edited by invoking the calculator while the value is highlighted. A sample Tc screen is provided.

WATERSHED INTERCONNECTED-NODAL MODELING PACKAGE
EDIT NODE - SCS TR55 HYDROGRAPH

Node: ONE, ACTIVE Description: Outflow Node: END

WATERSHED INTERCONNECTED MODELING PACKAGE - Tc CALCULATOR
Node: ONE Sub-Area: 2

	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
Manual 1							0
Manual 2							0.01
Kinematic Wave	0	0	0	0			0.000
SCS Lag	0			0	0		0.000
SCS Sheet	150	0.3		0.05		1.5	0.398
Shallow Paved	0			0			0.000
Shallow NPaved	752			0.025			0.082

Prompt: Manually calculated Tc, in hours Total Tc 0.480

Calculate Help Alt-H Quit-Esc End-F10

Each row of the calculator represents a Tc equation. While in the calculator, pressing Alt-C or selecting the Calculate button will calculate the total Tc based on all user input. The total Tc will be displayed at the lower right hand corner of the screen. Note that WIMP will only calculate a Tc row where all user-supplied input is valid.

Output All calculation parameters for the SCS TR-55 tabular hydrograph generation and the hydrograph for each sub-area will be included in the output. Plots containing both tabular and graphical representations of the hydrograph output are produced.

Example The input provided on the sample screen will produce a composite storm hydrograph from the combined hydrographs of two sub-areas.

B.11 T_C CALCULATION

The T_C calculator provided with WIMP contains several methods for T_C calculation. Each of the methods is identified and the appropriate equations are provided below. A hydrology reference can be sought for further explanation of the application and applicability of these equations.

B.11.1 Kinematic Wave Equation

$$T_c = \frac{0.94\, L^{0.6}\, n^{0.6}}{i^{0.4}\, S^{0.3}}$$

Where

T_C	Time of concentration, in hours
L	Length of overland flow, in feet
n	Mannings surface roughness coefficient
i	Rainfall intensity, in inches per hour
S	Average Overland Slope, in feet per feet

B.11.2 SCS Lag Equation

$$T_c = \frac{1.67 * L^{0.8} \left[\frac{1000}{CN} - 9\right]^{0.7}}{1900\, [100 * S]^{0.5}}$$

Where

T_C	Time of concentration, in hours
L	Length of overland flow, in feet
CN	SCS curve number
S	Average Overland Slope, in feet per feet

B.11.3 SCS Sheet Flow Equation

$$T_c = \frac{0.007\, (nL)^{0.8}}{P_2^{0.5}\, S^{0.4}}$$

Where

T_C	Time of concentration, in hours
L	Length of overland flow, in feet
n	Mannings surface roughness coefficient
P2	2-year 24-hour rainfall depth, in inches
S	Average Overland Slope, in feet per feet

B.2 HYDROGRAPH - SCS TR-55

TR-55 hydrographs generated by WIMP utilize the Soil Conservation Service Technical Release 55 (SCS TR-55) Tabular Hydrograph method. Below are the detailed steps taken by WIMP in the generation of SCS TR-55 hydrographs. This method requires two steps; first, the estimation of watershed parameters (rounded Tc and Tt, and SCS TR-55 parameters Q, Ia/P); the second step develops the hydrograph utilizing the SCS TR-55 unit discharge tables.

B.2.1 Calculation Step 1 - Estimation of Watershed Parameters

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Where

Q Runoff depth in inches

P 24 hour rainfall depth in inches

S Potential maximum retention before runoff begins (see below)

$$S = \frac{1000}{CN} - 10$$

Where

CN SCS Runoff Curve number (varies from 40 to 98, as supplied by user)

$I_a = 0.2S$ (used for the calculation of I_a/p)

Where

I_a Initial abstraction in inches

WIMP must round the user-supplied Tc and Tt values for each watershed sub-area to match those available from the TR-55 unit discharge tables. Valid table values of Tc are: 0.10, 0.20, 0.30, 0.40, 0.50, 0.75, 1.00, 1.25, 1.50, and 2.00 hours. Valid table values for Tt are: 0.0, 0.10, 0.20, 0.30, 0.40, 0.50, 0.75, 1.00, 1.50, 2.00, 2.50, and 3.00 hours. The rounded values of Tc and Tt are determined by performing and analyzing three roundings of the user-supplied values. The rounded values from the method providing the sum of rounded Tc and Tt closest to the sum of the user-supplied values are used for the development of the hydrograph in the second step. The three rounding methods are summarized below. The rounding performed by each method is done such that the values are rounded to the closest, valid table values.

Method	Tc	Tt
1	Nearest	Nearest
2	Down	Up
3	Up	Down

Node A will generate a composite SCS TR-55 Hydrograph

INPUT SUMMARY

24 Hour Rainfall : 3.9 (inches)
Rainfall Distribution Type : II

SUB	ENTERED		ROUNDED		AREA	CN
	Tc (hr)	Tt (hr)	Tc (hr)	Tt (hr)	(acre)	
1	{0.534}	0.000	0.5	0	6.200	79
2	{0.576}	0.000	0.5	0	26.700	79
3	{0.618}	0.000	0.5	0	16.100	79
4	{0.585}	0.000	0.5	0	26.700	79
5	{1.077}	0.000	1	0	9.000	79

Tc calculations for Node: A Sub-Area: 1

Node: A Sub-Area: 1

EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	580	0.15		0.043		2.7	0.534
						Total Tc (hours)	0.534

Tc calculations for Node: A Sub-Area: 2

Node: A Sub-Area: 2

EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	645	0.15		0.044		2.7	0.576
						Total Tc (hours)	0.576

Tc calculations for Node: A Sub-Area: 3

Node: A Sub-Area: 3							
EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	680	0.15		0.041		2.7	0.618
						Total Tc (hours)	0.618

Tc calculations for Node: A Sub-Area: 4

Node: A Sub-Area: 4							
EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	650	0.15		0.043		2.7	0.585
						Total Tc (hours)	0.585

Tc calculations for Node: A Sub-Area: 5

Node: A Sub-Area: 5							
EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	850	0.15		0.016		2.7	1.077
						Total Tc (hours)	1.077

SUB	Area (sq-mi)	Q (in)	Am Q (sq-mi-in)	Ia (in)	Ia/P	ROUNDED Ia/P
1	0.010	1.883	0.018	0.532	0.136	0.136
2	0.042	1.883	0.079	0.532	0.136	0.136
3	0.025	1.883	0.047	0.532	0.136	0.136
4	0.042	1.883	0.079	0.532	0.136	0.136
5	0.014	1.883	0.026	0.532	0.136	0.136

SCS TR-55 Unit Discharge tables used for interpolation

SUB	LOWER UNIT DISCHARGE TABLE			UPPER UNIT DISCHARGE TABLE		
	Tc (hr)	Tt (hr)	Ia/P	Tc (hr)	Tt (hr)	Ia/P
1	0.5	0	0.1	0.5	0	0.3
2	0.5	0	0.1	0.5	0	0.3
3	0.5	0	0.1	0.5	0	0.3
4	0.5	0	0.1	0.5	0	0.3
5	1	0	0.1	1	0	0.3

Project: Butterworth Surface Water Checks

Project Number 03938 By SGH Chk GRC Rev

Time (hr)	Sub-Area 1	Sub-Area 2	Sub-Area 3	Sub-Area 4	Sub-Area 5	Total (cfs)
11.00	0.25	1.09	0.66	1.09	0.24	3.33
11.30	0.34	1.48	0.89	1.48	0.32	4.51
11.60	0.48	2.06	1.24	2.06	0.43	6.26
11.90	0.85	3.68	2.22	3.68	0.63	11.05
12.00	1.43	6.17	3.72	6.17	0.76	18.25
12.10	2.71	11.68	7.04	11.68	1.04	34.15
12.20	5.12	22.03	13.28	22.03	1.64	64.10
12.30	8.01	34.49	20.80	34.49	2.63	100.42
12.40	9.33	40.18	24.23	40.18	4.04	117.94
12.50	9.02	38.85	23.43	38.85	5.66	115.80
12.60	7.26	31.24	18.84	31.24	7.20	95.78
12.70	5.42	23.36	14.08	23.36	8.30	74.51
12.80	4.16	17.91	10.80	17.91	9.04	59.81
13.00	2.62	11.27	6.79	11.27	8.19	40.13
13.20	1.82	7.85	4.74	7.85	6.27	28.54
13.40	1.42	6.11	3.69	6.11	4.65	21.98
13.60	1.18	5.08	3.06	5.08	3.57	17.96
13.80	1.03	4.42	2.67	4.42	2.79	15.33
14.00	0.92	3.95	2.38	3.95	2.27	13.47
14.30	0.80	3.43	2.07	3.43	1.75	11.48
14.60	0.70	3.03	1.83	3.03	1.40	9.98
15.00	0.63	2.71	1.64	2.71	1.13	8.82
15.50	0.57	2.46	1.49	2.46	0.94	7.93
16.00	0.51	2.21	1.33	2.21	0.83	7.11
16.50	0.46	1.96	1.18	1.96	0.75	6.31
17.00	0.42	1.79	1.08	1.79	0.66	5.74
17.50	0.40	1.71	1.03	1.71	0.60	5.46
18.00	0.38	1.62	0.98	1.62	0.58	5.17
19.00	0.32	1.39	0.84	1.39	0.50	4.43
20.00	0.28	1.21	0.73	1.21	0.44	3.88
22.00	0.24	1.04	0.63	1.04	0.35	3.31
26.00	0.00	0.00	0.00	0.00	0.00	0.00

Node B will generate a composite SCS TR-55 Hydrograph

INPUT SUMMARY

24 Hour Rainfall : 3.9 (inches)
Rainfall Distribution Type : II

SUB	ENTERED		ROUNDED		AREA	CN
	Tc (hr)	Tt (hr)	Tc (hr)	Tt (hr)	(acre)	
6	{0.875}	0.000	0.75	0	13.900	79
7	{0.795}	0.000	0.75	0	9.200	79
7A	{0.361}	0.000	0.4	0	6.200	79

Tc calculations for Node: B Sub-Area: 6

Node: B Sub-Area: 6

EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	715	0.15		0.019		2.7	0.875
						Total Tc (hours)	0.875

Tc calculations for Node: B Sub-Area: 7

Node: B Sub-Area: 7

EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	810	0.15		0.031		2.7	0.795
						Total Tc (hours)	0.795

Tc calculations for Node: B Sub-Area: 7A

Node: B Sub-Area: 7A

EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	420	0.15		0.06		2.7	0.361
						Total Tc (hours)	0.361

SUB	Area (sq-mi)	Q (in)	Am Q (sq-mi-in)	Ia (in)	Ia/P	ROUNDED Ia/P
6	0.022	1.883	0.041	0.532	0.136	0.136
7	0.014	1.883	0.027	0.532	0.136	0.136
7A	0.010	1.883	0.018	0.532	0.136	0.136

SCS TR-55 Unit Discharge tables used for interpolation

SUB	LOWER UNIT DISCHARGE TABLE			UPPER UNIT DISCHARGE TABLE		
	Tc (hr)	Tt (hr)	Ia/P	Tc (hr)	Tt (hr)	Ia/P
6	0.75	0	0.1	0.75	0	0.3
7	0.75	0	0.1	0.75	0	0.3
7A	0.4	0	0.1	0.4	0	0.3

Project: Butterworth Surface Water Checks

Project Number 03938 By SGH Chk GRC Rev

Time (hr)	Sub-Area 6	Sub-Area 7	Sub-Area 7A	Total (cfs)
11.00	0.43	0.29	0.27	0.99
11.30	0.60	0.40	0.37	1.37
11.60	0.80	0.53	0.54	1.87
11.90	1.20	0.80	1.16	3.16
12.00	1.55	1.02	2.19	4.76
12.10	2.32	1.53	4.42	8.27
12.20	4.07	2.69	7.96	14.73
12.30	7.13	4.72	10.43	22.27
12.40	11.13	7.37	10.21	28.70
12.50	14.69	9.72	7.80	32.21
12.60	16.61	10.99	5.46	33.06
12.70	16.30	10.79	4.00	31.09
12.80	14.78	9.78	3.05	27.62
13.00	10.26	6.79	1.97	19.02
13.20	7.10	4.70	1.48	13.28
13.40	5.14	3.40	1.22	9.76
13.60	3.93	2.60	1.07	7.60
13.80	3.16	2.09	0.95	6.20
14.00	2.63	1.74	0.86	5.23
14.30	2.13	1.41	0.75	4.29
14.60	1.80	1.19	0.67	3.65
15.00	1.54	1.02	0.61	3.16
15.50	1.36	0.90	0.55	2.82
16.00	1.20	0.79	0.50	2.49
16.50	1.07	0.71	0.44	2.22
17.00	0.97	0.64	0.42	2.03
17.50	0.90	0.60	0.39	1.89
18.00	0.85	0.56	0.36	1.78
19.00	0.76	0.50	0.32	1.59
20.00	0.67	0.45	0.28	1.40
22.00	0.54	0.36	0.24	1.14
26.00	0.00	0.00	0.00	0.00

28 SHEET 204

Project Number 03938 By SGH Chk GRC Rev

Node C will generate a composite SCS TR-55 Hydrograph

INPUT SUMMARY

24 Hour Rainfall : 3.9 (inches)
Rainfall Distribution Type : II

SUB	ENTERED		ROUNDED		AREA	CN
	Tc (hr)	Tt (hr)	Tc (hr)	Tt (hr)	(acre)	
8	{0.449}	0.000	0.4	0	6.700	79
9	{0.445}	0.000	0.4	0	11.300	79
10	{0.320}	0.000	0.3	0	4.900	79
11	{0.062}	0.000	0.1	0	2.600	79
12	{0.758}	0.000	0.75	0	21.700	79

Tc calculations for Node: C Sub-Area: 8

Node: C Sub-Area: 8

EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	445	0.15		0.039		2.7	0.449
						Total Tc (hours)	0.449

Tc calculations for Node: C Sub-Area: 9

Node: C Sub-Area: 9

EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	440	0.15		0.039		2.7	0.445
						Total Tc (hours)	0.445

Tc calculations for Node: C Sub-Area: 10

Node: C Sub-Area: 10							
EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	280	0.15		0.036		2.7	0.320
						Total Tc (hours)	0.320

Tc calculations for Node: C Sub-Area: 11

Node: C Sub-Area: 11							
EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	80	0.15		0.178		2.7	0.062
						Total Tc (hours)	0.062

Tc calculations for Node: C Sub-Area: 12

Node: C Sub-Area: 12							
EQUATION DESCRIPTION	L (ft)	n	i (in/hr)	S (ft/ft)	CN	P-2 (in)	Tc (hr)
SCS SHEET	685	0.15		0.025		2.7	0.758
						Total Tc (hours)	0.758

SUB	Area (sq-mi)	Q (in)	Am Q (sq-mi-in)	Ia (in)	Ia/P	ROUNDED Ia/P
8	0.010	1.883	0.020	0.532	0.136	0.136
9	0.018	1.883	0.033	0.532	0.136	0.136
10	0.008	1.883	0.014	0.532	0.136	0.136
11	0.004	1.883	0.008	0.532	0.136	0.136
12	0.034	1.883	0.064	0.532	0.136	0.136

SCS TR-55 Unit Discharge tables used for interpolation

SUB	LOWER UNIT DISCHARGE TABLE			UPPER UNIT DISCHARGE TABLE		
	Tc (hr)	Tt (hr)	Ia/P	Tc (hr)	Tt (hr)	Ia/P
8	0.4	0	0.1	0.4	0	0.3
9	0.4	0	0.1	0.4	0	0.3
10	0.3	0	0.1	0.3	0	0.3
11	0.1	0	0.1	0.1	0	0.3
12	0.75	0	0.1	0.75	0	0.3

Time (hr)	Sub-Area 8	Sub-Area 9	Sub-Area 10	Sub-Area 11	Sub-Area 12	Total (cfs)
11.00	0.29	0.49	0.24	0.15	0.68	1.84
11.30	0.40	0.68	0.33	0.21	0.94	2.57
11.60	0.58	0.98	0.48	0.33	1.25	3.63
11.90	1.26	2.12	1.42	2.30	1.88	8.98
12.00	2.37	3.99	2.94	4.84	2.41	16.55
12.10	4.77	8.05	5.93	7.62	3.62	30.00
12.20	8.61	14.52	9.35	4.66	6.35	43.48
12.30	11.27	19.00	9.48	1.66	11.13	52.53
12.40	11.03	18.60	6.60	1.16	17.37	54.77
12.50	8.43	14.22	4.13	0.98	22.93	50.69
12.60	5.90	9.95	2.89	0.83	25.93	45.50
12.70	4.32	7.29	2.18	0.69	25.45	39.92
12.80	3.30	5.56	1.71	0.61	23.08	34.25
13.00	2.13	3.60	1.22	0.53	16.02	23.49
13.20	1.60	2.70	1.01	0.46	11.08	16.85
13.40	1.32	2.22	0.87	0.42	8.03	12.85
13.60	1.15	1.94	0.78	0.38	6.13	10.39
13.80	1.03	1.74	0.71	0.34	4.93	8.75
14.00	0.93	1.57	0.65	0.31	4.10	7.56
14.30	0.81	1.36	0.57	0.28	3.33	6.34
14.60	0.72	1.22	0.51	0.26	2.80	5.52
15.00	0.66	1.12	0.48	0.24	2.40	4.89
15.50	0.60	1.01	0.44	0.22	2.13	4.39
16.00	0.54	0.90	0.38	0.19	1.87	3.88
16.50	0.47	0.80	0.34	0.17	1.67	3.46
17.00	0.45	0.76	0.32	0.17	1.52	3.21
17.50	0.43	0.72	0.30	0.16	1.40	3.01
18.00	0.39	0.66	0.29	0.15	1.33	2.81
19.00	0.35	0.59	0.25	0.13	1.19	2.50
20.00	0.30	0.51	0.21	0.11	1.05	2.18
22.00	0.26	0.44	0.19	0.10	0.85	1.84
26.00	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX C

FUGITIVE DUST CONTROL AND AMBIENT VOC MONITORING PLAN

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Fugitive Dust Control Plan

Fugitive dust may be generated during the remedial action by construction equipment traveling over unpaved surfaces, by unloading soil, or as a result of cover placement and grading activities. The primary objective of the fugitive dust control plan is to prevent transport of nuisance levels of dust across the landfill property lines or around the radio station building. Another objective is to ensure that concentrations of airborne contaminants do not exceed OSHA PELs. The primary control of fugitive dust emissions will be to water frequently-traveled unpaved roads or soil working surfaces on an as-needed basis. In addition, the wheels on construction vehicles will be washed before leaving the site. The soil haul truck beds will be covered as they enter and leave the site.

The effectiveness of the fugitive dust control effort will be evaluated through a combination of visual observation and regular measurement of dust concentrations in downwind property line locations and in the workers' breathing zone. Concentrations of particulates in the air will be measured with a real-time instrument three times each day when activities that could generate significant amounts of fugitive dust are taking place at the site. The measurements will be taken at three to four locations on the property line that are downwind of dust-generating activities and in the worker's breathing zone. Additionally, when dust-generating activities are taking place upwind of the radio station building, particulate monitoring will also be conducted around the radio station. If applicable, locations where visible dust is evident will be preferentially selected for monitoring.

Airborne particles will be measured using a MIE, Inc., Miniram monitor. This is a hand-held field instrument that senses and measures dust concentrations in the range of 0.01 to 100 mg/m^3. The Miniram displays the 10-second averaged concentration on a direct-read liquid crystal display. Three measurements will be made each time a location is monitored. The average of the three readings will be recorded and used as the basis to decide whether more aggressive dust control measures are needed. The level at which additional actions will be taken will be decided in the field in consultation with the agency oversight contractor and will be based on best professional judgment as to what might be considered a nuisance to nearby residents, radio station personnel, or site workers. Conservative judgment will be used in order to minimize potential concern by residents, radio station personnel, and workers. The measured levels will be compared to the National Ambient Air Quality Standard (NAAQS) for particulate matter of 150 $\mu g/m^3$ (0.15 mg/m^3). It should be noted however, that because the NAAQS is a 24-hour exposure criteria, it is not directly applicable to the real-time dust measurements that will be made at this site. If dust levels in excess of 0.15 mg/m^3 are frequently indicated using the real-time monitoring instrument (the Miniram), then more sophisticated equipment may be used to measure 24-hour averaged concentrations in order to confirm compliance with the NAAQS for particulate matter.

Nuisance dust and visible dust problems will be investigated promptly. The first time that real-time measurements exceed 0.01 mg/m^3 airborne dust in the workers' breathing zone in a work area, a determination of the airborne levels of arsenic and lead will be made using traditional industrial hygiene sampling methods. A personal sampler with a PVC filter will be used to collect samples of the airborne dust in the workers' breathing zone. The samples will be analyzed for total dust and for the content of arsenic and lead. If the airborne levels of arsenic or lead exceed their PELs, then workers will upgrade to the appropriate level of personal protective equipment as outlined in the Site Health and Safety Plan.

Speciated measurements of the airborne concentrations of arsenic and lead will be made the first time the real-time measurements exceed 0.01 mg/m^3 in the workers' breathing zone in a work area and if the real-time dust readings increase substantially. Additional actions will be taken as necessary to control fugitive dust (*e.g.*, increasing the water application frequency or reducing the work areas in which dust is being generated). If dust problems persist for more than 2 days, then the EPA will be notified.

A log book of fugitive dust monitoring activities will be maintained. This book will document the dates, times, and locations of dust measurements and visual observations, work activities being performed at the monitoring location (for breathing zone measurements), problems and corrective actions taken, maintenance, and the monitoring results. Any concerns or complaints from the general public will also be recorded in the log book.

Ambient VOC Monitoring Plan

The personal protective air monitoring performed for unspeciated volatile organic compounds (VOCs) in accordance with the Site Health and Safety Plan will be used as a screening level of monitoring for off-site ambient air. It will be assumed that as long as the VOC concentrations in the workers' breathing zone are acceptable, that the ambient air off-site is also protected.

During work at the site in which waste will be exposed, measurements will be taken with a photoionization or flame ionization detector in the workers' breathing zone. Readings will be taken every 30 minutes (more frequently if conditions warrant). The instrument readout will be allowed to stabilize at least one minute prior to recording the reading. Readings will be recorded in the field log book.

The following action levels and response activities will be used:

I. WORKER'S BREATHING ZONE MONITORING

A. If the reading in the worker's breathing zone is <u>less than 1 ppm</u>, no additional action is necessary. Record the location and the reading in the field log book and continue with the monitoring as scheduled.

B. If sustained readings in the workers' breathing zone (*i.e.*, for 5 to 10 minutes) is <u>greater than 1 ppm, but less than 5 ppm</u>, use colorimetric detector tubes to assess whether the concentrations of benzene or vinyl chloride in the workers' breathing zone exceeds the OSHA PEL (1 ppm for both). If the benzene and vinyl chloride levels are less than 1 ppm, then no additional action is needed. Record the location and the reading in the field log book and continue with the monitoring as scheduled. Monitoring using colorimetric detector tubes does not need to be performed each time sustained PID readings greater than 1 ppm are measured in the same location. Detector tube monitoring should be used when sustained PID readings are greater than 1 ppm at a new work location or under varying conditions at the same location. At a minimum, detector tube monitoring should be performed once a day if sustained PID readings are greater than 1 ppm, even if the work location is the same.

If the benzene or vinyl chloride levels are greater than 1 ppm, then workers will upgrade to the appropriate levels of personal protective equipment as outlined in the Site Health and Safety Plan prior to continuing with work in that location.

C. If the reading in the worker's breathing zone is <u>greater than 5 ppm, but less than 10 ppm</u>, workers will upgrade to the appropriate level of personal protective equipment as outlined in the Site Health and Safety Plan prior to continuing with any additional activity in the working area. The monitoring technician will proceed to the nearest downwind property line to take and record a reading with the photoionization or flame ionization detector. The downwind property line will be determined using directional information from a windsock. The reading taken at that location will dictate what, if any, further action is needed. As necessary, the area of exposed waste may be reduced or eliminated by placing clean soil over the waste.

D. If the reading in the workers' breathing zone is greater than 10 ppm, work will be halted and mitigation measures will be taken immediate at the excavation location to reduce the ambient concentration of organics. All non-essential personnel will be evacuated from the work zone. Workers will evacuate to an area that is not downwind of the intrusive work. The monitoring technician will proceed to the nearest downwind property line to take and record a reading with the photoionization or flame ionization detector. The reading taken at that location will dictate what, if any, further action is needed. The downwind property line will be determined using directional information from a windsock. Finally, workers will complete the activities in the affected area using the appropriate level of respiratory protection (as specified in the Site Emergency Response Health and Safety Plan) based on continued PID measurements.

II. PROPERTY LINE MONITORING

(Property line monitoring will be initiated only if the VOC levels in the workers' breathing zone exceed 5 ppm.)

A. If the reading at the property line is less than 1 ppm, no additional action is necessary. Record the location and reading at the property line in the field log book and continue with monitoring in the workers' breathing zone as scheduled. Readings will be taken and recorded at the property line every 15 minutes for at least one hour after the initial reading to ensure that an increase in levels is not occurring. If an increase is noted, continue monitoring until the concentration has stabilized, or immediate evacuation is indicated.

B. If the reading at the property line is greater than 1 ppm but less than 5 ppm, record the location and reading at the property line in the field log and continue with monitoring at the workers' breathing zone as scheduled. In addition to this, readings will be taken and recorded at the property line every 15 minutes for at least one hour to ensure that an increase in levels is not occurring. After at least one hour of stabilized readings, continue with property line monitoring at the rate of at least one reading per hour while intrusive work is continuing. Property line monitoring may be discontinued if the property line concentration is consistently less than 1 ppm.

C. If the reading at the property line is greater than 5 ppm, work will be halted and mitigation measures will be taken immediately at the excavation location to reduce the ambient concentration of organics. All non-essential personnel will be evacuated from the work zone. Workers will evacuate to an area that is not downwind of the intrusive work. Record the location and reading of the property line every 15 minutes for at least one hour to ensure that the mitigation measures taken are adequate and an increase in levels is not occurring. Property line sampling should continue until work has completed for the day, or the property line concentration is consistently less than 1 ppm.

APPENDIX D

LANDFILL COVER MATERIAL QUANTITIES AND SPECIFICATIONS

- Appendix D-1 Landfill Cover Material Quantities
- Appendix D-2 Borrow Source Approval Letters
- Appendix D-3 CSO Earthen Dam Slope Stability

APPENDIX D-1

LANDFILL COVER MATERIAL QUANTITIES

744 Heartland Trail (53717-8923) P. O. Box 8923 (53708-8923) Madison, WI (608) 831-4444 FAX: (608) 831-3334 VOICE: (608) 831-1989

PROJECT/PROPOSAL NAME	PREPARED By:	PREPARED Date:	CHECKED By:	CHECKED Date:	PROJECT/PROPOSAL NO.
Butterworth Landfill.	EAS	11/18/98	GRC	1-99	3938.64

Prep Grades of East and West Halfs of Butterworth Landfill

Purpose:

The purpose of these calculations is to determine the total volume of fill required to meet the proposed grading layer designs (drawings 39386402.dwg & 39386403.dwg)

Methodology:

Autodesk design software "Softdesk" was utilized to generate digital terrain models (3-dimensional surface model) of the existing conditions of the site and the proposed prep grades on the said drawings above.

The digital terrain models of each half were compared utilizing Softdesk prismoidal volume method to determine the amount of required fill needed to meet the proposed grades. The resulting volumes were checked by comparing the digital terrain models on a 10-foot grid utilizing Soft Desk's prismoidal volume method.

Assumptions:

- Volumes are in-place measure and do not account for shrinkage or swell of all materials either cut or filled.

Results:

Softdesk Prismoidal Volume - East Half : 70,566cy Fill → **SAY 70,600 cy Fill**
Softdesk Prismoidal Volume - West Half : 49,013 cy Fill → **SAY 49,000 cy Fill**

Attachments:

1. Figure 1 - Existing conditions with proposed construction prep grades superimposed.
2. Computation sheet

744 Heartland Trail (53717-8923) P. O. Box 8923 (53708-8923) Madison, WI (608) 831-4444 FAX: (608) 831-3334 VOICE: (608) 831-1989

PROJECT/PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
Butterworth Landfill.	EAS	11/18/98	GRC	1-99	3938.64

Purpose: Volume estimates between existing conditions and the proposed construction prep grading plan.

EAS
Prismoidal Volume
11/18/98
J:\03938\64\39386402.dwg J:\03938\64\39386403.dwg
J:\cadd\pro\393864\prepe.dtm
J:\cadd\pro\393864\prepw.dtm
J:\cadd\pro\393864\exist.dtm

Existing conditions/proposed construction prep grading plan
Original Surface: exist (existing conditoins)
Design Surface: Prepe & Prepw (proposed construction prep grading plan)

East Half

Cut (cu yd)	**Fill** (cu yd)	**Net** (cu yd)
27,058	97,624	70,566 Fill

West Half

Cut (cu yd)	**Fill** (cu yd)	**Net** (cu yd)
126,677	175,690	49,013 Fill

COMPUTATION SHEET

1143 Highland Drive, Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Cover Material and Misc. Quantities	By: JW/G	01/21/1999	By: GRC	01/25/1999	3938.64

OBJECTIVE: Estimate the amount of liner materials needed to build the final cover at the Butterworth LF. Estimate the amount of clay needed for additional landfill construction activities. Estimate the amount of waste that will need to be excavated and reconsolidated.

METHODOLOGY: Determine the areas for each different cap design shown in the attached figure. Multiply the areas by the thickness of each liner component to determine the amount of material needed. Compare with the DTM generated volume and adjust.

CONCLUSION: The amount of each construction material needed to construct the landfill cap are listed below:

Topsoil:	128,260	cubic yards
Frost Protection:	316,340	cubic yards
Low Perm Soil:	40,813	cubic yards
Clay:	427,174	cubic yards

Volume check by JW/ 1-22-97

Site Volume Table: Unadjusted

Cut yards	Fill yards	Net yards	Method	

==
===

Site: fce
Stratum: fce prepe fce

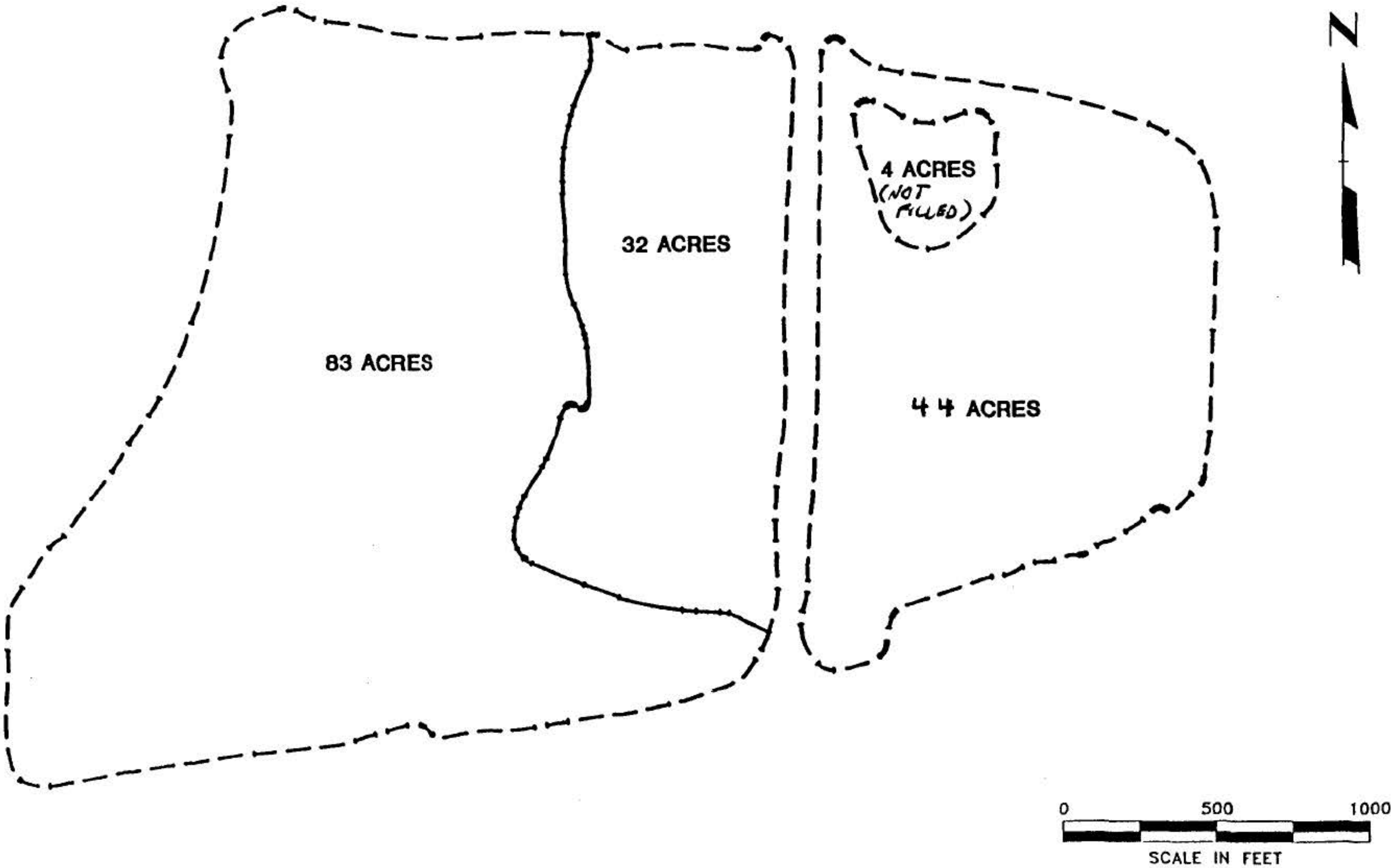
30.21	227852.25	227822.04 (F)	Grid	East Area - Final Cover vs Prep. Grades

Site: fcw
Stratum: fcw prepw fcw

25.67	544638.55	544612.88 (F)	Grid	West Area - Final Cover vs Prep. Grades (Includes area below)

Site: mid
Stratum: mid prepw mid

31.28	67433.42	67402.14 (F)	Grid	Radio Station Area - Final Cover vs Prep. Grades



BUTTERWORTH LF REMEDIAL DESIGN	DRAWN BY: SGH	PROJ. NUMBER 03938.14	RMT INC.
FINAL COVER AREAS	CHECKED BY:	FILE NUMBER 39381407	
	APP[illegible] BY:	DATE:	

1143 HIGHLAND DRIVE, SUITE B
ANN ARBOR, MI 48108-2237
P.O. BOX 991 48106-0991
PHONE [redacted]

COMPUTATION SHEET

RMT INC.

1143 Highland Drive, Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Cover Material and Misc. Quantities	By: JW/G	01/21/1999	By: GRC	01/25/1999	3938.64

CALCULATIONS:

- Determine the amount of material needed for each subarea

Area 1 - 83 acres west of the CSO Ditch

Liner Components:
- 6 inches of topsoil
- 18 inches of rooting zone
- 24 inches of clay

Topsoil =	66,953	cubic yards
Frost Protection=	209,860	cubic yards
Clay =	267,813	cubic yards

Area 2 - 32 acres west of the CSO Ditch

Liner Components:
- 6 inches of topsoil/rooting zone
- 6 inches of low-permeability soil

Topsoil/RZ =	25,813	cubic yards
Low Perm Soil =	40,813	cubic yards

Area 3 - 44 acres east of the CSO Ditch

Liner Components:
- 6 inches of topsoil
- 18 inches of rooting zone
- 24 inches of clay

Topsoil =	35,493	cubic yards
Frost Protection=	106,480	cubic yards
Clay =	141,973	cubic yards

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Cover Material and Misc. Quantities	By: SGH	9/24/97	By: GRC	10/1/98	3938.64

CALCULATIONS (cont.,):

- Determine the clay volume from liner key-in

Calculate volume of low-permeability clay required to tie-in proposed cap grades to existing grades at toe of cap (typical around entire perimeter).

Key-in Cross-section Area (Sheet 7 of 10) = 4 sq. ft
Perimeter around landfill = 14790 ft

Volume = 59,160 cu. ft
2,191 cu. yd

- Determine the clay volume for the CSO bottom and sides.

Calculate the in-place volume of clay required to line the CSO bottom and sides See Sheet 8 of 10 for dimensions.

Width = 100 feet
Length = 1700 feet
Depth = 1 foot

Volume = 170,000 cu ft
6296.3 cu. yd.

- Determine the clay volume for the CSO earthen dam

Calculate the in-place volume of the earthen dam; see Appendix D for dimensions.

Width of one side base and center rectangular section = 80 ft.
Length of base and rectangular center = 150 ft.
Depth of rectangular section = 20 ft.

Volume = 240,000 cu. ft.
8,900 cu. yd.

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PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Cover Material and Misc. Quantities	By: SGH	9/24/97	By: GRC	10/1/98	3938.64

CALCULATIONS (cont.,):

- Determine the volume of shallow waste excavation in the powerline corridor

Calculate the volume of waste to be excavated in the powerline corridor west of the CSO.

Width =	160	feet
Length =	600	feet
Depth (average of testpits 23-26) =	2.5	feet
Volume =	240,000	cu. ft
	8,889	cu. yd

- Determine the volume of waste excavation in Wetlands

NW Corner:	Area =	8358	sq. ft.
	Depth (from testpit 48) =	2.5	ft
	Volume =	20,895	cu. ft
		774	cu. yd
North End of Site, West of CSO	Area =	14387	sq. ft.
	Depth (from testpit 53) =	3	ft
	Volume =	43,161	cu. ft
		1,599	cu. yd
North End of Site, East of CSO	Area =	14387	sq. ft.
	Depth (from testpit 4, 13, 16) =	5	ft
	Volume =	71,935	cu. ft
		2,664	cu. yd
Wetland in the NESA	Area =	17393	sq. ft.
	Depth (from testpit 10) =	4	ft
	Volume =	69,572	cu. ft
		2,577	cu. yd
	Volume Total =	7,613	cu. yd

APPENDIX D-2

BORROW SOURCE APPROVAL LETTERS

Autumn Hills Recycling and Disposal Facility
700 - 56th Avenue
Zeeland, Michigan 49464
616/688-5777

A Waste Management Company

December 14, 1994

Terrance A. Hartman, R.S.
Environmental Sanitarian
Waste Management Division
MDNR - Grand Rapids District Office
350 Ottawa Street N.W.
Grand Rapids, Michigan 49503

SUBJECT: Clay Source
Autumn Hills RDF
Zeeland, Michigan

Dear Terry:

In response to our telephone conversation on Thursday, December 8, 1994, I would very much appreciate your assistance in having the clay at the Waste Management, Inc. Autumn Hills RDF, approved as a clay source for the Butterworth Landfill Superfund Project.

As I described to you, the Butterworth Landfill Cooperating Parties (BLCP) have selected the clay at Autumn Hills RDF as the same source of clay to be used for construction of the landfill cap at the Butterworth Site. However, Tarik Namour of the MDNR - Waste Management Division is concerned whether or not the Autumn Hills RDF clay source has been identified and classified to the satisfaction of the MDNR. During my telephone conversation with Mr. Namour on Tuesday, December 6, 1994, he expressed that he would be satisfied with the source identification and classification if your office was satisfied. At that time, I assured Mr. Namour that the analytical data for the Autumn Hills clay was on record at the Autumn Hills RDF and that certification reports were supplied to your office.

At this time, it would be most helpful if I could receive written verification, with courtesy copies to Tarik Namour and Rob Franks, from your office that the Autumn Hills RDF clay source has been identified and classified to the MDNR's satisfaction and that your records are available to Mr. Namour for review. All clay source analyses at Autumn Hills RDF are currently open for review to the USEPA, MDNR and the BLCP. The address for Tarik Namour and Rob Franks are as follows:

Tarik Namour	Rob Franks
Michigan Department of	Michigan Department of
Natural Resources	Natural Resources
Hazardous Waste Program Section	Environmental Response Division
John Hanah Bldg.	Knapps Center
P.O. Box 30241	300 S. Washington Square
Lansing, Michigan 48909	Lansing, Michigan 48933

A Waste Management Company

On behalf of the BLCP, I appreciate your assistance with our project. Currently, the BLCP has a contractor selected for this project and is awaiting final approval from the MDNR regarding the clay source and your assistance will greatly expedite the clay source approval process.

If you have any questions, please contact me at 616/688-5777.

Sincerely,

Phillip M. Mazor

Phillip M. Mazor
Remedial Projects Manager

cc: Tom Halmi (Earth Tech)
John Seymour (WCC)
John Dunn (BLCP)

PM\lr\120994

STATE OF MICHIGAN

JOHN ENGLER, Governor

DEPARTMENT OF NATURAL RESOURCES

ROLAND HARMES, Director

Grand Rapids District Office
350 Ottawa, NW, Grand Rapids, MI 49503

cc: ...
Fag 1010
U.S. EPA

RECEIVED
DEC 27 1994

December 21, 1994

Mr. Phillip M. Mazor
Remedial Projects Manager
Autumn Hills Recycling
and Disposal Facility
700 56th Avenue
Zeeland, MI 49464

RE: Clay Source, Autumn Hills RDF

Dear Mr. Mazor:

This correspondence will confirm our conversation regarding your plans to use clay from the Autumn Hills Landfill site for capping material at the Butterworth Landfill Superfund Project. As discussed, I can see no reason why the clay material in question would not be acceptable as capping material for the Butterworth project.

Documentation of the quality of the material provided to this agency in the past has demonstrated that it meets the requirements contained in Act 641. Therefore, I would assume that the material would meet the requirements for the Superfund project. My only concern would be in the placement of the material. Specifically, the material tends to remain in rather large clods when excavated, which has required additional conditioning prior to placement and compaction.

I trust the above will provide you with the information you need to [illegible] forward with approval of the clay source.

Sincerely,

Terrance A. Hartman

Terrance A. Hartman, R.S.
Environmental Sanitarian
Waste Management Division
[redacted]

TAH/bls

cc: Tarik Namour, MDNR, WMD
Rob Franks, MDNR, ERD

15

R 1026-E1
Rev. 12/93

Received 1/23/95
M.

STATE OF MICHIGAN

JOHN ENGLER, Governor

DEPARTMENT OF NATURAL RESOURCES

Stevens T. Mason Building, P.O. Box 30028, Lansing, MI 48909

ROLAND HARMES, Director

January 13, 1995

Mr. John Fagiolo, HSRW-6J
Remedial Project Manager
U.S. Environmental Protection Agency
Region 5
77 West Jackson Boulevard
Chicago, Illinois 60604

Dear John:

The Michigan Department of Natural Resources (MDNR) has reviewed the revised Remedial Design Stockpile Plan, dated January 1995, for the Butterworth Landfill Superfund site. The MDNR's Waste Management Division has approved of the clay for capping material and it appears as though the Cooperating Parties have incorporated Agency comments. Therefore, we recommend that the plan be approved.

If you would like to discuss this further, please contact me.

Sincerely,

Robert L. Franks
Superfund Section
Environmental Response Division
517-335-3392

cc: Mr. Mitch Adelman, MDNR / Butterworth Landfill File

R 1026
9/93

17

APPENDIX D-3

CSO EARTHEN DAM SLOPE STABILITY

COMPUTATION SHEET

RMT Inc.
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334 VOICE: (608) 831-1989

PROJECT / PROPOSAL NAME	PREPARED By	Date	CHECKED By	Date	PROJECT PROPOSAL NO
Butterworth – CSO Dam Design	JMS	12/4/97	[illegible]	2/17/97	393814

OBJECTIVE

EVALUATE SLOPE STABILITY FOR THE DAM THAT WILL BE CONSTRUCTED

GIVEN

1. EVALUATE 2H 1V + 1H:1V SLOPES UP + DOWN STREAM
2. TOP OF DAM WILL BE 30' WIDE + AT ELEVATION AS SHOWN ON SHEET 5.
3. BOTTOM OF DAM IS AT ELEVATION 584
4. SUBSURFACE CONDITIONS BASED ON BORING LOG FOR MW-10S.

SOIL STRENGTHS:

1. DAM WILL BE CONSTRUCTED OF COMPACTED CLAY. ASSUME CLAY WILL BE COMPACTED TO AT LEAST 95% COMPACTION BASED ON MODIFIED PROCTOR.

BASED ON EXPERIENCE + GENERAL RMT PROJECTS

$\gamma = 120$ pcf
$\gamma_s = 125$ pcf } SHORT-TERM
$\phi = 0°$ } UNDRAINED STRENGTHS
$C = 1,500$ PSF.

NOTE THAT DAM DESIGN TYPICALLY USES CD + CU TEST DATA. DUE TO TIME CONSTRAINTS, UU TEST DATA (CONSERVATIVE ASSUMPTION) WILL BE USED FOR ANALYSIS

2. NATIVE SOIL

BORING LOG MW-10S (SEE SHEETS 7 + 8) SHOW THAT THE DAM WILL BE FOUNDED ON A SAND AND GRAVEL LAYER. THE SAND + GRAVEL CAN BE STRATIFIED INTO 2 LAYERS.

COMPUTATION SHEET

RMT inc.
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334 VOICE: (608) 831-1989

PROJECT / PROPOSAL NAME	PREPARED By	Date	CHECKED By	Date	PROJECT / PROPOSAL NO
BUTTERWORTH / CSC - DAM	JNS	2/17/97	[illegible]	2/17/97	393817

THE UPPER SAND + GRAVEL IS LOOSE TO FIRM + HAS THE FOLLOW DESIGN PARAMETERS:

γ = 120 PCF } ASSUMED
γ_s = 125 PCF }

$\emptyset$ = 30° : BASED ON AVERAGE BPF OF 11 AND SHEET 9

C = 0 PSF : SAND + GRAVEL.

THE LOWER SAND + GRAVEL IS MEDIUM DENSE TO DENSE + HAS THE FOLLOWING DESIGN PARAMETERS:

γ = 125 PCF } ASSUMED
γ_s = 130 PCF }

$\emptyset$ = 40° : BASED ON AVERAGE BPF OF 43 AND SHEET 9.

C = 0 PSF : SAND + GRAVEL.

DAM LAYOUT:

USING THE CROSS SECTION SHOWN ON SHEET 5 AND BORING LOG MW-105, DESIGN PROFILE IS SHOWN ON SHEET 10. NOTE THAT THE CULVERT THROUGH THE DAM IS NOT SHOWN.

AVERAGE WATER LEVEL ELEVATION IS BASED ON DISCUSSION W/ SCOTT HUTSELL IN A[2]

COMPUTATION SHEET

RMT Inc. 744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334 VOICE: (608) 831-1989

PROJECT / PROPOSAL NAME	PREPARED By	Date	CHECKED By	Date	PROJECT / PROPOSAL NO
BUTTERWORTH / CSO DAM	JNC	12/14/93	[illegible]	2/4/?	3938.14

ANALYSIS:

1) PRIOR TO PERFORMING THE ANALYSIS REVIEWED LITERATURE FOR CONFIRMATION OF DAM LAYOUT. BUREAU OF RECLAMATION STATES THAT FOR SMALL DAMS WITH IMPERVIOUS EMBANKMENTS, THE EMBANKMENT SLOPE IS 2½:1, SEE SHEETS 11 + 12.

2) GIVEN THAT THE BUTTERWORTH DESIGN DOES HAVE A CULVERT THROUGH IT, THE EMBANKMENT SLOPE WILL BE EVALUATED AT 2:1 + 1:1.

3) SLOPE STABILITY ANALYSIS WAS PERFORMED USING XSTABL + ASSUMING CIRCULAR FAILURE

4) WORST CASE CONDITION IS DETERMINED TO BE STABLE WATER LEVEL AT ELEVATION 598 FOR A SUSTAINED PERIOD OF TIME SUCH THAT WATER LEVEL IN THE DAM IS STABILIZED THEN THE WATER LEVEL BEHIND THE DAM IMMEDIATELY DROPS TO ELEVATION 587.0

5) GIVEN THE IMMEDIATE DROP IN WATER LEVEL, SHORT-TERM OR UNDRAINED STRENGTHS WILL GOVERN. THE SHORT-TERM STRENGTHS ARE SHOWN ON SHEET 1.

RESULTS

1H:1V EMBANKMENT SLOPE

XSTABL RESULTS ARE ATTACHED

FOR W.L. @ ELE 587

FS = 1.8 < 2.0 N.G. UPSTREAM FAILURE

FS = 2.2 > 2.0 OK DOWNSTREAM FAILURE

RMT INC.
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334 VOICE. (608) 831-1989

COMPUTATION SHEET

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT / PROPOSAL NO
BUTTERWORTH / CSO DAM	JAS	2/14/97	MAK	2/97	3938 14

RESULTS

24:1V EMBANKMENT SLOPE

XSTABL RESULTS ARE ATTACHED

FOR WL @ ELE 584.0 (Post Construction Conditions)

FS = 2.1 > 2.0 OK UPSTREAM FAILURE
FS = 3.5 > 2.0 OK DOWNSTREAM

CONCLUSIONS

EVEN THOUGH LITERATURE RECOMMENDS EMBANKMENT SLOPES OF 2½ : 1 THE STABILITY ANALYSIS FOR 2:1 SLOPES INDICATES THE SLOPE WILL BE STABLE.

GIVEN LITERATURE'S SLOPE RECOMMENDATION AND THE XSTABL RESULT FOR THE AVERAGE WATER LEVEL (FS = 1.8), A 1:1 SLOPE IS NOT RECOMMENDED.

THE 100 YEAR FLOOD LEVEL SHOWS THAT THE UP + DOWN STREAM SLOPES SHOULD BE LINED WITH RIP RAP OR HEAVY VEGETATION TO MINIMIZE EROSION.

LABORATORY STRENGTH TESTING SHOULD BE PERFORMED DURING CONSTRUCTION TO VERIFY ASSUMED DAM SOIL STRENGTHS. STRENGTH TESTING SHOULD CONSIST OF CD + CU TESTS.

COMPUTATION SHEET

RMT

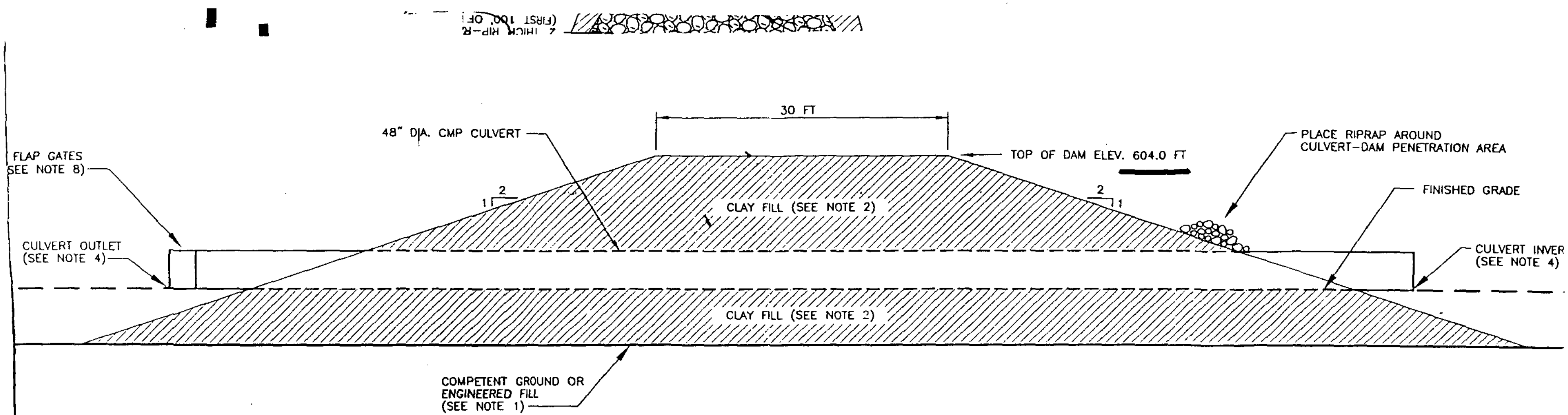
SHEET 4A OF 12

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334 VOICE: (608) 831-1989

PROJECT / PROPOSAL NAME	PREPARED By	Date	CHECKED By	Date	PROJECT / PROPOSAL NO
BUTTERWORTH / CSO DAM	JNS	2/19/97	[illegible]	2/97	3938.14

CONCLUSIONS

- DAM SHOULD BE CONSTRUCTED IN LOOSE 8" LIFTS COMPACTED TO AT LEAST 95 PERCENT COMPACTION.
- RMT SHOULD VERIFY COMPACTION DURING CONST.



3/8 **EARTHEN DAM**

(NOT TO SCALE)

5/12

87

2/14/97 7/1—

BORING NO. MW-10S	- TEST BORING LOG

PROJECT NO./NAME 00018-00-00001 /BUTTERWORTH | LOCATION GRAND RAPIDS, MI

DRILLING CONTRACTOR/DRILLER FOX DRILLING/J. KOOITECK

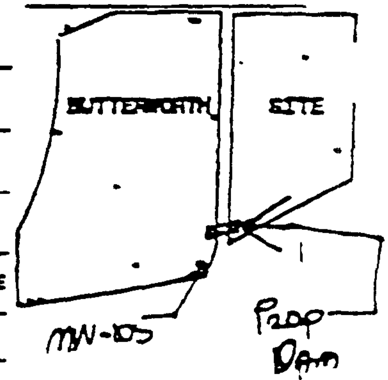
HART GEOLOGIST OFFICE R. MCLEOD/SOUTHFIELD

DRILLING EQUIPMENT/METHOD	SIZE/TYPE OF BIT	SAMPLING METHOD	START-FINISH DATE
Hollow Stem Auger to Mud Rotary		SS 1.5	5-11-88

WELL INSTALLED?	CASING MAT./DIA.	SCREEN: TYPE	MAT.	LENGTH	DIA.	SLOT
X YES ___ NO	PVC 2"		SS	32.1'	2"	10

ELEVATION OF: (FT. ABOVE M.S.L.)	GROUND SURFACE	TOP OF WELL CASING
	610.48	612.91

REMARKS:



LOG OF TEST BORING

DEPTH (FT)	SAMPLE NO. AND TYPE	RECOVERY (FT)	PENETRATION RESISTANCE BLOWS/FT	DESCRIPTION 610	REMARKS	WELL CONST.	GRAPHIC LITHO LOG
		1.2	1	Loose, yellow SAND. 0.2' of black silty soil			
			2				
			5				
		1.2	3	Loose, SAND with wood fragments. 0.1' of black			
			3	silty material.			
5			7				
		1.0	8	Loose, SAND with black ash, red-brown silty soil,			
			6	black ash, red-brown silty soil, some white material			
			6	(looks like sand crystals)			
10							
		1.0	6	Very dense, red-brown silty soil; 0.3' broken			
			51	concrete			
			26				
15							
		1.0	2	Loose, light brown SILT; Ash, bright red-brown			
			2	mixed with black SILT over yellow SAND			
			2				

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2/14/97

LOG OF TEST BORING

DEPTH (FT)	SAMPLE NO. AND TYPE	RECOVERY (FT)	PENETRATION RESISTANCE BLOWS/FT	DESCRIPTION	REMARKS	WELL CONST.	GRAPHIC LITHO LOG
		1.1	2 3 4	Loose brown-yellow fine SAND	wet spoon		
--25		1.5	1 2 4	Loose grey find SAND ↑ DAM ELV 587 ↓ FDN	natural material		
--30		1.6	5 6 6 (10)	Loose, grey coarse SAND with GRAVEL $\phi = 30^\circ$ AVG BPF = 11 C = 0 PSF γ = 120 PCF γ_s = 125 PCF			
		1.6	5 6 6 (12)	Firm, grey coarse SAND with GRAVEL ELV 576			
--35		1.5	7 9 13	Firm, grey coarse SAND with GRAVEL $\phi = 40^\circ$ AVG BPF = 43 C = 0 PSF			
--40		2.0	20 21 28 (49)	Dense, grey coarse SAND γ = 125 PCF γ_s = 130 PCF	Running sand switched to mud rotary drilling		
--45		2.0	2 4 6 (10)	Stiff grey CLAY 0.3; grey coarse SAND 0.7			
		1.0	29 62 (91)	Very stiff dark grey CLAY T.D. 49'	Pumped 2 2/3 boxes of mud without return. Pumped water through screen in and out of hole. Hole collapsed to 35 ft.		
--50							

91

3839 14
2/14/97 9/12

Soil Mechanics

T. William Lambe • Robert V. Whitman

Massachusetts Institute of Technology

1969

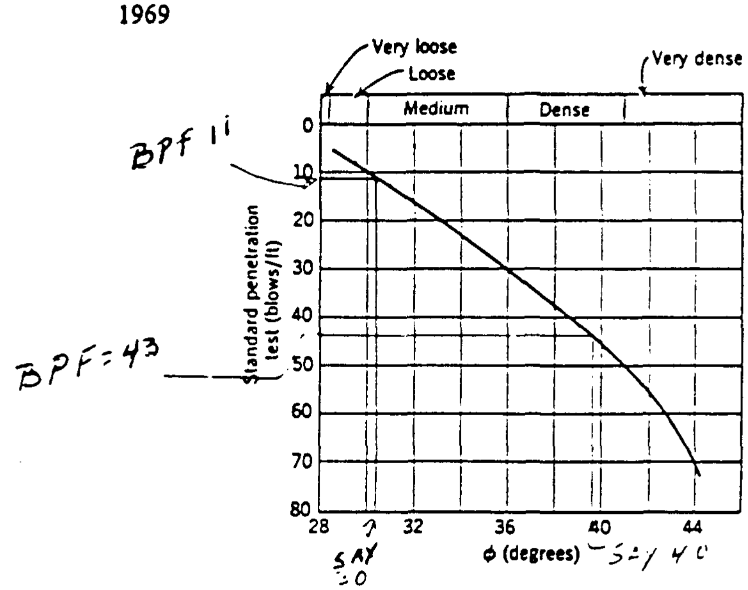

Fig. 11.14 Correlation between friction angle and penetration resistance (From Peck, Hanson, and Thornburn, 1953).

John Wiley & Sons, Inc.

New York London Sydney Toronto

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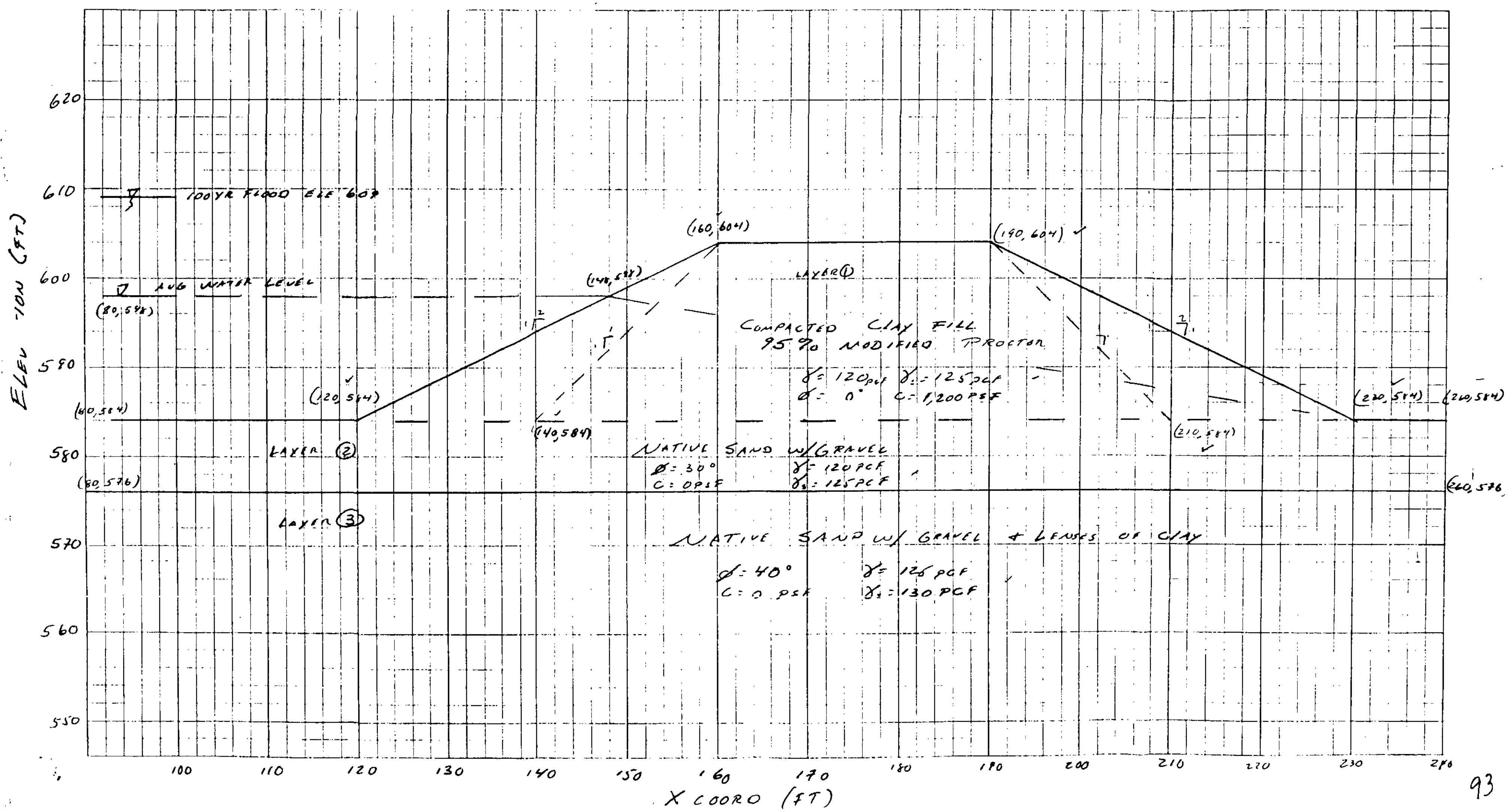
RMT INC.

COMPUTATION SHEET

SHEET 10 OF 12

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334

PROJECT/PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
BUTTERWORTH - DAM EVALUATION	JMS	2/14/97	[illegible]	2/97	3938.14



UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

DESIGN OF SMALL DAMS

A Water Resources Technical Publication

Second Edition

1973

Revised Reprint

1977

A storage dam subject to rapid drawdown of the reservoir should have an upstream zone with permeability sufficient to dissipate pore-water pressures exerted outwardly in the upstream part of the dam. The rate of reservoir drawdown is an important factor which affects the stability of the upstream part of the dam. For a method of designing free draining upstream shells, refer to Cedergren [30]. Where only fine material of low permeability is available, such as that predominating in clays, it is necessary to provide a flat slope if rapid drawdown is a design requirement. Conversely, if free-draining sand and gravel are available to provide a superimposed weight for holding down the fine material of low permeability, a steeper slope may be used. The same result may be secured by utilizing sound and durable rock from required excavations. In the latter case, a layer of sand and gravel or quarry fines must be placed between the superimposed rock and the surface of the impervious embankment to prevent damage and displacement from saturation and wave action.

Flood damage due to failure of the upstream face is very unlikely. Failure can take place only during construction or following a rapid drawdown; in both cases the reservoir should be virtually empty. The weight and seepage forces act as a stabilizing influence on the upstream face when the reservoir is full.

The usual downstream slopes for small earthfill dams are 2 : 1 where a downstream pervious zone is provided in the embankment, and 2½ : 1 where the embankment is impervious. These slopes are stable for soil types commonly used when drainage is provided in the design so that the downstream slope of the embankment does not become saturated by seepage.

The slopes of an earthfill dam depend on the type of dam (that is, diaphragm, modified homogeneous, or zoned embankment), and on the nature of the materials for construction. Of special importance is the nature of the soil which will be used for construction of the modified homogeneous dam or the core of a zoned dam. In the latter case, the relation of the size of the core to the size of the shell is also significant.

In this text, the slopes of the embankment are related to the classification of the soil to be used for construction, especially the impervious soils. The engineering properties of soils in the various classifications are shown in table 8 (sec. 94). The slopes chosen are necessarily conservative and are recommended only for small earthfill dams within the scope of this text, as discussed in section 124.

(c) *Diaphragm Type.*—A diaphragm dam consists of a thin impervious water barrier used in conjunction with a large pervious zone. The diaphragm can be constructed of earth, asphalt, concrete, or metal. If the diaphragm is constructed of impervious earth material, it must have a horizontal thickness at least great enough to accommodate construction equipment. Because it must hold back the full reservoir pressure, its construction must be carefully performed; to prevent piping or erosion it must be protected by graded filters. When an earth diaphragm is centrally located, it is also referred to as a "thin core." A typical earth-diaphragm constructed for Amarillo Regulating Reservoir is shown in figure 166.

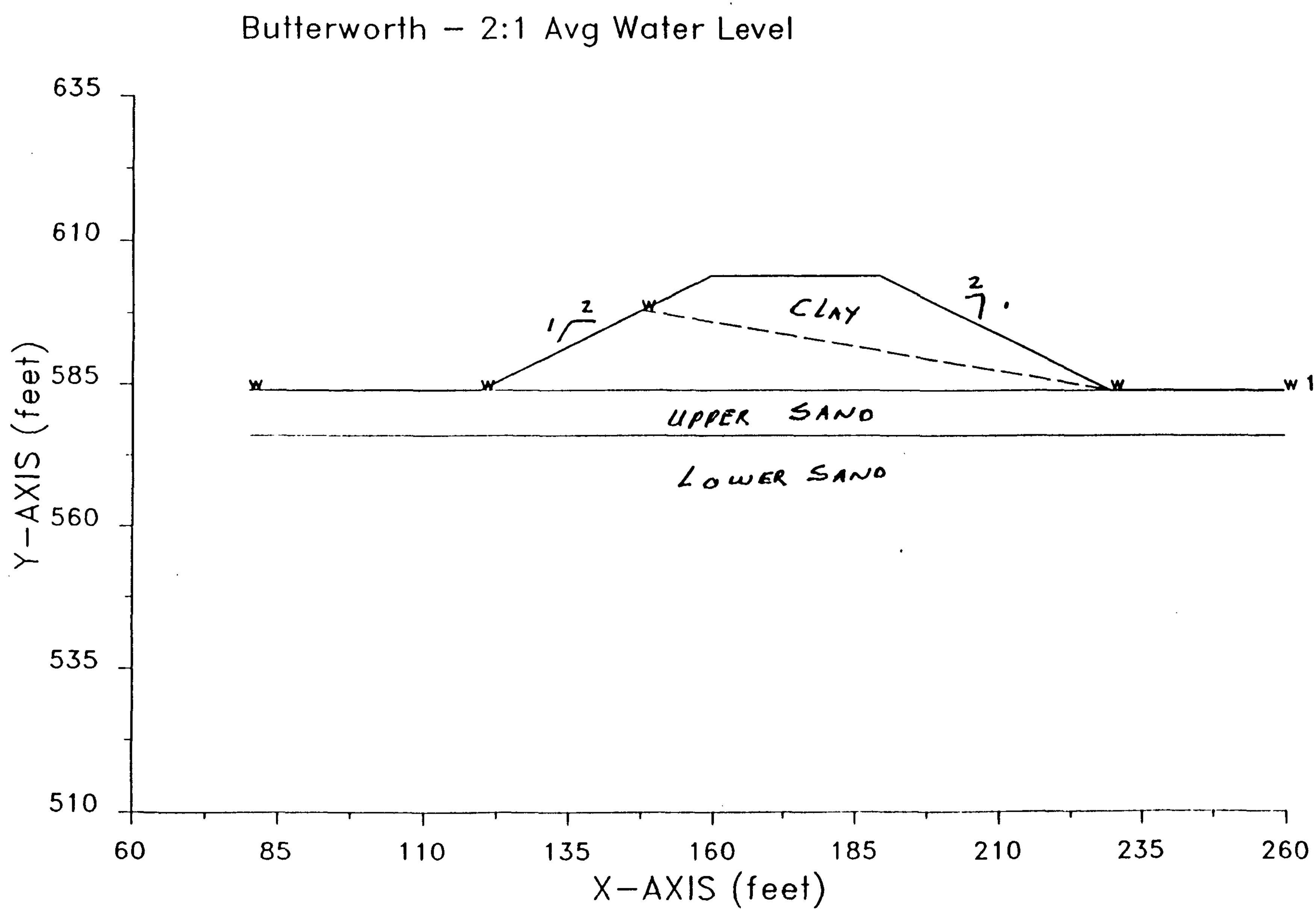
Diaphragm-type dams are generally used under the following conditions:

(1) A limited quantity of impervious material is available.
(2) Wet climatic conditions.
(3) Short construction seasons.

A diaphragm should be used only when the design and construction of the dam are performed under the supervision of an experienced earth dam designer. If this type of dam is selected, it is recommended that a diaphragm of manufactured material be placed on the upstream slope of an otherwise pervious embankment in lieu of a soil blanket. If the pervious material is rock, the dam is classified as a rockfill dam, the design of which is discussed in chapter VII.

The pervious material used in the construction of a diaphragm dam must be such that it can be compacted to form a stable embankment which will be subject to only small amounts of post-construction settlement. Poorly graded sands (SP) cannot be satisfactorily compacted; well-graded sand-gravel mixtures (SW-

1 2-17-97 14:37



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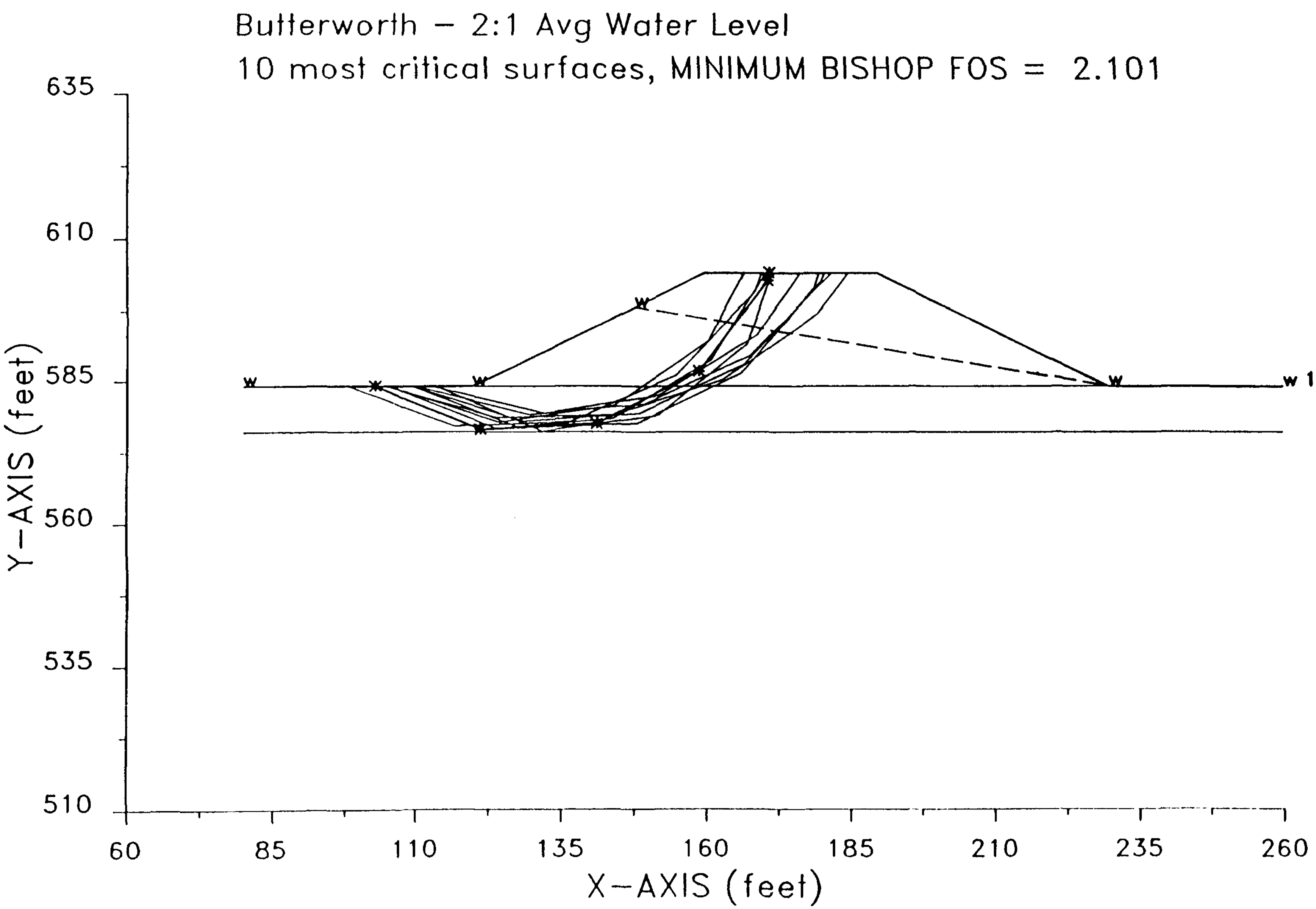
Butterworth - 2:1 Avg Water Level
10 most critical surfaces, MINIMUM BISHOP FOS = 2.101
635
610
585
560
535
510
Y-AXIS (feet)
60
85
110
135
160
185
210
235
260
X-AXIS (feet)
w 1

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```

Problem Description : Butterworth - 2:1 Avg Water Level JMK 2/97

SEGMENT BOUNDARY COORDINATES
----

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	80.0	584.0	120.0	584.0	2
2	120.0	584.0	148.0	598.0	1
3	148.0	598.0	160.0	604.0	1
4	160.0	604.0	190.0	604.0	1
5	190.0	604.0	222.0	588.0	1
6	222.0	588.0	230.0	584.0	1
7	230.0	584.0	260.0	584.0	2

2 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	120.0	584.0	230.0	584.0	2
2	80.0	576.0	260.0	576.0	3

ISOTROPIC Soil Parameters
----

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	120.0	125.0	1200.0	.00	.000	.0	1
2	120.0	125.0	.0	30.00	.000	.0	1
3	125.0	130.0	.0	40.00	.000	.0	1

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 5 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	80.00	584.00
2	120.00	584.00
3	148.00	598.00
4	230.00	584.00
5	260.00	584.00

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

900 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 90 points equally spaced along the ground surface between x = 90.0 ft
and x = 150.0 ft

Each surface terminates between x = 140.0 ft
and x = 230.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

20.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED BISHOP METHOD * * * * *

The most critical circular failure surface is specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	102.81	584.00
2	121.31	576.40
3	141.29	577.39
4	158.95	586.76
5	170.96	602.76
6	171.21	604.00

**** Simplified BISHOP FOS = 2.101 ****

The following is a summary of the TEN most critical surfaces

Problem Description : Butterworth - 2:1 Avg Water Level

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	2.101	129.09	621.68	45.94	102.81	171.21	2.553E+06
2.	2.128	130.49	619.45	43.37	105.51	170.58	2.352E+06
3.	2.137	136.30	624.39	48.44	109.55	179.72	3.065E+06
4.	2.166	135.09	630.34	52.92	109.55	180.67	3.226E+06
5.	2.175	125.05	627.40	51.09	98.09	169.82	2.765E+06
6.	2.209	132.72	645.13	67.19	104.83	184.91	4.343E+06
7.	2.233	134.37	629.08	49.92	112.92	176.49	2.691E+06
8.	2.237	136.95	612.60	36.92	113.60	171.59	2.075E+06
9.	2.245	128.29	620.39	42.93	105.51	166.84	2.115E+06
10.	2.247	134.21	636.38	57.61	110.22	181.78	3.437E+06

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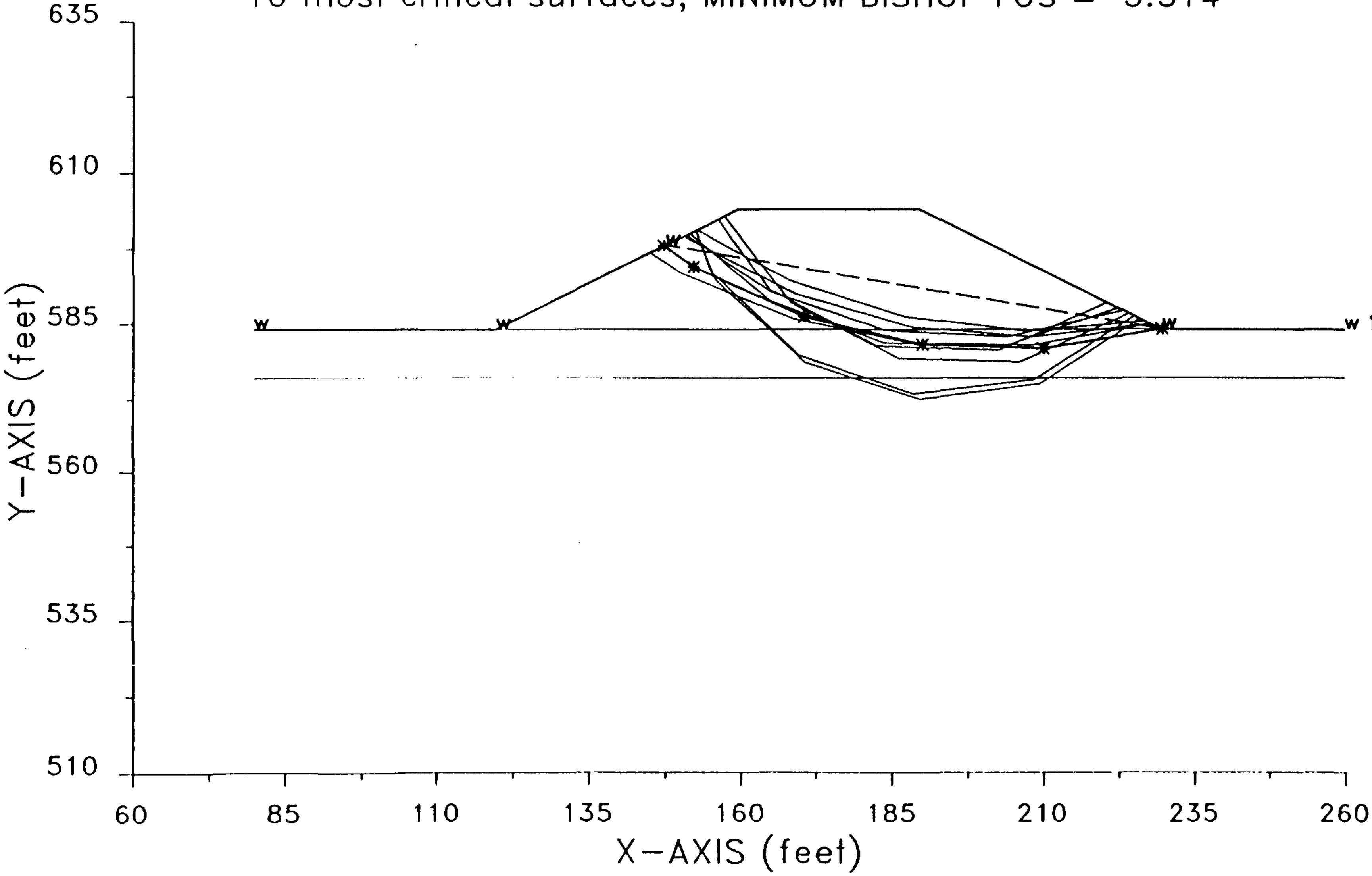
Butterworth - 2:1 Avg Water Level
10 most critical surfaces, MINIMUM BISHOP FOS = 3.514



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```

Problem Description : Butterworth - 2:1 Avg Water Level

SEGMENT BOUNDARY COORDINATES

---

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	80.0	584.0	120.0	584.0	2
2	120.0	584.0	148.0	598.0	1
3	148.0	598.0	160.0	604.0	1
4	160.0	604.0	190.0	604.0	1
5	190.0	604.0	222.0	588.0	1
6	222.0	588.0	230.0	584.0	1
7	230.0	584.0	260.0	584.0	2

2 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	120.0	584.0	230.0	584.0	2
2	80.0	576.0	260.0	576.0	3

ISOTROPIC Soil Parameters

---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	120.0	125.0	1200.0	.00	.000	.0	1
2	120.0	125.0	.0	30.00	.000	.0	1
3	125.0	130.0	.0	40.00	.000	.0	1

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

Water Surface No. 1 specified by 5 coordinate points

****

PHREATIC SURFACE,

****

Point No.	x-water (ft)	y-water (ft)
1	80.00	584.00
2	120.00	584.00
3	148.00	598.00
4	230.00	584.00
5	260.00	584.00

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

800 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 80 points equally spaced
along the ground surface between x = 160.0 ft
and x = 230.0 ft

Each surface terminates between x = 90.0 ft
and x = 160.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

20.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * *   SIMPLIFIED BISHOP METHOD   * * * * *

The most critical circular failure surface
is specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	230.00	584.00
2	210.26	580.77
3	190.27	581.46
4	170.81	586.05
5	152.62	594.37
6	147.76	597.88

**** Simplified BISHOP FOS = 3.514 ****

The following is a summary of the TEN most critical surfaces

Problem Description : Butterworth - 2:1 Avg Water Level

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	3.514	203.78	682.25	101.69	230.00	147.76	8.243E+06
2.	3.725	197.74	622.77	45.06	224.68	157.73	3.818E+06
3.	3.948	207.16	684.51	101.83	228.23	151.11	8.455E+06
4.	4.361	200.03	686.69	105.64	228.23	145.44	9.273E+06
5.	4.480	195.15	639.47	58.88	222.91	151.99	5.079E+06
6.	4.502	194.52	624.63	44.93	221.14	156.57	3.776E+06
7.	4.566	209.26	687.08	103.35	227.34	153.13	9.312E+06
8.	4.624	198.15	656.04	73.56	223.80	151.41	6.328E+06
9.	4.642	193.96	617.87	45.67	226.46	152.92	5.528E+06
10.	4.678	193.56	618.59	45.52	225.57	152.92	5.293E+06

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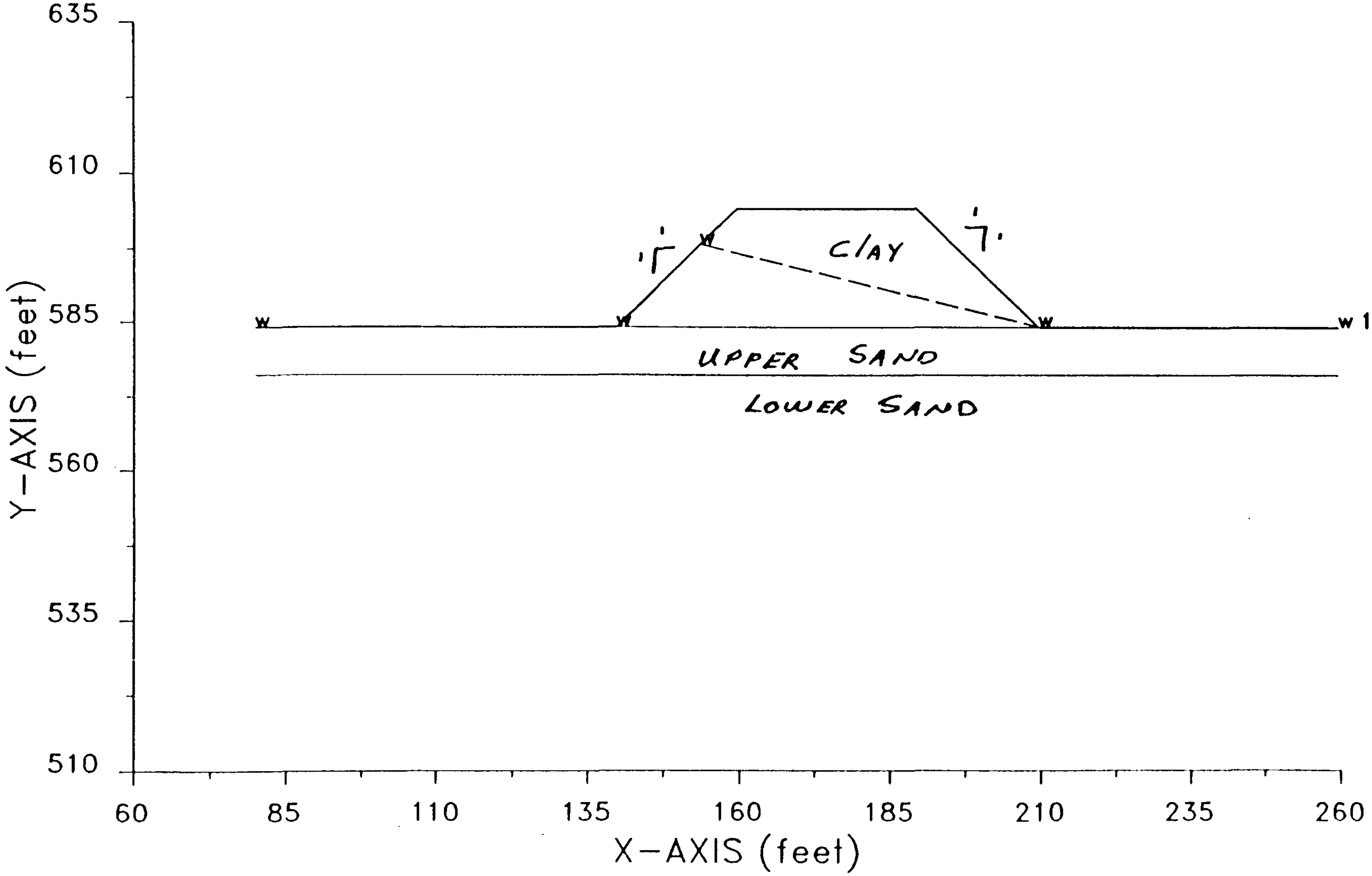
Butterworth - 1:1 Avg Water Level



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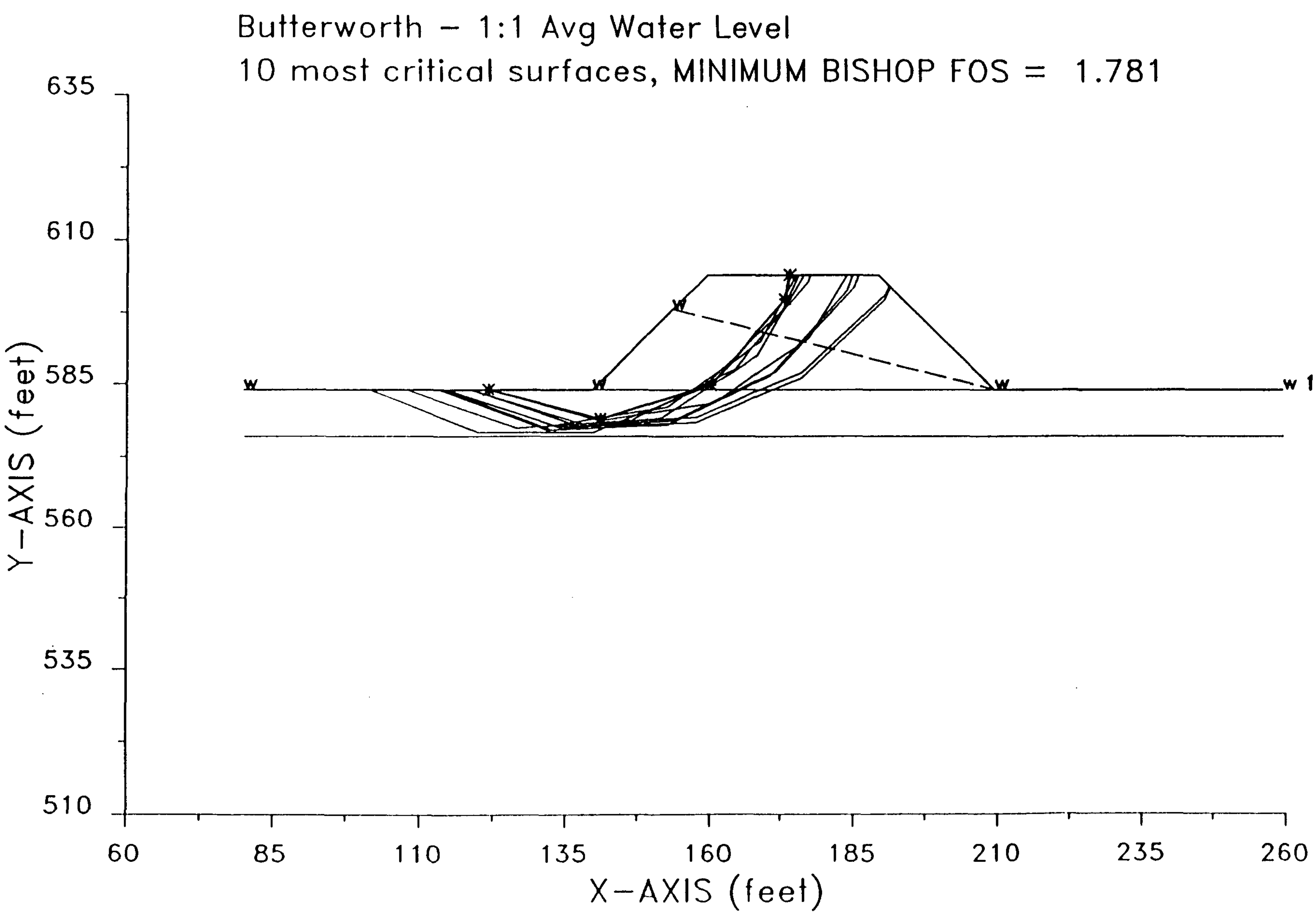

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```

Problem Description : Butterworth - 1:1 Avg Water Level

SEGMENT BOUNDARY COORDINATES

---

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	80.0	584.0	140.0	584.0	2
2	140.0	584.0	154.0	598.0	1
3	154.0	598.0	160.0	604.0	1
4	160.0	604.0	190.0	604.0	1
5	190.0	604.0	210.0	584.0	1
6	210.0	584.0	230.0	584.0	2
7	230.0	584.0	260.0	584.0	2

2 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	120.0	584.0	230.0	584.0	2
2	80.0	576.0	260.0	576.0	3

ISOTROPIC Soil Parameters

---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	120.0	125.0	1000.0	.00	.000	.0	1
2	120.0	125.0	.0	30.00	.000	.0	1
3	125.0	130.0	.0	40.00	.000	.0	1

1 Water surface(s) have been specified

Unit weight of water =   62.40 (pcf)

Water Surface No. 1 specified by 5 coordinate points

****
PHREATIC SURFACE,
****

Point No.	x-water (ft)	y-water (ft)
1	80.00	584.00
2	140.00	584.00
3	154.00	598.00
4	210.00	584.00
5	260.00	584.00

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

900 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 90 points equally spaced along the ground surface between x = 100.0 ft and x = 170.0 ft

Each surface terminates between x = 160.0 ft and x = 250.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

20.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED BISHOP METHOD * * * * *

The most critical circular failure surface
is specified by 5 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	122.02	584.00
2	141.38	578.96
3	160.50	584.80
4	173.74	599.80
5	174.47	604.00

**** Simplified BISHOP FOS = 1.781 ****

The following is a summary of the TEN most critical surfaces

Problem Description : Butterworth - 1:1 Avg Water Level

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	1.781	140.61	615.70	36.75	122.02	174.47	1.427E+06
2.	1.796	137.53	619.87	43.25	113.37	177.00	1.971E+06
3.	1.809	136.65	621.63	43.84	114.16	175.66	1.842E+06
4.	1.811	140.82	627.02	50.62	114.16	185.34	2.761E+06
5.	1.823	141.04	629.61	52.55	114.94	186.46	2.835E+06
6.	1.835	133.61	627.43	50.48	107.87	178.05	2.307E+06
7.	1.835	143.98	625.25	46.73	122.02	184.50	2.293E+06
8.	1.876	145.05	635.59	57.85	118.88	191.89	3.291E+06
9.	1.880	145.94	633.13	56.09	118.88	192.07	3.305E+06
10.	1.891	130.11	628.55	52.91	101.57	176.02	2.489E+06

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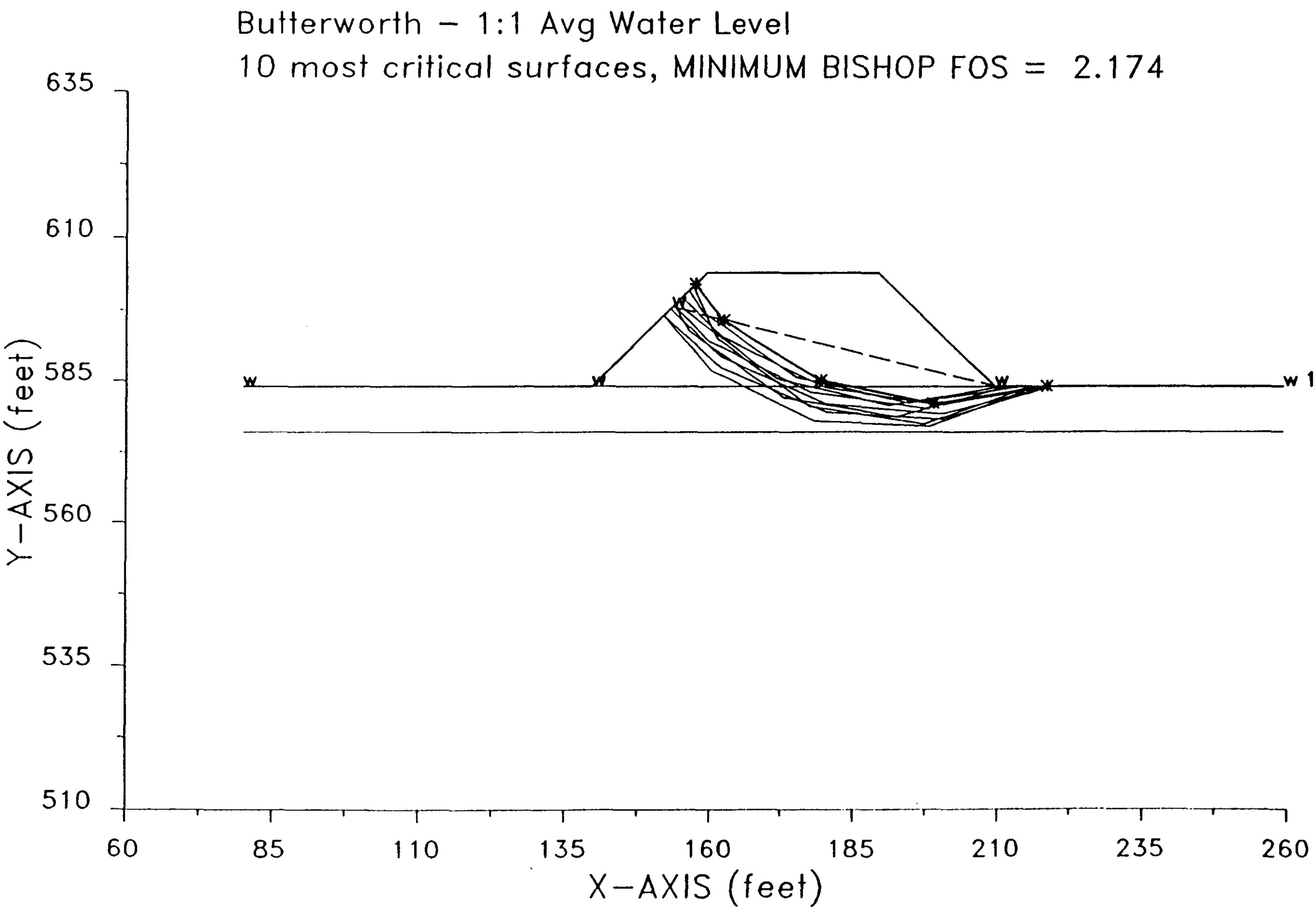

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Problem Description : Butterworth - 1:1 Avg Water Level

SEGMENT BOUNDARY COORDINATES
----

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	80.0	584.0	140.0	584.0	2
2	140.0	584.0	154.0	598.0	1
3	154.0	598.0	160.0	604.0	1
4	160.0	604.0	190.0	604.0	1
5	190.0	604.0	210.0	584.0	1
6	210.0	584.0	230.0	584.0	2
7	230.0	584.0	260.0	584.0	2

2 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	120.0	584.0	230.0	584.0	2
2	80.0	576.0	260.0	576.0	3

ISOTROPIC Soil Parameters
----

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	120.0	125.0	1000.0	.00	.000	.0	1
2	120.0	125.0	.0	30.00	.000	.0	1
3	125.0	130.0	.0	40.00	.000	.0	1

1 Water surface(s) have been specified

Unit weight of water = 62.40 (pcf)

113

Water Surface No. 1 specified by 5 coordinate points

```
**********************************
        PHREATIC SURFACE,
**********************************
```

Point No.	X-Water (ft)	Y-Water (ft)
1	80.00	584.00
2	140.00	584.00
3	154.00	598.00
4	210.00	584.00
5	260.00	584.00

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

700 trial surfaces will be generated and analyzed.

10 Surfaces initiate from each of 70 points equally spaced along the ground surface between x = 160.0 ft
and x = 220.0 ft

Each surface terminates between x = 90.0 ft
and x = 160.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

20.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED BISHOP METHOD * * * * *

The most critical circular failure surface
is specified by 5 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	219.13	584.00
2	199.36	580.99
3	179.78	585.06
4	162.84	595.70
5	158.00	602.00

**** Simplified BISHOP FOS = 2.174 ****

The following is a summary of the TEN most critical surfaces

Problem Description : Butterworth - 1:1 Avg Water Level

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	2.174	200.88	637.48	56.51	219.13	158.00	3.015E+06
2.	2.268	199.90	644.52	63.77	220.00	155.68	3.548E+06
3.	2.328	197.22	633.64	52.65	214.78	156.85	2.875E+06
4.	2.386	193.86	618.45	41.23	216.52	157.59	2.618E+06
5.	2.391	195.93	638.46	59.54	220.00	153.67	3.637E+06
6.	2.436	196.17	640.05	59.93	217.39	154.31	3.495E+06
7.	2.498	194.07	635.48	57.64	220.00	152.57	3.707E+06
8.	2.597	193.30	629.95	49.35	211.30	155.19	2.813E+06
9.	2.690	191.03	625.52	49.18	217.39	152.51	3.351E+06
10.	2.766	190.69	623.58	45.04	212.17	154.41	2.814E+06

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THIS REPRINT INCLUDES CHANGE 1

ENGINEER MANUAL

EM 1110-2-1902
1 APRIL 1970

ENGINEERING AND DESIGN

STABILITY OF EARTH AND ROCK-FILL DAMS

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
OFFICE OF THE CHIEF OF ENGINEERS

117

homogeneous earth dams and dams on thick deposits of fine-grained materials, whereas the wedge method is generally more applicable to rock-fill dams on firm foundations and to earth dams on foundations containing one or more weak layers. In addition, the infinite slope method is used to some extent to supplement the circular arc or wedge method. These methods provide a uniform basis for evaluating alternative designs and may be supplemented by other methods or alternative procedures at the discretion of the designer. The use of the modified Swedish method given in Appendix VI is optional. If desired, the forces on the vertical sides of slices may be ignored.

11. Design Conditions for Analysis. An embankment and its foundation are subjected to shear stresses imposed by the weight of the embankment and by pool fluctuations, seepage, or earthquake forces. The cases for which stability analyses shall be performed are designated (I) end of construction, (II) sudden drawdown from maximum pool, (III) sudden drawdown from spillway crest elevation, (IV) partial pool, (V) steady seepage with maximum storage pool, (VI) steady seepage with surcharge pool, and where applicable (VII) earthquake. Cases I and VII apply to both upstream and downstream slopes; Cases II, III, and IV apply to upstream slopes only; and Cases V and VI apply to downstream slopes.

a. Case I: End of Construction. In an embankment composed partially or entirely of impervious soils placed at water contents higher than those corresponding to ultimate water contents after complete consolidation under the imposed loading, pore pressure will be induced because the soil cannot consolidate readily during the construction period. Where this is indicated, applicable shear strengths are determined from Q tests on specimens compacted to anticipated field placement water contents and densities. The Q shear strength is also applicable to impervious foundation layers that are too thick to consolidate significantly during construction. The use of Q shear strengths implies that pore water pressures occurring in laboratory tests satisfactorily approximate field pore water pressures. Except for thick, impervious foundation strata, the use of Q shear strength is usually conservative, since some consolidation will occur during construction. For overconsolidated soils, the average strength based on Q tests may be higher than that based on R tests. Therefore, swelling may reduce the shear strength, which should be considered in selecting design values. Where consolidation during construction is significant, its effect can be estimated by performing stability analyses using strength values intermediate between Q and R as described in paragraph 9b. When an embankment is to be constructed on clays having low Q strengths, evaluation of the time rate of consolidation characteristics may show that stage construction would result in a significant gain in foundation strengths during the construction period and permit a more economical embankment design. For stage construction where excess pore water pressures are expected to develop in the foundation or embankment, piezometer observations should be used to reevaluate stability during construction (Appendix VIII). Further, at the completion of each stage, foundation samples must be tested to determine the actual change in shear strength due to consolidation caused by stage fill.

b. Cases II and III: Sudden Drawdown. Embankments may become saturated by seepage during prolonged high reservoir stages. If subsequently the reservoir pool is drawn down faster than pore water can escape, excess pore water pressures and unbalanced seepage forces result. Shear strengths to be used in Cases II and III shall be based on the minimum of the combined R and S envelopes (fig. 4). In general, analyses for these cases are based on the conservative assumptions that (1) pore pressure dissipation does not occur during drawdown and (2) the water surface is lowered instantaneously from maximum pool (Case II) or spillway crest elevation (Case III) to the minimum pool elevation. For embankments composed of impervious materials, the resisting friction forces should be determined using saturated or moist weights above the line of seepage at full pool and submerged weights below this level; driving forces should be determined using saturated weights above the lowered pool elevation, saturated weights

120

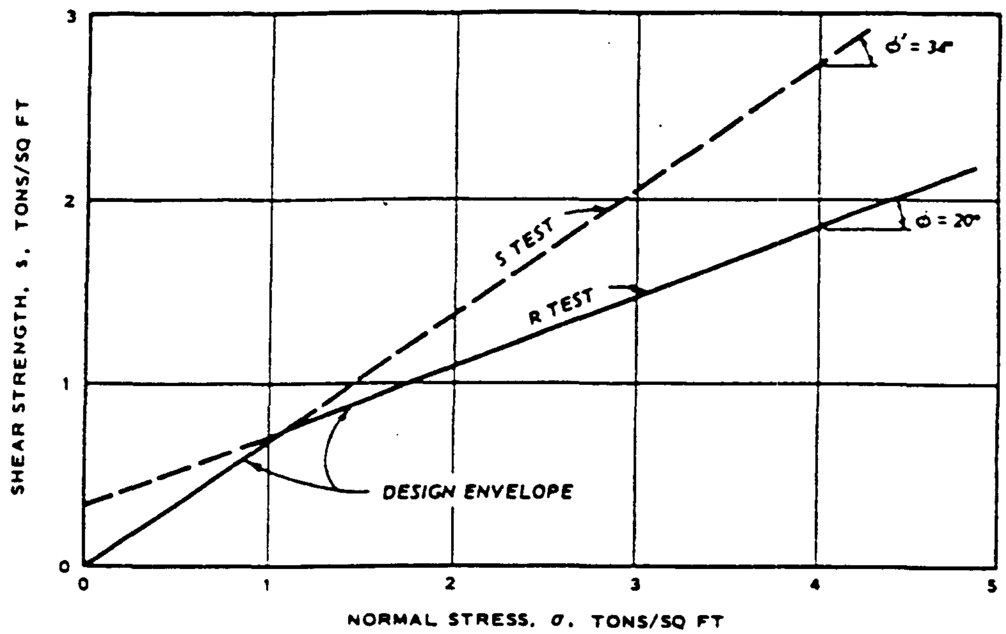


Figure 4. Design envelope for Cases II and III

within the drawdown zone, and submerged weights below the drawdown zone (assuming a horizontal extension of the minimum pool level). Shear strengths of free-draining shell materials, which are defined as those in which drainage of pore water can proceed concurrently with lowering of the pool or with only a minor time lag, are represented by S test conditions. Where sudden drawdown analyses control the design of the upstream slope and where this drawdown assumption appears to be excessively conservative, considering possible drawdown rates and the permeabilities of proposed embankment materials, analyses for relatively incompressible materials may be performed for expected drawdown rates and seepage forces determined from a flow net to evaluate effective normal stresses. Approximate criteria, given in Appendix III, for the lowering of the line of seepage may be used as a basis for constructing flow nets and determining seepage effects. The shear strength envelopes for these analyses should be the same as for sudden drawdown analyses.

c. <u>Case IV: Partial Pool.</u> Analyses of the upstream slope for intermediate reservoir stages should assume that a condition of steady seepage has developed at these intermediate stages. The design shear strength of impervious soils should correspond to a strength envelope midway between the R and S test envelopes where the S strength is greater than the R strength and to the S envelope where the S strength is less than the R strength (fig. 5). The design shear strength of freely draining cohesionless soils should be the S test envelope. The demarcation between moist and submerged soils may be approximated by a horizontal line from the pool to the downstream limit of the impervious zone, thus eliminating the need for flow net construction. Stability analyses should be performed for several pool elevations, and the factors of safety plotted as a function of reservoir stage to determine the minimum safety factor. The analysis must account for reduction in effective normal stresses where pore water pressures

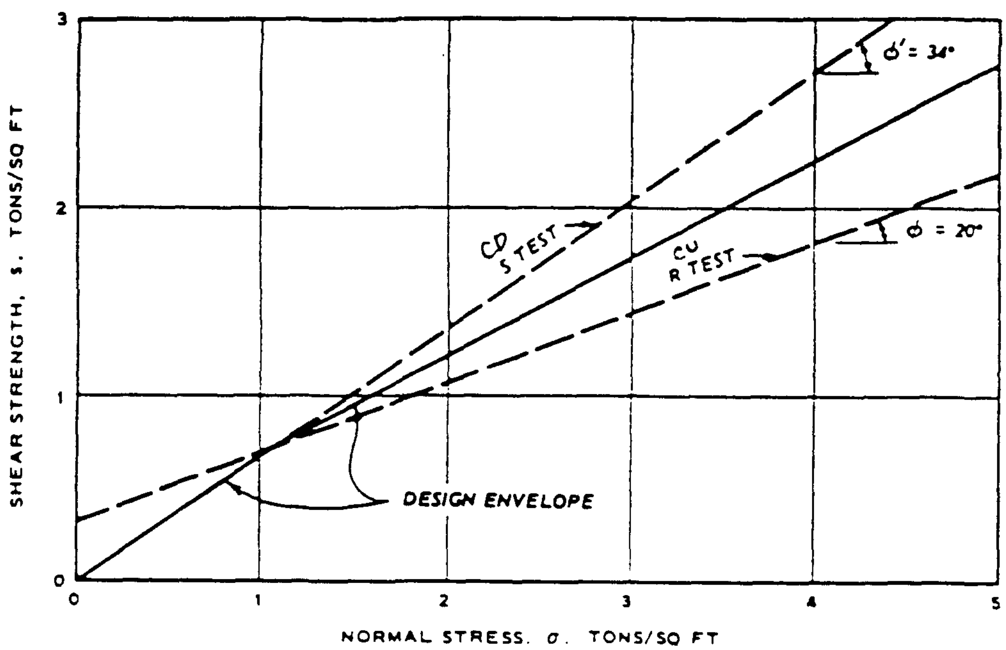


Figure 5. Design envelope for Cases IV, V, and VI

developed during construction are not dissipated before a partial pool condition can develop.

d. Case V: Steady Seepage with Maximum Storage Pool. A condition of steady seepage from the maximum water storage level that can be maintained sufficiently long to produce a condition of steady seepage throughout an embankment may be critical for downstream slope stability. A flow net should be constructed to determine the phreatic line and seepage forces when the assumption of a horizontal phreatic line in the impervious zone is overly conservative. Shear strengths used in Case V should be based on the same shear strength envelope used in Case IV, except for large downstream zones consisting of cohesionless materials that may be analyzed by the infinite slope method using the S strength envelope. The stability of upstream slopes need not be examined for this case. Where downstream slopes composed mainly of cohesionless soils rest on weak foundations, analyses by the infinite slope method should be supplemented with analyses by the circular arc or wedge methods to determine if a failure plane through the foundation is more critical.

e. Case VI: Steady Seepage with Surcharge Pool. The case where a steady seepage condition exists in an embankment and an additional horizontal thrust is imposed by a surcharge pool should also be examined for downstream slope stability. This condition is especially critical for rockfill dams with narrow central cores. Shear strengths used should be the same as those used in Case V, and analyses should be by the wedge or circular arc method. The surcharge pool should be considered as a temporary condition causing no saturation of impervious materials above the steady seepage saturation line.

f. Case VII: Earthquake. Much research is in progress on the behavior of earth dams subjected to earthquake shocks, and new analytical methods for evaluating seismic effects are being developed. However, at present, the traditional approach is still recommended. This assumes that the earthquake imparts an additional horizontal force F_h acting in the

APPENDIX E

STORM WATER MANAGEMENT CALCULATIONS

- Appendix E-1 Landfill Embankment Flood Stage Erosion Protection
- Appendix E-2 Surface Water Runoff Estimates for a 25-Year, 24-Hour Rainfall Event
- Appendix E-3 Discharge Culvert Design
- Appendix E-4 Erosion Estimates

APPENDIX E-1

LANDFILL EMBANKMENT FLOOD STAGE EROSION PROTECTION

COMPUTATION SHEET

RMT Inc.
1143 Highland Drive, Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO
Flood Protection Calculations	By: SGH	Date: 02/18/97	By:	Date:	3938.14

OBJECTIVE: Determine what erosion control measures will be necessary to protect the final cap design from flooding of the Grand River.

METHODOLOGY: Determine the maximum flow velocity during the 100-Year Flood event. Calculate the minimum requirements for any erosion control mat to protect the final cover from the design flood event.

CONCLUSION: The erosion control mat product shall meet the following requirements

Short-term design velocity:	8.1 fps
Long-term design velocity:	9.4 fps

As an example, Pyramat manufactured by Synthetic Industries meets both requirements:

Short-term Factor of Safety =	3.19
Long-term Factor of Safety =	1.60

G:\data\scottlt\excel\03938\floodway.xls

1143 Highland Drive. Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO
Flood Protection Calculations	By: SGH	Date: 02/18/97	By:	Date:	3938.14

CALCULATIONS:

- Determine the maximum flow velocity during the 100-year flood event

The maximum flow velocity for the 100-year flood event is 6.26 fps.
(taken from "Grand River Floodwall and Embankment Improvements, Butterworth Landfill Embankment, Flood Stage Impact Evaluation, prepared by Fishbeck, Thompson, Carr, & Huber, Inc., March 1996 included as Appendix A of Volume 2 of the Preliminary Remedial Design Project Plan, March 1996. See Sheet 3 of this calculation.)

- Determine the minimum requirements for the erosion control mat

Required Short-term Factor of Safety	1.3
Required Long-term Factor of Safety	1.5

Short-term minimum velocity = 1.3 * 6.26
= 8.1 fps

Long-term minimum velocity = 1.5 * 6.26
= 9.4 fps

- Determine if a soft-armour erosion control product meets the minimum requirements or if additional protection is required

Pyramat is manufactured by Synthetic Industries and has maximum design velocities as shown on Sheet 4 of this calculation.

Worst-case scenario is flood event after construction of cap but before revegetation of slope. Determine the factor of safety for the Pyramat design velocities compared to minimum design velocities.

Short-term Factor of Safety = 20 / 6.26
= 3.2 > 1.3 OK

Long-term Factor of Safety = 10 / 6.26
= 1.6 > 1.5 OK

The Pyramat can be used for erosion control.

TABLE 1 Grand River Floodwall Water Surface Elevations					
Station/Cross Section ID (ft)	100-Year Water Surface Elevation		Increase (ft)	Average Channel Velocity	
	Existing (ft)	Proposed (ft)		Existing (ft/s)	Proposed (ft/s)
0	607.67	607.67	0	5.04	5.04
500	607.88	607.88	0	3.93	3.93
800	607.90	607.88	-0.02	3.91	4.12
2000	607.93	607.89	-0.04	4.86	5.19
3200	607.94	607.96	0.02	6.22	6.26
4400	608.37	608.30	-0.07	4.99	5.49
5885	608.53	608.59	0.06	5.06	5.05
6345	608.76	608.81	0.05	3.85	3.84
6915	609.05	609.10	0.05	4.30	4.29
7565	609.18	609.24	0.06	5.65	5.64

STUDY AREA

The area of study for this analysis begins at the I-196 eastbound bridge over the Grand River and extends 7,565 feet upstream. The HEC-2 model was used to perform the analysis. The starting water surface elevations used in the Butterworth Landfill HEC-2 model were obtained from the HEC-2 model prepared by Fishbeck, Thompson, Carr & Huber, Inc. (FTC&H) for the Michigan Department of Transportation (MDOT) Level II Scour Analysis of the I-196 bridge over the Grand River. Cross section input data was obtained from the Level II Scour Analysis performed by FTC&H and from the existing USGS hydraulic model used in the current FEMA study. The first downstream cross section was input at the upstream face of the eastbound I-196 bridge. The bridge was not included in the HEC-2 model since all of the flood events pass underneath the bridge. The Level II scour analysis lists a minimum low chord elevation of 612.99 feet, and the maximum water surface elevation at the bridge is 610.13 feet for the 500-year flood event. Model results do not indicate any backwater at the bridge due in insufficient conveyance through the bridge structure. All cross sections begin at the centerline of Market Street, which runs along the south bank of the Grand River, and extends across the river into the landfill site. The abandoned railroad bridge

Performance of PYRAMAT™ erosion matrix has been extensively evaluated at a renowned hydraulics testing laboratory in the western United States.

Establishing a flow rate versus time continuum, performance (see graph below) has been quantified using vegetated and non-vegetated mattings versus non-reinforced vegetation and bare soil. These studies identify the "design window", which provides performance guidelines from time of installation, transitioning to a mature vegetated condition for the long-term design life of the project.

Peak Performance!

Maximum recommended permissible velocities and shear stresses for PYRAMAT™ erosion matrix are presented in the table above. Vegetated, PYRAMAT™ erosion matrix will resist flow velocities of up to 25 ft/sec at shear stresses up to 10 lbs/ft²!

Additionally, the resistance of unvegetated PYRAMAT™ erosion matrix to directly applied high velocity shear stresses was measured using a specially designed flume. The PYRAMAT™ erosion matrix structure resisted the maximum shear developed at full-flume capacity with no deformation whatsoever. Maximum shear stress developed was approximately 8 lbs/ft² at a velocity of 27 ft/sec!

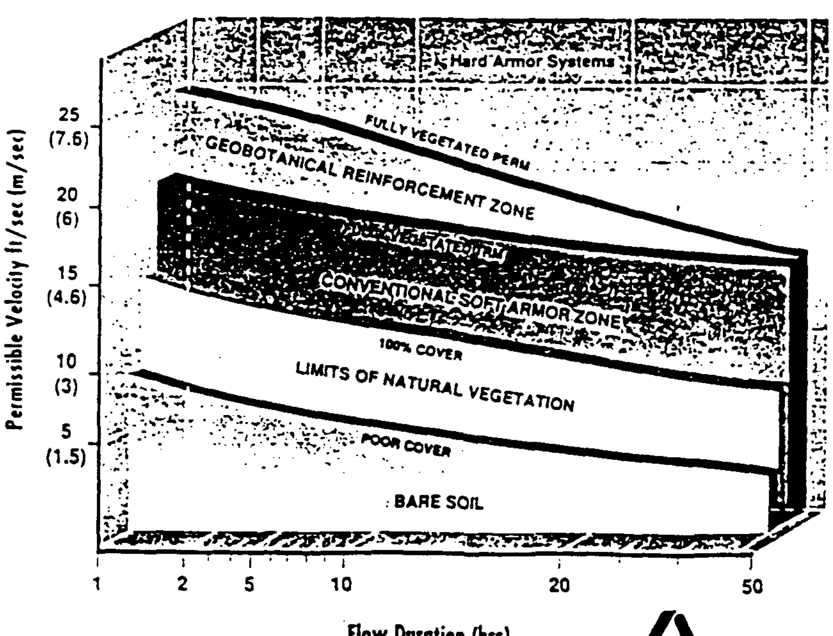
PYRAMAT™ MAXIMUM PERMISSIBLE DESIGN VALUES

PERFORMANCE	SHORT TERM (1/2 hr)	LONG TERM (50 hrs)
VELOCITY		
Vegetated	25 ft/sec (7.6 m/sec)	14 ft/sec (4.3 m/sec)
Unvegetated	20 ft/sec (6.1 m/sec)	10 ft/sec (3.0 m/sec)
SHEAR STRESS		
Vegetated	10 lbs/ft² (48.9 kg/m²)	6 lbs/ft² (29.3 kg/m²)
Unvegetated	8 lbs/ft² (39.2 kg/m²)	3 lbs/ft² (14.7 kg/m²)

The graph below illustrates the enhanced performance of PYRAMAT™ permanent erosion and reinforcement matrix above that of conventional *Biotechnical Composites™* and natural vegetation.

High velocity hydraulic flume testing.

LONG TERM PERFORMANCE GUIDELINES



PYRAMAT™ erosion matrix takes "geobotanical reinforcement" to unprecedented levels.

APPENDIX E-2

SURFACE WATER RUNOFF ESTIMATES FOR A 25-YEAR, 24-HOUR RAINFALL EVENT

1143 Highland Drive, Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Surface Water Calculations	WJK	Date: 10/2/98	By: SJK	Date: 10-2-98	3938.64

OBJECTIVE: Determine the surface water runoff from the 25-year, 24-hour storm event.

METHODOLOGY: Peak surface water run-off was calculated using the "Quick TR-55 Watershed Modeling Package (QUICK TR-55)" using methodology developed in "*Urban Hydrology for Small Watersheds*" (U.S. Dept. of Agriculture, 1986). Watershed areas and slopes were determined in AutoCAD based on the delineations shown on Sheet 3 of this calculation.

The surface water model requires the following input variables:

Hydrologic Soil Group:	Group C, see Sheet 4
Curve Number:	79, see Sheet 5
Rainfall Distribution:	Type II, see Sheet 6
2-year, 24-hour rainfall:	2.7", see Sheet 7
25-year, 24-hour rainfall:	4.6", see Sheet 8

The Quick TR-55 model determines surface water runoff based on the input variables shown above, the drainage basin area, and the time of concentration. The time of concentration values for this analysis includes sheet flow and shallow concentrated flow. Time of concentration calculations by Quick TR-55 are presented in Sheets 9 through 22.

Output from the QUICK TR-55 model is presented as Sheets 23 through 31 of this package. Note that Quick TR-55 only allows 10 sub-areas for each run, Watersheds 1-9 are shown in run 1 (Butter3), Watersheds 10-12 are shown in run 2 (Butter4).

CONCLUSION: See Sheet 2 of this package for a summary of watershed areas and peak flows

Results and data included in this calculation will be used to complete other design calculations (eg, culvert design and erosion estimation).

h:/d/p/butworth/swcalc98.xls

COMPUTATION SHEET

1143 Highland Drive, Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Surface Water Calculations	WJK	Date: 10/2/98	By:	Date:	3938.64

CALCULATIONS:

- Determine the peak surface run-off from the 25-year, 24-hour storm.

Output from the QTR-55 model is included in this package as sheets 04 though 18. A summary table of output is included below.

Watershed Area Designation	Area (acres)	Tc (hr)	CN	Peak Flow (cfs)
1	6.1	0.61	79	12.0
2	24.0	0.60	79	48.0
3	19.4	0.69	79	31.0
4	23.2	0.58	79	46.0
5	32.4	1.10	79	43.0
6	4.2	0.61	79	8.0
7	5.4	0.52	79	11.0
8	6.7	0.63	79	11.0
9	11.3	0.63	79	18.0
10	4.9	0.52	79	10.0
11	2.6	0.10	79	10.0
12	21.7	0.66	79	35.0

PLOT DATA

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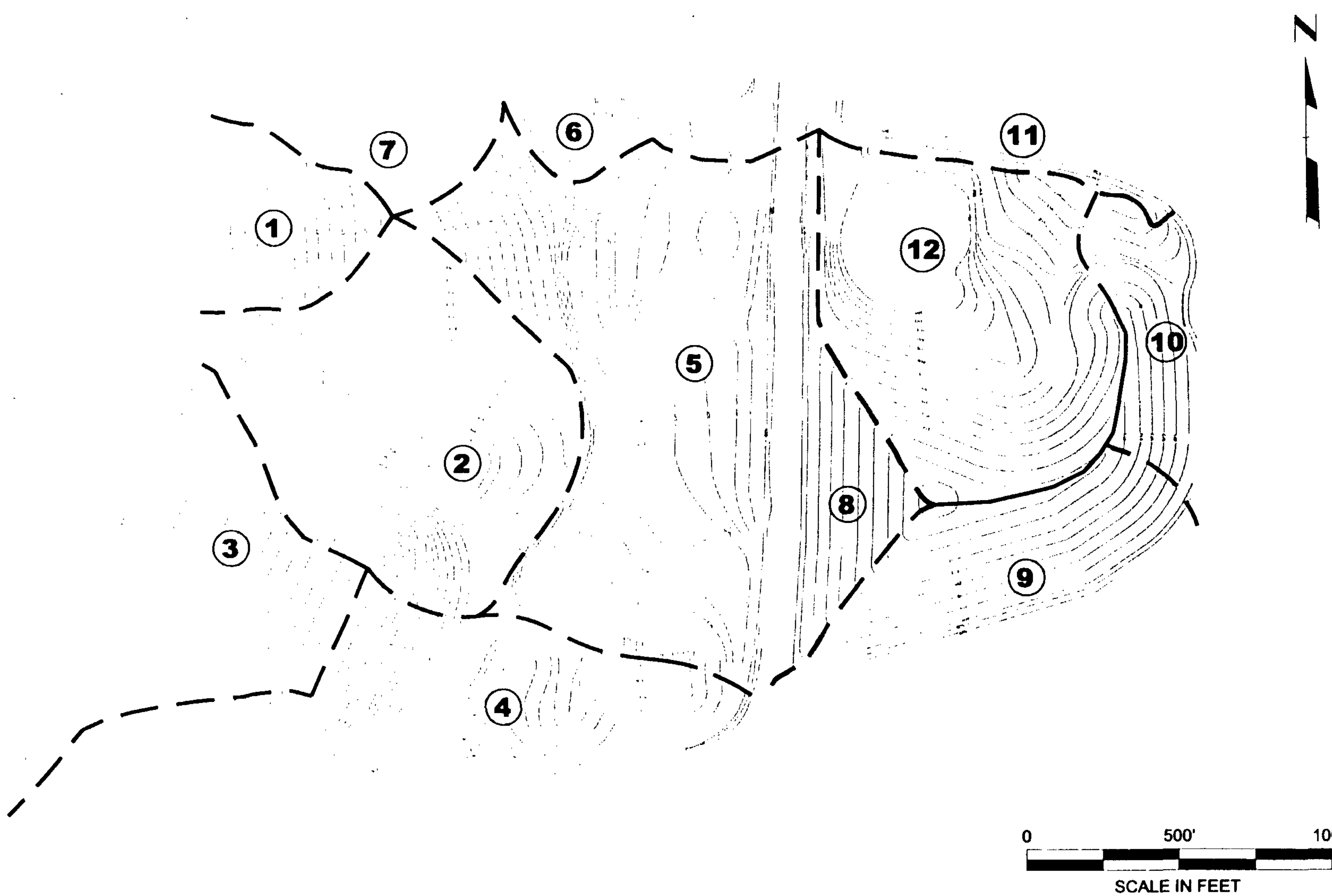


BUTTERWORTH LANDFILL
GRAND RAPIDS, MICHIGAN

WATERSHED AREAS

DRAWN BY:	SJL
APPROVED BY:	GRC
PROJECT NUMBER:	3938.64
FILE NUMBER:	39386410.DWG
DATE:	OCTOBER 1998

RMT® INC. MICHIGAN

RMT COMPUTER AIDED DESIGN AND DRAFTING

3 of 31

Appendix A: Hydrologic soil groups

Soils are classified into hydrologic soil groups (HSG's) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSG's, which are A, B, C, and D, are one element used in determining runoff curve numbers (see chapter 2). For the convenience of TR-55 users, exhibit A-1 lists the HSG classification of United States soils.

The infiltration rate is the rate at which water enters the soil at the soil surface. It is controlled by surface conditions. HSG also indicates the transmission rate—the rate at which the water moves within the soil. This rate is controlled by the soil profile. Approximate numerical ranges for transmission rates shown in the HSG definitions were first published by Musgrave (USDA 1955). The four groups are defined by SCS soil scientists as follows:

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

In exhibit A-1, some of the listed soils have an added modifier; for example, "Abrazo, gravelly." This refers to a gravelly phase of the Abrazo series that is found in SCS soil map legends.

Disturbed soil profiles

As a result of urbanization, the soil profile may be considerably altered and the listed group classification may no longer apply. In these circumstances, use the following to determine HSG according to the texture of the new surface soil, provided that significant compaction has not occurred (Brakensiek and Rawls 1983):

HSG	*Soil textures*
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Drainage and group D soils

Some soils in the list are in group D because of a high water table that creates a drainage problem. Once these soils are effectively drained, they are placed in a different group. For example, Ackerman soil is classified as A/D. This indicates that the drained Ackerman soil is in group A and the undrained soil is in group D.

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description: Cover type and hydrologic condition	Average percent impervious area[2]	Curve numbers for hydrologic soil group— A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	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
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

"Urban Hydrology for Small Watersheds", Technical Release 55,
U.S. Dept. of Agriculture, June 1986

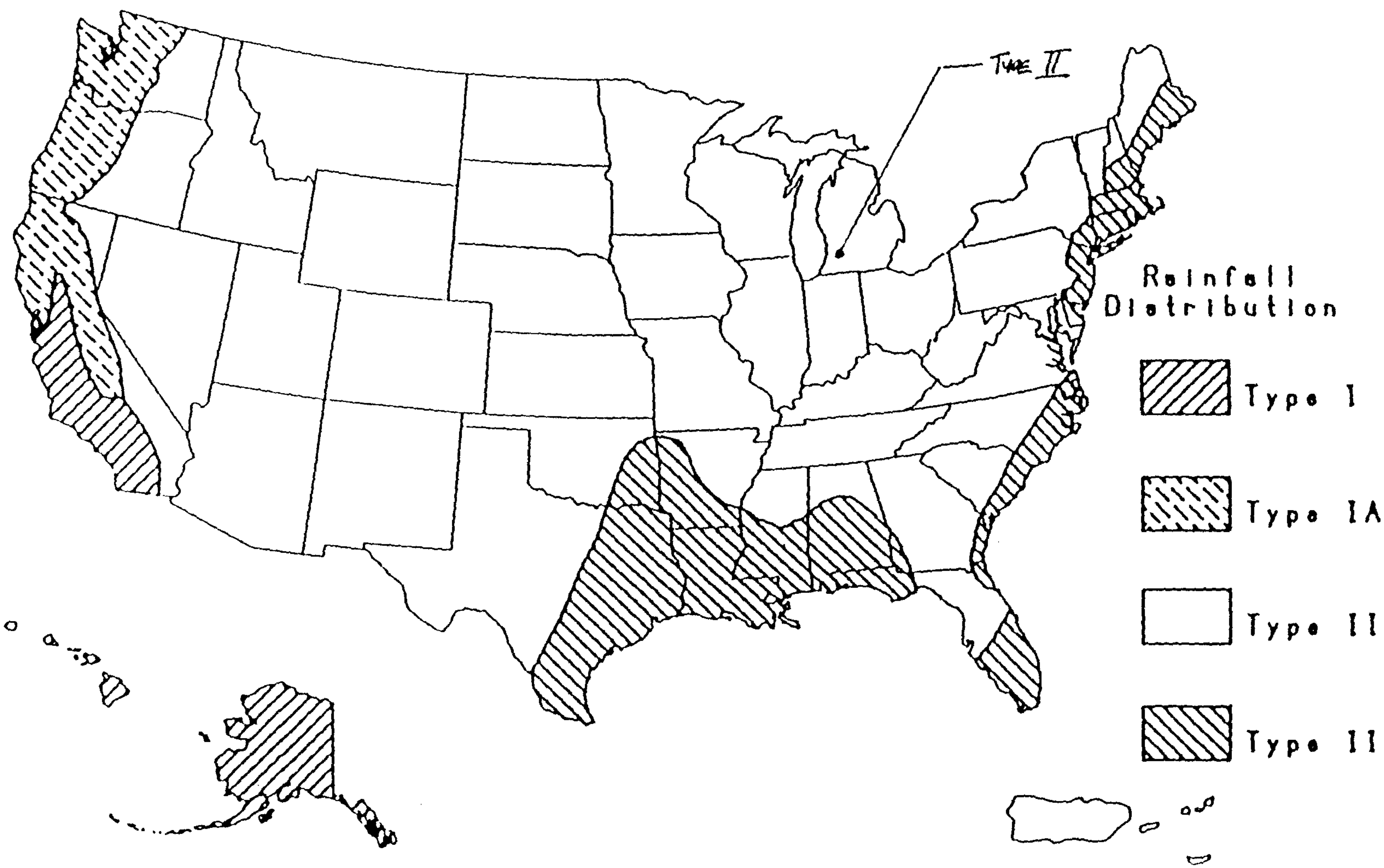
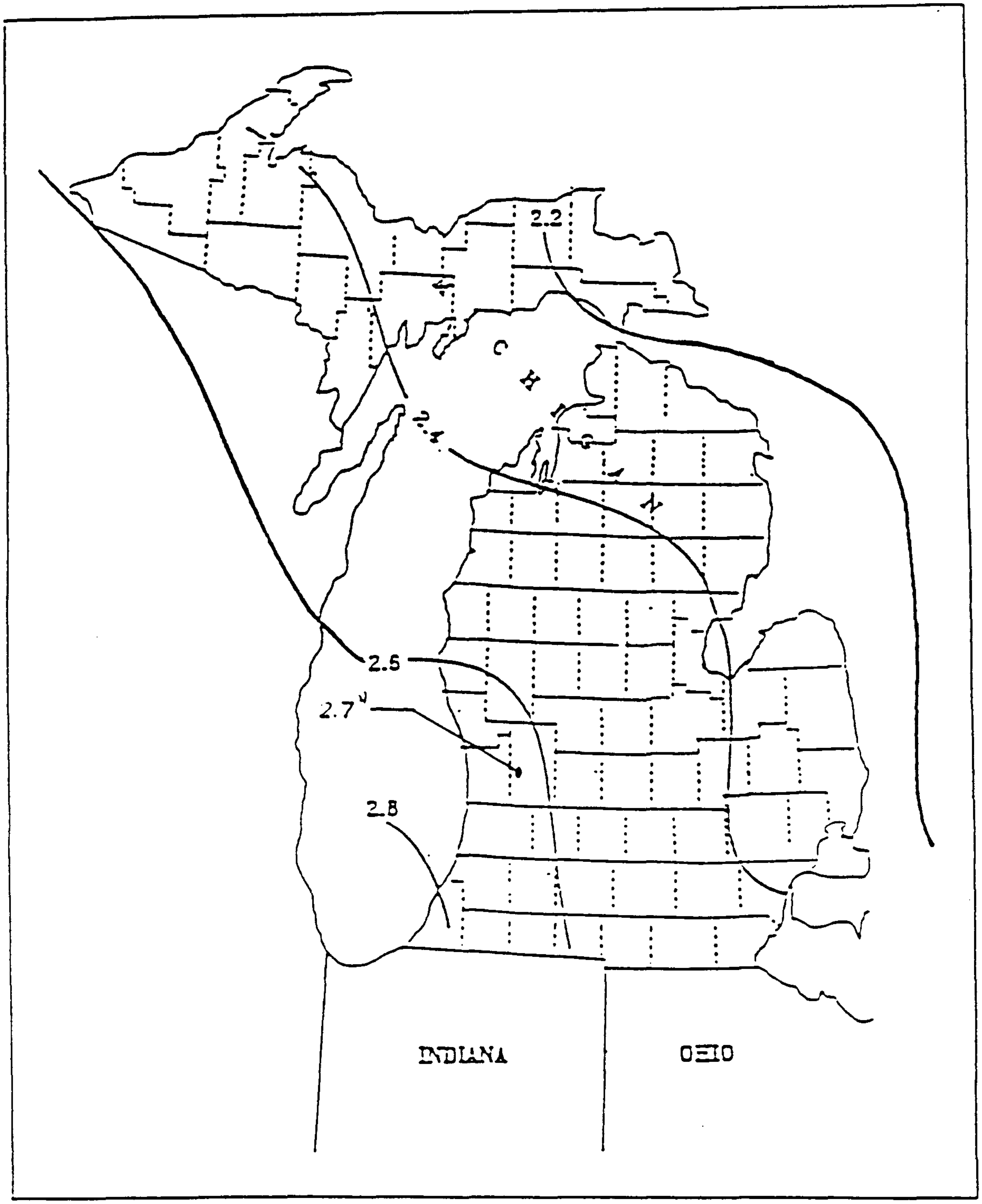


Figure B-2.—Approximate geographic boundaries for SCS rainfall distributions.

"Urban Hydrology for Small Watersheds", Technical Release 55,
U.S. Dept. of A·· ·ulture, June 1986

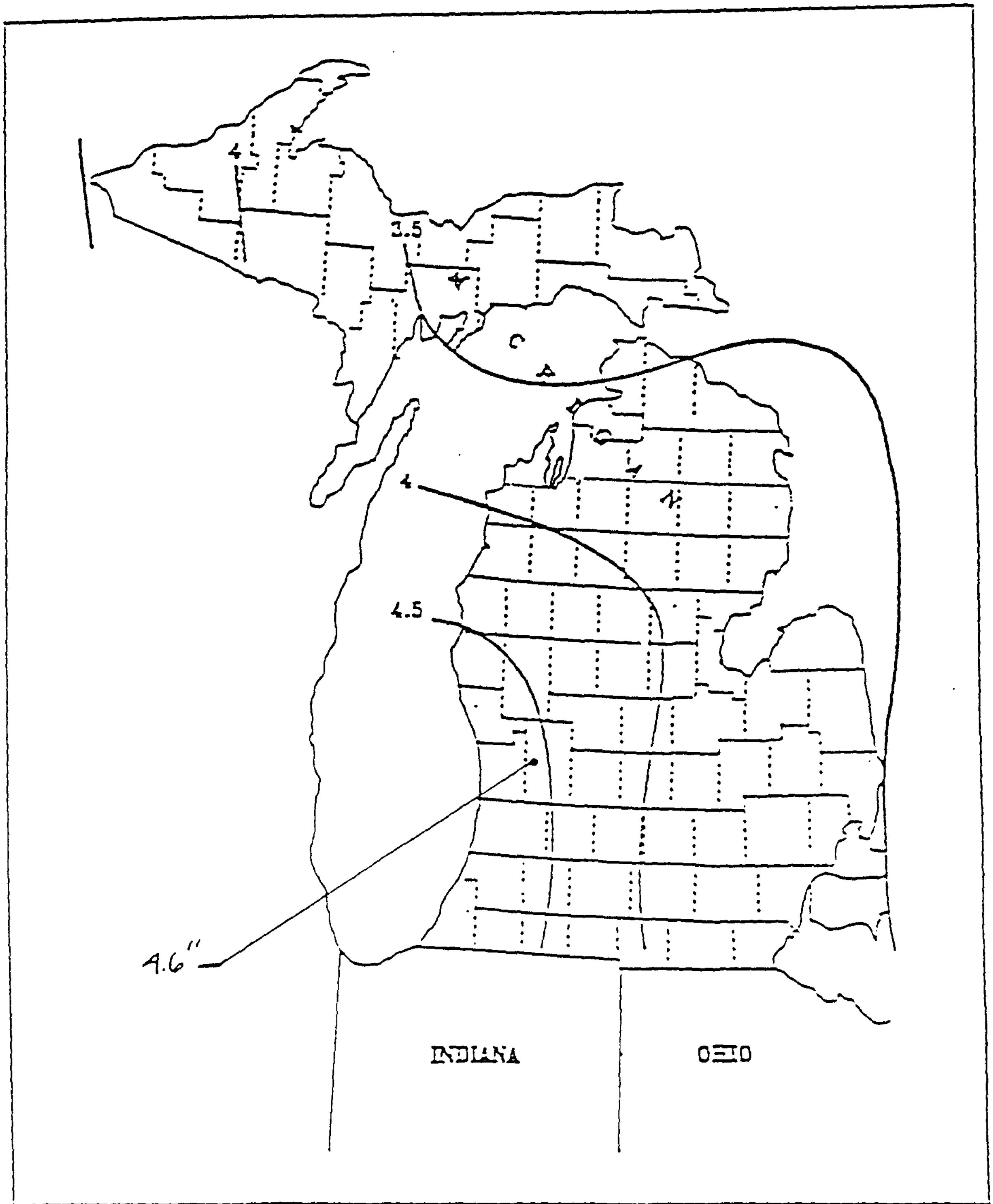
14

Figure 3.1 2-year, 24-hour rainfall



"Guidebook of Best Management Practices for Michigan Watersheds",
Michigan Department of Natural Resources, Surface Water Quality Division, 1994

Figure 3.4   25-year, 24-hour rainfall



"Guidebook of Best Management Practices for Michigan Watersheds",
Michigan Department of Natural Resources, Surface Water Quality Division, 1994

Quick TR-55 Ver.5.46 S/N:
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SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

Subarea descr.	Tc or Tt	Time (hrs)
1	Tc	0.61
2	Tc	0.60
3	Tc	0.69
4	Tc	0.58
5	Tc	1.10
6	Tc	0.61
7	Tc	0.52
8	Tc	0.63
9	Tc	0.63

Quick TR-55 Ver.5.46 S/N:
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SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

Subarea descr.	Tc or Tt	Time (hrs)
10	Tc	0.52
11	Tc	0.10
12	Tc	0.66

```
Quick TR-55 Ver.5.46   S/N:
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                          Butterworth Landfill
                            Grand Rapids, MI
                   Amended Remedial Design Project Plan

                        Tc COMPUTATIONS FOR: 1

SHEET FLOW (Applicable to Tc only)
    Segment ID                                      1
    Surface description                         Grass
    Manning's roughness coeff., n                  0.2400
    Flow length, L (total < or = 300)     ft      300.0 ✓
    Two-yr 24-hr rainfall, P2             in      2.700 ✓
    Land slope, s                         ft/ft   0.0240 ✓     17.7/780 = 0.023
                        0.8
        .007 * (n*L)
    T = --------------                    hrs      0.58                    =  0.58
           0.5    0.4
         P2    *  s

SHALLOW CONCENTRATED FLOW
    Segment ID                                     2
    Surface (paved or unpaved)?                    Unpaved
    Flow length, L                        ft       300.0
    Watercourse slope, s                  ft/ft    0.0370

                            0.5
    Avg.V =  Csf *  (s)                   ft/s     3.1035
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                      hrs      0.03                    =  0.03

CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a          sq.ft     0.00
    Wetted perimeter, Pw                  ft        0.00
    Hydraulic radius, r = a/Pw            ft        0.000
    Channel slope, s                      ft/ft     0.0000
    Manning's roughness coeff., n                   0.0000

                      2/3     1/2
         1.49   *   r    *   s
    V = --------------------              ft/s     0.0000
                    n

    Flow length, L                        ft           0

    T = L / (3600*V)                      hrs      0.00                    =  0.00

::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                              TOTAL TIME (hrs)        0.61
```

```
Quick TR-55 Ver.5.46   S/N:
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                          Butterworth Landfill
                            Grand Rapids, MI
                  Amended Remedial Design Project Plan


                        Tc COMPUTATIONS FOR: 2

 SHEET FLOW (Applicable to Tc only)
     Segment ID                                      1
     Surface description                        Grass
     Manning's roughness coeff., n                   0.2400
     Flow length, L (total < or = 300)          ft    300.0
     Two-yr 24-hr rainfall, P2                  in    2.700
     Land slope, s                            ft/ft   0.0250
                            0.8
           .007 * (n*L)
     T =   --------------                      hrs     0.57           =  0.57
              0.5     0.4
            P2    *   s

 SHALLOW CONCENTRATED FLOW
     Segment ID                                      2
     Surface (paved or unpaved)?                    Unpaved
     Flow length, L                              ft    320.0
     Watercourse slope, s                      ft/ft   0.0470

                              0.5
     Avg.V =  Csf *   (s)                     ft/s   3.4979
     where:   Unpaved Csf = 16.1345
              Paved   Csf = 20.3282

     T = L / (3600*V)                          hrs     0.03           =  0.03


 CHANNEL FLOW
     Segment ID
     Cross Sectional Flow Area, a            sq.ft     0.00
     Wetted perimeter, Pw                       ft     0.00
     Hydraulic radius, r = a/Pw                 ft    0.000
     Channel slope, s                         ft/ft   0.0000
     Manning's roughness coeff., n                    0.0000

                        2/3     1/2
           1.49   *   r    *   s
     V =   --------------------                ft/s   0.0000
                        n

     Flow length, L                              ft        0

     T = L / (3600*V)                          hrs     0.00           =  0.00

    ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                          TOTAL TIME (hrs)        0.60
```

```
Quick TR-55 Ver.5.46   S/N:
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                         Butterworth Landfill
                           Grand Rapids, MI
                  Amended Remedial Design Project Plan


                        Tc COMPUTATIONS FOR: 3

 SHEET FLOW (Applicable to Tc only)
     Segment ID                                   1
     Surface description                     Grass
     Manning's roughness coeff., n                0.2400
     Flow length, L (total < or = 300)    ft     300.0
     Two-yr 24-hr rainfall, P2            in     2.700
     Land slope, s                     ft/ft     0.0200
                          0.8
           .007 * (n*L)
     T =  --------------                 hrs      0.62            =   0.62
              0.5    0.4
           P2   *   s

 SHALLOW CONCENTRATED FLOW
     Segment ID                                   2
     Surface (paved or unpaved)?                Unpaved
     Flow length, L                       ft     550.0
     Watercourse slope, s              ft/ft     0.0200

                            0.5
     Avg.V =  Csf  *   (s)              ft/s     2.2818
     where:   Unpaved Csf = 16.1345
              Paved   Csf = 20.3282

     T = L / (3600*V)                    hrs      0.07            =   0.07


 CHANNEL FLOW
     Segment ID
     Cross Sectional Flow Area, a      sq.ft      0.00
     Wetted perimeter, Pw                 ft      0.00
     Hydraulic radius, r = a/Pw           ft     0.000
     Channel slope, s                  ft/ft    0.0000
     Manning's roughness coeff., n              0.0000

                      2/3     1/2
          1.49  *  r   *   s
     V =  --------------------          ft/s    0.0000
                    n

     Flow length, L                       ft         0

     T = L / (3600*V)                    hrs      0.00            =   0.00

   ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                             TOTAL TIME (hrs)         0.69
```

```
Quick TR-55 Ver.5.46   S/N:
Executed: 08:39:36   10-02-1998    H:/data/project/butworth/alt\BUTTER3.TCT

                         Butterworth Landfill
                          Grand Rapids, MI
                  Amended Remedial Design Project Plan


                      Tc COMPUTATIONS FOR: 4

 SHEET FLOW (Applicable to Tc only)
    Segment ID                                    1
    Surface description                       Grass
    Manning's roughness coeff., n                0.2400
    Flow length, L (total < or = 300)     ft     300.0
    Two-yr 24-hr rainfall, P2             in     2.700
    Land slope, s                      ft/ft    0.0400
                        0.8
         .007 * (n*L)
    T =  --------------                  hrs      0.47            =  0.47
            0.5    0.4
          P2   *   s

 SHALLOW CONCENTRATED FLOW
    Segment ID                                    2
    Surface (paved or unpaved)?                Unpaved
    Flow length, L                        ft     700.0
    Watercourse slope, s               ft/ft    0.0120

                         0.5
    Avg.V =  Csf *  (s)                 ft/s    1.7674
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                     hrs      0.11            =  0.11


 CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a       sq.ft      0.00
    Wetted perimeter, Pw                  ft      0.00
    Hydraulic radius, r = a/Pw            ft     0.000
    Channel slope, s                   ft/ft    0.0000
    Manning's roughness coeff., n               0.0000

                      2/3    1/2
         1.49  *  r    *  s
    V =  --------------------           ft/s    0.0000
                   n

    Flow length, L                        ft         0

    T = L / (3600*V)                     hrs      0.00            =  0.00

   ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                              TOTAL TIME (hrs)       0.58
```

```
Quick TR-55 Ver.5.46    S/N:
Executed: 08:39:36   10-02-1998    H:/data/project/butworth/alt\BUTTER3.TCT

                         Butterworth Landfill
                           Grand Rapids, MI
                 Amended Remedial Design Project Plan


                      Tc COMPUTATIONS FOR: 5

 SHEET FLOW (Applicable to Tc only)
     Segment ID                                      1
     Surface description                        Grass
     Manning's roughness coeff., n                   0.2400
     Flow length, L (total < or = 300)      ft     300.0
     Two-yr 24-hr rainfall, P2               in     2.700
     Land slope, s                        ft/ft    0.0070
                          0.8
           .007 * (n*L)
     T =  --------------                   hrs      0.95              =  0.95
               0.5     0.4
             P2    *   s

 SHALLOW CONCENTRATED FLOW
     Segment ID                                      2
     Surface (paved or unpaved)?                     Unpaved
     Flow length, L                          ft     750.0
     Watercourse slope, s                 ft/ft    0.0070

                              0.5
     Avg.V =  Csf *   (s)                 ft/s     1.3499
     where:   Unpaved Csf = 16.1345
              Paved   Csf = 20.3282

     T = L / (3600*V)                      hrs      0.15              =  0.15


 CHANNEL FLOW
     Segment ID                                      00
     Cross Sectional Flow Area, a        sq.ft      0.00
     Wetted perimeter, Pw                    ft      0.00
     Hydraulic radius, r = a/Pw              ft     0.000
     Channel slope, s                     ft/ft    0.0000
     Manning's roughness coeff., n                 0.0000

                         2/3     1/2
          1.49   *   r    *   s
     V =  --------------------             ft/s    0.0000
                      n

     Flow length, L                          ft         0

     T = L / (3600*V)                      hrs      0.00              =  0.00

   ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                            TOTAL TIME (hrs)          1.10
```

```
Quick TR-55 Ver.5.46   S/N:
Executed: 08:39:36   10-02-1998    H:/data/project/butworth/alt\BUTTER3.TCT

                        Butterworth Landfill
                          Grand Rapids, MI
                 Amended Remedial Design Project Plan


                      Tc COMPUTATIONS FOR: 6

 SHEET FLOW (Applicable to Tc only)
     Segment ID                                   1
     Surface description                      Grass
     Manning's roughness coeff., n                 0.2400
     Flow length, L (total < or = 300)     ft      300.0
     Two-yr 24-hr rainfall, P2             in      2.700
     Land slope, s                        ft/ft    0.0210
                       0.8
          .007 * (n*L)
     T =  --------------                   hrs      0.61              =   0.61
             0.5    0.4
           P2    *   s

 SHALLOW CONCENTRATED FLOW
     Segment ID
     Surface (paved or unpaved)?
     Flow length, L                        ft         0.0
     Watercourse slope, s                 ft/ft    0.0000

                         0.5
     Avg.V =  Csf *  (s)                  ft/s     0.0000
     where:   Unpaved Csf = 16.1345
              Paved   Csf = 20.3282

     T = L / (3600*V)                      hrs      0.00              =   0.00


 CHANNEL FLOW
     Segment ID
     Cross Sectional Flow Area, a        sq.ft      0.00
     Wetted perimeter, Pw                  ft       0.00
     Hydraulic radius, r = a/Pw            ft      0.000
     Channel slope, s                     ft/ft    0.0000
     Manning's roughness coeff., n                 0.0000

                      2/3    1/2
          1.49  *  r   *  s
     V =  --------------------             ft/s     0.0000
                   n

     Flow length, L                        ft          0

     T = L / (3600*V)                      hrs      0.00              =   0.00

    :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                                TOTAL TIME (hrs)      0.61
```

```
Quick TR-55 Ver.5.46   S/N:
Executed: 14:13:35   10-02-1998    H:/data/project/butworth/alt\BUTTER3.TCT

                         Butterworth Landfill
                           Grand Rapids, MI
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                     Tc COMPUTATIONS FOR: 7

SHEET FLOW (Applicable to Tc only)
    Segment ID                                        1
    Surface description                         Grass
    Manning's roughness coeff., n                     0.2400
    Flow length, L (total < or = 300)        ft      300.0
    Two-yr 24-hr rainfall, P2                in      2.700
    Land slope, s                          ft/ft     0.0370
                          0.8
         .007 * (n*L)
    T =  --------------                      hrs      0.49            =  0.49
              0.5    0.4
           P2   *   s

SHALLOW CONCENTRATED FLOW
    Segment ID                                        2
    Surface (paved or unpaved)?                    Unpaved
    Flow length, L                           ft      400.0
    Watercourse slope, s                   ft/ft     0.0350

                            0.5
    Avg.V =  Csf *  (s)                     ft/s     3.0185
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                         hrs      0.04            =  0.04


CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a          sq.ft       0.00
    Wetted perimeter, Pw                     ft       0.00
    Hydraulic radius, r = a/Pw               ft      0.000
    Channel slope, s                       ft/ft     0.0000
    Manning's roughness coeff., n                    0.0000

                       2/3    1/2
         1.49  *  r    *  s
    V =  --------------------               ft/s     0.0000
                  n

    Flow length, L                           ft          0

    T = L / (3600*V)                         hrs      0.00            =  0.00

    ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                            TOTAL TIME (hrs)         0.52
```

```
Quick TR-55 Ver.5.46   S/N:
Executed: 08:39:36   10-02-1998     H:/data/project/butworth/alt\BUTTER3.TCT

                         Butterworth Landfill
                           Grand Rapids, MI
                 Amended Remedial Design Project Plan


                       Tc COMPUTATIONS FOR: 8

 SHEET FLOW (Applicable to Tc only)
     Segment ID                                     1
     Surface description                       Grass
     Manning's roughness coeff., n                  0.2400
     Flow length, L (total < or = 300)       ft     300.0
     Two-yr 24-hr rainfall, P2               in     2.700
     Land slope, s                         ft/ft    0.0200
                         0.8
           .007 * (n*L)
     T =   --------------                   hrs     0.62              =   0.62
              0.5     0.4
            P2    *   s

 SHALLOW CONCENTRATED FLOW
     Segment ID                                     2
     Surface (paved or unpaved)?                 Unpaved
     Flow length, L                          ft     100.0
     Watercourse slope, s                  ft/ft    0.0300

                           0.5
     Avg.V =  Csf *  (s)                    ft/s    2.7946
     where:   Unpaved Csf = 16.1345
              Paved   Csf = 20.3282

     T = L / (3600*V)                       hrs     0.01              =   0.01


 CHANNEL FLOW
     Segment ID
     Cross Sectional Flow Area, a         sq.ft     0.00
     Wetted perimeter, Pw                    ft     0.00
     Hydraulic radius, r = a/Pw              ft     0.000
     Channel slope, s                      ft/ft    0.0000
     Manning's roughness coeff., n                  0.0000

                       2/3     1/2
           1.49   *   r    *   s
     V =   --------------------             ft/s    0.0000
                      n

     Flow length, L                          ft         0

     T = L / (3600*V)                       hrs     0.00              =   0.00

   ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                              TOTAL TIME (hrs)          0.63
```

```
Quick TR-55 Ver.5.46   S/N:
Executed: 08:39:36   10-02-1998    H:/data/project/butworth/alt\BUTTER3.TCT

                         Butterworth Landfill
                           Grand Rapids, MI
                  Amended Remedial Design Project Plan

                      Tc COMPUTATIONS FOR: 9

 SHEET FLOW (Applicable to Tc only)
     Segment ID                                    1
     Surface description                       Grass
     Manning's roughness coeff., n                 0.2400
     Flow length, L (total < or = 300)     ft      300.0
     Two-yr 24-hr rainfall, P2             in      2.700
     Land slope, s                       ft/ft     0.0200
                         0.8
          .007 * (n*L)
     T =  --------------                   hrs      0.62            =  0.62
             0.5    0.4
           P2    *   s

 SHALLOW CONCENTRATED FLOW
     Segment ID                                    2
     Surface (paved or unpaved)?                 Unpaved
     Flow length, L                          ft     140.0
     Watercourse slope, s                  ft/ft    0.0900

                          0.5
     Avg.V =  Csf *   (s)                  ft/s     4.8404
     where:   Unpaved Csf = 16.1345
              Paved   Csf = 20.3282

     T = L / (3600*V)                      hrs      0.01            =  0.01

 CHANNEL FLOW
     Segment ID
     Cross Sectional Flow Area, a         sq.ft      0.00
     Wetted perimeter, Pw                   ft       0.00
     Hydraulic radius, r = a/Pw             ft      0.000
     Channel slope, s                     ft/ft     0.0000
     Manning's roughness coeff., n                  0.0000

                      2/3     1/2
         1.49  *  r    *   s
     V = --------------------              ft/s     0.0000
                   n

     Flow length, L                         ft          0

     T = L / (3600*V)                      hrs      0.00            =  0.00

    ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                          TOTAL TIME (hrs)          0.63
```

Quick TR-55 Ver.5.46 S/N:
Executed: 08:37:21 10-02-1998 H:/data/project/butworth/alt\BUTTER4.TCT

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

Tc COMPUTATIONS FOR: 10

SHEET FLOW (Applicable to Tc only)

Segment ID		1	
Surface description		Grass	
Manning's roughness coeff., n		0.2400	
Flow length, L (total < or = 300)	ft	220.0	
Two-yr 24-hr rainfall, P2	in	2.700	
Land slope, s	ft/ft	0.0200	
$T = \frac{.007 * (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	0.49	= 0.49

SHALLOW CONCENTRATED FLOW

Segment ID		2	
Surface (paved or unpaved)?		Unpaved	
Flow length, L	ft	180.0	
Watercourse slope, s	ft/ft	0.0100	
$Avg.V = Csf * (s)^{0.5}$	ft/s	1.6135	
where: Unpaved Csf = 16.1345 Paved Csf = 20.3282			
T = L / (3600*V)	hrs	0.03	= 0.03

CHANNEL FLOW

Segment ID			
Cross Sectional Flow Area, a	sq.ft	0.00	
Wetted perimeter, Pw	ft	0.00	
Hydraulic radius, r = a/Pw	ft	0.000	
Channel slope, s	ft/ft	0.0000	
Manning's roughness coeff., n		0.0000	
$V = \frac{1.49 * r^{2/3} * s^{1/2}}{n}$	ft/s	0.0000	
Flow length, L	ft	0	
T = L / (3600*V)	hrs	0.00	= 0.00

::

TOTAL TIME (hrs) 0.52

```
Quick TR-55 Ver.5.46   S/N:
Executed: 08:37:21   10-02-1998    H:/data/project/butworth/alt\BUTTER4.TCT

                         Butterworth Landfill
                          Grand Rapids, MI
                   Amended Remedial Design Project Plan


                      Tc COMPUTATIONS FOR: 11

 SHEET FLOW (Applicable to Tc only)
    Segment ID                                        1
    Surface description                          Grass
    Manning's roughness coeff., n                      0.2400
    Flow length, L (total < or = 300)          ft       80.0
    Two-yr 24-hr rainfall, P2                   in      2.700
    Land slope, s                              ft/ft    0.1250
                        0.8
         .007 * (n*L)
    T =  --------------                        hrs       0.10                 =   0.10
            0.5    0.4
          P2    *   s

 SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?
    Flow length, L                              ft        0.0
    Watercourse slope, s                       ft/ft    0.0000

                          0.5
    Avg.V =  Csf *   (s)                       ft/s     0.0000
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                           hrs       0.00                 =   0.00


 CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a              sq.ft      0.00
    Wetted perimeter, Pw                        ft       0.00
    Hydraulic radius, r = a/Pw                  ft      0.000
    Channel slope, s                           ft/ft    0.0000
    Manning's roughness coeff., n                       0.0000

                      2/3     1/2
         1.49   *   r    *   s
    V =  --------------------                  ft/s     0.0000
                    n

    Flow length, L                              ft          0

    T = L / (3600*V)                           hrs       0.00                 =   0.00

   ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                                 TOTAL TIME (hrs)         0.10
```

```
Quick TR-55 Ver.5.46   S/N:
Executed: 08:37:21   10-02-1998    H:/data/project/butworth/alt\BUTTER4.TCT

                          Butterworth Landfill
                            Grand Rapids, MI
                  Amended Remedial Design Project Plan

                       Tc COMPUTATIONS FOR: 12

 SHEET FLOW (Applicable to Tc only)
     Segment ID                                      1
     Surface description                        Grass
     Manning's roughness coeff., n                  0.2400
     Flow length, L (total < or = 300)     ft      300.0
     Two-yr 24-hr rainfall, P2             in      2.700
     Land slope, s                       ft/ft     0.0230
                           0.8
          .007 * (n*L)
     T =  --------------                  hrs       0.59              =   0.59
              0.5     0.4
            P2    *   s

 SHALLOW CONCENTRATED FLOW
     Segment ID                                      2
     Surface (paved or unpaved)?                  Unpaved
     Flow length, L                        ft      470.0
     Watercourse slope, s                ft/ft     0.0130

                             0.5
     Avg.V =  Csf *  (s)                  ft/s     1.8396
     where:   Unpaved Csf = 16.1345
              Paved   Csf = 20.3282

     T = L / (3600*V)                     hrs       0.07              =   0.07


 CHANNEL FLOW
     Segment ID
     Cross Sectional Flow Area, a       sq.ft       0.00
     Wetted perimeter, Pw                  ft       0.00
     Hydraulic radius, r = a/Pw            ft      0.000
     Channel slope, s                    ft/ft     0.0000
     Manning's roughness coeff., n                 0.0000

                       2/3     1/2
          1.49  *  r    *  s
     V =  --------------------            ft/s     0.0000
                     n

     Flow length, L                        ft          0

     T = L / (3600*V)                     hrs       0.00              =   0.00

   :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                           TOTAL TIME (hrs)           0.66
```

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 10-02-1998 14:14:16
Watershed file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER3 .MOP
Hydrograph file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER3.HYD

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
1	6.10	79.0	0.50	0.00	4.60	2.46	I.12	.12
2	24.00	79.0	0.50	0.00	4.60	2.46	I.12	.12
3	19.40	79.0	0.75	0.00	4.60	2.46	I.12	.12
4	23.20	79.0	0.50	0.00	4.60	2.46	I.12	.12
5	32.40	79.0	1.00	0.00	4.60	2.46	I.12	.12
6	4.20	79.0	0.50	0.00	4.60	2.46	I.12	.12
7	5.40	79.0	0.50	0.00	4.60	2.46	I.12	.12
[illegible]	6.70	79.0	0.75	0.00	4.60	2.46	I.12	.12
[illegible]	11.30	79.0	0.75	0.00	4.60	2.46	I.12	.12

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 132.70 acres or 0.2073 sq.mi
Peak discharge = 201 cfs

WARNING: Drainage areas of two or more subareas differ by a factor of 5 or greater.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
1	0.61	0.00	0.50	0.00	Yes	--
2	0.60	0.00	0.50	0.00	Yes	--
3	0.69	0.00	0.75	0.00	Yes	--
4	0.58	0.00	0.50	0.00	Yes	--
5	1.10	0.00	1.00	0.00	Yes	--
6	0.61	0.00	0.50	0.00	Yes	--
7	0.52	0.00	0.50	0.00	Yes	--
8	0.63	0.00	0.75	0.00	Yes	--
9	0.63	0.00	0.75	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 10-02-1998 08:58:27
Watershed file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER3 .MOP
Hydrograph file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER3.HYD

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
1	12	12.4
2	48	12.4
3	31	12.6
4	46	12.4
5	43	12.8
6	8	12.4
7	11	12.4
8	11	12.6
9	18	12.6
Composite Watershed	201	12.5

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 10-02-1998 14:14:16
Watershed file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER3 .MOP
Hydrograph file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER3.HYD

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
1	0	0	1	1	2	4	7	11	12
2	1	2	3	5	8	15	27	42	48
3	1	1	2	2	3	5	8	14	21
4	1	2	3	5	8	14	26	40	46
5	1	2	2	3	4	5	8	13	20
6	0	0	0	1	1	3	5	7	8
7	0	0	1	1	2	3	6	9	11
8	0	0	1	1	1	2	3	5	7
9	1	1	1	1	2	3	5	8	12
Total (cfs)	5	8	14	20	31	54	95	149	185

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
1	12	9	7	5	3	2	2	1	1
2	46	37	27	21	13	9	7	6	5
3	27	31	30	27	19	13	9	7	6
4	45	36	27	20	13	9	7	6	5
5	28	35	40	43	39	30	22	17	13
6	8	6	5	4	2	2	1	1	1
7	10	8	6	5	3	2	2	1	1
8	9	11	10	9	6	4	3	2	2
9	16	18	18	16	11	8	5	4	3
Total (cfs)	201	191	170	150	109	79	58	45	37

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 10-02-1998 14:14:16
Watershed file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER3 .MOP
Hydrograph file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER3.HYD

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
1	1	1	1	1	1	1	1	1	0
2	5	4	3	3	3	3	2	2	2
3	5	4	3	3	2	2	2	2	2
4	4	4	3	3	3	2	2	2	2
5	11	8	6	5	4	4	3	3	3
6	1	1	1	1	0	0	0	0	0
7	1	1	1	1	1	1	1	0	0
8	2	1	1	1	1	1	1	1	1
9	3	2	2	2	1	1	1	1	1
Total (cfs)	33	26	21	20	16	15	13	12	11

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
1	0	0	0	0	0
2	2	2	1	1	0
3	1	1	1	1	0
4	2	2	1	1	0
5	3	2	2	2	0
6	0	0	0	0	0
7	0	0	0	0	0
8	1	0	0	0	0
9	1	1	1	1	0
Total (cfs)	10	8	6	6	0

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 10-02-1998 09:01:42
Watershed file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER4 .MOP
Hydrograph file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER4.HYD

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input	Ia/p used
10	4.90	79.0	0.50	0.00	4.60	2.46	I.12	.12
11	2.60	79.0	0.10	0.00	4.60	2.46	I.12	[illegible]
12	21.70	79.0	0.75	0.00	4.60	2.46	I.12	.12

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 29.20 acres or 0.04563 sq.mi
Peak discharge = 44 cfs

WARNING: Drainage areas of two or more subareas differ by a factor of 5 or greater.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
10	0.52	0.00	0.50	0.00	Yes	--
11	0.10	0.00	**	**	Yes	--
12	0.66	0.00	0.75	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 10-02-1998 09:01:42
Watershed file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER4 .MOP
Hydrograph file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER4.HYD

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
10	10	12.4
11	10	12.1
12	35	12.6
Composite Watershed	44	12.6

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 10-02-1998 09:01:42
Watershed file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER4 .MOP
Hydrograph file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER4.HYD

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
10	0	0	1	1	2	3	6	9	10
11	0	0	0	3	6	10	6	2	1
12	1	1	2	3	3	5	9	15	24
Total (cfs)	1	1	3	7	11	18	21	26	35

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
10	9	8	6	4	3	2	1	1	1
11	1	1	1	1	1	1	1	0	0
12	31	35	34	30	21	14	10	8	6
Total (cfs)	41	44	41	35	25	17	12	9	7

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 10-02-1998 09:01:42
Watershed file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER4 .MOP
Hydrograph file: --> H:/DATA/PROJECT/BUTWORTH/ALT\BUTTER4.HYD

Butterworth Landfill
Grand Rapids, MI
Amended Remedial Design Project Plan

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
10	1	1	1	1	1	1	0	0	0
11	0	0	0	0	0	0	0	0	0
12	5	4	4	3	3	2	2	2	2
Total (cfs)	6	5	5	4	4	3	2	2	2

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
10	0	0	0	0	0
11	0	0	0	0	0
12	2	1	1	1	0
Total (cfs)	2	1	1	1	0

APPENDIX E-3

DISCHARGE CULVERT DESIGN

RMT INC.

COMPUTATION SHEET

1143 Highland Drive, Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Culvert Design	By: SGH	Date: 02/27/97	GRC	10/2/98	3938.64

OBJECTIVE: Determine the size and outlet velocity for the following culverts:

- Culvert A (from Wetland A to Western Creek)
- Culvert B (from Wetland E to the CSO)
- Culvert C (from Wetland G to Wetland F)
- Culvert D (from Wetland F to the CSO)
- Culvert E (from Wetland C to Wetland B, across the LFG barrier)
- Culvert F (draining the CSO to the Grand River)

METHODOLOGY: Use the design methodology and nomographs presented in "Hydraulic Design of Highway Culverts", Federal Highway Administration, 1985. See Sheets 2 - 7 of this package.

Determine the flow for the 25-year, 24-hour storm event based on the "Surface Water Calculations" included with these appendices. These flows are listed below:

Culvert	Design Flow (cfs)	Basis
A	50	runoff from Watershed (WS) 2
B	6	3/4 of runoff from WS 6
C	10	runoff from WS 11
D	45	runoff from WS 11 and 12
E	6	1/2 runoff from WS 7A
F	181	estimate of past flow events

The design flow for culvert F is based on a peak CSO discharge estimate of 40,000 gpm plus runoff from areas 5, 6, 8, 11, and 12 (92 cfs)

40,000 gal/min * (1 min / 60 sec) * (1 cf / 7.48 gal) = 89.13 cfs

Total flow = 92 cfs + 89 cfs = 181 cfs

CONCLUSION: See the table below:

Culvert	Diameter (inches)	Invert Elevatio	Outlet Elevation	Outlet Vel. (fps)
A	48	600.2	599.1	2.78
B	21	600.4	596.2	3.9
C	24	599.7	595.4	3.25
D	36	600.9	597.3	5.15
E	21	599.6	599.1	2.35
F	2-48	586.5	586.3	1.8

p:\data\projects\3938\culverts.xls

Inlet control means that the discharge capacity of a culvert is controlled at the culvert entrance by depth of headwater (HW) and the entrance geometry, including the area, shape, and type of inlet edge. Inlet controlled flow may have an unsubmerged or submerged entrance. A mitered (beveled) entrance moves the control downstream to approximately the top of the miter.

With inlet control, the roughness and length of the culvert barrel and outlet conditions (including depth of tailwater) are not factors in determining culvert capacity. The barrel slope has some effect on discharge, but any adjustment for slope is considered minor and can be neglected for conventional culverts flowing with inlet control. With few exceptions, an increase in barrel slope will not increase the flow rate.

Headwater-discharge relationships for the various types of circular and pipe-arch culverts flowing with inlet control are based on laboratory research of models and verified in some instances by prototype tests.

The following charts give headwater-discharge relationships through a range of headwater depths and discharges for most conventional culvert shapes flowing with inlet control.

Calculating the inlet control is a quick and easy method to estimate the approximate size of culvert required when the culvert is on a steep slope and the depth of tailwater is not significant.

Inlet-Control Nomographs

Charts 3-4.1 Through 3-4.5

Instructions for Use

1. To determine headwater (HW)

   a. Connect with a straightedge the given culvert diameter or height (D) and the discharge Q, or $\frac{Q}{B}$ for box culverts; mark intersection of straightedge on $\frac{HW}{D}$ scale marked (1).

   b. If $\frac{HW}{D}$ scale marked (1) represents entrance type used, read $\frac{HW}{D}$ on scale (1). If some other entrance type is used, extend the point of intersection in (a) horizontally on scale (2) or (3) and read $\frac{HW}{D}$.

   c. Compute HW by multiplying $\frac{HW}{D}$ by D.

2. To determine culvert size.

   a. Given an $\frac{HW}{D}$ value, locate $\frac{HW}{D}$ on scale for appropriate entrance type. If scale (2) or (3) is used, extend $\frac{HW}{D}$ point horizontally to scale (1).

   b. Connect point on $\frac{HW}{D}$ scale (1) as found in (a) above to given discharge and read diameter, height, or size of culvert required.

3. To determine discharge (Q)

   a. Given HW and D, locate $\frac{HW}{D}$ on scale for appropriate entrance type. Continue as in 2a.

   b. Connect point $\frac{HW}{D}$ scale (1) as found in (a) above and the size of culvert on the left scale and read Q or $\frac{Q}{B}$ on the discharge scale.

   c. If $\frac{Q}{B}$ is read in (b), multiply by B to find Q.

Outlet-Control Nomographs

Charts 3-5.1 Through 3-5.6

Instructions for Use

These nomographs solve the equation $H = \left[1 + K_e + \frac{29n^2L}{R^{1.33}}\right]\frac{V^2}{2g}$ for head H when culverts flow full with outlet control. They are also used in approximating the head for some part-full flow conditions with outlet control. These nomographs do not give a complete solution for finding headwater HW.

A. To determine head H for a given culvert and discharge Q.

1. Locate appropriate nomograph for type of culvert selected.

2. Begin nomograph solution by locating starting point on length scale.

   a. To locate the proper starting point on the length scales, follow instructions below.

      (1) If the "n" value of the nomograph corresponds to that of the culvert being used, find the proper k_e from Table 3-6.1, and on the appropriate nomograph, locate starting point on length curve for that k_e. If a k_e curve is not shown for the selected k_e, see b below. If "n" value for the culvert selected differs from that the nomograph, see c below.

      (2) For the "n" of the nomograph and a k_e intermediate between the scales given, connect the given length on adjacent scales by a straight line and select a point on this line spaced between the two chart scales in proportion to the k_e values.

      (3) For a different value of roughness coefficient n_1 than that of the chart "n," use the length scales shown with an adjusted length L_1, calculated by the formula:

$$L_1 = L\left[\frac{n_1}{n}\right]^2$$

See Instruction B for "n" values.

3. Using a straightedge, connect point on length scale to size of culvert barrel and mark the point of crossing on the "turning line." See instruction 3 on following page for size considerations for rectangular box culvert.

4. Pivot the straightedge on this point on the turning line and connect given discharge rate. Read head in feet on the head (H)-scale. For values beyond the limit of the chart scales, find H by solving equation given on nomograph or by $H = KQ^2$ where K is found by substituting values of H and Q from chart.

B. Find the "n" value for the culvert selected by using the table below:

Concrete Pipe Vitrified Clay Pipe Smooth-Flow C.M.C.P.	n = 0.012
C.M.C.P. Asphalt Coated and 40% Paved Invert (Treatment 2 & 4)	n = 0.019
Plain Metal Culvert Pipe and Asphalt Coated (Treatment 1 & 3)	n = 0.024
Structural Plate Pipe and Plate Pipe Arches	n = 0.0302 to 0.0328
3" x 1" Corrugations and Plain (Treatment 1 & 3)	n = 0.027
3" x 1" Corrugations and 40% Paved Invert (Treatment 2 & 4)	n = 0.021

C. To use the box culvert nomograph, Chart 3-5.6, for full-flow for other than square boxes.

1. Compute cross-sectional area of the rectangular box.[1]

2. Connect proper point (see instruction A) on length scale to barrel area[1] and mark point on turning line.

3. Pivot the straightedge on this point on the turning line and connect given discharge rate. Read head in feet on the head (H) scale.

---

[1]The area scale on the nomograph is calculated for barrel cross-sections with span B twice the height D; its close correspondence with area of square boxes assures it may be used for all sections intermediate between square and B = 2D or B = 2/3D. For other box proportions use the equation shown on the nomograph for more accurate results.

3-6 PROCEDURE FOR SELECTION OF CULVERT SIZES

3-6.1 Culvert Hydraulic Calculations Form, WSDOT Form 235-006

List following data on WSDOT Form 235-006, as shown in Figure 3-6.1.

A. Design discharge Q, in cfs.

B. Slope of culvert (So) in feet/feet.

C. Approximate length (L) of culvert, in feet.

D. Inlet and outlet invert elevation.

E. Depth of tailwater (TW).

F. Allowable headwater depth (AHW), in feet, which is the vertical distance from the culvert invert (flow line) at the entrance to the water surface elevation permissible in the approach channel upstream from the culvert. Any important features should be identified to prevent headwater from causing damage. The damage level should be identified by elevation if the culvert invert has not yet been determined.

G. Culvert Type

Include barrel material, barrel cross-sectional shape, and entrance type.

H. Q (discharge)

Indicate design flow in cfs. Normally the 25-year MRI is used for design and the 100-year MRI is checked for overtopping the roadway embankment or causing excessive damage to upstream property owners. Calculations should be made for both the 25-year and the 100-year for all culverts.

I. Size

Indicate pipe size in inches.

J. HW/D (inlet control)

The headwater to diameter (vertical) ratio is found from the appropriate nomographs 3-4.1 through 3-4.5.

K. HW (inlet control)

This is found by multiplying Column 3 by Column 4 then dividing by Column 12. This is the headwater caused by inlet control. At this time, if the inlet control headwater should be greater than the allowable headwater, the pipe size should be increased. If the headwater is less than allowable, then proceed with next step.

L. K_e (entrance loss coefficient)

This is the entrance loss coefficient taken from Table 3-6.1L.

R. HW

This column shows the amount of headwater resulting from outlet control. It is determined by the following equation (see Figure 3-6.1R below):

$$HW = H + h_o - L S_o$$

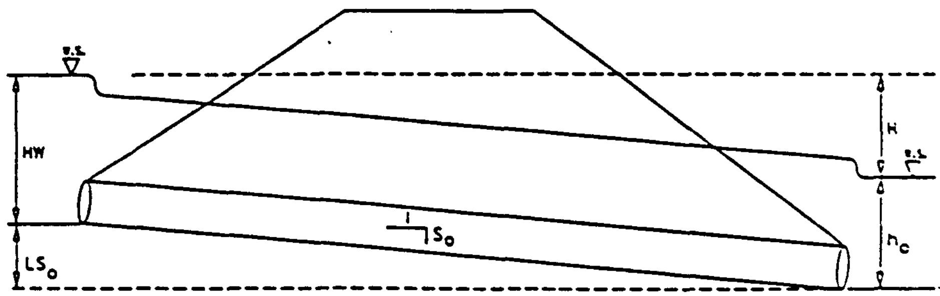


FIGURE 3-6.1R

S. Controlling HW

This column contains the controlling headwater which is taken from Column 5 or Column 12, whichever is greater. This is the actual headwater that will be caused by this culvert for this particular flow rate indicated in Column 2.

T. Outlet Velocity

The outlet velocity is a function of the depth of flow at the outlet, the pipe size, and the flow rate. The latter two variables are known for a given problem, but the first variable (flow depth) is not immediately obvious. The flow depth which occurs at the outlet is a function of the type and depth of flow in the pipe and the tailwater depth. The assumptions which determine outlet flow velocity are summarized in the following table:

Outlet Velocity Method Summary

Pipe Slope S_o	Quantities Calculated	Assumption
S_o is greater than $S_{critical}$ (supercritical flow condition) (Steep profile, $S_o > 0.01$)	- Normal Velocity (V_n) - Velocity corresponding to tailwater depth (V_{tw})	- Use the smaller of V_n and V_{tw} as the outlet velocity, as the outlet depth will tend to be the larger of the two depths.
S_o is less than $S_{critical}$ (subcritical flow condition) (Flat profile $S_o < 0.01$)	- Critical Velocity (V_c) - Velocity corresponding to tailwater depth (V_{tw})	- Use the smaller of V_c and V_{tw} as the outlet velocity. If tw depth is small, critical flow will occur at outlet; otherwise the tailwater depth will control.

Entering the partial flow curves intersecting the proportional area line read A/A_f = 0.89.

The partial flow area would be:

$$A = 0.89\, A_f = 0.89\, \pi\, (3\ ft)^2 = 25.2\ ft^2$$

$$V = Q/A = 130\ cfs/25.2\ ft^2 = 5.2\ fps$$

where:

A = partial flow area (ft^2)

A_f = full area of pipe (ft^2)

V = partial flow velocity (fps)

Q = actual flow (fps) under partial flow conditions

The partial flow curves can also be used to determine the partial discharge and the partial flow velocity.

ENTRANCE LOSS COEFFICIENTS

Outlet Control, Full or Partly Full Entrance Loss

$$H_e = k_e \frac{V^2}{2g}$$

Type of Structure and Design of Entrance	Coefficient k_e	Standard Plan
Pipe, Concrete		
Projecting from fill (no headwalls)		
Socket end (groove end)	0.2	
Square cut end	0.5	
Beveled end section (mitered to conform to fill slope)	0.7	B-7a
Mitered concrete headwall to conform to fill slope	0.7	B-9
Flared metal end sections (or concrete)	0.5	B-7 Design B
Vertical headwall with wingwalls		B-6 Series (Modified for Round Pipe)
Rounded edge or socket end	0.2	
Square edge	0.5	
Rounded (radius = 1/12 D)	0.2*	
Pipe or Pipe Arch, Corrugated Metal		
Projecting from fill (no headwalls)	0.9	
Beveled end section (mitered to conform to fill slope, no headwall)	0.7	B-7a
Mitered concrete headwall to conform to fill slope	0.7	B-9
Flared metal end sections	0.5	B-7 Design A
Vertical headwall with wingwalls	0.5	B-6 Series (Modified for Round Pipe)
Box, Reinforced Concrete		
Mitered concrete headwall to conform to fill slope		
Square-edged on 3 edges	0.5	
Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2*	
Wingwalls at 30 degrees to 75 degrees to barrel		
Square-edged at crown	0.4	
Crown edge rounded to radius of 1/12 barrel dimension, or beveled top edge	0.2*	
Wingwall at 10 degrees to 25 degrees to barrel		
Square-edged at crown	0.5	B-6 Series
Wingwalls parallel (extension of sides)		
Square-edged at crown	0.7	
Side- or slope-tapered inlet	0.2*	

* Note: Reference Section 3-7.6 for the design of special improved inlets with very low entrance coefficients.

COMPUTATION SHEET

RMT

Sheet 1 of 1

1143 Highland Drive, Suite B P.O Box 991 Ann Arbor, MI 48106-0991 (313) 971-7080 FAX: (313) 971-9022

Project / Proposal Name	Prepared		Checked		Project / Proposal No.
Culvert A	By: SGH	Date: 01/23/97	By: TAK	Date: 3/97	3938.14

Culvert Hydraulic Calculations

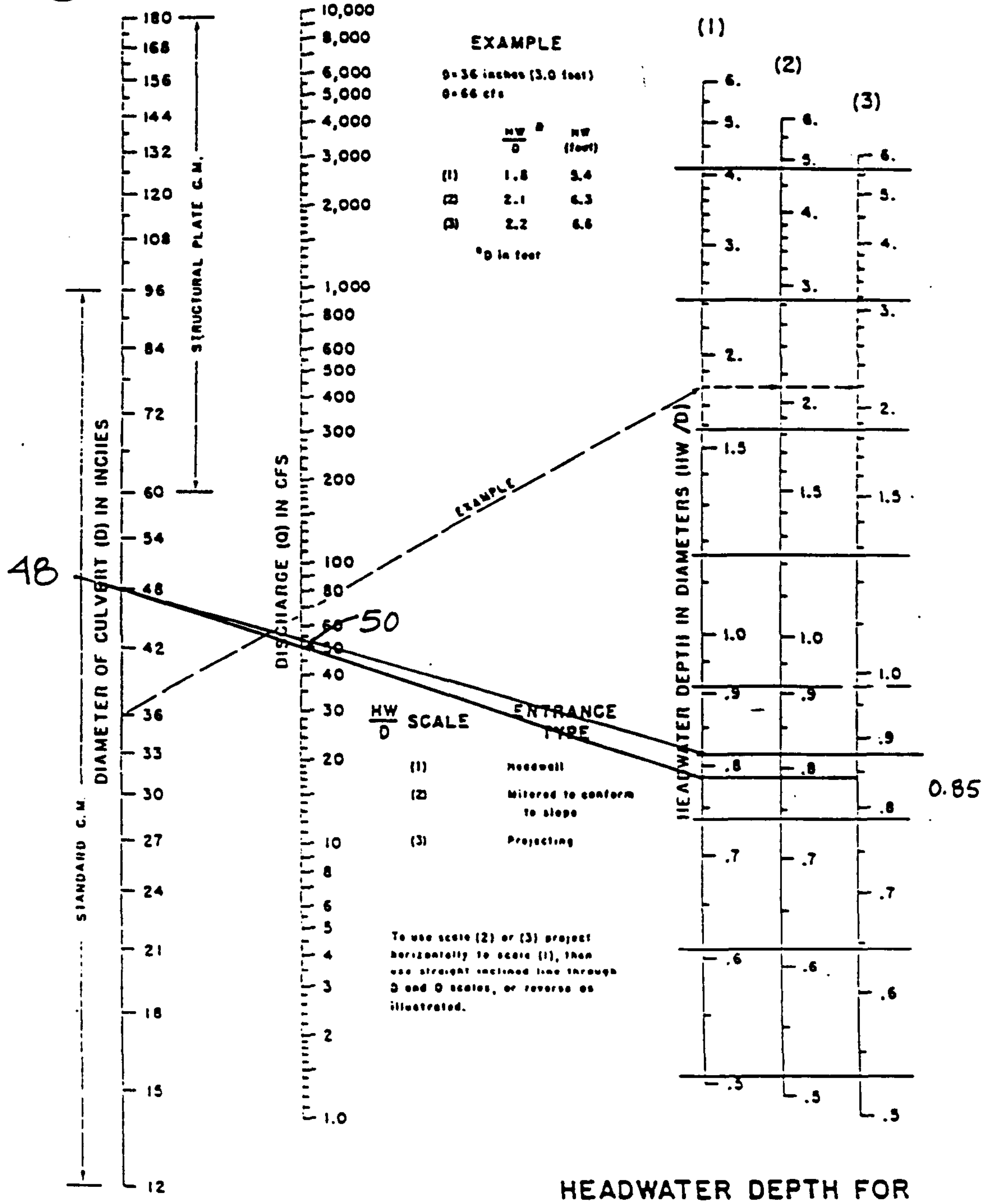
Q =	50 cfs
So =	0.005
L =	250 ft
Inv =	600.2 ft
Outlet =	599.1 ft
TW =	0

Culvert Type	Q	Size	Inlet Control		Outlet Control							Control.	Outlet
			HW/D	HW	Ke	Dc	(Dc+D)/2	Ho	H	LSo	HW	HW	Velocity
CMP	50	48	0.85	3.4	0.9	2.2	3.1	2.2	1.6	1.25	2.55	3.4	2.78

Select a 48" CMP Culvert, peak velocity at outlet is 2.78 fps.

Sheet 8 of 31

CHART 2

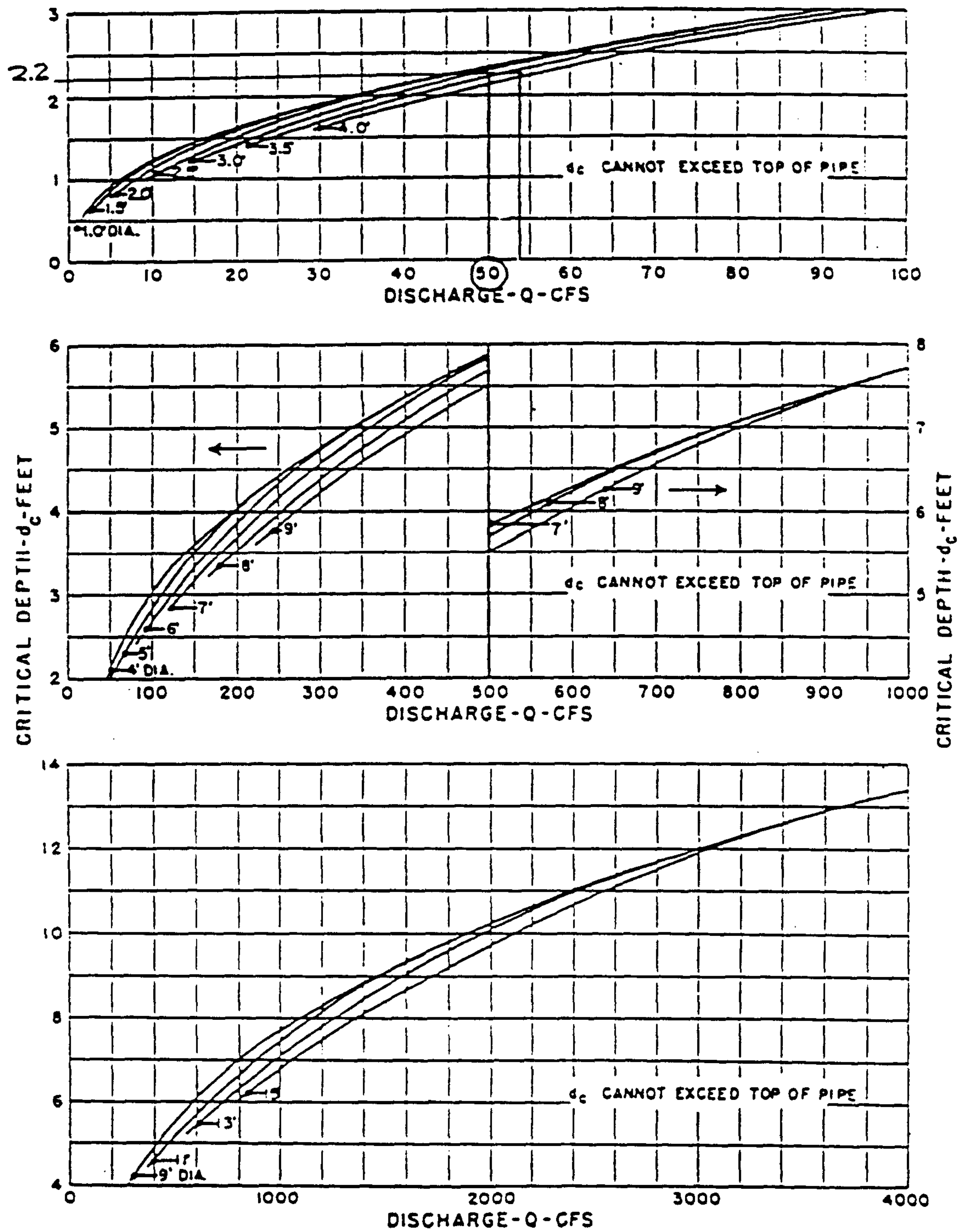


HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CULVERT A

CHART 4

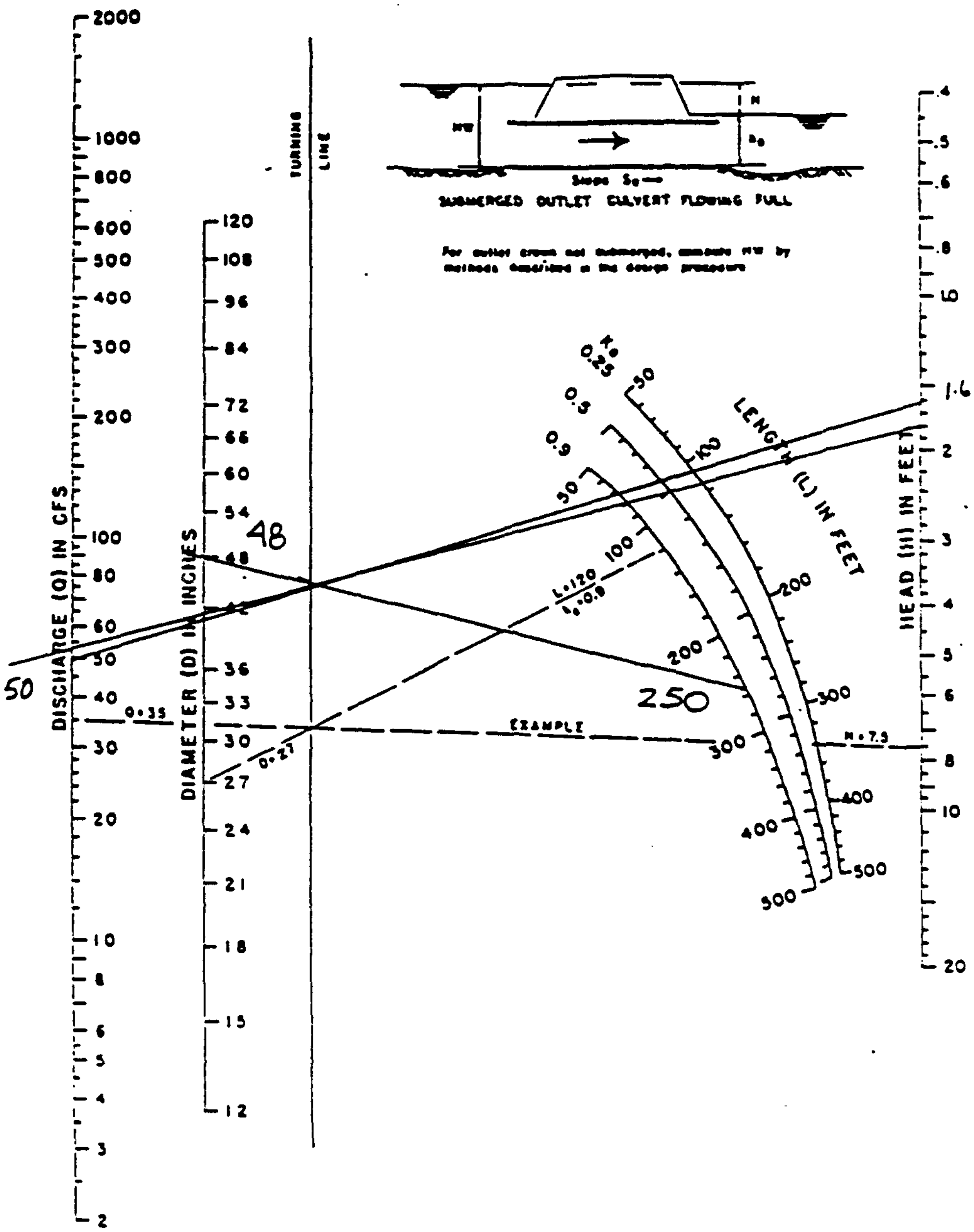


BUREAU OF PUBLIC ROADS
JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

Culvert A

CHART 6



HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert A

5

COMPUTATION SHEET

Sheet 1 of 1

RMT
1143 Highland Drive, Suite B P.O Box 991 Ann Arbor, MI 48106-0991 (313) 971-7080 FAX: (313) 971-9022

Project / Proposal Name	Prepared		Checked		Project / Proposal No.
Culvert B	By: SGH	Date: 01/23/97	By: [illegible]	Date: 3/97	3938.14

Culvert Hydraulic Calculations

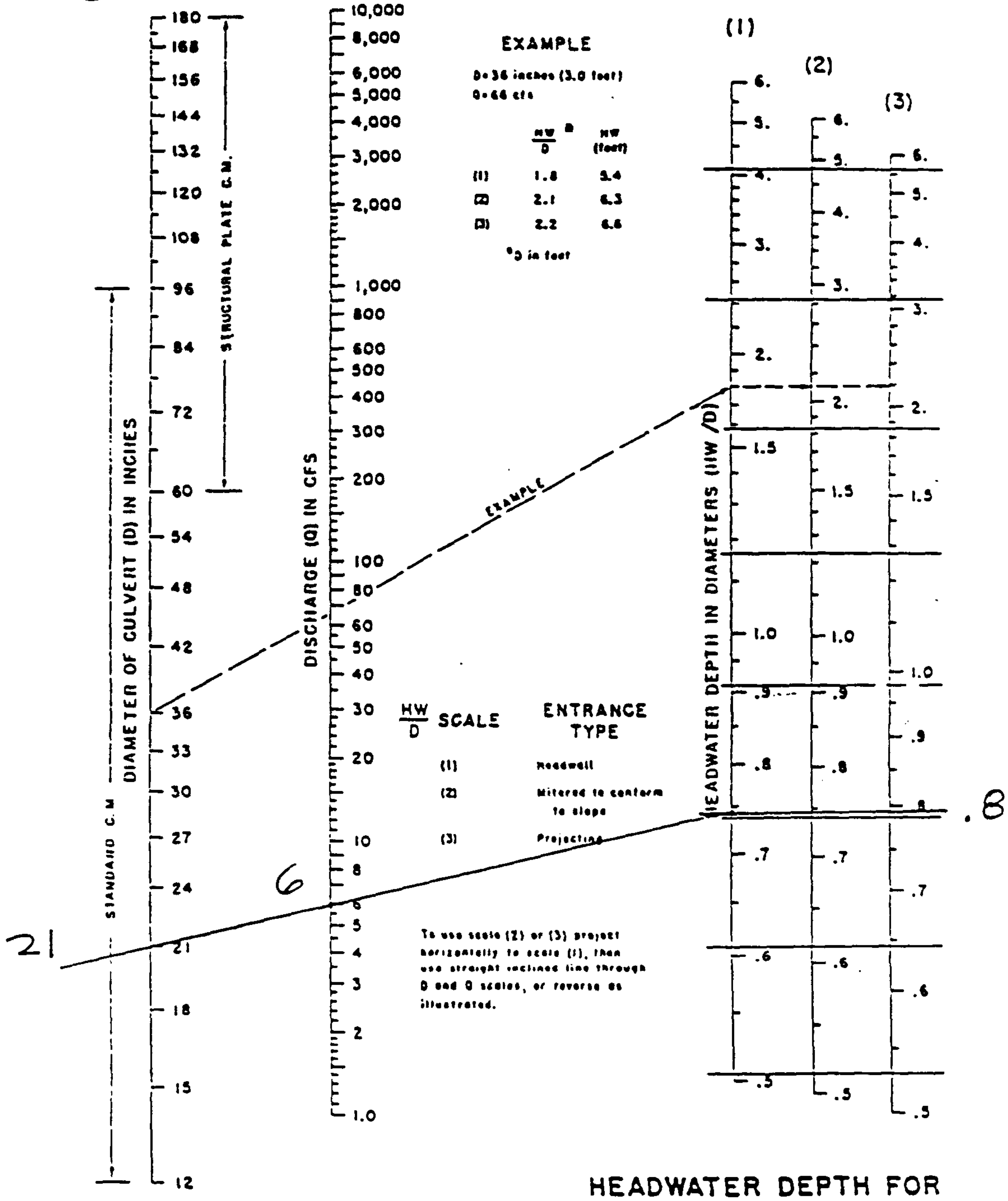
Q =	6 cfs
So =	0.020
L =	210 ft
Inv =	600.4 ft
Outlet =	596.2 ft
TW =	0

Culvert Type	Q	Size	Inlet Control		Outlet Control							Control. HW	Outlet Velocity
			HW/D	HW	Ke	Dc	(Dc+D)/2	Ho	H	LSo	HW		
CMP	6	12	1.5	1.5	0.9	0.5	0.75	0.5	8.7	4.2	5	5	
CMP	6	21	0.8	1.4	0.9	0.8	1.275	0.8	1.2	4.2	-2.2	1.4	3.90

Select an 21" CMP culvert, peak velocity at outlet is 3.90 fps

Culvert B

CHART 2



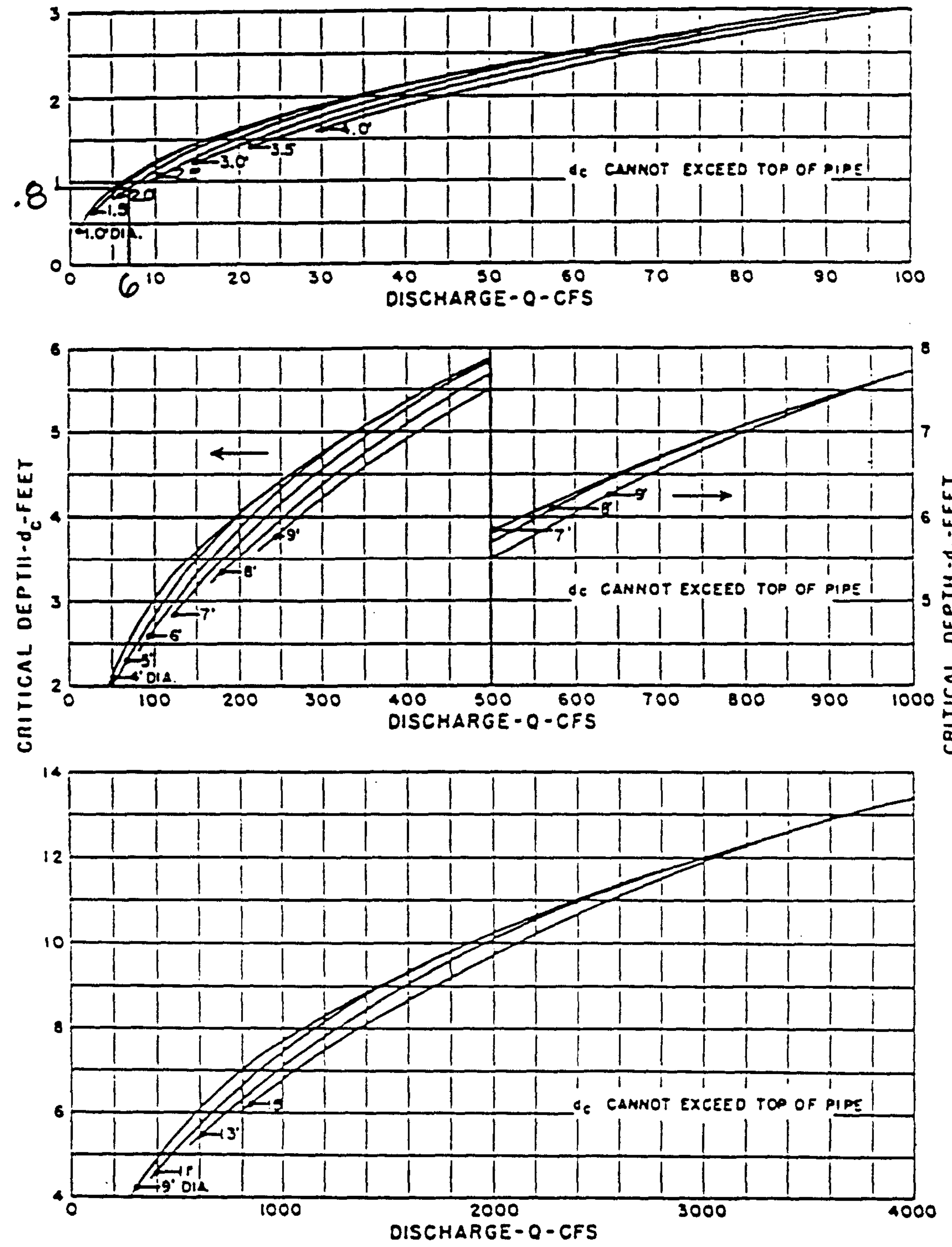
HEADWATER DEPTH FOR
C. M. PIPE CULVERTS
WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CULVERT B

Sheet 14 of

CHART 4



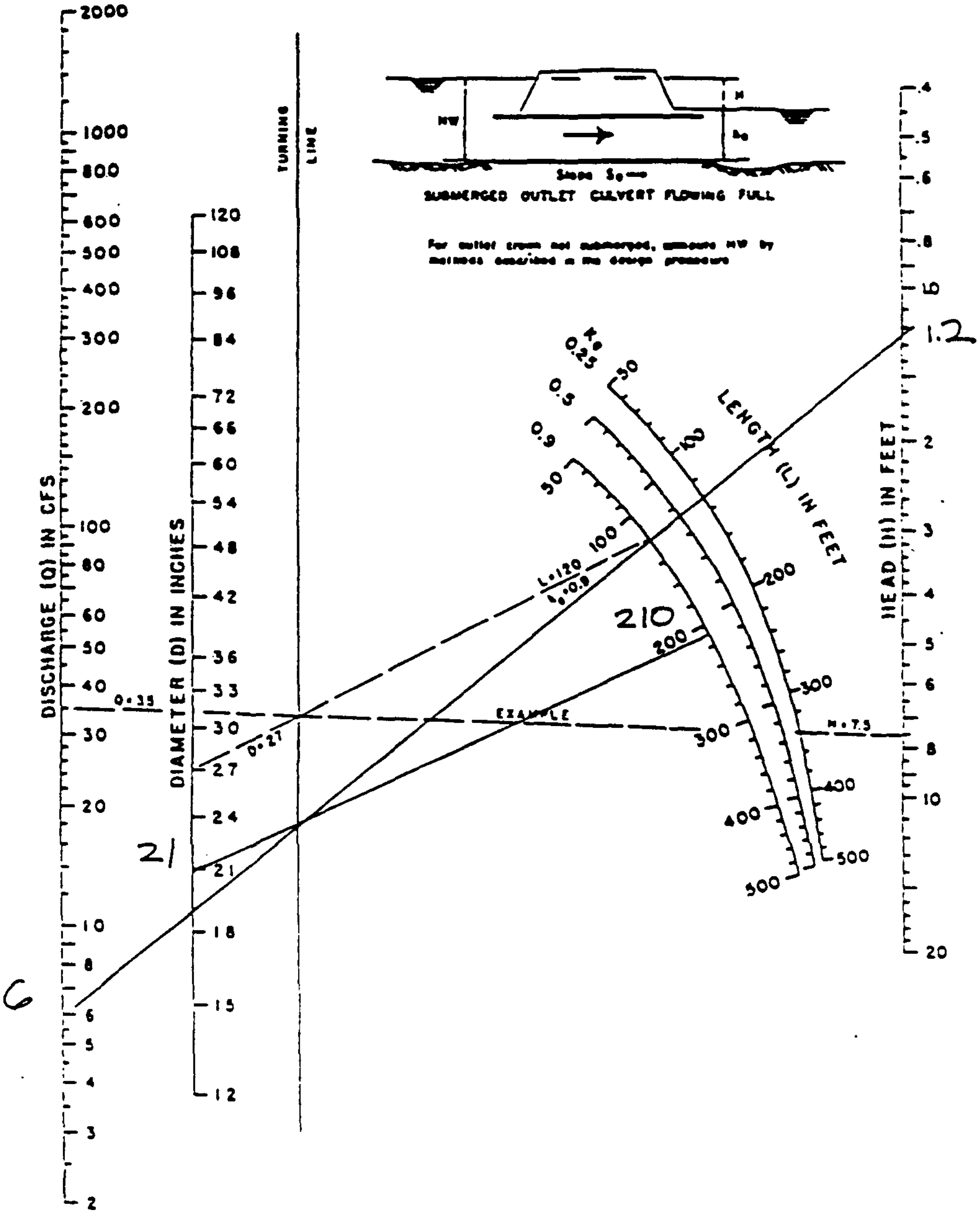
BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

Culvert B

CHART 6



HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

CULVERT B

RMT

COMPUTATION SHEET

Sheet 1 of 1

1143 Highland Drive, Suite B P.O Box 991 Ann Arbor, MI 48106-0991 (313) 971-7080 FAX: (313) 971-9022

Project / Proposal Name	Prepared		Checked		Project / Proposal No.
Culvert C	By: SGH	Date: 01/23/97	By: TAK	Date 3/97	3938.14

Culvert Hydraulic Calculations

Q =	10 cfs
So =	0.010
L =	430 ft
Inv =	599.7 ft
Outlet =	595.4 ft
TW =	0

Culvert Type	Q	Size	Inlet Control HW/D	Inlet Control HW	Outlet Control Ke	Dc	(Dc+D)/2	Ho	H	LSo	HW	Control. HW	Outlet Velocity
CMP	10	24	0.91	1.82	0.9	1.2	1.6	1.2	3	4.3	-0.1	1.82	3.25

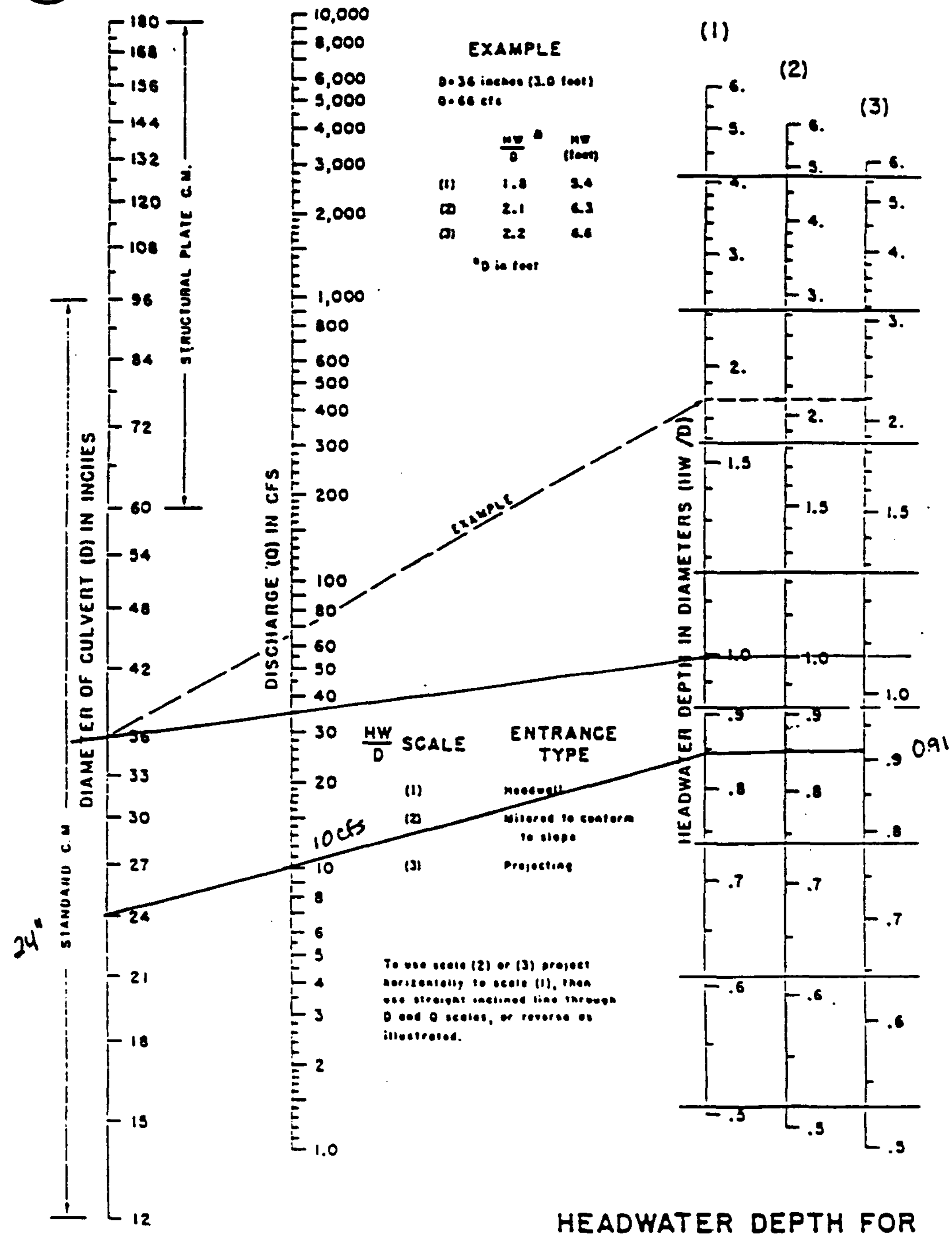
Select a 24" CMP culvert, peak velocity at outlet is 3.25 fps

Culvert C

58

SHEET 16 OF 31

CHART 2



HEADWATER DEPTH FOR
C. M. PIPE CULVERTS
WITH INLET CONTROL

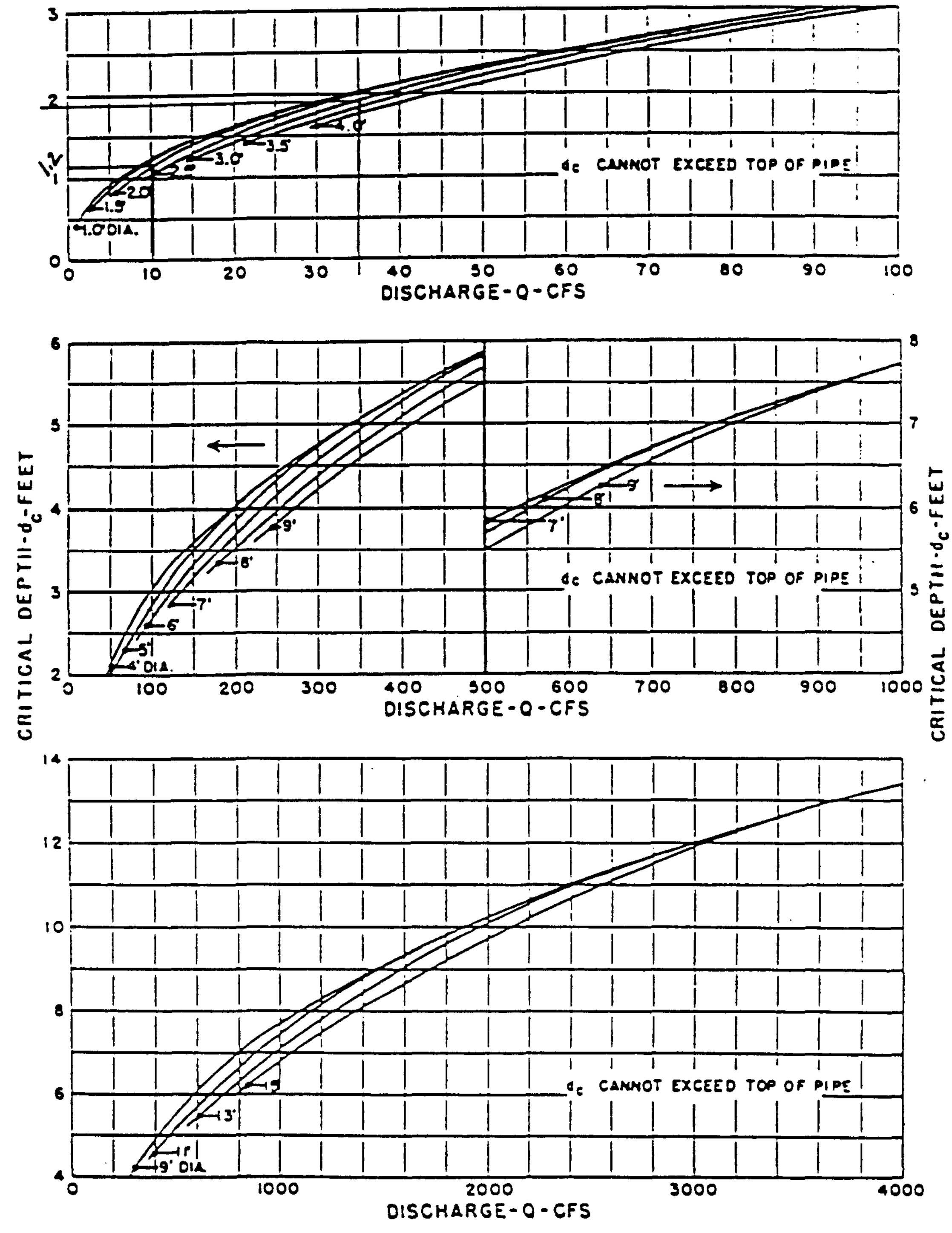
BUREAU OF PUBLIC ROADS JAN. 1963

Culvert C

59

SHEET 10c

CHART 4



BUREAU OF PUBLIC ROADS

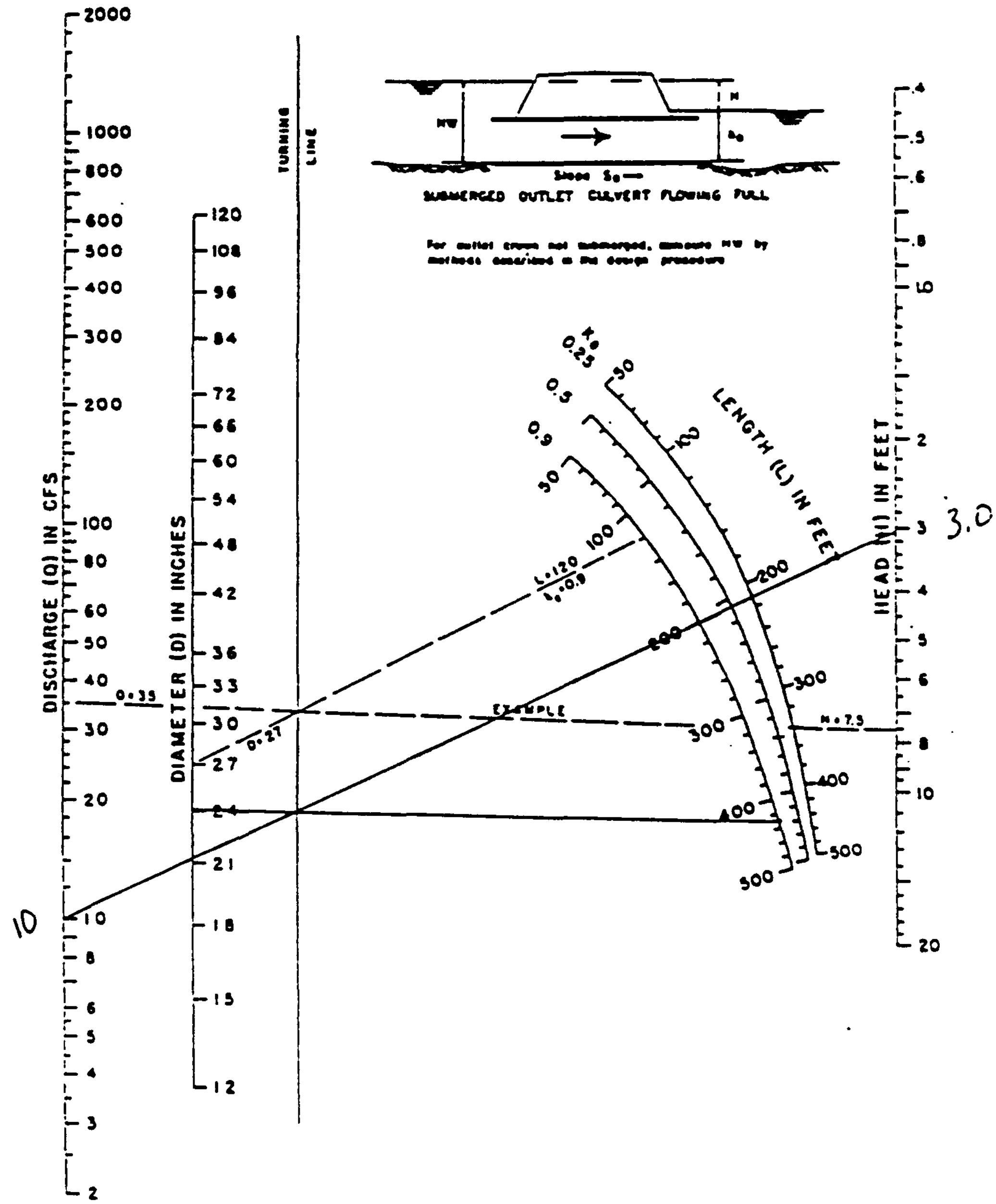
JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

CULVERT C

60

CHART 6



HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert C

RMT
1143 Highland Drive, Suite B P.O Box 991 Ann Arbor, MI 48106-0991 (313) 971-7080 FAX: (313) 971-9022

COMPUTATION SHEET

Sheet 1 of 1

Project / Proposal Name	Prepared		Checked		Project / Proposal No.
Culvert D	By: SGH	Date: 01/23/97	By: [illegible]	Date: 3/4 7	3938.14

Culvert Hydraulic Calculations

Q = 45 cfs
So = 0.020
L = 180 ft
Inv = 600.9 ft
Outlet = 597.3 ft
TW = 0

Culvert Type	Q	Size	Inlet Control		Outlet Control							Control. HW	Outlet Velocity
			HW/D	HW	Ke	Dc	(Dc+D)/2	Ho	H	LSo	HW		
CMP	45	36	1.3	3.9	0.9	2.2	2.6	2.2	4.1	3.6	2.7	3.9	5.15

Select a 36" CMP culvert, peak velocity at outlet is 5.15 fps

Culvert D

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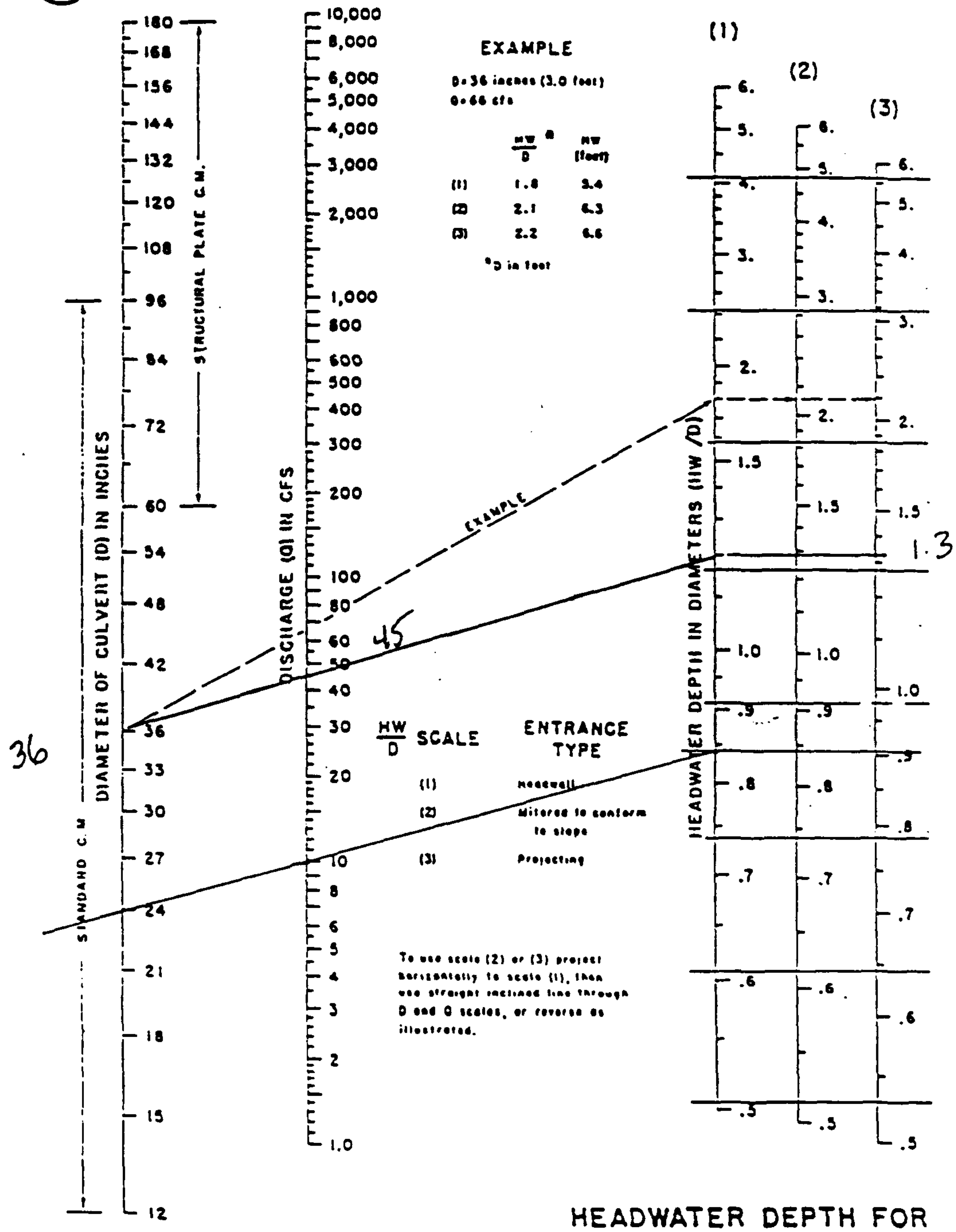
SHEET 20 OF 31

CHART 2



HEADWATER DEPTH FOR
C. M. PIPE CULVERTS
WITH INLET CONTROL

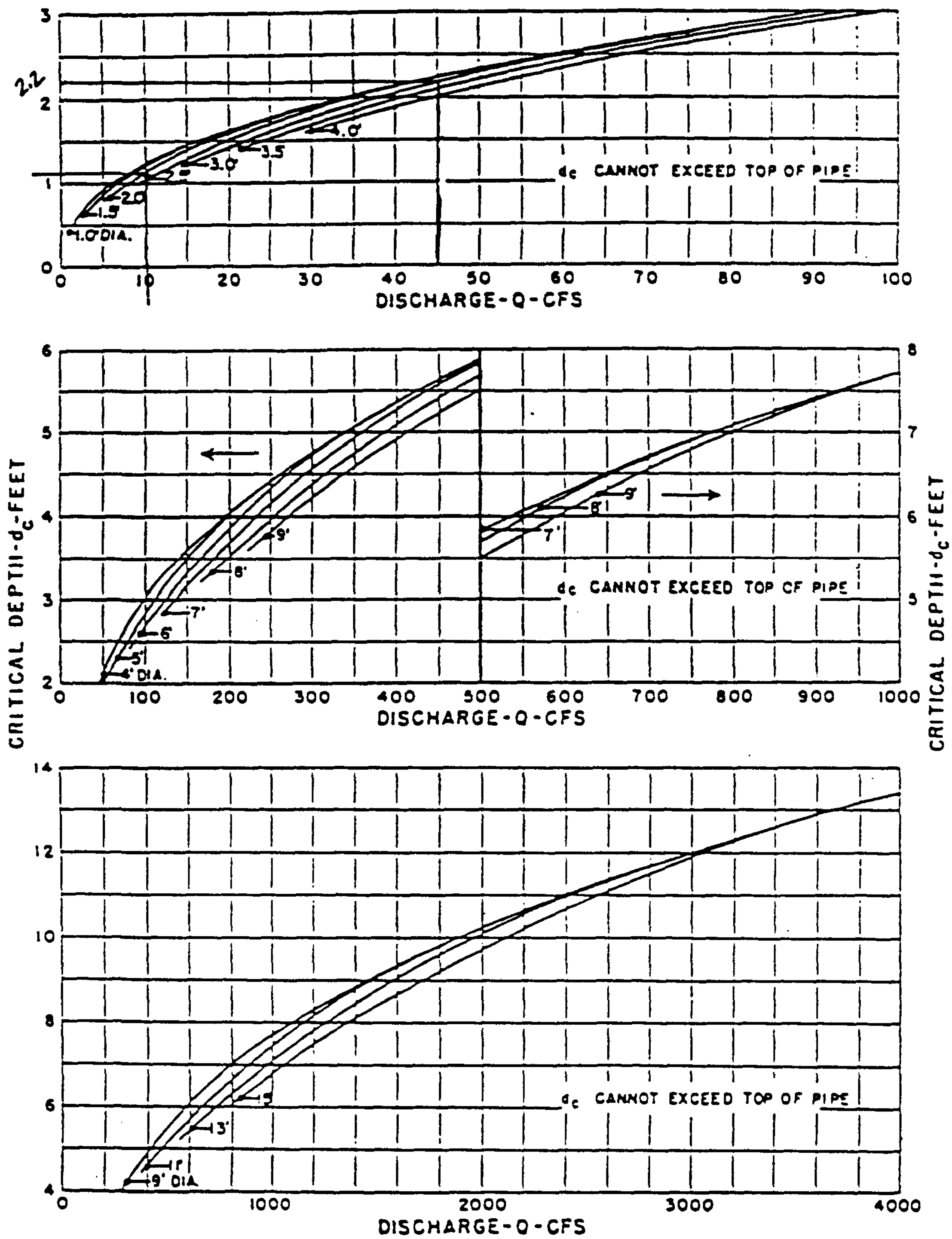
BUREAU OF PUBLIC ROADS JAN. 1963

Culvert D

6

SHEET 66

CHART 4



BUREAU OF PUBLIC ROADS
JAN. 1964

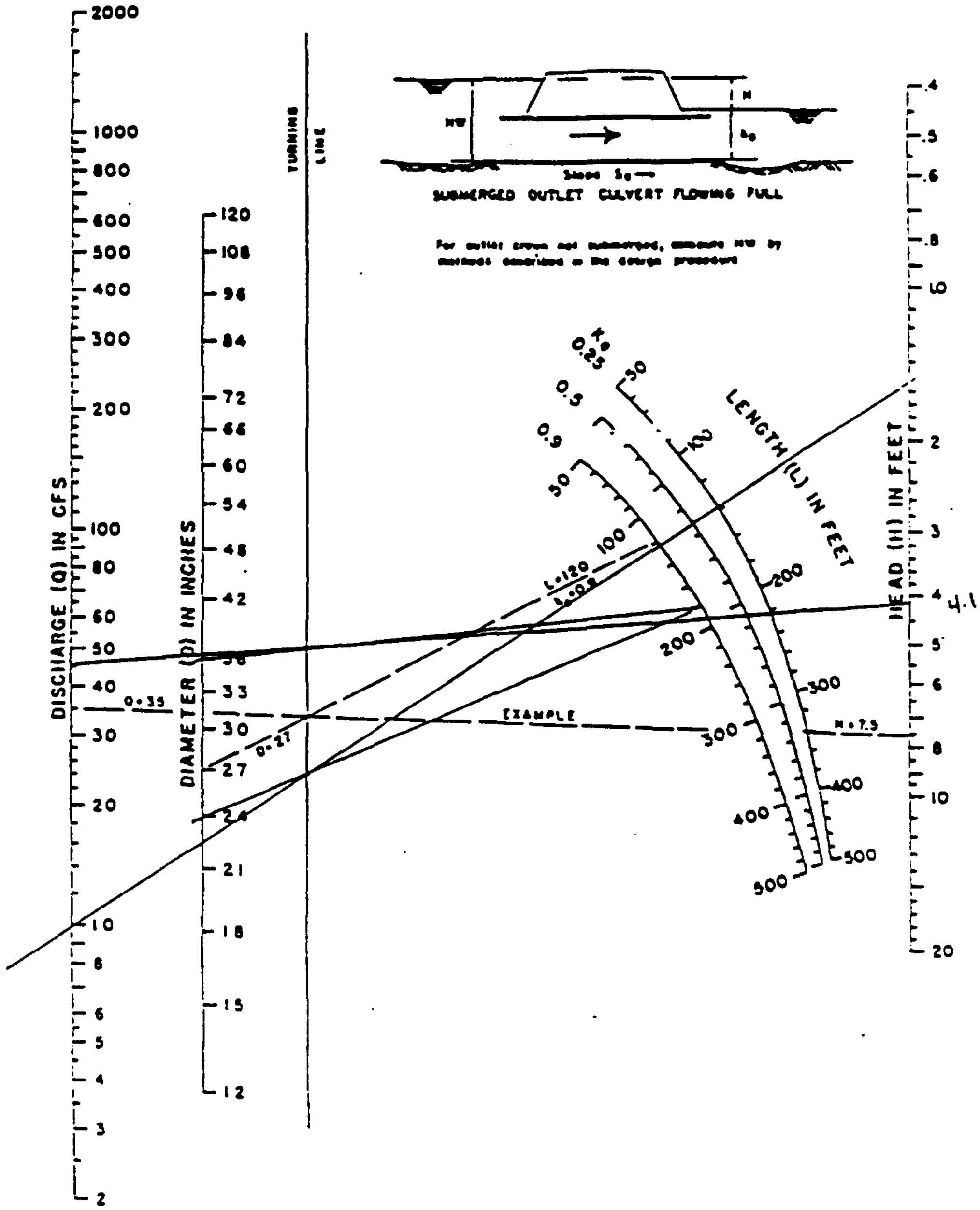
CRITICAL DEPTH
CIRCULAR PIPE

CULVERT D

6

SHEET 2 OF

CHART 6



HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert D

COMPUTATION SHEET

Sheet 1 of 1

RMT
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Project / Proposal Name	Prepared		Checked		Project / Proposal No.
Culvert E	By: SGH	Date: 01/23/97	By: [illegible]	Date: 3/97	3938.14

Culvert Hydraulic Calculations

Q =	6 cfs
So =	0.005
L =	100 ft
Inv =	599.6 ft
Outlet =	599.1 ft
TW =	0

Culvert			Inlet Control		Outlet Control							Control.	Outlet
Type	Q	Size	HW/D	HW	Ke	Dc	(Dc+D)/2	Ho	H	LSo	HW	HW	Velocity
CMP	6	21	0.79	1.4	0.9	0.9	1.325	0.9	0.7	0.5	1.1	1.4	2.35

Select a 21" CMP culvert, peak velocity at outlet is 2.35 fps

Culvert E

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SHEET 24 OF 31

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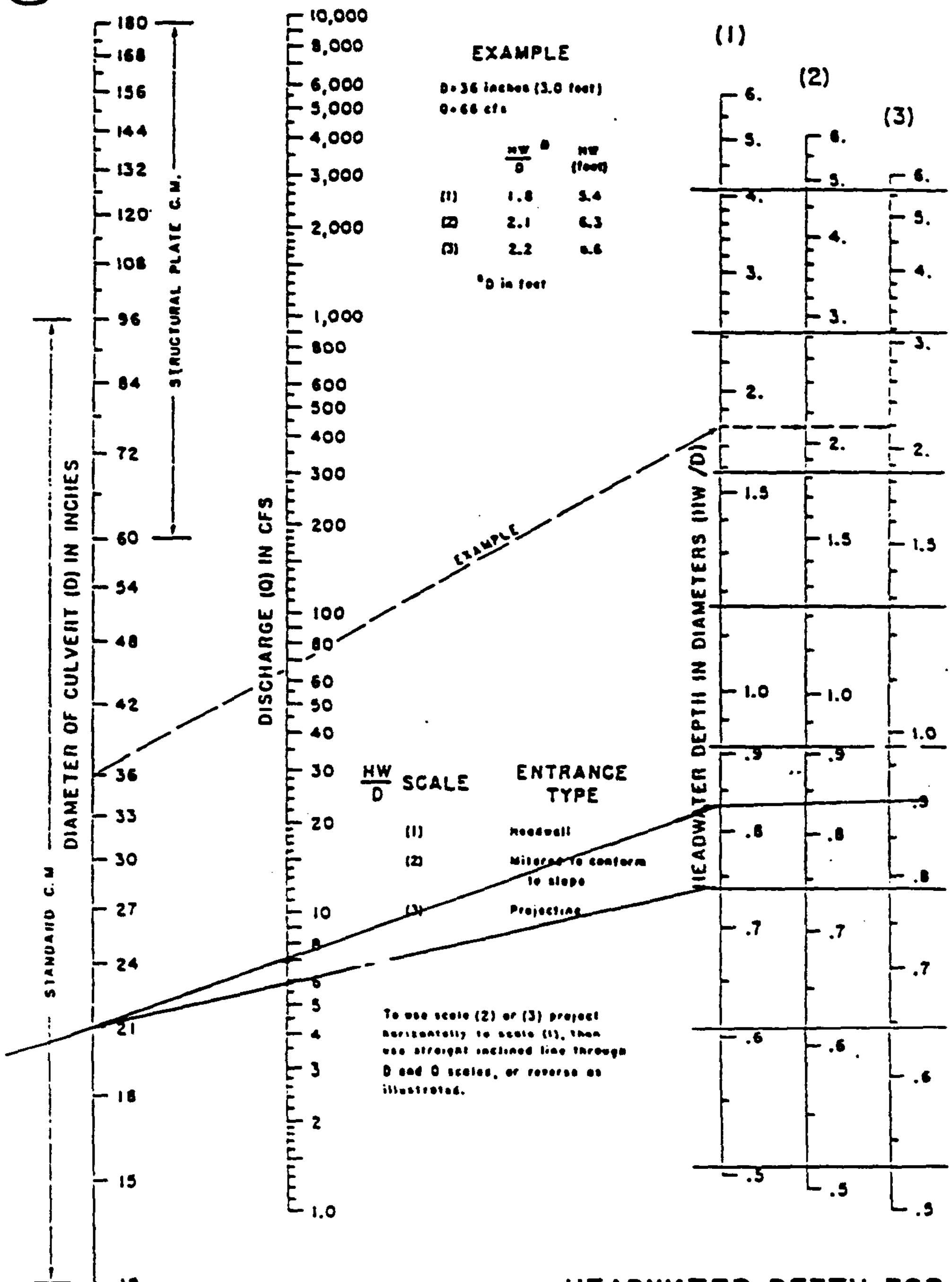
CHART 2



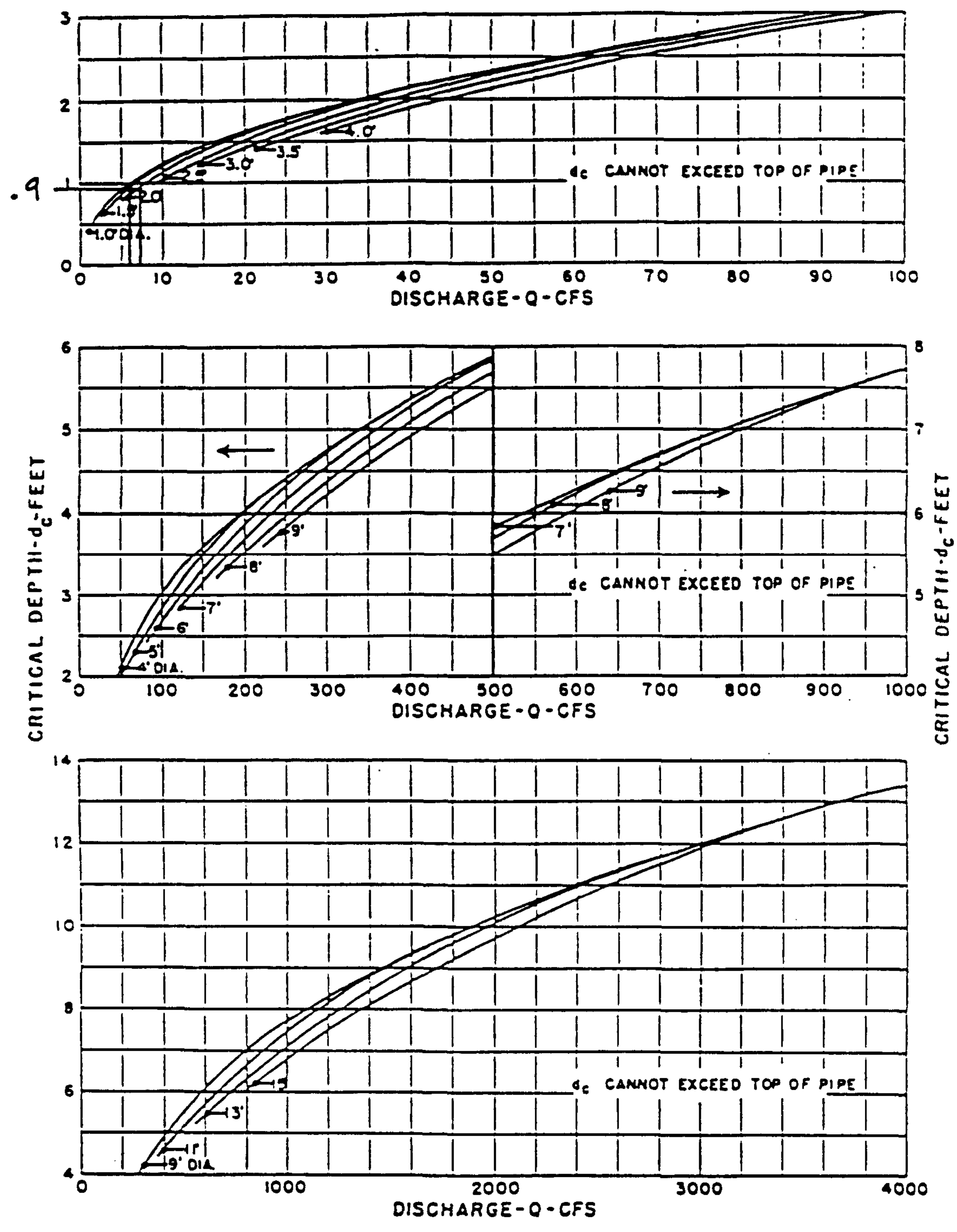
HEADWATER DEPTH FOR
C. M. PIPE CULVERTS
WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CULVERT E

6

CHART 4

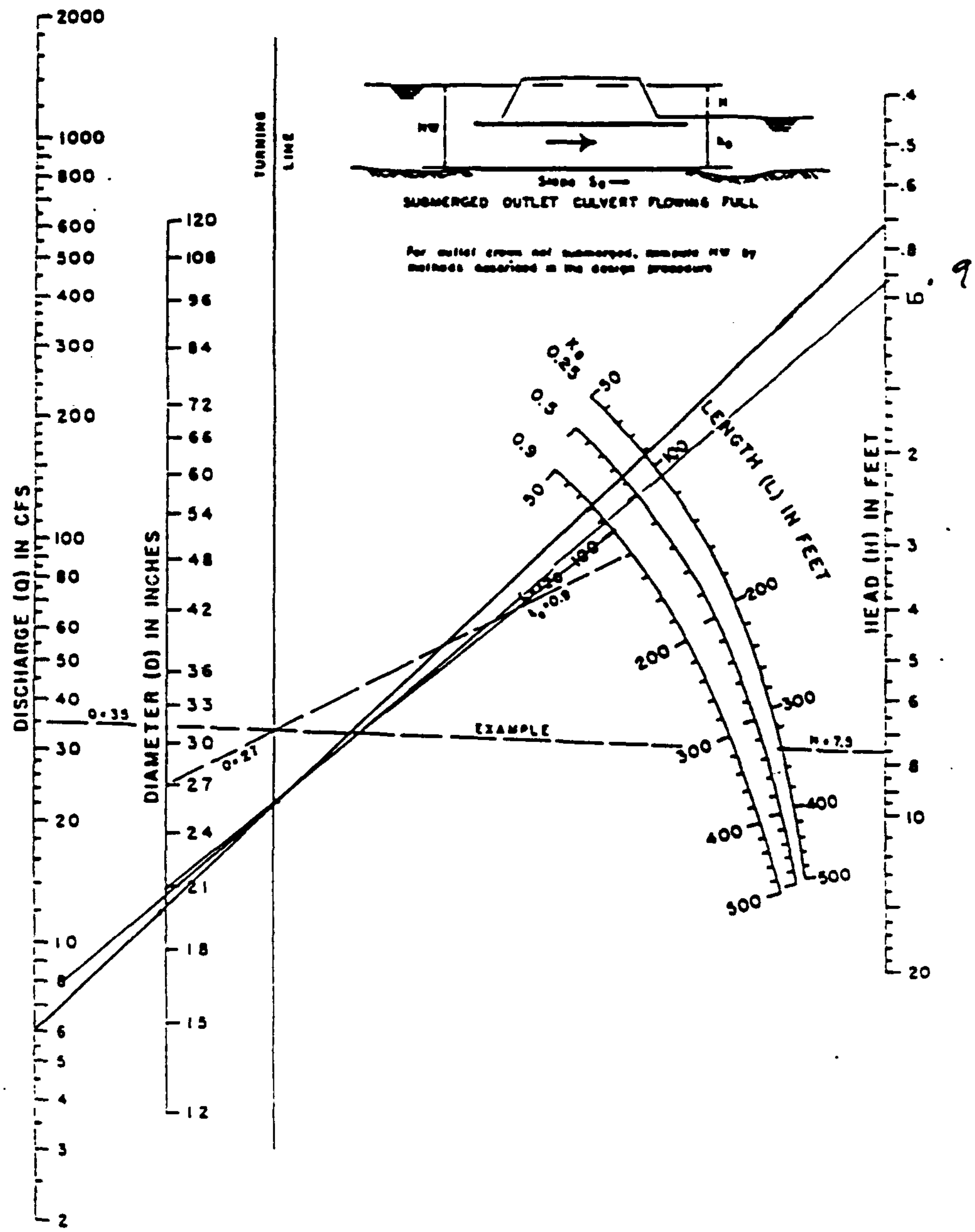


BUREAU OF PUBLIC ROADS
JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

CULVERT E

CHART 6



HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

CULVERT E

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COMPUTATION SHEET

Sheet 1 of 1

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Project / Proposal Name	Prepared		Checked		Project / Proposal No.
Culvert F	By: SGH	Date: 01/23/97	By: [illegible]	Date: 3/4/7	3938.14

Culvert Hydraulic Calculations

Q = 181 cfs
So = 0.001
L = 200 ft
Inv = 586.5 ft
Outlet = 586.3 ft
TW = 0

Culvert Type	Q	Size	Inlet Control		Outlet Control							Control.	Outlet
			HW/D	HW	Ke	Dc	(Dc+D)/2	Ho	H	LSo	HW	HW	Velocity
2-CMP's	90	48	1.31	5.24	0.9	2.8	3.4	2.8	4.3	0.2	6.9	6.9	1.80

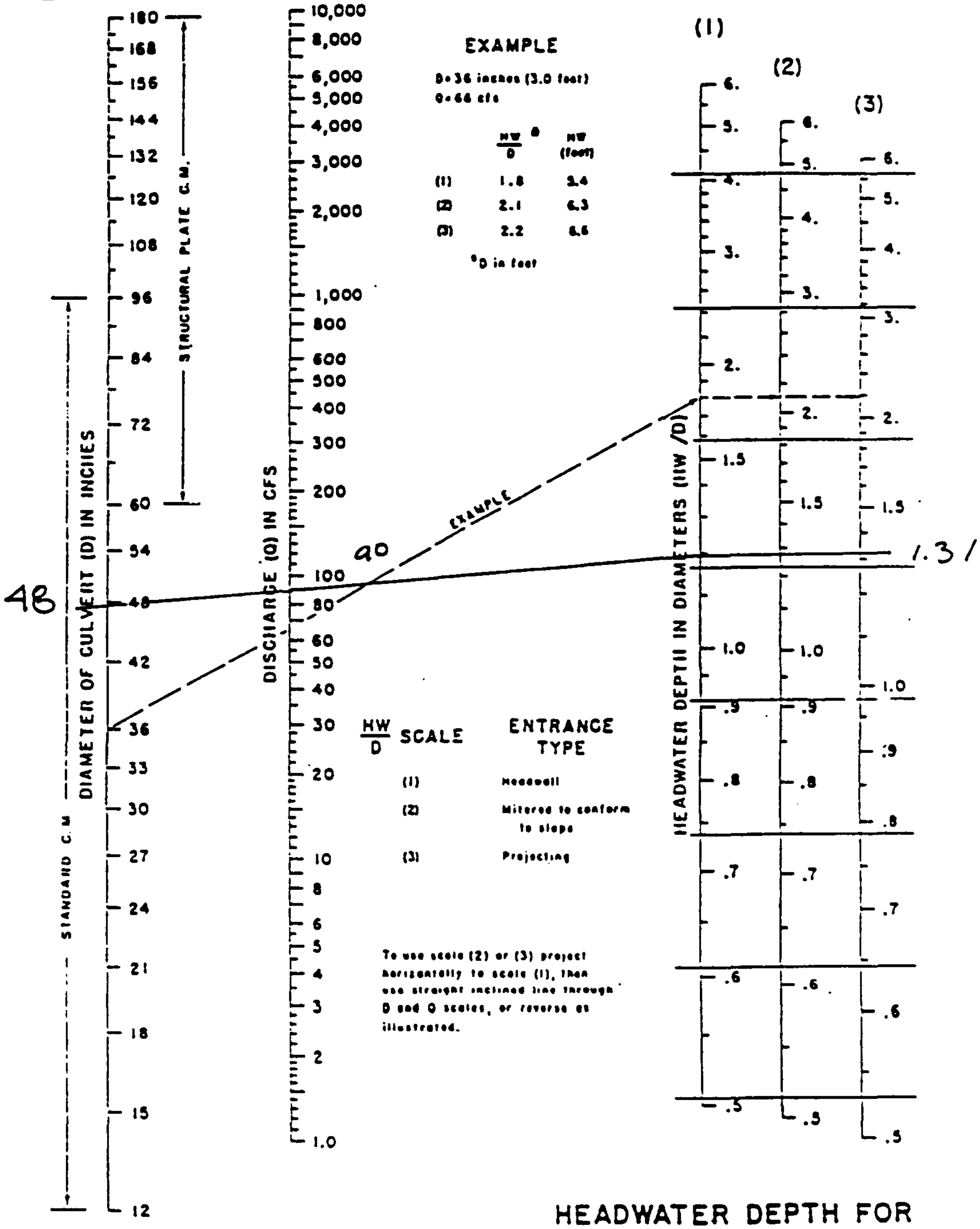
Select 2- 48" CMP culverts, peak velocity at outlet is 1.8 fps

Culvert F

\\excel\3938\culverts.xls

SHEET 26 OF 3

CHART 2



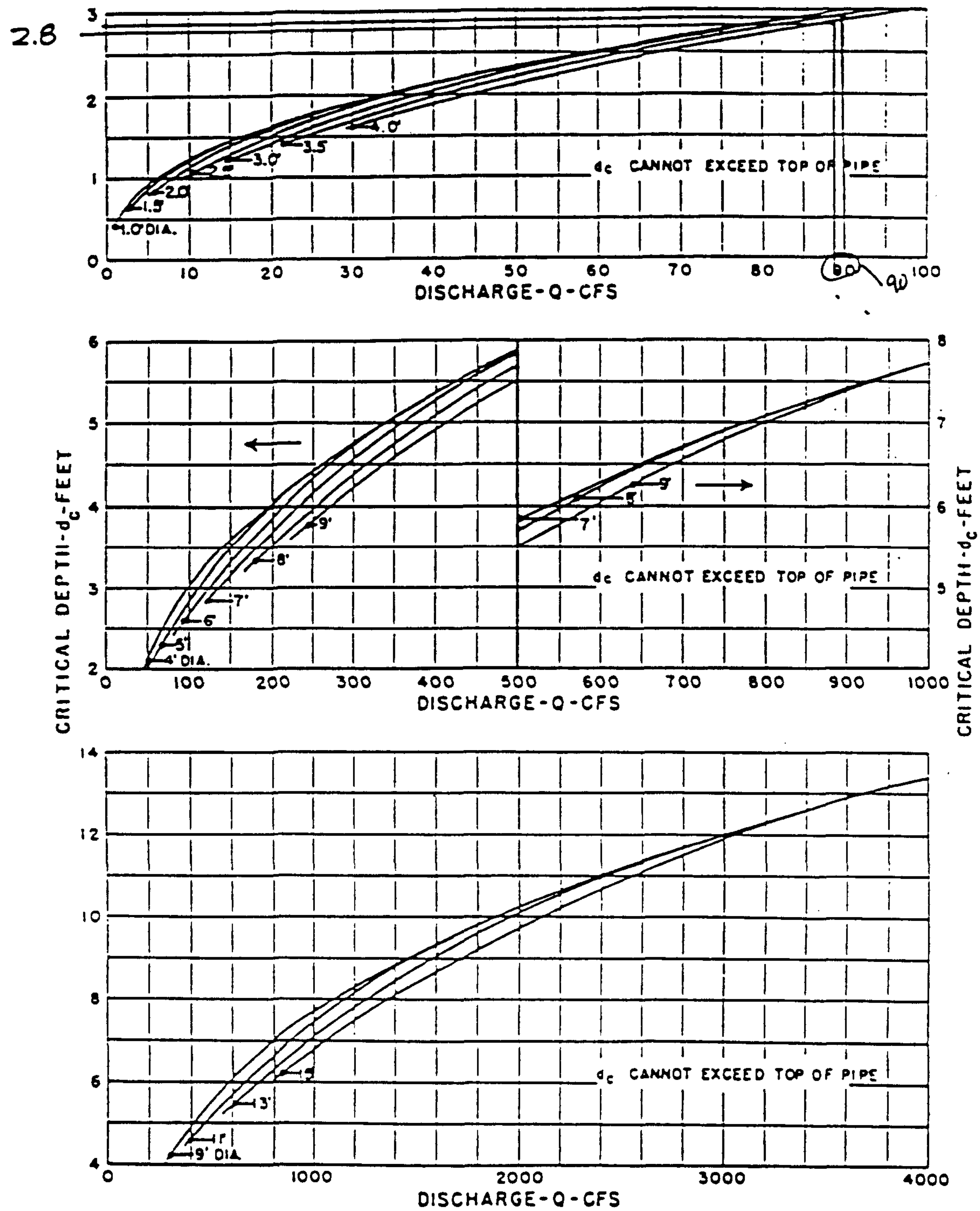
HEADWATER DEPTH FOR
C. M. PIPE CULVERTS
WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CULVERT F

Sheet No:

CHART 4



BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

Culvert F

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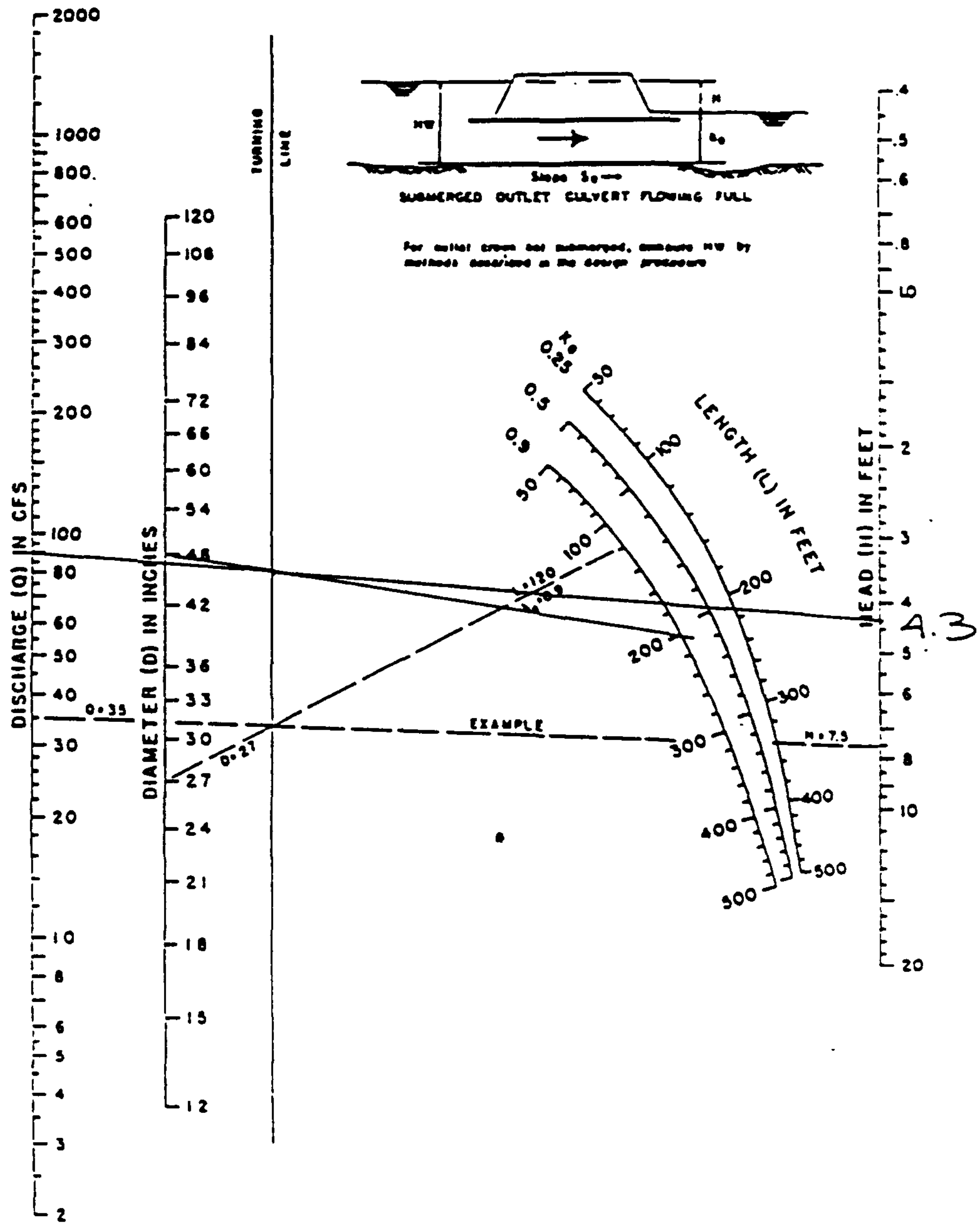
CHART 6



HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert F

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APPENDIX E-4

EROSION ESTIMATES

COMPUTATION SHEET

RMT Inc.

1143 Highland Drive, Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Soil Loss Estimate	By: SGH	Date: 02/17/97	By: MAL	Date: 3/7/97	3938.14

OBJECTIVE: Determine the average annual soil loss (A), in Tons/Acre for Irregular Slopes with two segments (drainage runs with unequal slopes of unequal lengths) by determining the LS Factor for slopes in question and inputting that value with other variables into the Universal Soil Loss Equation (USLE).

METHODOLOGY: Average Annual Soil loss can be computed using the Universal Soil Loss Equation:

1) $A = R * C * K * LS * P$ (see sheet 3 of this calculation)

where: A = soil loss (tons/acre-year)
R = average annual rainfall erosion index
C = ratio of soil loss from land cropped under specified conditions
K = soil erodibility factor
LS = slope length and steepness factor
P = practice factor

Determine the LS using the following formulas:

2) $LS = L * S$ (see sheet 4 of this calculation)

where: S = ([(65.41 *s^2)/(s^2+10000)] + [(4.56*s)/(Sqrt(s^2+10000))] + 0.065)
and s = slope in percent
L = (sl/72.6)^m
and sl = slope length
m = exponent depending on slope

This calculation will be made for each slope and length shown in the "Surface Water Calculations" included with these appendices. The case that produces the maximum soil loss is shown in these calculations.

CONCLUSION: Average Annual Soil Loss is 1.3 tons/acre for the following slope conditions:

SEGMENT	-
LENGTH (FT)	80
SLOPE (%)	17.8

2.0 tons/acre is the maximum soil loss allowed by regulatory agencies.
The calculated 1.3 tons/acre will require no additional erosion measures after the vegetated cap is established.

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RMT Inc.

COMPUTATION SHEET

1143 Highland Drive, Suite B P.O. Box 991 Ann Arbor, MI 48106-0991 (313)971-7080 Fax: (313) 971-9022

PROJECT/PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT PROPOSAL NO.
Soil Loss Estimate	SGH	02/17/97	MK	3/7/97	3938.14

CALCULATIONS:

Determine the average annual soil loss in tons per acre for irregular slopes

Determine the slope-length steepness factor. Use the equations in part 2) of the methodology section.

See sheet 2A for a figure that shows the maximum length of slope for the landfill site.

SEGMENT	
LENGTH	80
SLOPE (%)	17.8
m	0.5

L =	1.05
S =	2.87
LS =	3.02

m = .2, for slopes of 0 to 1 %
m = .3, for slopes of 1 to 3 %
m = .4, for slopes of 3.5 to 4.5 %
m = .5, for slopes greater than 5 %

(see sheet 4)

Determine the average annual soil loss

R =	100	Use factor for Kent County, see sheet 5 of this calculation
K =	0.42	Topsoil has high organic content*, use 0.42, see sheet 6
LS =	3.02	
C =	0.01	Final land use is meadow, use 0.01, see sheet 7
P =	1.00	Use 1.0 as conservative estimate, see sheet 8

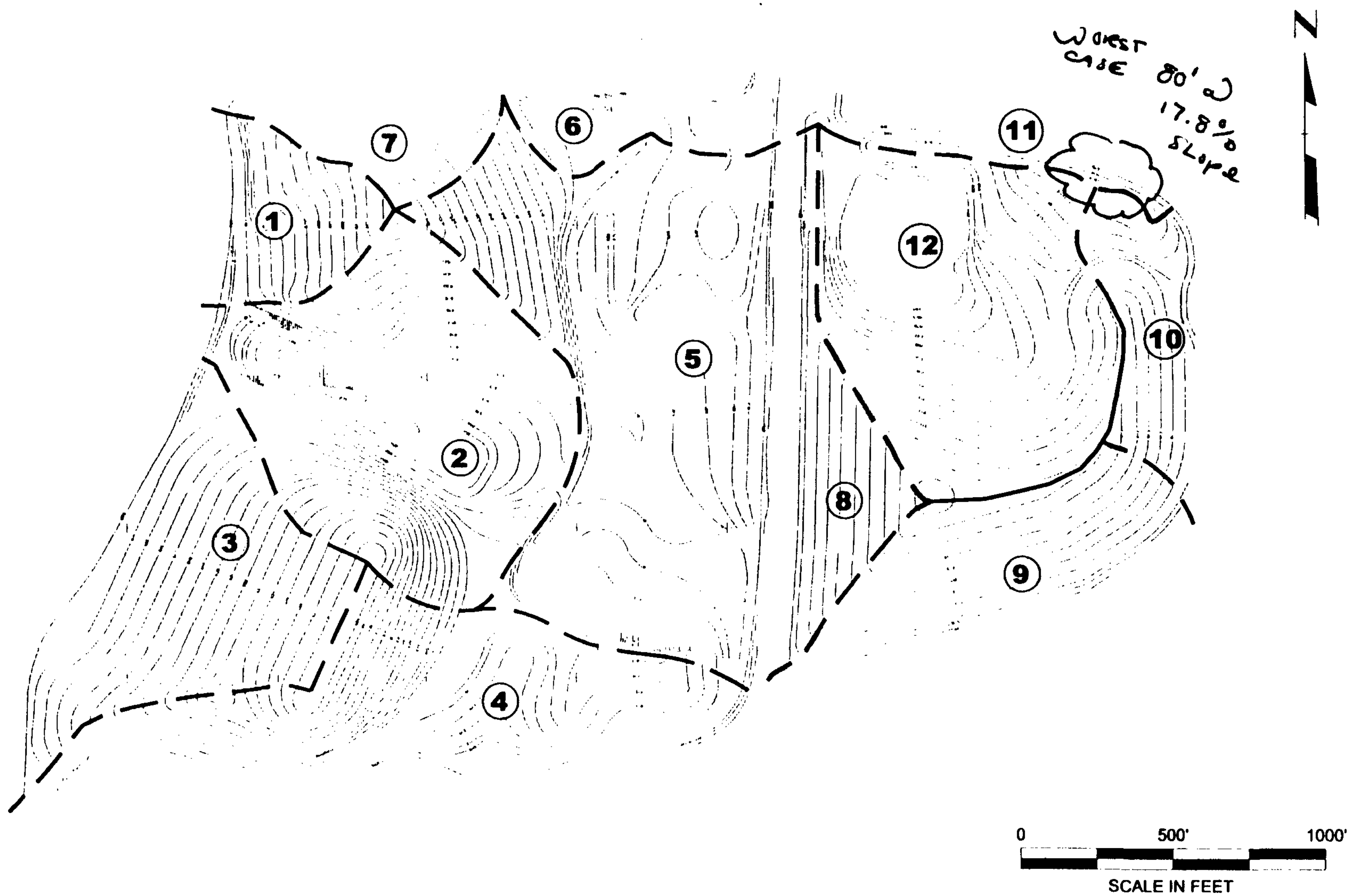
A = 1.3 tons/acre

* see Specification 02931 "Topsoil, Seeding, and Fertilizer"

2 tons/acre is the maximum soil loss allowed by regulatory agencies.
The estimated soil loss rate of 1.3 tons/acre is less than the regulatory standard. No additional erosion control measures will be required after the vegetated cap is established.

PLOT DATA

Drawing Name:	J:\03938\64\39386410.DWG	Operator Name:	lucidos	Dwg Size:	149619 Bytes	Plot Time:	3:58.4973 PM
		Scale:	1"=500'	Plot Date:	Friday, October 2, 1998	Attached Xref's:	No xref's Attached.



BUTTERWORTH LANDFILL
GRAND RAPIDS, MICHIGAN

WATERSHED AREAS

DRAWN BY:	SJL
APPROVED BY:	GRC
PROJECT NUMBER:	3938.64
FILE NUMBER:	39386410.DWG
DATE:	OCTOBER 1998

RMT® INC. MICHIGAN

RMT COMPUTER AIDED DESIGN AND DRAFTING

Sheet 3 of 8

Not only is erosion objectionable in itself but erosion can degrade the cover and seriously reduce its effectiveness.

Evaluate Erosion Potential — Step 19

The USDA universal soil loss equation (USLE) is a convenient tool for use in evaluating erosion potential. The USLE predicts average annual soil loss as the product of six quantifiable factors. The equation is:

$$A = R\,K\,L\,S\,C\,P$$

where A = average annual soil loss, in tons/acre
R = rainfall and runoff erosivity index
K = soil erodibility factor, tons/acre
L = slope-length factor
S = slope-steepness factor
C = cover-management factor
P = practice factor

The data necessary as input to this equation are available to the evaluator in a figure and tables included below. Note that the evaluations in Step 8 on soil composition and Steps 25-32 on vegetation all impact on the evaluation of erosion also.

Factor R in the USLE can be calculated empirically from climatological data. For average annual soil loss determinations, however, R can be obtained directly from Figure 20. Factor K, the average soil loss for a given

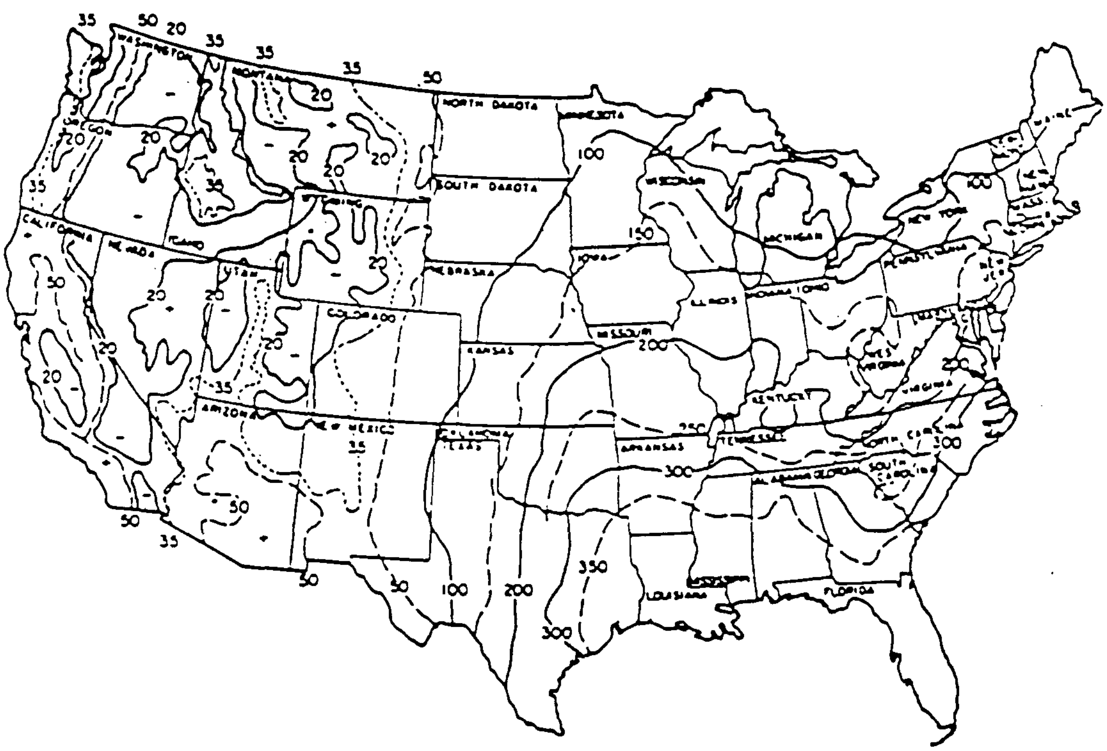


Figure 20. Average annual values of rainfall-erosivity factor R.[11]

"Evaluating Cover Systems for Solid and Hazardous Waste",
R.J. Lutton, USEPA, September 1982

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will be discussed later. For a first approximation of the erodibility of soil in a given area of the United States, refer to the soil erodibility maps, Figures 5-8 and 5-9, in the map pocket. For a specific construction site a better procedure is to take representative samples of the soil in question and determine their percentage of silt plus very fine sand (0.05 mm to 0.10 mm) and the percentage of sand (0.10 mm to 2.0 mm). The percentage organic matter should also be determined. With these values, enter Wischmeier's 1971 soil erodibility nomograph, Figure C-1, and determine the appropriate value of K to be used in the equation. If, for example, the soil from a construction site in northwestern Missouri contains 65 percent silt plus very fine sand, has 5 percent particles in the sand category, and contains 2.8 percent organic matter, the K value first approximation will be about 0.28 which corresponds also with the erodibility map in Figure 5-8. If in addition the soil is determined to have a structural value of 2 and a permeability of 4, the K value is 0.31 (structure and permeability value ranges are defined in Figure C-1).

<u>NOTE: VALUES DETERMINED FROM THE SOIL ERODIBILITY MAPS, FIGURES 5-8 AND 5-9, SHOULD BE USED ONLY WHEN SITE-SPECIFIC SOIL ANALYSES ARE NOT AVAILABLE.</u> These maps were prepared from the latest information available from the Soil Conservation Service and from individual states, but at best are only rough approximations of soil erodibility values of specific sites.

In those states where more detailed information was not available, values from the national soil survey were used. This procedure resulted in some instances in soil classifications following state boundaries, which, of course, is not according to fact.

TOPOGRAPHIC FACTOR LS
(see Appendix C for additional details)

The only manageable parts of the soil loss equation are the topographic factor LS and the erosion control factor VM. The rainfall factor R and the soil erodibility factor K have both been fixed by nature and cannot be altered by man's activities. The steepness and length of many of the slopes in highway construction, however, are determined by man after he considers the physical setting of the construction site and the requirement of the transportation system. It is obvious that flat slopes and short lengths will have less erosion than steep slopes and long lengths, but the amount of erosion expected for various combinations of length and steepness is not so obvious. The LS factor is therefore a numerical representation of the length-steepness combination to be used with the rainfall factor R and the soil erodibility factor K to estimate the erosion rate potential for a particular construction slope. Since the slope and length are determined by the highway designer, a knowledge of the LS factor will aid him in choosing proper combinations of slopes and lengths, and determining when to use berms, cross ditches, terraces or other control practices which effectively reduce the LS factor.

For determining the LS factor in the soil loss equation, the following relationship is given by Foster and Wischmeier (31) and by Wischmeier and Smith (48, 56).

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{65.41\, s^2}{s^2 + 10{,}000} + \frac{4.56\, s}{\sqrt{s^2 + 10{,}000}} + 0.065\right) \quad (2\text{-}3)$$

in which

- LS = topographic factor
- λ = slope length in feet
- s = slope steepness in percent
- m = exponent dependent upon slope steepness (0.2 for slopes < 1 percent, 0.3 for slopes 1 percent to 3 percent, 0.4 for slopes 3.5 to 4.5 percent, and 0.5 for slopes > 5 percent)

The graph in Figure 2-3 has been developed for solving Equation 2-3 and is used in the following manner. The value of the slope gradient is located on the bottom scale of the graph. This value is followed vertically to the appropriate slope length curve, and the corresponding LS value is read on the left hand scale of the graph. (See also Table C-1.)

Referring to Figure 2-3 it is determined that if the site calls for a fill slope 100 feet long at a steepness of 67 percent (1-1/2:1), the LS factor value from the graph is about 27. Reducing the slope to 50 percent increases the length to 124 feet (increasing the exposed area by 24 percent), and the new LS factor value becomes 20. The erosion rate potential has thus been reduced to 74 percent of the original and the erosion amount (rate x area) to 95 percent (assuming no erosion prior to exposure). Further reducing the slope to 3:1 (33 percent), the LS factor value becomes 13 or 47 percent of the original. A 6:1 slope would reduce the LS value to about 6 or nearly 21 percent of the first design, but the slope length has now more than tripled to 339 feet, and the total <u>amount</u> of erosion has reduced to about 71.1 percent of the original. <u>Cutting the slope length in half cuts the erosion by approximately one-third or to 70 percent of the original amount.</u>

EROSION CONTROL FACTOR VM
(see Appendix C for additional details)

The erosion control factor is applied in the equation as a single unit. It accounts for the effects of all erosion control measures that may be implemented on any particular construction site, including vegetation, mechanical manipulation of the soil surface, chemical treatments, etc. It does not include structures such as berms and ditches. These are part of the topographic factor, LS. For any site the soil loss equation may be solved with and without erosion control measures installed and the difference in the "A" values determined is an indication of the effectiveness of that particular control system.

From research results reported in the literature, it was noted that mulches had apparent VM factor values commonly around 0.01 until R·K·LS factor values exceeded a certain critical level at which point the mulch partially failed. Thus for each set of R·K·LS values it is assumed that a certain quantity of mulch is required to maintain the VM factor value at a level near 1 percent. Figures 2-4, 2-5, 2-6, and 2-7 were developed for this MANUAL using data gathered from both published and unpublished sources and show this relationship for straw or hay mulch not tacked (some states apply mulch in this

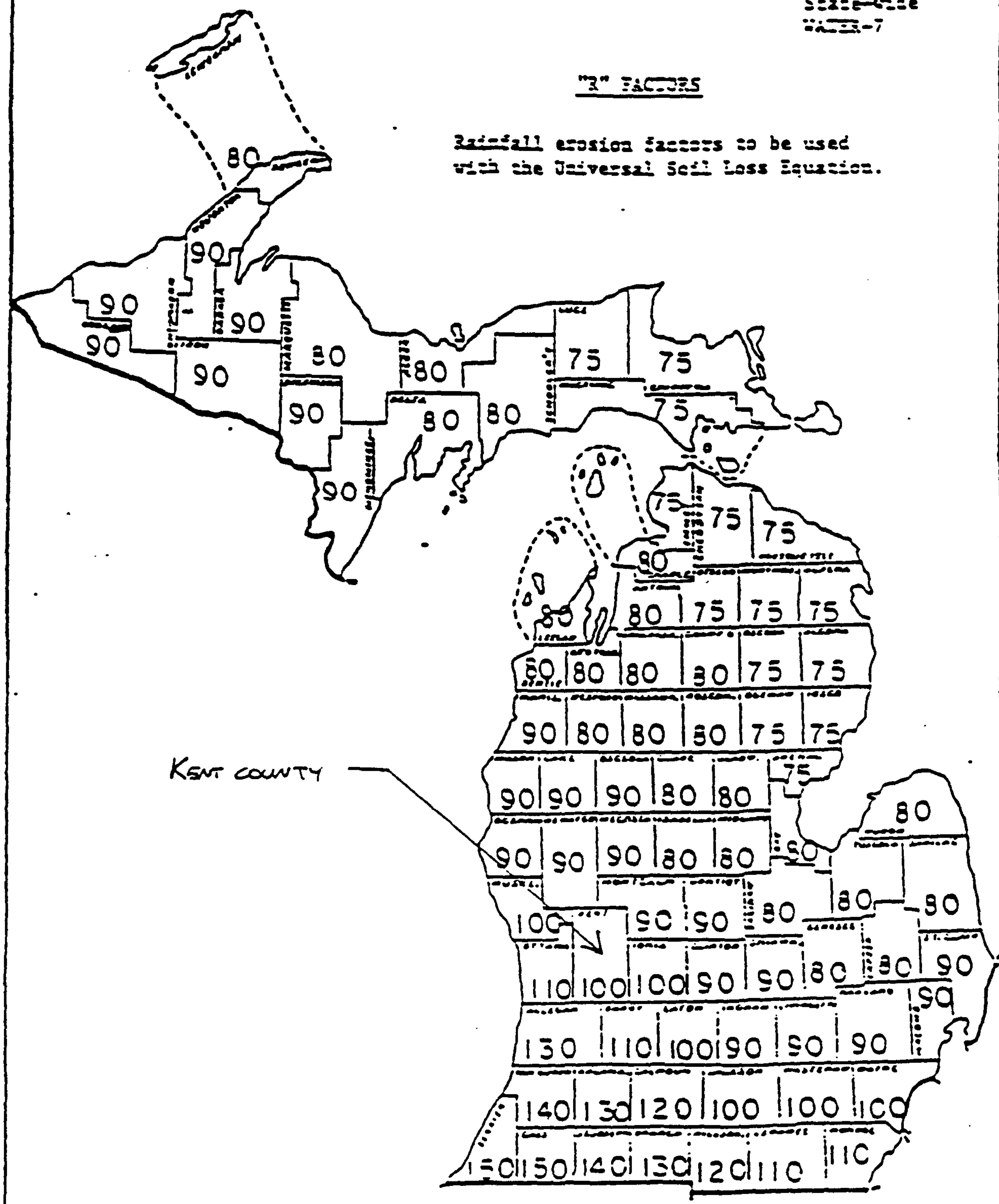
Rainfall Erosion Factors To Be Used With The Universal Soil Loss Equation

Sheet 5 of 8

TECHNICAL GUIDE
SECTION I-C
State-wide
WATER-7

"R" FACTORS

Rainfall erosion factors to be used with the Universal Soil Loss Equation.



USDA-SCS-MICH (Notice 69 - 9/87)

soil in a unit plot, pinpoints differences in erosion according to differences in soil type. Long-term plot studies under natural rainfall have produced K values generalized in Table 5 for the USDA soil types.

TABLE 5. APPROXIMATE VALUES OF FACTOR K FOR USDA TEXTURAL CLASSES[11]

Texture class	Organic matter content		
	<0.5%	2%	4%
	K	K	K
Sand	0.05	0.03	0.02
Fine sand	.16	.14	.10
Very fine sand	.42	.36	.28
Loamy sand	.12	.10	.08
Loamy fine sand	.24	.20	.16
Loamy very fine sand	.44	.38	.30
Sandy loam	.27	.24	.19
Fine sandy loam	.35	.30	.24
Very fine sandy loam	.47	.41	.33
Loam	.38	.34	.29
Silt loam	.48	.42	.33
Silt	.60	.52	.42
Sandy clay loam	.27	.25	.21
Clay loam	.28	.25	.21
Silty clay loam	.37	.32	.26
Sandy clay	.14	.13	.12
Silty clay	.25	.23	.19
Clay		0.13–0.29	

The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values.

The evaluator must next consider the shape of the slope in terms of length and inclination. The appropriate LS factor is obtained from Table 6. A nonlinear slope may have to be evaluated as a series of segments, each with uniform gradient. Two or three segments should be sufficient for most engineered landfills, provided the segments are selected so that they are also of equal length (Table 6 can be used, with certain adjustments). Enter Table 6 with the total slope length and read LS values corresponding to the percent slope of each segment. For three segments, multiply the chart LS values for the upper, middle, and lower segments by 0.58, 1.06, and 1.37, respectively. The average of the three products is a good estimate of the

TABLE 7. GENERALIZED VALUES OF FACTOR C FOR STATES EAST OF THE ROCKY MOUNTAINS[11]

Crop, rotation, and management	Productivity level	
	High	Mod.
	C value	
Base value: continuous fallow, tilled up and down slope	1.00	1.00
CORN		
C, RdR, fall TP, conv	0.54	0.62
C, RdR, spring TP, conv	.50	.59
C, RdL, fall TP, conv	.42	.52
C, RdR, wc seeding, spring TP, conv	.40	.49
C, RdL, standing, spring TP, conv	.38	.48
C-W-M-M, RdL, TP for C, disk for W	.039	.074
C-W-M-M-M, RdL, TP for C, disk for W	.032	.061
C, no-till pl in c-k sod, 95-80% rc	.017	.053
COTTON		
Cot, conv (Western Plains)	0.42	0.49
Cot, conv (South)	.34	.40
MEADOW		
Grass & Legume mix	0.004	0.01
Alfalfa, lespedeza or Sericia	.020	
Sweet clover	.025	
SORGHUM, GRAIN (Western Plains)		
RdL, spring TP, conv	0.43	0.53
No-till pl in shredded 70-50% rc	.11	.18
SOYBEANS		
B, RdL, spring TP, conv	0.48	0.54
C-B, TP annually, conv	.43	.51
B, no-till pl	.22	.28
C-B, no-till pl, fall shred C stalks	.18	.22
WHEAT		
W-F, fall TP after W	0.38	
W-F, stubble mulch, 500 lbs rc	.32	
W-F, stubble mulch, 1000 lbs rc	.21	

Abbreviations defined:

B - soybeans
C - corn
c-k - chemically killed
conv - conventional
cot - cotton
F - fallow
M - grass & legume hay
pl - plant
W - wheat
wc - winter cover

lbs rc - pounds of crop residue per acre remaining on surface after new crop seeding
% rc - percentage of soil surface covered by residue mulch after new crop seeding
70-50% rc - 70% cover for C values in first column; 50% for second column
RdR - residues (corn stover, straw, etc.) removed or burned
RdL - all residues left on field (on surface or incorporated)
TP - turn plowed (upper 5 or more inches of soil inverted, covering residues)

are listed in Table 8. These values are based on rather limited field data, but P has a narrower range of possible values than the other five factors.

TABLE 8. VALUES OF FACTOR P[11]

Practice	Land slope (percent)				
	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
	(Factor P)				
Contouring (P_c)	0.60	0.50	0.60	0.80	0.90
Contour strip cropping (P_{sc})					
R-R-M-M[1]	0.30	0.25	0.30	0.40	0.45
R-W-M-M	0.30	0.25	0.30	0.40	0.45
R-R-W-M	0.45	0.38	0.45	0.60	0.68
R-W	0.52	0.44	0.52	0.70	0.90
R-O	0.60	0.50	0.60	0.80	0.90
Contour listing or ridge planting (P_{cl})	0.30	0.25	0.30	0.40	0.45
Contour terracing (P_t)[2]	[3] $0.6/\sqrt{n}$	$0.5/\sqrt{n}$	$0.6/\sqrt{n}$	$0.8/\sqrt{n}$	$0.9/\sqrt{n}$
No support practice	1.0	1.0	1.0	1.0	1.0

Use 1.0, conservative

[1] R = rowcrop, W = fall-seeded grain, O = spring-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that rowcrop strips are always separated by a meadow or winter-grain strip.

[2] These P_t values estimate the amount of soil eroded to the terrace channels and are used for conservation planning. For prediction of off-field sediment, the P_t values are multiplied by 0.2.

[3] n = number of approximately equal-length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

Example: An owner/operator proposes to close one section of his small landfill with a sandy clay subsoil cover having the surface configuration shown in Figure 21. The factor R has been established as 200 for this locality. The evaluator questions anticipated erosion along the steep side and assigns the following values to the other factors in the USLE after inspecting Tables 5 through 8:

$$K = 0.14 \quad LS = 8.3 \quad C = 1.00 \quad P = 0.90$$

The rate of erosion for the steep slope of the landfill is calculated as follows:

$$A = 200\ (0.14\ \text{tons/acre})\ (8.3)\ (1.00)\ (0.90) = 209\ \text{tons/acre}$$

This erosion not only exceeds a limit recommended by the permitting authority but also indicates a potential

APPENDIX F

SPECIFICATIONS

TABLE OF CONTENTS

SECTION 02051
REMOVAL OF MISCELLANEOUS STRUCTURES

PART 1 GENERAL

1.01 WORK INCLUDED

A. Removing and disposing of pavement surfaces, fences, poles, gates, and buildings occurring within the limits of construction.

B. Removing, storing, and reinstalling, or protecting sections of pavement surfaces, fences, poles, gates, and buildings occurring within the limits of construction, as necessary to facilitate construction operations.

1.02 RELATED WORK

A. Section 02112 - Clearing and Grubbing

B. Section 02201 - Excavation/Grading

C. Section 02230 - Fill

PART 2 PRODUCTS

NOT APPLICABLE

PART 3 EXECUTION

3.01 PREPARATION

A. Protect existing structures which are not to be removed or disturbed.

B. Mark location of disconnected utilities. Identify utilities and indicate capping locations on Project Record Drawings.

3.02 EXECUTION

A. Remove indicated structures and appurtenances in an orderly and careful manner. Leave site in clean condition.

B. Dispose of demolition debris in designated waste reconsolidation areas.

C. Remove materials to be reinstalled or retained in manner to prevent damage.

D. Backfill excavated areas and open holes caused as a result of removal. Use soil or fill specified in Section 02230 - Fill.

E. Rough grade and compact areas affected by removal to maintain site grades and contours.

END OF SECTION

SECTION 02052
LANDFILL GAS PROBE ABANDONMENT

PART 1 GENERAL

1.01 REQUIREMENTS INCLUDED

A. Sealing and abandonment of landfill gas probes.

B. Restoration of surrounding area.

PART 2 PRODUCTS

2.01 MATERIALS

A. Grout: 6 parts Portland Cement, 3 parts water, 1 part bentonite by weight.

PART 3 EXECUTION

3.01 PREPARATION

A. Remove debris, pump, piping, unsealed liners, or other obstruction that may interfere with sealing.

3.02 ABANDONMENT

A. Remove probe casing where possible or drill out the casing with a larger diameter drill or auger.

B. Fill probe casing or redrilled borehole entirely with grout.

C. Apply grout through a conductor or tremie pipe. When grouting under water, insure that the bottom of the pipe is submerged in grout at all times.

3.03 RESTORATION

A. Restore area of probe abandonment to match the surrounding conditions, or to receive additional Work.

END OF SECTION

SECTION 02112
CLEARING AND GRUBBING

PART 1 GENERAL

1.01 WORK INCLUDED

A. Clearing, stripping, grubbing, removing, and disposing of the trees, shrubs, brush, logs, stumps, roots, windfalls, and other plant life, including dead and decayed matter, that exists within the construction areas and which are not specifically designated to remain.

PART 2 PRODUCTS

NOT APPLICABLE

PART 3 EXECUTION

3.01 PROJECT SITE CONDITIONS

A. Protection:

1. Protect existing utilities against damage. CONTRACTOR is responsible for contacting "Miss Dig" as necessary.

2. Locate existing underground utilities by hand excavation.

3. If uncharted utilities are encountered during excavation, notify ENGINEER and wait for instructions before proceeding.

   a. Repair, at CONTRACTOR'S expense, damage to utilities encountered when Work is continued without notifying ENGINEER.

4. Preserve and protect groundwater monitoring or piezometer wells and LFG probes. Damaged or destroyed wells shall be replaced at CONTRACTOR'S expense.

   a. CONTRACTOR shall be responsible for protection of existing groundwater monitoring and piezometer wells shown or not shown on Drawings.

5. Coordinate work in the radio tower and station building area with ENGINEER.

3.02 CLEARING AND GRUBBING

A. Remove trees, shrubs, brush, logs, stumps (to ground surface), and natural growth within Construction Limits of preparation fill areas.

B. Remove and grind or bury stumps, roots, and logs within Construction Limits of preparation cut areas. Spread ground chips at a maximum ½ inch thickness in close proximity of work and within Limits of Construction.

C. Maintain benchmarks, control monuments, and monitoring wells. Re-establish if disturbed, damaged, or destroyed, at no cost to OWNER.

3.03 DISPOSAL

A. Remove all debris and spoil within 30 days of accumulation and dispose of on-site. Burning of debris is not permitted.

3.04 PROTECTION OF EXISTING TREES AND VEGETATION

A. Preserve and protect from damage trees within the Construction Limits as designated that are identified by ENGINEER prior to construction.

B. Preserve and protect from damage trees and vegetation outside the Construction Limits.

C. Paint any cut or scarred trees and shrubs with asphaltum base tree paint.

END OF SECTION

SECTION 02201
EXCAVATION/GRADING

PART 1 GENERAL

1.01 WORK INCLUDED

A. Digging, loading, hauling, stockpiling, and disposing of earth materials, including finish grading to the extent and elevations shown on the Drawings.

B. Excavation/grading or placement of wastes in areas shown on the Drawings.

C. Digging, sorting, moving, and/or stockpiling of on-site clay soils.

D. Stockpiling of on-site topsoil. Finish grading of stockpile.

1.02 RELATED WORK

A. Section 02051 - Removal of Miscellaneous Structures

B. Section 02112 - Clearing and Grubbing

C. Section 02931 - Topsoil, seeding, and fertilizer

PART 2 PRODUCTS

NOT APPLICABLE

PART 3 EXECUTION

3.01 PREPARATION

A. Remove ice and snow before excavation.

B. Identify required construction survey control lines and datum.

3.02 EXCAVATION

A. Grade perimeter of excavation to prevent surface water drainage into excavation.

B. Notify ENGINEER of unexpected subsurface conditions and discontinue affected work in area until notified to resume work.

C. If drums are encountered during excavation, excavation activities will proceed as outlined in the Drum Contingency Plan and in the RA Health and Safety Plan.

D. Stockpile reusable earth material in area designated on-site. Grade to provide positive drainage. Stockpile sideslopes shall not exceed two on one.

E. Excavate wastes and place/compact at designated reconsolidation areas.

F. Cover graded and excavated waste daily with General Fill Types A or B.

3.03 FINISHING

A. Blend slopes with existing landscape features, at the intersection of cuts and fills; provide gradual slope between new and existing construction.

B. Finish grades to plus .25 percent/minus 0 percent of minimum 2% slopes shown on drawings.

3.04 PROTECTION

A. Notify all area utility companies prior to commencing work in accordance with state and local regulations.

B. Locate, identify, and protect existing utilities from damage.

C. Protect bench marks, survey monuments, monitoring wells, existing structures, fences and gates, sidewalks, paving, and curbs from damage by excavation equipment and vehicular traffic.

D. Protect excavations by shoring, bracing, sheet piling, or other methods required to prevent cave-in or loose soil from falling into excavation.

E. Underpin adjacent structures which may be damaged by excavation Work, including service utilities and piping.

F. Do not remove or disturb any materials outside the Construction Limits.

G. Keep excavations free from water by pumping or constructing diversion berms and/or ditches to divert water.

H. Protect bottom of excavations and soil adjacent to and beneath foundations from frost.

END OF SECTION

SECTION 02202
CSO (WEST SIDE DITCH) DREDGING

PART 1 GENERAL

1.01 WORK INCLUDED

A. Dredging of sediments from bottom of Combined Sewer Overflow (CSO) ditch (a.k.a. West Side Ditch).

B. Placement of Clay Fill on floor and sides of CSO ditch.

1.02 RELATED WORK

A. Section 02051 - Removal of Miscellaneous Structures

B. Section 02112 - Clearing and Grubbing

PART 2 PRODUCTS

NOT APPLICABLE

PART 3 EXECUTION

3.01 PREPARATION

A. Submit a dredging plan for approval by the ENGINEER. Required elements include proposed dredging methods, dredging sediment placement plan, and provisions for sediment control.

B. Identify required construction survey control lines and datum.

3.02 EXCAVATION

A. Notify ENGINEER of unexpected subsurface conditions and discontinue work in area until notified to resume work.

B. Dredge sediments to a minimum of one foot below design elevations shown on drawings.

3.03 FINISHING

A. Backfill to grades shown on construction plans with Clay Fill. Compact clay to an even surface.

B. Finish to elevations shown within 0.10 foot tolerance.

3.04 PROTECTION

A. Notify all area utility companies prior to commencing work in accordance with state and local regulations.

B. Locate, identify, and protect existing utilities from damage.

C. Protect bench marks, survey monuments, monitoring wells, and existing structures from damage by excavation equipment and vehicular traffic.

D. Protect excavations by shoring, bracing, sheet piling, or other methods required to prevent cave-in or loose soil from falling into excavation.

E. Underpin adjacent structures which may be damaged by excavation Work, including service utilities and piping.

F. Do not remove or disturb any materials outside the Construction Limits.

G. Keep excavations free from water by pumping or constructing diversion berms and/or ditches to divert water.

H. Protect bottom of excavations from frost.

END OF SECTION

SECTION 02230
FILL

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Moving, placing, and compacting earth fill materials in accordance with the lines, grades, thicknesses, and typical sections shown on the Drawings.

B. Reconsolidating excavated waste materials in areas shown on the Drawings.

1.02 REFERENCES

A. ASTM D1557 - Test Method for Laboratory Compaction Characteristic of Soil Using Modified Effort

B. ASTM D2487 - Test Method for Classification of Soils for Engineering Purposes

C. ASTM D2922 - Test Methods for Density of Soil and Soil-Aggregate In Place by Nuclear Methods

D. ASTM D3017 - Test Method for Water Content of Soil and Rock in Place by Nuclear Methods

E. ASTM D698 - Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort.

F. Michigan Department Transportation - 1996 Standard Specifications for Construction.

G. ACI 229R-94 Report - Controlled Low Strength Materials

H. Michigan Department of Environmental Quality - Part 115, Chapter 3, Act 451 (1994).

1.03 SUBMITTALS

A. Submit sequence of Fill placement with project schedule.

B. Submit material testing documentation and samples of General Fill A and B, Structural Fill, and flowable fill as described in Part 3 of this specification.

PART 2 PRODUCTS

2.01 GENERAL FILL - TYPE A

A. Materials free from organic matter and refuse, masonry, metal, sharp objects, boulders, snow, and ice.

B. No solid material larger than 12 inches in its largest dimension.

C. Materials free from contamination by petroleum or hazardous substances.

2.02 GENERAL FILL - TYPE B

A. Approved construction and demolition fill.

B. Approved industrial by-products tested as inert in accordance with MDEQ requirements.

2.03 STRUCTURAL FILL

A. COURSE AGGREGATE

Sieve Size	% Passing by Weight
3/4"	100
1/2"	95-100
3/8"	60-90
#4	5-30
#8	0-12

B. Pea gravel - rounded non-angular <3/8".

2.04 FROST PROTECTION LAYER

A. Frost Protection Layer: Natural soil material generally free from roots, woody vegetation, rocks greater than 6 inches in diameter, and other deleterious material. Composted material can be mixed with natural soils for frost protection.

2.05 CLAY FILL

A. Materials classified as ML, SC, CL, or CH according to the Unified Soil Classification System.

B. Clumps larger than 8 inches will be broken down with normal construction equipment to a size of 2 to 3 inches prior to compaction.

C. Maximum rock size: 6-inches in the longest dimension.

2.06 FLOWABLE FILL

A. Flowable mix of non-deleterious materials that meet the following specifications:

1. Cures at a compressive strength of 100 psi in 28 days or less
2. A maximum permeability of $1x10^{-7}$ cm/sec.
3. Limit aggregate size to #4 sieve and smaller.
4. Submit mix designs for approval by engineer.

2.07 LOW PERMEABILITY SOIL

A. Silty-clay soil from the Autumn Hills Recycling and Disposal Facility in Zeeland, MI.
B. Approved equal.

PART 3 EXECUTION

3.01 STOCKPILE

A. Stockpile materials on-site at locations indicated on Drawings

B. Stockpile Fill in sufficient quantities to meet project schedule and requirements.

C. Maintain stockpiles during construction. Grade stockpiles to provide positive drainage to prevent erosion or deterioration of materials. Provide erosion control around stockpile.

D. Regrade and restore stockpile areas or at completion of the project.

3.02 PREPARATION AND RESTORATION

A. Remove ice and snow before placing Fill. Do not place Fill on frozen subgrade.

B. Cut out soft areas of unsuitable subgrade consisting of natural soils on cover material.

C. Proof-roll areas of the subgrade consisting of natural soils on cover material to detect soft or loose zones prior to planning fill.

D. ENGINEER will document surface conditions of subbase fill layer prior to placement of Fill.

3.03 PLACEMENT AND COMPACTION OF GENERAL FILL

A. Spread and compact General Fill in lift thicknesses as required to develop stable base for clay placement. Maximum lift thicknesses of 12 inches after compaction will not be exceeded.

3.04 PLACEMENT AND COMPACTION OF STRUCTURAL FILL

A. Compact Structural Fill to a minimum 90% of the maximum dry density and no further appreciable consolidation is evident.

B. Remove and replace Structural Fill which does not meet specified material testing requirements at no additional cost to the OWNER.

3.05 PLACEMENT AND COMPACTION OF FROST PROTECTION LAYER

A. Maintain proper moisture content to achieve compaction sufficient to avoid settlement.

B. Spread and compact Frost Protection Layer to a minimum of 85% of the maximum dry density. Place fill in lift thicknesses as required to obtain sufficient compaction. Maximum lift thicknesses of 8 inches after compaction will not be exceeded.

3.06 PLACEMENT AND COMPACTION OF CLAY FILL

A. Place, blend, and spread Clay Fill. Remove lenses, pockets, streaks, or layers by additional blending.

B. Maintain proper moisture content to achieve specified compaction.

C. Place and spread Clay Fill in lift thicknesses as required to obtain the specified levels of compaction. Maximum lift thicknesses of 6 inches after compaction will not be exceeded.

D. Compact (except when noted otherwise) Clay Fill and subgrade in accordance with the following:

1. Maintain moisture content of at least 2 percent below and not more than 5 percent above the optimum value as determined by the Modified Proctor test.

2. Compact material to a minimum of 90% of the maximum dry density, as determined by the Modified Proctor test.

E. Remove and replace Clay Fill that does not meet specified material testing requirements, at no additional cost to the OWNER.

F. Place Frost Protection Layer material as soon as practical after completion of Clay Fill placement to avoid drying and desiccation of Clay Fill.

G. Scarify Clay Fill to a minimum depth of 2 inches between lifts when previous lift has dried out or been smooth drum-rolled. Add water as required to maintain specified moisture content.

3.07 PLACEMENT OF FLOWABLE FILL

A. Pump flowable fill after surrounding grade has been placed to provide form.

B. Apply corrosion protection to structural steel prior to pumping flowable fill material.

3.08 PLACEMENT OF LOW-PERMEABLE SOIL

A. Place and spread low-permeability soil to required thickness.

3.09 TRENCH BACKFILLING

A. Backfill immediately following completion of pipe installation and documentation required by the RPR.

B. Take necessary precautions with backfill and construction operations to protect completed utility system from damage.

C. Backfill with care around structures and cleanouts.

D. Backfill to the original ground elevation unless shown otherwise on Drawings.

3.10 FIELD QUALITY CONTROL OF FILL MATERIAL

A. CONTRACTOR is responsible for quality control of all fill materials and applicable performance standards.

B. Filling Tolerances

1. Grade General Fill to 2% slope (+.25%/-0%); 1% in RT&SB area.
2. Place clay and frost protection layer at specified thickness (+.1 feet/-0 feet)

END OF SECTION

SECTION 02273
RIPRAP

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Furnishing and placing riprap in accordance with the locations and thicknesses shown on the Drawings.

PART 2 PRODUCTS

2.01 MATERIALS

A. Submit source and specific gradation for the CSO ditch riprap (12-18 inches in diameter).

B. For other site work, stone pieces meeting the following size requirements:

Size	% Passing by Weight
6-inch	60-100
3-inch	25-50
1.5-inch	5-20

C. Concrete pieces: sound and free of reinforcement meeting the same size requirements for the CSO or site work may be substituted.

PART 3 EXECUTION

3.01 PREPARATION

A. Excavate to the lines and grades required for placement of the riprap.

B. Place Geotextile Filter over areas to receive riprap in accordance with Section 02776.

3.02 PLACEMENT

A. Minimum thickness of riprap layer is 12 inches measured perpendicular to the slope.

B. Place riprap to the limits shown on the plans, and to within a 3-inch tolerance for thickness.

C. Place riprap with care so no damage is done to Geotextile Filter or culvert pipe. Do not drop riprap from a height greater than 12 inches.

D. Place riprap from the base of the slope upward. Place smaller sized stones to fill voids between the larger sized stones.

SECTION 02275
SEDIMENT CONTROL FENCE/TURBIDITY CURTAIN

PART 1 GENERAL

1.01 WORK INCLUDED

A. Providing and maintaining sediment control fencing.

PART 2 MATERIALS

2.01 PRODUCTS

A. Envirofence 100x, manufactured by Mirafi Civil Engineering Fabrics

B. Woven monafilament curtain for turbidity control by Synthetic Industries.

C. Approved equals.

PART 3 EXECUTION

3.01 EROSION AND SEDIMENT CONTROL REQUIREMENTS

A. Techniques and practices for implementing erosion control measures shall conform to, but not be limited to, the General Rules and Guidelines of the "Soil Erosion and Sedimentation Control Act," Act 347.

B. Apply appropriate soil conservation measures to protect project area and adjacent wetlands. Measures shall include, but not be limited to, mulching, rapid growth vegetation, fabric mat, hay bales, filter barriers, sediment traps, silt fence, and check dams.

1. Maintain erosion control measures during course of construction through completion of the Work.

2. Remove erosion control measures upon establishment of permanent, surface stabilization, or as directed by ENGINEER.

C. Install turbidity controls for CSO earth dam construction to minimize turbidity near the Grand River.

3.02 EROSION CONTROL MEASURES

A. Install silt fence, straw bale berms, check dams, and other measures where shown on Drawings, and as needed throughout construction activities to protect wetlands and water from sediment. RPR will approve installation and condition of silt fence prior to authorizing payment.

B. Complete temporary or permanent surface stabilization of perimeter controls, dikes, swales, ditches, perimeter slopes, and slopes greater than 3:1 within 7 calendar days following final soil disturbance. Stabilize other disturbed areas within 14 calendar days.

3.03 INSTALLATION

A. Install hard wood posts 2 feet below grade, at maximum 8-foot spacing.

B. Anchor bottom 6 inches of fence netting below grade to create a continuous toe-in structure along fence installation.

C. Install silt fence in areas designated on the Drawings.

END OF SECTION

SECTION 02276
EROSION CONTROL AND REVEGETATION MATTING

PART 1 GENERAL

1.01 WORK INCLUDED

A. Provide Erosion Control and Revegetation Mat along waterways and slopes as shown on the Drawings

1.02 RELATED WORK

A. Section 02931 - Topsoil, Seeding, and Fertilizer

1.03 DELIVERY, STORAGE, AND HANDLING

A. Store out of sunlight.

B. Handle with care not to damage mat.

PART 2 PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Synthetic Industries.

B. Approved manufacturers.

2.02 MATERIALS

A. Turf Reinforcement Mat (TRM) Landlok 1060 or an equal product.

B. Polyjute open weave geotextile.

C. Matting Staples: minimum 6-inch length.

2.03 SUBMITTALS

A. Submit samples of materials for approval by Engineer.

PART 3 EXECUTION

3.01 PREPARATION

A. Grade area, remove sharp objects and other unsuitable materials prior to placement.

3.02 INSTALLATION

A. Overlap roll ends a minimum of 3 feet, with upslope mat on top.

B. Overlap adjacent edges a minimum of 4 inches.

C. Anchor edges in a minimum of 4 by 4 inch trench.

D. At a minimum interval of 25 feet and at terminal ends, wrap, and anchor mat in a minimum of 4 by 4-inch transverse trench.

E. Staple mat at 3 to 5 foot intervals. Staple mat at 3-foot intervals in 4 by 4 inch trenches.

F. Backfill all trenches with topsoil and compact.

G. Cut mat to fit around trees and staple in place at base of tree trunks.

END OF SECTION

SECTION 02432
SOIL BORINGS AND LANDFILL GAS MONITORING PROBES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Drill soil borings.

2. Soil sampling.

3. Visual classification of soil types.

4. Laboratory testing of geotechnical samples.

1.02 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. ASTM D420-87 - Standard Guide for Investigating and Sampling Soil and Rock.

2. ASTM D422-90 - Standard Method for Particle-Size Analysis of Soils.

3. ASTM D653-96 - Standard Terminology Relating to Soil, Rock, and Contained Fluids.

4. ASTM D1452-80 - Standard Practice Method for Soil Investigation and Sampling by Auger Borings.

5. ASTM D1586-84 - Standard Method of Penetration Test and Split-Barrel Sampling of Soils.

6. ASTM D1785-96 - Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.

7. ASTM D2487-93 - Standard Test Method of Classification of Soils for Engineering Purposes.

8. ASTM D2488-93 - Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

1.03 SUBMITTALS

A. Product Data:

1. Grain size curve of filter pack and fine sand filter pack seal.

2. Submit 5 days prior to drilling.

B. Test Results:

1. Laboratory Results: Submit 1 copy to ENGINEER within 30 working days after drilling is complete.

C. Miscellaneous:

1. Final Boring Logs.

a. Prepare final boring logs based on field information, laboratory test results, and further inspection of samples in laboratory.

b. Submit chart illustrating soil classification criteria, terminology, and symbols.

c. Submit 1 copy to ENGINEER within 30 working days after each boring is complete.

2. Well Construction Diagrams:

a. Submit 1 copy to ENGINEER within 30 working days after drilling is complete.

1.04 QUALITY CONTROL

A. Provide geologist, geotechnical engineer or other professional experienced in soil boring, sample logging, and installation of gas monitoring probes. Individual shall be responsible for supervising and documenting information related to refuse and soil-intrusive activities.

B. Prior to use, inspect well materials for cleanliness, deformations, and imperfections, and to ensure conformance with Specifications. Do not use defective materials.

PART 2 PRODUCTS

2.01 LANDFILL GAS MONITORING PROBES

A. PVC: ASTM D1785 with one of the following cell classifications: 12454-B, 12454-C, 11443-B, 14333-D, 13233, or 15223-B.

B. Riser:

1. Construct of nominal 1-in. ID (1.9-in. minimum diameter), Schedule 40 flush-threaded PVC.

C. Screen:

1. Construct of 1-in. diameter Schedule 40 PVC. PVC slip cap to bottom of screen.

D. Joints:

1. O-ring or Teflon taped.

E. Caps:

1. Top Cap: PVC labcock.

2. Bottom: PVC, threaded.

2.02 WATER

A. Water used for drilling, grout mixtures or concrete mixtures shall be free of bacterial or chemical contamination.

B. Record water source location and volumes used on probe installation form or soil boring log.

C. Water source may be subject to water quality analysis by ENGINEER prior to use.

2.03 CONCRETE

A. Cement: ASTM C150, Type I, air-entrained.

B. Aggregate: ASTM C33.

C. Concrete Mix: Measure and combine cement, aggregates, and water complying with ASTM C85.

D. Ready-Mixed Concrete: ASTM C94.

2.04 BENTONITE

A. General: Clay consisting of greater than 85% sodium montmorillonite, without additives.

B. Powdered: 200 mesh.

C. Chips: Angular fragments of formed bentonite.

2.05 GROUT

A. General:

1. Provide equipment for weighing a representative grout sample to determine mixed density.

2. Provide equipment for mixing grout to specified requirements.

3. Hydraulic Conductivity: Less than 1×10^{-7} cm/sec after grout hydration.

B. American Colloid Pure-Gold Grout:

1. Mixed Density: 10.2 lbs./gal.

2. Proportion:

a. Pure-Gold Volclay: 50 lbs.

b. Water: 14 gals.

3. Mix: Add Pure-Gold grout to water.

C. Cement - Bentonite:

1. Proportion:

a. Portland cement: 94 lbs., ASTM C150.

b. Powdered bentonite: 5 lbs., without additives.

c. Water: 8.5 gals.

2. Mix: Add bentonite to water and thoroughly mix; add cement and mix.

D. Neat Cement:

1. Proportion:

a. Portland cement: 94 lbs., ASTM C150.

b. Water: 5 to 6 gals.

2.06 WELL SCREEN BACKFILL

A. Filter Pack:

Size	Passing Sieve (%)
1 in.	100
¾ in.	90-100
3/8 in.	20-55
No. 4	0-10
No. 8	0-5

B. Intermediate Filter:

Size	Passing Sieve (%)
1 in.	100
¾ in.	90-100
3/8 in.	50-85
No. 4	35-65
No. 40	10-30
No. 200	3-5

2.07 TREMIE PIPES

A. Pipes used for seal placement shall consist of one of the following:

1. Metal pipe.
2. Rubber-covered hose reinforced with braided fiber or steel and rated for minimum 300 psi.
3. Thermoplastic pipe rated for minimum 100 psi including the following:
    a. Polyvinyl chloride (PVC).
    b. Chlorinated polyvinyl chloride (CPVC).
    c. Polyethylene (PE).
    d. Polybutylene (PB)
    e. Acrylonitrite butadiene styrene (ABS).

B. Pipe shall be side discharging.

2.08 WELL HEAD PROTECTION

A. Protective Casing:

1. 4-in. dia.
2. 7-ft. length
3. Locking hinged covers

4. Anodized Aluminum.

5. Keyed alike locks.

6. Vented.

7. Drain hole, ¼-in. dia.

B. Concrete Collar:

1. Neat cement.

2. Slope away from well.

3. Diameter equal to borehole diameter.

PART 3 EXECUTION

3.01 FIELD PREPARATION

A. Clear and grub drilling locations in accordance with specifications.

B. Construct access roads as necessary to drilling location.

C. Construct necessary drilling pads.

D. Drilling location may be moved if deemed unsafe or difficult to access. Consult Resident Project Representative and ENGINEER before relocating.

3.02 GENERAL

A. Perform auger borings in accordance with ASTM D1452.

B. Perform drilling and sampling in accordance with ASTM D1586 and D1587.

C. Take protective measures to prevent open boreholes from acting as safety hazard or conduit for contamination.

3.03 DECONTAMINATION OF EQUIPMENT, DRILL RIG

A. Decontamination of Equipment:

1. General:

a. Give special attention to cleaning threaded section of casing and drill rods. Do not use petroleum-based lubricants to prevent binding.

b. Provide equipment necessary for cleaning process.

c. Conduct equipment decontamination at location specified by Resident Project Representative.

d. Decontamination between borings is not necessary unless required by Resident Project Representative.

2. Clean drill rig and associated equipment prior to on-site mobilization to remove possible contaminating substances such as oil, grease, mud, and tar. Cleaning process occurs in following order and consists of:

a. High pressure hot water cleaning.

b. Alconox or Liquonox wash.

3.04 DRILLING

A. Drilling and sampling test methods shall be in accordance with ASTM D420.

B. Record measurements to nearest 0.1 ft.

C. Record static water level if encountered during drilling.

D. Classify soil types using USCS classification system in accordance with ASTM D2488.

E. Probe Depths:

1. Depth shall be determined based on field observation of samples.

3.05 SAMPLING

A. General:

1. Place opened sampler at location designated by ENGINEER.

2. Seal Shelby tube samples with wax, pack open space in tube with newspaper, cap ends of tube with plastic caps.

3. Clearly mark samples with sample number, depth, and Project location.

B. Soils:

1. Use standard 2-in. split barrel.

2. In coarse sands and gravels, use 3-in. split barrel.

3. Continuously sample fine-grained soils.

3.06 PROBE INSTALLATION

A. General:

1. Refer to probe detail shown on Construction Drawings.

2. Steam clean screen, riser, and end plug immediately prior to installation.

3. Store probe construction materials in secure area removed from potentially contaminated areas.

4. Record daily usage of probe construction materials.

5. Install screen above the water table.

B. Probe Screen Backfill:

1. Backfill with screen filter pack and fine sand seal, gravity placed by tremie pipe.

2. Extend screen filter pack 6 in. beneath well screen.

3. Extend screen filter pack 2 ft. above screen.

4. Extend fine sand seal 2 ft. above sandpack.

5. Calculate volume of annular space to be backfilled and compare to actual volumes used.

6. Measure depth to sand pack and filter pack by direct method.

C. Bentonite Seal:

1. Use bentonite pellets for seal material in boreholes.

2. Tamp bentonite pellet seal material after placement.

3. Hydrate seals minimum 4 hrs. before placement of overlying grout or concrete cap.

4. Seals shall be minimum 2 ft. thick.

5. Measure depth to seal to nearest 0.1 ft.

D. Grout Backfill:

1. Grout placement shall occur through tremie pipe submerged in sealant material throughout sealing process and withdrawn as annular space fills surface.

2. Grout shall be allowed to settle minimum of 2 hrs.

E. Concrete Cap:

1. Place 5-ft. concrete cap to ground surface. Do not enlarge borehole diameter for installation of concrete cap.

2. Slope concrete away from well at surface.

3. Check installation for concrete cap settlement approximately 24 hrs. after well complete. If settlement has occurred so level is below existing grade, place additional concrete to create slightly mounded condition.

F. Protective Pipe:

1. Place 7-ft. minimum length vented, protective pipe over well stick-up with hinged, locking covers. Vent shall consist of one ¼-in. diameter drain hole placed in protective pipe just above concrete cap. Provide PVC labcock plug for PVC riser pipe.

2. Allow 6-in. space between top of PVC riser pipe and cover to protective pipe.

3. Label well number on inside cover and outside of protective casing. Use nonfading permanent marker. Label in accordance with ENGINEER'S numbering system.

4. Provide keyed alike locks and keys for protective casing.

5. Label probes.

END OF SECTION

SECTION 02510
ASPHALT CONCRETE PAVING

PART 1 GENERAL

1.01 WORK INCLUDED

A. Construct access roads including subgrade preparation, aggregate base course, and asphaltic concrete pavement.

1.02 RELATED WORK

A. Section 02201 - Excavation/Grading.

B. Section 02230 - Fill.

1.03 REFERENCES

A. State of Michigan Department of Transportation, 1996 Standard Specifications for Construction.

B. The Asphalt Institute - Manual MS-4 - The Asphalt Handbook.

C. The Asphalt Institute - Manual MS-13 - Asphalt Surface Treatments and Asphalt Penetration Macadam.

D. ASTM D946 - Asphalt Cement for Use in Pavement Construction.

E. ASTM D698 - Standard Test Methods for Moisture-Density Relations of Soil and Soil-Aggregate Mixtures using 5.516 Rammer and 12-inch Drop: Standard Proctor.

1.04 SUBMITTALS

A. Submit test results indicating that the aggregate base course and asphalt concrete meets the required specifications.

B. Crushed or recycled concrete or bituminous pavement may be an acceptable ingredient in the production of Aggregate Base Course. Submit source of supply and test results from an accredited testing laboratory.

1.05 QUALITY ASSURANCE

A. Perform work in accordance with State of Michigan, Department of Transportation, 1996 Standard Specifications for Construction.

PART 2 PRODUCTS

2.01 MATERIALS

A. Aggregate Base Course: Michigan DOT Gradation 21AA depth specified on drawing.

- Percentage of wear: Not more than 50 percent as determined by AASHTO Designation T96.
- Soundness: Fraction of the aggregates retained on No. 4 sieve subjected to 5 cycles of the sodium sulfate soundness test, AASHTO Designation T104, weighted loss not more than 18 percent by weight.
- At least 50 percent by count of the number of particles of aggregate retained on No. 4 sieve to have at least one fractured surface or face resulting from the mechanical crushing operations of the aggregate.
- Sample and test in accordance with AASHTO Standard Methods.

B. Asphaltic Paving

1. Surface Course: MDOT 1100
Depth: 3 inch
Aggregate: Shall conform to MDOT Gradation No. 3.
Asphalt cement shall yield a Marshall stability of not less than 1000

2. Testing provided by CONTRACTOR

   - Provide 1 extraction test and 1 sieve analysis per day of paving.
   - Provide 2 field density test per day of paving.

3. Transport asphalt mixture in covered trucks during rainy weather or when temperature is less than 60°F.

C. Culverts

1. Use corrugated pipe conforming to Section 02613 of these specifications.

PART 3 EXECUTION

3.01 INSPECTION

A. ENGINEER to observe and approve subgrade prior to aggregate base course placement.

B. Apply water to dry subgrade before placement, and rework or recompact as necessary.

C. Verify gradients and elevations of base are correct.

D. Verify compacted subgrade is dry and ready to support paving and imposed loads.

3.02 INSTALLATION

A. Prepared subgrade shall be smoothed and trimmed to the required line grade and cross section to receive the base course and shall be compacted as required in Section 02230 - Fill. The subgrade shall be maintained in a smooth and compacted condition until the base course is placed. No base course material shall be placed until the subgrade has been approved by the ENGINEER.

B. Aggregate Base Course: Deposit base course material on the subgrade in a manner to minimize segregation and facilitate spreading to a uniform uncompacted layer not less than eight inches in depth. Install the road aggregate base course in two or more layers. Aggregate base course shall not be placed during freezing or other unfavorable weather conditions.

C. Add water as necessary to assist compaction. If excess water is apparent, aerate aggregate base course material to reduce the moisture content.

D. Mechanically compact each layer of aggregate base course material to the degree that no further appreciable consolidation or movement of the base is evidenced under action of the compaction equipment.

E. Rework or remove and replace soft or yielding areas as required until proper compaction is obtained. The cost of such reworking or removal and replacement shall be at the CONTRACTOR's expense.

F. Placement of the asphalt course shall conform to applicable sections of MDOT specifications.

G. Match existing pavement grades or grades indicated by ENGINEER.

H. Install drainage culverts as shown on Drawings. Bedding and backfill shall conform to requirements specified in Section 02230 of these specifications.

END OF SECTION

SECTION 02511
CRUSHED STONE PAVING

PART 1 GENERAL

1.01 CRUSH STONE ACCESS ROADS

1.02 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO):

1. AASHTO T99-86 - Standard Methods of Test for the Moisture-Density Relations of Soils Using 5.5-lb (2.5 kg) Rammer and 12-in. (305 mm) Drop.

2. AASHTO T104-86 - Standard Methods of Test for the Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate.

3. AASHTO T191-86 - Standard Methods of Test for Density of Soil In-Place by the Sand-Cone Method.

B. American Society for Testing and Materials (ASTM):

1. ASTM D2922-81 Standard test methods for density of soil and soil-aggregate in place by nuclear methods (shallow depth)

C. Michigan Department of Transportation - 1996 Standard Specifications for Construction

1.03 SUBMITTALS

A. Submit stone gradations to ENGINEER for review prior to bringing stone on site.

1.04 QUALITY ASSURANCE

A. Testing:

1. Obtain quarry or pit testing results for aggregate.

PART 2 PRODUCTS

2.01 MATERIALS

A. General:

1. Aggregates: Hard, durable particles of crushed stone or crushed gravel and filler of natural sand, stone sand or other finely divided mineral matter.

2. Remove oversize material encountered in deposits from which material is taken by screening or crushing to required sizes.

3. Composite material shall be substantially free from vegetable matter, shale, and lumps or balls of clay to conform to pertinent gradation requirements.

B. Soundness:

1. In event quality of material or conditions of deposition in quarry or deposit are such as to make questionable continuous compliance with this soundness requirement, ENGINEER reserves the right to require maintenance of stockpile or stockpiles of produced material sufficiently large as to preclude use of material which has not been previously approved by test.

C. Gradation Requirements: Aggregates shall be well-graded between limits specified and conform to following gradation requirements:

Sieve Size	Crushed Stone Gradation
1-1/2 in	---
1 in.	100
3/4 in.	---
1/2 in.	---
3/8 in.	60-85
No. 4	---
No. 8	25-60
No. 30	---
Loss by Washing	9-16

PART 3 EXECUTION

3.01 PREPARATION

A. Check subgrade as to soundness, outline, and contour. Prepare subgrade for areas to be paved by scraping down bumps and irregularities to obtain smooth, even bed.

B. Remove and replace with crushed stone any area, including soft or spongy spots, where displacement in subgrade is more than 1/2 in. in front of rollers.

C. Stockpile cleared material for use as general fill soil.

D. Place materials when surface is dry and atmospheric temperature is above 40°F.

3.02 INSTALLATION

A. Construct to width and selection shown on Drawings.

B. Maximum compacted thickness of any one layer shall not exceed 6 in. except when layer is placed upon loose sand subgrade which would otherwise displace or when vibrating or other approved types of special compacting equipment are used, compacted depth of single layer of base course may be increased to 8 in. upon approval of ENGINEER.

C. Deposit material on foundation or previously placed layer in manner to minimize segregation and facilitate spreading to uniform layer of required dimensions.

D. Avoid excessive manipulation or mixing which will cause segregation between coarse and fine materials.

E. Compact crush stone after layer or course has been placed and spread to required thickness, width, and contour. Unless otherwise required in Contract, each layer shall be compacted to extent required for standard compaction which contemplates consolidation of material to degree there will be no appreciable displacement laterally or longitudinally under compacting equipment.

F. Prior to and during compaction, operations material shall be shaped and maintained to proper dimensions and contour by means of blade graders or other suitable equipment. Keep surface of each layer true and smooth at all times.

3.03 FIELD QUALITY ASSURANCE

A. Areas where proper compaction is not obtainable due to segregation of materials excess fines or other deficiencies in aggregate, shall be reworked as necessary or material in them removed and replaced with material yielding required results.

END OF SECTION

SECTION 02613
CORRUGATED DRAIN PIPE

PART 1 GENERAL

1.01 WORK INCLUDED

A. Provide corrugated drain pipe and appurtenances.

1.02 RELATED WORK

A. Section 02201 - Excavation/Grading

B. Section 02230 - Fill.

1.03 REFERENCES

A. AASHTO M36 Standard Specifications for Metallic (Zinc or Aluminum) Coated Corrugated Steel Culverts and Underdrains.

B. ASTM F667, Standard Specification for Large Diameter Corrugated Polyethylene Pipe and Fittings.

C. AASHTO M294, Standard Specification for Corrugated Polyethylene Pipe, 12"-24" diameter.

PART 2 PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Corrugated Metal Pipe:

1. Contech Construction Products, Inc. (formerly Armco)
P.O. Box 800
Middletown, Ohio 45042

2. Republic Steel Corporation
Drainage Products Division
1436 Banbury Drive NE
Grand Rapids, Michigan 49505

3. Or Equal

B. Corrugated Plastic Pipe.

1. Advanced Drainage Systems Incorporated
3300 Riverside Drive
Columbus, Ohio 43221

2. Or Equal

2.02 MATERIALS

A. Corrugated Steel or Plastic Pipe: Size as noted on Drawings with 2-7/8 x ½-inch corrugations, complying with AASHTO M36.

B. Joints: Watertight connections.

PART 3 EXECUTION

3.01 INSPECTION

A. Inspect pipe, fittings, and other appurtenances before installation to verify quality of materials.

B. Bends to be prefabricated and metallic coated.

3.02 PREPARATION

A. Remove dirt and foreign material from pipe before assembly.

3.03 INSTALLATION

A. Install pipe and appurtenances to the line and grade shown on the Plans.

B. Backfill with care to ensure complete filling and compaction.

C. Form field joints by joining sections together with a band bolted firmly in place.

D. The maximum tolerance for grade is 0.10 foot.

3.04 FIELD QUALITY CONTROL

A. ENGINEER to observe prior to backfilling.

END OF SECTION

SECTION 02776
GEOTEXTILES

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary for the installation of geotextiles, as specified herein, and as shown on the Drawings.

1.02 QUALITY CONTROL

A. CONTRACTOR shall accept and retain full responsibility for all materials and installation and shall be held responsible for any defects in the completed system.

B. Quality Assurance Program: CONTRACTOR, MANUFACTURER, and INSTALLER shall agree to participate in, and conform with, all items and requirements of the quality assurance program as outlined in this Specification and in the Construction Quality Assurance (CQA) Plan.

1.03 SUBMITTALS

A. CONTRACTOR shall submit the following information no later than 7 days prior to delivery of first shipment.

1. A copy of the quality control certificate or letter including lot, batch, or roll numbers and identification.

B. Manufacturer's Certification

On the basis of the results of the tests performed by either the MANUFACTURER's laboratory or another outside laboratory with which the manufacturer has contracted at its sole cost and expense, the Manufacturer shall provide a written certification that the supplied geotextile meets the specifications.

1.04 DELIVERY, STORAGE AND HANDLING

A. Unload and handle geotextiles so as to cause no damage.

B. Protect geotextiles from sunlight, moisture, mud, dirt, and dust, excessive heat or cold, puncture, or other damaging conditions.

C. Handle with care so as not to rupture or puncture geotextiles.

PART 2 PRODUCTS

2.01 MATERIALS

A. See Table 02776-1.

2.02 ACCEPTABLE MANUFACTURERS

A. Synthetic Industries

B. Trevira

C. Approved Equal.

PART 3 EXECUTION

3.01 PREPARATION

A. Grade the area smooth; and remove all stones, roots, sticks, or other foreign material that would interfere with the geotextile being completely in contact with the soil prior to placing the geotextile.

3.02 HANDLING AND PLACEMENT

A. Handle all geotextiles in such a manner as to ensure they are not damaged in any way.

B. Take any necessary precautions to prevent damage to underlying layers during placement of the geotextile.

TABLE 02776-1

Properties and Requirements	Qualifier	Units	Specified Values[1]	Test Method
Polymer composition	Minimum	Percent	95 percent polypropylene or polyester by weight	
Permittivity	Minimum	1/s	1.6	ASTM D4491
Apparent opening size (AOS)	Maximum	Sieve	60	ASTM D4751
Grab strength[2]	Minimum	lb	180	ASTM D4632
Tear strength[2]	Minimum	lb	60	ASTM D4533
Puncture strength[3]	Minimum	lb	75	ASTM D4833
Burst strength	Minimum	psi	285	ASTM D3786

NOTES:

1 All values represent minimum average roll values (*i.e.*, all rolls in a lot shall meet or exceed the values in this table).

2 Minimum value measured in machine and cross machine direction.

3 Tension testing machine with a 1.75-inch-diameter ring clamp, the steel ball being replaced with a 0.31-inch-diameter solid steel cylinder with a flat tip centered within the ring clamp.

C. After deployment of the geotextile, the geotextile shall not be left exposed for a period in excess of exposure specified by manufacturer for maximum UV protection.

D. Take care not to entrap stones, excessive dust, or moisture in the geotextile during placement.

E. Secure all geotextiles with sandbags, or equivalent. Such sandbags shall be installed during placement and shall remain until overlying protective soil cover is in place. Sandbags shall not be left in place without prior approval from ENGINEER.

F. Examine the entire geotextile surface after installation to ensure that no potentially harmful foreign objects are present. Remove any such foreign objects, and replace any damaged geotextile.

G. Place all soil and geosynthetic materials on top of a geotextile as shown on the Drawings, in such a manner as to ensure that:

1. The geotextile and underlying materials are not damaged;

2. Minimum slippage occurs between the geotextile and underlying layers; and

3. Excess stresses are not produced in the geotextile.

3.03 SEAMS AND OVERLAPS

A. Overlap geotextiles a minimum of 6 inches.

3.04 REPAIR

A. Repair any holes or tears in the geotextile by placing an undamaged piece of geotextile over the hole or tear using a minimum 6-inch overlap.

B. Take care to remove any soil or other material that may have penetrated the torn geotextiles.

END OF SECTION

SECTION 02831
CHAINLINK FENCES AND GATES

PART 1 GENERAL

1.01 WORK INCLUDED

A. New fence and gate construction at locations designated on Drawings.

B. Fence restoration at areas of existing fence removed for grading and construction.

1.02 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. ASTM A53-96 - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless.

2. ASTM A121-92A - Standard Specification for Zinc-Coated (Galvanized) Steel Barbed Wire.

3. ASTM A123-89A - Standard Specification for Zinc (Hot-Dipped Galvanized) Coatings on Iron and Steel Products.

4. ASTM A153-95 - Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.

5. ASTM A491-96 - Standard Specification for Aluminum-Coated Steel Chainlink Fence Fabric.

6. ASTM A570-96 - Standard Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality.

7. ASTM A572-94C - Standard Specification for High-Strength Low- Alloy Columbium-Vanadium Steels of Structural Quality.

8. ASTM A585-92 - Standard Specification for Aluminum-Coated Steel Barbed Wire.

9. ASTM F626-96 - Standard Specification for Fence Fittings.

10. ASTM F900-94 - Standard Specification for Industrial and Commercial Swing Gates.

1.03 DESIGN CRITERIA

A. Fence height: 6 ft-0 in.

1.04 SUBMITTALS

A. Product Data
1. Fabric material.
2. Framework material.

B. Shop drawings:
1. Vehicle gate.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials with manufacturer's tags and labels intact and legible.

B. Handle and store to avoid damage.

1.06 PROJECT/SITE CONDITIONS

A. Do not drive equipment on areas to be landscaped except as approved by ENGINEER.

PART 2 PRODUCTS

2.01 FABRIC

A. Steel wire helically wound and interwoven to provide continuous mesh without knots or ties, conforming to requirements of ASTM A491.

B. Mesh Size: 2 in.

C. Wire Size: 9 ga, 0.148 in. nominal dia. of coated wire.

D. Aluminum Coating: In accordance with ASTM A491.

E. Fabric Ties: Minimum 9 ga aluminum or zinc wire.

F. Selvages:
1. Fabrics with 2- or 2-1/8-in. (50 or 54 mm) mesh, in heights 60 in. (1,520 mm) and under shall be knuckled at both selvages. Fabric 72 in. (1,830 mm) high and over shall be knuckled at one selvage and twisted at other.
2. Selvages of fabrics with meshes of less than 2 in. (50 mm) shall be knuckled.

2.02 FRAMEWORK (FENCE AND PEDESTRIAN GATES)

A. Conform posts, rails, and braces to the following.
1. Galvanized steel pipe conforming to ASTM A53, Schedule 40.

B. Dimensions and Weights:

	Uncoated Minimum Outside Dimensions	Uncoated Minimum Weight
Use and Shape	**(in.)**	**(lbs/ft)**
End, Corner, and Pull Posts (6 to 8 ft, round)	2.875	5.79
Gate Posts (leaf width, 6ft. or less, round)	2.876	5.79
Gate Post (leaf width 13 ft or less, round)	4.00	9.10
Gate Post (leaf width 18 ft or less, round)	6.625	18.97
Gate Post (leaf width over 18 ft, round)	8.625	28.55
Rails and Braces (round)	1.66	2.27
Line Posts (6 to 8 ft, round)	2.50	3.65

C. Tension Wire: Spiraled or crimped No. 7 ga coated with 0.40 oz aluminum/sq. ft.

D. Framework color shall match chainlink fence color.

2.03 GATES

A. Vehicle gates (2 required) shall be 20 ft. opening (two 10 ft. leaves) uncovered (no fabric) swing type, complete with latches, stops, keepers, and hinges.

B. Construct vehicle gates with top, bottom, and side framework of following dimensions and weights.

	Minimum Outside Dimensions	Minimum Weight
Use and Shape	**(in.)**	**(lbs/ft)**
Round (6 ft high, leaf width)	1.90	2.72
Round (over 8 ft)	1.90	2.72

C. Pedestrian gates (1 required) shall be 42 inch opening swing type, complete with latches, stops, keeper, and hinges.

D. Weld joints or assemble with fittings. Use 3/8 in. dia. truss rods on gates assembled with fittings. Provide vertical bracing at 8-ft maximum spacing. Provide horizontal brace or 3/8 in. dia. truss rod for leaves 10 ft wide and longer.

E. Cover with pedestrian gate with fence fabric, attached securely to frame with fabric ties at 15-in. maximum spacing.

F. Latch: Swinging gate shall be provided with a forked or plunger bar type with integral padlock eye to permit operation from either side of gate.

2.04 TENSION BARS

A. Minimum 3/16 in. by 3/4 in. galvanized steel bars.

B. One bar for each end and gate post, and two for each corner and pull post.

2.05 HARDWARE AND FITTINGS

A. Solid aluminum alloy/aluminum coated steel in compliance with ASTM F626 or hot dip galvanized in accordance with ASTM A153.

B. Standard post tops provided with hole suitable for through passage of top rail.

2.06 FOOTINGS

A. Redi-Mix concrete.

2.07 SIGNS

A. Provide signs, 2 ft by 2 ft in size, constructed of 3/16 in. metal plate with 2-in. lettering with words "No Trespassing".

B. Color of signs and lettering shall be black lettering on flat white background.

PART 3 EXECUTION

3.01 EXAMINATION

A. Examine conditions under which fence and gates to be installed. Notify ENGINEER in writing of improper Work conditions.

B. Do not proceed with Work until unsatisfactory conditions corrected.

C. Check location of underground work to make sure fence footings clear utilities and drainage work.

3.02 INSTALLATION

A. Framing:

1. Install line posts not more than 10 ft apart.

2. Install pull posts not more than 600 ft apart where straight run of fence exceeds 600 ft and fence line changes direction by more than 15 degrees, but less than 30 degrees.

3. Install corner posts where fence line changes direction by more than 30 degrees.

4. Set corner and gate posts in concrete footings, plumb and true to line.

5. Brace and truss end, pull, corner, and gate posts to adjacent line posts. Provide brace to match top rail spaced midway between top rail and tension wire and extending to adjacent line post. Truss diagonally with 5/16 in. dia. tension rod with turnbuckle.

6. Fasten top rail to end, pull, gate, and corner posts. Pass top rail through fittings of line posts.

7. Provide expansion and contraction joints in top rail for each 100 lin ft of fence.

8. Fasten bottom tension wire to end, pull, gate, corner, and line posts.

B. Footings:

1. Vertical sides to minimize uplift.

2. Rod and compact concrete around posts. Slope top of footings above level of adjacent grade and trowel finish.

3. Size:

a. 6-in. minimum dia., plus outside dimension of post.

b. Set corner, end, pull, and gate posts 42 in. into concrete.

c. Drive line posts 42 in. into subsurface.

d. Total depth of concrete 6 in. greater than required for post embedment.

4. Time of Set: 48 hours before rails erected or fabric applied or stretched.

C. Fabric:

1. Place fabric on outside of posts and stretch to avoid bulging or buckling.

2. Fasten at line posts, top rail, and bottom tension wire with aluminum or zinc ties. Space ties not more than 15 in. apart on line posts and not more than 24 in. apart on rail and tension wire.

3. Fasten at terminal posts at intervals not exceeding 15 in. using flat or beveled galvanized steel bands with 5/16 in. by 1-1/4-in. galvanized carriage bolts and nuts.

4. Make tie connections on interior side of fence.

D. Gates:

1. Provide gates at locations shown on Drawings.

E. Signs: "No Trespassing"

1. Secure signs on fence at 200-ft maximum spacing. Two signs shall be placed on each side of the perimeter.

F. Ground fence in accordance with manufacturers recommendations.

3.03 ADJUSTMENT AND CLEANING

A. Paint:

1. Paint posts or other work cut on job with heavy coat of approved zinc-rich primer paint and then with coat of silver finish paint to match color coating of fence.

2. Finish paint and matching color to match color of existing fence.

3. Paint abrasions or stripping of galvanizing on pipe, fittings or fabric as specified above.

B. Peen bolts located on lowest 72 in. of fencing.

C. Remove barricades and protection at Project completion. Repair damaged landscape surfaces.

END OF SECTION

SECTION 02931
TOPSOIL, SEEDING, AND FERTILIZER

PART 1 GENERAL

1.01 WORK INCLUDED

A. Preparation and placement of topsoil.

B. Provide and apply seed.

C. Provide and apply hydroseed.

D. Provide and apply mulch.

E. Provide and apply fertilizer.

1.02 DEFINITIONS

A. Weeds: Includes, but is not limited to, Dandelion, Jimsonweed, Quackgrass, Horsetail, Morning Glory, Rush Grass, Mustard, Lambsquarter, Chickweed, Cress, Crabgrass, Canadian Thistle, Nutgrass, Poison Oak, Blackberry, Tansy Ragwort, Bermuda Grass, Johnson Grass, Poison Ivy, Nut Sedge, Nimble Will, Bindweed, Bent Grass, Wild Garlic, Perennial Sorrel, and Brome Grass.

1.03 QUALITY ASSURANCE

A. Provide seed mixture in containers showing percentage of seed mix, year of production, net weight, date of packaging, and location of packaging.

1.04 DELIVERY, STORAGE AND HANDLING

A. Deliver grass seed mixture in sealed containers. Seed in damaged packaging is not acceptable.

B. Seed which is wet, moldy, or otherwise damaged is not acceptable.

C. Deliver fertilizer in waterproof bags showing weight, chemical analysis, and name of manufacturer.

PART 2 PRODUCTS

2.01 TOPSOIL MATERIALS - ON-SITE MATERIALS

A. Friable, fertile, loamy soil containing an amount of organic matter normal to the region, capable of sustaining healthy plant life.

B. Free from refuse, subsoils, materials toxic to plant growth, and foreign objects.

2.02 TOPSOIL MATERIALS - IMPORTED MATERIALS

A. Imported topsoil must contain a minimum 6 percent organic matter as determined by loss on ignition of moisture-free samples dried at 100°C and have a pH less than 8.0.

B. Seed Mixture:

1. General:

a. Fresh, clean, and new crop seed included in following varieties and proportioned by weight.

Percentage of each species in a mix will depend on availability.

Tall Grass Prairie (3 areas totaling about 31.7 acres)

Big bluestem	*Andropogon gerardii*
Little bluestem	*Andropogon scoparius*
Canada wild-rye	*Elymus canadensis*
Indiangrass	*Sorghastrum nutans*
Switchgrass	*Panicum virgatum*

Short Grass/Wildflower Prairie (16 areas totaling about 39.3 acres)

Little bluestem	*Andropogon scoparius*
Side-oats grama	*Bouteloua curtipendula*
Indiangrass	*Sorghastrum nutans*
Prairie dropseed	*Sporobolus heterolepsis*
Coreopsis	*Coreopsis lanceolata*
Milkweed	*Asclepias tuberosa*

Sand Prairie (1 area of about 1.1 acres)

Little bluestem	*Andropogon scoparius*
Side-oats grama	*Bouteloua curtipendula*
Lupine	*Lupinus perennis*
Bergamot	*Monardo fistulosa*
Coreopsis	*Coreopsis tripteris*

Maintained Grass (9 areas totaling about 38.4 acres)

Combination of:	
Fescue (50 percent)	*Festuca sp.* (highest percentage of mix for drought tolerance/less mowing)
Bluegrass	*Poa sp.*
Perennial ryegrass	*Lolium sp.*

Wet Meadow (2 areas totaling about 2.8 acres)

Joe-Pye weed	*Eupatorium maculatum*
Iris	*Iris versicolor*
Great blue lobelia	*Lobelia siphilitica*
Black-eyed Susan	*Rudbeckia fulgida*
Blue vervain	*Verbena hastata*
White turtlehead	*Chelone glabra*

Butterfly Meadow (3 areas totaling about 2.8 acres)

Milkweeds	*Asclepias incarnata*
Purple coneflower	*Echinacea purpurea*
Sunflowers	*Helianthus mollis*
Blazingstars	*Liatris spicata*
Lupine	*Lupinus perennis*
Asters	*Aster ericoides*
False dragonhead	*Physostegia virginiana*
Goldenrods	*Solidago canadensis and gigantea*

Seasonal Wildflower Meadows (9 areas totaling about 5.6 acres)

False indigos	*Baptisia leucantha*
Penstemons	*Penstemon digitalis*
Milkweeds	*Asclepias synaca*
Nodding pink onion	*Allium cernuum*
Green-headed coneflower	*Rudbeckia laciniata*
Goldenrods	*Solidago rigida*
Blazingstars	*Liatris spicata*

b. Weeds shall not exceed 0.25%.

c. The preliminary seed mixture (identified above) may be modified per the CONTRACTORS recommendations.

2. CONTRACTOR shall follow seasonal planting schedules in accordance with the industry standards.

C. Fertilizer: Recommended for grass, with fifty percent of the elements derived from organic sources; to the following proportions: Nitrogen 19 percent, phosphoric acid 19 percent, soluble potash 19 percent. These amounts to be adjusted based upon Michigan Agricultural Extension Service testing of topsoil.

2.03 ACCESSORIES

A. Mulching Material: Oat or wheat, straw, dry and free from weeds, foreign matter detrimental to plant life. Chopped cornstalks are not acceptable.

B. Water: Clean, fresh, and free of substances or matter which could inhibit vigorous growth of grass.

PART 3 EXECUTION

3.01 PREPARATION

A. Topsoil:

1. Do not place or work topsoil in frozen or muddy condition.

2. Disc topsoil to loosen clods and establish uniform mixture (of supplement).

B. Seeding:

1. Do not seed on saturated or frozen soil.

3.02 TOPSOIL/FINISH GRADING

A. Finish grade is established final grade as shown on Drawings. Grades not otherwise indicated are uniform levels or slopes between points where elevations given or between such points and existing finished grades.

B. Grade, rake, and roll with roller weighing not more than 100 lbs./lin ft. and not less than 25 lbs./lin ft.

C. Finish grade to within 0.10 ft of elevations shown on Drawings.

3.03 FERTILIZER

A. Apply Fertilizer at a rate of 450 lbs/acre or as prescribed by additional analyses.

3.04 SEEDING

A. Sow seed at rate of 200 lbs per acre, dividing seed equally or as recommended by CONTRACTOR.

B. If Brillion seeder is used, seed may be sown in one operation and raking and rolling operations after seeding may be omitted, except in areas inaccessible to seeder.

C. Method of seeding may be varied at discretion of CONTRACTOR on his own responsibility to establish smooth, uniform turf composed of specified grasses.

D. Do not seed following rain or if surface has been compacted by rain.

E. Do not seed when wind velocity exceeds 6 mph.

3.05 HYDROSEEDING

A. A hydroseeder may be used if deemed more appropriate for seeding, particularly for slopes. If used, the hydroseeder shall have continuous agitating action that keeps the seed uniformly mixed in the slurry until pumped from the tank.

B. Apply seeded slurry at a rate of 100 lbs of seed and fertilizer, as determined necessary by testing, per 1,000 sq. ft. evenly in two intersecting directions, with a hydraulic seeder. Do not hydroseed areas in excess of that which can be mulched on the same day.

3.06 MULCHING

A. Apply mulch to the seeded area at a rate of 3 tons per acre.

B. Unless otherwise directed, mulch lawn areas within 3 days after seeding is complete.

C. Place mulch loose or open enough to allow some sunlight to penetrate and air to slowly circulate, but thick enough to shade ground, conserve soil moisture, and prevent or reduce erosion.

D. Do not mulch during periods of excessively high winds which would preclude proper placing of mulch.

3.07 CLEAN-UP

A. Remove soil or similar material brought onto paved areas, keeping these areas clean.

3.08 MAINTENANCE

A. Maintenance shall be conducted in accordance with the O&M Plan (also included in this submittal).

3.09 INSPECTION FOR ACCEPTANCE

A. Inspection of landscaping work to determine completion of Work, exclusive of possible replacement of plants, will be made by ENGINEER after initial stand of vegetation is established.

B. After inspection, CONTRACTOR will be notified, in writing, by OWNER of acceptance of Work of this section or, if deficiencies, of requirements for completion of Work.

C. Work will be accepted in part by ENGINEER upon written application from CONTRACTOR, provided Work offered for acceptance comprised Work of this section entirely complete.

3.10 GUARANTEE

A. Guarantee seeded areas for duration of one (1) year after seeding to be alive and in satisfactory growth at the end of guarantee period.

1. For purposes of establishing acceptable standard, scattered bare spots, none larger than one (1) square foot will be allowed up to maximum of three (3) percent lawn area.

END OF SECTION
END OF SPECIFICATION

APPENDIX G

CONSTRUCTION, OPERATION, AND MAINTENANCE COST ESTIMATES

COST ESTIMATE SUMMARY
BUTTERWORTH LANDFILL
PRESENT WORTH
OPTION 1

Interest Rate = 7%

Inflation Rate = 0%

Present Worth of Capital (Grading/Cover) Cost	$19,830,000
Present Worth of O&M:	$1,158,392
Total Present Worth of Remedial Action:	$20,988,392

COST ESTIMATE SUMMARY
BUTTERWORTH LANDFILL
PRESENT WORTH
OPTION 2

Interest Rate = 7%

Inflation Rate = 3.8%

Present Worth of Capital (Grading/Cover) Cost	$19,830,000
Present Worth of O&M:	$1,807,759

Total Present Worth of Remedial Action:
$21,637,759

RMT, Inc

RA COST ESTIMATE -
BUTTERWORTH LANDFILL
ANNUALIZED OPERATION and MAINTENANCE COSTS

TABLE 1

DESCRIPTION	Year 1 to Year 2	Year 3 to Year 30	Remarks
LANDFILL COVER SYSTEM			
Clay Cover Component	$0	$5,000	Minor repairs due to differential settlement.
Rooting Zone and Topsoil Component	$0	$5,000	Minor repairs due to differential settlement and erosion.
Mowing	$8,000	$16,000	Once per year x 160 Acres
Revegetation/Reseeding	$8,000	$20,000	Spot Application
Refertilization & Herbicide (Woody Plants)	$8,000	$20,000	Spot Application
Fencing and Signs	$1,000	$500	Inspection and minor repairs
SURFACE WATER CONTROLS			
Erosion and Sediment Control	$10,000	$2,000	Cleaning culverts, riprap, sediment removal
LANDFILL GAS MIGRATION MONITORING			
LFG Probe Monitoring Inspection / Report	$12,000	$1,000	Year 0 - 2 monthly/ Year 3 to Year 30 - annually
REPORTS			
RA REPORTS	$20,000	$10,000	
ADMINISTRATION/LEGAL/ACCOUNTING	$20,000	$5,000	
Subtotals	$87,000	$84,500	
Contingency	$8,700	$8,450	10%
Grand Totals (Per Year)	$95,700	$92,950	

02/12/1999

RMT, Inc.

RA COST ESTIMATE - CLAY/SOIL COVER
BUTTERWORTH LANDFILL
CONSTRUCTION COST SUMMARY

TABLE 2

ITEM	ESTIMATED QUANTITY	U/M	UNIT COST	AMOUNT	REMARKS
Mobilization	1	LS	$ 100,000	$ 100,000	
General Conditions	12	Months	$ 15,000	$ 180,000	
Bonds & Insurance	1	LS	$ 269,900	$ 269,900	2% of Direct Costs
LFG Probes (new and existing)	15	ea	$ 2,000	$ 30,000	
Decon Facilities	1	LS	$ 100,000	$ 100,000	
Verification Sampling	1	LS	$ 25,000	$ 25,000	
West of CSO Ditch				$ 8,554,897	See detailed estimate
CSO Ditch				$ 365,570	See detailed estimate
East of CSO Ditch				$ 4,169,099	See detailed estimate
SUBTOTAL - DIRECT COSTS				$ 13,794,465	
Engineering & CQA	15	%		$ 2,069,170	
Construction Management	10	%		$ 1,379,447	
SUBTOTAL INDIRECT COSTS				$ 3,448,616	
SUBTOTAL - DIRECT & INDIRECT COSTS				$ 17,243,081	
Contingency	15	%		$ 2,586,462	
GRAND TOTAL				$ 19,830,000	

RMT, Inc.

RA COST ESTIMATE - CLAY/SOIL COVER
BUTTERWORTH LANDFILL

TABLE 2A

No.	WEST OF CSO DITCH ITEM	ESTIMATED QUANTITY	U/M	UNIT COST	AMOUNT	REMARKS
1	Clearing and Grubbing Vegetation	130	Acres	$ 3,000	$ 390,000	Heavy to Medium Vegetation
2	Temporary Soil Erosion Controls	1	LS	$ 40,000	$ 40,000	Silt Fence & Straw Bales
3	Riprap	500	Tons	$ 50.00	$ 25,000	Culverts
4	Shallow Waste Excavation/Reconsolidation	12,951	CY	$ 4.00	$ 51,805	
5	Backfill Waste Excavations	12,951	CY	$ 8.00	$ 103,610	
6	Grade Preparation - Cut Volume	126,667	CY	$ 4.00	$ 506,668	
7	Grade Preparation - Fill Volume	175,690	CY	$ 4.00	$ 702,760	
8	Additional Fill Purchase	6,296	CY	$ 4.00	$ 25,184	Fill minus Cut
9	Storm Water - 48" CMP	260	LF	$ 77.00	$ 20,020	Culvert A to Western Creek
10	Storm Water - 18" CMP	220	LF	$ 21.00	$ 4,620	Culvert B to CSO Ditch
11	Geotextile over Rubble Fill Areas	1,000	SY	$ 5.00	$ 5,000	
12	Place & Recompact Clay	268,909	CY	$ 3.50	$ 941,180	Cap & Key-In
13	Purchase Clay	268,909	CY	$ 6.50	$ 1,747,905	
14	Purchase and Place FP & low perm Soil	250,673	CY	$ 8.00	$ 2,005,384	
15	Place and Grade Topsoil	92,776	CY	$ 4.00	$ 371,104	
16	Purchase Topsoil	92,776	CY	$ 6.00	$ 556,656	
17	Seeding, Fertilizer, and Mulch	115	Acres	$ 2,000	$ 230,000	
18	Erosion Matting - Flood Protection	35,000	SY	$ 12.00	$ 420,000	
19	Paved Site Access Road	2,500	LF	$ 50.00	$ 125,000	
20	Crushed Stone Access Road	2,100	LF	$ 25.00	$ 52,500	
21	Vehicle Gate	1	EA	$ 1,500	$ 1,500	
22	Fencing	750	LF	$ 12.00	$ 9,000	
23	Radio Station Operation (Temp.)	1	LS	$ 150,000	$ 150,000	
24	Radio Station Drive & Parking	1	LS	$ 30,000	$ 30,000	
25	Radio Stations-Ground Plane Systems	1	LS	$ 40,000	$ 40,000	
	SUBTOTAL				$ 8,554,897	

RMT,Inc
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RA COST ESTIMATE - CLAY/SOIL COVER
BUTTERWORTH LANDFILL

TABLE 2B

No.	CSO DITCH ITEM	ESTIMATED QUANTITY	U/M	UNIT COST	AMOUNT	REMARKS
1	Construct New Earth Dam	8,900	CY	$ 10.00	$ 89,000	
2	Excavate Existing Earth Dam	4,000	CY	$ 4.00	$ 16,000	
3	Demo 120" Culvert	1	LS	$ 1,000.00	$ 1,000	
4	Dredge Ditch Bottom	16,000	CY	$ 6.00	$ 96,000	
5	Recompact Clay in Ditch	6,297	CY	$ 10.00	$ 62,970	
7	Seeding, Fertilizer, and Mulch	5	Acres	$ 2,000.00	$ 10,000	
8	Storm Water - 48" CMP (2 Each)	400	LF	$ 77.00	$ 30,800	
9	Flap Gates - Neoprene	2	EA	$ 6,000.00	$ 12,000	Red Valve Tideflex or equal
10	Fence	3,900	LF	$ 12.00	$ 46,800	
11	Pedestrian Gate	1	EA	$ 1,000.00	$ 1,000	
	SUBTOTAL				$ 365,570	

RMT,Inc
ANN ARBOR

RA COST ESTIMATE - CLAY/SOIL COVER
BUTTERWORTH LANDFILL

TABLE 2C

No.	EAST OF CSO DITCH ITEM	ESTIMATED QUANTITY	U/M	UNIT COST	AMOUNT	REMARKS
1	Clearing and Grubbing Vegetation	50	Acres	$ 3,000	$ 150,000	
2	Temporary Soil Erosion Controls	1	LS	$ 10,000	$ 10,000	Silt Fence & Straw Bales
3	Demo concrete slabs & poles (light & electric)	1	LS	$ 5,000	$ 5,000	
4	Demo Radio Tower	1	LS	$ 10,000	$ 10,000	
5	Demo parking lot (south)	1	LS	$ 5,000	$ 5,000	
6	Shallow Waste Excav/Reconsolidation	6,027	CY	$ 4.00	$ 24,109	
	Backfill Waste Excavation	6,027	CY	$ 8.00	$ 48,217	
7	Grade Preparation - Cut Volume	27,058	CY	$ 4.00	$ 108,232	
8	Grade Preparation - Fill Volume	97,624	CY	$ 4.00	$ 390,496	
9	Additional Fill Purchase	60,566	CY	$ 4.00	$ 242,264	
10	Storm Water - 36" CMP	240	LF	$ 52.00	$ 12,480	Culvert C to Wetland Ditch
11	Storm Water - 30" CMP	180	LF	$ 36.00	$ 6,480	Culvert D to CSO Ditch
12	Geotextile over Rubble Fill Areas	600	SY	$ 5.00	$ 3,000	
13	Place & Recompact Clay	141,973	CY	$ 3.50	$ 496,906	Cap & Key-In
14	Purchase Clay	143,069	CY	$ 6.50	$ 929,945	
15	Purchase and Place Rooting Zone Soil	106,480	CY	$ 8.00	$ 851,840	
16	Place and Grade Topsoil	35,493	CY	$ 4.00	$ 141,972	
17	Purchase Topsoil	35,493	CY	$ 6.00	$ 212,958	
18	Seeding, Fertilizer, and Mulch	44	Acres	$ 2,000	$ 88,000	
19	Erosion Matting - Flood Protection	20,000	SY	$ 12.00	$ 240,000	
20	Paved Access Road	2,400	LF	$ 50.00	$ 120,000	
21	Crushed Stone Access Road	2,300	LF	$ 25.00	$ 57,500	
22	Vehicle Gate	1	LS	$ 1,500	$ 1,500	
23	Fencing	1,100	LF	$ 12.00	$ 13,200	
	SUBTOTAL				$ 4,169,099	

02/12/1999

No.	ITEM	West Cut	West Fill	Ditch Cut	Ditch Fill	East Cut	East Fill	Misc.	Total Site Quantity	Stockpiled Onsite	Material Required
		In-Place Quantities									
1	**Waste Excavation/Fill**										
	- Powerline Corridor	8889	8,889			2,664	2,664				
	- Wetlands	1,599	1,599			2,577	2,577				
	- NW Corner	774	774			0	0				
	Total	**12,951**	**12,951**			**6,027**	**6,027**				
2	**Demolish Existing Earth Dam**			4,000							
3	**Site Grading**	126,667	175,690			27,058	97,624				
4	**CSO Dredging**			16,000							
	Total Cut	**139,618**		**20,000**		**33,085**			**192,703**		
	Total Fill		**188,641**		**0**		**103,651**		**292,292**		
	Net Fill (minus cut)		**49,023**		**-10,000**		**70,566**		**109,589**	**42,727**	**66,862**
5	**Clay Construction**										
	Clay Cap		267,813				141,973		**427,174**	465,380	-38,206
	Clay Cap Key-In							2191			
	New CSO Earth Dam				8,900						
	CSO Ditch Lining				6,297						
6	**Soil Construction**										
	Low-Permeability Soil - 6"		40,813								
	Frost Protection Layer - 18"		209.860				106,480		316,340	0	**316,340**
	Topsoil Layer - 6"		92,776				35,493		128,269	112,946	**15,323**

RMT, Inc

RA COST ESTIMATE
BASIS OF CONSTRUCTION PRICING
BUTTERWORTH LANDFILL

TABLE 2D

ITEM	Unit of Measure	UNIT COST	Basis of Pricing
Mobilization	LS	$ 100,000	Recent Bid experience
General Conditions	Months	$ 15,000	Recent Bid experience
Bonds & Insurance	LS	$ -	2% of Direct Costs
Decon Facilities & Decon	LS	$ 100,000	Designer Judgement
Clearing and Grubbing Vegetation	Acres	$ 3,000	Means/Dozer - medium brush to 4" diameter
Temporary Soil Erosion Controls	LS	$ 40,000	$4/LF for Silt Fence plus $4000.
Rip Rap	Tons	$ 50.00	Recent bid pricing for riprap (CYx1.6=Tn)
Shallow Waste Excav/Recon	CY	$ 4.00	$2/CY Excav. & $2/CY Recon.
Fill Shallow Waste Excavation	CY	$ 8.00	Supplier/Contractor Quote
Grade Preparation - Cut Volume	CY	$ 4.00	$4/CY Excav. & Haul
Grade Preparation - Fill Volume	CY	$ 4.00	$4/CY Place & Compact
Purchase Additional Fill	CY	$ 4.00	Quote - Supply to Site
Storm Water - 48" CMP	LF	$ 77.00	Means - Pipe & Struc. Backfill
Storm Water - 36" CMP	LF	$ 52.00	Means - Pipe & Struc. Backfill
Storm Water - 30" CMP	LF	$ 36.00	Means - Pipe & Struc. Backfill
Storm Water - 18" CMP	LF	$ 21.00	Means - Pipe & Struc. Backfill
Geotextile over Rubble Fill Areas	SY	$ 5.00	Recent Bid Experience
Geosynthetic Clay Liner	SY	$ 15.00	Supplier Quote
Place and Compact Clay	CY	$ 3.50	Contractor Quote
Purchase Additional Clay	CY	$ 6.50	Supplier Quote
Purchase & Place Rooting Zone	CY	$ 8.00	Quote (Supplier & Contractor)
Place Topsoil	CY	$ 4.00	Contractor Quote
Purchase Additional Topsoil	CY	$ 6.00	Contractor Quote/Delivered to Site
Seeding, Fertilizer, Mulch, Herb.	Acres	$ 2,000	Contractor Quote
Erosion Matting - Flood Protection	SY	$ 12.00	Supplier Quote
Paved Access Road	LF	$ 50.00	Asphalt, Subbase, Geotextile
Crushed Stone Access Road	LF	$ 25.00	Crushed Stone, Geotextile
Access Road Gates	EA	$ 1,500	Means - 6 ft x 12 ft swing
Fencing	LF	$ 12.00	Means - 6 ft./9ga./with 3 strands BW
Excavate Existing CSO Dam	CY	$ 4.00	$4/CY Excav & Fill Onsite
Demo 120" CSO Culvert	LS	$ 1,000	Allowance - Designer's Judgement
New CSO Earth Dam	CY	$ 10.00	Purchase & Place Clay
Dredge/Excavate CSO Ditch Bottom	CY	$ 6.00	$4/CY Excav. & $2/CY Spread
Recompact Clay in CSO Ditch	CY	$ 10.00	Purchase & Place Clay

BUTTERWORTH LANDFILL
FINAL REMEDIAL (100%) DESIGN
(AMENDED VERSION)
JUNE 1999

DRAWINGS
10 PAGES

SHEET NUMBER	SHEET TITLE
1	TITLE SHEET/INDEX
2	EXISTING CONDITIONS MAP
3	PREPARATION GRADES/ SITE WORK - WEST SIDE
4	PREPARATION GRADES / SITE WORK - EAST SIDE
5	FINAL GRADING PLAN - WEST SIDE
6	FINAL GRADING PLAN - EAST SIDE
7	COVER AND SEDIMENT CONTROL DETAILS
8	COMBINED SEWER OVERFLOW - DREDGING PLAN AND PROFILE
9	LANDFILL GAS BARRIER AND DETAILS
10	CULVERT DETAILS

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