Durham Yard Waste Compost Facility
Wastewater Management

RECEIVED
MAR 13 20[illegible]
SOLID WASTE SECTION

Site Address:
2115 E. Club Blvd.
Durham, NC 27704

APPROVED
MES 6/9/10

NORTH CAROLINA PROFESSIONAL SEAL 7468 ENGINEER DAVID M. KOSS

Prepared By:

KCI Associates of NC, P.A.
4601 Six Forks Road
Landmark Center II, Suite 220
Raleigh, NC 27609

KCI Associates of NC, P.A. KCI

TABLE OF CONTENTS

FIGURES

APPENDICES

WASTEWATER MANAGEMENT PLAN

1.0 Project Description

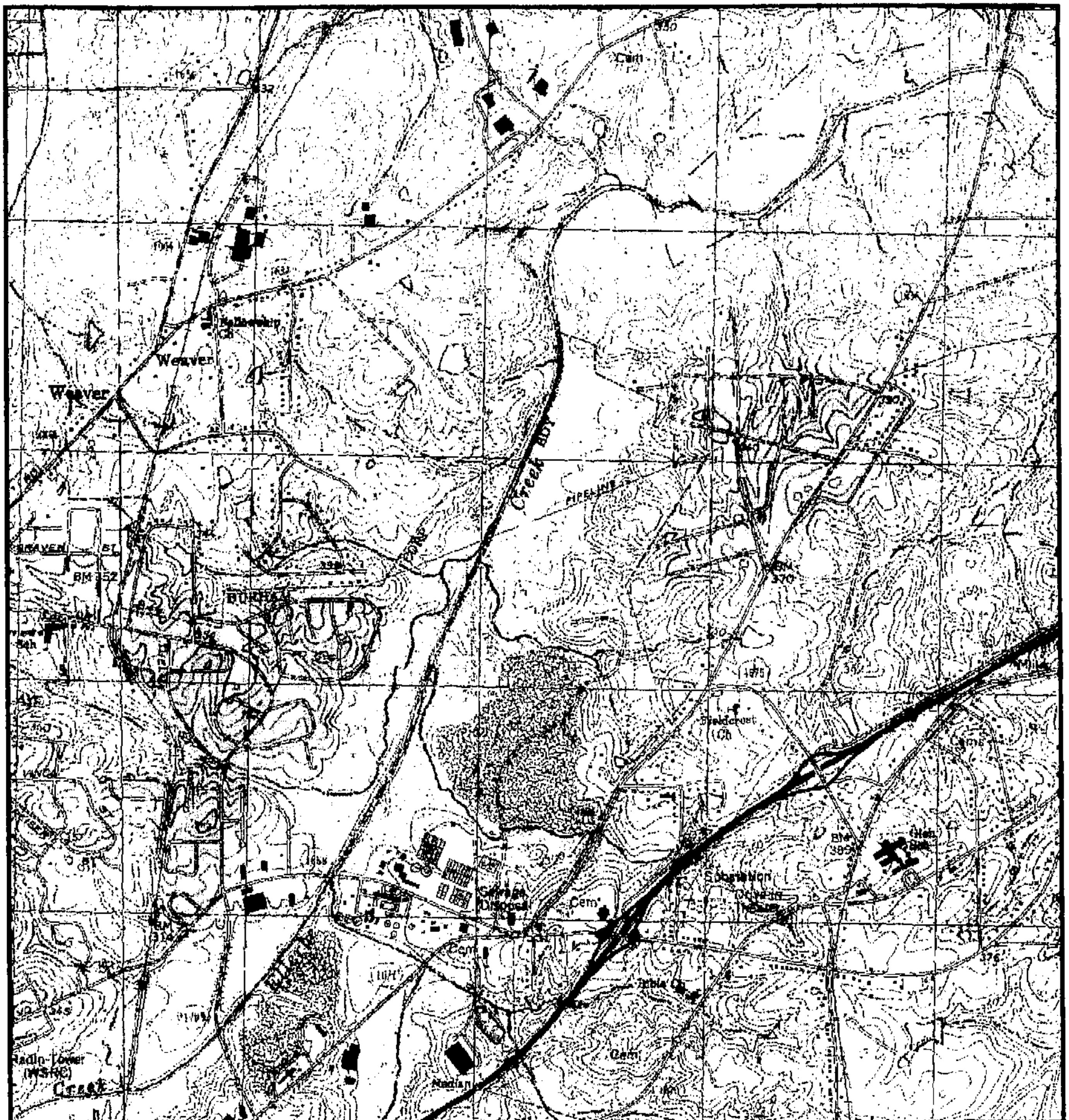
The project site, approximately 26.2 acres, is an existing developed site located in the northeast section of the City of Durham. The project is located in the Neuse River Basin. The nearest body of water to the project site and the ultimate receiving water for this project site is Ellerbe Creek. Ellerbe Creek is approximately 0.25 miles away from the project site. (See Figure 1). The project site is accessed from a service road located northwest of the intersection of Glenn Road and E. Club Boulevard. The project site is an existing yard waste facility. The scope of this project is to re-develop the site by establishing defined composting and curing areas for processing the yard waste into compost for retail distribution. DWQ has classified the stormwater runoff generated from the yard waste compost as wastewater; see Appendix E for the wastewater analysis provided by DWQ from a similar yard waste compost site. Wastewater pond will be constructed to retain the stormwater runoff of the 100-yr 24-hr storm event. There is no discharge from the pond. An Industrial Pump and Haul permission adhering to the criteria stated in regulation number 15A NCAC 02T.1000 is being requested to allow transport of the wastewater to the City of Durham WWTP located on site.

Approximately 4.1 acres of the northwest corner of the site is located in the 100-year floodplain of Ellerbe Creek as shown on the FIRM # 0843 370086J. The 100-year floodplain elevation at sections 287 & 297 are 288.4 & 288.9 respectively. Ellerbe Creek is classified as a Class C, NSW, and WS-IV water body. (See Appendix A). The remainder of the site is above the floodplain elevation.

The site is presently open-graded with the land covered by 12" of compost in the processing areas and a brush-weed-grass mixture for the remainder of the site. Essentially all surface runoff originates within project area with approximately 3.79 acres of off-site runoff from high ground east of the project site. (See Aerial Photo shown in figure 2). There are no existing perennial, intermittent or ephemeral streams within the project site.

The project site is located in the uplands of the Piedmont Region of North Carolina. The native soil in this area is White Store-Creedmoor as shown on the soil survey map for Durham County, North Carolina. The White Store-Creedmoor soils have fine sandy loam particles which makes them moderately well drained with a very firm clay layer underneath. White Store soils belong to the hydrologic soil Group D. Since over 85% of the site is above the 100-year floodplain, the site does not have a high water table and the site does not stay inundated. Therefore the site was categorized in the hydrologic soil group C, with moderate slopes of 6.5 to 10 percent. The existing compost has a very high absorption rate and therefore will be categorized the same as the brush-weed-grass mixture listed in Table 2-2c of TR-55. (Appendix B). Approximately 0.85 acres along the eastern border of the site is bedrock, with a high runoff rate.

Vicinity Map
Figure 1



Durham Yard Waste Composting Facility - Vicinity Map

KCI ASSOCIATES OF NC

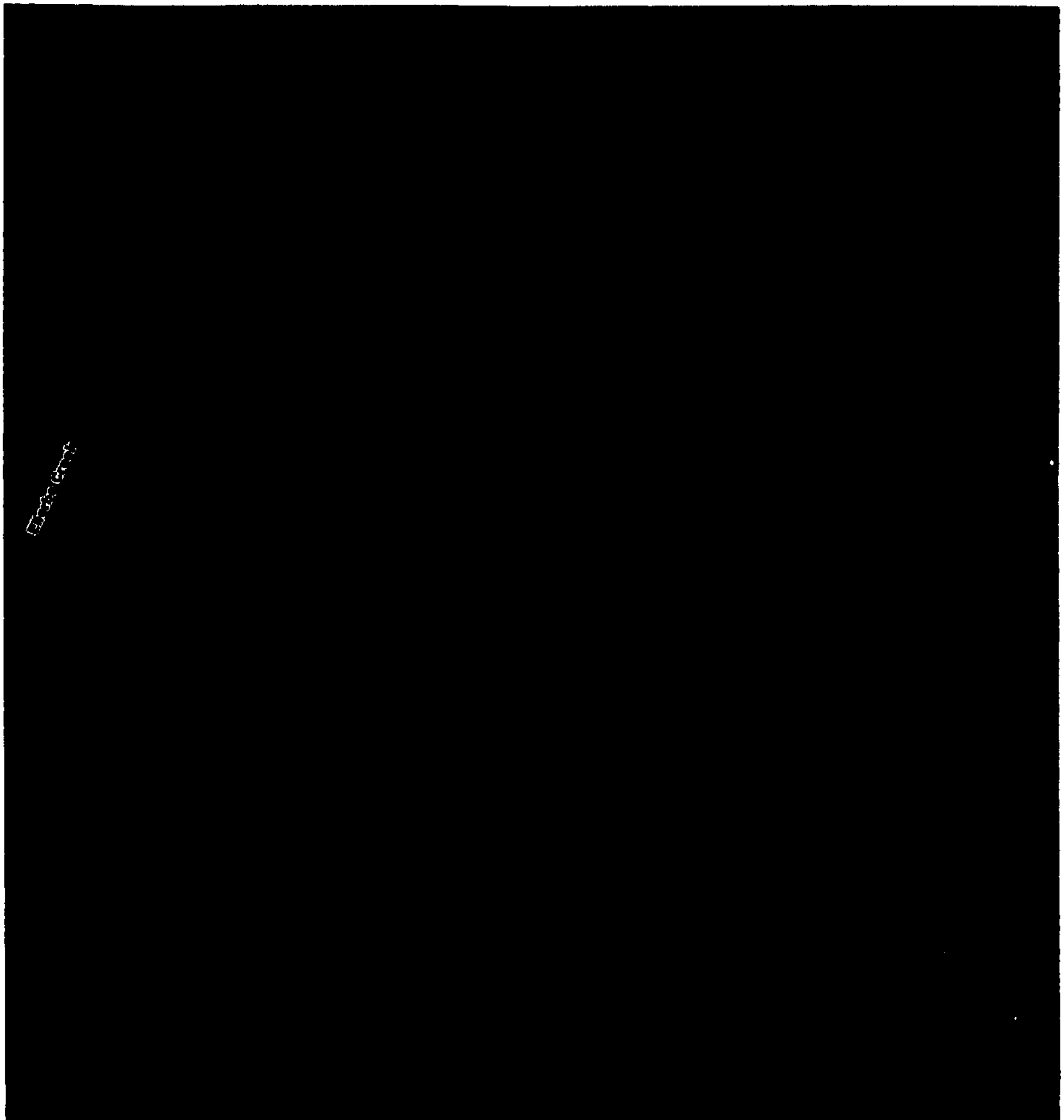
Approximate Site Location

1:24,000
1 inch equals 2,000 feet

2,000 1,000 0 2,000 Feet

Image Source: USGS Topographic Quadrangles Northeast Durham (1987) and Northwest Durham (1987)

Aerial Photo
Figure 2



KCI
ASSOCIATES OF NC

Durham Compost Site

Streams
Approximate Site Boundary

1:6,000
1 inch equals 500 feet
500 250 0 500
Feet

Source: City of Durham GIS, Orthoimagery 2005

2.0 Proposed Development

The project involves the grading of one (1) new windrow areas, a new grinding area, the re-grading of a screening area and the re-grading of one (1) product storing area. The existing road will be widened from 15' to 25' and a stretch of new road will be constructed where there is no road presently. Approximately 11.02 acres (42%) of the total site area of 26.2 acres will be disturbed as part of the proposed development. The project will result in an impervious area of 2.0 acres (7.8%), which includes the gravel roads of 1.2 acres and a gravel waste receipt area of approximately 0.8 acres. NCDENR Solid Waste Management Section has established a 1.95 acre section of the site that cannot be developed.

A gravel access road will be constructed along the perimeter of the site and will act as a dam along the western edge adjacent to the floodplain. No major changes to the existing drainage pattern are proposed by this development. No *major* grading is proposed for this site. The composting processing requires the establishment of windrow areas and storage areas. The maximum grade for these areas is 6%. The majority of the site is already at 6.5% slope, with a small portion of the site along the northeast edge sloped at 10%. .

3.0 Hydraulic Analysis Procedures

The wastewater pond is proposed along the western edge of the site, to collect all the wastewater generated by the composting process on site. The pond volume was designed using the urban hydrology and detention pond modeling software Hydraflow. The pond is sized to capture the 100-year peak discharge and store the 100-year 24-hour storm event. An emergency spillway has been designed to allow safe passage of an extreme storm event.

The precipitation data was taken from the NOAA's National Weather Service Atlas 14 for Durham, North Carolina, (Appendix C). The 24-hour precipitation depths were used in the NRCS Runoff Curve Number Method to create the Runoff Hydrographs. The CN value of 65 was derived from the existing land cover condition described in section 1.0 paragraph 4 of this report. This value will be used for both the pre and post development conditions. The yard waste compost is very absorptive and behaves similar to the brush-weed-grass mixture originally covering the site. A CN value of 98 has been assigned to the areas developed into roads and the product receiving area.

The runoff from the project site including the gravel roads will be directed to two custom sediment basins during construction, which will be converted to the full build out of the wastewater pond once construction is complete and the site is stable. All surface runoff will either sheet flow into the pond or be collected in constructed channels and directed to the pond. Drainage Area 'A' is considered clean water and will run to roadside ditches and diverted around the project area, see the drainage area plan sheet in Appendix D.

The routing method used for the design of the wastewater pond was the "Discharge In equals Discharge Out". This method is based on the continuity equation. It processes the average inflow, interpolates between elevations to compute values of storage during a 0.05hour time increment to yield an average outflow. The pond will retain all runoff from the site and the stormwater (wastewater) will be transported to the WWTP via Pump and Haul tanker truck on a routine schedule. The peak inflow, peak outflow, maximum water surface elevations and storage volumes for the pond are summarized in Appendix D.

4.0 Wastewater Pond Design

Based on the calculated runoff, the new impervious roadway and waste receipt areas have increased the 25-year post-development discharge by 38% on average. However, the stormwater runoff rate will be controlled by the proposed wastewater pond located along the western edge of the site. The pond will retain the runoff up to and including the 100-year storm and the water used for irrigation of the compost within the facility. See Appendix D for a complete set of computations for the wastewater pond.

The embankment of the pond will be built-up to an elevation of 304'. The embankment of the Pond #1 is 15' above the 100-year floodplain elevation of 289'. The emergency spillway of Pond #1 will be set at 303' which is 0.18' above the 100-yr water surface elevation in the pond. The pond requires a geosynthetic liner at the bottom and along the sides up to the emergency spillway elevation to prohibit seepage out of the pond.

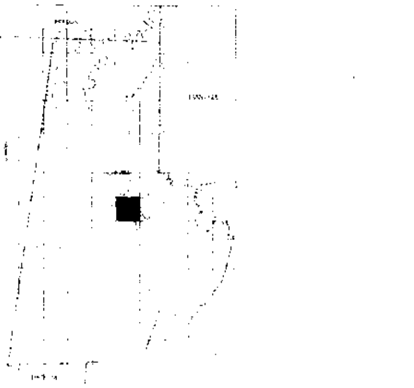
All applicable Neuse River Buffer Rules were accommodated. There is no net increase in the 1-year 24-hour post peak discharge. There are no oils or chemical (fertilizer) pollutants associated with the runoff from the yard waste composting facility. There are no concentrated discharges into the buffer zones of Ellerbe Creek. Ellerbe Creek is more than 0.25 miles away. The runoff from the impervious surfaces is being retained in the wastewater pond.

5.0 Pond Maintenance Plan

The specifications for the pond liner are shown in Appendix F. The pond will require regular maintenance. The two primary maintenance activities involve removing accumulated sediment from the bottom of the pond to maintain the designed storage volume. Direct access is provided to the pond from the newly graded roads.

APPENDIX A

STATE OF NORTH CAROLINA FIRM PANEL LOCATOR DIAGRAM



DATUM INFORMATION

The **projection** used in the preparation of this map was the North Carolina State Plane (FIPSZONE 3200). The **horizontal datum** was the North American Datum of 1983, GRS80 ellipsoid. Differences in datum, ellipsoid, projection, or Universal Transverse Mercator zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdictional boundaries. These differences do not affect the accuracy of this FIRM. All coordinates on this map are in U.S. Survey Feet, where 1 U.S. Survey Foot = 1200/3937 Meters

Flood elevations on this map are referenced to the North American Vertical Datum of 1988 (NAVD 88). These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. An average offset between NAVD 88 and the National Geodetic Vertical Datum of 1929 (NGVD 29) has been computed for each North Carolina county. This offset was then applied to the NGVD 29 flood elevations that were not revised during the creation of this statewide format FIRM. The offsets for each county shown on this FIRM panel are shown in the vertical datum offset table below. Where a county boundary and a flooding source with unrevised NGVD 29 flood elevations are coincident, an individual offset has been calculated and applied during the creation of this statewide format FIRM. See Section 6.1 of the accompanying Flood Insurance Study report to obtain further information on the conversion of elevations between NAVD 88 and NGVD 29. To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the North Carolina Geodetic Survey at the address shown below. You may also contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242**, or visit its website at www.ngs.noaa.gov.

North Carolina Geodetic Survey
121 West Jones Street
Raleigh, NC 27601
(919) 733-3836
www.ncgs.state.nc.us

County Average Vertical Datum Offset Table

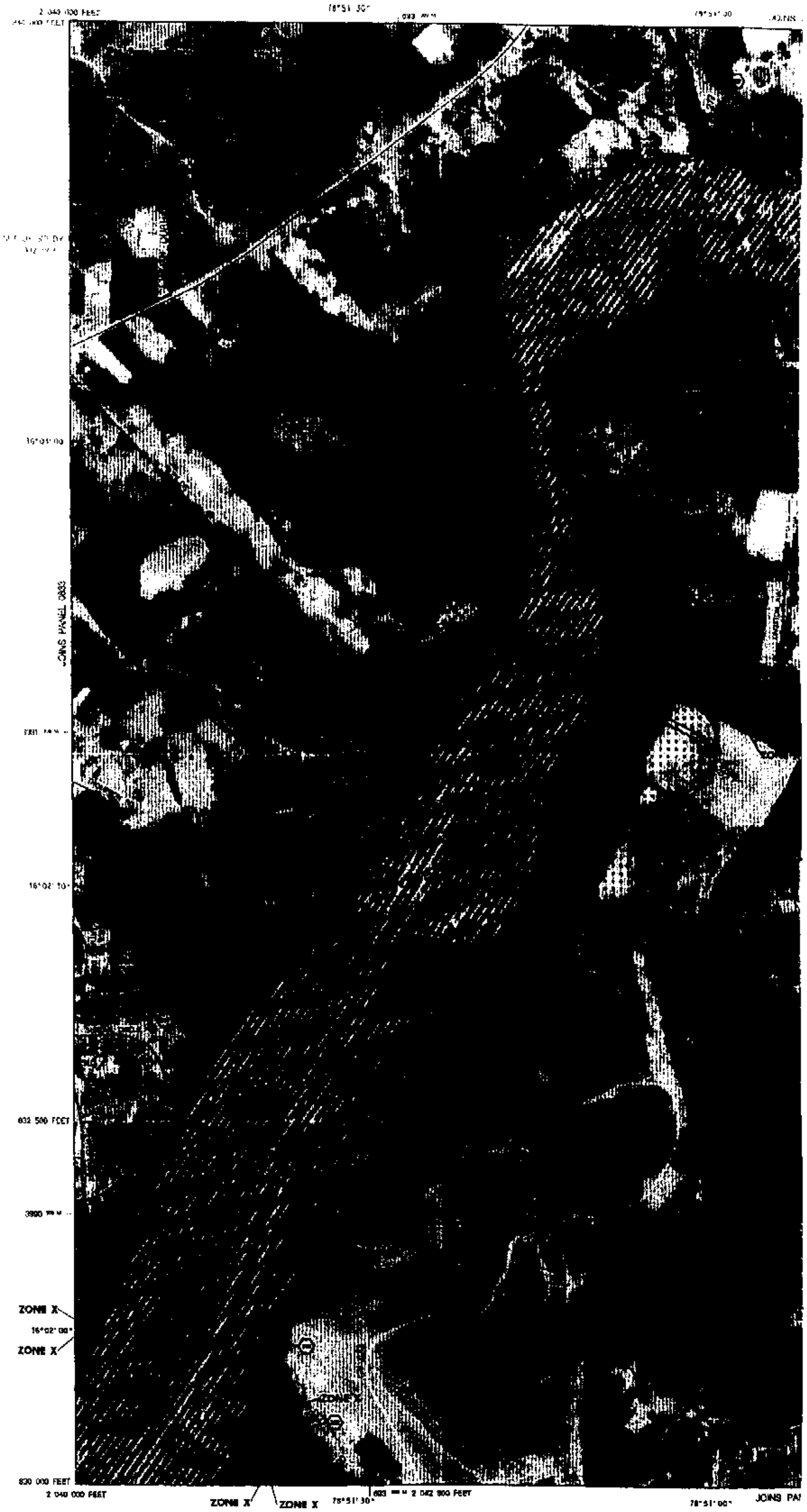
County	Vertical Datum Offset (ft)
Durham	- 0.83
Example: NAVD 88 = NGVD 29 + (-0.83)	

All streams listed in the **Flood Hazard Data Table** below were studied by detailed methods using field survey. Other flood hazard data shown on this map may have been derived using either a coastal analysis or limited detailed riverine analysis. More information on the flooding sources studied by these analyses is contained in the Flood Insurance Study report.

FLOOD HAZARD DATA TABLE

Cross Section	Stream Station[1]	Flood Discharge (cfs)	1% Annual Chance (100-year) Water-Surface Elevation (feet NAVD 88)	Floodway Width (feet) Left/Right Distance From the Center of Stream to Encroachment Boundary (Looking Downstream) or Total Floodway Width
ELLERBE CREEK				
198	19,828	NA	273.6	706
207	20,666	NA	274.4	888
214	21,403	NA	275.2	765
222	22,169	NA	276.3	706
227	22,676	NA	277.0	910
237	23,566	NA	278.1	798
242	24,242	NA	278.8	670
247	24,678	NA	279.0	225
255	25,561	NA	284.5	187
265	26,470	NA	286.9	700
272	27,183	NA	287.7	815
278	27,803	NA	288.0	955
287	28,720	NA	288.4	1,000
297	29,670	NA	288.9	1,308
301	30,099	NA	289.0	1,230
307	30,681	NA	289.3	1,259
315	31,466	NA	289.6	1,072
322	32,215	NA	290.1	1,181

[1] Feet above confluence with Neuse River



This digital Flood Insurance Rate Map (FIRM) was produced through a unique cooperative partnership between the State of North Carolina and the Federal Emergency Management Agency (FEMA). The State of North Carolina has implemented a long term approach of floodplain management to decrease the costs associated with flooding. This is demonstrated by the State's commitment to map floodplain areas at the local level. As a part of this effort, the State of North Carolina has joined in a Cooperating Technical State agreement with FEMA to produce and maintain this digital FIRM.

www.ncfloodmaps.com

NOTES T

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

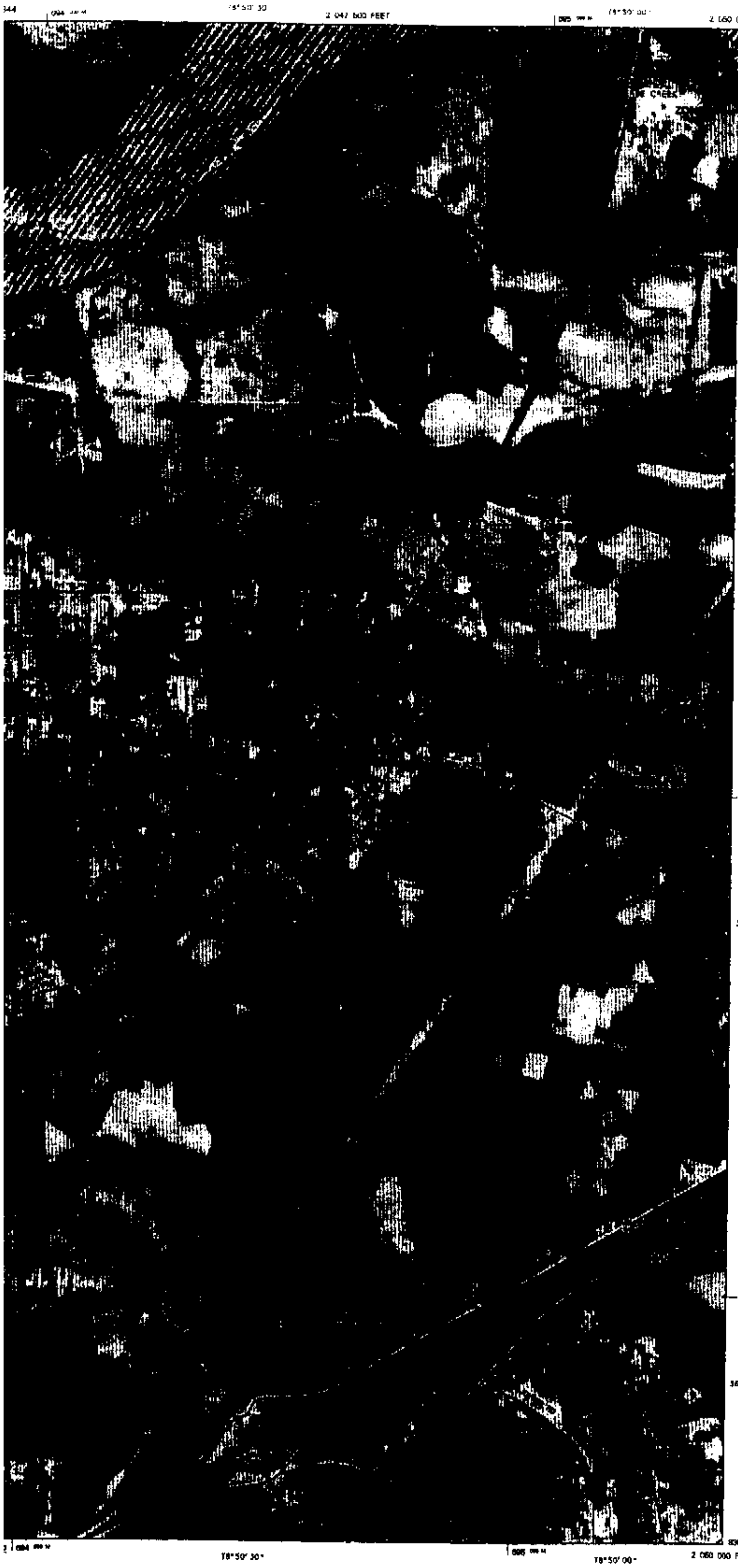
To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles, Floodway Data, Limited Detailed Flood Hazard Data, and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Boundaries of **regulatory floodways** shown on the FIRM for flooding sources studied by detailed methods were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data for flooding sources studied by detailed methods as well as **non-encroachment widths** for flooding sources studied by limited detailed methods are provided in the FIS report for this jurisdiction. The FIS report also provides instructions for determining a floodway using non-encroachment widths for flooding sources studied by limited detailed methods.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 4.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures in this jurisdiction.

Base map information and geospatial data used to develop this FIRM were obtained from various organizations, including the participating local community(ies), state and federal agencies, and/or other sources. The primary base for this FIRM is aerial imagery acquired by Durham County. The time period of collection for the imagery is 1999. Information and geospatial data supplied by the local community(ies) that met FEMA base map specifications were considered the preferred source for development of the base map. See geospatial metadata for the associated digital FIRM for additional information about base map preparation.

Base map features shown on this map, such as **corporate limits**, are based on the most up-to-date data available at the time of publication. **Changes in the corporate limits may have occurred since this map was published.** Map users should consult the appropriate community official or website to verify current conditions of jurisdictional boundaries and base map features. This map may contain roads that were not considered in the hydraulic analysis of streams where no new hydraulic model was created during the production of this statewide format FIRM.



LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

	1% annual chance floodplain boundary
	0.2% annual chance floodplain boundary
	Floodway boundary
	Zone D Boundary
	CBRS and OPA boundary
	Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
~~ 513 ~~~	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

(A)——(A)	Cross section line
(23)- - - -(23)	Transect line
97°07'30", 32°22'30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
4276000M	1000-meter Universal Transverse Mercator grid ticks, zone 17
1 077 500 FEET	2500-foot grid values: North Carolina State Plane coordinate system (FIPSZONE 3200, State Plane NAD 83 feet)
BM5510 ×	North Carolina Geodetic Survey bench mark (see explanation in the Datum Information section of this FIRM panel).
BM5510 ⊗	National Geodetic Survey bench mark (see explanation in the Datum Information section of this FIRM panel).
• M1.5	River Mile

GRID NORTH

MAP SCALE 1" = 500' (1 : 6,000)

250 0 500 1000 FEET

150 0 150 300 METERS

USERS

[...] map reflects more detailed and up-to-date **stream channel configurations** than [tho]se shown on the previous FIRM for this jurisdiction. The floodplains and floodways [tha]t were transferred from the previous FIRM may have been adjusted to conform to [the]se new stream channel configurations. As a result, the Flood Profiles and Floodway [...] tables in the Flood Insurance Study report (which contains authoritative hydraulic [data]) may reflect stream channel distances that differ from what is shown on this map.

[Plea]se refer to the separately printed **Map Index** for an overview map of the county [sho]wing the layout of map panels, community map repository addresses, and a Listing of [Co]mmunities table containing National Flood Insurance Program dates for each community [as] well as a listing of the panels on which each community is located.

[If y]ou have **questions about this map**, or questions concerning the National Flood [Ins]urance Program in general, please call **1-877-FEMA MAP** (1-877-336-2627) or visit the [FEM]A website at www.fema.gov.

[An] accompanying Flood Insurance Study report, Letter of Map Revision (LOMR) or Letter [of] Map Amendment (LOMA) revising portions of this panel, and digital versions of this [FIR]M may be available. Visit the **North Carolina Floodplain Mapping Program** website [at] www.ncfloodmaps.com, or contact the **FEMA Map Service Center** at 1-800-358-9616 [for] information on all related products associated with this FIRM. The FEMA Map Service [Cen]ter may also be reached by Fax at 1-800-358-9620 and its website at www.msc.fema.gov.

MAP REPOSITORY

Refer to listing of Map Repositories on Map Index or visit www.ncfloodmaps.com.

EFFECTIVE DATE OF FLOOD INSURANCE RATE MAP PANEL
MAY 2, 2006

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to statewide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent, the North Carolina Division of Emergency Management or the National Flood Insurance Program at the following phone numbers or websites:

NC Division of Emergency Management		National Flood Insurance Program	
(919) 715-8000	www.nccrimecontrol.org/nfip	1-800-638-6620	www.fema.gov/nfip

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0843J

FIRM
FLOOD INSURANCE RATE MAP
NORTH CAROLINA

PANEL 0843

(SEE LOCATOR DIAGRAM OR MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	CID No.	PANEL	SUFFIX
DURHAM, CITY OF	370086	0843	J
DURHAM COUNTY	370085	0843	J

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

EFFECTIVE DATE
MAY 2, 2006

MAP NUMBER
3720084300J

State of North Carolina
Federal Emergency Management Agency

WATERSHED CLASSIFICATION ATTACHMENT (FORM: WSCA 10-06)

Applicant's name: CITY OF DURHAM

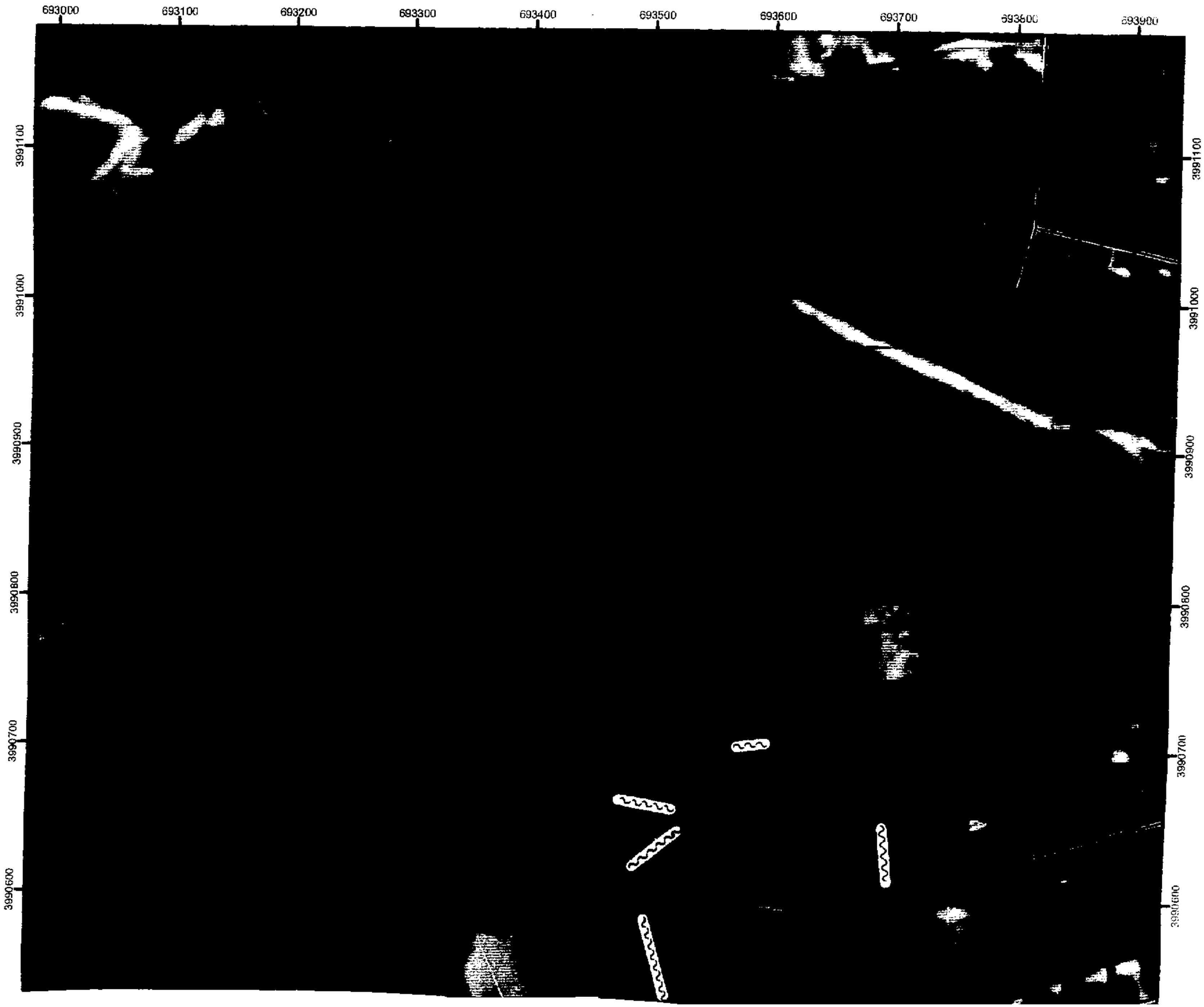
Site/Field ID	County	Latitude	Longitude	Location Datum	Location Method Code	Location Accuracy	Waterbody Subbasin and Stream Index No.	Current and Proposed Class
Durham Yard Waste/ Compost Facility	Durham	36° 02′ 19″	78° 51′ 08″	NAD 83	MAP	Nearest Second	Ellerbe Creek Neuse Watershed 27-5 (0.3), [illegible]	[illegible]

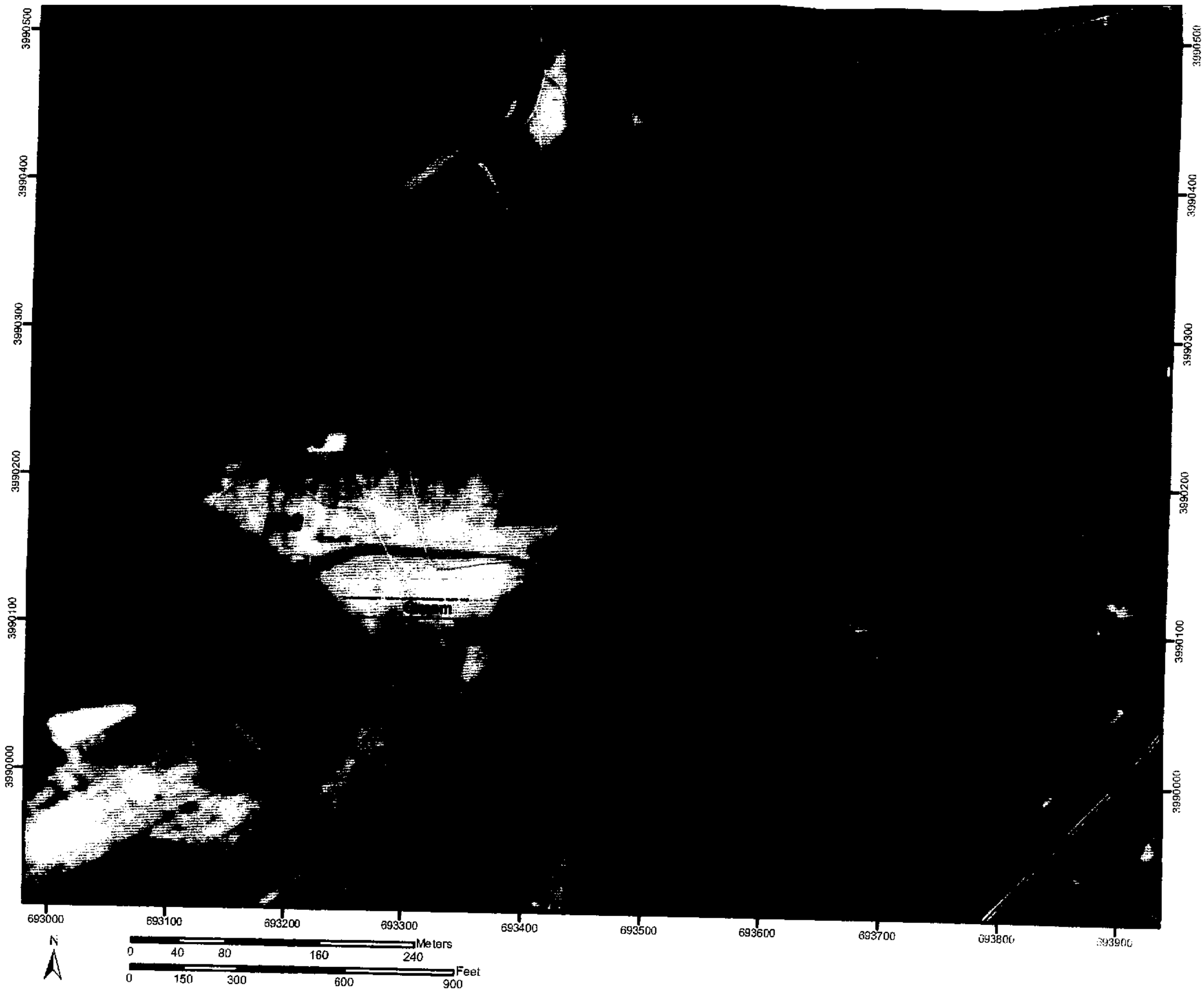
I, AUDREY BURNETTE, PE, attest that this attachment form has been prepared by me and is accurate and complete to the best of my knowledge. I understand that if all required parts of this attachment are not completed and that if all required supporting information is not included, this application package will be returned as incomplete.

Signature [signature] Date 2/26/08

APPENDIX B

Soil Map–Durham County, North Carolina
(DURHAM YARD WASTE FACILITY)




3990500
3990400
3990300
3990200
3990100
3990000
693000
693100
693200
693300
693400
693500
693600
693700
693800
693900
N
0 40 80 160 240 Meters
0 150 300 600 900 Feet

Map Unit Legend

Durham County, North Carolina (NC063)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AlA	Altavista silt loam, 0 to 2 percent slopes	5.3	2.7%
Ch	Chewacla and Wehadkee soils	13.8	7.0%
CrC	Creedmoor sandy loam, 6 to 10 percent slopes	4.6	2.3%
Gu	Gullied land, clayey materials	9.8	5.0%
IrB	Iredell loam, 2 to 6 percent slopes	0.6	0.3%
IrC	Iredell loam, 6 to 10 percent slopes	6.5	3.3%
MfC	Mayodan sandy loam, 6 to 10 percent slopes	0.5	0.2%
Ro	Roanoke silt loam	34.9	17.8%
Wh	Wahee loam, alkaline subsoil variant (Hornsboro)	17.4	8.9%
WsB	White Store sandy loam, 2 to 6 percent slopes	30.0	15.3%
WsC	White Store sandy loam, 6 to 10 percent slopes	41.5	21.1%
WsE	White Store sandy loam, 10 to 25 percent slopes	31.7	16.1%
Totals for Area of Interest (AOI)		196.6	100.0%

Exhibit A: Hydrologic Soil Groups for the United States

WAUBERG D
WAUCHULA B/D
WAUCHULA, Depr[illegible] D
WAUCOBA D
WAUCONDA B
WAUKENA D
WAUKENABO B/D
WAULD C
WAURIKA D
WAUTOMA B/D
WAVELAND B/D
WAVELAND D
WAWAKA B
WAWASEE B
WAWINA A
WAX C
WAXPOOL D
WAYCUP B
WAYLAND C/D
WAYMET B
WAYMOR B
WEA A
WEALTHWOOD A/D
WEASH C
WEATHERFORD B
WEATHERWAX D
WEAVER C
WEAVERVILLE B
WEBB C
WEBBRIDGE B
WEBBTOWN C
WEBFOOT C
WEBILE C
WECHECH D
WEDDERBURN B
WEDGE A
WEDGEMONT B
WEEDING D
WEEDMARK B
WEEDPATCH C
WEEDZUNIT B
WEEKIWACHEE D
WEEKS C
WEENA D
WEEPAH C
WEESATCHE B
WEETOWN B
WEEZWEED B
WEGERT A
WEGLIKE A
WEIDER B
WEINBACH C
WEIR D
WEIRMAN D
WEISBURG C
WEISSENFELS C
WEITAS B
WEITCHPEC C
WELAKA A
WELCH B
WELCHLAND B
WELCOME B
WELDA C
WELEETKA D
WELLESLEY B
WELLIE A
WELLINGTON D
WELLMAN B
WELLROCK B
WELLS B
WELLSBENCH B
WELLSCREEK B
WELLSDAM C
WELLSED C
WELLSFORD D
WELOY C
WELSUM D
WELTER D
WEMPLE B
WENAS C/D
WENATCHEE C
WENDANE B/C
WENDELL C
WENGLER A
WENONAH B

WENOTA D
WENZEL B
WEOGUFKA C
WEOTT D
WEPO C
WERELD B
WERITO C
WERNOCK B
WESFIL D
WESIX D
WESKA D
WESLEY B
WESPAC, Sandy Surface, Alkali
WESPAC, Alkali D
WESSEL C
WESTBEND B
WESTBORO D
WESTBROOK D
WESTBUTTE B
WESTERVILLE B
WESTFORK D
WESTGATE C
WESTINDIAN C
WESTLAKE, Thin Surface C
WESTLAKE D
WESTMION D
WESTMORE C
WESTOLA B
WESTON D
WESTOVER B
WESTPHALIA B
WESTPLAIN D
WESTPORT A
WESTPORT, Thin Surface B
WESTSHORE D
WESTSIDE C
WESTSUM D
WESTVACO C
WESTVIEW B
WESTVILLE B
WESTWEGO D
WESWIND C
WESWOOD B
WETA D
WETBETH C
WETHEY A/C
WETHEY C
WETSAW C
WETTERDON B
WETZEL D
WEWELA B
WEWOKA C
WEYANOKE C
WEYERS C/D
WEYMOUTH B
WHAKANA B
WHALESHEAD B
WHALEY D
WHATCOM C
WHATELY D
WHEATBELT D
WHEATON B
WHEATWOOD B
WHEELER B
WHEELERPEK D
WHEELERVILLE B
WHEELON, Cool B
WHEELON D
WHEELRIDGE A
WHEELS D
WHERRY D
WHETSOON C
WHETSTONE C
WHICHMAN B
WHIDBEY C
WHILPHANG D
WHIPP D
WHIPPANY C
WHISK D
WHISKEY B
WHISKEYCREEK C
WHISKLAKE C
WHISPERING C
WHISTLE B

WHITE STORE D
WHITE SWAN D
WHITEARTH C
WHITEBIRD B
WHITECAP D
WHITECLOUD B
WHITEDEER B
WHITEFACE C
WHITEFIELD D
WHITEFORD B
WHITEHALL B
WHITEHORN D
WHITEHORSE B
WHITEKNOB B
WHITEMARSH C/D
WHITEOAK B
WHITEPEAK D
WHITEPINE D
WHITERIVER C
WHITEROCK D
WHITESBORO C
WHITESBURG C
WHITESIDE B
WHITESON D
WHITETHORN B
WHITEWATER D
WHITEWOOD, Nonflooded B/D
WHITEWOOD C/D
WHITEWRIGHT C
WHITEYE D
WHITING B
WHITINGER C
WHITLEY B
WHITNEY C
WHITSON D
WHITTEMORE C/D
WHITVIN D
WHITWELL C
WHORLED C
WICHITA C
WICKAHONEY D
WICKENBURG D
WICKERSHAM B
WICKETT C
WICKIUP C
WICKSBURG B
WICKWARE B
WICUP C
WIDEN C
WIDOWSPRING B
WIERGATE D
WIFFO B
WIFTON B
WIGTON A
WILAHA B
WILBANKS D
WILBUR B
WILCO C
WILCOX D
WILCOXSON C
WILDALE C
WILDCAT D
WILDER A
WILDGEN B
WILDHILL C
WILDHORSE A
WILDMESA C
WILDORS C
WILDROSE C
WILE C
WILHOIT B
WILKESON B
WILL B/D
WILLABY C
WILLAKENZIE C
WILLAMETTE C
WILLANCH D
WILLAPA C
WILLARD B
WILLETTE A/D
WILLHILL C
WILLHO D
WILLIAMSBURG B
WILLIAMSPORT C
WILLIAMSTOWN C

WILLIAMSVILLE C
WILLIMAN B/D
WILLISTON C
WILLOSIPPI C
WILLOW CREEK B
WILLOWDALE B
WILLOWFORK B
WILLSPRINGS C
WILLYNAT B
WILMA [illegible]
WILMER [illegible]
WILMONT D
WILMONTON D
WILPAR
WILPOINT D
WILSALL D
WILSHIRE A
WILSON D
WILSONGULCH B
WILSONVILLE D
WILSOR B
WILSPRING C
WILST C
WILT B
WILTON B
WIMPEY C
WINADA C
WINBERRY C
WINBLOW C
WINCHUCK C
WIND RIVER B
WINDCOAT D
WINDCOMB D
WINDEGO B
WINDER D
WINDERE B
WINDERNOT B
WINDICREEK A
WINDLASS C
WINDMILL B
WINDRY D
WINDTHORST C
WINDWHISTLE B
WINDYBUTTE B
WINDYHOLLOW C
WINDYPOINT B
WINEDALE D
WINEG B
WINEGAR C
WINEVADA C
WINFALL B
WINFIELD B
WING D
WINGATE B
WINGDALE D
WINGINA B
WINGINAW D
WINGROCK B
WINGVILLE D
WINKLEMAN D
WINKLER B
WINKLO C
WINLER D
WINLO D
WINN C
WINNEBAGO B
WINNEMUCCA C
WINNETT C
WINNETT D
WINNIPEG B
WINNSBORO C
WINOM D
WINOOSKI B
WINOPEE B
WINRIDGE D
WINSAND B
WINSTON B
WINT D
WINTERCANYON C
WINTERIM C
WINTERMUTE C
WINTERS C
WINTERSBURG B
WINTERSET C
WINTLEY B

Table 2-2c Runoff curve numbers for other agricultural lands [1]

Cover description	Hydrologic condition	Curve numbers for hydrologic soil group A	B	C	D
Pasture, grassland, or range—continuous forage for grazing [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm). [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
Poor: <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

APPENDIX C

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

North Carolina 36.0425 N 78.9625 W 498 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3
G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2004

Extracted: Tue Oct 23 2007

Confidence Limits | Seasonality | Location Maps | Other Info. | GIS data | Maps | Help | Docs | U.S. Map

Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	0.41	0.65	0.81	1.11	1.38	1.66	1.77	2.13	2.52	2.93	3.44	3.83	4.40	5.00	6.66	8.29	10.53	12.68
2	0.47	0.76	0.95	1.32	1.65	1.99	2.12	2.56	3.02	3.54	4.14	4.58	5.24	5.94	7.85	9.75	12.33	14.77
5	0.54	0.87	1.10	1.56	2.01	2.43	2.60	3.13	3.73	4.41	5.11	5.63	6.35	7.12	9.27	11.31	14.11	16.64
10	0.60	0.96	1.22	1.77	2.30	2.82	3.03	3.66	4.38	5.09	5.85	6.43	7.22	8.05	10.40	12.53	15.51	18.09
25	0.66	1.06	1.34	1.99	2.65	3.28	3.55	4.32	5.22	6.00	6.83	7.52	8.40	9.30	11.96	14.14	17.34	19.94
50	0.71	1.13	1.43	2.15	2.92	3.66	3.99	4.88	5.95	6.72	7.60	8.38	9.33	10.28	13.18	15.38	18.75	21.34
100	0.75	1.19	1.50	2.30	3.17	4.02	4.42	5.44	6.69	7.44	8.38	9.25	10.28	11.28	14.41	16.61	20.13	22.69
200	0.78	1.24	1.56	2.43	3.41	4.38	4.86	6.02	7.48	8.19	9.16	10.14	11.24	12.29	15.68	17.84	21.51	24.00
500	0.81	1.29	1.62	2.58	3.70	4.85	5.43	6.80	8.55	9.21	10.22	11.35	12.56	13.66	17.41	19.48	23.34	25.69
1000	0.84	1.33	1.67	2.70	3.94	5.25	5.94	7.48	9.51	10.01	11.05	12.30	13.60	14.73	18.75	20.75	24.74	26.95

Text version of table

* These precipitation frequency estimates are based on a partial duration series. **ARI** is the Average Recurrence Interval. Please refer to the documentation for more information. NOTE: Formatting forces estimates near zero to appear as zero.

Confidence Limits | Seasonality | Location Maps | Other Info. | GIS data | Maps | Help | Docs | U.S. Map

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

North Carolina 36.0425 N 78.9625 W 498 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3
G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2004

Extracted: Tue Oct 23 2007

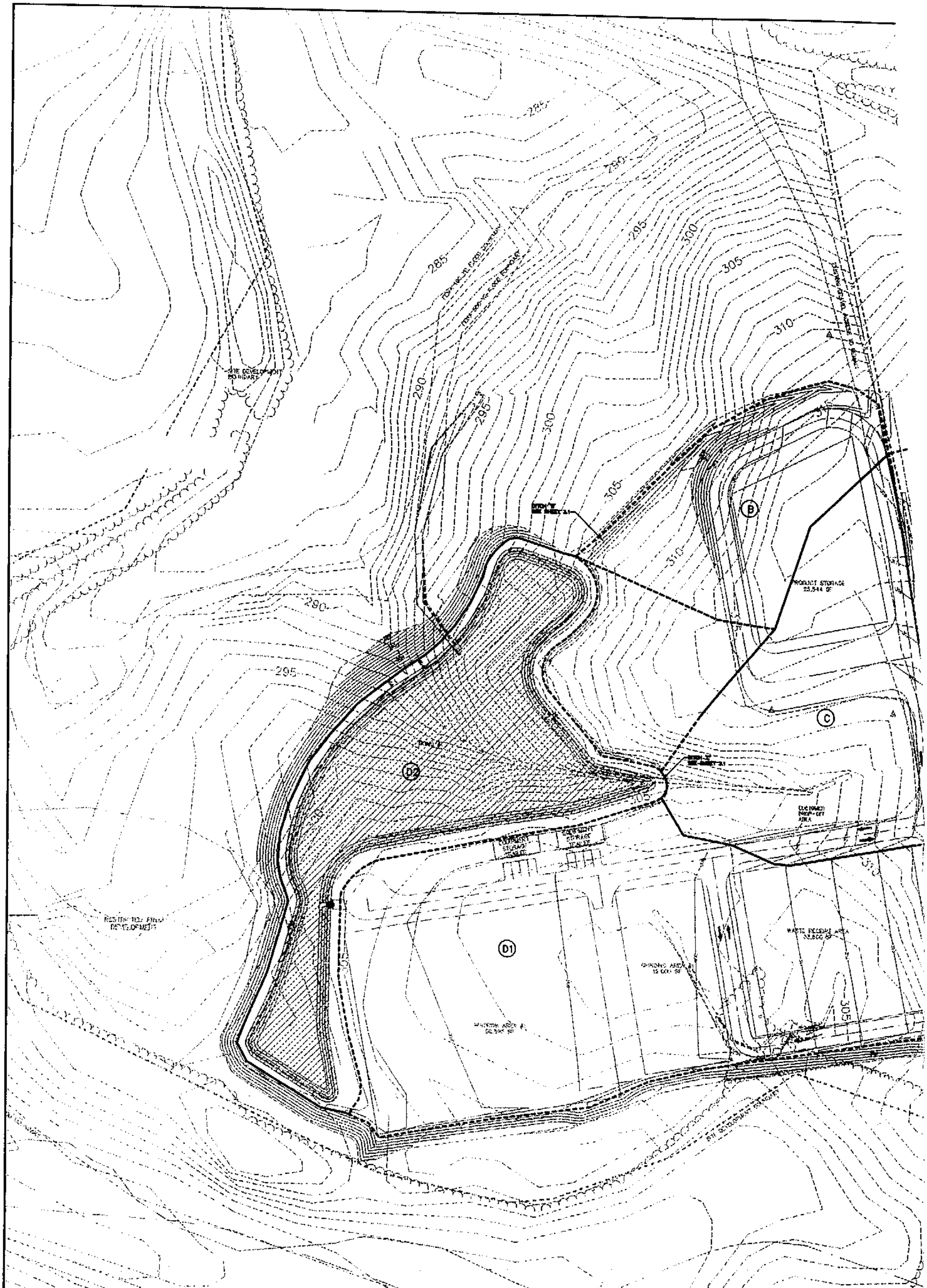
Precipitation Intensity Estimates (in/hr)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	4.86	3.88	3.23	2.22	1.38	0.83	0.59	0.36	0.21	0.12	0.07	0.04	0.03	0.02	0.01	0.01	0.01	0.01
2	5.69	4.55	3.82	2.63	1.65	0.99	0.71	0.43	0.25	0.15	0.09	0.05	0.03	0.02	0.02	0.01	0.01	0.01
5	6.53	5.23	4.40	3.13	2.01	1.22	0.87	0.52	0.31	0.18	0.11	0.06	0.04	0.03	0.02	0.02	0.01	0.01
10	7.25	5.79	4.88	3.54	2.30	1.41	1.01	0.61	0.36	0.21	0.12	0.07	0.04	0.03	0.02	0.02	0.01	0.01
25	7.97	6.35	5.37	3.97	2.65	1.64	1.18	0.72	0.43	0.25	0.14	0.08	0.05	0.04	0.02	0.02	0.02	0.01
50	8.51	6.77	5.72	4.30	2.92	1.83	1.33	0.82	0.49	0.28	0.16	0.09	0.06	0.04	0.03	0.02	0.02	0.01
100	8.96	7.13	6.00	4.60	3.17	2.01	1.47	0.91	0.56	0.31	0.17	0.10	0.06	0.05	0.03	0.02	0.02	0.02
200	9.36	7.42	6.24	4.86	3.41	2.19	1.62	1.01	0.62	0.34	0.19	0.11	0.07	0.05	0.03	0.02	0.02	0.02
500	9.78	7.73	6.49	5.16	3.70	2.43	1.81	1.14	0.71	0.38	0.21	0.12	0.07	0.06	0.04	0.03	0.02	0.02
1000	10.13	7.97	6.67	5.40	3.94	2.62	1.98	1.25	0.79	0.42	0.23	0.13	0.08	0.06	0.04	0.03	0.02	0.02

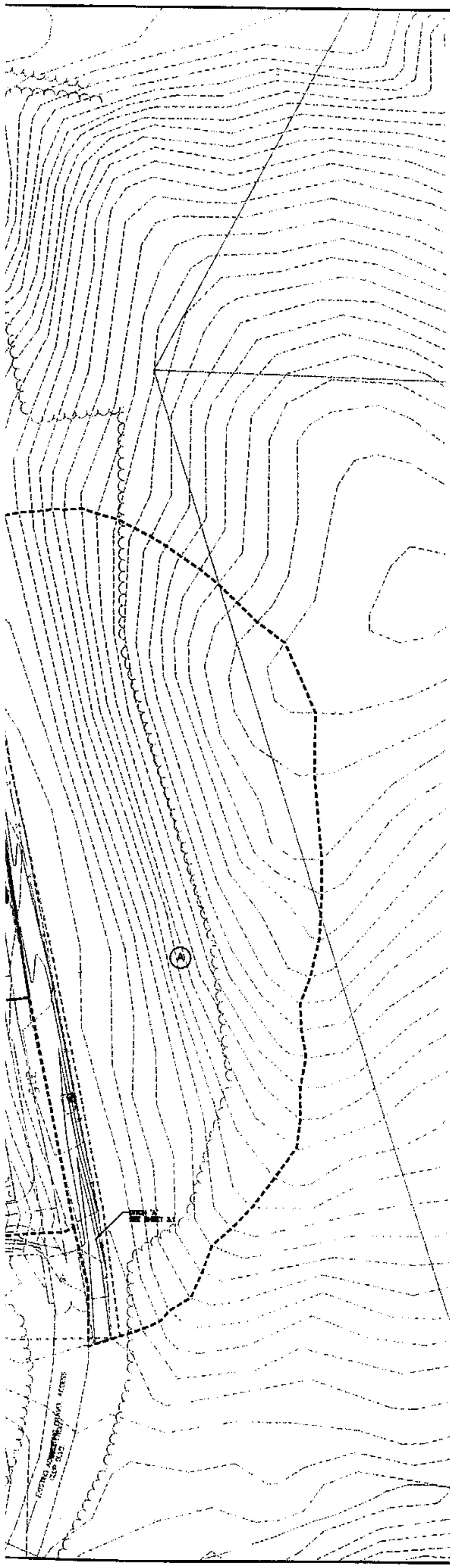
Text version of table

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval. Please refer to the documentation for more information. NOTE: Formatting forces estimates near zero to appear as zero.

APPENDIX D



285
290
295
300
305
310
SITE DEVELOPMENT BOUNDARY
B
PRODUCT STORAGE
23,544 SF
C
CUSTOMER DROP-OFF AREA
D2
D1
WASTE RECEIPT AREA
305
RESTRICTED FROM DEVELOPMENT



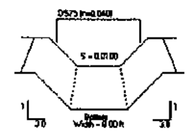
Rational Method					
Rainfall Frequency .	10 year(s) Storm				
Area Description	Area ac	Coef	Tc min	Intensity in/hr	Flow cfs
A	3.7950	0.3500	5.0000	7.2500	9.9599
B	1.0720	0.4000	5.0000	7.2500	3.1089
C	1.7000	0.4000	5.0000	7.2500	4.9300
D1	4.7096	0.4000	5.0000	7.2500	13.6577
D2(POND AREA)	2.2046	1.0000			

DITCH 'A'

HYDRAULICS:

Discharge (cfs)	Peak Flow Period (hrs)	Velocity (fps)	Area (sq ft)	Hydraulic Radius(ft)	Normal Depth (ft)
10.0	0.1	2.49	4.02	0.88	1.16

$B + C + D_1 = 7.4815$ Acres



LINER RESULTS:

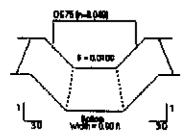
Not to Scale

Reach	Matting Type / Staple Pattern	Stability Analysis	Vegetation Characteristics: Phase	Class	Type	Density	Permissible Shear Stress (psf)	Calculated Shear Stress (psf)	Safety Factor	Remarks
Straight	DS75	Unvegetated					1.55	0.72	2.16	STABLE
	Staple D									

DITCH 'B'

HYDRAULICS:

Discharge (cfs)	Peak Flow Period (hrs)	Velocity (fps)	Area (sq ft)	Hydraulic Radius(ft)	Normal Depth (ft)
3.1	0.1	1.92	1.82	0.38	0.80



LINER RESULTS:

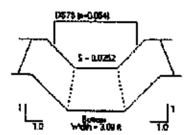
Not to Scale

Reach	Matting Type / Staple Pattern	Stability Analysis	Vegetation Characteristics: Phase	Class	Type	Density	Permissible Shear Stress (psf)	Calculated Shear Stress (psf)	Safety Factor	Remarks
Straight	DS75	Unvegetated					1.55	0.50	3.11	STABLE
	Staple D									

DITCH 'C'

HYDRAULICS:

Discharge (cfs)	Peak Flow Period (hrs)	Velocity (fps)	Area (sq ft)	Hydraulic Radius(ft)	Normal Depth (ft)
4.9	0.1	2.50	1.96	0.43	0.56



LINER RESULTS:

Not to Scale

Reach	Matting Type / Staple Pattern	Stability Analysis	Vegetation Characteristics: Phase	Class	Type	Density	Permissible Shear Stress (psf)	Calculated Shear Stress (psf)	Safety Factor	Remarks
Straight	DS75	Unvegetated					1.55	0.87	1.78	STABLE
	Staple D									

GRAPHIC SCALE

60' 0 60' 120'

(IN FEET)
1 inch = 60 ft.

CITY OF DURHAM
PUBLIC WORKS DEPARTMENT
APPROVED

ENGINEERING ________ DATE ____
STORM WATER ________ DATE ____
TRANSPORTATION ________ DATE ____
________ DATE ____
________ DATE ____

FINAL DESIGN-NOT FOR CONSTRUCTION

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
A			
B			

KCI Associates of North Carolina, PA
Engineers • Planners • Scientists • Construction Managers
4601 Six Forks Road, Landmark Center II, Suite 220
Raleigh, NC 27609-5210
Phone (919) 783-9214
Fax (919) 783-9266
http://www.kci.com

KCI ASSOCIATES OF NORTH CAROLINA, PA

DURHAM YARD WASTE CONSTRUCTION PLANS

DURHAM COUNTY   CITY OF DURHAM

DRAINAGE AREA MAP & DITCH CALCULATIONS

SEAL: NORTH CAROLINA PROFESSIONAL SEAL 7466 ENGINEER DAVID M. KOSS

HORZ SCALE:	
VERT SCALE:	
DRAWN BY:	ACL
CHECKED BY:	FR
DATE:	06-25-08
PROJECT NO:	12065870A
SHEET NO.	C-3.1
SHEET	OF

Table of Contents

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow Hyd(s)	Peak Outflow (cfs)								Hydrograph description
			1-Yr	2-Yr	3-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	
1	SCS Runoff	-------	6.767	6.082	-------	10.23	13.73	18.28	22.26	26.35	PROPOSED
3	Reservoir	1	0.000	0.000	-------	0.000	0.000	0.000	0.000	0.000	POND 1

Proj. file: DurhamWaste-March-2009.gpw | Friday, Mar 6 2009, 2:51 PM

Hydrograph Summary Report

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to peak (min)	Volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Maximum storage (cuft)	Hydrograph description
1	SCS Runoff	18.28	3	732	82,209	----	------	------	PROPOSED
3	Reservoir	0.000	3	0	0	1	302.28	192,609	POND 1

DurhamWaste-March-2009.gpw	Return Period: 25 Year	Friday, Mar 6 2009, 2:51 PM

Hydrograph Plot

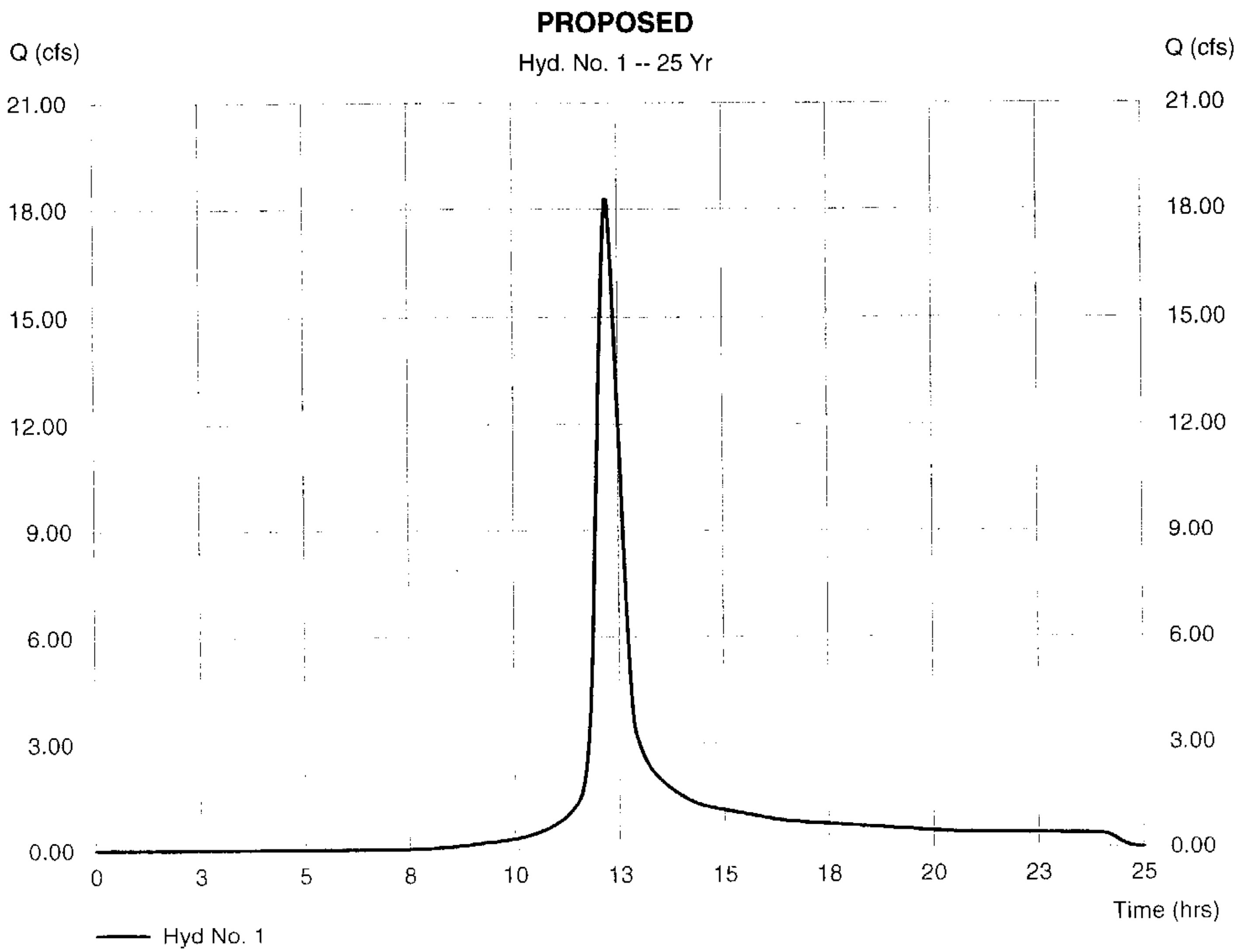
Hydraflow Hydrographs by Intelisolve — Friday, Mar 6 2009, 2:51 PM

Hyd. No. 1

PROPOSED

Hydrograph type = SCS Runoff	Peak discharge = 18.28 cfs
Storm frequency = 25 yrs	Time interval = 3 min
Drainage area = 7.480 ac	Curve number = 79
Basin Slope = 0.0 %	Hydraulic length = 0 ft
Tc method = TR55	Time of conc. (Tc) = 31.00 min
Total precip. = 5.20 in	Distribution = Type II
Storm duration = 24 hrs	Shape factor = 484

Hydrograph Volume = 82,209 cuft



TR55 Tc Worksheet

Hydraflow Hydrographs by Intelisolve

Hyd. No. 1

PROPOSED

Description		A		B		C		Totals
Sheet Flow								
Manning's n-value	=	0.240		0.011		0.011		
Flow length (ft)	=	300.0		0.0		0.0		
Two-year 24-hr precip. (in)	=	3.26		0.00		0.00		
Land slope (%)	=	2.95		0.00		0.00		
Travel Time (min)	=	**29.15**	+	**0.00**	+	**0.00**	=	**29.15**
Shallow Concentrated Flow								
Flow length (ft)	=	300.00		0.00		0.00		
Watercourse slope (%)	=	3.47		0.00		0.00		
Surface description	=	Unpaved		Paved		Paved		
Average velocity (ft/s)	=	3.01		0.00		0.00		
Travel Time (min)	=	**1.66**	+	**0.00**	+	**0.00**	=	**1.66**
Channel Flow								
X sectional flow area (sqft)	=	3.00		0.00		0.00		
Wetted perimeter (ft)	=	1.25		0.00		0.00		
Channel slope (%)	=	3.47		0.00		0.00		
Manning's n-value	=	0.015		0.015		0.015		
Velocity (ft/s)	=	33.27		0.00		0.00		
Flow length (ft)	=	300.0		0.0		0.0		
Travel Time (min)	=	**0.15**	+	**0.00**	+	**0.00**	=	**0.15**

Total Travel Time, Tc .... 31.00 min

Hydrograph Plot

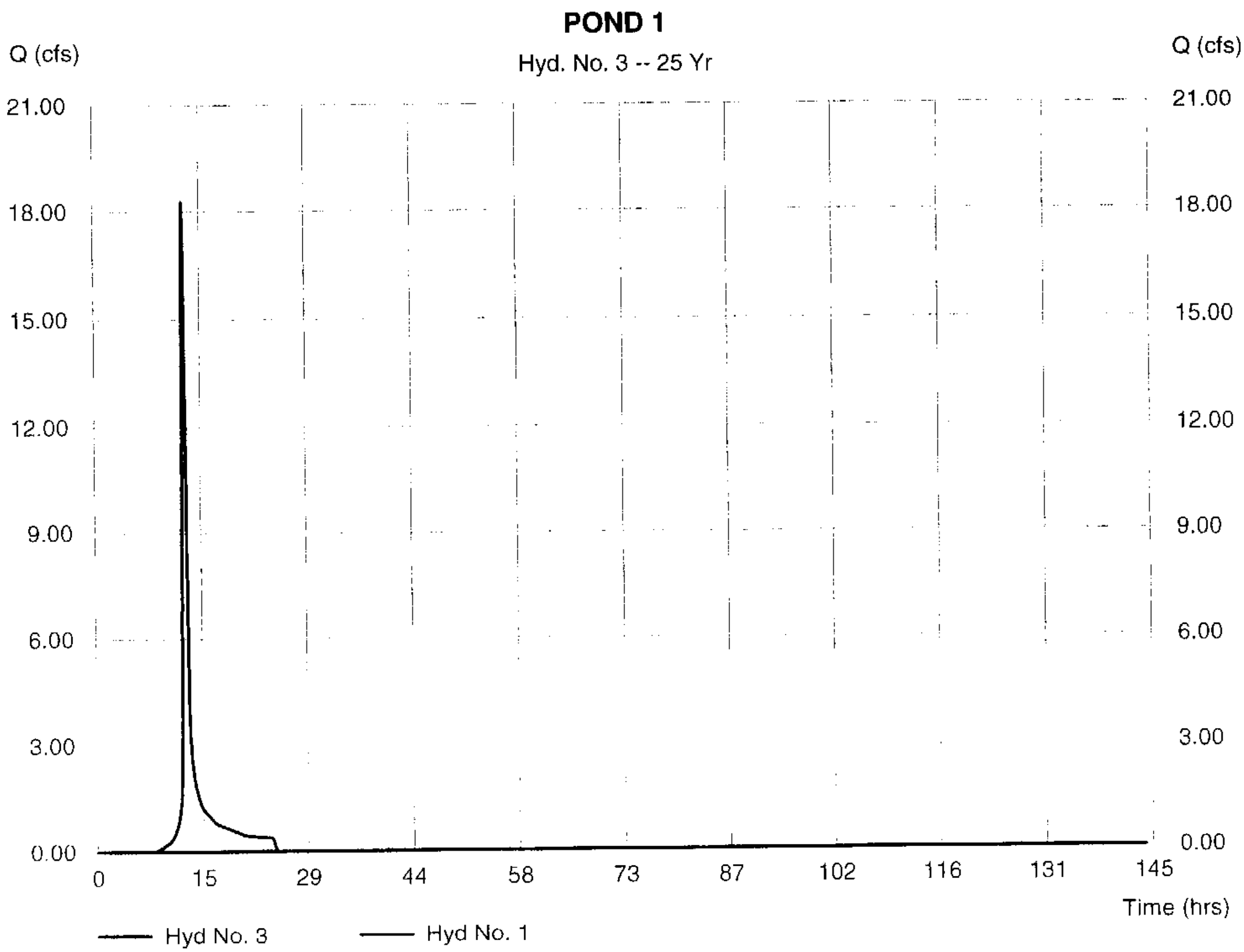
Hydraflow Hydrographs by Intelisolve — Friday, Mar 6 2009, 2:51 PM

Hyd. No. 3

POND 1

Hydrograph type	= Reservoir	Peak discharge	= 0.000 cfs
Storm frequency	= 25 yrs	Time interval	= 3 min
Inflow hyd. No.	= 1	Max. Elevation	= 302.28 ft
Reservoir name	= POND 1- OPTION 1	Max. Storage	= 192,609 cuft

Storage Indication method used. Wet pond routing start elevation = 301.00 ft. — Hydrograph Volume = 0 cuft



Pond Report

Hydraflow Hydrographs by Intelisolve Friday, Mar 6 2009, 2:51 PM

Pond No. 1 - POND 1- OPTION 1

Pond Data

Pond storage is based on known contour areas. Average end area method used.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	299.00	50,233	0	0
1.00	300.00	55,161	52,697	52,697
2.00	301.00	60,245	57,703	110,400
3.00	302.00	65,419	62,832	173,232
4.00	303.00	70,652	68,036	241,268
5.00	304.00	75,943	73,298	314,565

Culvert / Orifice Structures

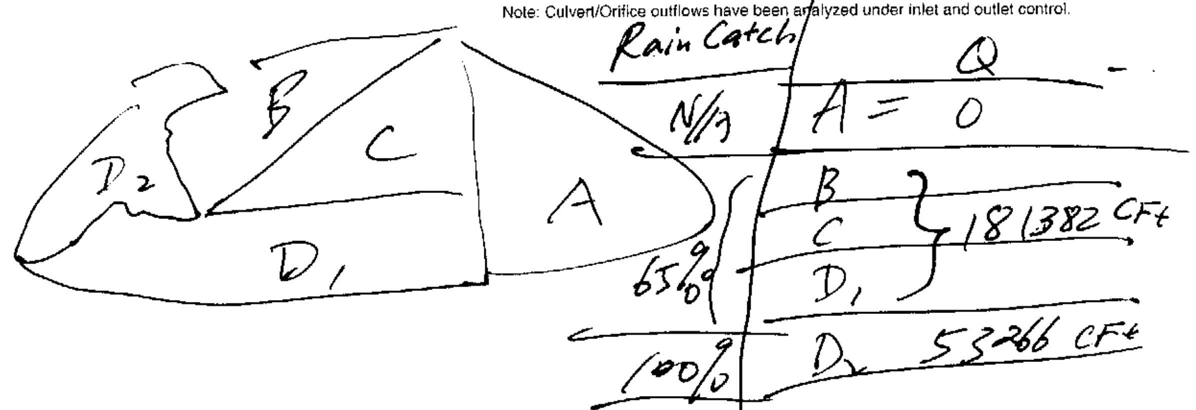
	[A]	[B]	[C]	[D]
Rise (in)	= 0.00	0.00	0.00	0.00
Span (in)	= 0.00	0.00	0.00	0.00
No. Barrels	= 0	0	0	0
Invert El. (ft)	= 0.00	0.00	0.00	0.00
Length (ft)	= 0.00	0.00	0.00	0.00
Slope (%)	= 0.00	0.00	0.00	0.00
N-Value	= .000	.000	.000	.000
Orif. Coeff.	= 0.00	0.00	0.00	0.00
Multi-Stage	= n/a	No	No	No

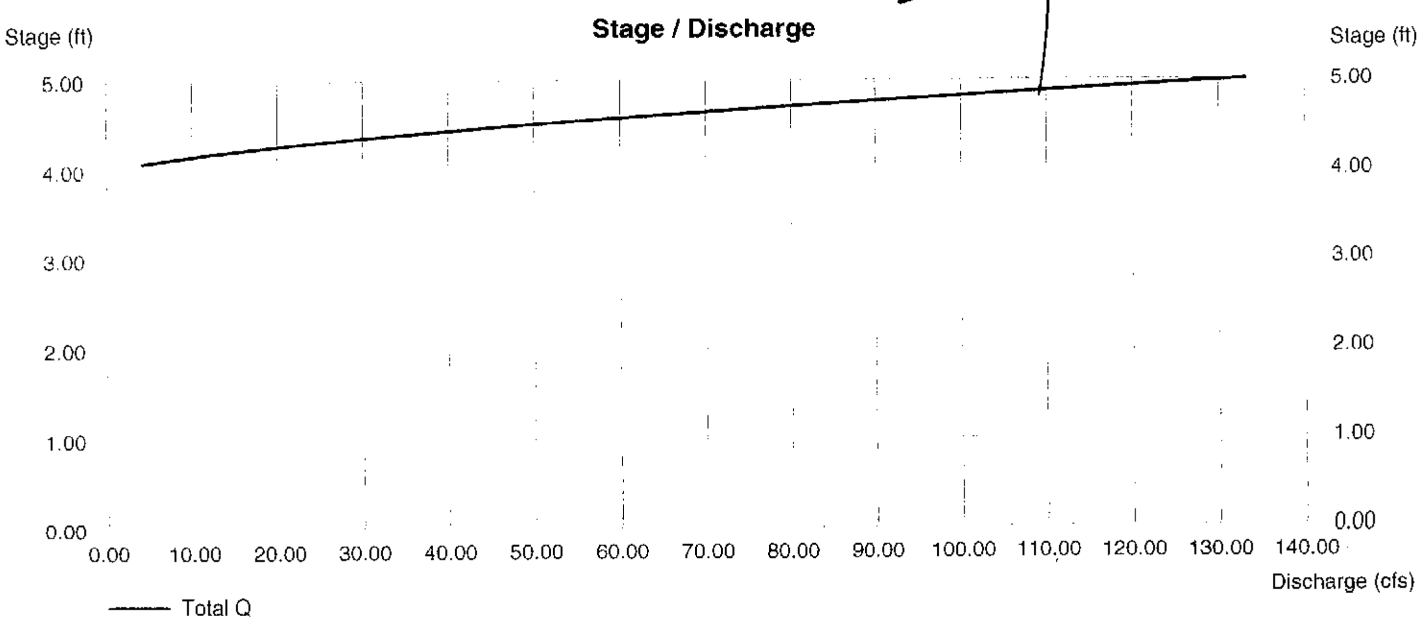
Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 40.00	0.00	0.00	0.00
Crest El. (ft)	= 303.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	0.00	0.00	0.00
Weir Type	= Rect	---	---	---
Multi-Stage	= No	No	No	No

Exfiltration = 0.000 in/hr (Contour) Tailwater Elev. = 0.00 ft

Note: Culvert/Orifice outflows have been analyzed under inlet and outlet control.





Hydrograph Summary Report

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to peak (min)	Volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Maximum storage (cuft)	Hydrograph description
1	SCS Runoff	26.35	3	732	118,382	----	------	------	PROPOSED
3	Reservoir	0.000	3	0	0	1	302.82	228,782	POND 1

DurhamWaste-March-2009.gpw	Return Period: 100 Year	Friday, Mar 6 2009, 2:51 PM

Hydrograph Plot

Hydraflow Hydrographs by Intelisolve — Friday, Mar 6 2009, 2:51 PM

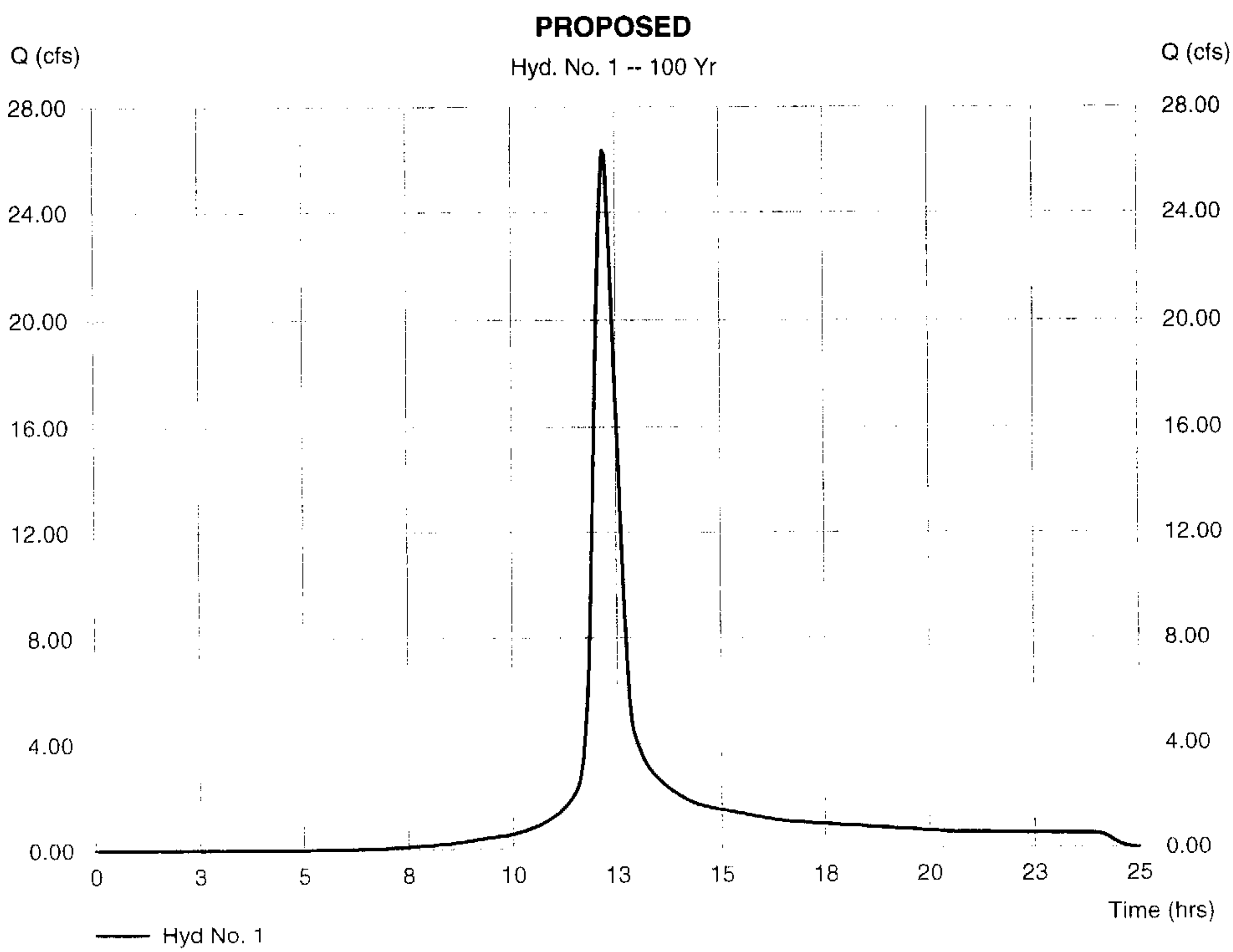
Hyd. No. 1

PROPOSED

Hydrograph type	= SCS Runoff	Peak discharge	= 26.35 cfs
Storm frequency	= 100 yrs	Time interval	= 3 min
Drainage area	= 7.480 ac	Curve number	= 79
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 31.00 min
Total precip.	= 6.67 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

3.47%? see next page

Hydrograph Volume = 118,382 cuft



TR55 Tc Worksheet

Hydraflow Hydrographs by Intelisolve

Hyd. No. 1

PROPOSED

Description		A		B		C		Totals
Sheet Flow								
Manning's n-value	=	0.240		0.011		0.011		
Flow length (ft)	=	300.0		0.0		0.0		
Two-year 24-hr precip. (in)	=	3.26		0.00		0.00		
Land slope (%)	=	2.95		0.00		0.00		
Travel Time (min)	=	**29.15**	+	**0.00**	+	**0.00**	=	**29.15**
Shallow Concentrated Flow								
Flow length (ft)	=	300.00		0.00		0.00		
Watercourse slope (%)	=	3.47 ←		0.00		0.00		
Surface description	=	Unpaved		Paved		Paved		
Average velocity (ft/s)	=	3.01		0.00		0.00		
Travel Time (min)	=	**1.66**	+	**0.00**	+	**0.00**	=	**1.66**
Channel Flow								
X sectional flow area (sqft)	=	3.00		0.00		0.00		
Wetted perimeter (ft)	=	1.25		0.00		0.00		
Channel slope (%)	=	3.47		0.00		0.00		
Manning's n-value	=	0.015		0.015		0.015		
Velocity (ft/s)	=	33.27		0.00		0.00		
Flow length (ft)	=	300.0		0.0		0.0		
Travel Time (min)	=	**0.15**	+	**0.00**	+	**0.00**	=	**0.15**

Total Travel Time, Tc .... **31.00 min**

Hydrograph Plot

Hydraflow Hydrographs by Intelisolve — Friday, Mar 6 2009, 2:51 PM

$Q_{D_2} = 2.2046 \text{ Ac} \times 43{,}560 \left(\frac{Ft^2}{Ac}\right) \times 7'' \left(\frac{1}{12}\right) \left(\frac{Inch}{Foot}\right)$

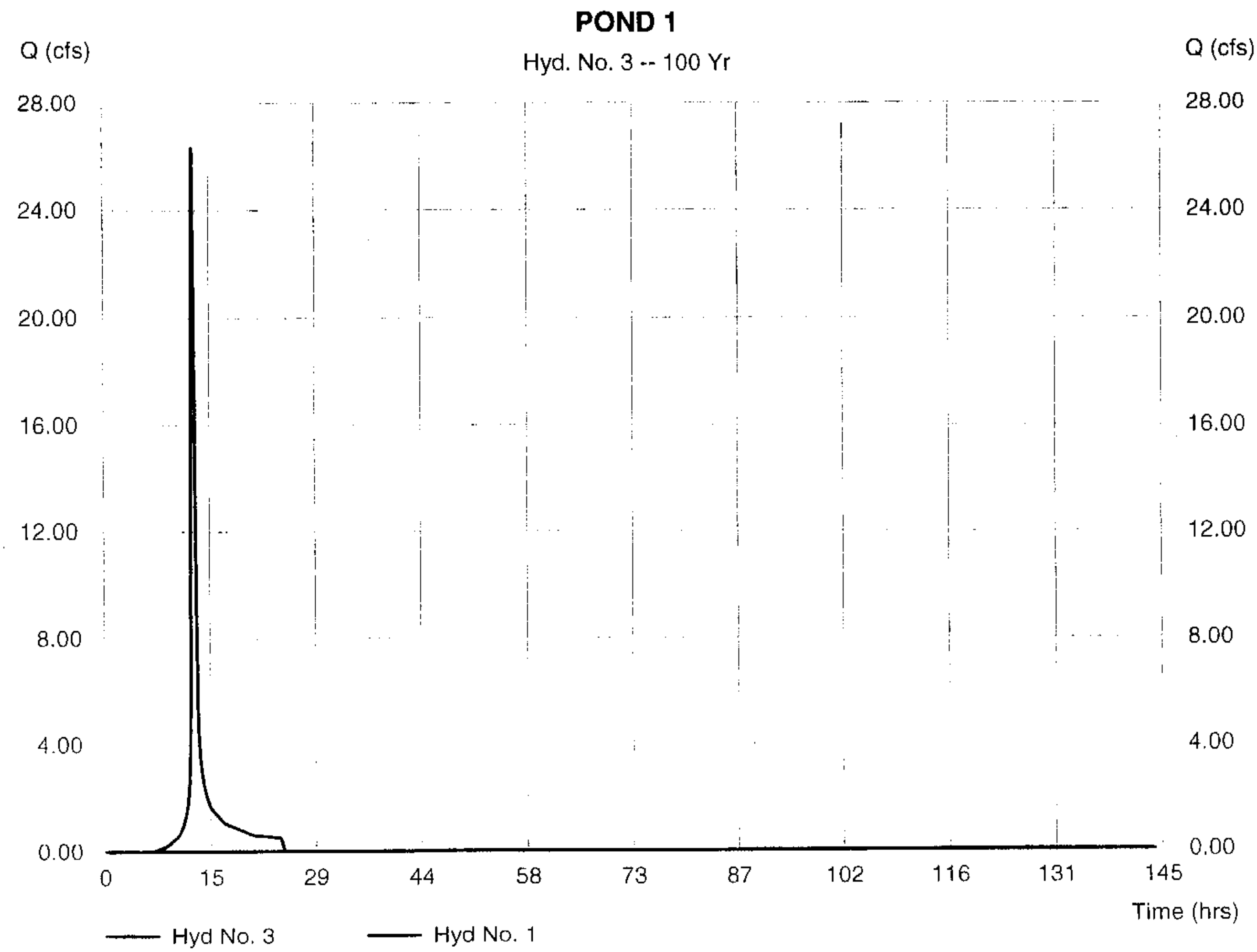
$= 56{,}016$ CFt/24hr

Hyd. No. 3

POND 1

Hydrograph type	= Reservoir	Peak discharge	= 0.000 cfs
Storm frequency	= 100 yrs	Time interval	= 3 min
Inflow hyd. No.	= 1	Max. Elevation	= 302.82 ft ←
Reservoir name	= POND 1- OPTION 1	Max. Storage	= 228,782 cuft

Storage Indication method used. Wet pond routing start elevation = 301.00 ft. — Hydrograph Volume = 0 cuft



Pond Report

Hydraflow Hydrographs by Intelisolve | Friday, Mar 6 2009, 2:51 PM

Pond No. 1 - POND 1- OPTION 1

Pond Data

Pond storage is based on known contour areas. Average end area method used.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	299.00	50,233	0	0
1.00	300.00	55,161	52,697	52,697
2.00	301.00	60,245	57,703	110,400
3.00	302.00	65,419	62,832	173,232
4.00	303.00	70,652	68,036	241,268
5.00	304.00	75,943	73,298	314,565

Culvert / Orifice Structures

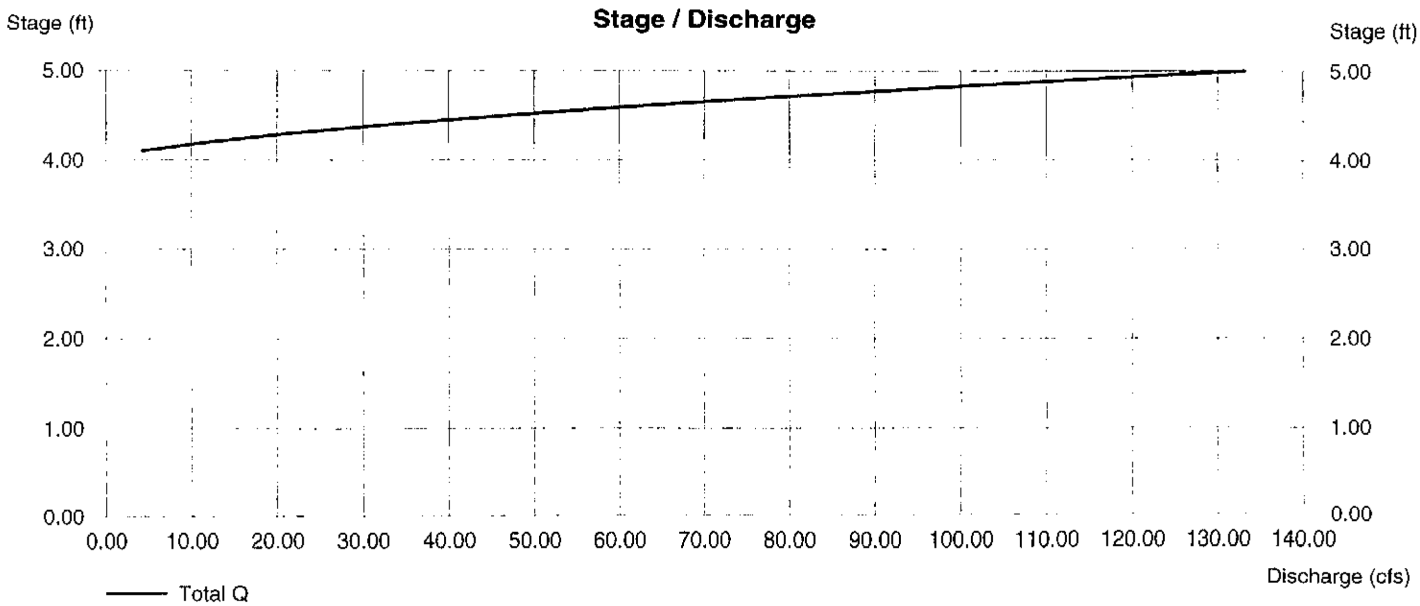
	[A]	[B]	[C]	[D]
Rise (in)	= 0.00	0.00	0.00	0.00
Span (in)	= 0.00	0.00	0.00	0.00
No. Barrels	= 0	0	0	0
Invert El. (ft)	= 0.00	0.00	0.00	0.00
Length (ft)	= 0.00	0.00	0.00	0.00
Slope (%)	= 0.00	0.00	0.00	0.00
N-Value	= .000	.000	.000	.000
Orif. Coeff.	= 0.00	0.00	0.00	0.00
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 40.00	0.00	0.00	0.00
Crest El. (ft)	= 303.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	0.00	0.00	0.00
Weir Type	= Rect	---	---	---
Multi-Stage	= No	No	No	No

Exfiltration = 0.000 in/hr (Contour) Tailwater Elev. = 0.00 ft

Note: Culvert/Orifice outflows have been analyzed under inlet and outlet control.



APPENDIX E

STORMWATER DISCHARGE OUTFALL (SDO)
MONITORING REPORT

Permit Number: NC S000382 or
Certificate of Coverage Number: NCG

FACILITY NAME Compost Central
PERSON COLLECTING SAMPLE(S) P. Ronald Eubanks
CERTIFIED LABORATORY(S) Mecklenburg County Lab # 192
Lab #

SAMPLES COLLECTED DURING CALENDAR YEAR: 2003
(This monitoring report shall be received by the Division no later than 30 days from the date the facility receives the sampling results from the laboratory.)
COUNTY Mecklenburg
PHONE NO. (704) 336-5500

(SIGNATURE OF PERMITTEE OR DESIGNEE)
By this signature, I certify that this report is accurate complete to the best of my knowledge.

Part A: Specific Monitoring Requirements

Outfall No.	Date Sample Collected	50050 Total Flow	Biochemical Oxygen Demand	Chemical Oxygen Demand	Total Kjeldahl Nitrogen	Nitrate + Nitrite Nitrogen	Ammonia Nitrogen	Total Phosphorus	Fecal Coliform
	mo/dd/yr	MG	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	colonies/100ml
SDO 1	12/17/03	0.14	22.3	842	19	0.24	0.42	10.4	44,000
SDO 2	12/17/03	0.42	31.4	247	5.8	0.25	0.77	1.95	43,000

Does this facility perform Vehicle Maintenance Activities using more than 55 gallons of new motor oil per month? __ yes __no
(if yes, complete Part B)

Part B: Vehicle Maintenance Activity Monitoring Requirements

Outfall No.	Date Sample Collected	50050 Total Flow	00556 Oil and Grease	00530 Total Suspended Solids	00400 pH	New Motor Oil Usage
	mo/dd/yr	MG	mg/l	mg/l	unit	gal/mo
SDO 1	12/17/03	0.14	<6	51	7.65	>55
SDO 2	12/17/03	0.42	<6	34	7.73	>55

STORM EVENT CHARACTERISTICS:

Mail Original and one copy to:
Division of Water Quality
Attn: Central Files
1617 Mail Service Center
Raleigh, North Carolina 27699-1617

Date 12/17/03
Total Event Precipitation (inches): 0.20
Event Duration (hours): 3.0

(if more than one storm event was sampled)

Date ________
Total Event Precipitation (inches): ___________
Event Duration (hours): ________

"I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations."

________________________________ 12/17/03
(Signature of Permittee) **(Date)**

STORMWATER DISCHARGE OUTFALL (SDO)
MONITORING REPORT

Permit Number: NC S000382 or
Certificate of Coverage Number: NCG

SAMPLES COLLECTED DURING CALENDAR YEAR: 2002
(This monitoring report shall be received by the Division no later than 30 days from the date the facility receives the sampling results from the laboratory.)

FACILITY NAME Compost Central
PERSON COLLECTING SAMPLE(S) P. Ronald Eubanks
CERTIFIED LABORATORY(S) Mecklenburg County Lab # 192
Lab #

COUNTY Mecklenburg
PHONE NO. (704) 336-5500

(SIGNATURE OF PERMITTEE OR DESIGNEE)
By this signature, I certify that this report is accurate complete to the best of my knowledge.

Part A: Specific Monitoring Requirements

Outfall No.	Date Sample Collected	50050 Total Flow	Biochemical Oxygen Demand	Chemical Oxygen Demand	Total Kjeldahl Nitrogen	Nitrate + Nitrite Nitrogen	Ammonia Nitrogen	Total Phosphorus	
	mo/dd/yr	MG	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
SD01	12/13/02	0.031	14.3	486	15	0.14	0.61	3.61	
SD02	12/13/02	0.094	50.8	244	5.3	0.59	0.10	1.76	

Does this facility perform Vehicle Maintenance Activities using more than 55 gallons of new motor oil per month? ✓ yes __no
(if yes, complete Part B)

Part B: Vehicle Maintenance Activity Monitoring Requirements

Outfall No.	Date Sample Collected	50050 Total Flow	00556 Oil and Grease	00530 Total Suspended Solids	00400 pH	New Motor Oil Usage
	mo/dd/yr	MG	mg/l	mg/l	unit	gal/mo
SD01	12/13/02	0.031	< 5	285	8.19	>55
SD02	12/13/02	0.094	< 5	47	7.06	>55

Form SWU-246-051100

STORM EVENT CHARACTERISTICS:

Date 12/13/02
Total Event Precipitation (inches): 0.95
Event Duration (hours): 15.0

(if more than one storm event was sampled)

Date ________
Total Event Precipitation (inches): ________
Event Duration (hours): ________

Mail Original and one copy to:
Division of Water Quality
Attn: Central Files
1617 Mail Service Center
Raleigh, North Carolina 27699-1617

"I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations."

____
(Signature of Permittee)

12/13/02
(Date)

NUTRIENT MOVEMENT FROM A WINDROW OF DAIRY BEDDING/LEAF MULCH COMPOST

Rose Mary Seymour[1] and Michael Bourdon[2]

AUTHORS: [1]Public Service Assistant, Biological and Agricultural Engineering Department, University of Georgia, 1109 Experiment St., Griffin, GA 30223; and [2]Former Graduate Research Assistant, Ecology and Environmental Sciences, University of Maine Orono, ME 04469.

REFERENCE: Proceedings of the 2003 Georgia Water Resources Conference, held April 23-24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. To evaluate movement of nutrients from compost windrows, a test bed was designed to capture the runoff from and effluent leaching (leachate) through a moderate size compost windrow. For six natural rain events, discharge volume over time was measured for leachate and runoff from a windrow created on top of the test bed along with rainfall intensity. Samples from leachate and runoff were analyzed for chemical constituents of nitrate-nitrogen, ammonium-nitrogen, total Kjeldahl nitrogen, dissolved phosphorus and pH. Nutrient concentrations from the compost effluents varied greatly for the six rainfall events. Nitrate-N concentration in leachate varied from 1.8 to 120 mg/L for the rainfall events. Nitrate-N concentrations from runoff ranged from 0.1 to 6.7 mg/L. Phosphorus concentrations were consistently higher in the leachate than in the runoff. The concentration of the nutrients in the leachate for some of the rain events were high enough to warrant concern for the pollution potential of large windrows placed directly on soils.

INTRODUCTION

There is little to no data available on the effects of rainfall on nutrient movement from composting windrows. Large uncovered windrows placed directly on soil surfaces or where runoff is not controlled can be a source of pollution from nutrients leaving the windrows in runoff or leachate infiltrating into soil during and after a rain event.

Composting is a recommended practice for dairy waste solids and for municipal leaf waste. Because the composting organic material has a high level of nutrients, the compost windrows may create a potential pollution problem from runoff and water leaching below the compost windrow into subsurface soils. For actively composting materials in a given setting, the amount of nutrients and mechanisms for movement of nutrients during rain events is poorly understood. Thus, the potential for pollution from composting windrows is unknown.

Without a better understanding of nutrient movement from compost windrows, improved practices to prevent the loss of nutrients from windrows cannot be sensibly recommended. A study was designed to measure nutrient movement from composting windrows due to natural rainfall. Samples of runoff and leachate were taken from composting windrows of dairy bedding (manure, urine and wood shavings) and municipal leaf waste. Chemical constituent concentrations of the effluent samples were measured, and the hydrology of the water movement through and over the windrows was quantified.

BACKGROUND AND RELATED WORK

Field studies to measure movement of nutrients from composting windrows have looked at different composting mixtures and constituents. In a study of different composting windrow mixtures of manure and straw, Ulen (1993) found elevated nitrogen (N) concentrations in leachate and increased concentrations of other nutrients such as phosphorus (P) and potassium (K) in runoff. Richard and Chadsey (1990), took water samples with suction lysimeters at various depths below municipal leaf waste composting in windrows. Nitrate and potassium levels in the soils below the compost site were higher than surrounding soils. Warman and Termeer (1996) studied leachate from various mixtures of composting racetrack manure, grass clippings and municipal biosolids. They concluded that the grass clippings contain elevated nitrates due to lawn fertilization and when the grass cell walls rupture during decomposition, the nitrates could quickly leach from the windrow. Elevated macronutrient levels were observed only for the windrows containing grass clippings. Controlling excess losses of nitrate and phosphorus would require either decreasing the quantity of grass clippings or adding more of some other substrate with a higher C:N ratio. Eghball et al. (1997) sampled effluent from a concrete pad that held composting dairy manure and found the runoff from the windrows could contribute nutrients in concentrations high enough to pollute surface and ground waters.

METHODS

The study was set up at a farm composting facility on the Witter Farm in Old Town, Maine. A test bed with dimensions of 3.3 m X 15.2 m was established for the study. The test bed consisted of a gravel filled trench with an impermeable barrier below the gravel and a tile drain pipe at the bottom of the trench to capture the leachate coming out of the compost. The impermeable barrier was attached to PVC pipes cut in half and placed like gutters around the perimeter of the bed to capture runoff.

Runoff and leachate flow through the pipes were measured by ISCO flow meters. The flow meters also signaled ISCO automated samplers to take samples during the rainfall events according to the volume of water passing by the flow meters. Samples were taken at 50 L intervals during rainfall events. Samples were removed at the end of a rainfall event. Hydrologic data and effluent samples were collected from four different windrows that were established consecutively on the test bed. The number of samples varied from event to event and ranged from two samples to eight samples taken during an event. There were a total of six measured events.

Each sample was analyzed for nutrient concentrations. Chemical concentration results presented are the averaged concentrations of all samples taken for each event. Samples were filtered through a 2 micron filter. Chemical analysis of the filtrates included nitrate-N, ammonium-N, total Kjeldahl nitrogen (TKN), total dissolved phosphorus and pH for both the leachate and runoff. The detection limit for the TKN was 60 mg/L. For the nitrate-N and ammonium-N the detection limits were 0.05 mg/L.

The windrows were built to cover the entire collection pad with dimensions of 15.2 m X 3.3 m X 1.22 m. A tractor with a bucket formed the windrows. After the windrow was formed, a windrow turner mixed the substrates further.

The dairy manure was a heterogeneous mixture of manure and wood shavings used as animal bedding. This material was used in all windrows so the term 'manure' is used to describe the above mixture.

The yard waste was material collected from the University of Maine Campus and five surrounding municipalities and delivered to the composting site. This material was comprised primarily of fallen leaves (> 95% by volume), though there was some cut brush and other organic residuals. To provide proper C:N ratio (35:1) and moisture content (50 %) for composting, a volumetric ratio of 3:1, yard waste to manure was determined for the composting mix.

Each windrow was on the test bed for only 28 days. This length was chosen to focus on the initial composting phase because this is when the most rapid organic breakdown occurs during composting (NRAES 1992).

Temperature changes were used to determined when the windrow needed turning and mixing. The temperature was measured with a probe inserted into the center of the cross section of the windrow at three locations along the length of the windrow. The temperature was checked twice a week, and the windrow turned if the temperature reached or exceeded 66° C or when the temperature declined below 32° C. If neither of these conditions were met the windrow was turned 14 days from the last turning. The turning was carried out with a windrow turner attached to the side of a tractor.

RESULTS

Table 1 provides summary runoff and leachate discharge and rain data for the six events. The number of rain events and the amount of data collected were limited by a drought during the months the study was conducted. However, the results provided valuable information on some aspects of the hydrology and nutrient movement from the composting windrows. The observed characteristics were a unique combination for each rainfall event. The average rainfall intensity for an event ranged from 1.8 to 8.2 mm/hr. The duration of the rain events

Table 1. Summary of the rainfall, leachate and runoff data and the number of days since the compost windrow was established until the particular rainfall event occurred

Date and Pile ID	Total Time*	Age of Compost#	Cumulative Volume mm			Ratio of Effluent to Rain %		Rain in Windrow %	Max Rain mm/hr	Ave Rain mm/hr
			Rain	Leachate	Runoff	Leachate /Rain	Runoff/ Rain			
5/20/99-A	11:15	17	19.1	10.1	2.3	52.8	12.3	34.8	6.1	2.3
5/24/99-A	9:00	21	9.9	9.1	6.7	92.2	68.4	----	8.1	2.4
6/7/99-B	10:30	2	30.8	10.5	7.5	34.1	24.3	41.6	49.8	8.2
6/8/99-B	14:15	3	18.1	7.9	4.5	43.6	24.7	31.7	9.1	2.6
7/10/99-C	3:15	1	6.0	1.0	5.4	16.0	89.9	----	3.0	1.8
8/10/99-D	22:45	4	57.2	26.1	19.0	45.6	33.2	21.3	26.4	7.3

*Format of time interval is hours:minutes.
Age of compost is the number of days between when the pile was first established and the rainfall event occurred.

ranged from 3 hours and 15 minutes to 22 hours and 45 minutes.

On the gravel test bed, the percentage of rainfall that permeated the windrows was higher than the percentage that ran off the outside of the windrow for all but the lowest intensity event. The ratios of leachate to rain and runoff to rain were not related to average or maximum intensities of the rainfall. For all rain events, more of the total rainfall became runoff or leachate than was and held in the windrow mixture.

Unexpectedly, there were two events where the volumes of runoff and leachate together exceeded the volume of rainfall measured. The two rain events on May 24 and July 10 had the lowest total precipitation and were low intensity events, but there was more total volume of leachate and runoff from the windrow than the total volume of rainfall that fell on the windrow.

On May 24, 60 % of the total of the effluents was leachate. This excess leachate was due to the antecedent moisture conditions of the windrow, the windrow temperature and the ambient weather conditions just before and during the rain event. Just 3 days previously, on May 20, there had been rain that had left the windrow saturated. This windrow had been in place for 21 days and was past the hottest part of the composting process. There was little to no heat within the windrow to drive evaporation of the excess water from the windrow. Because it was late May and weather was overcast between May 20 and 24, the ambient conditions would not have created much evaporation from the windrow either for those three days. In this case, the runoff and leachate volumes together were 160 % of the estimated total rainfall volume that fell on the windrow.

The rain event on July 10 had a total of runoff and leachate that was 6 % more than the measured volume of rainfall for the event. While the rain gauge for measuring the rain was within 3 m of the windrow test bed, rain intensity is spatially highly variable. This 6+ % discrepancy was some combination of instrument error for the discharge measurements and error due to spatial variability of rain intensity at the site.

For the events where the total of leachate and runoff volumes were less than the total rain volume, the longer the storm duration the higher the percentage of the rain that became leachate and runoff. The rain event duration had more effect on the percentage of rain that became effluents than the rain intensities which showed no correlation with the percentage of rain that became leachate or runoff.

Tables 2 and 3 show the nutrient concentrations for the runoff and leachate samples, respectively. Nutrient concentrations were much lower in the runoff samples than the leachate samples for all events. Nitrate-N was over the drinking water standard concentration of 10 mg/L in leachate for all events except the largest rainfall intensity event. Nitrate-N in runoff was never over the drinking water standard. Ammonium-nitrogen did not have consistently higher concentrations for either runoff or leachate samples. Phosphorus was higher in the leachate than in the runoff for all but the longest lasting storm.

DISCUSSION

Results indicated that nitrogen can move out of composting windrows at concentrations that exceed drinking water standards under some rain conditions. The high concentrations of nitrate-N results from water moving out of and through the windrow due to wetting from rain. This leachate can infiltrate directly into soil below a windrow or with impervious surfaces, it would become a part of the runoff. However, proper design of the surface area where large scale composting will take place can minimize or prevent this problem.

An impermeable liner or compacted clay placed at or below a composting facility surface would prevent the leachate from windrows from moving deeper into the soil. The liner or clay would need to have some additional materials such as gravel or woodchips on top to allow for capture and drainage of the surface so that heavy turning

Table 2. Nitrogen and phosphorus concentrations and pH of runoff samples from compost windrows for six rainfall events

Date	NH4-N mg/L	NO3-N mg/L	TKN mg/L	P mg/L	pH
5/20	2.1	0.1	<60	12.0	7.6
5/24	6.3	0.8	<60	7.4	8.2
6/7	10.6	6.7	430	15.0	7.7
6/8	5.1	4.8	<60	11.1	7.7
7/10	7.7	1.4	181	16.3	8.6
8/10	38.6	1.8	284	27.8	8.3

Table 3. Nitrogen and phosphorus concentrations and pH of leachate samples from compost windrows for six rainfall events

Date	NH4-N mg/L	NO3-N mg/L	TKN mg/L	P mg/L	pH
5/20	1.4	34.1	83	20.3	8.0
5/24	0.6	12.0	73	20.7	8.2
6/7	28.4	21.0	171	20.6	8.7
6/8	34.3	11.0	190	26.0	8.6
7/10	2.2	120	185	17.0	8.9
8/10	0.3	1.8	235	19.0	8.1

and loading equipment could move over the surface soon after rain events.

However, this would result in more water collected on the surface and an increase in runoff as well as an increase in the nutrient concentrations in the runoff. To prevent the increase in nutrient concentration in the runoff, windrows can be covered with impermeable covers. Care must be taken in doing this so that the covers do not inhibit the flow of air into the windrows to maintain oxygen levels for the composting process. Serious odor problems could arise if the covers prevented air movement into the windrows.

Alternatively, windrows could remain uncovered and the runoff from the composting area could be captured. The captured runoff could be re-applied to the windrows when they needed moisture or it could be treated through constructed wetlands or other natural means and allowed to flow into nearby streams after treatment.

RECOMMENDATIONS

The study presented was limited in duration and only dealt with one mix ratio of dairy bedding and leaf waste. Other mixtures and composting materials would have different nutrient concentrations and characteristics, so other compost substrates need to be evaluated in similar studies.

The study only looked at the first 28 days of the windrow composting process. NRAES (1992) states that the maturing phase of the compost process accompanies an increase in nitrate concentrations in the compost. Also, Inbar et al. (1991) found increasing concentrations of nitrates in compost occurred after the rapid phase of the composting process. This suggests that at later stages there would be higher nitrate concentrations in both runoff and leachate from windrows. This hypothesis needs to be investigated as well as further studies on the mechanisms of nutrient movement throughout the composting process.

Another poorly understood issue with the movement of nutrients from open composting windrows is how the soil microbiology below the windrows are affected. Knowledge of soil microbiology changes that occur under compost windrow facilities could provide insight into the movement of nutrients in the soil and subsoil below windrow facilities.

ACKNOWLEDGEMENTS

This study was funded by the Maine Agricultural Experiment Station located at the University of Maine, Orono, Maine.

LITERATURE CITED

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APPENDIX G

APPENDIX F

Drexel UNIVERSITY

Geosynthetic Research Institute

475 Kedron Avenue
Folsom, PA 19033-1208 USA
TEL (610) 522-8440
FAX (610) 522-8441

GRI GEI GII GSI GAI GCI

Rev. 6: June 23, 2003
Revision schedule on pg. 14

GRI Test Method GM13*

Standard Specification for

"Test Properties, Testing Frequency and Recommended Warranty for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/ml, or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

1.4 This standard specification is intended to ensure good quality and performance of HDPE geomembranes in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive

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*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

values for test indicated, may be necessary under conditions of a particular application.

1.5 This specification also presents a recommended warrant which is focused on the geomembrane material itself.

1.6 The recommended warrant attached to this specification does not cover installation considerations which is independent of the manufacturing of the geomembrane.

Note 2: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

D 792 Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004 Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
D 1603 Test Method for Carbon Black in Olefin Plastics
D 3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5397 Procedure to Perform a Single Point Notched Constant Tensile Load – (SP-NCTL) Test: Appendix
D 5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
D 5885 Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
D 5994 Test Method for Measuring the Core Thickness of Textured Geomembranes
D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes

2.2 GRI Standards

GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet

GM 11 Accelerated Weathering of Geomembranes using a Fluorescent UVA-Condensation Exposure Device

GM 12 Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gage

2.3 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities." EPA/600/R-93/182, September 1993, 305 pgs.

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.
ref. EPA/600/R-93/182

Formulation, n - The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

4. Material Classification and Formulation

4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/ml, or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth HDPE geomembranes and Table 2 is for single and double sided textured HDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is soft.

Note 3: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of 23°C ± 2°C. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of 21°C ± 2°C. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of 23°C ± 2°C should be utilized for testing purposes.

Note 4: There are several tests often included in other HDPE specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693)
- Wide Width Tensile
- Water Vapor Transmission
- Water Absorption
- Ozone Resistance
- Modulus of Elasticity
- Hydrostatic Resistance
- Tensile Impact
- Field Seam Strength
- Multi-Axial Burst
- Various Toxicity Tests

Note 5: There are several tests which are included in this standard (that are not customarily required in other HDPE specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet

Note 6: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Puncture Resistance
- Stress Crack Resistance
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

Note 7: There are several GRI tests currently included in this standard. Since these topics are not covered in ASTM standards, this is necessary. They are the following:

- UV Fluorescent Light Exposure
- Asperity Height Measurement

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The properties of the HDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 8: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

11. Warranty

11.1 Upon request of the purchaser in the contract or order, a manufacturer's warrant of the quality of the material shall be furnished at the completion of the terms of the contract.

11.2 A recommended warranty for smooth and textured HDPE geomembranes manufactured and tested in accordance with this specification is given in Appendix A.

11.3 The warranty in Appendix A is for the geomembrane itself. It does not cover subgrade preparation, installation, seaming, or backfilling. These are separate operations that are often beyond the control, or sphere of influence, of the geomembrane manufacturer.

Note 9: If a warrant is required for installation, it is to be developed between the installation contractor and the party requesting such a document.

ENGLISH UNITS

Table 1(a) – High Density Polyethylene (HDPE) Geomembrane -Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. ave.)	D5199	nom.	Nom.	Nom.	Nom.	Nom.	Nom.	Nom.	Per roll
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density mg/l (min.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,00 lb
Tensile Properties *(1)* (min. ave.) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	63 lb/in. 114 lb/in. 12% 700%	84 lb/in. 152 lb/in. 12% 700%	105 lb/in. 190 lb/in. 12% 700%	126 lb/in. 228 lb/in. 12% 700%	168 lb/in. 304 lb/in. 12% 700%	210 lb/in. 380 lb/in. 12% 700%	252 lb/in. 456 lb/in. 12% 700%	20,000 lb
Tear Resistance (min. ave.)	D 1004	21 lb	28 lb	35 lb	42 lb	56 lb	70 lb	84 lb	45,000 lb
Puncture Resistance (min. ave.)	D 4833	54 lb	72 lb	90 lb	108 lb	144 lb	180 lb	216 lb	45,000 lb
Stress Crack Resistance *(2)*	D5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	per GRI-GM10
Carbon Black Content (range)	D 1603 *(3)*	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	20,000 lb
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(5)* (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	200,000 lb
Oven Aging at 85°C *(5)*, *(6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	per each formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	GM 11 D 3895 D 5885	N.R. *(8)* 50%	N.R. *(8)* 50%	N.R. *(8)* 50%	N.R. *(8)* 50%	N.R. *(8)* 50%	N.R. *(8)* 50%	N.R. *(8)* 50%	per each formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 in.

(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(3) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Adoption and Revision Schedule

for

HDPE Specification per GRI-GM13

"Test Properties, Testing Frequency and Recommended Warrant for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"

Adopted:	June 17, 1997
Revision 1:	November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.
Revision 2:	April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: "(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)" and to Note (4) in the property tables.
Revision 3:	June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the the designated test method.
Revision 4:	December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".
Revision 5:	May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.
Revision 6:	June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.