4873

NATURAL RESOURCE IMPACT ASSESSMENT AND NATURAL RESOURCE RESTORATION PLAN

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

JANUARY 2002

U.S. DEPARTMENT OF ENERGY
FERNALD AREA OFFICE

20300-RP-0002 REV. 0
212E-PL-0003 REV. 0

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LIST OF ACRONYMS

AWQC	Ambient Water Quality Criteria
BTV	Benchmark Toxicity Value
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	constituent of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ER-L	Effects Range - Lower
ER-M	Effects Range - Median
FEMP	Fernald Environmental Management Project
FRL	final remediation level
FS	Feasibility Study
gpm	gallons per minute
IEMP	Integrated Environmental Monitoring Plan
IRDP	Integrated Remedial Design Package
µg/l	micrograms per liter
mg/kg	milligrams per kilogram
MSL	mean sea level
NRDA	Natural Resource Damage Assessment
NRIA	Natural Resource Impact Assessment
NRRDP	Natural Resource Restoration Design Plan
NRRP	Natural Resource Restoration Plan
OEPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
PAH	polynuclear aromatic hydrocarbon
RI	Remedial Investigation
ROD	Record of Decision
SEP	Sitewide Excavation Plan
SERA	Sitewide Ecological Risk Assessment
TQ	toxicity quotient

Section 1.0

1.0 INTRODUCTION

The objective of this report is to present the natural resource impacts at the Fernald Environmental Management Project (FEMP) as defined by the Natural Resource Trustees (hereafter referred to as the Trustees). This assessment is being prepared to meet the regulatory responsibilities of the Trustees pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the National Oil and Hazardous Substance Pollution Contingency Plan. This report presents an assessment of past impacts and anticipated future impacts resulting from past releases of hazardous substances and planned remediation activities, as well as potential postremedial residual impacts.

This Natural Resource Impact Assessment (NRIA) is designed to identify injury to, loss of, or destruction of natural resources (here and after referred to as impact) that has occurred at the FEMP as a result of releases of CERCLA hazardous substances from past production operations and waste management processes, along with future remedial activities. Existing information has been utilized to assess the impacts of historic releases of CERCLA hazardous substances at the FEMP and the associated restoration activities that have been or will be undertaken. This impact assessment will meet the substantive requirements of an injury determination under CERCLA Section 107 by outlining all impacts for which the U.S. Department of Energy (DOE) is liable due to releases or threat of releases of hazardous substances.

The Trustees have chosen to focus on a restoration-based approach to resolve their concerns rather than the pursuit of a formal Natural Resource Damage Assessment (NRDA) that would calculate natural resource injury and corresponding damages (dollar amounts). If this approach proves to be sufficient, the Trustees will be able to save the time and expense of an NRDA. Upon concurrence with this NRIA, the Trustees will collectively develop a Natural Resource Restoration Plan (NRRP), which will outline appropriate restoration activities.

The NRRP (which will compensate for natural resource impacts) will be fully integrated with the CERCLA remedial design process for the excavation and remediation of soil at the site. This will allow restoration planning to be accelerated by implementing activities in sequence with soil excavation and grading. The NRRP will also provide a habitat equivalency analysis to ensure that proposed restoration activities are commensurate with the severity of the impacts outlined in the impact assessment. Both the

NRIA and NRRP will be made available to the public independently once all Trustees have concurred with the documents.

The Trustees have also prepared a letter of consensus describing the intended approach for implementing Trustee activities at the FEMP. The letter was signed in September 1996 and submitted to the U.S. Environmental Protection Agency (EPA). In addition, the letter was made available to all FEMP Stakeholders through notices in various publications and availability in the Public Environmental Information Center. This letter serves as a first step in formalizing an agreement among the Trustees to resolve natural resource impact issues at the FEMP through the restoration process. The process for resolving natural resource impacts will be outlined in this plan and the NRRP.

1.1 ASSESSMENT FORMAT

The approach for outlining impacts at the FEMP is to present past, future and residual impacts "area by area." The designation of FEMP "areas" for the purpose of this impact assessment is presented in Figure 1-1. The "areas" are based on those outlined in the Sitewide Ecological Risk Assessment (SERA) and the Miami University Biological and Ecological Characterization Survey. In some cases, the areas presented in the SERA have been consolidated due to the similarity in habitat types.

Past and future impacts are addressed separately in this assessment. A past impact is identified as either a physical disturbance to a portion of the site, a release of a hazardous substance to a portion of the site, or both. It is anticipated that areas of past impact to soils will be remediated to final remediation levels (FRLs) and physically impacted during remedial action. The areal extent of the groundwater contamination is presented in acres and volume. However, the quantification of the groundwater impact differs from other impacts since it does not constitute a habitat.

The designation of future impacts identifies areas that will be disturbed during remedial actions or areas that will be impacted by the future spread of contamination and does not necessarily include areas of past impact for the purposes of calculated acreage. In other words, if an area is identified as a past impact it is not counted again as a future impact, unless separate impacts to habitat occur.

Removal actions and other interim response actions will be discussed as either contributing to or possibly mitigating past impact. In some instances, actions have already been implemented at the FEMP to

address contamination issues (e.g., waste pit area storm water runoff control) and it may be appropriate for the Trustees to provide DOE credit for such projects when considering the severity of impacts and subsequent level of required restoration. Likewise, past response actions may have caused impact to a certain area and it may be appropriate to identify those as past impacts when considering severity.

As stated above, the Trustees have agreed to evaluate natural resource impacts to the extent possible using the existing information presented in Section 1.2. Since the original objectives of the existing reports and surveys were not to determine natural resource injury, certain assumptions must be made within this assessment. For instance, the purpose of the SERA was not to determine whether ecological receptors had been impacted. The purpose of the risk assessment was only to determine whether there was a *potential* for impact. The results of the ecological risk assessment have been used to determine the ecological impact contributing to each NRIA study area at the site. These impacts have been factored into the overall assessments of impacts outlined in this document. The Trustees must evaluate the severity of the potential ecological risks when determining appropriate restoration.

An important aspect of natural resource impact determination is the calculation of time frames. It is difficult to define time frames for all impacts using existing information, since establishment of detailed time frames for individual releases was not the intent of those documents. It has been assumed that past impacts could have occurred from 1952, the inception of production at the FEMP, and could continue until the onset of remedial activities. Where more detailed information is available, it is presented within the area-by-area assessments.

As stated above, once the Trustees have agreed upon the impacts that have occurred at the FEMP, they will then determine the appropriate restoration activities to compensate for those impacts. These activities will be conceptually addressed in the NRRP, which will be referenced in the SEP as the final restoration guidance document for excavated areas. Final grading plans will be established in the area-specific Integrated Remedial Design Packages (IRDPs). From that point, Natural Resource Restoration Design Plans (NRRDPs) will be developed for each ecological restoration project established in the NRRP. Each NRRDP will contain the site-specific design for ecological restoration. NRRDPs will consider site preparation, soils, species to be planted, densities, cover, maintenance, and monitoring.

1.2 PRIMARY SOURCES OF INFORMATION

1.2.1 RI/FS Process, Records of Decision, and Remedial Design

Remedial Investigations (RIs) and Feasibility Studies (FSs) have been prepared for Operable Units 1 through 5 to identify the extent of contamination and evaluate remedial action alternatives to address environmental concerns. A Proposed Plan and Record of Decision (ROD) were developed after each FS to document the selected alternative following consideration of EPA, Ohio Environmental Protection Agency (OEPA), and public comments. Each FS and ROD was written integrating the requirements of the National Environmental Policy Act into the evaluation of the anticipated environmental impacts associated with the implementation of cleanup actions for each of the five operable units. These anticipated environmental impacts were based on the implementation of the identified selected remedy in each ROD and are subject to change throughout the remedial design and remedial action process.

Figure 1-2 illustrates the extent of off-site uranium above-background concentrations in soil around the FEMP (DOE 1995a). These soil concentrations are approximately 6,942 acres and are recognized as an impact within the impact assessment. Although uranium concentrations in soils around the FEMP exceed background, they do not present an unacceptable risk to human and ecological receptors provided they are below accepted cleanup levels. While the goal of remediation may be to manage risk at acceptable levels, the goal of restoration is to return natural resources to baseline conditions to compensate for interim lost services.

FRLs at the FEMP (DOE 1995b) have been used to determine past impact with respect to the areal extent of soil contamination. The predicted "footprint" of soil excavation is primarily driven by FRL concentrations, and is shown on Figure 1-3. This footprint is used as the primary basis for establishing past impacts to soil throughout this assessment. Figure 1-3 also identifies areas of past ecological impact. These are discussed throughout Section 2.0 as "Past Impacts" for each study area.

A similar approach has been used for determining groundwater impacts. Figure 1-4 illustrates the extent of uranium in the Great Miami Aquifer that is above background [3 micrograms per liter (μg/l)]. As with soil, this is recognized as an impact even though it does not require remediation and does not require natural resource restoration. For the purpose of quantifying impacts, the extent of contamination is limited to 20 μg/l. This concentration is the proposed standard for uranium in drinking water and is the

cleanup level established in the Operable Unit 5 ROD (DOE 1995b). Non-uranium contamination for both soil and groundwater is not considered for estimating impacts for this assessment.

1.2.2 Sitewide Ecological Risk Assessment

The SERA is an appendix to the Operable Unit 5 RI and was conducted to determine if radiological and non-radiological constituents associated with actions at the FEMP represent a current or future risk to ecological receptors inhabiting this facility and nearby areas, including the Great Miami River. These receptors include all organisms, exclusive of humans and domestic animals, that may potentially be exposed to FEMP site constituents.

To evaluate potential exposure of ecological receptors to these constituents, the FEMP property was divided into study areas based on habitat type and home-range size. This approach allowed constituent concentrations within a given habitat to be quantified, which allowed more contaminated habitats to be evaluated separately from less contaminated study areas.

Analytical data used to prepare this assessment are from the sitewide RI/FS database, which has been validated pursuant to EPA guidance. Although data have been collected since 1988, the SERA has preferentially examined data collected in 1993, when available. In those instances when such data were limited, data collected before 1993 were evaluated.

Non-radiological and radiological risks were evaluated within the SERA. Potential radiological risks to ecological receptors due to chronic exposure to low levels of radiological constituents were evaluated. To calculate the internal and external doses, media- and site-specific data were evaluated in a model, and the results compared to a target level dose published in 1992 by the International Atomic Energy Agency. The basis for the target level dose is presented in *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards* (International Atomic Energy Agency 1992).

Results from this risk assessment indicated that on- and off-property soil concentrations of radionuclides did not result in a radiological dose exceeding the target level (36.5 rad/year) used to evaluate the potential risk posed to ecological receptors exposed to radionuclide constituents. The International Atomic Energy Agency (1992) has concluded there is no convincing evidence from the scientific

literature that chronic radiation dose rates below 36.5 rad/year will harm animal or plant populations. All calculated doses conducted in this ecological risk assessment are below the trigger level dose of 36.5 rad/year. The highest calculated dose for any receptor was 3.12 rad/year, which is an order of magnitude lower than the target level of 36.5 rad/year. Therefore, based on the measured levels of radioactivity on the FEMP, there is no threat of radiation effects to populations of terrestrial plants or terrestrial or aquatic animals.

For non-radiological risks, media-specific constituents levels were compared to media-specific benchmark toxicity values (BTVs), which are literature-derived concentrations considered protective of ecological receptors. Constituents exceeding these values were regarded as final constituents of concern (COCs) and the relative risk each of these might pose to FEMP ecological receptors was evaluated.

In general, BTVs are derived from various sources and are updated on a regular basis. An exceedance of BTVs does not prove impact; it only indicates an increased probability of impact. BTVs are divided into representative concentrations for each area to obtain a toxicity quotient (TQ). TQs only identify the magnitude to which the constituent exceeds the BTV, but they do not estimate the probability or risk level. Although BTVs often include general considerations of bioavailability, site-specific conditions can increase or decrease exposure. Examples include percent of clay for metals in soil, total suspended solids in surface water, and total organic carbon for non-polar compounds in sediment. Some of these conditions were preliminarily considered in the SERA. BTVs are not threshold levels that drive the extent of excavation. BTVs provide a conservative screen that indicates the potential for ecological impacts.

The SERA indicated that a number of non-radiological contaminants are present in soil, surface water, and sediment in concentrations that pose a potential current risk to ecological receptors. These findings are discussed in greater detail later in this document. The remedial design approach for addressing ecological risks is found in Appendix C to the Sitewide Excavation Plan (SEP, DOE 1998).

Appendix C of the SEP expands the scope of the SERA to include all source Operable Units, and it provides an updated BTV screen using the latest sitewide data. During re-evaluation it was determined that many of the constituents identified in the SERA are no longer a concern. Therefore, it is important to realize that while the SERA was used during the development of the NRIA as a baseline

impact-defining document, new information has revealed that some of the SERA results are no longer accurate. For most of the study areas, the lists of parameters in each section have been amended within Appendix C of the SEP. The NRRP provides a summary of the SEP Appendix C findings.

1.2.3 Biological and Ecological Characterization of the Feed Materials Production Center

Researchers from Miami University conducted comprehensive surveys of the flora and fauna of the FEMP site in 1986 and 1987. Various methods were used to conduct on-property species counts of herbaceous and woody plants, terrestrial invertebrates, benthic macroinvertebrates, fish, birds, small mammals, and game animals. In addition, an attempt was made to evaluate impacts on the genetic structure of FEMP flora and fauna. Samples were collected to conduct electrophoretic analysis of select species of plants, insects, amphibians, benthic macroinvertebrates, and fish.

The goal of this research effort was to identify habitats and biota at the FEMP site, determine the species abundance and distribution of FEMP site flora and fauna, and identify, if possible, "stress-induced" differences between on-property and off-property biota.

Findings from this effort prompted several follow-up studies on FEMP robins and spring peeper frogs and tadpoles. These follow-up studies are discussed further in Sections 2.4 and 2.6.

1.3 FEMP NATURAL RESOURCES

The FEMP lies within the Till Plains region of the Central Lowland Physiographic Province in southwestern Ohio. This area is characterized by gently to steeply rolling hills, which were formed as a result of several periods of glaciation. The topography of the area ranges from approximately 500 feet above mean sea level (MSL) along the Ohio River to almost 900 feet MSL on the hilltops (DOE 1993).

In the vicinity of the FEMP site, the hilly topography is separated by broad, flat areas that comprise the floodplains of the larger surface water features. Prominent geographical areas in the vicinity of the FEMP site include the floodplains of the Great Miami River and the floodplains of the Whitewater River and Dry Fork Creek southwest of the FEMP (DOE 1993). The FEMP site lies directly over the Great Miami Aquifer, which is the principal groundwater resource within the region. The Great Miami Aquifer has been designated as a sole-source aquifer under the provisions of the Safe Drinking Water Act and Ohio Administrative Codes. Principal sources of recharge for the Great Miami Aquifer include direct

precipitation and natural and induced stream infiltration. Bedrock serves as a limited source of recharge in the area of the FEMP with water movement restricted through fractures and along bedding planes due to the impermeable nature of the shale units (DOE 1993).

In the vicinity of the FEMP, three surface water features predominate. These include the Great Miami River, Paddys Run, and a tributary to Paddys Run referred to as the Storm Sewer Outfall Ditch. Paddys Run parallels the western property boundary of the site and flows south into the Great Miami River. The Storm Sewer Outfall Ditch and headwater of the tributary are located in the southern portion of the FEMP site and feed into Paddys Run. The Great Miami River flows just east of the FEMP and exhibits sharp meandering patterns.

The FEMP and surrounding areas lie in a transition zone between two distinct sections of the Eastern Deciduous Forest Province as described by Bailey (1978): the Oak-Hickory and the Beech-Maple forests. The region is characterized by the presence of a mosaic of these forest types. The Oak-Hickory and Beech-Maple forest sections share many characteristics (e.g., white oak as a common species).

Terrestrial ecological communities on the FEMP site consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, riparian woodlands, and the "reclaimed flyash pile area." The reclaimed flyash pile area coincides with the South Field and the Inactive Flyash Pile and was considered a distinct habitat by researchers at Miami University because of its status as an old field (Facemire *et al.* 1990). A total of 47 species of trees and shrubs, 190 species of herbaceous plants, 20 mammal species, 98 bird species, 10 species of amphibians and reptiles, 21 species of fish, 47 families of benthic macroinvertebrates, and 132 families of terrestrial invertebrates were catalogued at the FEMP site by Miami University researchers.

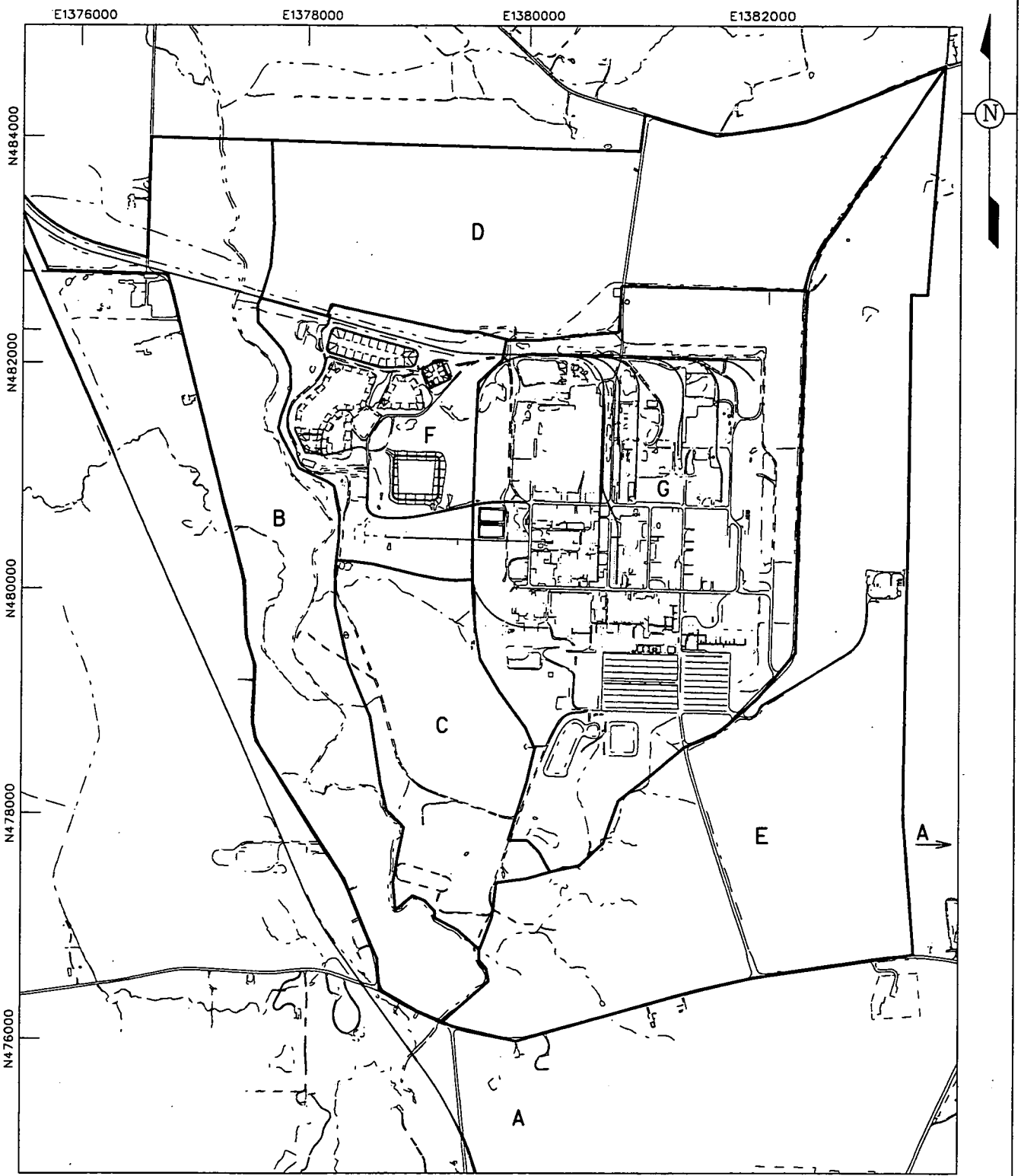
Several surveys for threatened and endangered species have been conducted at the FEMP. Between 1993 and 1995, surveys were conducted for the federally-endangered Indiana bat (*Myotis sodalis*) and running buffalo clover (*Trifolium stoloniferum*), the state-endangered cave salamander (*Eurycea lucifuga*), spring coralroot (*Corallhorhiza wisteriana*), slender fingergrass (*Digitaria filiformis*), and mountain bindweed (*Polygonum cilinode*), and the state-threatened Sloan's crayfish (*Orconectes sloanii*). Results of these surveys show that the FEMP has a population of Sloan's crayfish within Paddys Run, and suitable habitat for the Indiana bat, running buffalo clover, and spring coralroot. Surveys indicated no

species or suitable habitat. Several state threatened or endangered migratory birds were sighted on the FEMP during the Miami University study but are not actually residing on property. These include the northern harrier (*Circus cyaneus*), northern waterthrush (*Seiurus noveboracensis*), and dark-eyed junco (*Junco hyemalis*).

A sitewide wetlands delineation was conducted in January 1993 in accordance with the 1987 U.S. Army Corps of Engineers Wetlands Delineation Manual and was approved on August 12, 1993 by the U.S. Army Corp of Engineers, Louisville District. The purpose of the delineation was to determine the extent of jurisdictional wetlands and waters of the United States at the FEMP site so response actions could be planned to avoid or minimize impacts to these resources. Results from the sitewide delineation indicate a total of 36.4 acres of jurisdictional freshwater wetlands on the FEMP site. Approximately 26 acres of these wetlands occur as forested wetlands in the northern woodlot.

A watershed study on the forested wetland was completed in 1996. The results of the study will provide information on the feasibility of expanding the forested wetland to support on-property wetland mitigation. If expanding the forested wetland is feasible, plans to do so will be factored into the NRRP.

FILE NAME /res3028/fig1.dgn 8x11 gru5 7-17-96 GES STATE PLANAR COORDINATE SYSTEM 1927

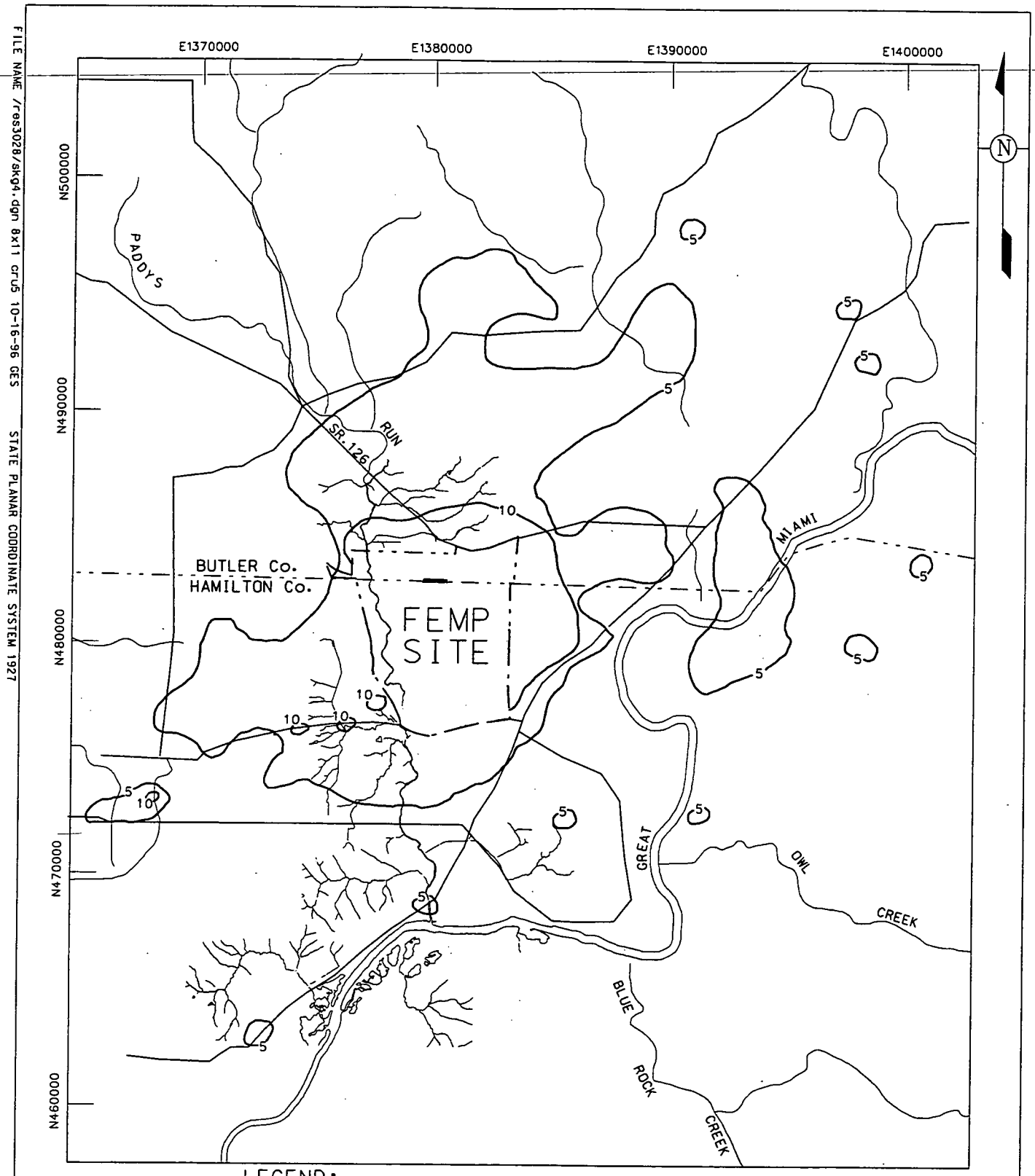


LEGEND:

——— FEMP BOUNDARY
A– G.M.R. + G.M.A.
B– PADDYS RUN CORRIDOR
C– SOUTHERN PINES AND WASTE UNITS
D– NORTHERN PINES AND WOODLOT
E– GRASSLANDS
F– WASTE STORAGE AREA
G– PROCESS AREA

SCALE
1200 -600 0 1200 FEET

FIGURE 1-1. IMPACT ASSESSMENT STUDY AREAS



LEGEND:

— · · — FEMP BOUNDARY

5 5. 10 AND 20 mg/kg ISOCONCENTRATION CONTOUR FOR TOTAL URANIUM IN SOIL.

SCALE

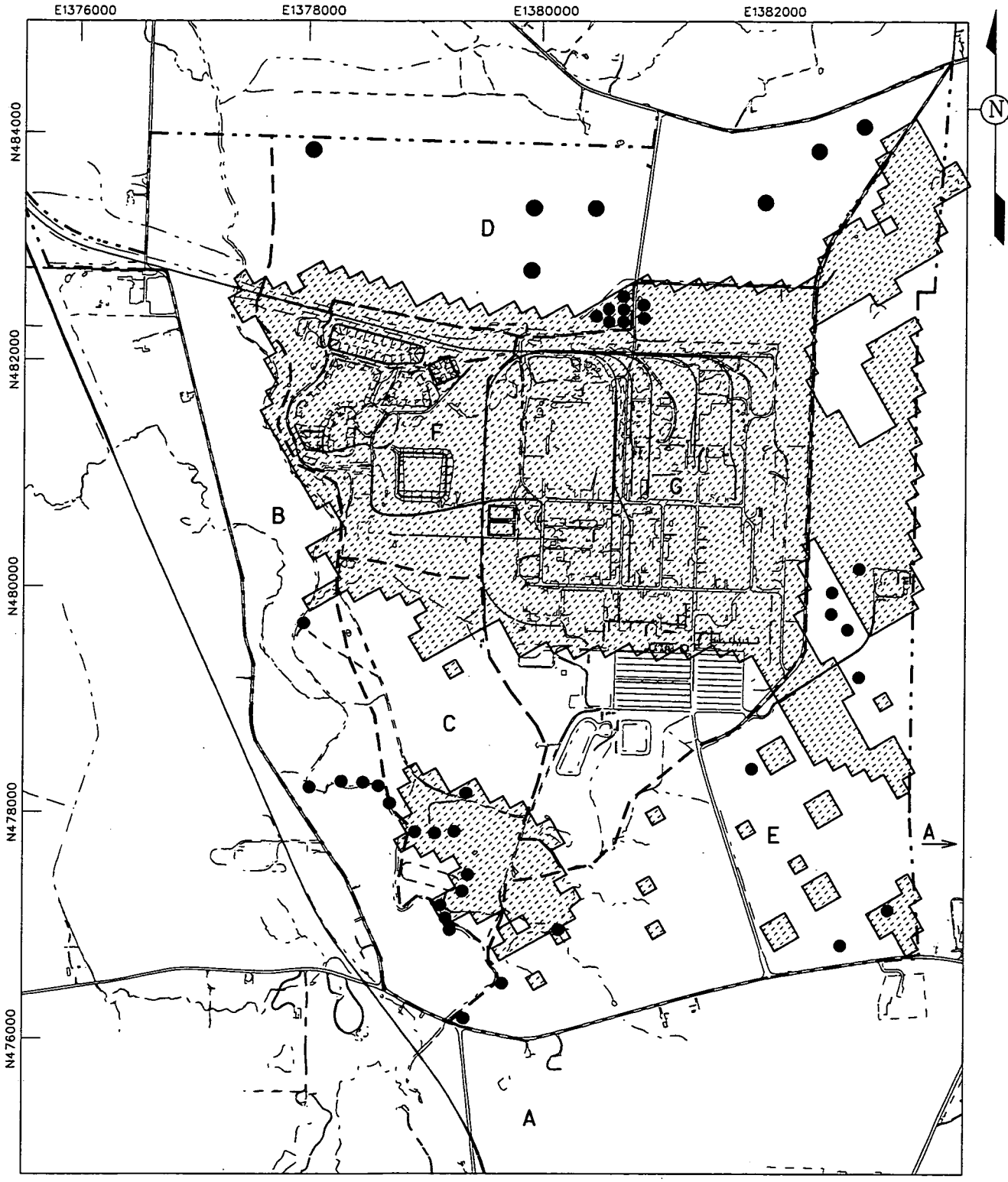
0 3000 6000 FEET

000016

FILE NAME /res3028/skg4.dgn 8x11 cru5 10-16-96 GES STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 1-2. OFF-SITE ISOCONCENTRATION CONTOURS FOR TOTAL URANIUM IN SOIL ABOVE BACKGROUND CONCENTRATIONS

FILE NAME /res3028/fig1-1a.dgn 8x11 cru5 7-17-96 GES STATE PLANAR COORDINATE SYSTEM 1927



LEGEND:

- FEMP BOUNDARY
- AREAL EXTENT OF SOIL CONTAMINATION AT THE FEMP
- AREAS OF PAST ECOLOGICAL RISK
- STUDY AREAS

SCALE

1200 600 0 1200 FEET

FIGURE 1-3. CONTAMINATED AREAS AT THE FEMP SITE (ABOVE FRLs AND BTVs)

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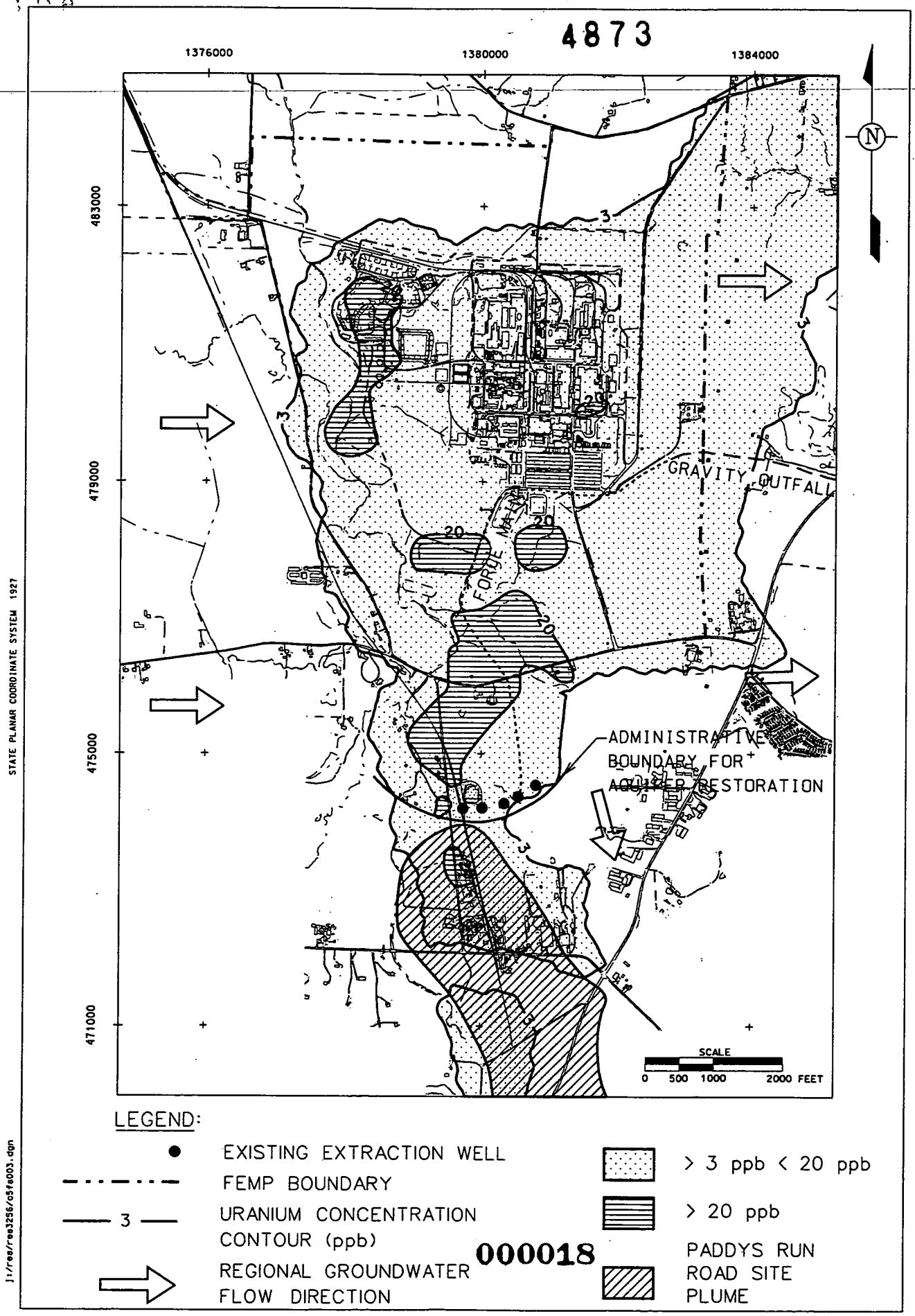

000018

FIGURE 1-4. EXTENT OF URANIUM CONTAMINATION IN THE GREAT MIAMI AQUIFER

Section 2.0

2.0 IMPACT ASSESSMENT

This section describes the extent of past impacts and anticipated future and residual impacts based on the information in Section 1.0.

2.1 GROUNDWATER

A summary of FEMP groundwater impacts is presented below. This Impact Assessment will consider the Great Miami Aquifer with respect to past and anticipated future impacts. Remediation of perched groundwater will be addressed during soil excavation (discussed further below).

2.1.1 Great Miami Aquifer

2.1.1.1 Past Impacts

An assessment of past impacts to the Great Miami Aquifer can be made from the conclusions of the Operable Unit 5 RI. Using data collected in 1993, the Operable Unit 5 RI demonstrated that uranium was the primary groundwater contaminant within the Great Miami Aquifer. As described in Section 1.2.1 and shown on Figure 1-4, past impacts to the Great Miami Aquifer are recognized as the extent of above-background uranium concentrations. For the purpose of quantifying impacts, the remedial action level of 20 µg/l was assessed. Using the current 20 µgl total uranium contour as shown on Figure 2-1, the areal extent of contamination to be remediated within the Great Miami Aquifer is 172 acres. The total uranium remediation goal for the Great Miami Aquifer was obtained by using the proposed maximum contaminant level of 20 µg/l for uranium under the Safe Drinking Water Act.

This contamination is primarily the result of six distinct point or line source plumes that originate from the following areas: the Waste Storage Area (1952); the stretch of Paddys Run adjacent to the Waste Storage Area (1952); Plant 6 (1952); the Inactive Flyash Pile (1957), South Field (1957), and Active Flyash Pile (mid 1960s); the southern stretch of Paddys Run and the Storm Sewer Outfall Ditch (1951); and the stretch of Paddys Run south of New Haven Road (1951). It is reasonable to assume that the Great Miami Aquifer has been receiving contamination from these sources as long as these waste units have been in place. Therefore, the time frames have been provided in parenthesis to indicate when the source was constructed or approximately when the source began contributing to the contamination of the aquifer.

Researchers did not consider groundwater a specific medium of concern when conducting the SERA. It was assumed instead that surface water samples would reflect contaminant concentrations to which ecological receptors were exposed, regardless of the source of the contamination, be it groundwater, nonpoint, or point source discharge. Miami University researchers did not investigate groundwater in the site characterization study.

Other Actions

Several CERCLA Removal Actions have been conducted in recent years that have reduced contaminant loading to the Aquifer and migration of the off-property portion of the plume in the Great Miami Aquifer. The most influential of these is the South Groundwater Contamination Plume Removal Action. This removal action is designed to protect public health by pumping and treating uranium-contaminated groundwater in an area south of the FEMP site. The action consists of five parts. Part 1, initiated in May 1992, provides an alternate water supply to an industrial user affected by the contamination plume. Part 2, initiated in July 1992, consists of the installation of a recovery well system to remove the contaminated water and pump a portion of it to the FEMP site for treatment, monitoring, and discharge. It also includes increasing the pump-out capacity of the storm water retention basin to reduce the potential for future overflows. Pumping of the recovery wells is projected to continue for about 25 years. Part 3 is construction of an interim advanced wastewater treatment system to remove uranium from FEMP site waste water streams. Part 4, implemented through the FEMP's existing groundwater monitoring program, involves monitoring and institutional controls to prevent the use of contaminated groundwater by including more frequent monitoring of private wells located near areas of known contamination. Part 5 is additional investigations to identify the location and extent of any remaining contamination attributable to the FEMP site south (downgradient) of the recovery wells being installed under Part 3.

Implementation of the South Plume Removal Action has had a positive impact on natural resources by preventing further migration of the plume. Well installation did result in the commitment of several acres of land for access roads and well heads.

Other Removal Actions have been beneficial to the Great Miami Aquifer by indirect reduction or elimination of contaminant sources. Examples of these are the Waste Pit Area Runoff Control and the

Inactive Flyash Pile Removal Actions. Refer to Section 2.2 for a more detailed description of these Removal Actions.

The DOE also provided $5.4 million to partially fund the installation of a public water line to local residents. Residents/businesses in the vicinity of the FEMP and the contaminated groundwater plume were connected to the water line in the spring of 1996. This project essentially eliminated the need to use the Great Miami Aquifer as a drinking water source within the impacted zone.

In addition to impacts to the Great Miami Aquifer, impacts to perched groundwater have also occurred as a result of past releases. Perched groundwater impacts have occurred in approximately 96 acres within the footprint of Study Areas C, E, F, and G (Figure 2-2). Remediation of approximately 72 acres of perched groundwater contaminated above the FRLs will occur as part of soil remediation. Since perched groundwater impacts have occurred in areas already identified as impacted in Figure 2-2, the 96 acres will not be counted twice in calculating required restoration acreage. However, perched groundwater impacts should be considered when the severity of impacts in a specific study area are considered.

2.1.1.2 Future Impacts

According to the Operable Unit 5 FS (DOE 1995c), anticipated future impacts include areas of the Great Miami Aquifer exceeding FRLs that will be restored through extraction, re-injection, and treatment. Modeling to derive the base case groundwater remedy in the Operable Unit 5 FS identified the need for 28 extraction wells with a combined maximum pumping rate of 4,000 gallons per minute (gpm) from the extraction well system for 27 years. The 4,000 gpm includes treated groundwater (1,800 gpm) and untreated groundwater (2,200 gpm) which equate to 9.4×10^8 and 1.1×10^9 gallons per year, respectively. Assuming the 4,000 gpm is maintained for 27 years, a total of 5.0×10^{10} gallons of water from the Great Miami Aquifer will be pumped over approximately 27 years, until the proposed 20 μg/l drinking water standard is met. The accelerated cleanup plan calls for remediation or the Great Miami Aquifer in approximately 10 years. This effort requires the installation of eight additional extraction wells and an increase in the pumping rate to 4,700 gpm. The Baseline Remedial Strategy for Aquifer Restoration (DOE 1997) outlines the approach and schedule for aquifer restoration at the FEMP. The continued pumping of the wells will not impact the aquifer as a whole due to its size and volume and re-injection efforts. In addition, the aquifer does not function as a geological or ecological support mechanism and the risk of subsidence due to continued pumping is negligible.

Groundwater extraction from the South Plume recovery well installed as part of Removal Action Number 3 (approved by EPA and implemented in 1993) has drawn groundwater contaminated above the uranium FRL further south (Figure 2-3). Continued pumping to remediate the aquifer will result in groundwater contaminated above the FRL being drawn even further south towards the existing South Plume extraction wells in off-property areas. In effect, this will result in the migration of groundwater contaminated above the FRL into areas that are not currently contaminated above 20 µg/l. This will occur directly south of the FEMP property and is not expected to affect more than 15 additional acres (DOE 1997).

2.1.1.3 Residual Impacts

After completion of the proposed remedy, there will be a certain amount of groundwater remaining that is below the 20 µg/l cleanup level yet still above the background concentration of 3 µg/l, which is difficult to quantify. Figure 2-3 shows approximately 1,198 acres of above-background contamination as of the completion of the Operable Unit 5 RI/FS. Since the extent of post-remediation residual contamination is unknown, it is assumed that the extent of this above-background contamination will be similar to current conditions (i.e., about 1,198 acres). However, there are two factors influencing this estimate. First, the remedial action will pump and treat some quantity of groundwater below 20 µg/l. Second, once remedial actions have been completed, the remaining groundwater above background concentrations (but below the FRL) will dissipate over time, gradually decreasing in concentration until it reaches background conditions.

2.1.2 Great Miami River

2.1.2.1 Past Impacts

Samples of surface water from the Great Miami River were taken in 1993. Results of this sampling effort reveal that there was some increase in uranium contamination downstream of the FEMP, as maximum concentrations (2.1 µg/l) were less than two times above background values (1.4 µg/l). It is assumed that increased concentrations of uranium were present downstream of the FEMP from the inception of production (1952). In recent years, these concentrations have decreased as a result of improved stormwater control efforts and improved water treatment facilities. These improvements are reflected in results of surface water sampling conducted by the Radiological Environmental Monitoring department for inclusion in the annual Site Environmental Reports. A further discussion of various water quality improvements is provided in Section 2.2.

Sediment samples collected in 1993 from the Great Miami River revealed total uranium concentrations similar to background values [3 milligrams per kilogram (mg/kg)]. Elevated levels of aluminum, beryllium, and zinc, as well as several volatiles and semivolatiles, were detected in sediment samples. As is typical with a river of its size, sediments in the Great Miami River are influenced by a variety of point and non-point discharges.

A removal action under CERCLA was completed to remove contaminated soil from the bank of the Great Miami River as part of the installation of the new outfall line from the site to the Great Miami River. Past site operations resulted in the contamination of the banks of the Great Miami River to above background levels due to the continuous discharge of uranium through the outfall line combined with past flood events. An additional remedial action was completed at Manhole 180 between the site and the Great Miami River to remove soil contaminated due to overflow during a flood event. Final remediation of remaining contaminated soil and debris will be considered as future impacts to the Great Miami River. Figure 2-4 shows contaminated areas of the Great Miami River.

Surface Water

The SERA identified COCs for aquatic organisms within the Great Miami River (Table 2-1). For surface water upstream of the FEMP outfall, mercury and ammonia were identified as COCs. Downstream of the FEMP outfall, aluminum, cyanide, and cadmium were determined to be COCs. Seven COCs identified at the confluence with Paddys Run were cadmium, cyanide, lead, manganese, barium, aluminum, and bis(2-ethylhexyl)phthalate. Since chronic toxicity data was not available, manganese (found in the Great Miami River) and Di-n-octyl phthalate (found in Paddys Run) BTVs were based on lethal concentrations to 50 percent of test populations (LC_{50}) divided by 100. This method has been employed by EPA Office of Pesticide Programs to protect sensitive wildlife species (Urban and Cook 1986). The BTVs for the remaining constituents were based on either the Ambient Water Quality Criteria (AWQC, EPA 1988a), Water Quality Advisory (EPA 1988b), or warm water criteria (OEPA 1993). These values are considered to represent levels which are protective of aquatic organisms.

As indicated in the ecological risk assessment, the toxicity of many of the metals identified have been demonstrated to change depending on hardness (i.e., calcium and magnesium content of the water). The values were adjusted for hardness by using the average hardness of Paddys Run and the Great Miami

River, not based on specific sample conditions. Several of the metals are also considered to be naturally occurring.

Ecological risk to aquatic organisms in the Great Miami River is difficult to assess since there are many contributory (industrial, municipal, etc.) influences upstream of the FEMP effluent line. Fish studies conducted on the Great Miami River indicate that the FEMP has had no impact on the general fish population. In addition, no records of fish kills or fishing advisories were found for the Great Miami River near the FEMP.

Sediment

For sediments downstream of the FEMP outfall, barium, iron, lead, manganese, zinc, and phenanthrene were determined to be COCs. Sediments sampled at the confluence of Paddys Run showed barium, manganese, and zinc as COCs. The sediment BTVs identified in the Operable Unit 5 Ecological Risk Assessment came from three literature sources which used different approaches in developing the protective levels:

- Long and Morgan (1991) used values called Effects Range - Lower (ER-L). The values were determined based on a distribution of sediment levels observed to cause deleterious effects to aquatic organisms. Many of these values were based on marine and estuary data but commonly used for freshwater systems. Based on the distribution of values, an ER-L and Effects Range - Median (ER-M) were identified. The ER-L is generally considered to be protective of aquatic life as long as the sediment is not disturbed. The ER-M is considered to be harmful to an aquatic system.

- EPA developed Sediment Quality Criteria for the Protection of Benthic Organisms (EPA 1993). BTVs are developed from a model that assumes toxicity from sediment contamination is a function of the pore or interstitial water concentrations of the sediment contaminants. The Equilibrium Partitioning Model estimates the sediment levels required to have interstitial water concentrations greater than the AWQC by considering the total organic carbon of the sediment and physical properties of the constituents.

- Baudo *et al.* (1990, Sediments: Chemistry and Toxicity of In-Place Pollutants) based BTVs on summaries of various toxicity testing and field observations.

Drinking Water

The SERA also considered the risk to terrestrial organisms that use the Great Miami River as a source for drinking water. This investigation revealed that upstream of the FEMP effluent, mercury was determined to be a COC. Downstream of the FEMP effluent, the COCs were aluminum, beryllium, and

cadmium. At the confluence with Paddys Run, the COCs identified were aluminum, cadmium, and bis(2-ethylhexyl)phthalate. The drinking water BTV for aluminum was based on the AWQC, and for mercury, was based on warmwater criteria from the OEPA (OEPA 1993). Both the AWQC and warmwater criteria are considered protective of aquatic organisms. However, these values were used in the absence of drinking water criteria for wildlife or humans to preliminarily identify constituents which may pose a risk to ecological receptors which use the surface water body as a sole source of drinking water. Beryllium and cadmium BTVs were derived from the EPA's Drinking Water Regulations and Health Advisories (EPA 1994). The remaining BTVs are based on OEPA's Ohio Water Quality Standards (OEPA 1993) established for drinking water.

Although several constituents were identified as potential risks to terrestrial receptors drinking the surface water and TQs were calculated, the ecological risk assessment did not clearly indicate the magnitude of the risk. A TQ equal to or greater than one was considered an indication that the constituent may pose risk to one or more species. The greater the TQ value, the more the species may be affected. TQs should be considered in the interpretation of the magnitude of risk and potential impact associated with ecological receptors drinking surface water.

The representative concentration compared to the drinking water standard was always the maximum detected value. This is extremely conservative when evaluating terrestrial receptors using the surface water as a drinking source. This assumes that all water consumption is from that location at that elevated level. A more realistic concentration would be the upper bound of the mean.

Although background conditions were taken into account, aluminum was identified as a potential drinking water risk above the drainage area of the production area, suggesting that the levels are in part a function of the natural presence of aluminum in soils and sediments. However, aluminum levels in the pilot plant drainage ditch and confluence of Paddys Run and the Great Miami River were noticeably elevated relative to the other areas and may be a function of sediment load. Similarly, cadmium was detected upstream of the production area at levels above those found at other on-property and off-property locations, suggesting that the source is not solely the FEMP. Mercury was identified at two locations as a potential risk to drinking water receptors; however, both locations are located upstream of the FEMP's primary influence.

In general, the constituents identified should be considered as potential risk to ecological receptors but emphasis relative to FEMP impact should be placed on lead, beryllium, uranium, 1,2-dichloroethene, bis(2-ethylhexyl)phthalate, and Di-n-octyl phthalate.

Fauna

As with groundwater, Miami University did not investigate Great Miami River fauna in its site characterization study. However, there is other information available regarding the determination of past impact to the Great Miami River. Miller *et al.* (1985-1993) collected fish data from the Great Miami River from 1984 to 1995. Electrofishing was conducted at specified locations both above and below the FEMP outfall (Figure 2-5). The goal of the sampling program was to determine changes in the health of the fish community between sampling sites on the river compared to past years. This was accomplished through an evaluation of fish species richness, diversity, and biomass. Over the 12-year period of monitoring, the Great Miami River fish community showed an expected diversity with respect to habitat and water quantity. While changes in water quantity from year to year influenced the fish communities, these changes were not attributed to the FEMP, but rather upstream nutrient loading that results in hypereutrophic conditions (Miller 1993). A second goal of the annual electrofishing survey was to collect and prepare samples for laboratory analysis as part of the FEMP Radiological Environmental Monitoring program. Samples were analyzed for total uranium content to determine if the FEMP had any impact on the individual species, between species or among the general fish population. Analytical results from this effort indicated that the FEMP had not impacted fish found in the Great Miami River.

2.1.2.2 Future Impacts

Future remedial actions will involve the removal of the outfall from the FEMP to the Great Miami River (Figure 2-6). In addition, any soil and contaminated debris at the outfall requiring cleanup will also be removed. It is anticipated that this will impact approximately four acres of the Great Miami River bank and the outfall line. Included within this impacted area is approximately 0.25 acres of riparian habitat along the bank of the Great Miami River.

2.2 PADDYS RUN CORRIDOR

A summary of impacts to Paddys Run corridor is presented below and in Table 2-2. This section includes Paddys Run, drainage-ways into Paddys Run, and the associated riparian corridor that is found on either side of the stream.

2.2.1 Past Impacts

A portion of the Paddys Run corridor has been impacted from past releases of contamination (as presented in Figure 1-3) and several activities that resulted in the relocation of the stream bed. For the purposes of calculating impacts in this document, the width of the stream bed of Paddys Run was estimated to be 75 feet on average. (Note that the width of the riparian corridor is more than 75 feet on average, but impacts have been limited to the stream itself and areas immediately east of the stream). Areas adjacent to the Waste Storage Area, K-65 Silos, Inactive Flyash Pile and South Field areas have been impacted from past activities. Contamination and areas disturbed from past relocation overlap and are estimated to comprise approximately 5,700 feet of the Paddys Run corridor. Therefore, approximately 10 acres of Paddys Run have been impacted from past activities.

Several media were considered during the SERA. Since Paddys Run is a primary land feature within this area, soil was evaluated in addition to sediment and surface water. The results are summarized on Table 2-2. For soil, uranium was the only COC found within the Paddys Run Corridor. As discussed in Section 1.2, there were no radiological risks to ecological receptors at the FEMP. Uranium was considered a COC based on its potential toxicity as a heavy metal.

An analysis of on-property sediment data revealed four COCs to ecological receptors: barium, cadmium, cyanide, and manganese. Off-property sediment data identified manganese as a COC.

For surface water, six constituents were identified as COCs to ecological receptors. These COCs were aluminum, bis(2-ethylhexyl)phthalate, cadmium, Di-n-octyl phthalate, lead, and silver. Off-property, the COCs were lead, bis(2-ethylhexyl)phthalate, and Di-n-octyl phthalate. Of particular concern is lead, bis(2-ethylhexyl)phthalate, and Di-n-octyl phthalate due to the higher TQs and continued detection off site.

Flora and Fauna

Trees, shrubs, and herbaceous vegetation were surveyed from June 1986 to August 1986. Herbs were sampled again in April 1987 and May 1987. For the Paddys Run corridor, Miami University reported that "the riparian communities lacked the typical large dominant sycamores, silver maples, and cottonwoods of a mature riparian system." This finding was attributed to the intermittent nature of Paddys Run and the historical management of the stream. The stream channel of Paddys Run has been

altered twice in the past to mitigate erosion problems. Indeed, the riparian community was more diverse in the northern section of Paddys Run (RN 1, Figure 2-7), where no channel alterations have occurred and water flow is present the entire year. Shrubs and herbs were found to be most diverse in the lower section of the Paddys Run corridor (RN 2, Figure 2-7), suggesting an earlier state of succession, along with possible impacts in the northern section due to cattle grazing (Facemire *et al.* 1990).

Miami University collected fish from Paddys Run in June 1986, as well as March 1987 and June 1987. Results of these surveys indicated that "Paddys Run appears to have a relatively diverse ichthyofauna in the area of stream above the K-65 Storage Tanks." This finding correlates with the intermittent nature of Paddys Run, which goes dry much of the year in the vicinity of the K-65 Silos. Low species diversity was generally observed in the lower reaches of Paddys Run, Site 3 (Figure 2-7) also exhibited a reduced diversity in March 1987. Miami University stated that the reasons for the low diversity "were not known" but may have been attributable to runoff "or some other factors affecting habitat quality" (Facemire *et al.* 1990). To address this, the SERA compared Paddys Run fish data from various sources spanning 35 years (Table 2-3). The data summarized in Table 2-3 suggest that the fish community in Paddys Run is diverse and stable. The variability that exists in the data can be attributed to the seasonal fluctuations of flow.

Miami University surveyed macroinvertebrates in November 1986 and December 1986 and again in February 1987. As with fish, upstream reaches of Paddys Run (Sites 1 through 4, Figure 2-7) showed greater densities and higher diversity than the lower reaches of Paddys Run (Sites 5 through 10, Figure 2-7). The researchers reported that "the most probable cause of the observed changes in the macroinvertebrate communities downstream of Site 4 was the dry period preceding sampling." In the discussion of the February 1987 sample period, Miami University concluded that Paddys Run macoinvertebrate data provided "a clear indication of increasing environmental impact with distance from the stream source." The SERA addressed this finding, by evaluating Miami University's community indices and comparing their data with other macroinvertebrate data for Paddys Run. The SERA concluded that "the data collected in February 1987 represent an anomaly; measurements calculated from data collected before and after this period are higher than those based on the February samples" (DOE 1995a, Table 2-4).

Miami University surveyed the avifauna of the FEMP from June 1986 to July 1986, December 1986 to March 1987, and April 1987 to May 1987. The riparian corridor had the highest diversity of bird species at the site. Researchers concluded that "a diverse avifauna exists at the FMPC." However, it was noted that nighthawks and other insectivores were expected but missing. This finding is probably attributed to survey methods (i.e., the time of day and the time frame with respect to the breeding season). As shown on Table 2-5, other surveys have observed numerous insectivores (including nighthawks) at the FEMP.

As indicated on Table 2-5, the raptor population on the FEMP site was determined to be essentially normal in the results of the Miami Study. A survey for raptors was conducted as part of the summer and winter surveys in 1986. However, the spring survey in 1987 focused only on migratory birds and did not look for raptors. The species that were identified were as expected, except for the Cooper's Hawk, which is rare in this area. The species absent on Table 2-5 were identified as rare or uncommon winter residents in Southwestern Ohio. In addition, the Miami Study concluded that suitable habitats did not exist on the FEMP for the owl species that were not found on the FEMP.

Other Actions

Paddys Run was relocated in 1962 to prevent the erosion of the waste pit area. The relocation of the stream had a short-term impact on the habitat in Paddys Run. Several removal actions have influenced impacts to the Paddys Run corridor in recent years. A summary of these removal actions and their impact (both positive and negative) is provided below. The Waste Pit Area Stormwater Runoff Control Removal Action, completed in July 1992, provided a system for the collection and treatment of potentially contaminated storm water runoff from the waste pit area to prevent it from reaching Paddys Run. A similarly-scoped removal action was conducted for a portion of the Former Production Area. The Uncontrolled Production Area Runoff (Northeast) Removal Action was successful in collecting storm water runoff from perimeter areas of the Former Production Area, which were not draining into the storm water retention basins at the time.

The Inactive Flyash Pile Removal Action was conducted to install a long-term erosion control measure on the east bank of Paddys Run at the Inactive Flyash Pile. The erosion control was a riprap berm which was constructed during Phase I of the Time-Critical Removal Action in April and May of 1993. Phase II of this removal action increased the nominal height of the berm three feet to Elevation 540 feet MSL in critical areas. The added weight of the rock increased the forces resisting any slope failure and provided

more stability. This rock also covered the exposed vertical soil face above Elevation 537 feet MSL to minimize erosion during high water. Stones were also placed along the toe of the berm to achieve a tumble-down effect of stone into eroded areas created by the stream at the base of the berm. This Removal Action had a negative impact to approximately 200 feet of Paddys Run due to stream habitat alteration.

2.2.2 Future Impacts

Anticipated future impacts include the excavation of the waste pits and associated regrading of the waste pit area resulting in the loss of approximately 13.2 acres of riparian habitat along Paddys Run (includes Sloan's crayfish habitat). Included within this acreage is approximately 0.25 acres impacted due to the stablization of the eastern bank of Paddys Run in the vicinity of the K-65 Silos. Excavation and construction activities associated with the Inactive Flyash Pile will result in the loss of approximately 4.4 acres of early/mid-successional and riparian woodlands. The excavation of contaminated soil will result in the loss of approximately 16.5 acres of riparian habitat (includes Sloan's crayfish habitat). The total impacted riparian habitat is approximately 34 acres (Figure 2-8).

2.2.3 Residual Impacts

As identified on Figure 1-3, COCs at above-BTV levels have been identified in the sediment and surface water of Paddys Run during past sampling events. At the conclusion of soil remediation, any soils exceeding FRLs during certification sampling within Paddys Run will remediated pursuant to the Operable Unit 5 ROD. Any COCs exceeding BTVs will also be identified and addressed as part of postremediation sampling [e.g., Integrated Environmental Monitoring Plan (IEMP)] as part of the methodology outlined in the NRRP and agreed upon by the Trustees. In addition, BTV exceedances identified during postremediation sampling may be considered additional residual impacts and factored into the NRRP as determined appropriate by the Trustees.

2.3 SOUTHERN PINES AND WASTE UNITS

This section describes past and future anticipated impacts to the southern pines and waste units area. This area includes the southern pine plantation, the Inactive Flyash Pile, the South Field, the Active Flyash Pile, and adjacent riparian areas. Several separate areas have been included in this section, since they were originally considered as part of a single area within the SERA (Figure 1-1).

2.3.1 Past Impacts

The areal extent of contamination, as determined for the preferred alternative in the Operable Unit 5 RI/FS process, was used to determine past impacts to land within the southern pines and waste units area. There is no acreage within the southern pine plantation that was contaminated during production operations, as indicated by the Operable Unit 5 RI/FS process (Figure 1-3). The Inactive Flyash Pile and South Field constitute approximately 19.7 acres of land that has been contaminated by FEMP operations. Acreage for the other areas include approximately 10 acres of the Pilot Plant Drainage Ditch area, approximately 5.4 acres of soil underneath the Active Flyash Pile, and approximately 5.0 acres of riparian habitat along the Storm Sewer Outfall Ditch for a total of 40 acres of past impacts (Figure 1-3).

The SERA identified three COCs for soil; antimony, cadmium, and silver. For surface water, the COCs identified were aluminum and beryllium. In this instance, the COCs were considered a risk to terrestrial organisms that use the surface water as a drinking and/or bathing source (Table 2-6).

Flora and Fauna

During the 1986 and 1987 characterization of the FEMP, researchers at Miami University investigated two separate habitats within this area; the southern pine plantation and the Inactive Flyash Pile. As with other areas of the FEMP, various flora and fauna were surveyed. A summary of their findings is provided below.

As expected, the southern pine plantation ranked low with respect to tree diversity. All expected species were present and herbs were more diverse than expected. In 1986 and 1987, the Inactive Flyash Pile was not a radiologically controlled area, so it was surveyed by Miami University as a separate, distinct habitat. The researchers concluded that the area is primarily an old-field type habitat with lower expected diversity than later successional habitats (woodlots and riparian habitats).

Both the southern pine plantation and the reclaimed flyash pile showed lower diversities of birds when compared to other habitats on-property. This is attributed to habitat quality (old field habitat and introduced monoculture). See the previous discussion in Section 2.2 for Miami University's findings regarding avian species at the FEMP.

Surveys for small mammals were conducted between July 1986 and August 1986. The species trapped were expected, but several species that were expected were not trapped. Furthermore, there appeared to be a disparity in the species caught in certain habitats. For instance, with the exception of one cottontail rabbit, short tail shrews were the only species captured within the reclaimed flyash pile. In addition, after 360 trap-nights of effort, only two individuals were captured within the three pastures. Researchers did offer an explanation for these findings, stating that rabbit populations may be lower than surrounding areas due to predation and land management. Despite low catch rates for some species across the site, normal populations were found for the white-footed mouse, meadow vole and chipmunk.

In some cases, low catch rates were identified in certain areas such as those stated for the meadow jumping mouse and house mouse. Overall, the Miami Study stated that small mammal populations were essentially normal for the site and that lower population levels were likely due to land management and/or population cycles.

In addition, as discussed in Section 2.2.1, raptor populations on the FEMP were determined to be essentially normal. Therefore, it is assumed that prey species (e.g., small mammals) are adequate to support the raptor population on site.

Other Actions

The Active Flyash Pile Controls Removal Action was conducted to mitigate potential wind and water erosion at the Active Flyash Pile. Minor grading and compaction were conducted, a silt fence was installed around the base of the pile, wind barriers were erected, and a chemical spray was applied to the surface of the flyash pile to mitigate wind erosion and provide surface stabilization. The pile is now inactive and will no longer receive new ash deposits. The potential use of flyash as an additive to soil for backfill, structural fill, and slope stability applications was also investigated. This removal action reduced the impact from runoff into the adjacent riparian and stream habitat and was completed in June 1992. In addition, 5 acres of the southern pines were disturbed due to clearing to support the meteorological tower and other projects.

2.3.2 Future Impacts

Anticipated future impacts include the excavation and construction activities at the Inactive Flyash Pile, resulting in the loss of approximately 4.7 acres of old field habitat. In addition, remediation of the South

Field and Pilot Plant Drainage Ditch would result in the loss of approximately 13.0 acres of old field habitat, 7.5 acres of woodland and 0.6 acres of wetlands, respectively (Figure 2-8). Approximately 3 acres of the southern pines were impacted due to the installation of the Haul Road and soil stockpile area.

2.4 NORTHERN WOODLOT AND NORTHERN PINE PLANTATION

This section describes past impacts and anticipated future impacts to the northern woodlot area and the northern pine plantation. A major feature of the northern woodlot is the 26-acre forested wetland. Early and mid-successional woodlands and old field habitats are also found within the northern woodlot.

2.4.1 Past Impacts

Using the areal extent of contamination to determine past impact, the acreage impacted within the northern woodlot is approximately 2.6 acres. For the northern pine plantation, approximately 1.4 acres of land have been impacted. As shown on Figure 1-3, minor contamination is found within these areas.

Results from the SERA are summarized on Table 2-7. For soil in the northern woodlot, seven COCs were identified. These were cadmium, molybdenum, zinc, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and chrysene. As shown on Figure 1-3, many of these COCs were concentrated around the Fire Training Facility. Zinc was identified as a concern in the northern woodland. However, this was based on one sample exceeding the BTV in the area of the Fire Training Facility, which is not part of the northern woodlands. Soil COCs identified within the northern pine plantation were aluminum, manganese, and molybdenum. Aluminum and molybdenum appear to have scattered results above the BTV and do not follow any patterns of contamination seen in other constituents. The interpretation of the risk associated with the levels of aluminum is further complicated by the range of background levels. Both surface (11,900 mg/kg) and subsurface (16,100 mg/kg) soil concentrations are within the 95th percentile of background levels as established in the Operable Unit 5 RI/FS which are greater than the BTV (10,103 mg/kg). Thus, aluminum appears to be part of natural background. COCs for surface water in the northern woodlot were identified as aluminum, cadmium, mercury, and uranium (as a heavy metal). As with the southern pines and waste units area, the risk from surface water was attributed to terrestrial organisms using water as a drinking and/or bathing source.

Flora and Fauna

In the Miami University characterization study, several findings were made within the northern woodlot and northern pine plantation. The northern woodlots were some of the more diverse habitats with respect to trees, shrubs, and herbs. Woodlot Number 3 was the most mature of the three sections (Figure 2-7). The northern pine plantation, on the other hand, was much less diverse. This would be expected since the northern pine plantation is an introduced monoculture.

The northern woodlot exhibited varying degrees of diversity with respect to avifauna, while the northern pine plantation was less diverse than all habitats except the grasslands. One finding from the Miami University Characterization Report regarding birds in several areas, including the northern pine plantation, was the suppressed growth of robin and dove nestlings. Doves from the northern pine plantation and robins from the southern pine plantation showed statistically significant differences in several growth parameters when compared to off-property locations. Researchers postulated that "species differences in suppressed growth could be attributable to species specific differences in diet or to potential on-site physiological stressors, including differences in accumulating radiological or chemical loads." To investigate this further, several follow-up studies were conducted. Robins were evaluated because they appeared more severely stressed.

The 1991 follow-up study found that while FEMP robins produced normal-sized clutches, normal-sized eggs, and fledged a normal percentage of young nestlings exhibited suppressed growth in four of five prefledgling growth parameters (Osborne 1991). The second follow-up study in 1992 showed that FEMP robins still exhibited suppressed growth in two of four parameters measured (Osborne 1992). Heavy metals and pesticides were evaluated as a stressor through the soil-earthworm pathway. No metals above background, or pesticides were detected in FEMP soil and earthworm samples. Based on the results of this final study, the researchers concluded that the growth suppression of robin nestlings at the FEMP is related to land management practices that affect both food availability and the quality of diet (Osborne 1992). The previous discussion in Section 2.2 provides a critique of Miami University's avifauna surveys. See Section 2.3 for discussion of small mammal surveys.

Other Actions

Removal actions have influenced impacts to the northern woodlot. The Fire Training Facility Removal Action removed contamination associated with the Fire Training Facility (Building 63) structures,

equipment, surficial soils, and surface water. Prior to dismantling and removal activities, all liquids were removed from the open top tank, skid tank pond, the sump, and the horizontal pressure vessel end piece. These liquids were treated prior to disposal. Each of these structures, in addition to the block building and asphalt pad, were demolished and removed for disposal. As stated earlier, most of the COCs from the SERA associated with the northern woodlot were concentrated around the Fire Training Facility. This removal action, therefore, has reduced much of the impact to ecological receptors within the northern woodlot.

There are some soil parameters identified through the SERA that are not anticipated to be excavated (Figure 2-9). Based on the approach set forth in Section 1.2.3, these COCs are considered residual impacts at this time. This evaluation may be revised at a later date, depending on the results of the certification process.

2.4.2 Future Impacts

Anticipated future impacts for the northern woodlot and northern pine plantation include construction of the buffer area associated with the On-Site Disposal Facility (OSDF) resulting in the loss of approximately 40 acres of the northern pine plantation (Figure 2-8).

2.4.3 Residual Impacts

It is anticipated that residual impacts may occur due to the continued presence of ecological COCs at above BTV concentrations in approximately 5 acres of the northern woodlot.

2.5 INTRODUCED GRASSLANDS

Past impacts and anticipated future impacts to grasslands at the FEMP are presented below. As Figure 1-1 shows, the grassland area encompasses the entire eastern portion of the FEMP. The OSDF will be constructed within this area.

2.5.1 Past Impacts

The areal extent of contamination as determined in the Operable Unit 5 RI/FS process reveals a past impact to soil of approximately 93 acres (Figure 1-3).

The SERA showed 13 COCs for soil in the grasslands area. These COCs were aluminum, antimony, lead, manganese, molybdenum, uranium (as a heavy metal), benzo(g,h,i)perylene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene. Most of these constituents are only found in localized areas, which are known and expected to be contaminated with multiple constituents, such as the Sewage Treatment Plant. Aluminum and molybdenum concentrations above the BTV are scattered and do not follow the patterns of contamination seen in other constituents. Again, the interpretation of the risk associated with the levels of aluminum is further by the range of background levels. The polynuclear aromatic hydrocarbons (PAHs), lead, and uranium are COCs exhibiting defined areas of contamination, and thus are considered to have the greatest impact to ecological receptors from exposure to soil within the grasslands area, the PAHs are generally focused around the Sewage Treatment Plant. Uranium will be addressed through the FRL-driven soil remediation process, since the BTV is a higher concentration than the FRL. Lead is a contaminant concentrated in the trap firing range. It is expected that soil remediation will also mitigate ecological risk associated with the PAHs and lead.

For surface water (as a source of drinking water for terrestrial organisms), the COCs were aluminum and beryllium. Two COCs, manganese and lead, were identified for off-property soil (Table 2-8).

Flora and Fauna

The Miami University characterization study revealed typical diversity for introduced grasslands, both grazed and ungrazed. Refer to Section 2.3 for the discussion regarding the surveys for small mammals.

Other Actions

The Contaminated Soils Adjacent to Sewage Treatment Plant Incinerator Removal Action was undertaken to prevent any potential contaminant migration in soils near the inactive Sewage Treatment Plant incinerator. This action involved the characterization, removal, containerization, storage, and disposal of soils with elevated uranium levels in the vicinity of an out-of-service solid waste incinerator at the Sewage Treatment Plant. Excavation of contaminated soils and post-excavation sampling activities were completed on October 16, 1992. As with the Fire Training Facility, many of the COCs identified in the SERA were located near the Sewage Treatment Plant. Therefore, this removal action greatly reduced risks to terrestrial organisms within the grassland area. Excavation resulted in a negative impact to approximately 10 acres of an off-property woodlot adjacent to the Sewage Treatment Plant.

2.5.2 Future Impacts

Future impacts include the construction of the OSDF and associated buffer area resulting in the loss of approximately 86 acres of introduced grassland habitat. Excavation and construction activities associated with the Vitrification Plant would result in the loss of approximately 2.5 acres of grassland habitat. The excavation of contaminated soil would result in the loss of approximately 115 acres of grassland habitat and 0.6 acres of wetlands. Total impacted introduced grassland is approximately 204 acres (Figure 2-8).

2.6 WASTE STORAGE AREA

2.6.1 Past Impacts

Past impacts associated with the Waste Storage Area include approximately 37 acres of land attributed to the areal extent of contamination, which includes 5 acres of on-property wetlands.

The SERA and the Miami University characterization survey did not investigate habitats within the Waste Storage Area. Although Miami University did not evaluate wetlands specifically in its report, it did address population genetics of spring peeper treefrogs. Electrophoretic analysis of select FEMP plant and animal species, including spring peeper treefrogs, was conducted. This research found that spring peeper tadpoles and frogs collected from a wetland near the waste pits exhibited a null allele that was not present in an off-property control population. This null allele was not found in the heterozygous condition. The researcher suggested that this finding could be from some sort of on-site chemical or radiological stress. A follow-up study was conducted in 1991 and the results showed that the null allele was present in off-property spring peepers up to 20 kilometers away (Guttman 1991). A third study in 1992 looked at spring peepers as far away as Wheeling, West Virginia and still found the presence of the null allele (Guttman 1992). Also, the original off-property control was re-evaluated and the null allele was determined to be present in that sample as well. Therefore, the researcher concluded that the presence of the null allele in spring peeper frogs and tadpoles is not attributable to any kind of on-property chemical or radiological stress, but rather a regional phenomenon that reaches across the southern half of Ohio.

2.7 FORMER PRODUCTION AREA

2.7.1 Past Impacts

Past impacts within the Former Production Area include approximately 136 acres of land attributed to the areal extent of contamination and 4 acres of on-property wetlands.

The SERA and the Miami University characterization survey did not investigate habitats within the Former Production Area, since this area is characterized as an industrial area with limited quality habitat due to land management practices.

TABLE 2-1
ECO-RISK DATA FOR THE GREAT MIAMI RIVER

Constituent	Upstream of Outfall	Between Outfall and Paddys Run	Confluence With Paddys Run	Benchmark Toxicity Value
Barium	-	130[a]	228[b] 89[a]	145[b] 40[a]
Iron	-	19,800[a]	-	17,000
Lead	-	39.7[a]	44.2[b]	35[a]/30[b]
Phenathrene	-	2200[a]	-	6.3[a]
Manganese	-	729[a]	561[b] 667[a]	300[a] 98[b]
Zinc	Not Analyzed	90[a]	171[a]	120
Mercury	0.7[cb]	-	-	0.2[bc]
Ammonia	1900[b]	-	-	1,000
Aluminum	Not Analyzed (Surface Water)	674[bc]	19,100[b] 19,100[c]	87[bc]
Cyanide	Not Analyzed	16.8[b]	21.4[b]	12
Cadmium	-	5.3[bc]	18[b]/18[c]	3.5[b] 5[c]
Bis (2) Phthalate	Not Analyzed (Surface Water)	-	160[bc]	8.4[b] 18[c]
Beryllium	Not Analyzed (Surface Water)	7.70[c]		4.0

[a] Sediment (mg/kg)
[b] Surface Water (µg/l)
[c] Terrestrial Organisms (µg/l)

TABLE 2-2
ECO-RISK DATA FOR PADDYS RUN

	Soil	Sediment	Surface Water	Drinking Water	Benchmark Toxicity Value
Uranium	254[a]	-	-	-	230[c]
Barium	-	58.7[a]	-	-	40[d]
Cadmium	-	5.5[a]	5.0[a]	5.0[a]	3.5[f] 5.0[df]
Cyanide	-	0.49[a]	-	-	0.10[d]
Manganese	-	1070[a] 499[b]	-	-	300[d]
Bis (2) Phthalate	-	-	40[a]/22[b]	40[a] 22[b]	8.4[e] 18[f]
Di-n-Octyl Phthalate	-	-	52[a]/89[b]	52[a] 89[b]	47.7[ef]
Lead	-	-	156[a]/69.7[b]	156[a] 69.7[b]	30[e] 50[f]
Silver	-	-	4.0[a]	-	1.3[e]
Aluminum	-	-	145[a]	145[a]	87[ef]

[a] On-property
[b] Off-property
[c] Soil (mg/kg)
[d] Sediment (mg/kg)
[e] Surface Water (mg/l)
[f] Terrestrial Organisms (mg/l)

TABLE 2-3
PADDYS RUN FISH DATA COMPARISON

Scientific Name	Common Name	Area[g]				
		1	2	3	4	5
Clupeidae (Herring Family)						
Dorosoma cepedianum	gizzard shad		f			c
Cyprinidae (Minnow Family)						
Campostoma anomalum	central stoneroller	c	a,b,c,d,e,f	a,b,f	b,c,d	b,c,d,f
Cyprinella spiloptera	spotfin shiner	c	b,c	b,f	c	b,c
Cyprinella whipplei	steelcolor shiner			a		
Luxilus chrysocephalus	striped shiner		b,e,f	a,b,f		
Luxilus cornutus	common shiner	c	c,d		c,d	d,c
Lythrusus ardens	rosefin shiner	c	a,b,c,f	a,b,f		b
Lythrurus umbratilis	redfin shiner		d		d	d
Notropis atherinoides	emerald shiner		b			c
Notropis boops	bigeye shiner					c
Notropis buccattus	silverjaw minnow	c	a,b,c,d,e,f	a,b,f		b,d,f
Notropis stramineus	sand shiner		b,c	f		
Phenacobius mirabilis	suckermouth minnow			f		b
Phoxinus erythrogaster	southern redbelly dace		c,d,f	b,f	d	d
Pimephales notatus	bluntnose minnow		a,b,c,d,e,f	a,b,f	c,d	b,c,d,f
Pimephales promelas	fathead minnow	c	c,d		d	
Rhinichthys atratulus	blacknose dace		a,b,c,d,f	b,f	d	b,d
Semotilus atromaculatus	creek chub		a,b,d,e,f	a,b,f	b,d	b,d
Catastomidae (Sucker Family)						
Catastomus commersoni	white sucker		a,b,c,d,e,f	a,f	d	b,d
Centrarchidae (Sunfish Family)						
Lepomis cyanellus	green sunfish	c	c,d,f	f	d	d,f
Lepomis macrochirus	bluegill	c	c,f	f		c
Lepomis megalotis	longear sunfish		c,d,f	f		

TABLE 2-3
PADDYS RUN FISH DATA COMPARISON
(Cont'd)

Scientific Name	Common Name	Area[g]				
		1	2	3	4	5
Lepomis spp.	sunfish hybrid		f	b	b	b
Micropterus salmoides	largemouth bass	c	c,f	f		f
Micropterus dolomieui	smallmouth bass			f		d
Ictaluridae (Catfish Family)						
Ameiurus natalis	yellow bullhead		d,f	f		
Ictalurus melas	black bullhead			f		f
Notorus flavus	stonecat mad tom			f		
Percidae (Darter Family)						
Etheostoma caeruleum	rainbow darter					b
Etheostoma flabellare	fantail darter	c	a,b,c,d,e,f	a,b,f	d	b
Etheostoma nigrum	johnny darter		a,b,c,d,e,f	a,b,f	d	b,d
Etheostoma spectabile	orangethroat darter		a,b,c,d,e,f	a,b,f	b,d	b,d
Cottidae (Sculpin Family)						
Cottus bairdi	mottled sculpin		d	f	d	d
Number of Species Observed (All Reports)		10	24	15	16	24

[a] Facemire, June-August 1986
[b] Facemire, January-March 1987
[c] Bauer, December 1972-October 1973
[d] Tarzwell, 1952
[e] Pomeroy, 1977
[f] OEPA, 1995
[g] Locations sampled in various studies were grouped by "Area" on Paddys Run. These sampling locations were grouped as follows:

Area 1 = Bauer's station 1
Area 2 = Bauer's stations 2 and 3, Tarzwell's station 1, Facemire's stations 1 and 2, OEPA station 1, and Pomeroy's only sampling station
Area 3 = Facemire's stations 3, 4, 5, 6, 7, OEPA Stations 2, 3, 4 (Flow typically intermittent)
Area 4 = Facemire's station 8, 9, 10; Bauer's station 4; and Tarzwell's station 2 (Flow typically intermittent)
Area 5 = Bauer's stations 5 and 6, Facemire's station 11, OEPA stations and Tarzwell's station 3 (Flow typically intermittent)

TABLE 2-4
PADDYS RUN MACROINVERTEBRATE DATA COMPARISON

Station	Study						
	Pomeroy July 1977[a]	Facemire June 1986[b]	Facemire Mar./June 1987[b]	RI/FS May/June 1989[c]	RI/FS Nov./Dec. 1989[c]	RI/FS Mar./May 1990[c]	RI/FS June/Aug. 1990[c]
SHANNON DIVERSITY[d]							
PR1		3.2	0.97				
PR2	1.39	2.06		2.29	3.24	3.5	3.3
PR3		2.4	0.43	2.54	2.43	2.99	2.81
PR4		1.9					
PR5		1.69	0.21	1.06	1.06	3.01	3.11
PR6		2.68		0.55	1.04	3.31	no data
PR7		2.02					
PR8		1.8					
PR9		2.63		1.43	NA	3.33	no data
PR10		1.96					
PR11			0.66				
SIMPSON DIVERSITY[e]							
PR1	0.4	0.844	0.744				
PR2		0.653		0.75	0.86	0.88	0.87
PR3		0.677	0.114	0.77	0.77	0.81	0.8
PR4		0.591					
PR5		0.599	0.043	0.28	0.31	0.8	0.85
PR6		0.777		0.15	0.36	0.87	no data
PR7		0.6					
PR8		0.474					
PR9		0.794		0.5	NA	0.85	no data
PR10		0.623					
PR11			0.156				

TABLE 2-4
PADDYS RUN MACROINVERTEBRATE DATA COMPARISON
(Cont'd)

Station	Study						
	Pomeroy July 1977[a]	Facemire June 1986[b]	Facemire Mar./June 1987[b]	RI/FS May/June 1989[c]	RI/FS Nov./Dec. 1989[c]	RI/FS Mar./May 1990[c]	RI/FS June/Aug. 1990[c]
SIMPSON DOMINANCE[e]							
PR1	0.6	0.156	0.256				
PR2		0.347		0.25	0.14	0.12	0.13
PR3		0.323	0.886	0.23	0.22	0.19	0.2
PR4		0.409					
PR5		0.401	0.956	0.71	0.69	0.2	0.15
PR6		0.222		0.84	0.64	0.13	no data
PR7		0.399					
PR8		0.526					
PR9		0.206		0.5	NA	0.15	no data
PR10		0.377					
PR11			0.844				
PIELOU'S EVENESS[f]							
PR1	0.37	0.741	0.218				
PR2		0.484		0.82	0.8	0.81	0.79
PR3		0.556	0.114	0.8	0.73	0.66	0.72
PR4		0.499					
PR5		0.729	0.062	0.33	0.35	0.7	0.79
PR6		0.725		0.24	0.52	0.75	no data
PR7		0.583					
PR8		0.431					
PR9		0.76		0.55	NA	0.77	no data

TABLE 2-4
PADDYS RUN MACROINVERTEBRATE DATA COMPARISON
(Cont'd)

Station	Study						
	Pomeroy July 1977[a]	Facemire June 1986[b]	Facemire Mar./June 1987[b]	RI/FS May/June 1989[c]	RI/FS Nov./Dec. 1989[c]	RI/FS Mar./May 1990[c]	RI/FS June/Aug. 1990[c]
DENSITY							
PR1		2939.5	4846.1				
PR2	4339.16	5023.5		100	240	568.9	577.2
PR3		5184.7	9077.6	151.1	184.4	773.3	586.7
PR4		3391.7					
PR5		55.1	6138.6	173.3	217.8	457.8	542.2
PR6		623.3		295.6	33.3	557.8	no data
PR7		308.1					
PR8		4158					
PR9		351.1		162.2	2.2	955.6	no data
PR10		330.1					
PR11			9163.1				

[a] Pomeroy 1977
[b] Facemire *et al.* 1990
[c] DOE 1992a
[d] Shannon Diversity was calculated as follows:

$$H' = \frac{[(N \log N - \Sigma\, ni \log ni) * 3.321928]}{N}$$

Where:

N = the total density of all families collected
3.321928 = conversion to log base 2

TABLE 2-4
PADDYS RUN MACROINVERTEBRATE DATA COMPARISON
(Cont'd)

[e] In order to calculate Simpson Diversity (D_s) community dominance is initially calculated as follows:

$$L = \frac{\Sigma\, n_i(n_i - 1)}{N(N - 1)}$$

then:

$$D_s = 1 - L$$

[f] Pielou's Eveness is calculated as follows:

$$J' = \frac{H'}{H'_{max}}$$

Where:

H' = Shannon diversity
H'_{max} = log (number of families)

TABLE 2-5
AVIAN SPECIES DATA COMPARISON

Species[a]	Occurrence[f]	Insectivorous (I) or Foliage Gleaning (FG)[g]	Study Dates			
			Summer 1977[b]	Summer 1986[c]	Winter 1986[d]	Spring 1987[e]
Blue-winged Warbler	C	I and FG				x
Northern Parula Warbler	U	I and FG				
Yellow Warbler	C	I and FG		x		
Cerulean Warbler	C	I and FG				
Yellow-rumped Warbler	U	I and FG				x
Black-throated Green Warbler	C	I and FG				x
Yellow-throated Warbler	U	I and FG				
Blackpoll Warbler	R	I and FG				x
Prairie Warbler	U	I and FG				
Ovenbird	U					
Louisiana Waterthrush	C	I		x		
Northern Waterthrush	R	I				x
Kentucky Warbler	C	I				
Mourning Warbler	R	I				x
Common Yellowthroat	C	I and FG	x	x		
Yellow-breasted Chat	C	I and FG	x	x		
Hooded Warbler	R	I and FG				
American Redstart	U	I and FG				x
House Sparrow	A		x	x	x	
Eastern Meadowlark	A		x	x	x	
Red-winged Blackbird	A		x	x	x	
Common Grackle	A		x	x		
Brown-headed Cowbird	C		x	x		
Orchard Oriole	U	I and FG	x	x		
Northern Oriole	C	I and FG		x		
Scarlet Tanager	U	I and FG	x	x		
Summer Tanager	U	I and FG		x		
Cardinal	A		x	x	x	
Rose-breasted Grosbeak	U			x		x

TABLE 2-5
AVIAN SPECIES DATA COMPARISON
(Cont'd)

Species[a]	Occurrence[f]	Insectivorous (I) or Foliage Gleaning (FG)[g]	Study Dates			
			Summer 1977[b]	Summer 1986[c]	Winter 1986[d]	Spring 1987[e]
Indigo Bunting	A		x	x		
Evening Grosbeak	I					
Purple Finch	U					
Pine Siskin	I					
American Goldfinch	A		x	x	x	
Red Crossbill	I					
Rufous-sided Towhee	C		x	x	x	
Savannah Sparrow	U		x	x		
Grasshopper Sparrow	U		x	x		
Henslow's Sparrow	R					
Dark-eyed Junco	A				x	
Tree Sparrow	U				x	
Chipping Sparrow	C			x		
Field Sparrow	A		x	x		
White-crowned Sparrow	U					
White-throated Sparrow	A				x	
Fox Sparrow	R					
Swamp Sparrow	U					x
Song Sparrow	C		x	x	x	
Great blue heron	U			x		
Green Heron	C		x	x		
Canada Goose	C					
Mallard	C			x		
Black Duck	C					
Wood Duck	C			x		
Common Goldeneye	U					
Oldsquaw	R					
Turkey Vulture	C			x		

TABLE 2-5
AVIAN SPECIES DATA COMPARISON
(Cont'd)

Species[a]	Occurrence[f]	Insectivorous (I) or Foliage Gleaning (FG)[g]	Study Dates			
			Summer 1977[b]	Summer 1986[c]	Winter 1986[d]	Spring 1987[e]
Black Vulture	R					
Sharp-shinned Hawk	R					
Cooper's Hawk	U			x	x	
Red-tailed Hawk	C		x	x	x	
Red-shouldered Hawk	U				x	
Broad-winged Hawk	U					
Rough-legged Hawk	R					
Marsh Hawk	U			x		
American Kestrel	C			x	x	
Bobwhite	C		x	x	x	
Killdeer	C	I	x	x	x	
American Woodcock	U			x		
Spotted Sandpiper	C			x		
Solitary Sandpiper	U			x		x
Herring Gull	C					
Ring-billed Gull	U					
Rock Dove	A			x		
Mourning Dove	A		x	x	x	
Yellow-billed Cuckoo	C	I and FG	x	x		
Black-billed Cuckoo	U	I and FG		x		
Barn Owl	R					
Screech Owl	C			x	x	
Great Horned Owl	C			x	x	
Snowy Owl	I					
Barred Owl	C					
Long-eared Owl	R					
Short-eared Owl	R					
Saw-whet Owl	U					
Common Nighthawk	C	I	x			

TABLE 2-5
AVIAN SPECIES DATA COMPARISON
(Cont'd)

Species[a]	Occurrence[f]	Insectivorous (I) or Foliage Gleaning (FG)[g]	Study Dates			
			Summer 1977[b]	Summer 1986[c]	Winter 1986[d]	Spring 1987[e]
Chimney Swift	A	I	x	x		
Belted Kingfisher	C		x	x	x	
Ruby-throated Hummingbird	C	I		x		
Common Flicker	C	I	x	x	x	
Pileated Woodpecker	U	I		x	x	
Red-bellied Woodpecker	C	I	x	x	x	
Red-headed Woodpecker	R	I		x		
Yellow-bellied Sapsucker	U	I				
Hairy Woodpecker	U	I		x	x	
Downy Woodpecker	A	I	x	x	x	
Eastern Kingbird	U	I		x		
Great Crested Flycatcher	C	I		x		
Eastern Phoebe	C	I		x		
Willow Flycatcher		I		x		
Arcadian Flycatcher	C	I		x		
Alder Flycatcher	U	I				
Eastern wood Pewee	C	I	x	x		
Horned Lark	U	I				
Bank Swallow	U	I				
Rough-winged Swallow	U	I	x	x		
Barn Swallow	C	I	x	x		
Purple Martin	C	I		x		
Blue Jay	A		x	x	x	
Common Crow	A		x	x	x	
Carolina Chickadee	A	I and FG	x	x	x	
Tufted Titmouse	A	I and FG	x	x	x	
White-breasted Nuthatch	C	I		x	x	
Red-breasted Nuthatch	R	I				
Brown Creeper	U	I			x	

TABLE 2-5
AVIAN SPECIES DATA COMPARISON
(Cont'd)

Species[a]	Occurrence[f]	Insectivorous (I) or Foliage Gleaning (FG)[g]	Study Dates			
			Summer 1977[b]	Summer 1986[c]	Winter 1986[d]	Spring 1987[e]
House Wren	C	I		x		
Winter Wren	R	I				
Carolina Wren	C	I		x	x	
Mockingbird	C	I	x	x	x	
Gray Catbird	C	I	x	x		
Brown Thrasher	C	I		x		
American Robin	A		x	x	x	
Wood Thrush	C	I	x	x		
Eastern Bluebird	U	I		x	x	
Blue-gray Gnatcatcher	C	I and FG	x	x		
Golden-crowned Kinglet	C	I and FG			x	
Ruby-crowned Kinglet	U	I and FG				
Cedar Waxwing	U			x		
Loggerhead Shrike	R					
Starling	A		x	x	x	
White-eyed Vireo	C	I and FG		x		
Yellow-throated Vireo	U	I and FG				
Solitary Vireo	U	I and FG				x
Red-eyed Vireo	A	I and FG	x	x		
Philadelphia Vireo	R	I and FG		x		
Warbling Vireo	U	I and FG		x		
Prothonotary Warbler	R	I and FG				
Black-and-white Warbler	C	I		x		
Tennessee Warbler	C	I and FG		x		x
Worm-eating Warbler	R					

[a] Species list derived from CNC (1978) and includes birds which regularly nest within the area and those expected during the winter months. The list also includes several unexpected species observed during one or more of the studies.
[b] Observed June 27 - 28, 1977 (Pomeroy *et al.* 1977).
[c] Observed June 25 - July 25, 1986 (Facemire *et al.* 1990).

TABLE 2-5
AVIAN SPECIES DATA COMPARISON
(Cont'd)

[d] Observed December 5, 1986 - March 6, 1987 (Facemire *et al.* 1990).
[e] Observed April - May 1987 (Facemire *et al.* 1990).
[f] Abbreviations:
A = Abundant (may be seen more than 75 percent of the time in the proper habitat and at the right time of the year)
C = Common (may be seen more than 50 percent of the time)
U = Uncommon (may be seen between 10 and 50 percent of the time)
R = Rare (may be seen 10 persent or less of the time)
I = Irregular (occur in varying numbers from year to year, and in some years may not appear at all) (CNC 1978)
[g] Insectivorous species depend on insects for food. Foliage gleaning species obtain food off of plant foliage.

TABLE 2-6
ECO-RISK DATA FOR SOUTH PINES AND WASTE UNITS

	Soil	Drinking Water	Benchmark Toxicity Value
Antimony	29.5	-	10[b]
Cadmium	5.8	-	5[b]
Silver	10.3	-	10[b]
Aluminum	-	1830[a]	87[a]
Beryllium	-	66[a]	4[a]

[a] Concentrations in µg/l
[b] Concentrations in mg/kg

TABLE 2-7
ECO-RISK DATA FOR NORTH PINES AND WOODLOTS

	Soil - Woodlot[a]	Drinking Water - Woodlot[b]	Soil[a] - Pines	Benchmark
Cadmium	5.90	6.30	-	5[cd]
Molybdenum	11.7	-	12.4	10[c]
Zinc	707	-	-	500[c]
Benzo(a)anthracene	2.10	-	-	1[c]
Benzo(b)fluoranthene	2.10	-	-	1[c]
Chrysene	2.10	-	-	1[c]
Aluminum	-	232	10,700	10,103[c]/87[d]
Mercury	-	0.6	-	0.2[d]
Uranium	-	944	-	890[d]
Manganese	-	-	1530	1500[c]
Benzo(a)pyrene	1.60	-	-	1[c]

[a] Concentrations in mg/kg
[b] Concentrations in mg/l
[c] Soils (mg/kg)
[d] Terrestrial Organisms (µg/l)

TABLE 2-8
ECO-RISK DATA FOR GRASSLANDS

	Soil	Drinking Water	Off-Property Soil	Benchmark Toxicity Value
Aluminum	25,700	1830[a]	-	10,103[b]/87[c]
Antimony	21.5	-	-	10[b]
Lead	2180	-	1150	200[b]
Manganese	2100	-	3420	1500[b]
Molybdenum	14.5	-	-	10[b]
Uranium	3620	-	-	230[b]
Benzo(g,h,i)perylene	3.10	-	-	1[b]
Benzo(a)pyrene	1.15	-	-	1[b]
Benzo(b)fluoranthene	3.70	-	-	1[b]
Benzo(k)fluoranthene	3.30	-	-	1[b]
Chrysene	3.20	-	-	1[b]
Dibenzo(a,h)anthracene	1.10	-	-	0.088[b]
Indeno(1,2,3)pyrene	3.0	-	-	1[b]
Beryllium	-	66[a]	-	4[c]

[a] Addressed with the south pines and waste units
[b] Soils (mg/kg)
[c] Terrestrial Organisms (µg/l)

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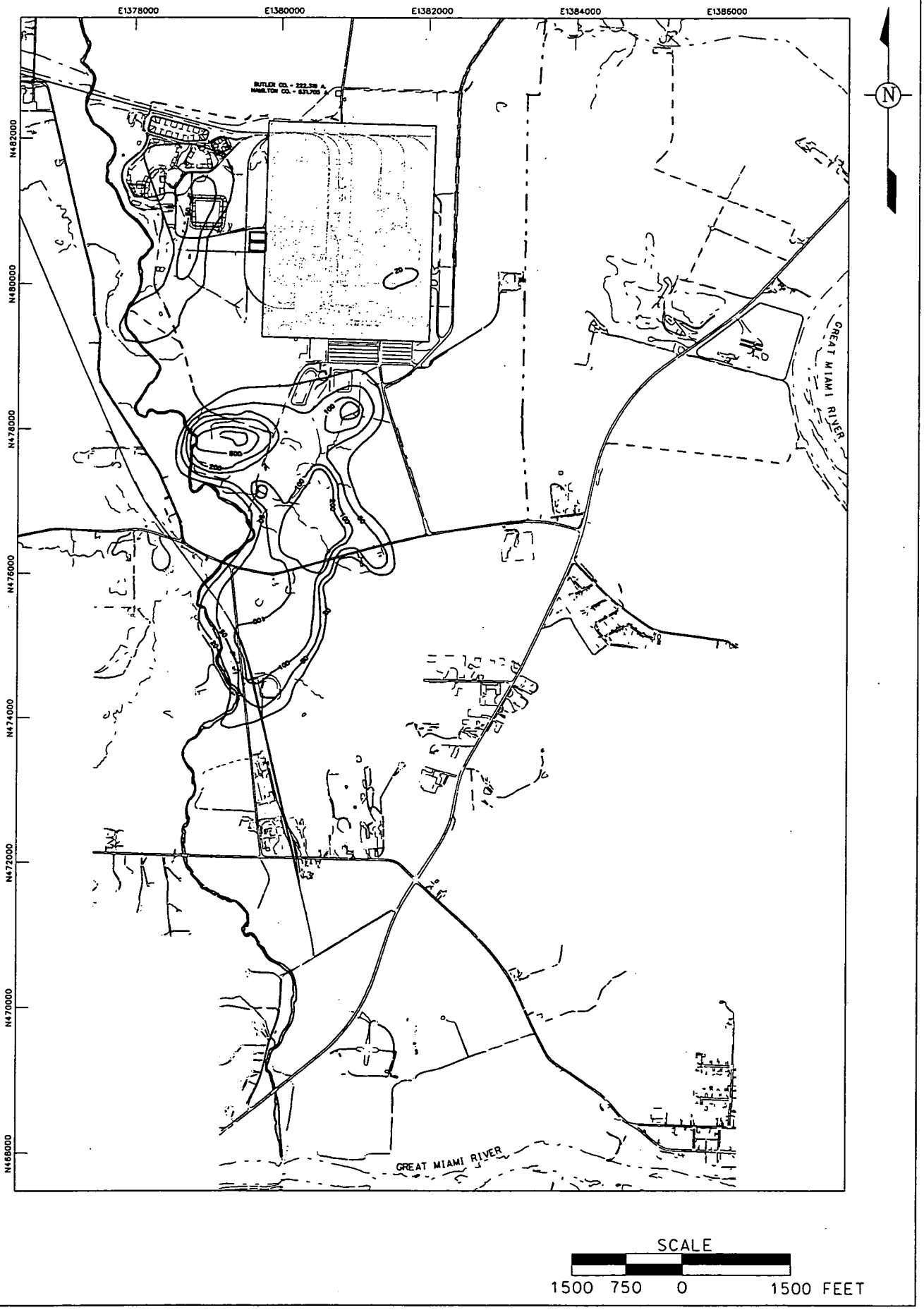

FIGURE 2-1. EXTENT OF GREAT MIAMI AQUIFER REMEDIATION

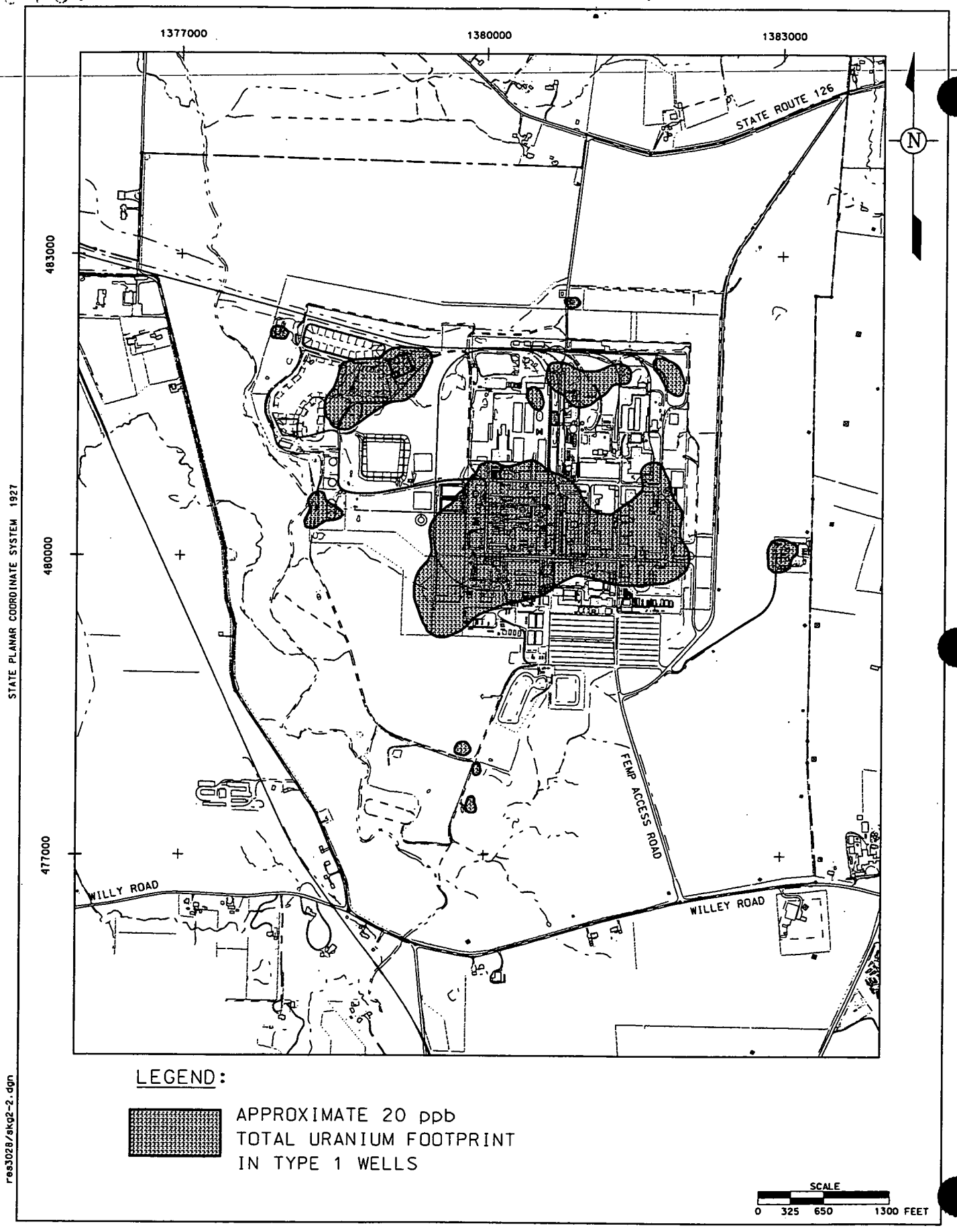

FIGURE 2-2. IMPACTED AREAS OF THE PERCHED GROUNDWATER SYSTEM

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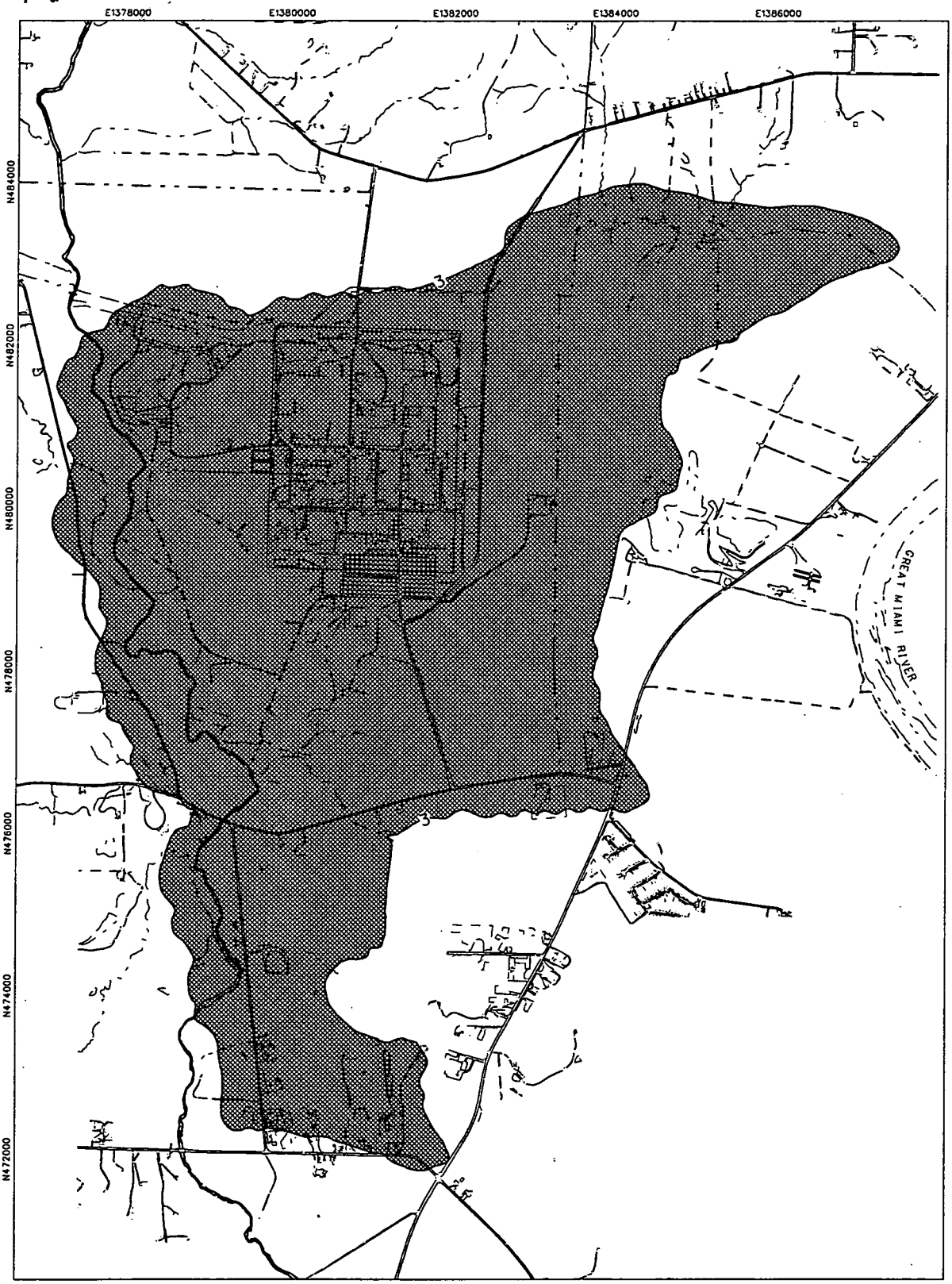

LEGEND:

1198 ACRES

3 CONCENTRATION CONTOUR (ppb)

SCALE

1500 750 0 1500 FEET

FIGURE 2-3. RESIDUAL IMPACTS TO GREAT MIAMI AQUIFER

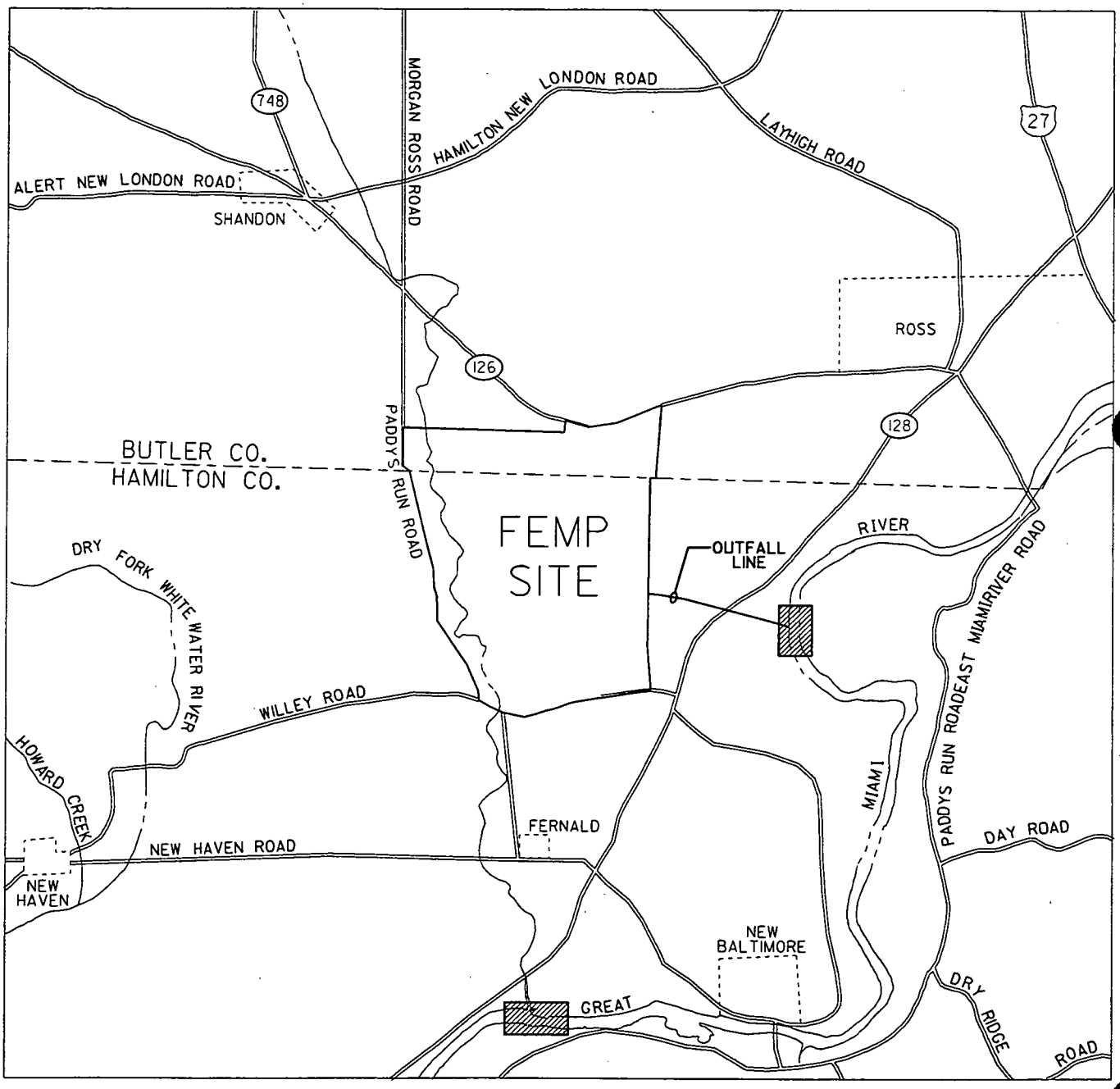

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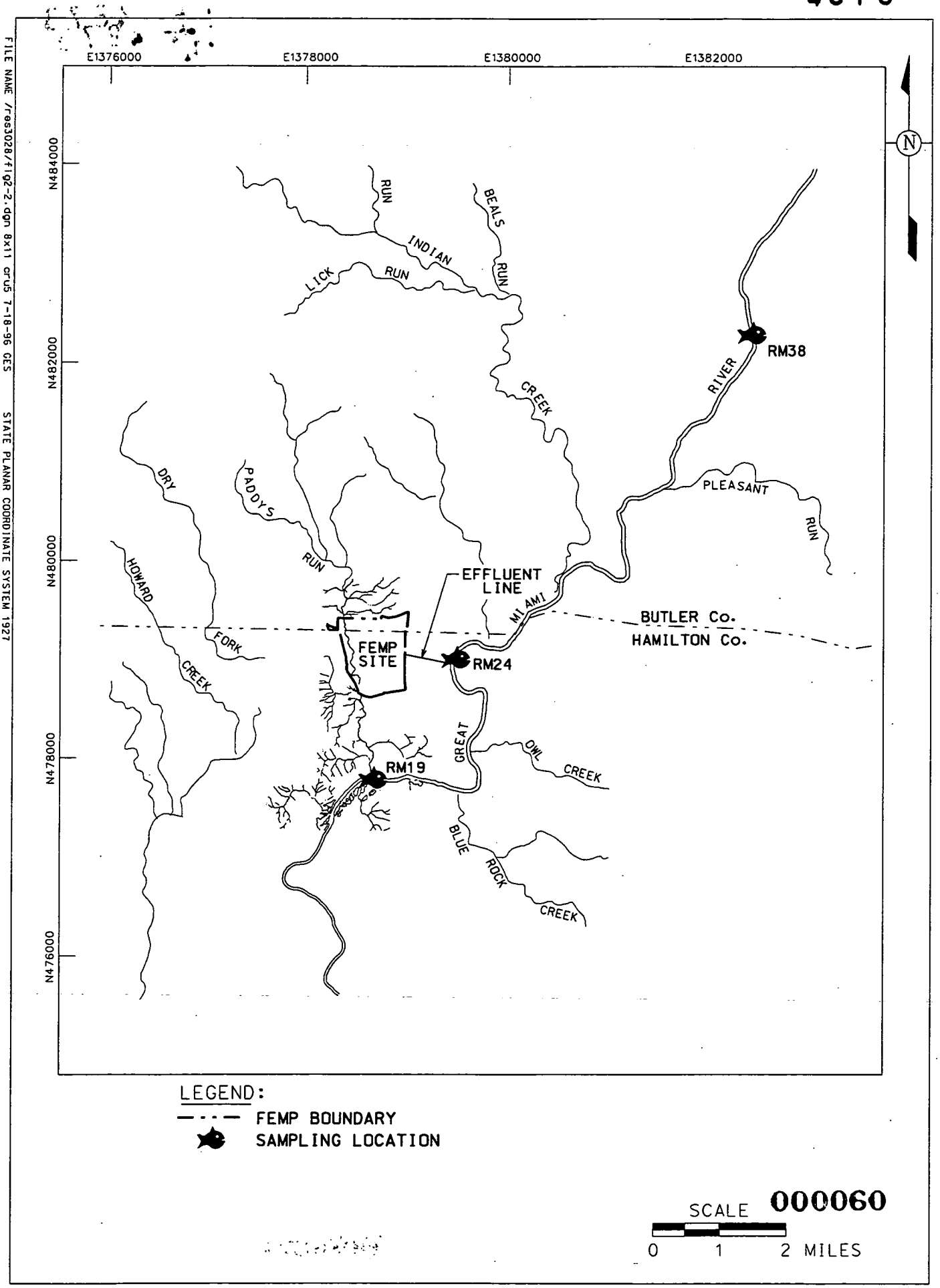
FIGURE 2-4. CONTAMINATED AREAS AT GREAT MIAMI RIVER.



FILE NAME /res3028/fig2-2.dgn 8x11 cru5 7-18-96 GES STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-5. FISH SAMPLE LOCATIONS ON THE GREAT MIAMI RIVER

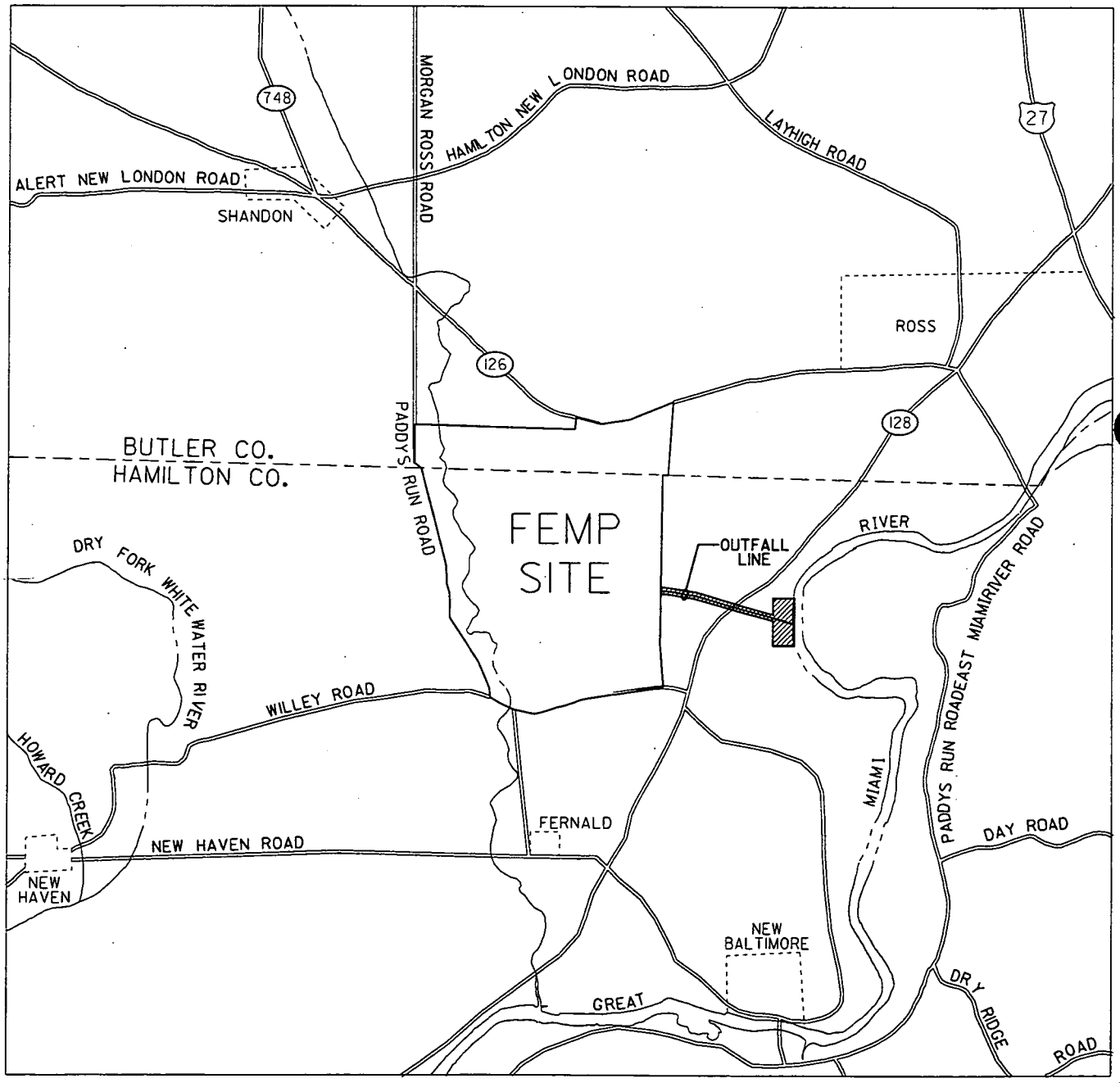


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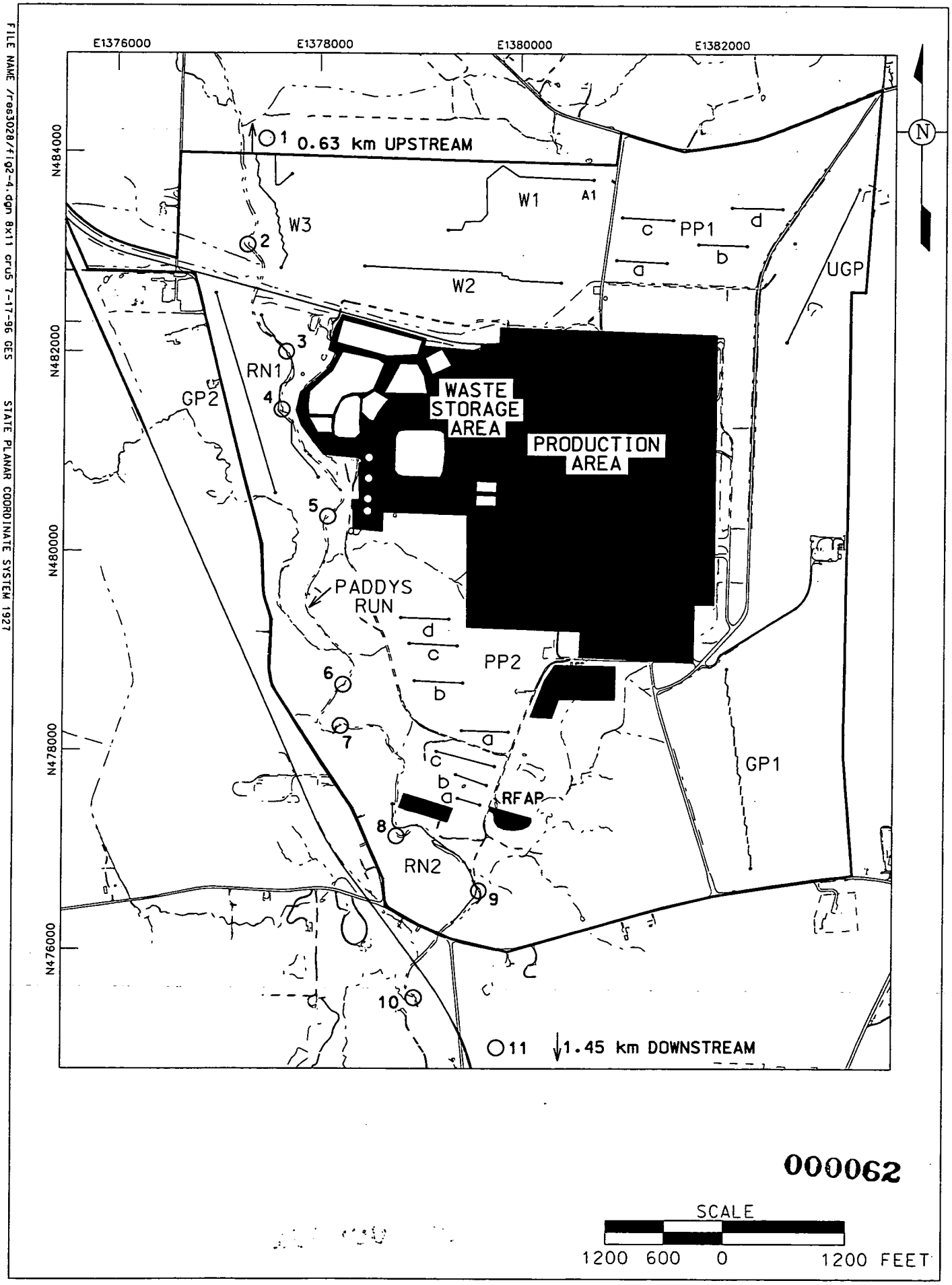
FIGURE 2-6. EXTENT OF GREAT MIAMI RIVER REMEDIATION.



FILE NAME /res3028/fig2-4.dgn 8x11 cru5 7-17-96 GES STATE PLANAR COORDINATE SYSTEM 1927

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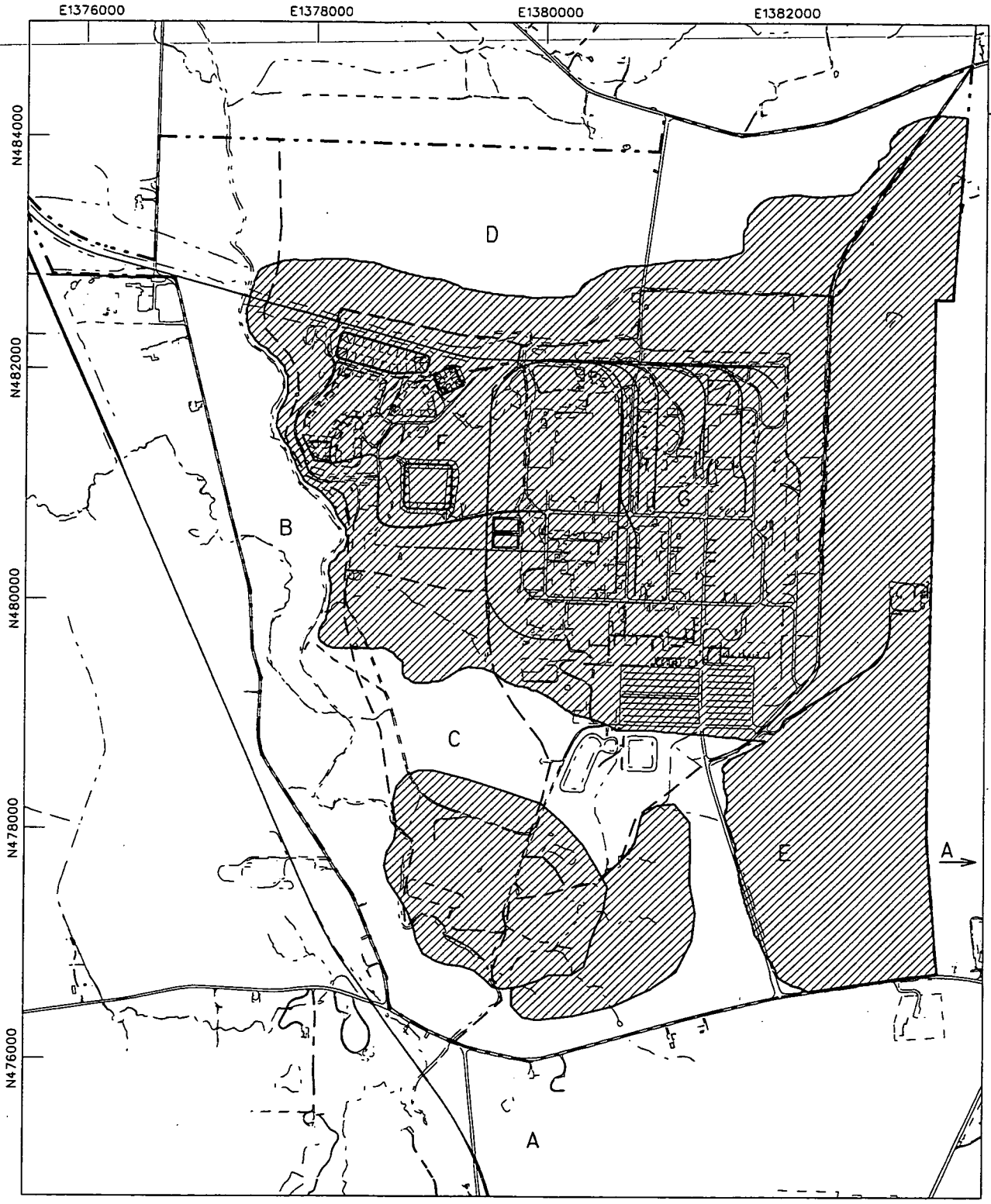
FIGURE 2-7. MIAMI UNIVERSITY SURVEY TRANSECTS AND AQUATIC SAMPLE LOCATIONS

FILE NAME /res3028/fig1-1b.dgn 8x11 cru5 7-17-96 GES STATE PLANAR COORDINATE SYSTEM 1927



LEGEND:

FEMP BOUNDARY

AREAL EXTENT OF TOTAL DISTURBANCE FROM REMEDIAL ACTIVITIES

STUDY AREAS

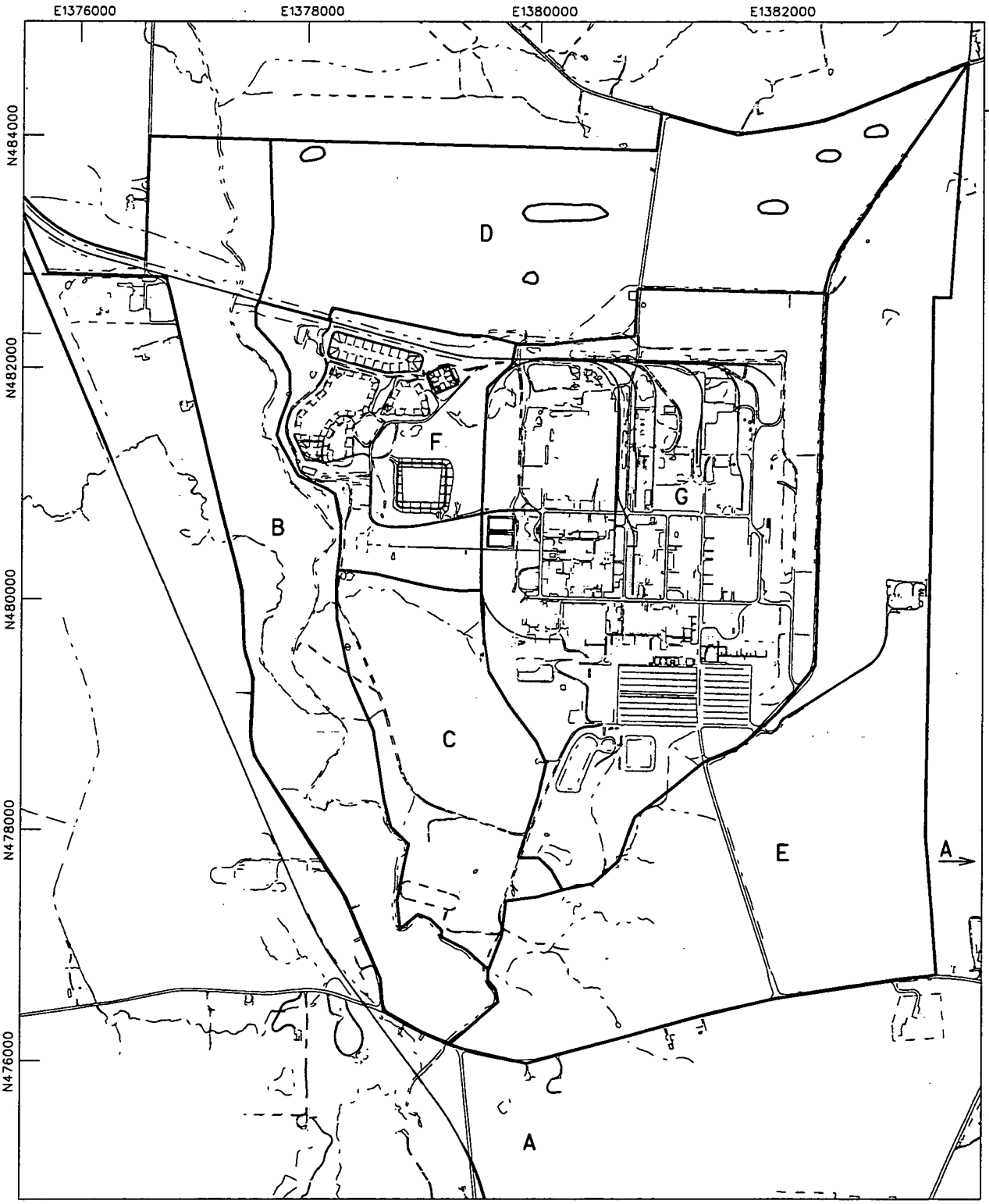
SCALE

1200 600 0 1200 FEET

000063

FIGURE 2-8. AREAL EXTENT OF TOTAL DISTURBANCE FROM REMEDIAL ACTIVITIES AT THE FEMP

FILE NAME /res3028/fig1a.dgn 8x11 cru5 7-17-96 GES STATE PLANAR COORDINATE SYSTEM 1927



LEGEND:

FEMP BOUNDARY

A– G.M.R. + G.M.A.
B– PADDYS RUN CORRIDOR
C– SOUTHERN PINES AND WASTE UNITS
D– NORTHERN PINES AND WOODLOT
E– GRASSLANDS
F– WASTE STORAGE AREA
G– PROCESS AREA

RESIDUAL IMPACTS TO ECOLOGICAL RECEPTORS 5.3 ACRES

000064

SCALE

1200 600 0 1200 FEET

FIGURE 2-9. RESIDUAL IMPACTS TO ECOLOGICAL RECEPTORS

3.0 SUMMARY

Impacts to natural resources at the FEMP were presented using information which characterizes the interaction of the ecology and past and anticipated future activities of the site. Past impacts were derived from a combination of process knowledge, RI studies, and ecological reports. Anticipated future impacts were derived from RIs, FSs, RODs, and available information from remedial design. The impacts presented in this document will be evaluated by the Trustees and used to determine appropriate restoration measures.

The following summarizes past, future, and residual impacts for each area:

- 172 acres of groundwater impacts
- 618 acres of past and anticipated future impacts to various areas of the site.

Table 3-1 presents an area-by-area summary of past and future impacts.

Areas identified as past impacts with respect to the areal extent of contamination were not counted again as future impacts. Past impacts were identified when a release of a hazardous substance resulted in the contamination and/or physical disturbance of portions of the site. It is anticipated that the identified past impact areas, with the exception of groundwater, will be physically disturbed during remediation. Future impacts are those areas that will be physically disturbed from remedial activities and do not include areas of past impact (e.g., construction of the OSDF, excavation of Borrow Area).

The purpose of this assessment is to provide reasonable inferences of past impacts and anticipated future impacts from remedial activities. Upon concurrence with the NRIA, the Trustees will determine appropriate restoration activities to compensate for natural resource impacts. These restoration activities will be developed within a restoration plan which will be integrated with the remedial design and remedial action documentation being prepared at the FEMP pursuant to CERCLA.

SUMMARY OF KEY NATURAL RESOURCE IMPACTS

Great Miami Aquifer

Past Impacts

- 172 acres of quantified groundwater impact (20 µg/l) to the Great Miami Aquifer (Figure 2-1)
- 96 acres of perched groundwater impacts in Study Areas C, E, F and G

Future Impacts

- 5.0×10^{10} gallons of groundwater anticipated to be pumped from the Great Miami Aquifer due to remedial activities
- Up to 15 acres of additional off-property impacted due to plume migration

Residual Impacts

- Approximately 1,198 acres of above background (3 µg/l) uranium groundwater plume will remain after remedial action is complete (Figure 2-3)

Other Information

- Removal actions and the Public Water Supply Project have mitigated impacts and/or service losses to the Great Miami Aquifer

Great Miami River

Past Impacts

- Slight increases (less than two times background) in Great Miami River surface water uranium concentrations downstream of the FEMP (Figure 2-4)
- Elevated levels of aluminum, beryllium, zinc, VOAs, and semi-VOAs detected in sediments, but difficult to attribute specifically to the FEMP (Figure 2-4)
- 12 COCs found in sediment and/or surface water in the Great Miami River (Figure 2-3 and Table 2-1). Again, these are difficult to attribute specifically to the FEMP

Future Impacts

- 3 acres of impact anticipated for the Great Miami River due to remedial activities, including 0.25 acres of riparian habitat (Figure 2-6)

Residual Impacts

Not Applicable

Other Information

- Removal Actions have mitigated impacts and/or service losses to Great Miami River
- Fish data from 1984 to 1995 reveal that the FEMP has not impacted fish communities upstream or downstream of the FEMP

Paddys Run Corridor

Past Impacts

- 10 acres of quantified soil impact to the Riparian Corridor (Figure 1-3)
- Paddys Run Relocation in 1962
- 10 ecological COCs found in soil, sediment, and/or surface water (Figure 1-3 and Table 2-2)

Future Impacts

- 34 acres of impact anticipated due to remedial activities (Figure 2-8)

Other Information

- Riparian flora is more diverse in the upstream section of Paddys Run, possibly because of stream alterations downstream
- Paddys Run fish community is diverse and stable, with variabilities occurring because of seasonal fluctuations in flow
- Paddys Run macroinvertebrates show higher diversity upstream, which is attributed to the intermittent nature of the stream
- Riparian corridor has high avian diversity
- Removal actions have mitigated and/or attributed to impacts and/or service losses in the Paddys Run corridor

Southern Pines and Waste Units

Past Impacts

- 40 Acres of quantified soil impact to the southern pines and other waste units (Figure 1-3)
- Three ecological COCs found in soil or surface water (Figure 1-3 and Table 2-6)

Future Impacts

- 17 acres of impact anticipated due to remedial activities of the waste units [i.e., Inactive Flyash Pile, South Field (Figure 2-8)]

Other Information

- Flora and fauna diversities were expected with respect to habitat quality (old field and introduced monoculture)
- Removal Actions have mitigated and/or attributed to impacts and/or service losses
- Approximately 5 acres of the southern pines impacted from project clearing activity

Northern Woodlot and North Pine Plantation

Past Impacts

- 4 acres of quantified soil impact to the northern woodlot and north pine plantation (Figure 1-3)
- 11 COCs found in soil and surface water, most of which concentrated in the vicinity of the Fire Training Facility (Figure 1-3 and Table 2-7)

Future Impacts

- 40 acres of impact anticipated due to remedial activities (Figure 2-8)

Residual Impacts

- 5 acres of residual impact anticipated due to the continued presence of potential ecological COCs at above BTV concentration (Figure 2-9)

Other Information

- Diverse flora and fauna exist in the northern woodlots. The diversity of the north pine plantation is as expected (introduced monoculture)
- Impacts to robins attributed to land management practices
- Removal Actions have mitigated impacts and/or service losses

Introduced Grasslands

Past Impacts

- 93 acres of quantified soil impact to the grasslands (Figure 1-3)
- 10 acres of off-property woodlot clearing during removal action
- 13 ecological COCs found in soil and surface water, most of which concentrated around the Sewage Treatment Plant (Figure 1-3 and Table 2-8)

Future Impacts

- 204 acres of impact anticipated due to remedial activities (Figure 2-8)

Other Information

- Grasslands exhibited typical diversity
- Removal Actions have mitigated and/or attributed to impacts and/or service losses

Waste Storage/Production Area

Past Impacts

- 173 acres of quantified soil impact to the Waste Storage and Production Area (Figure 1-3)

Future Impacts

- 9 acres of wetlands filled due to remedial activities

Other Information

- Treefrog null allele attributed to regional conditions, not the FEMP

TABLE 3-1
IMPACT SUMMARY

Study Area	Past	Future
GMA/GMR	172 acres*	15 acres
Paddys Run	10 acres	34 acres
Southern Pines/Units	40 acres	17 acres
Northern Woodlot/Pines	4 acres	40 acres
Grasslands	93 acres	204 acres
Waste Pits/Process	173 acres	
Subtotal	492 acres	298 acres
Total Impact = 790 acres*		

* Includes aerial extent of Groundwater Plume

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NATURAL RESOURCE RESTORATION PLAN

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

JANUARY 2002

U.S. DEPARTMENT OF ENERGY
FERNALD AREA OFFICE

212E-PL-0003
REVISION 0
FINAL

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LIST OF ACRONYMS AND ABBREVIATIONS

BTV	benchmark toxicity value
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COEC	constituents of ecological concern
CRO	Community Reuse Organization
DOE	U.S. Department of Energy
EA	Environmental Assessment
EPA	U.S. Environmental Protection Agency
FCAB	Fernald Citizens Advisory Board
FEMP	Fernald Environmental Management Project
FLHP	Fernald Living History Project
FONSI	Finding of No Significant Impact
FRESH	Fernald Residents of Environment, Safety, and Health
FRL	final remediation level
gpm	gallons per minute
HEA	Habitat Equivalency Analysis
IRDP	Integrated Remedial Design Package
MCL	maximum contaminant level
μg/L	micrograms per liter
MUEF	Multi-Use Education Facility
NEPA	National Environmental Policy Act
NRDA	Natural Resource Damage Assessment
NRIA	Natural Resource Impact Assessment
NRRDP	Natural Resource Restoration Design Plan
NRRP	Natural Resource Restoration Plan
NRTs	Natural Resource Trustees
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
OU	Operable Unit
PAHs	polyaromatic hydrocarbons
ROD	Record of Decision
SCS	Soil Conservation Service
SEP	Sitewide Excavation Plan
SER	Society for Ecological Restoration
SERA	Site-wide Ecological Risk Assessment
SSOD	Storm Sewer Outfall Ditch
USFWS	U.S. Fish and Wildlife Service

Section 1.0

1.0 INTRODUCTION

The Natural Resource Restoration Plan (NRRP) outlines the approach for ecological restoration (hereafter referred to as "restoration") of the Fernald Environmental Management Project (FEMP). Restoration of the FEMP will transition the majority of the site from postremediation conditions to the selected final land use, an undeveloped park with an emphasis on wildlife habitat. The NRRP also outlines the comprehensive approach for final settlement of the U.S. Department of Energy's (DOE's) natural resource injury (hereafter referred to as "impact") liability at Fernald, including the 1986 State of Ohio claim against DOE for injuries to Natural Resources. The NRRP presents the strategy for site restoration based on a series of restoration projects that are designed to address compensatory requirements on the part of DOE for natural resource impacts, as well as regulatory-driven mitigation requirements. The restoration of the FEMP will involve the revegetation of the site using native plants present during the pre-European settlement condition. The NRRP also outlines the plan for integrating restoration with the sitewide remediation process including the excavation plans outlined in the Sitewide Excavation Plan (SEP, DOE 1998). In addition, the NRRP outlines the plan for public use amenities to be integrated into restored areas consistent with stakeholder input and the desires of the Natural Resource Trustees (NRTs). The NRTs support public accessibility to the site for educational purposes as outlined in Section 3.1.5 of the plan. A final decision on the construction of a Multi-Use Education Facility (MUEF) is not within the scope of this plan and will be subject to a separate public review process. Restoration projects to be implemented at the FEMP are driven by terrestrial impacts as outlined in Sections 1.3 and 1.4. The NRRP also includes the NRT's agreement to resolving liability associated with groundwater injuries (Section 1.5).

1.1 ADMINISTRATIVE GOALS OF THE NRRP

The ultimate goal of the NRRP is to resolve DOE liability for past, present and future natural resource impacts at the FEMP while meeting regulatory commitments and addressing stakeholder concerns. The NRRP reflects the collective agreements between the NRTs and stakeholders (see Section 6.0) regarding restoration of the FEMP. The NRRP will be used as the basis for the development of project-specific restoration designs. The specific administrative goals that guided the development of the NRRP are as follows:

- Establish a restoration plan that is satisfactory to the NRTs, and upon implementation, will resolve DOE liability for impacts to natural resources associated with the FEMP (including groundwater);

- Ensure the Fernald site is transitioned to the selected final land use for the FEMP site and considers the interests of all stakeholders to the degree possible. Any future public use will be compatible with restoration plans for the FEMP as determined appropriate by the NRTs, DOE and stakeholders;

- Ensure that restoration of the FEMP is accomplished in a manner that is consistent with the decisions reached in the various operable unit records of decision;

- Establish a restoration plan that can be fully integrated with the ongoing remedial design and remedial action processes at the FEMP.

1.2 NATURAL RESOURCE RESTORATION STRATEGY

The natural resource restoration strategy for the FEMP is to implement a series of specific projects fully integrated with the completion of site remediation. The strategy includes:

- Utilize grading activities at the end of remedial actions to prepare areas for restoration to the degree possible.

- Stabilize remediated areas immediately in a manner that supports future restoration work to the degree possible.

- Utilize excavated areas to support open water, wetland or vernal pool features whenever possible to avoid the need to backfill.

The goal for natural resource restoration at the site is to begin restoration projects in parallel with site remediation activities consistent with prioritization of sitewide remedial activities. The remediation schedule will dictate the timing and sequence of restoration work. Remediated areas will be given priority for restoration and non-remediated areas will be restored as the schedule permits. Projected ecological restoration projects are discussed in Section 4.0. The conceptual final land use of the FEMP, once all ecological restoration projects have been implemented, is shown on Figure 1-1.

The NRRP strategy will also incorporate the restoration goals of the NRTs and the input of other stakeholders in establishing an acceptable final land use for the FEMP (see Section 6.0). Institutional controls for the FEMP property will be developed as part of stewardship planning to support final land use agreements.

1.3 SUMMARY OF NATURAL RESOURCE IMPACT ASSESSMENT

The Natural Resource Impact Assessment (NRIA, DOE 2001a) identified the impacts (i.e., injuries) at the site resulting from past contamination, and those impacts expected to occur as part of future remedial actions. The NRIA identified impacts to the extent possible on an acreage basis sorted by habitat type. Groundwater impacts were identified on both an acre and volumetric basis, as groundwater does not constitute a "habitat." In general, impacts were quantified using existing remedial investigation/ feasibility study information. Past impacts were measured using the soil excavation footprint, which included soils that were considered a risk to human receptors [i.e., soil concentrations exceeding final remediation levels (FRLs)]. The presence of ecological contaminants of concern was also used to measure past impacts as summarized in Appendix A. Future impact acreage was identified in cases where physical disturbances have resulted from or will result in the destruction of or reduction in the quality of a particular habitat.

The purpose of the NRIA is to establish a "baseline" level of impact from which appropriate restoration activities can be developed. The NRIA was designed to function in a manner analogous to an Injury Determination in the formal Natural Resource Damage Assessment (NRDA) process [43 Code of Federal Regulations (CFR) 11]. Since the intent of the NRTs is to pursue a more streamlined evaluation and assessment process and not to conduct a formal NRDA, the NRIA and NRRP were designed to meet the substantive aspects of the formal NRDA process to the extent practicable. The NRIA has been finalized based on impacts assessed in 1998 by the NRTs.

The level of impacts identified in the NRIA was used to assess a required level of natural resource restoration as presented in the NRRP. The Habitat Equivalency Analysis (HEA) process described in Section 1.4 and Appendix B was used to determine the amount of restoration required to compensate for impacts to terrestrial habitats. The Fernald NRTs have negotiated other projects to compensate for groundwater impacts as discussed in Section 1.5 of this plan. The results of the HEA and NRT negotiations were used to establish the restoration activities outlined in Section 4.0 of this plan. The NRIA and NRRP will be approved as a final document with no further revisions. However, the progress of restoration at the FEMP will be tracked by the NRTs to ensure proper implementation of the NRRP.

Implementation of the NRRP will facilitate a resolution of DOE's natural resource damage liability. Any liability settlement documentation among the NRTs will include re-opener provisions in the event of an unanticipated release and subsequent injuries to natural resources.

1.4 SUMMARY OF HABITAT EQUIVALENCY ANALYSIS

The HEA process was utilized to ensure that the level of natural resource restoration outlined in this NRRP is commensurate with the level of impact identified in the NRIA. HEA methodology provides a means of compensating for natural resource impacts through the calculation of habitat restoration acreage. By linking estimates of service loss over time to service gains through restoration projects, potentially contentious dollar damage estimates were avoided. A summary of the HEA process is provided below. Appendix B provides a detailed description of the process and area specific HEA calculations.

Based on the information provided in the NRIA, the NRTs agreed on annual percent service losses for each area on site, from the time impacts started through ecological restoration. In many instances, the NRTs had to make conservative assumptions regarding service losses, because detailed information was not available. For example, unless data showed otherwise, releases were assumed to have started in 1952, when full-scale operations began at the FEMP. These annual service losses were converted to acres and summed to obtain an "effective acre-years lost" value. The NRTs then negotiated the amount of service gains that would result from restoring the impacted area to its baseline (pre-release) condition. This effort is termed "primary restoration," and is assumed to be equivalent to the amount of acreage originally impacted. By summing the acres gained through recovery, the NRTs calculated the amount of effective acre-years gained for each acre of primary restoration. This value was then divided into the effective acre-years lost value to calculate the amount of compensatory restoration required. It should be noted that a discount rate is applied to all calculations in order to compare to present-day values. As stated above, this process is described in detail within Appendix B.

Through this HEA methodology, approximately 540 acres would be required to compensate for past and anticipated future ecological service losses at the FEMP. Therefore, the NRTs demonstrated that the projects described in the NRRP sufficiently compensate for natural resource injuries at the FEMP. Note that the scope of this effort is limited to ecological services. A separate approach is required for groundwater. Compensation for groundwater is described in Section 1.5 below.

1.5 SETTLEMENT OF GROUNDWATER ISSUES

The HEA process is appropriate for estimating restoration acreage when impacts are associated with ecological functions and habitat loss. Service losses to humans, such as contamination of a drinking water supply, cannot easily be equated to habitat restoration. Restoration activities must be conducted to replace, restore, or acquire the equivalent of the impacted natural resource. Therefore, it is very difficult to compensate for groundwater impacts through ecological restoration.

The Great Miami Aquifer is a significant natural resource and a major focus of remediation activities at the FEMP. As discussions regarding compensation for groundwater impacts have progressed, the FEMP NRTs have recognized that many actions have been taken to date. The Operable Unit (OU) 5 Record of Decision (ROD, DOE 1996) committed DOE to pump and treat contaminated groundwater in order to reach the 20-micrograms per liter (μg/L) total uranium FRL. Originally, this effort called for the installation of 28 extraction wells pumping at a combined rate of 4,000 gallons per minute (gpm) for approximately 27 years. An enhanced groundwater remedy was approved as part of the Baseline Remedial Strategy Report. This approach called for the installation of additional extraction wells and the use of groundwater re-injection technology. By implementing this revised strategy, the time to complete groundwater remediation could be shortened by as much as 17 years. Groundwater extraction actually started before the OU5 ROD was finalized, with the implementation of the OU5 South Plume Removal Action. Additionally, the FRL has since been revised in accordance with promulgation of federal drinking water standards for uranium. The 20-μg/L uranium FRL was based on the proposed maximum contaminant level (MCL) for uranium established by the U.S. Environmental Protection Agency (EPA) under the Safe Drinking Water Act. Since the signing of the OU5 ROD, EPA has established a final MCL for uranium at 30 μg/L. Because of this change, DOE has completed a revision to the ROD that establishes the revised FRL as 30 μg/L.

In addition to groundwater remediation activities, DOE has undertaken several other efforts to address groundwater contamination. An alternate water supply was provided to several local industries as part of the South Plume Removal Action. Also, in the late 1980s, DOE began providing bottled water to local residents potentially effected by uranium-contaminated groundwater. This program was discontinued when a public water supply was installed in the Fernald area in 1996. DOE contributed $6.4 million towards the installation of the public water supply for residents near the FEMP.

Because the FEMP NRTs originally agreed to focus on habitat restoration as compensation for all impacts, an attempt was made to calculate restoration acreage due to groundwater impact. Several scenarios for using HEA were proposed, but the NRTs were not satisfied that justification was adequate. As a result, the FEMP NRTs agreed to abandon the use of HEA for groundwater compensation. Instead, the NRTs agreed to ensure that all on-property areas are ecologically restored [with the exception of the 123-acre On-Site Disposal Facility (OSDF) and the 23 acres of land set aside by DOE for potential future development. The majority of the specific ecological restoration projects described in Section 4.0 of the NRRP contribute in some way to the protection of groundwater recharge areas.

The NRTs further agreed that the most appropriate way to address the damages to the ground water resource is through a focus upon environmental education. The environmental education should be aimed at reducing future sources of ground water contamination and increasing understanding of the environmental damages and subsequent restoration at the Fernald site. The proposed Final Natural Resource settlement requires that DOE provide $5 million to fund a Groundwater Education Project. The NRTs have agreed that the Groundwater Education Project, in conjunction with the other remedial actions described above, will adequately compensate for groundwater injuries. The goals of the Groundwater Education Project have been outlined by the NRTs as follows:

1. Provide an understanding of the environmental contamination that occurred at the Fernald site along with the extensive efforts to remediate and restore the site.

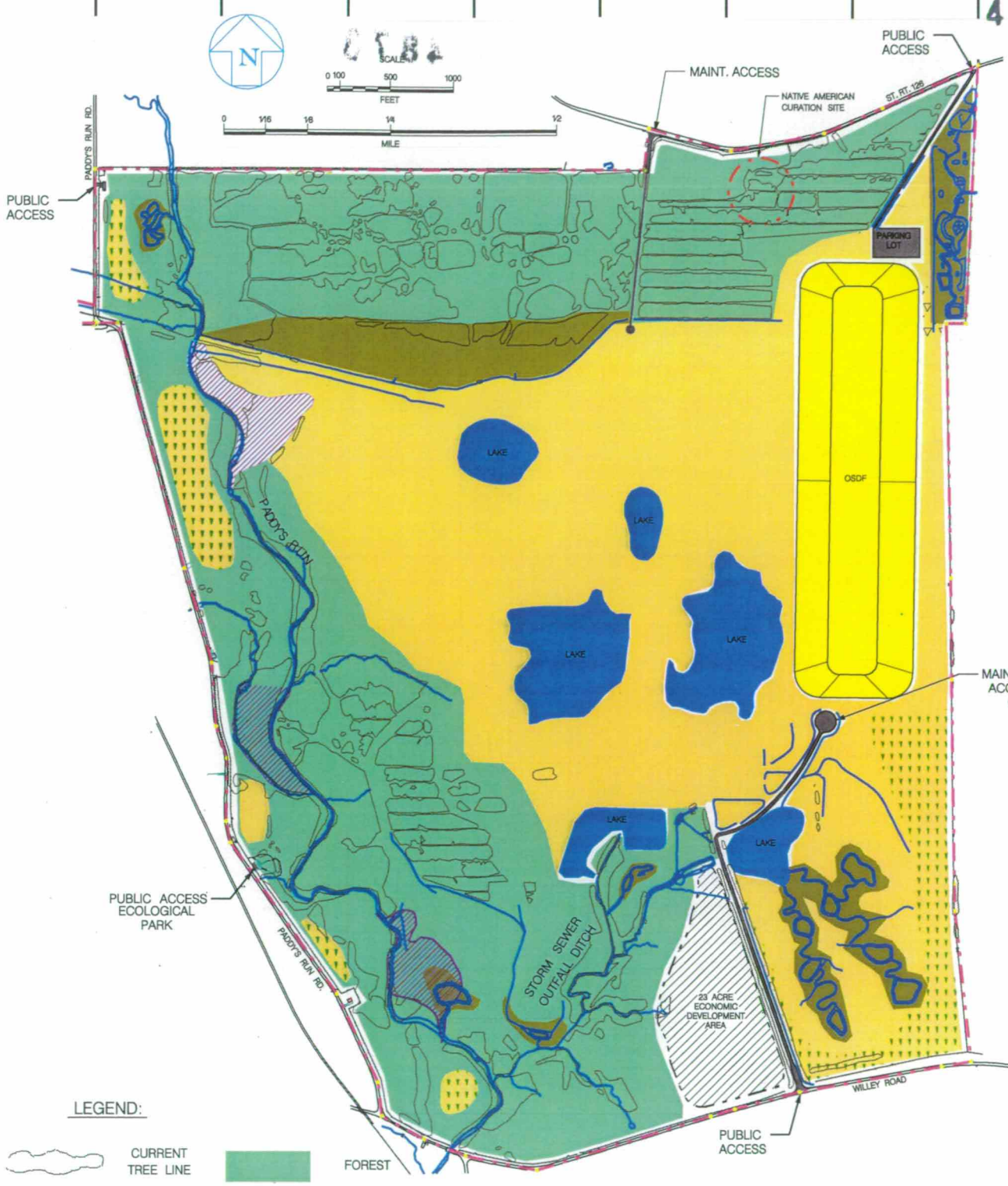
2. Provide information to the public regarding the residual contamination and risks associated with the site.

3. Educate visitors on the value of ground water resources and the importance of protecting them from contamination.

4. Educate visitors on the rich cultural history of the Fernald area and the role of cultural resources in the history of the area. (Since the NRDA did not specifically address cultural resources, it is important to address them in the education facility).

5. Provide a centralized location for teaching, researching and monitoring stewardship requirements, natural resources, and other relevant issues at the site.

The NRTs expect the $5 million will be used to support development of an on-site MUEF and associated environmental education activities.



LEGEND:

- CURRENT TREE LINE
- WATER
- PROPERTY LINE
- FENCE LINE
- FOREST
- PRAIRIE
- SAVANNA
- WETLANDS
- LAKE
- PUBLIC ACCESS ROAD
- EXPANDED FLOODPLAIN

FERNALD
CONCEPTUAL FINAL
LAND USE

FIGURE 1-1

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Section 2.0

2.0 RESTORATION PLANNING

The ecological restoration projects proposed in this NRRP have been developed by considering the extent of excavation and grading and the sequence of remediation activities so that restoration and establishment of the future land use can be expedited. In addition, consideration was given to uncertainties and a variety of other regulatory and technical considerations. This section will provide the basis for the proposed ecological restoration projects and conceptual final land use outlined in this plan.

2.1 ECOLOGICAL RESTORATION GOALS

Ecological restoration goals form the foundation from which conceptual restoration planning decisions are made. They also provide the basis for monitoring to determine the progress of restoration. The ecological restoration goals are stated and described below.

2.1.1 Restoration of Native Vegetation

Goal: *Enhance and restore, as feasible given postexcavation landforms, soils and surrounding conditions, early stage vegetative communities containing species present in pre-settlement southwestern Ohio.*

Ecological restoration at the FEMP will be conducted to promote the native flora of southwestern Ohio. This primarily involves the restoration of contiguous tracts of upland and riparian forest and tallgrass prairie interspersed with open water and/or wetland systems. Section 3.0 provides a more detailed description of habitat types that existed at the FEMP prior to industrial and agricultural development. The intent of this restoration plan is to use the natural dynamics of ecological systems to the extent possible. The vegetative species mix will depend on many factors, including soil, elevation, slope, drainage, adjacent existing vegetation, cost, and availability.

2.1.2 Paddys Run Restoration

Goal: *Enhance the natural dynamic stream characteristics and aquatic systems of Paddys Run, as feasible.*

Just as most other streams in southwestern Ohio, Paddys Run has been significantly altered due to channeling, erosion control, and removal of sand and gravel. In most instances, existing development prevents the restoration of a natural stream function. However, since undeveloped land is available at the

FEMP, the potential exists to enhance the Paddys Run floodplain and subsequent natural stream habitat. Section 3.1.4 provides additional information regarding Paddys Run stream restoration.

2.1.3 Wildlife Promotion

Goal: *Enhance and restore ecological systems that promote the habitation of wildlife populations native to southwestern Ohio.*

Wildlife use will be considered when selecting flora. Wildlife structures and cover (i.e., bird boxes, brush piles) will continue to be included in ecological restoration designs.

2.1.4 Meet Mitigation Requirements

Goal: *Integrate regulatory mitigation requirements into natural resource restoration plans.*

DOE is required to mitigate certain impacts to natural resources through laws and regulations. These include commitments under the National Environmental Policy Act (NEPA) and wetland mitigation under Section 404 of the Clean Water Act. To the extent possible, these actions will be conducted on-property and combined with adjacent restoration projects to allow for the contiguous restoration of the FEMP. Similar constraints as outlined in Section 2.1.1 must be taken into consideration during design and implementation.

2.2 INTEGRATION WITH SITEWIDE EXCAVATION PLAN

The sequencing of the implementation of the restoration projects proposed in this plan will be coordinated with the timing and sequencing of soil excavation. In addition, the final restoration of the site will be a function of the extent of excavation and final grading required during soil remediation. This section addresses how implementation of the projects outlined in the NRRP will be integrated with the guidelines established in the SEP and its appendices.

2.2.1 Sitewide Excavation Plan

The NRRP is fully integrated into the SEP. Many issues identified in the SEP apply directly to the NRRP, such as:

- Restoration strategy,
- Regulatory drivers,
- Certification and benchmark toxicity values (BTVs),
- Restoration grading guidelines,

- Environmental monitoring, and
- Quality assurance/quality control.

2.2.2 Postexcavation Strategy

A key component of the proposed future land use is a series of interconnected open water and wetland habitats. A fundamental assumption was that excavations required for soil remediation would be utilized for natural resource restoration to the maximum extent possible. There will be a variety of excavations in and adjacent to the Former Production Area that could potentially accommodate wetland and open water habitat (Figure 2-1). The specific locations and sizes of the open water/wetland areas were based on the requirements for excavation. In addition, the general pattern of site drainage for proposed final land use were established through the utilization of excavations formed through removal of site utilities.

2.2.3 Sitewide Sequencing Plan

The Sitewide Sequencing Plan, Appendix B in the SEP, dictates the sequence and timing of soil remediation activities, which will dictate the appropriate schedule for implementation and completion of long-term restoration projects. For example, revegetation of the Former Production Area would be delayed until the certification process is complete for the area-specific constituents of concern of a remediation area. The sequence of restoration projects has been designed to be implemented in tandem with soil remediation. However, the certification of areas to below-FRL concentrations will occur prior to the implementation of restoration projects.

2.2.4 Implementation of Construction

Implementation of Construction, which is Appendix F of the SEP, will provide the transition from the excavated areas resulting from soil remediation to the appropriate grades to support natural resource restoration. The final grading designs established in the Integrated Remedial Design Plans (IRDPs) will ensure that appropriate drainage is established, slopes are stabilized through the use of erosion control matting (as appropriate) or other means, and appropriate surface water diversion and retention are established to support open water/wetland habitats. These designs will also ensure that the floodplain of Paddys Run is not restricted as a result of soil remediation and that areas of the site for alternative use will be graded appropriately. The grading and stabilization of slopes (e.g., erosion matting) required to transition from remediation-driven excavation to a restoration configuration is termed "interim restoration." Any amendment to remediated/disturbed soil would also be carried out as part of "interim restoration."

2.3 UNCERTAINTIES AND CONSIDERATIONS DURING RESTORATION

There are several aspects of the NRRP and the natural resource restoration process that involve uncertainties that must be addressed through careful consideration in the project specific design processes. These issues are discussed in the following sections.

2.3.1 Potential for Cross-Contamination During Phasing of Excavation

The potential for cross-contamination is a concern that must be addressed during the excavation and grading processes. The overall excavation and grading processes will require that particular areas of the site be excavated and graded before or in parallel with other areas. Appropriate administrative and engineering controls must be in place so that cross-contamination is avoided. The specific projects outlined in this plan will not be implemented until the certification process is complete for each respective project area and appropriate controls are established to ensure the risk of cross-contamination has been minimized.

2.3.2 Ecological Risk Factors

Appendix C of the SEP contains the sitewide review of contaminants of ecological concern. The results of this review indicate that antimony, cadmium, lead, molybdenum, silver, and several polyaromatic hydrocarbons (PAHs) may be a concern in certain areas of the site. Remedial activities are anticipated to address any ecological concerns, and the presence of these constituents will be verified during the certification process. Appendix A of the NRRP provides a summary of Appendix C of the SEP.

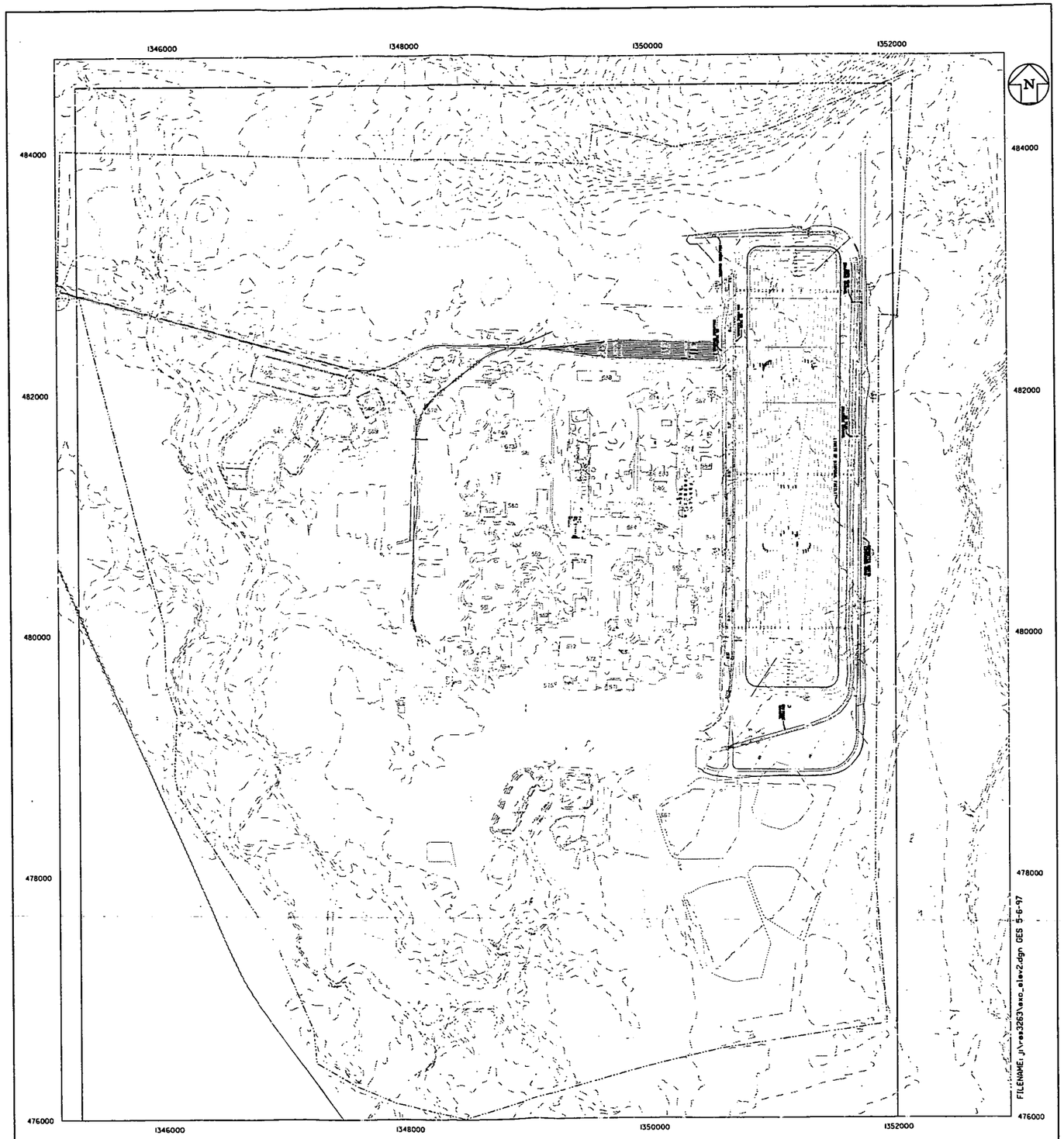

FIGURE 2-1. PROJECTED POST-EXCAVATION TOPOGRAPHIC MAP WITH O.S.D.F. DESIGN FEATURES

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3.0 GENERAL ECOLOGICAL RESTORATION PLAN

The purpose of this section is to present the general plans for restoring specific habitats at the FEMP. This section also presents the factors that will be considered during the ecological restoration design of specific areas.

3.1 SITEWIDE RESTORATION CONSIDERATIONS

This section outlines other considerations that were factored into the establishment of the specific restoration projects and the final land use outlined in this plan in addition to the issues outlined in Section 2.0.

3.1.1 Soil Balance and Pre-FEMP Topography (i.e., Cut and Fill Maps)

Topographic maps for the site prior to the construction of Fernald have been utilized to construct a profile of drainage patterns in the years prior to 1952. In designing the natural resource restoration projects, every effort will be made to re-establish original drainage patterns to the extent possible. The premise for this approach is that the site, over the long term, will tend to erode back to conditions that existed prior to construction of the FEMP. Therefore, re-establishing the approximate "natural" drainage patterns should facilitate restoration projects (i.e., wetlands and open water) in the long term.

3.1.2 Sequence of Natural Resource Restoration Projects

The long-term restoration projects will be implemented as soil remediation is completed and areas can be graded to support restoration. Specific restoration design schedules are provided on a project basis (to the extent they can be defined) in Section 4.0.

Sequencing in conjunction with remediation of individual excavation areas will require that some areas undergo interim restoration. Interim restoration involves grading to stabilize slopes and seeding with native grasses pursuant to guidelines established in the SEP. These actions are required when an area is excavated and certified clean, but cannot undergo final restoration until project activities are completed, such as the possible need for borrow material within the area and sequencing with adjacent projects.

3.1.3 Available Watershed

The Water Availability Study (Appendix C) provides quantitative modeling results regarding the surface water routing involving four open water areas under postremediation conditions at the FEMP. The modeling results indicate that four open water areas can be established in the Former Production Area and its vicinity as a result of soil excavation activities. Average water depths were determined by dividing the pond storage capacity by the surface water area. The average water depths in the four open water areas is anticipated to be 8.2, 10.5, 4.5, and 14.8 feet respectively. The acreage associated with the four open water areas under normal conditions at the minimum stage is anticipated to be 10, 12.5, 6.1, and 3.3 acres, respectively. This evaluation concludes that the postremediation topography could support the establishment of open water/wetland systems. The size and configuration of open water areas are not limited by this study and will be determined during natural resource restoration design.

Many other areas of the site will also be graded and restored to utilize available watershed for the creation of wetlands and ponds. Wetlands and ponds have already been created in the Area 1, Phase I Wetland Mitigation Project and the Area 8, Phase II Forest Demonstration Project. Additional ponds, vernal pools and wetlands are planned as part of most restoration projects (e.g., OSDF/Borrow Area, Northern Woodlot, Southern Waste Units). The creation/expansion of ponds, vernal pools and wetlands will occur as available watershed and topography will allow.

3.1.4 Restoration Plan for Paddys Run

Within certain reaches of the FEMP property, Paddys Run is characterized by extremely high banks and a stream bed that is deeply cut into the surrounding topography. These features result from both the natural geology and stream dynamics of Paddys Run, and historic activities at the FEMP (i.e., stream relocation, dredge of materials). Consequently, the current floodplain of Paddys Run has been greatly reduced from its previous extent, and undissipated flow is carried downstream during storm events. This increased downstream flow works to further cut existing stream banks, causing accelerated loss of riparian habitat, and lowering the elevation of the stream bed.

To counter this process, DOE-FEMP is committed to implementing a restoration strategy that creates additional floodplain along the Paddys Run corridor. This effort will involve using remediated areas to increase the amount of floodplain created during restoration activities. Remediation activities will result in increased floodplain in the Waste Pit Area and the Southern Waste Units. Additional floodplain can

be created in the "Oxbow Area" of Area 8, Phase III north with minimal excavation. Interim management strategies will also be established to ensure that these long-term restoration goals are considered when immediate erosion measures are required.

As much floodplain as possible will be created in these areas to absorb the flows generated by one to two-year storm events. Flows from one to two-year storm events are considered the channel-forming flows because of their increased frequency over time when compared to larger, more powerful, but infrequent storm events (Leopold 1994, Rosgen 1996). This information will be used to support specific restoration design decisions, as summarized below.

Specific restoration activities, in addition to the creation of additional floodplain, would increase the riparian corridor along Paddys Run generally enhancing the quality of habitat along the stream corridor. Restoration Design Plans would include vegetation to stabilize the expanded floodplain and enhance habitat along the stream. Also, bioengineering principles and techniques will be promoted as part of the restoration design to prevent unwanted bank erosion whenever feasible.

The NRTs, with input from the Army Corps of Engineers and the Ohio Department of Natural Resources (ODNR), are also committed to evaluating the rate of incision in the streambed of Paddys Run. The NRTs will take appropriate steps (e.g., input from outside consultants) to determine if incision in Paddys Run could create problems with the long-term stability of the stream and/or threaten restored areas of the stream. No specific actions are defined in this plan, but if the NRTs agree collectively that the rate of incision must be addressed, appropriate measures will be designed and implemented.

3.1.5 Future Public Use

In the fall of 1998, DOE released the Environmental Assessment on Proposed Final Land Use at the FEMP (EA, DOE 1999). During the same timeframe the draft NRRP was also made available for public review (see Section 6.0). The public review of the EA was supplemented by a public meeting to obtain input. The EA proposed that the majority of the FEMP (904 acres) be committed to natural resource restoration (i.e., an Undeveloped Park), the OSDF (123 acres) remain committed for its intended land-use, and that a 23-acre area be set aside for potential development in the future. Public comments on the EA were generally supportive of the proposed Land Use and DOE issued its final decision in

June of 1999 in the form of a Finding of No Significant Impact (FONSI). Figure 1-1 presents the most current version of the conceptual final land use.

The public input process in the fall of 1998 also generated a great deal of input regarding future public use of the FEMP. DOE requested that the Fernald Citizens Advisory Board (FCAB) take a lead role in evaluating the public's desires regarding future public use of the FEMP and make specific recommendations to DOE. The FCAB co-sponsored with Fernald Residents for Environment, Safety, and Health (FRESH), the Community Reuse Organization (CRO), and the Fernald Living History Project (FLHP), three public workshops during 1999 and 2000 regarding future public use of the FEMP. The recommendations and feedback provided to DOE as a result of the public workshops include the following:

1. Recommendation to proceed forward as soon as possible with the re-interment of Native American Remains on the Fernald Site (Recommendation #00-3).

2. A collective vision of the future of the Fernald Site was developed that included the Fernald Site being a regional educational center, with a focus on environmental, cultural and other historical information related to the site (Recommendation #00-4).

3. Additional recommendations were made regarding the establishment of trails and a multi-use educational facility (Recommendation #2001-02 and 2001-03).

All of the FCAB recommendations can be found on their web site at www.fernaldcab.org. DOE is currently considering the recommendations and will pursue a decision regarding public use of the Fernald Site. The NRTs have collectively agreed that future public use of the site for educational and research purposes, including the construction of interpretive trails and an educational facility, is consistent with the goals of the NRTs. Reburial of Native American remains can occur within restored areas with no impact on the restoration plans outlined in this plan. DOE will issue a Master Plan for Public Use at the FEMP for stakeholder review and comment prior to making a final decision.

The NRTs have agreed that low-impact trails (i.e., walking/hiking) should be integrated in select restored areas to further educational and interpretive use of the FEMP. The NRTs have agreed that no more than four miles of mulched trails (or suitable alternative) should be included in the southern and western portions of the FEMP. Trails should focus on the Paddys Run stream corridor, portions of the Borrow Area, and the Southern Waste Units. Trails should provide viewing areas for the OSDF, Former

Production Area and Northern Woodlot, but should limit entry into these areas. Boardwalks of approximately one mile should be incorporated into the trail design for restored areas to provide viewing of wetlands. Interpretive signs/displays should be installed at no more than 20 locations on the trail and no more than five overlooks should be constructed at various points on the trail.

The NRTs also support approximately one mile of improved (e.g., paved) trails providing handicap access to the restored areas of the FEMP, as determined appropriate by the NRTs. The NRTs also support trails providing access to Native American reinterment areas as determined appropriate by DOE working with Native American tribes and groups. The NRTs do not support any use of trails that will result in an activity destructive to restored areas of the FEMP. The NRTs do not support trails for biking or off-road vehicles.

The NRTs expect the $5 million settlement among DOE and the other NRTs will be used to support development of an on-site MUEF and groundwater education activities.

3.1.6 Soil Preparation

Specific ecological restoration designs will take into consideration the types of soil present when determining vegetation plans. In general, the restoration design process will include a predesign investigation that will evaluate the condition of soils present (e.g., pH, organic content) to determine if soil amendment/fertilization is required to establish the desired vegetation. For undisturbed areas, Hamilton and Butler County soil survey maps will be used as a preliminary guide [Soil Conservation Service (SCS) 1982a, 1982b]. Where necessary, analysis may be conducted to determine the specific characteristics of the soil, such as moisture and organic content.

For excavated areas, the remaining subsoils may not be amenable to revegetation. The NRRP addresses nutrient deficient excavated areas by considering native prairie grasses and pioneer tree and shrub species that survive in nutrient-poor soil conditions. Nevertheless, soil amendments (woodchips, compost, or suitable alternative) may be necessary. Research is being conducted on site to assist in determining the optimal amendment strategy for the restoration of native prairie grasses. If applicable, results of this effort will be used to guide soil preparation activities in excavated areas.

3.1.7 Use of Plants and Seeds and Invasive Plant Species Management

All plants and seeds used for ecological restoration at the FEMP will be native to southwest Ohio. To preserve regional genotypes, an effort will be made to obtain plants and seeds from local sources. However, because of the scope and scale of restoration projects planned at the FEMP, non-local plants and seeds may be needed. When feasible, restored areas may be interseeded with seeds collected on-property. Appropriate invasive species control during the first few years after planting will be incorporated into applicable Natural Resource Restoration Design Plans (NRRDPs) to help planted material become established.

3.1.8 Maintenance of Restored Areas

Ecological restoration design will provide recommendations regarding maintenance and management of restored areas. All restored areas of the FEMP will undergo maintenance actions as needed to facilitate establishment of vegetation and maintain the integrity of the areas throughout the restoration process. The maintenance actions outlined below represent minimum maintenance actions to be carried out until the completion of restoration work on the FEMP as defined by Site Closure plus one year. A Restored Area Maintenance Plan outlining more specific actions will be developed and submitted to the NRTs by July 1, 2002. All decisions on maintenance actions to be carried out in restored areas after the completion of restoration are being deferred to long-term stewardship planning. The following are the general maintenance actions that will be carried out in each restored area during restoration:

- Controlling invasive/noxious species per the pending maintenance plan and NRRDP requirements as determined appropriate by the NRTs collectively. Control will occur by spot removal using manual, mechanical or chemical methods.
- Reseeding and/or replanting of restored areas as required by implementation monitoring and adaptive management decisions to ensure appropriate vegetative cover.
- Maintain prairie and savanna ecosystems and diversity through appropriate disturbance regimes and thatch removal. Activities may include mowing, burning, or physical disturbance.
- Correcting soil erosion problems at drainage channels, stream banks, outfall structures or wetland berms by appropriate means that are impacting or have the potential to impact restored areas.
- Repairing wildlife structures/boxes as needed.

- Clearing debris, tripping hazards, overhanging limbs, excessive weed growth, and replace mulch on pathways and public access areas.
- Keeping access points and parking areas in good condition including the replacement of gravel and mowing and trimming as appropriate.
- Repairing wooden overlooks, bridges, boardwalks, steps, rails, etc., to ensure a safe working condition.
- Repairing interpretive signs and displays.

As noted above, long-term maintenance and management is beyond the scope of this plan and will be evaluated as part of the stewardship planning at the FEMP.

3.2 HABITAT-SPECIFIC RESTORATION PLANS

The majority of ecological restoration at the FEMP will consist of a combination of upland forest, riparian forest, tallgrass prairie/savanna and wetland/open water systems, as well as enhancement of existing habitats such as pine plantations. The individual restoration projects set forth in Section 4.0 specify each habitat that will be designed, and describe the area-specific factors that must be considered in the design. The descriptions below provide the basis for restoration of these specific habitats.

3.2.1 Upland Forest

Prior to settlement of the area, the land now occupied by the FEMP probably consisted of forest. The sitewide characterization report describes the FEMP as existing in a transition zone between the Oak-Hickory and Beech-Maple sections of the Eastern Deciduous Forest province (DOE 1993). Braun (1989) describes the area slightly differently, as a transition from Beech-Maple to Western Mesophytic forest. Regardless, these forests share many similar species, such as American beech (*Fagus grandifolia*), sugar maple (*Acer saccharinum*), tulip poplar (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), northern red oak (*Quercus rubra*), Ohio buckeye (*Aesculus glabra*), and shagbark hickory (*Carya ovata*). Therefore, restoration of upland forests at the FEMP will focus on the establishment of this Beech-Maple, Oak-Hickory transition zone.

Specific planting plans will be detailed in individual NRRDPs. Each NRRDP will specify soil preparation, species mix, species density, planting instructions, cover, short-term maintenance, herbivore control, and monitoring. Other revegetation design methodologies may be used as well, depending on the specific needs identified in individual NRRDPs. Revegetation of each area will depend on a variety

of factors, including soils, topography, hydrology, existing vegetation availability, cost, and relation to other restoration projects. Trees and shrubs will be selected from the comprehensive tree and shrub guide established for the FEMP on Table 3-1. The trees and shrubs selected for forest restoration projects will be consistent with the templates used in the Area 8, Phase II Forest Demonstration Project to the degree practicable. A mix of trees and shrubs will be selected based on contribution to wildlife (e.g., cover diversity and forage). In some projects, consideration may be given to natural successional processes. Pioneer tree species may be planted in disturbed areas, while late successional species may be used to enhance existing woodlots.

Table 3-1 has been provided as a comprehensive list of trees and shrubs for use in designing restoration projects at the FEMP. The trees and shrubs listed are all native to southwestern Ohio, as described by Braun (1989). The master list has been divided into general categories of upland, riparian, and wetland vegetation. However, site-specific conditions will dictate the species mix within each NRRDP. To assist in these decisions, supplemental information is included in Table 3-1. The plant form and its primary function is described, along with additional comments regarding growth habits, site-specific suitability, and other considerations. DOE will take all of this information into consideration when developing species lists for project-specific NRRDPs.

3.2.2 Riparian Forest

The Paddys Run floodplain will be expanded as part of the long-term management plan for Paddys Run. Within these floodplain areas, the corridor of Paddys Run and the Storm Sewer Outfall Ditch (SSOD) will be expanded through revegetation as described above for upland forests. The trees species chosen from Table 3-1 are those that can withstand periodic inundation. Typical species that will be planted in floodplain areas include eastern cottonwood (*Populus deltoides*), swamp white oak (*Quercus bicolor*), black willow (*Salix nigra*), American sycamore (*Platanus occidentalis*), and green ash (*Fraxinus pennsylvanica*). As with the upland forest revegetation, individual NRRDPs will establish planting plans based on a variety of site-specific factors.

3.2.3 Tallgrass Prairie/Savanna

The FEMP is generally located east of the range where tallgrass prairies and savannas were predominant, but prairie remnants did exist in Ohio prior to European settlement [Society for Ecological Restoration (SER 1997)]. At one point, at least 300 prairies were present across Ohio (Gordon 1969). Remnant wet

meadow has appeared as part of a wetland restoration several miles west of the FEMP (Klein 1996). The original Crosby Township Land Survey documents the presence of numerous small prairies in the area (Hamilton 1819). Also, since prairie grasses and forbs are tolerant of nutrient-poor soils, they are potentially ideal for re-establishing vegetation in excavated areas. A tallgrass prairie restoration has been successfully completed on an interstate borrow pit outside of Dayton, Ohio (Geiger 1997). This effort involved similar sub-soil conditions that will be present in several deep excavations at the FEMP. For these reasons, tallgrass prairie and savanna restoration will be undertaken at the FEMP, primarily in disturbed areas.

Prairie restoration will involve application of soil amendments (as needed), seeding of grasses and forbs, and maintenance through mowing and/or controlled burns until the end of restoration. Large areas of prairie will be established in the Former Production Area, Borrow Area, and OSDF with smaller prairies scattered throughout other portions of the FEMP. Figure 3-1 outlines the areas of the FEMP that will be established as prairies. Other prairies will be established for diversity in habitat and then left unmanaged over time to convert to woodlots. Figure 3-1 identifies prairies expected to be managed on the FEMP throughout the restoration process. Research is currently being conducted to determine the optimal use of soil amendments for prairie grass establishment. Results of the research and area-specific soil sampling will guide NRRDP specifications for each area. After required soil preparation, seeding of grasses and forbs will primarily be conducted with a Truax seed drill. Table 3-2 outlines the species of grasses and forbs to be used in restoration of the FEMP.

Where specified, savannas will be established by planting a sparse mix of bur oak (*Quercus macrocarpa*), along with white oak (*Quercus alba*) and shrubs such as gray dogwood *(Cornus racerosa*), hazelnut (*Corylus americana*), and smooth sumac (*Rhus glabra*) and seeding the area with the grass mix described above. Specific mixes and densities will be established in NRRDPs.

3.2.4 Wetlands/Open Water

Prior to the rise of agriculture in the region, portions of the FEMP and surrounding area may have consisted of wetlands. Several areas of poorly drained soils are located on FEMP property (DOE 1993). High-quality forested wetlands are also located just west of the FEMP (Davis 1994). In addition, DOE has a responsibility to provide approximately 16 acres of mitigated wetlands under Section 404 of the Clean Water Act, as described in more detail below. For these reasons, wetland mitigation will be

pursued in appropriate areas of the FEMP. Some open water areas will also be established as a result of deep excavations within the Former Production Area. These areas will provide additional wildlife habitat.

Approximately 11 acres of jurisdictional wetlands have been or will be dredged or filled as a result of remedial activities at the FEMP. In June 1995, DOE met with EPA, Ohio Environmental Protection Agency (OEPA), U.S. Fish and Wildlife Service (USFWS), and ODNR to discuss mitigation of the impacted wetlands. DOE agreed to mitigate wetlands at a 1.5 to 1 ratio, replacing 1.5 acres of wetlands for every 1 acre dredged or filled. DOE also agreed to implement the mitigation on property if possible. Because wetland design will be area-specific, conceptual design details are described in the area-specific descriptions (Sections 4.2 and 4.6).

In addition to the wetland mitigation process, upland and riparian forest revegetation in various areas will be designed to restore wet woods. Soil characteristics and hydrology will be considered when planting areas with wetland trees and shrubs. Detailed analyses will be conducted and presented in NRRDPs to determine specific planting schemes.

TABLE 3-1
MASTER WOODY PLANT SPECIES LIST

Scientific Name	Common Name	Form	Function	Use	Comments
Acer nigrum	black maple	canopy tree	cover	upland	Similar to *Acer saccharum*, but likes slightly moister conditions.
Acer rubrum	red maple	canopy tree	cover	riparian, upland, wetland	Tolerates a wide variety of conditions. Can pioneer disturbed sites
Acer saccharinum	silver maple	canopy tree	cover	riparan, wetland	Fast growing. Pioneers disturbed banks following *Populus deltoides*
Acer saccharum	sugar maple	canopy tree	cover, mast	upland	Co-dominant in beech-maple forest
Aesculus glabra	ohio buckeye	understory tree	diversity	riparian, upland	Tolerates a wide variety of conditions. Avoided by deer
Aesculus octandra	yellow buckeye	understory tree	diversity	riparian, upland	Generally found east of FEMP in unglaciated portions of Ohio
Alnus serrulata	brookside alder	shrub	cover	riparan, wetland	Obligate wetland species
Amelanchier arborea	downy serviceberry	shrub	fruit, diversity	upland	Found mostly east of FEMP. Associated with *Acer rubrum*
Amelanchier laevis	allegheny serviceberry	shrub	cover	upland	Not common in Ohio. Abundant in southern Appalachian highlands
Amorpha fruticosa	false indigo-bush	shrub	cover	wetland	Fast growing. Avoided by deer. Facultative wetland species
Aronia melanocarpa	black chokeberry	shrub	aesthetics	riparian, wetland	Found in wet areas and dry ledges/slopes. Found mostly east of FEMP
Asimina triloba	paw paw	understory tree	fruit, diversity	riparian, upland	Forms clustered stands in forest understory. Tap root
Campsis radicans	trumpet creeper	vine	aesthetics	riparian, upland	Showy. Naturalized in Ohio
Carpinus caroliniana	hornbeam	understory tree	diversity, mast	riparian, wetland	Very shade tolerant. Found in moist and mesophytic woods
Carya cordiformis	bitternut hickory	canopy tree	cover	upland	Common *Carya* spp. at FEMP. Tap root
Carya laciniosa	shellbark hickory	canopy tree	cover, mast	riparian, upland	Found in moist to wet sites and along streams
Carya ovata	shagbark hickory	canopy tree	cover, mast	riparian, upland	Similar to *Carya laciniosa*, but found in drier areas as well
Castanea dentata	chestnut	canopy tree	diversity, mast	upland	Rare due to chestnut blight. Historically found mostly east of FEMP
Ceanothus americanus	new jersey tea	shrub	diversity	upland	Found mostly east of FEMP
Celastrus scandens	bittersweet	vine	diversity	riparian, upland	Drought and flood tolerant
Celtis occidentalis	hackberry	canopy tree	diversity	riparian, upland	Common at FEMP in a variety of habitats
Cephalanthus occidentalis	buttonbush	shrub	cover	wetland	Emergent species that forms pure stands
Cercis canadensis	redbud	understory tree	aesthetics	riparian, upland	Showy edge species
Cornus alternafolia	alternate-leaved dogwoo	understory tree	diversity, cover	riparian, upland	Found mostly east of FEMP
Cornus amomum	silky dogwood	shrub	cover	riparian, wetland	Can reproduce by dormant live cuttings. Suitable for erosion control
Cornus drumondii	roughleaf dogwood	shrub	cover	upland	Edge species
Cornus florida	flowering dogwood	understory tree	aesthetics	upland	Showy shade tolerant species
Cornus racemosa	grey dogwood	shrub	cover	upland	Seems to compete well with *Lonicera mackii*
Cornus stolonifera	red-osier dogwood	shrub		riparian, wetland	Can reproduce by dormant live cuttings. Suitable for erosion control

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TABLE 3-1
MASTER WOODY PLANT SPECIES LIST

Scientific Name	Common Name	Form	Function	Use	Comments
Corylus americana	hazel nut	shrub	diversity	upland	Found in a variety of habitats. Can form large patches
Crataegus crus-galli	cockspur hawthorne	shrub	diversity	upland	Thorny edge species
Crataegus mollis	downy hawthorne	understory tree	cover	upland	Thorny
Crataegus phaenopyrum	Washington hawthorne	understory tree	diversity	upland	Thorny
Decodon verticillatus	water willow	shrub	diversity	wetland	Emergent species
Diospyros virginiana	persimmon	understory tree	fruit	upland	Edible fruit. Found mostly east of FEMP in unglaciated areas
Euonymus atropurpureus	eastern wahoo	understory tree	aesthetics	riparian, upland	Showy
Fagus grandifolia	beech	canopy tree	cover, mast	upland	Co-dominant in beech-maple forest
Fraxinus americana	white ash	canopy tree	cover	riparian, upland	Common at FEMP in a variety of habitats
Fraxinus nigra	black ash	canopy tree	cover, diversity	riparian, wetland	Can tolerate standing water. Smaller than *Fraxinus americana*
Fraxinus pennsylvanicum	green ash	canopy tree	cover	riparian, wetland	Flood tolerant bottomland species
Fraxinus quadrangulata	blue ash	canopy tree	cover, diversity	upland	Most drought-resistant *Fraxinus* spp.
Gymnocladus dioica	kentucky coffeetree	canopy tree	diversity	riparian, upland	Most common in southwestern portion of Ohio
Hamamelis virginiana	witch hazel	understory tree	cover	upland	Found in a variety of habitats singularly or in groups
Hydrangea arborescens	wild hydrangea	shrub	aesthetics	upland	Found in ravines and shaded bluffs
Hypericum spathulatum	shrubby st. john's wort	shrub	diversity	riparian, wetland	Showy species that can form large patches
Ilex verticallata	winterberry	shrub	aesthetics	riparian, wetland	Found mostly east of FEMP
Juglans cinerea	butternut	canopy tree	mast, diversity	upland	Rare Ohio species
Juglans nigra	black walnut	canopy tree	mast, diversity	upland	Allelopathic. Can form pure stands
Juniperus virginiana	eastern red cedar	understory tree	cover	upland	Only coniferous species native to FEMP
Lindera benzoin	spicebush	shrub	cover	upland	Common shrub of beech-maple forest
Liquidambar styraciflua	sweetgum	canopy tree	diversity	riparian, wetland	Southern tree found mostly east and south of FEMP
Liriodendron tulipifera	tulip poplar	canopy tree	cover, aesthetics	upland	Tallest deciduous species in the eastern U.S.
Lonicera sempervirens	trumpet honeysuckle	vine	aesthetics	upland	Southern species uncommon in Ohio
Morus rubra	red mulberry	understory tree	fruit	riparian, upland	Fast growing. Shade tolerant
Nyssa sylvatica	black gum	canopy tree	diversity, aesthetics	riparian, upland, wetland	Found in a variety of habitats
Ostrya virginiana	hop-hornbeam	understory tree	diversity	riparian, upland, wetland	Found in a variety of habitats
Parthenocissus quinquefolia	Virginia creeper	vine	diversity	upland	Showy in autumn
Physocarpus opulifolius	ninebark	shrub	diversity	upland	Plant in open areas

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TABLE 3-1
MASTER WOODY PLANT SPECIES LIST

Scientific Name	Common Name	Form	Function	Use	Comments
Platanus occidentalis	sycamore	canopy tree	cover	riparian, wetland	Fast growing streamside spp. Can also pioneer old fields
Populus deltoides	cottonwood	canopy tree	cover	riparian	Fast growing streamside spp. Can also pioneer old fields
Prunus americana	American plum	understory tree	diversity, fruit	upland	Forms large patches
Prunus serotina	black cherry	canopy tree	fruit	upland	Found in a variety of habitats. Largest *Prunus* spp. In Ohio
Prunus virginiana	choke cherry	shrub	cover	upland	Found mostly north of FEMP
Quercus alba	white oak	canopy tree	cover, mast	upland	Found in a variety of habitats.
Quercus bicolor	swamp white oak	canopy tree	cover, mast	riparian, wetland	Flood tolerant bottomland spp.
Quercus coccinea	scarlet oak	canopy tree	cover, mast	upland	Found mostly east of FEMP
Quercus inbricaria	shingle oak	canopy tree	diversity	upland	Found in a variety of habitats
Quercus macrocarpa	bur oak	canopy tree	diversity, mast	upland	Burn resistant woody dominant of savanna habitat
Quercus muehlenbergii	chinqapin oak	canopy tree	diversity, mast	upland	Most common in southwestern portion of Ohio
Quercus palustris	pin oak	canopy tree	cover	riparian, wetland	Can form pure stands in bottomlands
Quercus prinus	chestnut oak	canopy tree	diversity	upland	Found mostly east of FEMP in unglaciated areas
Quercus rubra	red oak	canopy tree	cover, mast	upland	Found in a variety of upland habitats
Quercus shumardii	shumard oak	canopy tree	diversity, mast	upland	Southern tree found in southwest Ohio
Quercus velutina	black oak	canopy tree	cover, mast	upland	Similar to *Quercus rubra*
Rhus aromatica	fragrant sumac	shrub	cover, aesthetics	upland	Prefers dry, gravelly, rocky banks
Rhus glabra	smooth sumac	shrub	aesthetics	upland	Showy species. Most abundant *Rhus* spp. In Ohio
Rhus typhina	staghorn sumac	shrub	aesthetics	upland	Similar to *Rhus glabra*
Ribes americanum	black currant	shrub	diversity	wetland	Found mostly north of FEMP
Rosa caroliniana	carolina rose	shrub	aesthetics	upland	Prefers dry open areas
Rosa palustris	swamp rose	shrub	aesthetics	wetland	Prefers wet areas and banks of slow-flowing stream
Rosa setigera	prairie rose	shrub	aesthetics	upland	Can form large stands
Rubus allegheniensis	blackberry	shrub	fruit	upland	Thorny. Edible fruit
Rubus occidentalis	black raspberry	shrub	fruit	upland	Thorny. Edible fruit
Salix amygdaloides	peach-leaf willow	understory tree	cover	riparian	Can reproduce by dormant live cuttings. Suitable for erosion control
Salix discolor	pussy willow	shrub	cover	riparian, wetland	Can reproduce by dormant live cuttings. Suitable for erosion control
Salix eriocephala	heart-leaved willow	shrub	diversity	riparian, wetland	Can reproduce by dormant live cuttings. Suitable for erosion control
Salix exigua	sandbar willow	understory tree	cover	riparian	Can reproduce by dormant live cuttings. Suitable for erosion control

TABLE 3-1
MASTER WOODY PLANT SPECIES LIST

Scientific Name	Common Name	Form	Function	Use	Comments
Salix humila	prairie willow	shrub	cover	upland	Can reproduce by dormant live cuttings.
Salix nigra	black willow	understory tree	cover	riparian, wetland	Can reproduce by dormant live cuttings. Suitable for erosion control
Salix sericea	silky willow	shrub	cover	riparian, wetland	Can reproduce by dormant live cuttings. Suitable for erosion control
Sambucus canadensis	elder	shrub	fruit	riparian, wetland	Can reproduce by dormant live cuttings. Suitable for erosion control
Sassafras albidum	sassafras	understory tree	diversity	upland	Can form pure stands
Smilax rotundifolia	greenbriar	shrub	diversity	upland	Thorny.
Spiraea alba	meadow sweet	shrub	aesthetics	wetland	Found mostly north of FEMP
Spiraea tomentosa	steeple bush	shrub	aesthetics	wetland	Found mostly north and east of FEMP
Staphylea trifolia	bladdernut	shrub	diversity	riparian, upland	Prefers shaded banks
Symphoricarpos orbiculatus	coral berry	shrub	diversity	riparian, upland	Can form large patches in disturbed areas
Tilia americana	basswood	canopy tree	cover, aesthetics	upland	Common in glaciated portion of Ohio
Ulmus americana	american elm	canopy tree	cover	riparian, upland, wetland	Found in a variety of habitats. Impacted by dutch elm disease
Ulmus rubra	slippery elm	canopy tree	cover	riparian, upland, wetland	Found in a variety of habitats
Vaccinium corymbosum	highbush blueberry	shrub	fruit	upland, wetland	Boreal relic found in wet areas within glaciated portion of Ohio
Viburnum acerifolium	mapleleaf viburnum	shrub	diversity	upland	Associated with *Fagus grandifolia*
Viburnum dentatum	arrowwood	shrub	cover	wetland	Found mostly east of FEMP
Viburnum lentago	nannyberry	shrub	cover	upland	Found mostly north of FEMP
Viburnum prunifolium	blackhaw viburnum	understory tree	cover	upland	Found in a variety of habitats singularly or in groups
Zanthozylum americanum	prickly ash	understory tree	diversity	upland	Thorny. Can form large stands

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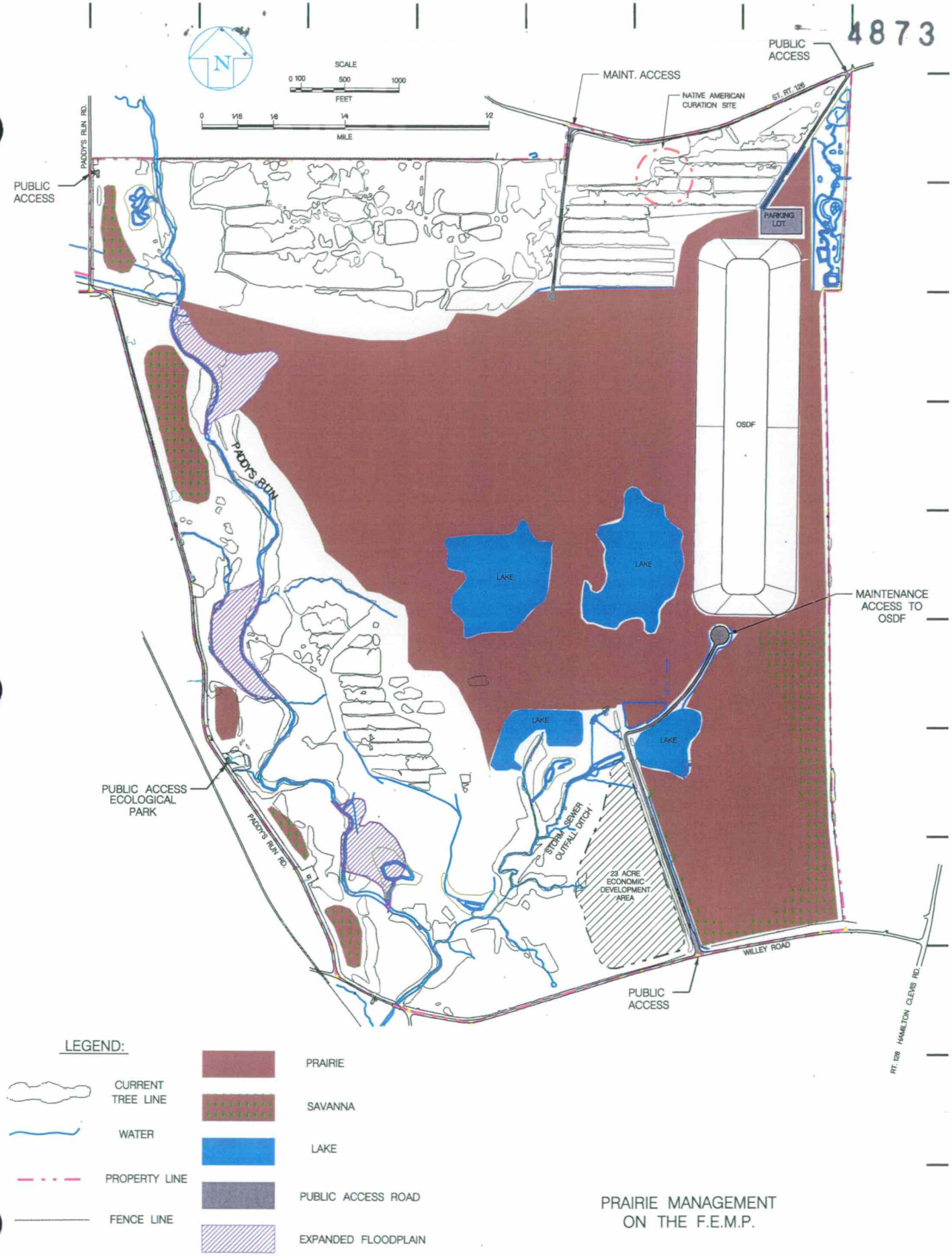
TABLE 3-2
SEED MIX IN WET AND DRY AREAS FOR PERMANENT VEGETATION

Species Name	
Dry Areas	**Wet Areas**
Big Bluestem (*Andropogon gerardii*)	Big Bluestem (*Andropogon gerardii*)
Little Bluestem (*Schizachyrium scoparius*)	Canada Wild-Rye (*Elymus candensis*)
Side-Oats Grama (*Bouteloua curtipendula*)	Switch Grass (*Panicum virgatum*)
Indian Grass (*Sorghastrum nutans*)	Blue Joint Grass (*Calamagrostis canadensis*)
Canada Wild-Rye (*Elymus canadensis*)	Porcupine Sedge (*Carex hystericina*)
Switch grass (*Panicum virgatum*)	Fox Sedge (*Carex vulpinoidea*)
Annual Rye (*Lolium multiflorum*)	Dark Green Bulrush (*Scirpus atrovirens*)
	Annual Rye (*Lolium multiflorum*)
Wildflowers, uniform mix of the following:	Prairie Cordgrass (*Spartina pectinata*)
Butterflyweed (*Asclepias tuberosa*)	Wildflowers, uniform mix of the following:
New England Aster (*Aster novae-angliae*)	
Smooth Aster (*Aster laevis*)	Red Milkweed (*Asclepias incarnata*)
Canada Milkvetch (*Astragalus Canadensis*)	New England Aster (*Aster novae-angliae*)
Purple Prairie Clover (*Petalostemum purpureum*)	Wild Senna (*Cassia hebecarpa*)
Ox-eye Sunflower (*Heliopsis helianthoides*)	Canada Tick Trefoil (*Desmodium canadense*)
Bergamot (*Monadara fistulosa*)	Prairie Blazingstar (*Liatris pycnostachya*)
Purple Coneflower (*Echinacea purpurea*)	Great Blue Lobelia (*Lobelia siphilitica*)
Pale Purple Coneflower (*Echinacea pallida*)	Bergamot (*Monadara fistulosa*)
Yellow Coneflower (*Ratibida pinnata*)	Yellow Coneflower (*Ratibida pinnata*)
Black-Eyed Susan (*Rudbeckia hirta*)	Branched Coneflower (*Rudbeckia hirta*)
Spiderwort (*Tradescantia ohioensis*)	Blue Vervain (*Verbena hastata*)
Blue Vervain (*Verbena hastata*)	Angelica (*Angelica atropurpurea*)
Hoary Vervain (*Verbena stricta*)	Sweet Joe-Rye Weed (*Eupatorium purpureum*)
Beardtongue (*Penstemon grandiflorus*)	
Cupplant (*Silphium perfoliatum*)	
Sweet Joe Pye-Weed (*Eupatorium purpureum*)	
White False Indigo (*Baptisia leucantha*)	
Blue False Indigo (*Baptisia australis*)	
Partridge Pea (*Cassia fasciculata*)	
Rattlesnake Master (*Eryngium yuccifolium*)	
Round-headed Bush Clover (*Lespedea Capitata*)	
Stiff Goldenrod (*Solidago risida*)	



PRAIRIE MANAGEMENT ON THE F.E.M.P.

FIGURE 3-1

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4.0 NATURAL RESOURCE RESTORATION PROJECTS

This section describes restoration projects completed and proposed for the FEMP. These descriptions provide conceptual components required for each project. The completed restoration projects are discussed below in the sequence of implementation. Figure 4-1 shows the location of completed projects.

4.1 PROJECTS COMPLETED TO DATE

4.1.1 Aesthetic Barrier Along Willey Road

This restoration project involved establishment of an aesthetic barrier, approximately 50 feet wide, using densely planted trees to provide a visual screen and aesthetic appeal between Willey Road and FEMP construction activities (Figure 4-1). The FCAB recommended that DOE provide screening of remedial activities as feasible and appropriate (Recommendation #97-1). Immediate, effective visual screening was achieved through dense planting of evergreens (eastern white pine, Norway spruce) and deciduous trees (red maple, green ash, American crabapple, tulip poplar, hawthorn, oak, and redbud) (Photo 1). Aesthetic appeal is provided by using spring flowering trees (e.g., American crabapple, redbud) and trees with vivid yellow and red foliage (e.g., red maple). By designing the barrier to include a mixture of evergreens and deciduous trees, the barrier will provide year-round screening and quality habitat to wildlife species.

Safety hazards that can be created by restricting visibility or creating additional deer habitat too close to the road were considered during the design. As a result, the barrier was set back 50 feet from the road. This project was implemented and completed in the fall of 1998.

4.1.2 Wetland Mitigation – Phase I

This restoration project was conducted in approximately 12 acres of Area 1, Phase I, from March 1999 to November 1999 (Figure 4-2, Photo 2). As a result of remedial activities at the FEMP, approximately 11 acres of jurisdictional wetlands were dredged or filled. As stated in Section 3.2.4, DOE negotiated a 1.5 to 1 wetland mitigation ratio with Regulatory Agencies (EPA, OEPA, ODNR, USFWS). Phase I wetland mitigation was performed to address a portion of the required 15 mitigated acres of wetlands.

The Phase I wetland mitigation performed in Area 1, Phase I was designed to produce more than 6 acres of constructed wetlands, with the remaining portions of the site functioning as early stage upland forest and grassland. Design considerations included grading, hydrology, planting, wildlife features and erosion control. Grading was performed using naturally occurring curves and shapes to provide a natural appearance and considered specification and details related to topsoil requirements and placement.

The Wetland Mitigation Project was initiated in March 1999. The majority of the project area had been previously remediated resulting in the removal of the top 6 inches of topsoil, except for the northern portion of the project. Grading began in mid-March 1999, with the stockpiling of topsoil in the northern end of the project. Grading moved north to south with the creation of Basins 8, 7 and 6 respectively. Grading then moved to the southern end of the project with the creation of Basins 4, 3, 2, 5 and 1 in succession. Each basin was proctor tested to ensure proper completion of the basin and drainage swales. Concrete headwall structures were installed to control flow out of Basins 2, 3 and 6. Existing topsoil was used to cover Basins 2, 6, 7 and 8. The topsoil layer on basin 1 was mixed with composted sewage sludge as a soil amendment. Basins 3 and 4 received a combination of wood chips and saw dust mixed with surface soil. Basin 5 received only wood chips. All grading was complete in May 1999.

The planting of vegetation included species native to Hamilton, Butler, and/or nearby counties and was conducted during the months of April, May, October and November 1999. All woody plants were mulched with wood chips following planting. Various wildlife habitat requirements and features for species of birds, mammals, reptiles, and amphibians were also included, such as duck boxes, bat boxes, bird boxes and a snake hibernaculum. A total of 17 wildlife structures are located within the project area. To the extent possible, herbaceous and woody plant species were selected and specified based on their ability to provide food or cover for selected wildlife species. Natural materials (coconut logs and coconut fiber matting) were used to control erosion as part of the planting specifications.

The hydrologic regime of the mitigation site and the surrounding landscape was assessed to efficiently use available water sources to maximize wetland conditions. Outfall structures with stop boards were required between three of the basins. Open water areas have specified depths designed for specific biological needs and choices of habitat.

The wetland mitigation project will be monitored for five years following project completion as outlined in the NRRDP. Monitoring will ensure that a minimal survival rate of 80 percent is maintained on trees and shrubs and that 90 percent native cover is maintained. A Consolidated Monitoring Report will be submitted to the NRTs and Agencies at the end of each calendar year in which the monitoring is conducted.

4.1.3 Area 8, Phase II Revegetation

This demonstration project involved the creation of native forest cover in approximately 20 acres of grazed pasture located in the northwestern corner of the FEMP, west of Paddys Run (Figure 4-3, Photo 3). The purpose of this project is to provide an area of finished reforestation early in the overall restoration process that will effectively demonstrate the feasibility and advantages of restoring natural habitats. The demonstration forest provides early stages of an upland and riparian forest, wetland, and prairie habitats and various habitats for many forms of wildlife. The grazing lease for this area was terminated as part of the continued phase-out of grazing lease agreements at the FEMP. The project was implemented in Fiscal Year 2000.

This project consists of developing both early stage upland and riparian forest. The upland forest is located along a portion of the north property boundary and the west property boundary, extending southward to the rail spur. The riparian forest extends along the existing riparian corridor of the west bank of Paddys Run from the northern property line southward to the rail spur. This project is part of the required restoration for impacts to the Paddys Run Corridor.

Earthwork was carried out in the fall of 1999 to create a new gravel access roadway and turnaround area. Approximately 2 acres of the project area are used as a handling area for organic material, such as wood chips. Drainage channels, leading to a pair of basins, were cut around both sides of the material handling area. The basins feed a filter wetland before the water is discharged toward Paddys Run. A vernal pool was also created as part of the project. The basin and filter wetland was sized to meet storm water requirements. Approximately 4 acres of the project area along Paddys Run has existing, mid-early successional trees that can contribute to a beneficial riparian corridor.

The upland forest is typical of a mid-western upland successional forest, consisting of a canopy and shrub layer by randomly planting hardwood trees and shrubs. Within Area 8, Phase II, a large number of

native trees already exist. The existing vegetation was taken into consideration while designing the planting plan for Area 8, Phase II. Approximately 8 acres of the area were restored as a Beech-Maple, Oak-Hickory or Mesophytic forest community, planted at a target density of approximately 450 plants per acre. The plantings included 160 saplings, 90 shrubs (in half of the patches), and 400 seedlings per acre, assuming only 50 percent survival of the seedlings. The upland and riparian forests were planted, in a random patch design, toward the goal of 450 plants per acre within a specified area. The existing riparian corridor was enhanced with additional understory and shrub species at a density of approximately 60 plants per acre (i.e., 40 trees and 20 shrubs). The pasture areas that were established as forest plots were sprayed with roundup to kill existing vegetation in the fall of 1999 and again in the spring of 2000. The forest plots were seeded with a prairie seed mix after the planting was complete.

The riparian forest is typical of a plant community found in somewhat poorly drained soils, consisting of a canopy and shrub layer of plant materials that have root systems that are tolerant of prolonged moisture. Sections 3.2.1 and 3.2.2 provide characteristics of upland and riparian forest. Wetland creation/restoration was also integrated into the riparian forest design, as described in Section 3.2.4.

Approximately 2.5 acres were planted as savanna with a total of 84 trees, 74 shrubs (five saplings and 30 shrubs per acre). The savanna also required a specific seed mix for native prairie grass and forbs that were seeded after the plantings were completed. Native prairie grasses were also used to seed other portions of the project (e.g., material handling area, forest plantings).

Monitoring of the Area 8, Phase II Restoration Project will occur for three years after the project is complete. Monitoring will ensure that a minimal survival rate of 80 percent is maintained on trees and shrubs and that 90 percent native cover is maintained. A Consolidated Monitoring Report will be submitted to the NRTs and Agencies at the end of each calendar year in which the monitoring is conducted.

4.2 FUTURE RESTORATION PROJECTS

The following outlines the restoration projects to be completed at the FEMP. Figure 4-4 provides the location of each project. NRRDPs will be prepared for each of the restoration projects outlined below. NRRDPs will be submitted based on anticipated completion dates for completion of remediation commitments.

4.2.1 Southern Waste Units Restoration (Area 2, Phase I)

The remediation of Area 2, Phase I will result in a significant change in the topography of this area. The Inactive Flyash Pile and Active Flyash Pile have been removed, resulting in a decrease in the existing elevation. Because this area is adjacent to Paddys Run, the proposed restoration will involve revegetating remediated areas in a manner that will expand the riparian corridor along Paddys Run and allow for the expansion of floodplain along Paddys Run. The sediment ponds used during remediation may be relined to control sediment loading to Paddys Run (Figure 4-5).

A portion of this project will constitute the required restoration for impacts to the Southern Pines and Southern Waste Units. The completed project will encompass approximately 30 acres of restored vegetative community.

Restoration Objective

The main restoration objective for the southern waste units is to expand the riparian corridor, create several open water areas, and early stages of an upland forest. Enhancement of the riparian corridor will provide a native vegetative community, terrestrial wildlife habitat, increased water quality, and reduced erosion. In low-order streams such as Paddys Run, riparian vegetation provides shading that reduces water temperature, discourages eutrophication, and provides organic material in the form of detritus, which is important for the health of the stream.

Pursuant to the long-term management plan for Paddys Run, restoration of Area 2, Phase I will serve to increase the Paddys Run floodplain, thereby absorbing surface water flow stress during typical storm events. The lower elevation areas of Area 2, Phase I, such as the sediment basins, would be converted into floodplain habitat with water tolerant plant species that can withstand periods of inundation.

Higher elevation areas will be restored to the early stages of an upland forest and tied into existing adjacent vegetation. This effort will meet the ecological restoration goals of restoring native vegetative communities and promoting wildlife habitat.

Required Construction Activities

Remediation activities and interim restoration in the Inactive Flyash Pile and South Field will be completed in 2002. Remediation of the Active Flyash Pile and "Carolina Area" were completed by the

end of 2000. Remediated areas are graded and stabilized through seeding and ersoion matting as appropriate. Grading during final stages of remediation will promote flooding of the Southern Waste Unit area by Paddys Run during a two-year storm event or greater.

Since most of Area 2, Phase I will be excavated, remaining soil will be amended during interim restoration. Soil amendment will occur through the application of a wood chip layer at least 1 inch in depth (or other organic matter) and incorporation by rototiller (or equivalent) during interim restoration.

Installation of a clay liner as needed and outfall structures (emphasizing the use of bioengineering techniques to the degree practicable) will occur in select depressions and swales during interim restoration. Berms of depressions will be stabilized with coir fabric and willow staking during interim restoration to stabilize areas prior to final restoration.

Additional construction activities in Area 2, Phase I include the installation of groundwater extraction wells as part of the Aquifer Restoration Project. Until a final decision is made, Area 2, Phase I will be seeded with native grasses pursuant to the guidelines set forth in Appendix F of the SEP. Revegetation of upland and riparian areas will be conducted pursuant to Section 3.2.1 and 3.2.2.

Planting and Special Features

Final restoration activities will include plantings across the 30-acre project area. Seventeen acres of the area will be restored as forest over three planting seasons. The plantings will include Beech-Maple, Oak-Hickory, mesophytic, and riparian forest plots. Total plant material will include 2,805 saplings, 1,564 shrubs, and 6,800 seedlings.

Approximately 3 acres will consist of the restored retention basins. The remaining project area will be seeded with permanent prairie seed mix and cover crop during interim restoration. All areas designated as prairie will be seeded with the seed drill in combination with the appropriate application of organic matter and soil inoculant. The same approach will be used in the establishment of prairies for all of the projects. Approximately 20 wildlife structures will be installed in the project area as determined appropriate (e.g., duck boxes, bird boxes, bat boxes).

Approaches for seeding and installation of trees and shrubs may be modified where seeps are present or wetland conditions are anticipated (e.g., converted basins). Planting approaches may also be modified in areas where soil conditions are consistently sandy. The use of wetland plant plugs will also be used in the converted basins to establish desired wetland vegetation and diversity.

Monitoring and Maintenance

The Southern Waste Units project area will be monitored for one year to ensure 80 percent survival of plantings or 90 percent cover of grasses. During the monitoring period steps will be taken to replace plantings if a project area does not meet the 80 percent survival goal. Further detail on monitoring can be found in Section 5.0.

All woody plants will be mulched with wood chips and watered as they are planted. Shrubs and seedlings will be sprayed with deer repellant. Other maintenance actions for deer control will be implemented per the FEMP Deer Management Plan. Control for invasive species will occur throughout the project area. Other maintenance actions will be carried out as needed.

4.2.2 Northern Woodlot

The Northern Woodlot covers a total of 196 acres and is divided into three separate projects: the Northern Pine Plantation Enhancement, the Northern Woodlot Enhancement, and the Wetland Mitigation, Phase II (Figure 4-6). Some areas of the Area 1, Phase I woodlots will be subjected to construction activity and related impacts since the area is adjacent to the OSDF and Former Production Area. Therefore, the activities discussed above will improve the survival of the remaining stand of trees. This project, in part, will constitute the required restoration for impacts to the northern woodlots.

4.2.2.1 Northern Pine Plantation Enhancement (Area 1, Phase I)

This restoration project involves the enhancement of the Northern Pine Plantation by interplanting deciduous trees and shrubs among thinned pines (Figure 4-7). The existing stand of deciduous trees in the northern portion of Area 1 will remain unchanged other than the removal of invasive species (e.g., honeysuckle). Deciduous planting sites will be formed by partial removal of the Austrian pine (*Pinus nigra*) and White pine (*Pinus strobus*). Upland forest species will be interplanted among the remaining pines. Non-native and/or invasive vegetation (e.g., multiflora rose, honeysuckle spp., wild grape) will be controlled by appropriate means. In addition, openings will be made to diversify habitat

and allow brush piles and snags to be created in the Area 1, Phase I woodlots. Openings will be enhanced with brush piles using cut trees.

Restoration Objective

The main restoration objective for the Northern Pine Plantation is to enhance the existing pine plantation by removing diseased and dying trees, increasing the diversity of forest habitat, and creating several wetland features. The project area covers approximately 70 acres. The pine plantation covers approximately 50 acres and the existing deciduous forest covers approximately 20 acres.

Forest communities will be established by interplanting the pine plantation into an upland forest association, which will transition into the existing upland forest to the north. Plant species selected for planting among the pines will be typical of those found in gently sloping areas with deep, rich, mesic soils. Plant species selected for the transition portion will be typical of drier slopes and ridges. Consideration will be given to the establishment of a buffer zone around the OSDF where no trees and shrubs will be planted to minimize the rate of tree and shrub seedlings establishing on the OSDF (Figure 4-7).

Wildlife habitat will be provided for interior forest species upon maturation. Prior to maturation of the proposed forest communities, the mosaic of existing forest cover combined with patched plantings of herbaceous vegetation and tree seedlings will provide good habitat for edge-dwelling forest wildlife.

Required Construction Activities

Clearing that is required will focus on the rows of Austrian pines with some select cutting in the White pines. Approximately 40 percent of the pine plantation (approximately 20 acres) will be cleared. Two large open areas (3 to 5 acres each) will be left after the removal of the pines. Brush piles will be created in the open areas with roughly 5 percent of the trees. The remaining trees will be chipped and staged in properly managed stockpiles in the open areas to be used as mulch during restoration. Surplus wood chips (or other organic matter) will be transported to the Southern Waste Units and either stockpiled or spread across the area for use in soil amendments and mulch during restoration. Soil analysis will determine if pH needs to be adjusted through the addition of lime or other method. In the event that soil amendment is necessary, soil will be tilled first, then amendment and/or inoculant will be added. Minor changes to drainage patterns will be made, if necessary, to encourage development of

wetland/vernal pool features. In an effort to retain more water in the area to be restored, any drain tiles from past agricultural activity will be broken and/or crushed. Following seeding, coir matting or jute matting will be installed in areas prone to erosion.

Planting and Special Features

Planting will occur over 18 acres of the site and will include Beech-Maple and Oak-Hickory plots. The total plants required include 2,970 saplings, 1,656 shrubs, and 7,200 seedlings.

A vernal pool, approximately 0.25 acre in size will be installed in each of the two open areas. Open areas will be approximately 5 acres in size and seeded with prairie grass and wetland plant plugs after vernal pools are created and wood chips have been removed. Boxes for wildlife use (e.g., bird boxes, bat boxes) will be included in the design.

The northern portion of the project area contains existing deciduous woodlots that have some areas of dense honeysuckle and wild grape. The E-Z Ject lance (and other appropriate methods) will be used to extirpate a significant amount of the honeysuckle and wild grape in that area. No other restoration work will occur in this portion of the project area.

Monitoring and Maintenance

The Northern Pines areas will be monitored for one year to ensure 80 percent survival of plantings and 90 percent cover of grasses. During the monitoring period steps will be taken to replace plantings if the area does not meet the 80 percent survival goal. Further detail on monitoring can be found in Section 5.0.

All woody plants will be mulched with wood chips and watered as planted. Shrubs and seedlings will be sprayed with deer repellants after planting. Other maintenance actions for deer control will be implemented per the FEMP Deer Management Plan. Control for invasive species will occur throughout the project area. Other maintenance actions will be carried out as needed.

4.2.2.2 Northern Woodlot Enhancement

This restoration project involves the enhancement and expansion of 25 acres of a large woodland, which will provide habitat diversity. The former pasture areas will be seeded with native grasses to establish

approximately 30 acres of prairie. An invasive species control program over the remainder of the woodlot will be implemented as described in Section 3.1.7. The grazing lease has been terminated for this area.

Restoration Objective

The main restoration objectives are to expand the existing successional forest and restore former pasture area to prairie. These objectives will meet the goals for restoring native vegetative communities and promotion of wildlife habitat. The enhanced forest cover will provide a significant block of closed canopy native forest to provide suitable habitat for interior forest dwelling wildlife.

A comprehensive revegetation program, which involves the connection of fragmented woodlots with native deciduous tree species, will be implemented. Most of the upland areas already support deciduous forest. The existing forest cover will be preserved, with the larger gaps being filled by planting tree seedlings as necessary and allowing natural succession to proceed toward climax forest.

A portion of this project will constitute the required restoration for impacts to the northern woodlots. Part of this project will contribute to the required restoration for impacts to grasslands and the Great Miami River as outlined in the NRIA. Once completed, the restored Area 1, Phase III will encompass approximately 116 acres of restored vegetative communities.

Required Construction Activities

In an effort to retain more water in the area to be restored, any drain tiles located from past agricultural activity will be broken and/or crushed. Seed will be applied with a seed drill, or broadcast where a drill is not practical. Coir matting or jute matting will be installed in areas prone to erosion. The Wetland Mitigation Phase II Project (described in Section 4.2.2.3) may result in the ponding of additional water in the Northern Woodlot, but will not require additional construction activities under the scope of this project.

Planting and Special Features

Approximately 30 acres of the Northern Woodlot will be seeded with native grasses, consisting of a mixture of upland and wetland mixes to match soil conditions. No more than 1,000 wetland plant plugs will be installed in wetland areas as determined appropriate to increase wetland density.

Approximately 20 wildlife structures will be installed throughout the project area.

Monitoring and Maintenance

Monitoring in the Northern Woodlot will include the general health of replanted and seeded areas and amount of wildlife use. Seedlings will be over-planted to assume 50 percent mortality and will not require a minimum survival rate. Further detail on monitoring can be found in Section 5.0.

All woody plants will be mulched with wood chips. Control for invasive species will occur throughout the project area. Maintenance actions for deer control (e.g., spraying repellants) will be carried out per the FEMP Deer Management Plan. Other maintenance actions will be carried out as needed.

4.2.2.3 Wetland Mitigation - Phase II (Area 1, Phase III)

A wetlands system will be developed on 10 acres of the southern portion of the project area. As stated in Section 3.2.4, DOE agreed to mitigate wetlands at a 1.5 to 1 ratio, replacing 1.5 acres of wetlands for every 1 acre dredged or filled. DOE also agreed to implement the mitigation on property if possible. To meet those two commitments, DOE has proposed the expansion of the northern forested wetland (Area 1, Phase III), if feasible (Figure 4-8). The 1996 watershed study indicated that some wetland expansion is possible, contributing to a portion of the required wetland mitigation, upon agreement by the Agencies. DOE will initiate the design process for expansion of the northern forested wetland as part of on-property wetland mitigation.

Restoration Objective

The main restoration objective for this area is to create approximately 8 acres of wetlands to contribute toward meeting the mitigation ratio and to provide wildlife habitat. The proposed area for wetland mitigation is located south and adjacent to the Northern Woodlot, which contains a contiguous and diverse mosaic forest cover that provides good habitat for interior forest dwelling wildlife. Wetland mitigation performed south of the Northern Woodlot may consist of a palustrine forested, broad-leaved deciduous wetland, which would provide additional habitat for interior forest dwelling species. The feasibility of expanding existing wetland acreage in the Northern Woodlot will also be considered during design of the project. Wetland acreage in the Northern Woodlot may be expanded by limiting the flow of water out of the area.

Required Construction Activities

Earthwork is required to create four depressions with berms over 8 acres of the 10-acre project area. Topsoil will be reapplied to the project area or existing soil will be supplemented with wood chips (as needed) in approximately 8 of the 10 acres. Storm water controls will be installed and maintained throughout construction activities. The controls will be removed when the soils are stabilized through seeding and installation of erosion control matting.

Soils in the existing wetlands are mapped in the Ragsdale and Fincastle soil series and soils in the proposed wetland mitigation area are mapped in the Fincastle and Xenia soil series (SCS 1982a). The Ragsdale, Fincastle, and Xenia soils represent a catena of soil series that are of similar mineralogy but have different drainage classifications. The Ragsdale series consists of very poorly drained soils typically found in depressional areas and shallow basins. The Fincastle series consists of somewhat poorly drained soils, often in intermediate landscape positions between Ragsdale and Xenia soils. The Xenia series consists of moderately well drained soils, often found upslope of Fincastle soils. A detailed analysis of the soil and hydrological conditions in this area would be required to determine the suitability of wetland formation.

The successful establishment of wetland soils will involve ensuring the bottom of the wetland area contains impermeable material. A clay liner will be installed in the bottoms of the depressions as necessary. Most of the proposed area for wetland mitigation is mapped as containing Fincastle soils with 0 to 2 percent slopes, which indicates these soils experience brief seasonal periods of poor drainage. During excavation, silt fences would be installed to separate the mitigation area from existing wetlands to prevent sediment deposition into the new wetlands until vegetation is established. Soil from the A-horizon will be stockpiled on nearby uplands to topsoil the new wetlands after excavation is complete. It may be necessary to over-excavate by 4 to 6 inches to provide adequate volume for topsoil.

The best source of available topsoil for this wetland mitigation project would be from the stripped topsoil of the wetland mitigation area, if this soil is certified as clean. Such topsoil would contain a bank of native wetland plant propagules (seeds and rhizome fragments), along with native mycorrhizal fungi, which are symbiotic soil fungi essential to the growth of many plants. Efforts will be made to use topsoil from the project area. If adequate topsoil is not available soil will be amended using woodchips, biosolids or other organic matter.

Planting and Special Features

The approximately 5 acres surrounding the wetland areas will be revegetated with trees and wetland plants. Approximately 1,155 saplings and 644 shrubs will be planted interspersed with areas of marsh and prairie. No seedlings will be planted in the wetland.

Approximately 750 wetland grass and forb plugs will be planted around the perimeter of the normal water level. A dense herbaceous cover will be rapidly established to prevent erosion of exposed soils and sedimentation from existing wetlands. The grass seed will consist of species that are indigenous to wet meadow habitats and provide value to wildlife and would be intermixed and broadcast. Woody tree and shrub species would then be randomly planted with the intent to establish forest cover. These species would be typical of seasonally saturated wetland forests and well drained riparian uplands. Water collection areas will be inoculated with pond muck from healthy ponds.

Approximately 20 wildlife structures will be installed in the wetland project.

Monitoring and Maintenance

The Wetland Mitigation Phase II areas will be monitored for a period of four years to ensure 80 percent survival of plantings and 90 percent cover of grasses. During the monitoring period steps will be taken to replace plantings if a project area does not meet the 80 percent survival goal. Parameters such as water availability, water levels, and soil analysis will also occur as part of monitoring. Further detail on monitoring can be found in Section 5.0.

All woody plants will be mulched with wood chips. Control for invasive species will occur throughout the project area. Maintenance actions for deer control (e.g., spraying repellants) will be implemented per the FEMP Deer Management Plan. Other maintenance actions will be carried out as needed.

4.2.3 Paddys Run Corridor

The Paddys Run corridor covers a total of 248 acres. Restoration projects have been divided into those west of Paddys Run and those east of Paddys Run.

4.2.3.1 Paddys Run Corridor Expansion East (Area 2, Phase II)

The corridor east of Paddys Run is located in Area 2, Phase II (Figure 4-4). The Paddys Run riparian corridor will be restored pursuant to the long-term management plan for Paddys Run, as described in Section 2.3.4 (Figure 4-9). Also included with Paddys Run East is the expansion of the riparian corridor along the SSOD adjacent to the 23 acres set aside for potential development.

Part of this project will involve clearing 40 percent (approximately 20 acres) of the Southern Pine Plantation and converting it to early stages of an upland forest. The clearing will promote pine canopy openings for the planting of hardwoods, as described for the Northern Pine Plantation. Upland forest species will be planted among the remaining pines. Non-native and/or invasive vegetation will be controlled pursuant to the Invasive Species Management Plan. In addition, openings will be made to diversify habitat and allow brush piles and snags to be created.

Soil certification of Area 2, Phase II may require some excavation in the 30 acres of the existing woodlot adjacent to Paddys Run. If this is necessary expedited restoration for this area may be possible. Any excavated area adjoining the stream bank of Paddys Run would be stabilized as an interim restoration step using bioengineering techniques immediately after the removal of the contaminated soil. Bioengineering would include the installation of coir material, willow stakes and seeding.

Restoration Objective

The first restoration objective for the east corridor of Paddys Run is to expand the riparian corridor along Paddys Run. This objective will be accomplished by clearing approximately 40 percent of the southern pines to convert the area to the early stages of an upland forest. The edges of wooded areas will then be seeded to prairie. This objective meets the Paddys Run restoration and native vegetation goals established in Section 2.1.

The second objective for this project is to expand the riparian corridor along the SSOD. Revegetation of both of these corridors will promote habitats typical of southwest Ohio. This meets the goal of enhancing wildlife habitat, as a contiguous corridor will be established along the length of both Paddys Run and the SSOD.

This project will compensate for impacts to the Paddys Run corridor and the Great Miami Aquifer. Restoration of the Paddys Run corridor will result in protection of an important recharge area for the Great Miami Aquifer. Once completed, the ecological restoration of the corridor east of Paddys Run will encompass approximately 80 acres of restored vegetative communities, 50 acres of which includes the southern pines. The riparian corridor along the SSOD encompasses approximately 36 additional acres.

Required Construction Activities

Clearing that is required will focus on the rows of Austrian pines with some select cutting of the White pines. Approximately 40 percent of the pine plantation will be cleared. Two large open areas, approximately 3 to 5 acres in size, will be created after the removal of the pines. Brush piles will be created in the open areas with roughly 5 percent of the trees. The remaining trees will be chipped and stockpiled in the open areas to be used as mulch during restoration. Surplus wood chips will be transported to the Wetland Mitigation Area south of the Northern Woodlot and stockpiled for use in soil amendments and mulch during restoration. Any surplus wood chips will be moved to Area 8, Phase II or alternate location for storage in a properly managed stockpile or transported to an upcoming restoration project for use as soil amendment and mulch. A vernal pool will be installed in each of the two open areas. The open areas will then be seeded with prairie grass.

The restoration design will seek to minimize earth moving, but some regrading will be required. These efforts will be coordinated with excavation and certification activities. It may be necessary for some areas to remain in interim restoration status until adjacent excavation areas are available for final restoration. In these situations the area will be graded and seeded for interim restoration pursuant to the guidelines established in the SEP.

In an effort to retain more water in the area to be restored, any drain tiles located from past agricultural activity will be broken and/or crushed.

Excavated areas that are to be revegetated may require the addition of topsoil, wood chips (or other organic matter) to increase organic matter in the existing soil. Wood chips from the Southern Pines will be used as a soil amendment as necessary. A layer of chips will be spread across the soil and tilled in as the final step in interim restoration. Also, the vegetation to be established will consist of pioneer species

that naturally root in poor soils. The specific plant species used will also be tolerant of periodic inundation.

Planting and Special Features

Planting of forest plots along Paddys Run will occur over 14 acres and will include Beech-Maple and Oak-Hickory plots. Section 3.2.2 provides further detail regarding the selection of plant species for floodplain area. Total plant material required will include 2,240 saplings, 1,260 shrubs, and 5,600 seedlings.

A vernal pool, approximately 0.25-acre in size, will be installed in each of the two open areas in the southern pines. Open areas will be approximately 5 acres in size and will be seeded with prairie grass after vernal pools are created and wood chips have been removed.

The riparian corridor along the SSOD in Area 2, Phase III will be planted with an additional 1,584 saplings, 828 shrubs and 4,000 seedlings. Approximately 38 acres of riparian corridor remnants along the SSOD will be restored with a lower density of trees and shrubs to enhance existing vegetation. All disturbed areas will be seeded with wet meadow or prairie seed mix as appropriate.

Wildlife use boxes will be installed in the riparian corridor along Paddys Run and the SSOD as appropriate. Examples of boxes to be used include bird boxes, bat boxes and duck boxes.

Monitoring and Maintenance

Paddys Run Corridor Expansion East restored areas will be monitored for a period of one year to ensure 80 percent survival of plantings or 90 percent cover of grasses. During the monitoring period steps will be taken to replace plantings if a project area does not meet the 80 percent survival goal. Further detail on monitoring can be found in Section 5.0.

All plants will be mulched with wood chips and watered as planted. Shrubs and seedlings will be sprayed with deer repellants after planted. Other maintenance actions for deer control will be implemented per the FEMP Deer Management Plan. Control for invasive species will occur throughout the project area. Other maintenance actions will be carried out as needed.

4.2.3.2 Paddys Run Corridor Expansion West (Area 8, Phase III)

Expansion of the corridor west of Paddys Run will occur in Area 8 (Figure 4-4). This project is similar in scope to the eastern corridor expansion described above, with the exception of a few additional considerations. Area 8 is a perimeter area addressed under Appendix E in the SEP, and no remediation is expected with the possible exception of a small area near the Pilot Plant Drainage Ditch. The project consists of three distinct components: the restoration of a forest/savanna community in the northern portion of Area 8, Phase III; restoration of a forest community in the southern portion; and restoration of floodplain in the former Paddys Run stream channel. Figure 4-6 identifies the location of proposed floodplain expansion and savanna restoration west of Paddys Run. Restoration of Paddys Run West will result in 15 acres of new forest and approximately 11 acres of savanna. The remainder of former pastures in Paddys Run will be converted to prairie through seeding.

Restoration Objective

A primary objective of this project is to expand the riparian corridor along Paddys Run through forest restoration plantings. A secondary objective is to convert grazed pasture to early stages of a forest with wet prairie, upland prairie, and savanna interspersed. A third objective is to restore the floodplain in the former Paddys Run stream channel by removing an existing soil berm, that was installed when the stream channel was altered in the past, to allow flooding of the floodplain during approximately a two-year storm event.

Required Construction Activities

In an effort to retain more water in the area that is to be restored, any drain tiles located from past agricultural activities will be broken and/or crushed. Minor grading may also occur to enhance drainage channels or enlarge depressions for wetland formation.

Approximately 200 feet of an existing soil berm will be removed. The soil berm is approximately 15 feet high by 25 feet wide. Soil removed from the berm will be used to create a stable, gradually sloping berm that will allow overflow from Paddys Run during approximately a two-year storm event. Coir matting and aggregate (as needed) will be used to stabilize approximately 250 feet of relocated stream bank to control erosion of the newly created berm. Approximately 50 feet of soil berm in the southern portion of the stream channel will be removed to allow storm water to flow out of the former stream channel. Bioengineering techniques may also be implemented in other areas on the west bank of

Paddys Run where erosion is currently problematic. It is anticipated that not more than an additional 500 feet of bioengineering will be required in eroding areas.

Planting and Special Features

The northern portion of Area 8, Phase III will be restored in the following manner. Herbicide will be applied to the existing grass in the pasture. Planting over three planting seasons will include 12 acres of Beech-Maple and Oak-Hickory plots. The total number of plants required would be 1,920 saplings, 1,080 shrubs, and 4,800 seedlings. Approximately 8 acres in a lower pasture of Area 8, Phase III will be restored as an Oak savanna with a total of 324 saplings and 167 shrubs. The remaining acres will be seeded as a wet meadow or prairie.

The southern portion of Area 8, Phase III will be restored in the following manner. Herbicide will be applied to the existing grass in the pasture. Planting will include 3 acres of Beech-Maple and Oak-Hickory plots. Total plants required will be 466 saplings, 270 shrubs, and 1,200 seedlings. The remaining acres will be seeded as wet meadow or prairie to accommodate future Native American reinterment activities.

Approaches for seeding and installation of trees and shrubs may be modified in areas where seeps are present or wetland conditions are anticipated. Planting approaches may also be modified in areas where soil conditions are consistently sandy.

Wildlife use boxes will be installed in the riparian corridor along Paddys Run and the SSOD as appropriate. Examples of boxes to be used include bird boxes, bat boxes, and duck boxes.

Monitoring and Maintenance

Paddys Run Corridor Expansion West restored areas will be monitored for one year to ensure 80 percent survival of plantings and 90 percent cover of grasses. During the monitoring period steps will be taken to replace plantings if a project does not meet the 80 percent survival goal. Further detail on monitoring can be found in Section 5.0.

All woody plants will be mulched with wood chips and watered as planted. Shrubs and seedlings will be sprayed with deer repellants after planted. Other maintenance actions for deer control will be

implemented per the FEMP Deer Management Plan. Control for invasive species will occur throughout the project area. Other maintenance actions will be carried out as needed.

4.2.4 Borrow Area Restoration (Area 1, Phase II)

The Borrow Area and OSDF Perimeter Restoration Projects will cover approximately 228 acres. Excavation of the Area 1, Phase II Borrow Area will be used to form a wetland system, with upgradient areas revegetated as a tallgrass prairie transitioning to areas of savanna (Figure 4-10). This area also includes the former Sewage Treatment Plant area. Once complete, approximately 90 acres will be restored.

Restoration Objective

The main restoration objective for this area is to restore the Borrow Area and former Sewage Treatment Plant area in phases to predominantly wet prairie, marsh and upland prairie ecosystem with a surrounding buffer of upland savannas. Open water will also remain in the northwest corner of the project.

The restoration project will meet ecological restoration goals by restoring native vegetative communities and protecting wildlife habitat. Wildlife habitat will be provided by establishing a variety of ecosystems and edge habitat. Wetland construction may also be used to partially fulfill regulatory wetland mitigation requirements. This restoration project will provide compensation for impacts to grasslands.

Required Construction Activities

Final grading and seeding of the Borrow Area will occur in a phased approach as sections of borrow activities are completed. Each phase of the Borrow Area will be graded using excess soil so that depressions are created near the center of each phase. Drainage channels will move water from the depressions during storm events or high flow conditions toward an open water feature in the northwest corner of the Borrow Area (former Sedimentation Basin). As grading in each phase is completed, excavated areas that are to be revegetated may require the addition of wood chips (or suitable alternative) to increase organic matter in the existing soil. A layer of wood chips at least 1 inch in depth (or suitable alternative) will be spread across the soil and tilled in as the final step in interim restoration.

Planting and Special Features

Seeding will occur using a combination of wet prairie mix and prairie mix. The wetland features created in the Borrow Area will be planted with approximately 1,530 shrubs and select placement of plant plugs in and around water features. The installation of shrubs and plant plugs in the Borrow Area will be accelerated as funding and schedules allow. The vegetation of seasonally inundated wetlands will consist of vegetation typical of pond/edge habitats tolerant of regular to permanent inundation that are indigenous to southwestern Ohio in shallow open waters 3 feet in depth. These plant species include a mixture of species that produce submerged growth, emergent growth, and floating leaves that will maximize habitat diversity. Pond muck will be placed in open water areas to establish flora and fauna within the water.

An additional 165 saplings will be planted around the perimeter of the Borrow Area to establish a savanna community. Approximately 30 acres will be established as an Oak savanna. The existing basins of the remediated Sewage Treatment Plant area will also be planted with shrubs and plugs to enhance habitat. Wildlife boxes (e.g., duck boxes, bird boxes, bat boxes) will be installed within the Borrow Area as appropriate.

Monitoring and Maintenance

The Borrow Area project will be monitored for a period of one year to ensure 80 percent survival of plantings or 90 percent cover for grasses. During the monitoring period steps will be taken to replace plantings if a project area does not meet the 80 percent survival goal. Further detail on monitoring can be found in Section 5.0.

All woody plants will be mulched with wood chips and watered as planted. Maintenance actions for deer control (e.g., spraying deer repellants) will be implemented in a manner consistent with the FEMP Deer Management Plan. Control for invasive species will occur throughout the project area. Other maintenance actions will be carried out as needed.

4.2.5 OSDF Perimeter Buffer Restoration (Area 1, Phases I and II)

Restoration of the OSDF perimeter will include establishing native prairie grasses and providing nest boxes for wildlife species. This project will compensate for required restoration for impacts to

grasslands. Once completed, the OSDF buffer will encompass approximately 100 acres of restored wildlife habitat.

Restoration Objective

The primary restoration goal of this project is to restore the perimeter of the OSDF as a prairie. Woody plant species (i.e., trees and shrubs) will not be planted adjacent to the OSDF to help reduce the establishment of trees and shrubs on the OSDF cap. Access in and around the OSDF for inspection and monitoring will be more easily accomplished in a prairie habitat.

Required Construction Activities

No construction activities are required.

Planting and Special Features

The project is anticipated to include primarily seeding areas around the perimeter of the OSDF. The 80 acres receiving 1 inch of wood chips (or suitable alternative) will be seeded with a seed drill. The seeded areas around the OSDF will provide restored prairie habitat that will function as a buffer to the OSDF. Trees and shrubs will not be planted adjacent to the OSDF to minimize introduction of woody vegetation on the OSDF cap.

Monitoring and Maintenance

The OSDF Buffer Area project will be monitored for one year to ensure 90 percent cover for grasses. Maintenance actions for deer control will be implemented per FEMP Deer Management Plan. During the monitoring period steps will be taken to re-seed areas if a project area does not meet the 90 percent cover requirement. Further detail on monitoring can be found in Section 5.0.

4.2.6 Silos Area (Area 7)

The Silos Area will be restored similar to the corridor east of Paddys Run (Figure 4-4). Interim restoration at the conclusion of remediation should establish several acres of new floodplain along Paddys Run. Approximately 5 acres along the Pilot Plant Drainage Ditch will transition into an upland forest. The total project encompasses approximately 10 acres.

Restoration Objective

The primary restoration objective for this area is to restore the riparian corridor along the eastern edge of the Paddys Run and along the Pilot Plant Drainage Ditch.

Required Construction Activities

Wetland/pond habitat will be established in excavated areas by grading to encourage water retention. If necessary, drainage patterns will be adjusted to support the creation of wetlands and vernal pools. Disturbed areas around the silos will require the application and tilling of at least 1 inch of wood chips (or suitable alternative) as a soil amendment prior to planting and seeding. Project areas that are prone to erosion will require the installation of coir matting or jute.

Planting and Special Features

Trees and shrubs will be planted to expand the wooded corridors along the Pilot Plant Drainage Ditch and Paddys Run. The remaining areas will be seeded with native prairie grasses and forbs that will be contiguous with the prairie areas established in the Former Production Area and the Waste Pit Area. Total number of plant material for the Silos area includes 825 saplings, 450 shrubs, and 2,000 seedlings.

Pond muck will be placed in open water areas that are created to establish flora and fauna within the water. Willow cuttings will be placed in the matting adjacent to the streams. Wildlife structures (e.g., duck boxes, bird boxes) will be installed as appropriate.

Monitoring and Maintenance

The Silos area will be monitored for one year to ensure 80 percent survival of plantings or 90 percent cover for grasses. Maintenance actions for deer control will be implemented per the FEMP Deer Management Plan. During the monitoring period steps will be taken to replace plantings if a project area does not meet the 80 percent survival goal. Further details on monitoring can be found in Section 5.0.

All woody plants will be mulched with wood chips and watered as planted. Shrubs and seedlings will be sprayed with deer repellants after being planted. Control for invasive species will occur throughout the project area. Other maintenance actions will be carried out as needed.

4.2.7 Production/Waste Pit Area

4.2.7.1 Former Production Area Restoration (Areas 3, 4 and 5)

Restoration of the Former Production Area will utilize the postexcavation topography to establish a series of open water/wetland systems surrounded by tallgrass prairie. A transition to the early stages of an upland forest and connection with the expanded riparian corridor will occur in the west portion of the Former Production Area (Figure 1-1). Interim restoration could be necessary before final remediation begins. Once completed, the restored Former Production Area will encompass approximately 160 acres of restored wildlife habitat.

This project involves the formation of wetlands and open water areas and as such will require an assessment to determine the type of aquatic habitats that are present. A Water Availability Study has been conducted and is presented in Appendix C. This study shows that the formation of open water and/or wetlands is feasible. However, further investigation will be required once detailed design is initiated. Also, soil types will be assessed to characterize the soil profile underlying the proposed final grade. A layer of wood chips (or suitable alternative) at least 1 inch thick is planned as a soil amendment in the Former Production Area. Specific sources of suitable topsoil or other amendments will be identified before the design is finalized.

Restoration Objective

The primary restoration objective of this project is to convert the remediated Production Area into a combination of open water, wetland and prairie ecosystems with some perimeter forest buffer. After remedial activities have been completed, the Former Production Area will consist of several deep excavations and areas of exposed subsoil (Figure 2-1). The postexcavation topography will be converted to open water and/or wetland habitat to meet the goal of providing wildlife habitat. This approach will minimize the amount of backfill and regrading, resulting in a considerable cost savings. Prairie revegetation will stabilize the exposed soil.

Restoration of the Former Production Area will compensate for impacts to grassland and the Great Miami Aquifer. Since this area contributes to the Paddys Run watershed, restoration activities will provide protection of an aquifer recharge zone.

Required Construction Activities

Portions of the Former Production Area may undergo interim restoration, since the area consists of several excavation areas. At the conclusion of remediation of an excavation area, interim restoration will take place to establish stable slopes and topography to support potential wetland and open water areas and to establish appropriate prairie grasses. Slopes of the deep excavations will be graded to 5 to 1 from top to bottom during interim restoration. Slopes of 5 to 1 will allow for the formation of a littoral zone on the waters' edge and provide a safe configuration for people who may need to access the area. The gentle slopes will facilitate revegetation, reduce the likelihood of gully erosion, and be more compatible with the surrounding landscape. The perimeter of the deep excavations will be graded to establish depressions, and compacted to ensure water retention in areas where the topography and clay material was suitable.

Approximately 88 acres surrounding the deep excavations, designated for a prairie community, will be covered with a layer of wood chips at least 1 inch thick (or suitable alternative) that will be tilled into the top layer of soil. Clay liners at least 3 feet thick will be installed in the bottom of the deep excavations as part of interim restoration. The deep excavations are expected to cover approximately 35 acres of the project area. The above process will be repeated as remediation is completed in each portion of the Former Production Area.

Planting and Special Features

If hydrological conditions permit, certain depressions may contain a transition from shallow open water to seasonally inundated wetlands. The vegetation of seasonally inundated wetlands will consist of vegetation typical of pond edge habitats and tolerant or regular to permanent inundation up to 1 foot. Non-persistent plant species selected would be noninvasive plant species that are indigenous to southwestern Ohio in shallow open waters 3 feet in depth. These plant species include a mixture of species that produce submerged growth, emergent growth, and floating leaves, which will maximize habitat diversity.

The tallgrass prairie and upland forest restoration around the open water areas will be conducted in accordance with Section 3.2.1 and 3.2.3. Although prairie grasses and forbs are tolerant of the poor soil conditions after excavation, additional amendments may be needed to optimize growth. On-site research as part of the OU4 Ecological Research Grant Program will provide further information as to the type of

amendment providing optimal plant growth. The tallgrass prairie may consist of a seed mix containing Indian grass, big bluestem, little bluestem, side-oats grama, and switchgrass.

Planting in the Former Production Area would include the installation of 1,631 shrubs. Shrub patches would be concentrated in and around wetland and open water features. The remaining areas will be seeded with prairie mix. Wildlife structures (e.g., duck boxes, bird boxes) would be installed throughout the project area as determined appropriate.

Monitoring and Maintenance

Monitoring will be carried out in the Former Production Area for one year. All woody plants will be mulched with wood chips and watered as planted. Shrubs will be sprayed with deer repellants after being planted. Control for invasive species will occur throughout the project area. Maintenance actions required for deer control will be implemented per the FEMP Deer Management Plan. Other maintenance actions will be carried out as needed.

4.2.7.2 Waste Pit Area Restoration (Area 6)

The Waste Pit Area will be restored similar to the corridor east of Paddys Run. The results of the Paddys Run floodplain modeling will determine the extent of riparian habitat that will be established. Interim restoration at the conclusion of remediation should establish several acres of new floodplain along Paddys Run. The riparian habitat will transition into an upland forest. This project encompasses approximately 30 acres. Five acres will be restored as forest to enhance the riparian corridor.

Restoration Objective

The primary restoration objective of this project is to expand the floodplain of Paddys Run and restore the riparian corridor along the eastern edge of the stream channel and floodplain. Floodplain restoration will meet the goals of native vegetation, Paddys Run restoration, and wildlife habitat. Other portions of the Waste Pit Area will be restored as a prairie ecosystem.

Required Construction Activities

Deep excavations will be graded to retain water and establish stable side slopes (approximately 5 to 1) and seeded to establish native prairie vegetation. Clay liners and drainage control structures will be installed. If necessary, drainage patterns may be adjusted to support the creation of wetlands and vernal

pools. Remediated areas will require soil amendment and tilling prior to planting or seeding. Coir matting or jute will be installed in areas that are prone to erosion.

Planting and Special Features

Wetland features will be established over 5 acres in shallow depressions around the deep excavations to the degree possible. Wetland and wet prairie vegetation (including plant plugs) will be established along the waters edge and swales. Native prairie grasses and forbs will be established in both wet and upland portions of the project area. The total number of plants includes approximately 825 saplings, 450 shrubs, and 2,000 seedlings. Pond muck will be placed in open water areas to begin the establishment of flora and fauna in the water. Willow cuttings will be placed in the matting that is placed along the stream.

Expansion of the floodplain on the western side of the Waste Pits area (eastside of Paddys Run) will occur to the degree possible. Wildlife structures will be installed as appropriate.

Monitoring and Maintenance

The Waste Pits area will be monitored for one year after planting to ensure 80 percent survival of saplings and shrubs, and the 90 percent cover requirements are met and that there are no erosion problems, etc. All woody plants will be mulched with wood chips and watered as planted. Shrubs and seedlings will be sprayed with deer repellants after being planted. Maintenance actions required for deer control will be implemented per the FEMP Deer Management Plan. Control for invasive species will occur throughout the project area. Other maintenance actions will be carried out as needed.

4.3 RESTORATION PROJECT SCHEDULES

Annual NRRDPs will be submitted to the NRTs based on anticipated completion dates for completion of remediation commitments. Planned submittal dates for the NRRDPs are subject to change based on available funding and prioritization of work. Restoration projects will be planned in an effort to meet the 2006 site closure date. The NRTs have agreed that restoration and monitoring work not completed prior to the site closure date will be completed during the site completion and post-site closure periods. Changes in the completion of remediation for these areas may cause adjustments in design submittals and project implementation that will be addressed as necessary in each NRRDP.

Preparation activities will be implemented in select perimeter areas of the site (e.g., the Northern Woodlot, Paddys Run West) where remediation is not required in order to accelerate the restoration of those areas. Activities to be implemented include the widespread application of herbicide to control invasives and noxious plants. Former pastures located in perimeter areas of the FEMP are dominated by non-native grasses and weeds. The understory of some wooded areas are dominated by invasive plants such as bush honeysuckle. The appropriate, repeated application of herbicide will help eliminate the existing invasive plants and allow for native plants to become established. In former pasture areas, the systematic seeding of native prairie grasses will follow herbicide applications to facilitate the establishment of prairie grasses.

Other activities that will be carried out to prepare for future restoration include the following: 1) Securing contracts for the plant and shrub material to be used during restoration work; 2) Conducting hydrologic investigations in select areas to facilitate future restoration designs; and 3) Implementing control measures per the FEMP Deer Management Plan to reduce the level of impact in later years during the implementation of restoration work.

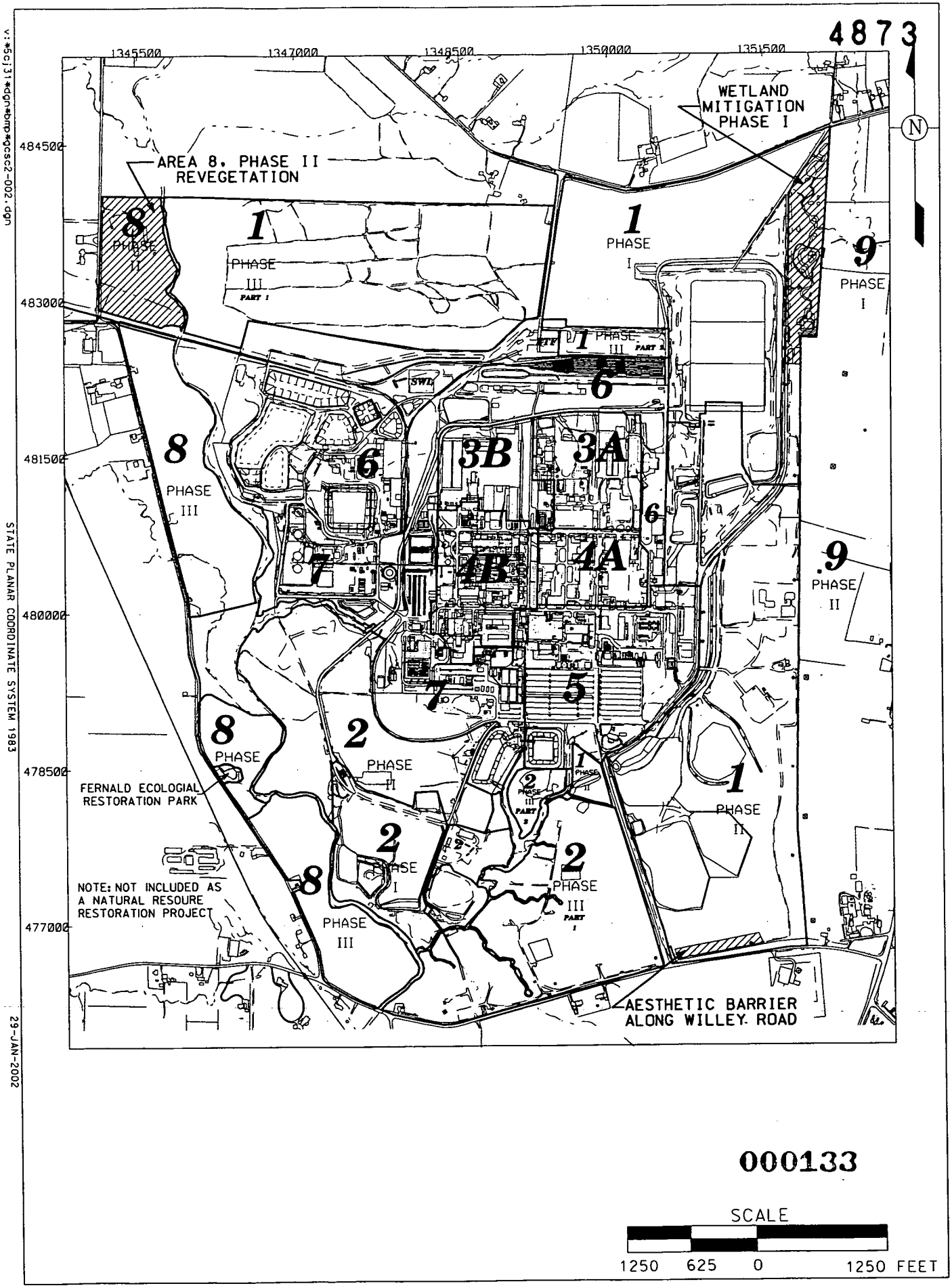

FIGURE 4-1. NATURAL RESOURCE RESTORATION PROJECTS IN PROGRESS OR COMPLETED TO DATE

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Legend

- Bat House
- Bird House
- Snake Hole
- Telephone Pole
- Air Monitoring Station
- Well
- Ballard
- Concrete Weir
- Fence Post
- Circuit Box
- Culvert
- Basin Monitoring Well
- Pole Drain
- Pipe Invert

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FIGURE 4-2. WETLAND MITIGATION - PHASE I

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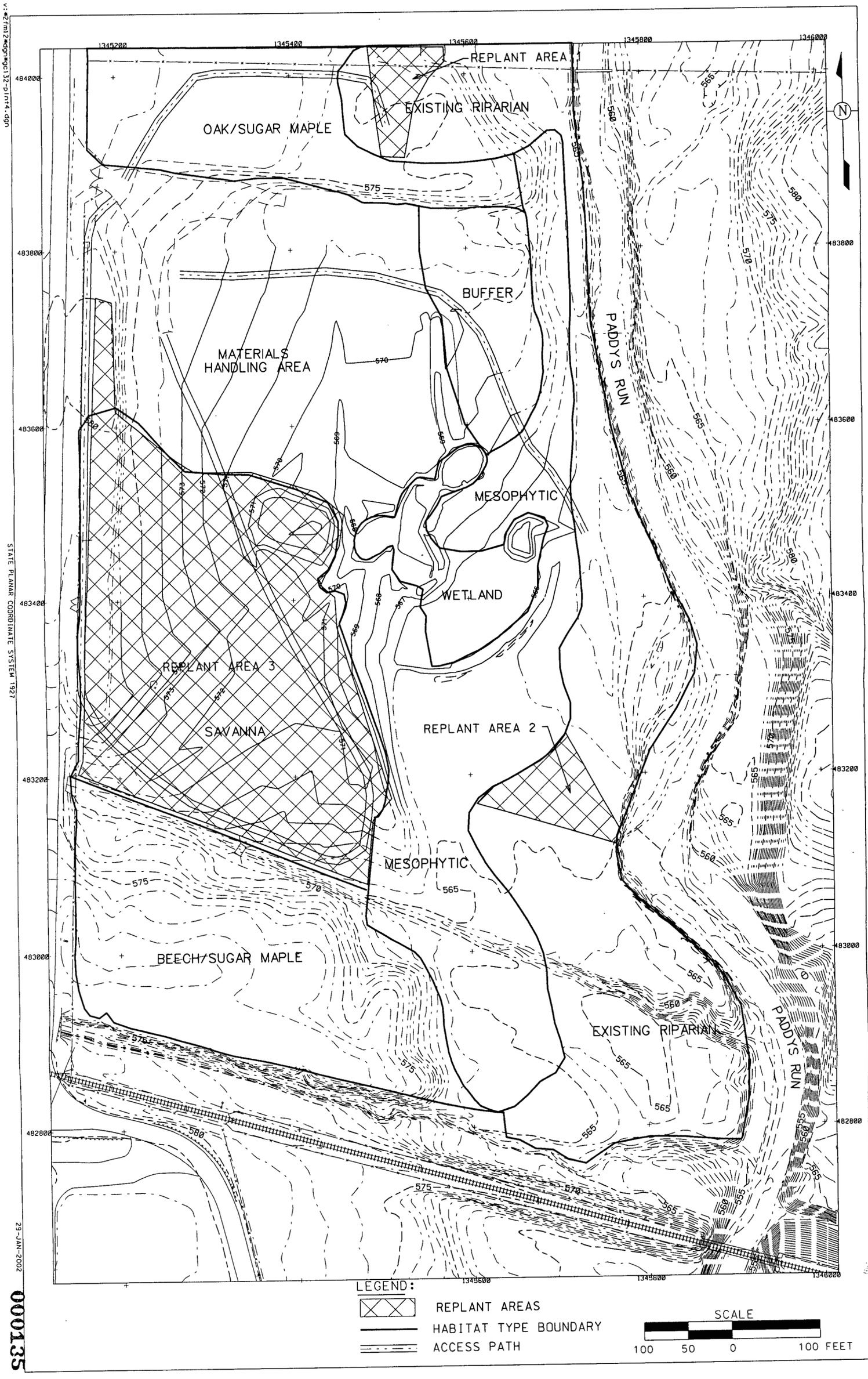

FIGURE 4-3. AREA 8, PHASE II REVEGETATION

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STATE PLANAR COORDINATE SYSTEM 1927
29-JAN-2002
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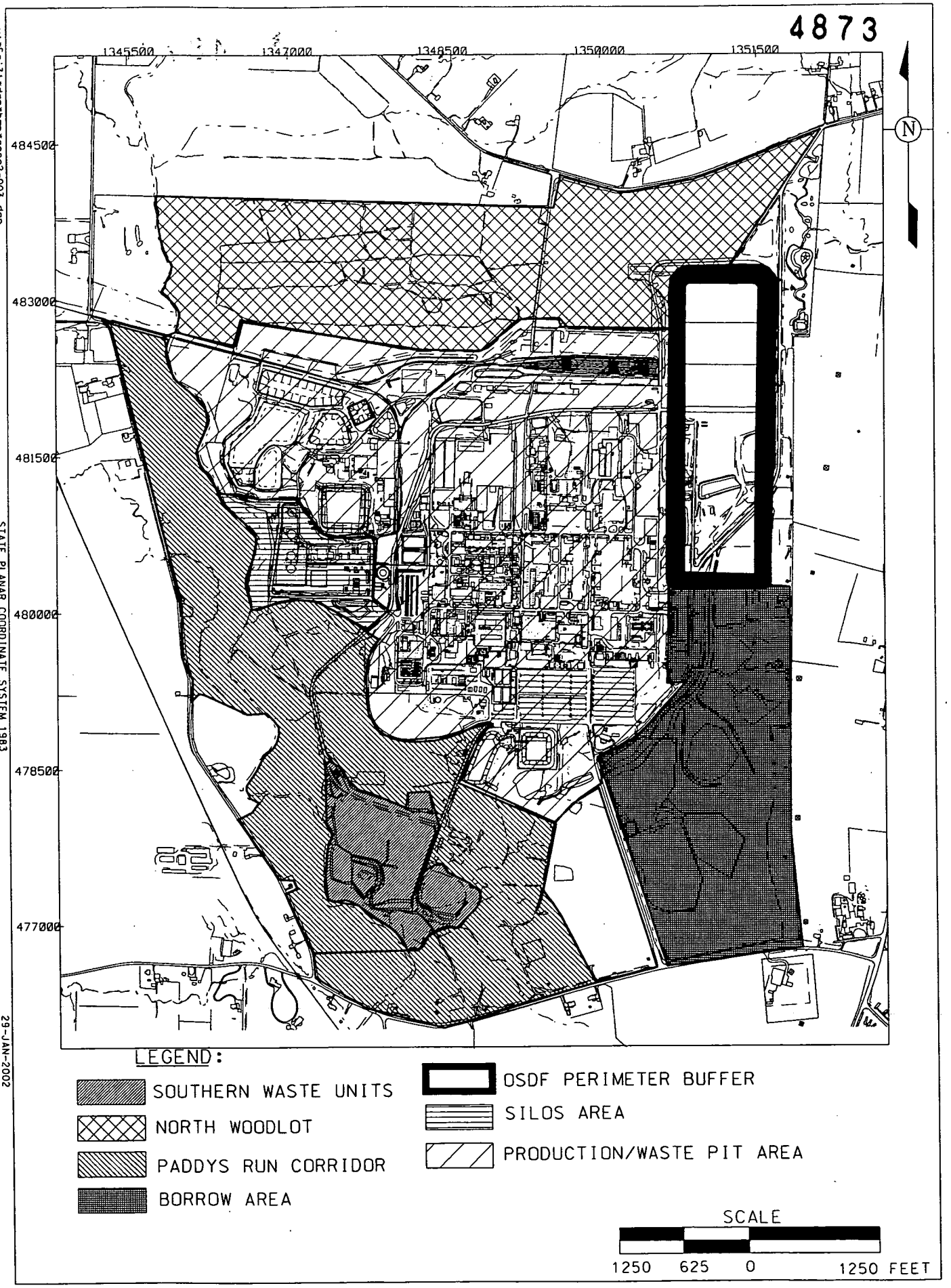
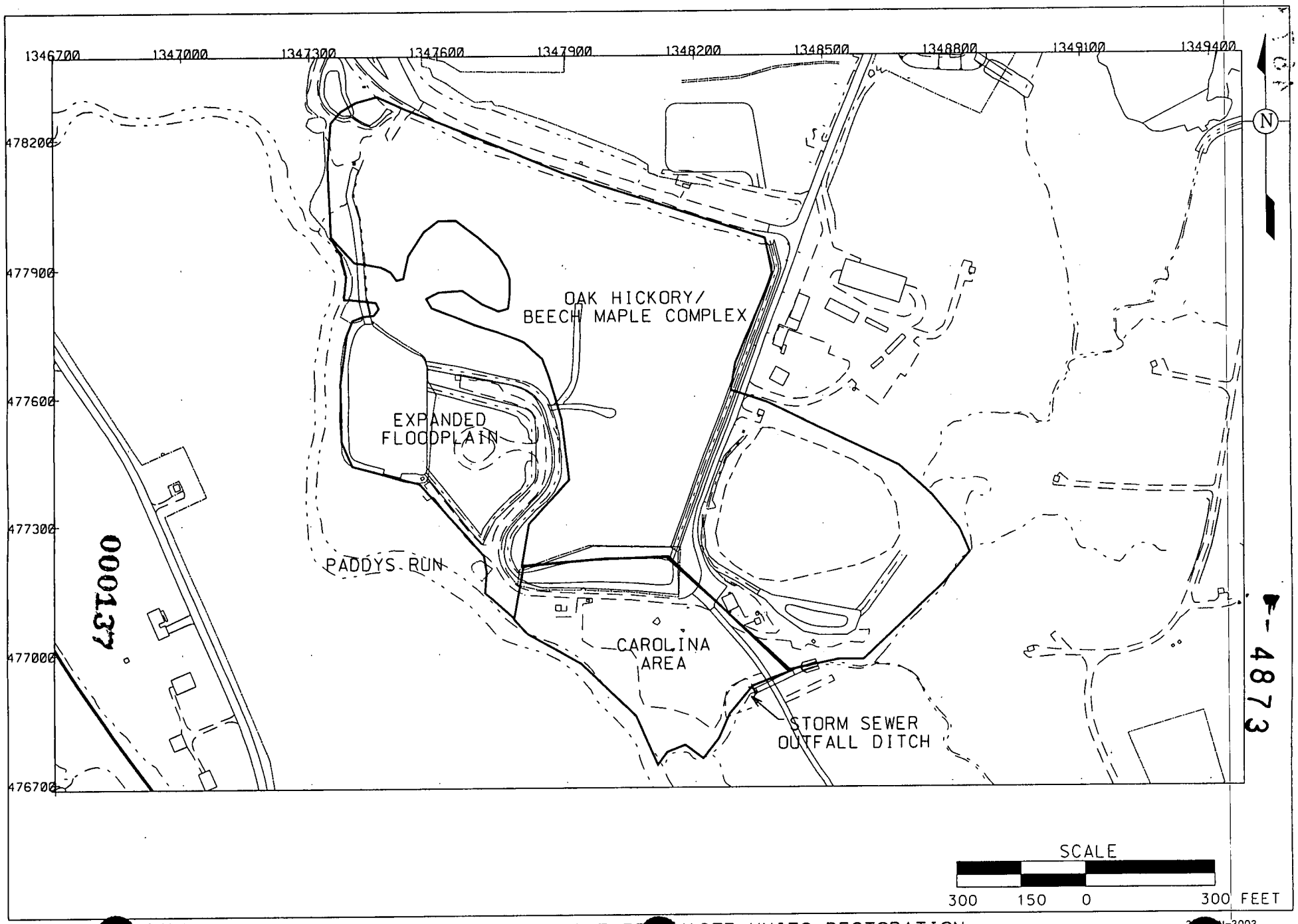


FIGURE 4-4. FUTURE NATURAL RESOURCE RESTORATION PROJECTS



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STATE PLANAR NATE SYSTEM 1983

FIGURE 4-5. SOUTHER WASTE UNITS RESTORATION

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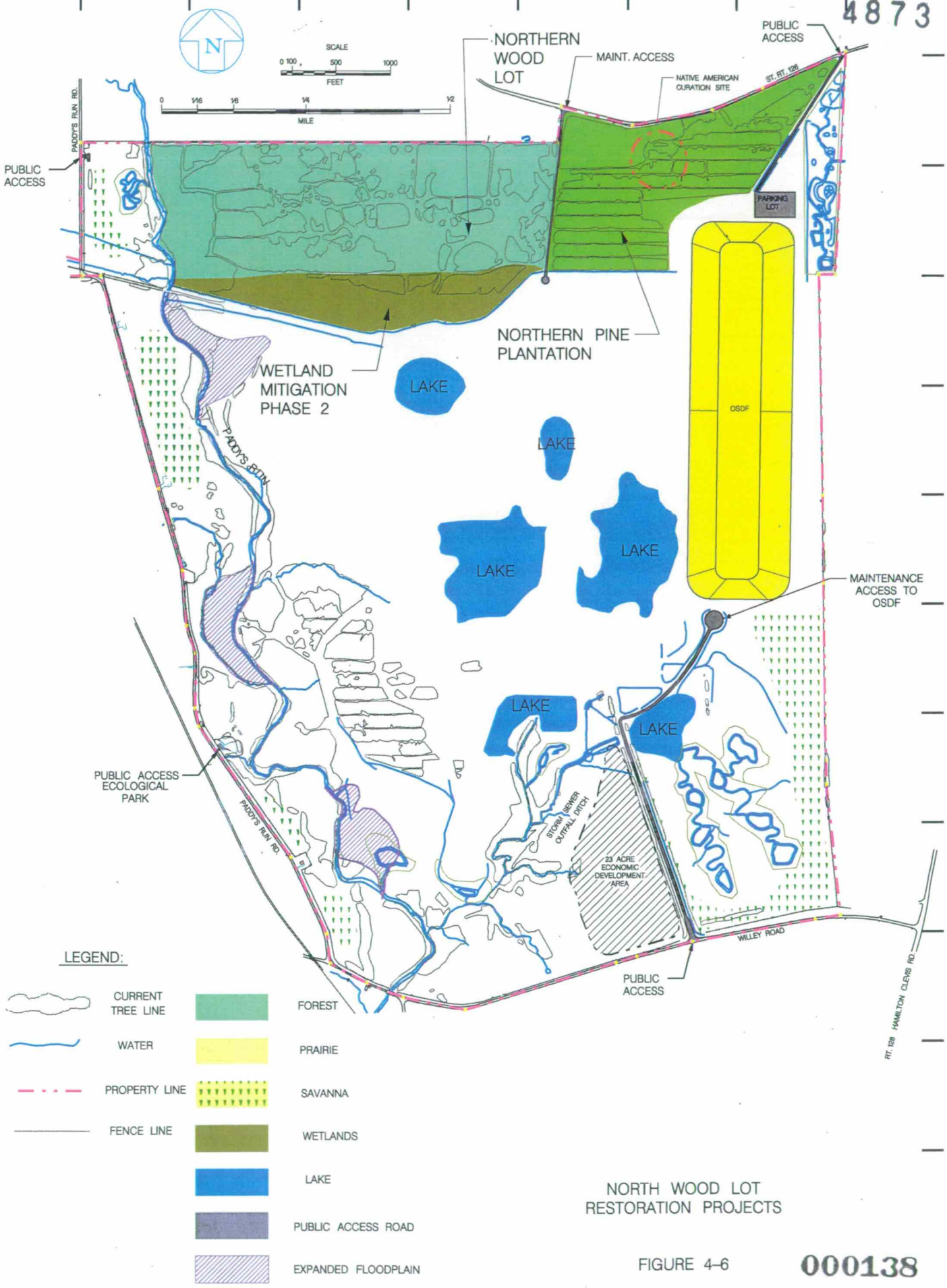

NORTH WOOD LOT
RESTORATION PROJECTS

FIGURE 4-6

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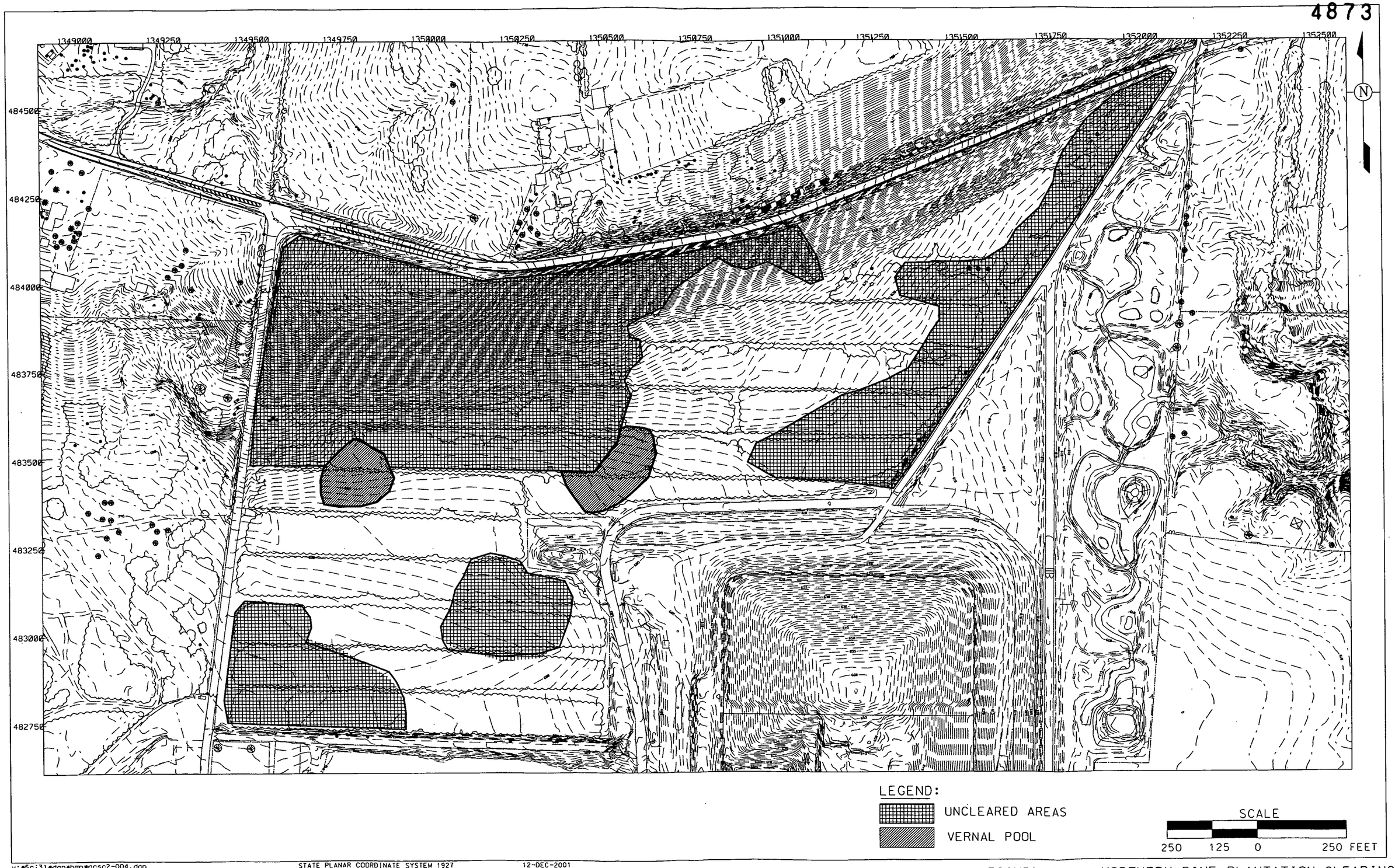

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FIGURE 4-7. NORTHERN PINE PLANTATION CLEARING

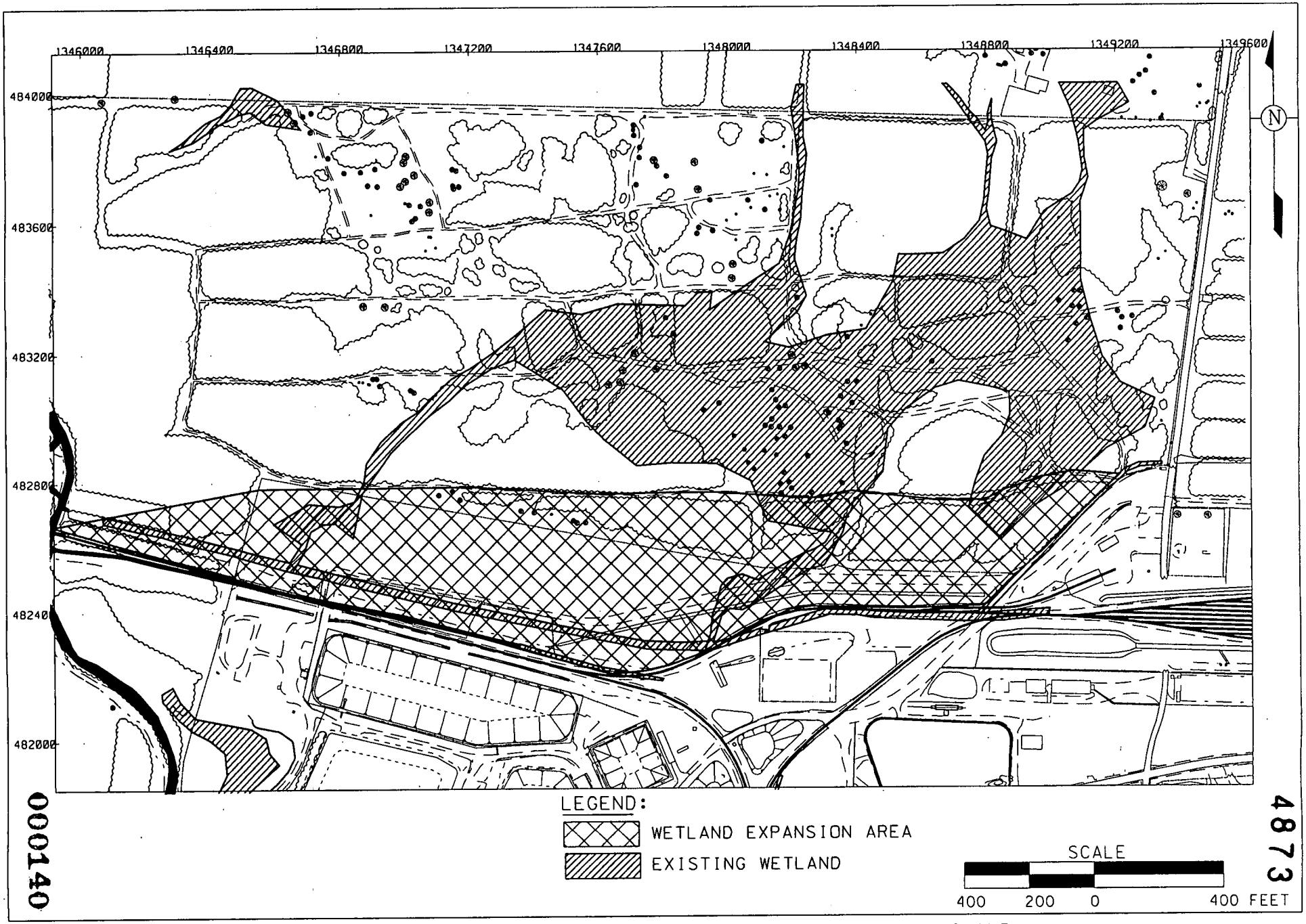

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FIGURE 4-8. EXPANSION OF NORTHERN FORESTED WETLAND

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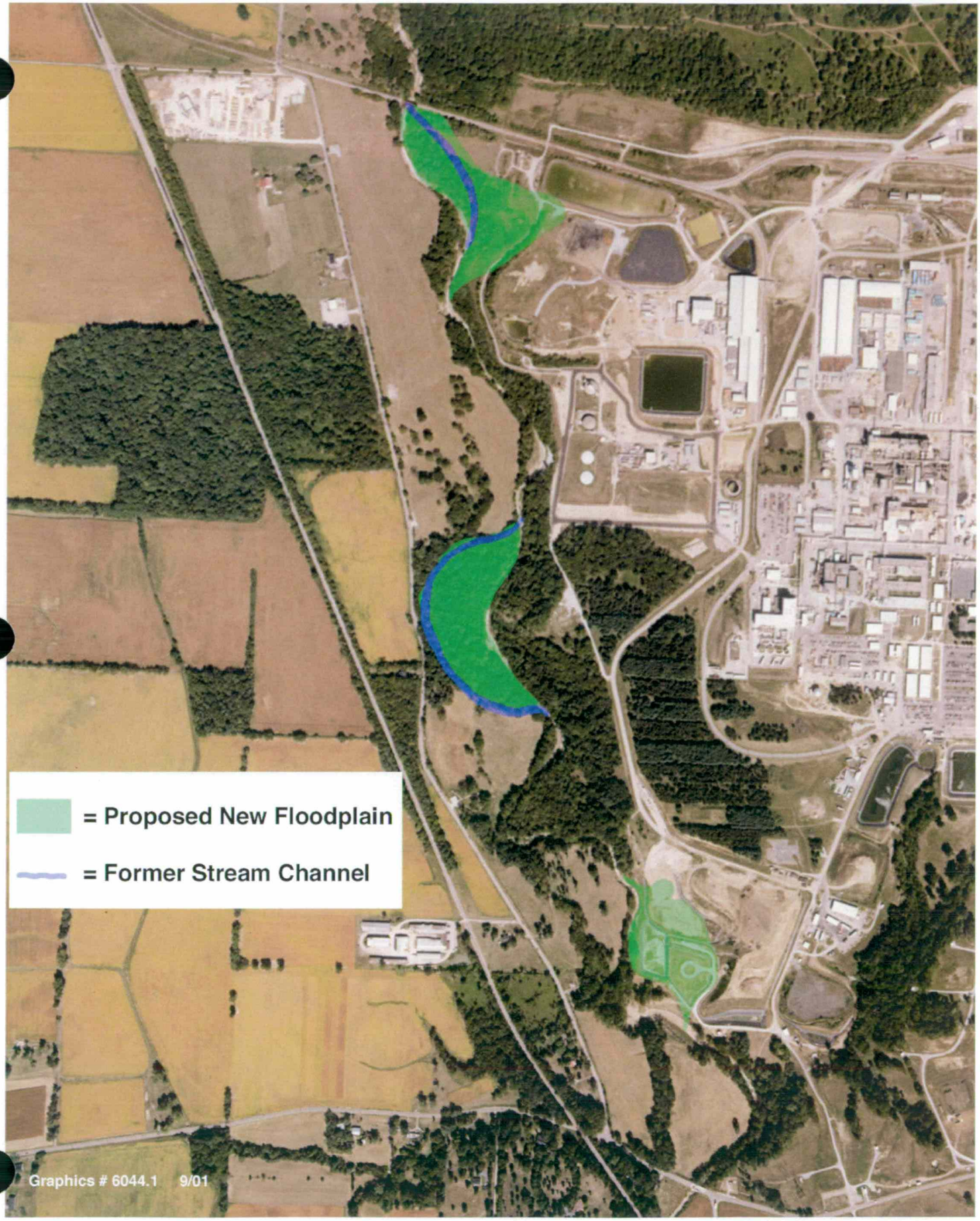
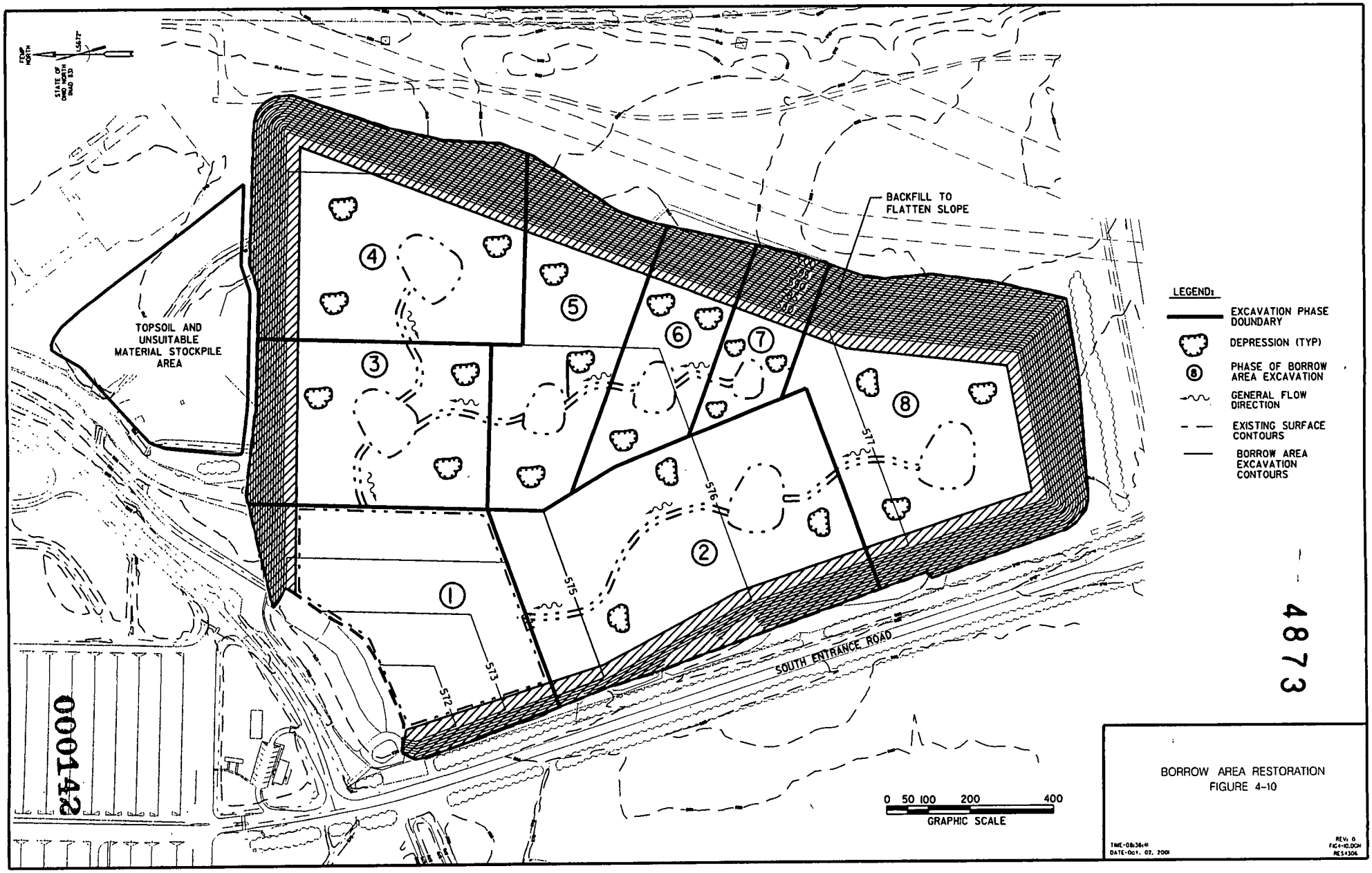


Figure 4-9 Floodplain Expansion Along Paddys Run



BORROW AREA RESTORATION
FIGURE 4-10

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Section 5.0

5.0 MONITORING

Monitoring will be implemented in two phases to assess the progress of each restoration project and to assess the progress of the various types of habitats that will be restored at the FEMP. Project Implementation Success Monitoring will be performed in the first growing season following planting to ensure that a project is completed consistent with the requirements of the NRRDP. Implementation Monitoring will not be carried out past the completion of restoration (Site Closure plus one year). Implementation Monitoring will generally be carried out for one year following project completion (except for wetland mitigation projects). Implementation Monitoring will help evaluate whether plant material installed is meeting the 80 percent minimum survival requirements for saplings and shrubs, and seeding is providing 90 percent cover as specified in the NRRDP. The 80 percent minimum survival requirement for saplings and shrubs excludes deer damage where appropriate controls have been implemented. Implementation Monitoring will employ standard vegetative measurement techniques (e.g., percent survival, percent cover, species diversity) for monitoring of completed restoration projects. The results of Implementation Monitoring will be a pass/fail determination resulting in the project either performing in a satisfactory manner or requiring some type of maintenance or management action in the case of failure.

The second tier of monitoring will be Habitat Functional Success Monitoring. Habitat Functional Success Monitoring will focus on an entire habitat (e.g., prairie, wetland, forest) instead of an individual project. Habitat Monitoring will help determine if restored habitats at the FEMP are progressing when compared to baseline conditions and established reference sites. Habitat Functional Monitoring will be carried out until the end of restoration (Site Closure plus one year) and will have a lower frequency of data collection (e.g., every three years). Habitat Monitoring will not be a pass/fail determination, but will quantitatively evaluate progress of a restored habitat against a baseline and towards an established reference site. Parameters such as vegetation indices (e.g., Floristic Quality Analysis, Simpson's Index) and wildlife use will be measured in 2001 and 2002 in existing areas of the FEMP in order to establish baseline conditions at the site. The same measurements will be taken in 2002 and 2003 to establish conditions of functioning reference sites (agreed upon by the NRTs) to establish data on successful systems. Starting in 2003 and throughout restoration of the FEMP, restored habitats will be grouped together as wetlands, prairies/savannas, or forest/riparian and will be measured in the same manner as the

baseline and reference sites. The overall success of restored habitats will be assessed based on the measured progress of restored areas from baseline condition towards a reference site condition.

The concept of "Adaptive Management" will be used in making decisions regarding needed maintenance and management of restored areas. Adaptive Management is defined as, "a continuing process of planning, monitoring and adjusting with the objective of improving the project implementation and outcomes." Adaptive management will allow the NRTs flexibility in making decisions regarding needed maintenance and management of restored areas. Restored areas will be very dynamic in nature and set standards or rules may not always apply to all situations in the field. The goal of restored area monitoring and the use of adaptive management will be to optimize the progress of restored areas towards functional success of restored habitats. Adaptive management will not be used to increase the scope of restoration projects.

A monitoring report will be generated addressing all restoration projects monitored in that year. The Consolidated Monitoring Report for Restored Areas at the FEMP will be submitted to the NRTs by December 15 of the calendar year in which the monitoring was conducted. The report will include implementation and functional monitoring methods, implementation monitoring results, functional monitoring results, a description of corrective measures to address areas of concern, and a summary of adaptive management activities that have taken place in the past year.

The anticipated schedule for restored area monitoring is shown on Table 5-1. This schedule has been developed based on planned completion dates for restoration projects and is subject to change based on available funding and prioritization of work. Stewardship planning will identify any long-term monitoring requirements for restored areas.

TABLE 5-1
PLANNED MONITORING ACTIVITIES IN RESTORED AREAS

Year	Implementation Monitoring	Functional Monitoring
2001	A1PI Wetland Mitigation A8PII Forest Demonstration	baseline sites
2002	A1PI Wetland Mitigation	reference sites
2003	Southern Waste Units Northern Woodlot (prairie/forest) OSDF/Borrow Area (accelerated) A1PI Wetland Mitigation	A1PI Wetland Mitigation A8PII Forest Demonstration (wetland) OSDF/Borrow Area (wetland)
2004	Northern Woodlot (wetland mitigation) Northern Pines OSDF/Borrow Area (accelerated) Paddys Run Corridor East	A8PII Forest Demonstration (savanna) Northern Woodlot (prairie) Paddys Run Corridor West (prairie/savanna)
2005	OSDF/Borrow Area (accelerated) Paddys Run Corridor West Northern Woodlot (wetland mitigation)	A8PII Forest Demonstration (forest) Northern Pines (forest) Paddys Run Corridor West (forest/riparian) Southern Waste Units (forest/riparian) Northern Woodlot (forest)
2006	Silos Area Northern Woodlot (wetland mitigation) OSDF/Borrow Area (final)	A1PI Wetland Mitigation Waste Pit Area (wetland) Production Area (wetland) A8PII Forest Demonstration (wetland) Northern Woodlot (wetland) Borrow Area (wetland)
2007	Northern Woodlot (wetland mitigation) Production Area/Waste Pits	A8PII Forest Demonstration (savanna) Paddys Run Corridor West (prairie/savanna) Borrow Area/OSDF Perimeter (prairie) Waste Pit Area (prairie) Production Area (prairie) Northern Woodlot (prairie)

Assumptions:
1) One year for implementation monitoring
2) Monitoring year is the first growing season post-construction (i.e., if field implementation is completed Spring 2003, then implementation monitoring takes place in 2003)
3) Wetland mitigation implementation monitoring is conducted in four years
4) Functional monitoring complete in 2007

Section 6.0

6.0 STAKEHOLDER INVOLVEMENT

Stakeholder involvement will be essential to successful development and implementation of this restoration plan. All meeting summaries generated from NRT meetings are made available to the public. Stakeholders have had several opportunities to provide input. On September 21, 1998, the NRRP and the Final Land Use Environmental Assessment were made available to the public for a 30-day review and comment period. On September 23, 1998, the FEMP NRTs conducted a public workshop to discuss the NRRP and the proposed settlement of natural resource trusteeship issues. A separate DOE-sponsored public hearing on final land use was held at the October 13, 1998 Cleanup Progress Briefing. A fact sheet explaining the relationship of final land use, the FEMP NRTs, and the NRRP was made available to the public on September 8, 1998.

The final NRRP will be made available for stakeholders prior to any final settlement agreement between the NRTs.

In order to obtain stakeholder input on individual NRRDPs, the FCAB and any other interested stakeholders will receive copies of the designs for review and comment. The NRRDPs will also be made available in the Public Environmental Information Center. As described in Section 1.5, DOE will provide an opportunity for public comment on the decision regarding future public use of the FEMP. Any of the Fernald NRTs and/or DOE-FEMP can be contacted with any questions or comments regarding restoration of the FEMP.

Section 7.0

7.0 INSTITUTIONAL CONTROLS AND FUTURE LAND USE

Institutional controls are established in the OU5 selected remedy as a means of ensuring continued protection of human and ecological receptors. These include:

- Continued access controls at the site during the remediation period,
- Alternate water supplies to affected residential and industrial wells,
- Continued federal ownership of the FEMP property,
- Deed restrictions necessary to preclude residential and agricultural uses only and ensure recreational use of the remaining areas of the FEMP property,
- Application of conservation easements for habitat restoration, and
- Enhancement of off-property areas, and the possible purchase of additional property adjacent to the FEMP.

Additionally, proper notifications, as mandated by Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and DOE requirements, will be provided before the transfer of any federal real property known to contain, or used in the processing of, hazardous substances. These measures will minimize the potential for human exposure to contaminated soil and groundwater during the implementation of sitewide remedial actions, and to the contaminated material contained in the OSDF following completion of remedial activities at the site. Specific institutional control measures will be established during the remedial design and remedial action processes.

Stewardship planning will provide the plan for long-term care of the FEMP, including Institutional Controls. Stewardship planning will also provide periodic updates as the FEMP moves closer the completion of remedial actions. Once finalized, this plan will function as the Institutional Control Plan and Future Land Use Plan for the site.

The FCAB issued recommendations regarding future use of the FEMP property in March 1996. The FCAB recommended that the area of the FEMP containing the disposal facility and associated buffer zone remain under the continued ownership of the federal government. Additionally, the FCAB recommended that the remaining portions of the FEMP property be made available for the uses deemed

most beneficial to the surrounding communities. The FCAB encouraged DOE to consult with the local communities to establish their preferences for future public use of the site. Consistent with these recommendations, DOE will issue a Master Plan for Future Public Use at the FEMP and work with local stakeholders to develop the most appropriate plan for the FEMP. An institutional control plan, focused on specifying the institutional control measures to be applied at the site, will be developed as part of stewardship planning at the FEMP. The following key components are identified for institutional controls and monitoring:

- Continuation of access controls at the FEMP, as necessary, during the conduct of remedial actions. Continued property ownership of the FEMP by the federal government.
- Maintenance of the OSDF to ensure its long-term performance and the continued protection of human health and the environment.
- Conduct of an environmental monitoring program during and following remedy implementation to assess the short- and long-term effectiveness of remedial actions.
- Provision of an alternate water supply to domestic, agricultural and industrial users relying upon groundwater from the area of the aquifer exhibiting concentrations of contaminants exceeding the FRLs. The alternate water supply will be provided until such time as the area of the aquifer impacting the user is certified to have attained the FRLs.

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Photo 1 Aesthetic Barrier Along Willey Road

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Photo 2 Wetland Mitigation - Phase I

7081-D249

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Photo 3 Area 8, Phase II Revegetation

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Appendix A

APPENDIX A

SUMMARY OF ECOLOGICAL CONSTITUENT OF CONCERN REVIEW

SUMMARY OF THE ECOLOGICAL CONSTITUENT OF CONCERN REVIEW

DOE must ensure that ecological receptors are not adversely impacted by residual contamination that may remain after remediation is complete. One early step towards this goal was taken with the publication of the Site-wide Ecological Risk Assessment (SERA), which was conducted as part of the Operable Unit 5 Remedial Investigation.

The SERA considered both radiological and non-radiological risks to ecological receptors within distinct study areas at the FEMP. For radiological risks, site concentrations within each study area were used to calculate the radiological dose rates accrued by individuals of various representative species. All of these doses fell well below the target level dose of 36.5 rad/year, as established by the International Atomic Energy Agency.

For non-radiological risks, potential constituents of ecological concern (COECs) were determined for each study area by comparing existing data to literature-derived benchmark toxicity values (BTVs). The results of this effort showed that 17 soil COECs were present in one or more study areas across the FEMP. Several other COECs were identified for surface water, sediment in Paddys Run and the Great Miami River.

BTVs are not ecological cleanup levels, but rather threshold values that are protective of ecological receptors. An exceedance of a BTV indicates that further investigation may be needed, and does not necessarily indicate ecological impact. Because of this, further investigation of information developed in the SERA was to have been deferred until after all human health-driven remediation has been completed. However, as negotiations with the FEMP Natural Resource Trustees progressed, it became clear that in order to resolve all Trustee concerns, ecological impacts must be considered before remedial activities have been completed. Therefore, a second ecological risk screening was conducted, which is found in Appendix C of the Sitewide Excavation Plan (SEP).

For soil, 103 potential COECs were identified at the FEMP. After BTVs were established for each potential COEC, they were screened in several steps. First, all potential COECs with BTVs greater than corresponding final remediation levels were eliminated from further review. The remaining potential COECs were then compared against maximum sitewide soil detections. Any parameter with a maximum

concentration less than its BTV was eliminated from further evaluation. A few potential COECs were screened out when their BTV exceedances were the result of background conditions or were from locations that no longer existed. Potential COECs that remained were then screened against anticipated postexcavation soil concentrations. The results of this process were presented on maps that showed the depth below or height above excavation that a particular BTV exceedance was located (Figures C-3 through C-8). Through this process, COECs were identified in several areas that may be a concern after remedial activities have been completed. These COECs include antimony, cadmium, lead, molybdenum, silver, and a suite of polyaromatic hydrocarbons (PAHs). DOE-FEMP will investigate these COECs further through evaluation of predesign, precertification, and/or certification data.

Potential surface water and sediment COECs were screened as well. Parameters with BTVs greater than corresponding FRLs were identified, along with COECs where BTV exceedances are associated with background conditions. Remaining surface water and sediment COECs will then be included in the Integrated Environmental Monitoring Plan sampling protocol. The surface water COECs to be sampled include barium, cadmium, and silver. For sediment, barium, cadmium, iron, lead, and zinc will be included as part of the IEMP monitoring.

Appendix B

APPENDIX B

HABITAT EQUIVALENCY ANALYSIS BRIDGE DOCUMENT

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LIST OF ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
FEMP	Fernald Environmental Management Project
FS	feasibility study
HEA	Habitat Equivalency Analysis
NRDA	Natural Resource Damage Assessment
NRIA	Natural Resource Impact Assessment
NRRP	Natural Resource Restoration Plan
NRTs	Natural Resource Trustees
OSDF	On-Site Disposal Facility
RI	remedial investigation

1.0 INTRODUCTION

The goal of negotiations between the Fernald Natural Resource Trustees (NRTs) is to resolve the U.S. Department of Energy's (DOE's) liability for natural resource injuries, including the settlement of the State of Ohio's 1986 claim against DOE, by implementing an on-property natural resource restoration plan. The NRTs have tentatively agreed to pursue resolution of their concerns without conducting a formal Natural Resource Damage Assessment (NRDA). Therefore, any restoration plan for the Fernald site must be justified through a process that meets at least all of the substantive aspects of the NRDA process and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

A key aspect of the natural resource trusteeship process is ensuring that restoration adequately compensates for injuries. Within an NRDA, this is accomplished by converting injuries to dollar damages, which are then spent to replace, restore, or acquire natural resources equivalent to those injured. The NRTs have agreed to pursue an alternate method to ensure that the level of natural resource restoration at the Fernald site is commensurate with the impacts that have occurred.

To accomplish this, the NRTs have tentatively agreed to pursue the use of the Habitat Equivalency Analysis (HEA) process to bridge the gap between the Natural Resource Impact Assessment (NRIA) and the Natural Resource Restoration Plan (NRRP). The NRIA provides a baseline of past and anticipated future impacts to terrestrial and surface water impacts that have occurred at the Fernald site. Based on those impacts, the NRTs have formulated the appropriate level of restoration, as defined by the evaluation in this addendum, to compensate for the agreed-upon impacts and to address all stakeholder concerns. As stated in Section 1.5 of the NRRP, groundwater impacts will be addressed separately.

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2.0 HABITAT EQUIVALENCY METHODOLOGY

The HEA process is one of the methods available to determine the appropriate compensation for the loss of natural resources. By using the HEA methodology, the NRTs have the flexibility to calculate the acreage of a habitat replacement project necessary to compensate for the loss of services provided by a natural resource. An example of a service loss would be the contamination of groundwater to the extent it cannot be used for drinking water or the contamination or destruction of a wetland system to the point it no longer provides the beneficial functions of a healthy wetland. The HEA process calculates compensatory restoration that accounts for interim loss of services. This restoration is in addition to any primary restoration, which is required to return a resource to baseline conditions.

Although there is a distinction made between primary and compensatory restoration projects for the purposes of compliance with regulatory requirements and implementation of the HEA process, the two may involve the same restoration activities (e.g., revegetation, creation of wetlands). However, it is important to note that there can be distinct and different projects implemented to meeting primary and compensatory restoration requirements. At the Fernald site, the intent is to propose and implement a comprehensive restoration plan (as outlined conceptually in the NRRP) to meet both primary and compensatory restoration requirements.

The ultimate goal of the HEA process is to calculate compensation based on some agreed upon level of injury for each natural resource area. This calculation will serve to demonstrate the increase in services provided by the replacement project will be of equivalent value to the public as the value of services lost due to the injury. Because detailed quantitative data is generally lacking to value the exact loss of services from a past (or future) injury, HEA calculates an equivalency between the quantity of services lost due to the injury and the quantity of services provided by the replacement projects over time.

The NRTs will negotiate the amount of yearly service loss for a particular area based upon the amount of injury that has occurred. In the case of the Fernald site, the injuries or impacts have been outlined by distinct study areas in the NRIA. Therefore, the NRTs will negotiate an appropriate level of service loss for each particular study area outlined in the NRIA. In addition, the NRTs will negotiate the appropriate level of service gain provided by the restoration projects. Based on the negotiated level of service loss and gain, the HEA methodology will calculate the amount of compensatory restoration required (in

acres) to offset of natural resource impacts or injuries. The compensatory restoration acres are calculated as explained in Section 2.1.

The resulting acreage will be addressed through specific restoration projects, as conceptually described in the NRRP. Roughly 850 acres are available for on-property restoration, which is estimated by taking the total site acreage (1,050 acres) and subtracting land required for the On-Site Disposal Facility (OSDF), various Operable Unit 4 supplemental environmental projects, and the 23 acres designated for potential use by the Community Reuse Organization.

It should be noted that utilizing the HEA process may appear to be very accurate, in reality there is a significant amount of uncertainty involved. The negotiated service levels were not quantitatively derived, but rather qualitatively set based on conservative assumptions and existing information, as discussed in the following sections. The Fernald Environmental Management Project (FEMP) NRTs agreed that the qualitative HEA process provides an order of magnitude estimate of restoration required. To illustrate this point, all HEA calculations have been rounded to the nearest 10 acres.

2.1 CALCULATIONS

Two worksheets were developed to calculate HEA acreage for each NRIA area. These worksheets provided for each area will include the columns described below. The first (left side) worksheet calculates the interim loss in services by determining *effective acre-years* lost. This is accomplished by taking the negotiated service level (column 3) for each year (column 1) and subtracting from 100 percent to get an annual percent service loss (column 4). In column 5, the average annual percent service loss is calculated by averaging the given year and the following year service losses. For instance, if year one had a service loss of 20 percent and year 2 had a service loss of 40 percent, the average annual percent service loss would be 30 percent. A discount factor of three percent is then applied in column 6 using the following equation: $1/(1+0.03)^{\text{given year} - 1997}$. This discount factor is then multiplied by the average annual percent service loss to obtain an average service loss per acre (column 7). This value is then multiplied by the total area acreage (found in the "Related Information" section at the bottom right of the various worksheets) to get an effective acres lost value for each year of impact. These annual acreage are then summed at the bottom of the worksheet to obtain a total discounted effective acre-years lost.
Service increases are then calculated. The first three columns of the service increase worksheet have similar values with respect to the percent service levels for the given years. Rather than calculating loss,

however, an average percent service level change is calculated for each year. This is accomplished by again averaging the percent service change in a given year with the following year (column 4). This value is again discounted using the same discount factor equation as described above (column 5) and multiplying it by the average annual percent change to determine an effective acre-years per acre gain (column 6). These annual values are summed at the bottom of the worksheet to obtain a total gain in discounted effective acre-years per acre restored.

To determine the amount of compensatory restoration that is required, the total interim loss acre-years are divided by the total gains in effective acre-year per restoration acre in order to obtain the total amount of compensatory acreage needed. These calculations are shown below the service increases tables on each worksheet. The compensatory restoration acreage is then added to the primary restoration acreage to determine the total restoration acreage required.

2.2 CONDITIONS AND ASSUMPTIONS FOR USE

In order to use HEA in the determination of compensatory restoration requirements, four conditions must be met. Each of these conditions and their applicability to the FEMP are discussed below. The use of HEA to calculate groundwater compensation will be discussed separately.

2.2.1 Values of Lost Services are Comparable to Replacement Services

Primary and compensatory restoration plans must provide services comparable to the services lost due to injuries. Restoration alternatives at the FEMP are centered around expansion, enhancement, and restoration of site habitats that have been or will be impacted due to CERCLA releases and/or remedial activities. Most of the habitats proposed in the NRRP are habitats that have been or are presently located on FEMP property, which will provide the same services with respect to wildlife habitat, nutrient cycling, etc. Therefore, replacement services will be comparable to lost services. It should be noted that in some instances lower quality habitats will be replaced with higher quality habitats. For instance, many of the introduced grasslands located on property will be converted into deciduous woodlots. In these cases, an adjustment factor is used in the HEA calculations as an increase in service levels over 100 percent.

2.2.2 Injuries Primarily Affect Ecological Services

The use of HEA is recommended only if on-property human uses are limited and off-property human uses are difficult to quantify. This condition is met at the FEMP, where human access to the site is restricted and service losses are primarily the result of ecological impacts due to habitat loss.

2.2.3 Replacement of Habitat Services is Feasible

Service losses due to habitat impacts can be replaced with the expansion, enhancement, and restoration of representative habitats. These actions consist of standard erosion controls, grading, and revegetation, which will be detailed in the NRRP. The land for these actions is available on property, with the final land use scenario being an undeveloped park. Therefore, natural resource restoration at the FEMP will replace lost habitat services. The NRRP is conceptual at this time. As design progresses, specific restoration plans may be altered for technical reasons. Any plan revisions must still meet the restoration goals identified through the HEA process and through negotiations with the NRTs.

2.2.4 Nature of Injuries and Replacement Projects are Sufficiently Understood to Estimate HEA Parameters

Through the remedial investigation/feasibility study (RI/FS) process, volumes of information have been collected with respect to natural resource injuries and associated service losses at the FEMP. Likewise, remedial design efforts provide sufficient information to estimate service gains through restoration projects. Certain service loss and gain percentage calculations require the use of assumptions derived from existing information, current remedial design schedules, and the science of ecology. These assumptions are spelled out below.

The assumptions used to apply HEA at the FEMP can be divided into three major categories: general assumptions; assumptions associated with service losses; and assumptions associated with service gains. in addition, specific assumptions have been made for each of the areas evaluated in separate HEA calculations. These assumptions are described within the corresponding description of the area-specific HEA calculations.

2.3 GENERAL ASSUMPTIONS

The first general assumption used in the FEMP HEA calculations is that the future impact acreage identified in the NRIA is equivalent to the primary restoration project for the area in question. In other

words, if no natural resource injury compensation were required, DOE would mitigate the loss of impacted habitats at a 1 to 1 ratio. This is the case for all areas evaluated at the FEMP except for the Former Production Area/Waste Storage Area, where primary restoration equals 15 acres of wetland mitigation, resulting in a 1.5 to 1.0 ratio. This is due to DOE's existing regulatory commitment for mitigation of 10 acres of wetlands that will be filled during remedial activities.

The second general assumption is the use of an annual discount rate of 3 percent. This rate applies to both past and future impacts.

2.4 SERVICE LOSS ASSUMPTIONS

Several assumptions are used in estimating service level impacts for each area. First, when information to the contrary is not available, service losses were assumed to have started in 1952, when full-scale operations began at the FEMP. Likewise, excavation impacts are assumed to start entirely within the first year of excavation, based on current remedial design schedules. Excavation impacts are calculated by dividing the future impact acreage (which is also the primary restoration acreage) into the total area acreage to obtain a percent service level loss. Specific details of each of these assumptions is provided in the text for each area calculated.

2.5 SERVICE GAIN ASSUMPTIONS

The assumptions used in the calculation of service level gains are as follows. First, it is assumed that recovery is complete in 20 years for all habitats restored at the site. Some habitats will recover sooner than 20 years, based on the nature of the restored habitat. Also, because existing habitats will be enhanced and/or replaced with better quality habitats through the restoration process, service gains may be estimated above 100 percent, or baseline conditions. This may still be the case even when it is acknowledged that residual contamination may remain in the soil after remediation and restoration have been completed. If it is determined that the residual contamination will not adversely effect ecological receptors and the quality of the habitat has increased, then the service level may be estimated at above 100 percent. To calculate service gains through infinity, discounted service gains are calculated and summed for 200 years.

Resolving the recovery periods used in the HEA calculations are intended to estimate the point where the functional objectives of a given ecological restoration are met. Ecological succession processes

may take much longer for some habitats. However, if the goal of a particular project is to establish a successional system, and secondary wildlife habitat goals are met, then the "recovery" is complete. In other words, the ecological restoration has succeeded, and further natural processes may continue.

3.0 RESULTS OF HABITAT EQUIVALENCY ANALYSIS

This section outlines the results of the HEA process for each area of the site as evaluated in the NRIA. Each area of the site is divided into a discussion of assumptions and results. The HEA worksheets for each area were based on the impacts identified in the NRIA. These impacts (both past and future) are summarized in the discussion of assumptions for each area. The discussion of assumptions also points out decisions that were made concerning the timing and severity of impacts in each area so that the HEA worksheet could be completed. The discussion of results identifies the restoration acreage that will be required to compensate for the impacts in each area. In addition, the results discussion also references the appropriate sections of the NRRP where specific restoration projects are proposed to address the required restoration acreage.

3.1 PADDYS RUN RIPARIAN CORRIDOR

The Paddys Run Corridor encompasses approximately 98 acres along the western side of the FEMP. This area includes both riparian terrestrial habitat and aquatic habitat.

3.1.1 Assumptions

- Impacts due to contamination occurred in approximately 10 acres of the Paddys Run Corridor. Impacts are assumed to have initially began in 1953 when production started and uncontrolled runoff began to flow into Paddys Run. This increase resulted in a linear decrease in service levels to 91 percent in 1961.

- Relocation of Paddys Run near the Waste Pit Area occurred in 1962 causing impact to the stream. A 16 percent reduction in services to 75 percent was estimated because the relocation involved approximately 25 percent of the portion of Paddys Run that receives flow throughout the year (Exhibit D). This accounts for impacts on both banks of Paddys Run.

- Recovery of the stream channel and adjacent revegetation was assumed to start immediately and is reflected in the HEA worksheet in the following year.

- It was assumed that full recovery of the stream occurred in approximately 9 years. The service level in 1971 is not at pre-relocation levels because vegetation recovery has not been completed.

- Full recovery of the vegetation was assumed to require 20 years as shown. The service level in 1982 is the same percentage (90 percent) that would have been present in 1962 had relocation not occurred (Exhibit G).

- The installation of stormwater controls started in late 1986, limiting runoff to Paddys Run and increasing the service level 1 percent from 1987 on.

- Service levels were assumed to increase 1 percent in 1989 as a result of the Stormwater Retention Basin expansion in late 1988 and the cessation of production in 1989 (Exhibit J).

- Service levels were again assumed to increase 1 percent in 1992 as a result of the Waste Pit Area Stormwater Runoff controls installation.

- In 1993, erosion controls using rip rap was installed at the Inactive Flyash Pile which was assumed to slightly decrease service levels 1 percent due to minor physical impacts. The reduction was also only 1 percent because Removal Action 16 was implemented in 1993 as well, which further controlled runoff from the Former Production Area. The service reduction accounts for impacts to both banks of Paddys Run.

- Approximately 1 acre of habitat was impacted with the installation of riprap on this bank of Paddys Run in the vicinity of the K-65 Silos in 1998.

- The remediation of contaminated soil will occur in three stages, beginning in 1997 with the Southern Waste Units remedial activities and ending in 2005. Remediation will result in a significant decrease (22 percent) in the service level due to the clearing of vegetation and excavation of 34 acres of riparian corridor, which is approximately 35 percent of the entire area. The 27 percent decrease is added to the 9 percent baseline decrease in 1996 to get an overall 35 percent decrease. The service reductions are staggered between 1997, 2000, and 2005 to represent the staged excavation of the corridor.

- Restoration of the corridor is assumed to begin immediately after the last stage of remediation and is reflected in the year following excavation in 2006.

- Recovery of the corridor is assumed to be complete in 20 years when the restored stream and vegetation reaches a reasonable level of maturity.

- The restoration of the corridor is assumed to improve the quality of the corridor over current conditions and thus the service level at completion will exceed 100 percent to a total of 110 percent.

3.1.2 Results

Using the impacts outlined in the NRIA, along with the assumptions outlined above, a total of 90 acres of replacement habitat would be required to compensate for impacts to the Paddys Run Corridor. Impacted areas of the existing riparian corridor and the stream will be restored at the completion of remediation. Additional restoration to compensate for the impacts to the Paddys Run Corridor will focus on the

expansion and enhancement of riparian habitat adjacent to the stream. Specific projects proposed as compensation for impacts to Paddys Run are identified in Sections 4.3, 4.4, 4.7, and 4.8 of the NRRP.

3.2 NORTHERN WOODLOT AND NORTHERN PINE PLANTATION

The Northern Woodlots include approximately 60 acres of the Northern Pine Plantation and an additional 100 acres of mixed deciduous forest including a forested wetland. The HEA worksheet for this area is outlined in Table 2 and the assumptions utilized are as follows:

3.2.1 Assumptions

- Injury was assumed to begin in 1953 as a result of airborne deposition of contaminants from production operations, causing a linear decrease in service levels to 95 percent in 1957.

- There were minor physical impacts to the area at various points in time, but these were not directly linked to a release and were not factored into HEA as a loss of service.

- Approximately 14 acres of the northern woodlots were cleared in 1988 for use as borrow material. This impact resulted in a 4 percent decrease in services for 1988 and subsequent years. Ground clearing would normally be considered a 100 percent loss. However, because baseline services are calculated according to the current 162 acres, the ground clearing for the Borrow Area in 1988 was not calculated on a 100 percent service loss. Instead, the impact was essentially discounted 50 percent.

- The Northern Pine Plantation was planted in 1972, but was not considered as a beneficial habitat until 1987 when the plantation reached a reasonable state of maturity. A 1 percent increase in service levels was included at that point (Exhibit I).

- Excavation activities to support the OSDF will be initiated in 1997 with the clearing of approximately 9 acres of the Northern Pines resulting in a drop in service level to 87 percent. This service level is estimated by dividing 15 acres into the total area (162 acres). Fifteen acres were used to calculate impacts rather than 9 acres, in order to account for edle-effect service decreases. The area of the Northern Woodlots that will be impacted will be utilized for the OSDF.

- Restoration will be initiated in the year 2002 and will involve enhancing other areas of the Northern Woodlot.

- Due to the maturity of the habitat in much of the Northern Woodlot, it was assumed that only 15 years would be necessary for full recovery (i.e., maturity) of the area.

- The restoration of the woodlots is assumed to improve the quality of the woodlots over current conditions, thus the service level at completion will exceed 100 percent (to a total of 106 percent).

3.2.2 Results

Based on the acres of impacts outlined in the assumptions listed above regarding loss of services, a total of 50 acres of restoration will be required to compensate for impacts to the Northern Woodlots. The area of primary impact in the Northern Woodlot will not be available for restoration due to utilization by the OSDF. Therefore, restoration activities outlined in the NRRP in Sections 4.5 and 4.6 will focus on enhancing other areas of the Northern Woodlot.

3.3 SOUTHERN PINES AND WASTE UNITS

The Southern Pines and Southern Waste Units encompasses approximately 66 acres south-west of the Former Production Area. Table 3 provides the HEA worksheet for the Southern Pines and Waste Units. Assumptions used in the HEA for this area are as follows:

3.3.1 Assumptions

- Injury was assumed to begin in 1953 as a result of production runoff into the Pilot Plant Drainage Ditch and due to the use of the Inactive Flyash Pile and South Field as a disposal area, which caused a linear reduction in services to 85 percent in 1960 (Exhibit C). The linear decrease in percent service level to 85 percent is based on soil contamination and not habitat loss.

- The initiation of the Active Flyash Pile in 1966 resulted in an 8 percent reduction in services to 77 percent. The 8 percent reduction is estimated by determining the percentage of the Southern Pines and Waste Units that the Active Flyash Pile represents (5 acres/66 acres, or 7.5 percent).

- The 80 percent service level continues until use of the Inactive Flyash Pile in 1965 is terminated and successional growth begins to take over in approximately 1970 (Exhibit E). In 1970, service levels show a linear increase to 90 percent in 1979. This represents a 15-year recovery to an old field habitat.

- The Southern Pine Plantation was planted in 1972, but was not considered a beneficial habitat until 1987, when the plantation reached a reasonable state of maturity. A 2 percent increase in service level was included at this point. Note that while the habitats and time frames are similar, the Southern Pine Plantation provides more benefit (as reflected in service level increases) because it represents a greater percentage of the overall area (Exhibit J).

- The clearing of several areas in the Southern Pines occurred in the 1990s resulting in additional decreases in service levels.

- Excavation, soil stockpiles, and haul road impacts in 1997 result in a 64 percent service level. The 64 percent service level is obtained by calculating the percentage of habitat loss due to excavation (24 acres/66 acres, or 36 percent).

- These areas are assumed to provide beneficial habitat even though they are contaminated.

- Restoration of this area will occur in the year 2001.

- The recovery period is expected to be approximately 20 years until a reasonable level of maturity is achieved (100 percent service level).

3.3.2 Results

Using the above-listed assumptions and the acres of impact from the NRIA, 60 acres of restoration will be required to compensate for impacts to the Southern Pines and Waste Units. The NRRP references projects to be implemented for impact compensation in Sections 4.4 and 4.7.

3.4 GRASSLANDS

The Grasslands encompass approximately 235 acres in the eastern and southern portions of the FEMP. Table 4 provides the HEA worksheets for this area. The following provides the assumptions that were utilized in developing the HEA for the grassland areas.

3.4.1 Assumptions

- Production operations resulted in air deposition contaminating approximately 93 acres of grassland areas which is identified by a slight decrease in service levels to 98 percent in 1954. The reason only a 2 percent reduction is estimated is because of the limited habitat services the grasslands provide.

- Use of the Trap Range starting around 1960 resulted in lead contamination in an isolated portion of the grasslands which is also reflected by decreased service levels to 96 percent (Exhibit D).

- It is assumed that service levels essentially remained constant until contaminated soil was excavated along with approximately 5 acres of off-property woodlot as part of Removal Action 14 in 1992. This resulted in an additional 2 percent reduction in services.

- A significant decrease in service levels was assumed to occur with the excavation of Area 1, Phase I in 1996. From 1996 to 2004, grassland excavations are staggered and reduced linearly to reflect the large scale excavations that will be taking place. The staggered reductions for the different phases of excavation (Area 1 Phase I, Area 1 Phase II, and Area 2 Phase II) are based on qualitative estimates of the ration of a given phase to the overall acreage of the grasslands.

- In the year 2002 it is anticipated that almost all grassland areas (approximately 204 acres) will be excavated as reflected by the decrease to a 12 percent service level.

- The restoration of the grassland areas will occur where possible; however, a significant portion will be utilized for the OSDF and unavailable for restoration.

- It is assumed that restoration will occur in approximately 2005 at the time that use of the Borrow Area and excavation of Area 2, Phase II is complete.

- The recovery for the restoration of the grassland area is assumed to be approximately 5 years since portions of the area will be converted to native prairies and wetlands which are assumed to have less maturation time than an area of exclusively forest habitat. The recovery is assumed to be linear to a 110 percent service level, since restored prairies and wetlands will provide higher quality habitat than the present-day introduced grasslands.

3.4.2 Results

Based on the acres of impact identified in the NRIA coupled with the assumptions that have been made above regarding loss of services, a total of 280 acres of restoration is required to compensate for impacts to grassland areas. Restoration of the grassland areas will be focused on the Borrow Area, southern portions of the site and the buffer around the OSDF. Proposed restoration projects area outlined in Sections 4.9 and 4.12 in the NRRP and would focus on the establishment of a mosaic of wetland/open water, woodland and prairie habitats.

3.5 WASTE STORAGE/PRODUCTION AREA

The Waste Storage Area encompasses approximately 37 acres adjacent to the production areas. The Production Area encompasses approximately 136 acres in the center of the FEMP. Table 5 provides the HEA worksheet for these areas. The assumptions used in developing the HEA data for this area are as follows.

3.5.1 Assumptions

- The Waste Storage Area and Production Area provided very little habitat as both were disturbed as part of construction of the site (Exhibit C).
- It is assumed that both areas were impacted in their entirety due to contamination from site operations.
- A linear decrease in service level to 95 percent in 1957 is identified beginning in 1953. Decreases are not as significant due to the lack of good habitat in both areas.
- After the initial 5 percent decrease in service levels in the early years of production, service levels are assumed to remain constant until remediation begins in these areas.
- Remediation of the areas is assumed to impact the entire area and result in a 5 percent decrease in service levels starting in 1999 with a linear reduction to 89 percent service level in 2000. The 89 percent service level is calculated from the percentage of wetlands impacted (10 acres/173 acres, or 6 percent), which is added to the baseline 5 percent impact.
- The recovery of the area after remediation, is assumed to require approximately 15 years for full maturation of the habitat. Service levels are estimated to increase to 150 percent because the mitigated, contiguous wetland system will provide more quality habitat than the unmanaged, fragmented drainage ditches that encompass the majority of the 10 acres of wetlands.

3.5.2 Results

A total of 50 acres will be required to compensate for impacts given the above assumptions. Restoration of the Waste Storage/Production Area will focus on the conversion of excavated areas into wetland/open water habitat where possible, and revegetating other areas. Proposed restoration projects are outlined in Sections 4.10 and 4.11 of the NRRP.

3.6 GREAT MIAMI RIVER

The Great Miami River is the major water feature in the vicinity of the FEMP. It flows through several urban areas before joining the Ohio River. As expected, the Great Miami River receives point and nonpoint discharges from a variety of industrial, municipal, and agricultural sources. The HEA calculations for impacts to the Great Miami River were modified in that no primary restoration service gains were estimated and divided into the total loss in effective acre-years. Rather, the total interim loss was incorporated entirely into the on-property restoration acreage. The assumptions used in calculating the HEA worksheet are outlined below.

3.6.1 Assumptions

- For the purposes of calculating HEA, the total effected area of the Great Miami River was assumed to encompass 3.22 acres. This value is estimated from 2.97 acres of stream habitat and 0.25 acres of riparian habitat in the vicinity of the FEMP outfall line. The 2.97 acres of stream habitat were estimated from two sampling sites along the western shore of the Great Miami River that are surveyed by the University of Cincinnati as part of annual electrofishing surveys. The sampling sites are downstream of the FEMP outfall line (River Mile 24) and downstream of the confluence with Paddys Run (River Mile 19). The acreage estimate was obtained by taking the linear feet of each sample site and multiplying by 10 feet to estimate an area measurement.

- Service levels are estimated by assuming a 1 percent reduction for every 1000 kg of uranium released annually into the Great Miami River. Where actual records of annual discharge are not available, estimates were made based on historic trends.

- The 1993 service level is estimated at 91 percent based on an 8 percent reduction due to the removal of contaminated riprap in the vicinity of the FEMP outfall line. 0.25 acres of riparian habitat were impacted by the riprap removal. The percentage reduction is calculated by the ratio of impacted habitat to the total area (0.25/2.97, or 8 percent). The additional percent loss is due to the 1993 discharge of approximately 550 kg of uranium into the Great Miami River.

- Impacts are assumed to occur to the river until the year 2006, when all remedial actions at the FEMP will have been completed.

3.6.2 Results

The results of the HEA calculations indicate that 10 acres of restoration will be required to compensate for impacts to the Great Miami River. This restoration acreage will be added to the overall on-property restoration acreage in the NRRP.

4.0 CONCLUSIONS

The results of the HEA worksheets for each area of the site add up to a total of 540 acres of restoration required to compensate for the impacts identified in the NRIA. The NRRP outlines the proposed projects to address this required restoration acreage. Additional acreage will be restored to account for groundwater impacts, which were negotiated separately from the HEA process.

TABLE 1

HEA Analysis for the Paddys Run Corridor

Interim Losses due to Riparian Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annua % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	0
1953	injury begins	99%	1%	1.5%	3.67	5.5%	10
1954		98%	2%	2.5%	3.56	8.9%	10
1955		97%	3%	3.5%	3.46	12.1%	10
1956		96%	4%	4.5%	3.36	15.1%	10
1957		95%	5%	5.5%	3.26	17.9%	20
1958		94%	6%	6.5%	3.17	20.6%	20
1959		93%	7%	7.5%	3.07	23.1%	20
1960		92%	8%	8.5%	2.99	25.4%	20
1961		91%	9%	17.0%	2.90	49.3%	50
1962	stream relocation	75%	25%	25.0%	2.81	70.3%	70
1963	stream recovery begins	75%	25%	25.0%	2.73	68.3%	70
1964		75%	25%	25.0%	2.65	66.3%	60
1965		75%	25%	25.0%	2.58	64.4%	60
1966		75%	25%	24.5%	2.50	61.3%	60
1967		76%	24%	23.5%	2.43	57.0%	60
1968		77%	23%	22.5%	2.36	53.0%	50
1969		78%	22%	21.5%	2.29	49.2%	50
1970		79%	21%	20.5%	2.22	45.5%	40
1971	stream recovery complete	80%	20%	19.5%	2.16	42.1%	40
1972	vegetation recovery continues	81%	19%	18.5%	2.09	38.7%	40
1973		82%	18%	17.5%	2.03	35.6%	30
1974		83%	17%	16.5%	1.97	32.6%	30
1975		84%	16%	15.5%	1.92	29.7%	30
1976		85%	15%	14.5%	1.86	27.0%	30
1977		86%	14%	13.5%	1.81	24.4%	20
1978		87%	13%	12.5%	1.75	21.9%	20
1979		88%	12%	11.5%	1.70	19.6%	20
1980		89%	11%	11.0%	1.65	18.2%	20
1981		89%	11%	10.5%	1.60	16.8%	20
1982	vegetation recovery complete	90%	10%	10.0%	1.56	15.6%	20
1983		90%	10%	10.0%	1.51	15.1%	10
1984		90%	10%	10.0%	1.47	14.7%	10
1985		90%	10%	10.0%	1.43	14.3%	10
1986		90%	10%	9.5%	1.38	13.2%	10
1987	SWRB	91%	9%	9.0%	1.34	12.1%	10
1988	SWRB expansion	91%	9%	8.5%	1.30	11.1%	10
1989	production stops	92%	8%	8.0%	1.27	10.1%	10
1990		92%	8%	8.0%	1.23	9.8%	10
1991		92%	8%	7.5%	1.19	9.0%	10
1992	waste pits stormwater controls	93%	7%	7.5%	1.16	8.7%	10
1993	inactive flyash disposal area R.A.	92%	8%	8.0%	1.13	9.0%	10
1994		92%	8%	8.0%	1.09	8.7%	10
1995		92%	8%	8.0%	1.06	8.5%	10
1996		92%	8%	12.5%	1.03	12.9%	10
1997	excavation (SWU)	83%	17%	17.5%	1.00	17.5%	20
1998	Silos east bank stabilization	82%	18%	18.0%	0.97	17.5%	20
1999		82%	18%	22.0%	0.94	20.7%	20
2000	excavation (waste pits)	74%	26%	26.0%	0.92	23.8%	20
2001		74%	26%	26.0%	0.89	23.1%	20
2002		74%	26%	26.0%	0.86	22.4%	20
2003		74%	26%	26.0%	0.84	21.8%	20
2004		74%	26%	30.5%	0.81	24.8%	20
2005	excavation remaining areas	65%	35%	35.0%	0.79	27.6%	30
2006	primary restoration	65%	35%	34.5%	0.77	26.4%	30
2007	recovery begins	66%	34%	32.5%	0.74	24.2%	20
2008		69%	31%	29.5%	0.72	21.3%	20
2009		72%	28%	26.5%	0.70	18.6%	20
2010		75%	25%	23.5%	0.68	16.0%	20
2011		78%	22%	20.5%	0.66	13.6%	10
2012		81%	19%	17.5%	0.64	11.2%	10
2013		84%	16%	15.0%	0.62	9.3%	10
2014		86%	14%	13.0%	0.61	7.9%	10
2015		88%	12%	11.0%	0.59	6.5%	10
2016		90%	10%	9.0%	0.57	5.1%	10
2017		92%	8%	7.0%	0.55	3.9%	0
2018		94%	6%	5.0%	0.54	2.7%	0
2019		96%	4%	3.0%	0.52	1.6%	0
2020		98%	2%	1.0%	0.51	0.5%	0
2021		100%	0%	-1.0%	0.49	-0.5%	0
2022		102%	-2%	-3.0%	0.48	-1.4%	0
2023		104%	-4%	-5.0%	0.46	-2.3%	0
2024		106%	-6%	-7.0%	0.45	-3.2%	0
2025		108%	-8%	-9.0%	0.44	-3.9%	0
2026	recovery complete	110%	-10%	-10.0%	0.42	-4.2%	0

Total Discounted effective acre-years lost = 1510

HEA Analysis for the Paddys Run Riparian Corridor

Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2006	primary restoration	65%	65.5%	0.77	1
2007	recovery begins	66%	67.5%	0.74	1
2008		69%	70.5%	0.72	1
2009		72%	73.5%	0.70	1
2010		75%	76.5%	0.68	1
2011		78%	79.5%	0.66	1
2012		81%	82.5%	0.64	1
2013		84%	85.0%	0.62	1
2014		86%	87.0%	0.61	1
2015		88%	89.0%	0.59	1
2016		90%	91.0%	0.57	1
2017		92%	93.0%	0.55	1
2018		94%	95.0%	0.54	1
2019		96%	97.0%	0.52	1
2020		98%	99.0%	0.51	1
2021		100%	101.0%	0.49	0
2022		102%	103.0%	0.48	0
2023		104%	105.0%	0.46	0
2024		106%	107.0%	0.45	0
2025		108%	109.0%	0.44	0
2026	recovery complete	110%	110.0%	0.42	0
2027	to infinity	110%	110.0%	na	18

Total gain in discounted effective acre-years/acre = 29

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 1510

Present discounted gain in effective acre-years/acre (G) = 29

Acres of replacement habitat required for compensation (R, R=L/G) = 53

Total restoration acreage required = 90

Related Information

Total acres of riparian habitat = 98

Acres of revegetation for the primary restoration project = 34

Annual discount rate = 3.00%

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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TABLE 2

HEA Analysis for the Northern Woodlots

Interim Losses due to Northern Woodlot Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annua % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	0
1953	injury begins	99%	1%	1.5%	3.67	5.5%	10
1954		98%	2%	2.5%	3.56	8.9%	10
1955		97%	3%	3.5%	3.46	12.1%	20
1956		96%	4%	4.5%	3.36	15.1%	20
1957		95%	5%	5.0%	3.26	16.3%	30
1958		95%	5%	5.0%	3.17	15.8%	30
1959		95%	5%	5.0%	3.07	15.4%	20
1960		95%	5%	5.0%	2.99	14.9%	20
1961		95%	5%	5.0%	2.90	14.5%	20
1962		95%	5%	5.0%	2.81	14.1%	20
1963		95%	5%	5.0%	2.73	13.7%	20
1964		95%	5%	5.0%	2.65	13.3%	20
1965		95%	5%	5.0%	2.58	12.9%	20
1966		95%	5%	5.0%	2.50	12.5%	20
1967		95%	5%	5.0%	2.43	12.1%	20
1968		95%	5%	5.0%	2.36	11.8%	20
1969		95%	5%	5.0%	2.29	11.4%	20
1970		95%	5%	5.0%	2.22	11.1%	20
1971		95%	5%	5.0%	2.16	10.8%	20
1972	north pine plantation planted	95%	5%	5.0%	2.09	10.5%	20
1973		95%	5%	5.0%	2.03	10.2%	20
1974		95%	5%	5.0%	1.97	9.9%	20
1975		95%	5%	5.0%	1.92	9.6%	20
1976		95%	5%	5.0%	1.86	9.3%	20
1977		95%	5%	5.0%	1.81	9.0%	10
1978		95%	5%	5.0%	1.75	8.8%	10
1979		95%	5%	5.0%	1.70	8.5%	10
1980		95%	5%	5.0%	1.65	8.3%	10
1981		95%	5%	5.0%	1.60	8.0%	10
1982		95%	5%	5.0%	1.56	7.8%	10
1983		95%	5%	5.0%	1.51	7.6%	10
1984		95%	5%	5.0%	1.47	7.3%	10
1985		95%	5%	5.0%	1.43	7.1%	10
1986		95%	5%	4.5%	1.38	6.2%	10
1987	NPP habitat service increase	96%	4%	6.0%	1.34	8.1%	10
1988	ground clearing for borrow area	92%	8%	8.0%	1.30	10.4%	20
1989		92%	8%	8.0%	1.27	10.1%	20
1990		92%	8%	8.0%	1.23	9.8%	20
1991		92%	8%	8.0%	1.19	9.6%	20
1992		92%	8%	8.0%	1.16	9.3%	20
1993		92%	8%	8.0%	1.13	9.0%	10
1994		92%	8%	8.0%	1.09	8.7%	10
1995		92%	8%	8.0%	1.06	8.5%	10
1996		92%	8%	12.5%	1.03	12.9%	20
1997	excavation: clearing of 15 acres	83%	17%	17.0%	1.00	17.0%	30
1998		83%	17%	17.0%	0.97	16.5%	30
1999		83%	17%	17.0%	0.94	16.0%	30
2000		83%	17%	17.0%	0.92	15.6%	30
2001		83%	17%	17.0%	0.89	15.1%	20
2002	primary restoration	83%	17%	17.0%	0.86	14.7%	20
2003	recovery begins	83%	17%	16.5%	0.84	13.8%	20
2004		84%	16%	15.5%	0.81	12.6%	20
2005		85%	15%	14.5%	0.79	11.4%	20
2006		86%	14%	13.5%	0.77	10.3%	20
2007		87%	13%	12.5%	0.74	9.3%	20
2008		88%	12%	11.0%	0.72	7.9%	10
2009		90%	10%	9.0%	0.70	6.3%	10
2010		92%	8%	7.0%	0.68	4.8%	10
2011		94%	6%	5.0%	0.66	3.3%	10
2012		96%	4%	3.0%	0.64	1.9%	0
2013		98%	2%	1.0%	0.62	0.6%	0
2014		100%	0%	-1.0%	0.61	-0.6%	0
2015		102%	-2%	-3.0%	0.59	-1.8%	0
2016		104%	-4%	-5.0%	0.57	-2.9%	0
2017	recovery complete	106%	-6%	-6.0%	0.55	-3.3%	-10

Total Discounted effective acre-years lost = 1030

HEA Analysis for the Northern Woodlots

Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2002	primary restoration	83%	83.8%	0.86	1
2003	recovery begins	83%	84.5%	0.84	1
2004		84%	85.5%	0.81	1
2005		85%	85.5%	0.79	1
2006		86%	86.5%	0.77	1
2007		87%	87.5%	0.74	1
2008		88%	89.0%	0.72	1
2009		90%	91.0%	0.70	1
2010		92%	93.0%	0.68	1
2011		94%	95.0%	0.66	1
2012		96%	97.0%	0.64	1
2013		98%	99.0%	0.62	1
2014		100%	101.0%	0.61	1
2015		102%	103.0%	0.59	1
2016		104%	105.0%	0.57	1
2017	recovery complete	106%	106.0%	0.55	1
2018	to infinity	106%	106.0%	na	23

Total gain in discounted effective acre-years/acre = 33

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 1030

Present discounted gain in effective acre-years/acre (G) = 33

Acres of replacement habitat required for compensation (R, R=L/G) = 31

Total restoration acreage required = 50

Related Information

Total acres of north woodlot habitat = 162

Acres of revegetation for the primary restoration project = 15

Annual discount rate = 3.00%

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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TABLE 3

HEA Analysis for the Southern Pines and Waste Units

Interim Losses due to Southern Pines and Waste Units Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annua % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	1.0%	3.78	3.8%	0
1953	injury begins	98%	2%	3.0%	3.67	11.0%	10
1954		96%	4%	5.0%	3.56	17.8%	10
1955		94%	6%	7.0%	3.46	24.2%	20
1956		92%	8%	9.0%	3.36	30.2%	20
1957		90%	10%	11.0%	3.26	35.9%	20
1958		88%	12%	13.0%	3.17	41.2%	30
1959		86%	14%	14.5%	3.07	44.6%	30
1960		85%	15%	15.0%	2.99	44.8%	30
1961		85%	15%	15.0%	2.90	43.5%	30
1962		85%	15%	15.0%	2.81	42.2%	30
1963		85%	15%	15.0%	2.73	41.0%	30
1964		85%	15%	15.0%	2.65	39.8%	30
1965	cessation of disposal activities	85%	15%	19.0%	2.58	48.9%	30
1966	active flyash pile initiated	77%	23%	23.0%	2.50	57.5%	40
1967		77%	23%	23.0%	2.43	55.8%	40
1968		77%	23%	23.0%	2.36	54.2%	40
1969		77%	23%	22.5%	2.29	51.5%	30
1970	successional growth in S.W.U.	78%	22%	21.5%	2.22	47.8%	30
1971		79%	21%	20.5%	2.16	44.2%	30
1972	south pine plantation planted	80%	20%	19.5%	2.09	40.8%	30
1973		81%	19%	18.5%	2.03	37.6%	20
1974		82%	18%	17.5%	1.97	34.5%	20
1975		83%	17%	16.5%	1.92	31.6%	20
1976		84%	16%	15.5%	1.86	28.8%	20
1977		85%	15%	14.5%	1.81	26.2%	20
1978		86%	14%	13.5%	1.75	23.7%	20
1979		87%	13%	13.0%	1.70	22.1%	10
1980		87%	13%	13.0%	1.65	21.5%	10
1981		87%	13%	13.0%	1.60	20.9%	10
1982		87%	13%	13.0%	1.56	20.3%	10
1983		87%	13%	13.0%	1.51	19.7%	10
1984		87%	13%	13.0%	1.47	19.1%	10
1985		87%	13%	13.0%	1.43	18.5%	10
1986		87%	13%	12.0%	1.38	16.6%	10
1987	SPP habitat increase	89%	11%	11.0%	1.34	14.8%	10
1988		89%	11%	11.0%	1.30	14.4%	10
1989		89%	11%	11.0%	1.27	13.9%	10
1990		89%	11%	11.0%	1.23	13.5%	10
1991		89%	11%	12.0%	1.19	14.3%	10
1992	clearing for Met. tower	87%	13%	13.0%	1.16	15.1%	10
1993		87%	13%	13.0%	1.13	14.6%	10
1994		87%	13%	14.0%	1.09	15.3%	10
1995	clearing for Bldg. 45 access road	85%	15%	15.0%	1.06	15.9%	10
1996		85%	15%	25.5%	1.03	26.3%	20
1997	excavation, instal. of haul road	64%	36%	36.0%	1.00	36.0%	20
1998		64%	36%	36.0%	0.97	35.0%	20
1999		64%	36%	36.0%	0.94	33.9%	20
2000		64%	36%	36.0%	0.92	32.9%	20
2001	primary restoration	64%	36%	35.0%	0.89	31.1%	20
2002	recovery begins	66%	34%	33.0%	0.86	28.5%	20
2003		68%	32%	31.0%	0.84	26.0%	20
2004		70%	30%	29.0%	0.81	23.6%	20
2005		72%	28%	27.0%	0.79	21.3%	10
2006		74%	26%	25.0%	0.77	19.2%	10
2007		76%	24%	23.0%	0.74	17.1%	10
2008		78%	22%	21.0%	0.72	15.2%	10
2009		80%	20%	19.5%	0.70	13.7%	10
2010		81%	19%	18.5%	0.68	12.6%	10
2011		82%	18%	17.5%	0.66	11.6%	10
2012		83%	17%	16.5%	0.64	10.6%	10
2013		84%	16%	15.5%	0.62	9.7%	10
2014		85%	15%	13.5%	0.61	8.2%	10
2015		88%	12%	11.0%	0.59	6.5%	0
2016		90%	10%	9.0%	0.57	5.1%	0
2017		92%	8%	7.0%	0.55	3.9%	0
2018		94%	6%	5.0%	0.54	2.7%	0
2019		96%	4%	3.0%	0.52	1.6%	0
2020		98%	2%	1.0%	0.51	0.5%	0
2021	recovery complete	100%	0%	0.0%	0.49	0.0%	0

Total Discounted effective acre-years lost = 1130

HEA Analysis for the Southern Pines and Waste Units

Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2001	primary restoration	73%	73.0%	0.89	1
2002	recovery begins	73%	73.5%	0.86	1
2003		74%	74.5%	0.84	1
2004		75%	75.5%	0.81	1
2005		76%	76.5%	0.79	1
2006		77%	77.5%	0.77	1
2007		78%	78.5%	0.74	1
2008		79%	79.5%	0.72	1
2009		80%	80.5%	0.70	1
2010		81%	81.5%	0.68	1
2011		82%	82.5%	0.66	1
2012		83%	83.5%	0.64	1
2013		84%	84.5%	0.62	1
2014		85%	86.5%	0.61	1
2015		88%	89.0%	0.59	1
2016		90%	91.0%	0.57	1
2017		92%	93.0%	0.55	1
2018		94%	95.0%	0.54	1
2019		96%	97.0%	0.52	1
2020		98%	99.0%	0.51	1
2021	recovery complete	100%	100.0%	0.49	0
2022	to infinity	100%	100.0%	na	19

Total gain in discounted effective acre-years/acre = 31

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 1130

Present discounted gain in effective acre-years/acre (G) = 31

Acres of replacement habitat required for compensation (R, R=L/G) 37

Total restoration acreage required = 60

Related Information

Total acres of southern pines and waste units habitat = 66

Acres of revegetation for the primary restoration project = 22

Annual discount rate = 3.00%

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

0001179

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TABLE 4

HEA Analysis for the Grasslands

Interim Losses due to Grasslands Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annua % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	0
1953	injury begins	99%	1%	1.5%	3.67	5.5%	10
1954		98%	2%	2.0%	3.56	7.1%	20
1955		98%	2%	2.0%	3.46	6.9%	20
1956		98%	2%	2.0%	3.36	6.7%	20
1957		98%	2%	2.0%	3.26	6.5%	20
1958		98%	2%	2.0%	3.17	6.3%	10
1959		98%	2%	3.0%	3.07	9.2%	20
1960	use of trap range initiated	96%	4%	4.0%	2.99	11.9%	30
1961		96%	4%	4.0%	2.90	11.6%	30
1962		96%	4%	4.0%	2.81	11.3%	30
1963		96%	4%	4.0%	2.73	10.9%	30
1964		96%	4%	4.0%	2.65	10.6%	20
1965		96%	4%	4.0%	2.58	10.3%	20
1966		96%	4%	4.0%	2.50	10.0%	20
1967		96%	4%	4.0%	2.43	9.7%	20
1968		96%	4%	4.0%	2.36	9.4%	20
1969		96%	4%	4.0%	2.29	9.2%	20
1970		96%	4%	4.0%	2.22	8.9%	20
1971		96%	4%	4.0%	2.16	8.6%	20
1972		96%	4%	4.0%	2.09	8.4%	20
1973		96%	4%	4.0%	2.03	8.1%	20
1974		96%	4%	4.0%	1.97	7.9%	20
1975		96%	4%	4.0%	1.92	7.7%	20
1976		96%	4%	4.0%	1.86	7.4%	20
1977		96%	4%	4.0%	1.81	7.2%	20
1978		96%	4%	4.0%	1.75	7.0%	20
1979		96%	4%	4.0%	1.70	6.8%	20
1980		96%	4%	4.0%	1.65	6.6%	20
1981		96%	4%	4.0%	1.60	6.4%	20
1982		96%	4%	4.0%	1.56	6.2%	10
1983		96%	4%	4.0%	1.51	6.1%	10
1984		96%	4%	4.0%	1.47	5.9%	10
1985		96%	4%	4.0%	1.43	5.7%	10
1986		96%	4%	4.0%	1.38	5.5%	10
1987		96%	4%	4.0%	1.34	5.4%	10
1988		96%	4%	4.0%	1.30	5.2%	10
1989		96%	4%	4.0%	1.27	5.1%	10
1990		96%	4%	4.0%	1.23	4.9%	10
1991		96%	4%	4.5%	1.19	5.4%	10
1992	Removal Action No. 14	95%	5%	4.5%	1.16	5.2%	10
1993		96%	4%	4.0%	1.13	4.5%	10
1994		96%	4%	4.0%	1.09	4.4%	10
1995		96%	4%	20.0%	1.06	21.2%	50
1996	A1P1 excavation	64%	36%	36.0%	1.03	37.1%	90
1997		64%	36%	53.0%	1.00	53.0%	120
1998	A1P2 excavation	30%	70%	70.5%	0.97	68.4%	160
1999		29%	71%	71.5%	0.94	67.4%	160
2000		28%	72%	72.5%	0.92	66.3%	160
2001		27%	73%	79.5%	0.89	70.6%	170
2002	A2P2 excavation	14%	86%	86.5%	0.86	74.6%	180
2003		13%	87%	87.0%	0.84	72.9%	170
2004		13%	87%	87.0%	0.81	70.7%	170
2005	primary restoration	13%	87%	83.5%	0.79	65.9%	150
2006	recovery begins	20%	80%	65.0%	0.77	49.8%	120
2007		50%	50%	37.5%	0.74	27.9%	70
2008		75%	25%	12.5%	0.72	9.0%	20
2009		100%	0%	-5.0%	0.70	-3.5%	-10
2010	recovery complete	110%	-10%	-10.0%	0.68	-6.8%	-20

Total Discounted effective acre-years lost = 2490

HEA Analysis for the Grasslands

Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2005	primary restoration	12%	16.0%	0.79	0
2006	recovery begins	20%	35.0%	0.77	0
2007		50%	62.5%	0.74	0
2008		75%	87.5%	0.72	1
2009		100%	105.0%	0.70	1
2010	recovery complete	110%	110.0%	0.68	1
2011	to infinity	110%	110.0%	na	29

Total gain in discounted effective acre-years/acre = 32

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 2490

Present discounted gain in effective acre-years/acre (G) = 32

Acres of replacement habitat required for compensation (R, R=L/G) 78

Total restoration acreage required = 280

Related Information

Total acres of grassland habitat = 235

Acres of revegetation for the primary restoration project = 204

Annual discount rate = 3.00%

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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TABLE 5

HEA Analysis for the Waste Storage/Production Area

Interim Losses due to Production/Waste Storage Area Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annua % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	0
1953	injury begins	99%	1%	1.5%	3.67	5.5%	10
1954		98%	2%	2.5%	3.56	8.9%	20
1955		97%	3%	3.5%	3.46	12.1%	20
1956		96%	4%	4.5%	3.36	15.1%	30
1957		95%	5%	5.0%	3.26	16.3%	30
1958		95%	5%	5.0%	3.17	15.8%	30
1959		95%	5%	5.0%	3.07	15.4%	30
1960		95%	5%	5.0%	2.99	14.9%	30
1961		95%	5%	5.0%	2.90	14.5%	30
1962		95%	5%	5.0%	2.81	14.1%	20
1963		95%	5%	5.0%	2.73	13.7%	20
1964		95%	5%	5.0%	2.65	13.3%	20
1965		95%	5%	5.0%	2.58	12.9%	20
1966		95%	5%	5.0%	2.50	12.5%	20
1967		95%	5%	5.0%	2.43	12.1%	20
1968		95%	5%	5.0%	2.36	11.8%	20
1969		95%	5%	5.0%	2.29	11.4%	20
1970		95%	5%	5.0%	2.22	11.1%	20
1971		95%	5%	5.0%	2.16	10.8%	20
1972		95%	5%	5.0%	2.09	10.5%	20
1973		95%	5%	5.0%	2.03	10.2%	20
1974		95%	5%	5.0%	1.97	9.9%	20
1975		95%	5%	5.0%	1.92	9.6%	20
1976		95%	5%	5.0%	1.86	9.3%	20
1977		95%	5%	5.0%	1.81	9.0%	20
1978		95%	5%	5.0%	1.75	8.8%	20
1979		95%	5%	5.0%	1.70	8.5%	10
1980		95%	5%	5.0%	1.65	8.3%	10
1981		95%	5%	5.0%	1.60	8.0%	10
1982		95%	5%	5.0%	1.56	7.8%	10
1983		95%	5%	5.0%	1.51	7.6%	10
1984		95%	5%	5.0%	1.47	7.3%	10
1985		95%	5%	5.0%	1.43	7.1%	10
1986		95%	5%	5.0%	1.38	6.9%	10
1987		95%	5%	5.0%	1.34	6.7%	10
1988		95%	5%	5.0%	1.30	6.5%	10
1989		95%	5%	5.0%	1.27	6.3%	10
1990		95%	5%	5.0%	1.23	6.1%	10
1991		95%	5%	5.0%	1.19	6.0%	10
1992		95%	5%	5.0%	1.16	5.8%	10
1993		95%	5%	5.0%	1.13	5.6%	10
1994		95%	5%	5.0%	1.09	5.5%	10
1995		95%	5%	5.0%	1.06	5.3%	10
1996		95%	5%	5.0%	1.03	5.2%	10
1997		95%	5%	5.0%	1.00	5.0%	10
1998		95%	5%	7.5%	0.97	7.3%	10
1999	excavation	90%	10%	10.5%	0.94	9.9%	20
2000		89%	11%	11.0%	0.92	10.1%	20
2001		89%	11%	11.0%	0.89	9.8%	20
2002		89%	11%	11.0%	0.86	9.5%	20
2003		89%	11%	11.0%	0.84	9.2%	20
2004		89%	11%	11.0%	0.81	8.9%	20
2005	primary restoration	89%	11%	11.0%	0.79	8.7%	20
2006	recovery begins	89%	11%	10.5%	0.77	8.0%	10
2007		90%	10%	10.0%	0.74	7.4%	10
2008		90%	10%	10.0%	0.72	7.2%	10
2009		90%	10%	10.0%	0.70	7.0%	10
2010		90%	10%	10.0%	0.68	6.8%	10
2011		90%	10%	7.5%	0.66	5.0%	10
2012		95%	5%	5.0%	0.64	3.2%	10
2013		95%	5%	5.0%	0.62	3.1%	10
2014		95%	5%	5.0%	0.61	3.0%	10
2015		95%	5%	5.0%	0.59	2.9%	10
2016		95%	5%	2.5%	0.57	1.4%	0
2017		100%	0%	-2.5%	0.55	-1.4%	0
2018		105%	-5%	-7.5%	0.54	-4.0%	-10
2019		110%	-10%	-12.5%	0.52	-6.5%	-10
2020	recovery complete	115%	-15%	-15.0%	0.51	-7.6%	-10

Total Discounted effective acre-years lost = 980

HEA Analysis for the Waste Storage/Production Area

Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2005	primary restoration	89%	89.0%	0.79	1
2006	recovery begins	89%	89.5%	0.77	1
2007		90%	90.0%	0.74	1
2008		90%	90.0%	0.72	1
2009		90%	90.0%	0.70	1
2010		90%	90.0%	0.68	1
2011		90%	92.5%	0.66	1
2012		95%	95.0%	0.64	1
2013		95%	95.0%	0.62	1
2014		95%	95.0%	0.61	1
2015		95%	95.0%	0.59	1
2016		95%	97.5%	0.57	1
2017		100%	102.5%	0.55	1
2018		105%	107.5%	0.54	1
2019		110%	112.5%	0.52	1
2020	recovery complete	115%	115.0%	0.51	1
2021	to infinity	115%	100.0%	na	22

Total gain in discounted effective acre-years/acre = 32

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 980

Present discounted gain in effective acre-years/acre (G) = 32

Acres of replacement habitat required for compensation (R, R=L/G) = 30

Total restoration acreage required = 50

Related Information

Total acres of production area/waste storage area habitat = 173

Acres of revegetation for the primary restoration project = 15

Annual discount rate = 3.00%

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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TABLE 6
HEA Analysis for the Great Miami River
Interim loss and resulting restoration acreage required

Year	Project Status	% Service Level	% Service Loss	vg. Annua % Loss	Discount Factor	vg. Servic Loss/Acre	Effective Acres Lost
1952	kg U released from site: 11	100%	0%	0.0%	3.78	0.0%	0
1953	106	100%	0%	0.0%	3.67	0.0%	0
1954	347	100%	0%	0.5%	3.56	1.8%	0
1955	657	99%	1%	1.0%	3.46	3.5%	0
1956	1485	99%	1%	2.0%	3.36	6.7%	0
1957	2595	97%	3%	3.5%	3.26	11.4%	0
1958	3641	96%	4%	5.5%	3.17	17.4%	1
1959	6388	93%	7%	5.5%	3.07	16.9%	1
1960	4445	96%	4%	4.5%	2.99	13.4%	0
1961	5386	95%	5%	4.5%	2.90	13.0%	0
1962	3543	96%	4%	4.0%	2.81	11.3%	0
1963	4466	96%	4%	7.0%	2.73	19.1%	1
1964	10304	90%	10%	7.0%	2.65	18.6%	1
1965	3630	96%	4%	4.0%	2.58	10.3%	0
1966	3640	96%	4%	3.0%	2.50	7.5%	0
1967	2305	98%	2%	2.0%	2.43	4.9%	0
1968	1855	98%	2%	2.0%	2.36	4.7%	0
1969	2290	98%	2%	2.0%	2.29	4.6%	0
1970	1914	98%	2%	2.0%	2.22	4.4%	0
1971	1637	98%	2%	1.5%	2.16	3.2%	0
1972	1140	99%	1%	1.0%	2.09	2.1%	0
1973	1126	99%	1%	1.0%	2.03	2.0%	0
1974	1066	99%	1%	1.5%	1.97	3.0%	0
1975	1852	98%	2%	1.5%	1.92	2.9%	0
1976	875	99%	1%	1.0%	1.86	1.9%	0
1977	179	99%	1%	1.0%	1.81	1.8%	0
1978	965	99%	1%	1.0%	1.75	1.8%	0
1979	880	99%	1%	1.0%	1.70	1.7%	0
1980	1175	99%	1%	1.0%	1.65	1.7%	0
1981	685	99%	1%	1.0%	1.60	1.6%	0
1982	576	99%	1%	1.0%	1.56	1.6%	0
1983	755	99%	1%	1.0%	1.51	1.5%	0
1984	564	99%	1%	1.0%	1.47	1.5%	0
1985	1054	99%	1%	1.0%	1.43	1.4%	0
1986		99%	1%	1.0%	1.38	1.4%	0
1987		99%	1%	1.0%	1.34	1.3%	0
1988	SER results: 858	99%	1%	1.0%	1.30	1.3%	0
1989	841	99%	1%	1.0%	1.27	1.3%	0
1990	786	99%	1%	1.0%	1.23	1.2%	0
1991	810	99%	1%	1.0%	1.19	1.2%	0
1992	595	99%	1%	5.0%	1.16	5.8%	0
1993	583, outfall line riprap upgrad	91%	9%	5.0%	1.13	5.6%	0
1994	460	99%	1%	1.0%	1.09	1.1%	0
1995	310	99%	1%	1.0%	1.06	1.1%	0
1996	297	99%	1%	1.0%	1.03	1.0%	0
1997	391	99%	1%	1.0%	1.00	1.0%	0
1998		99%	1%	1.0%	0.97	1.0%	0
1999		99%	1%	1.0%	0.94	0.9%	0
2000		99%	1%	1.0%	0.92	0.9%	0
2001		99%	1%	1.0%	0.89	0.9%	0
2002		99%	1%	1.0%	0.86	0.9%	0
2003		99%	1%	1.0%	0.84	0.8%	0
2004		99%	1%	0.7%	0.81	0.5%	0
2005		99%	1%	0.5%	0.79	0.4%	0
2006	remedial action complete	100%	0%	0.0%	0.77	0.0%	0

Total Discounted effective acre-years lost and restoration acreage required = 10

Effective acres lost are based on 3.22 total acres, from an estimated 2.97 acres of stream habitat and 0.25 acres of riparian habitat by the outfall line.

Percent service level is estimated at a 1% reduction for every 1,000 kg uranium released into the Great Miami River from the FEMP.

1993 percent service level is estimated at 91% based on an 8% reduction due to the contaminated riprap BMP (0.25/3.22) and the estimated 550 kg of uranium relaeased int the Great Miami River.

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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Exhibit A (8/20/38)

Exhibit B (1/9/51)

Exhibit C (5/28/53)

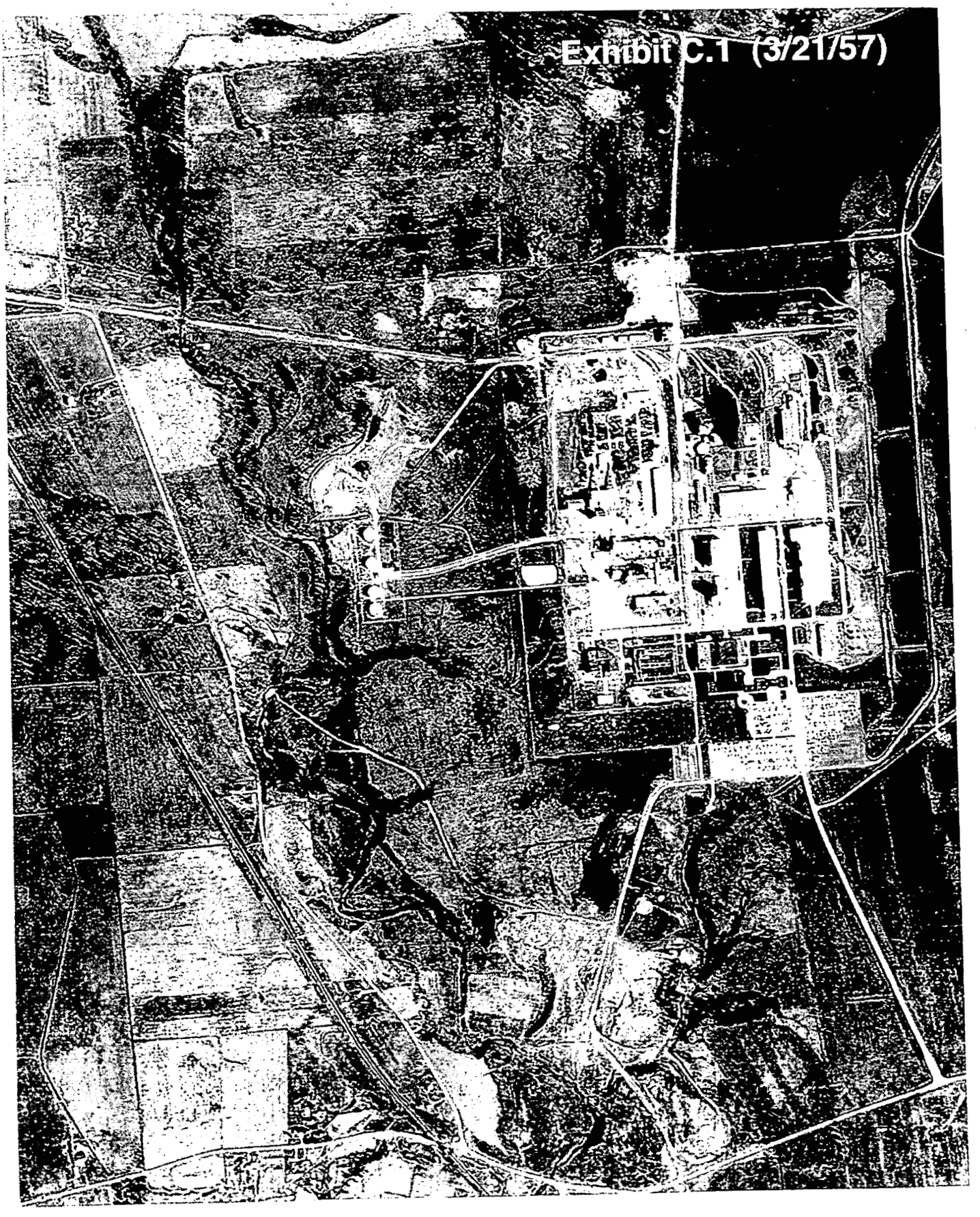


Exhibit C.1 (3/21/57)

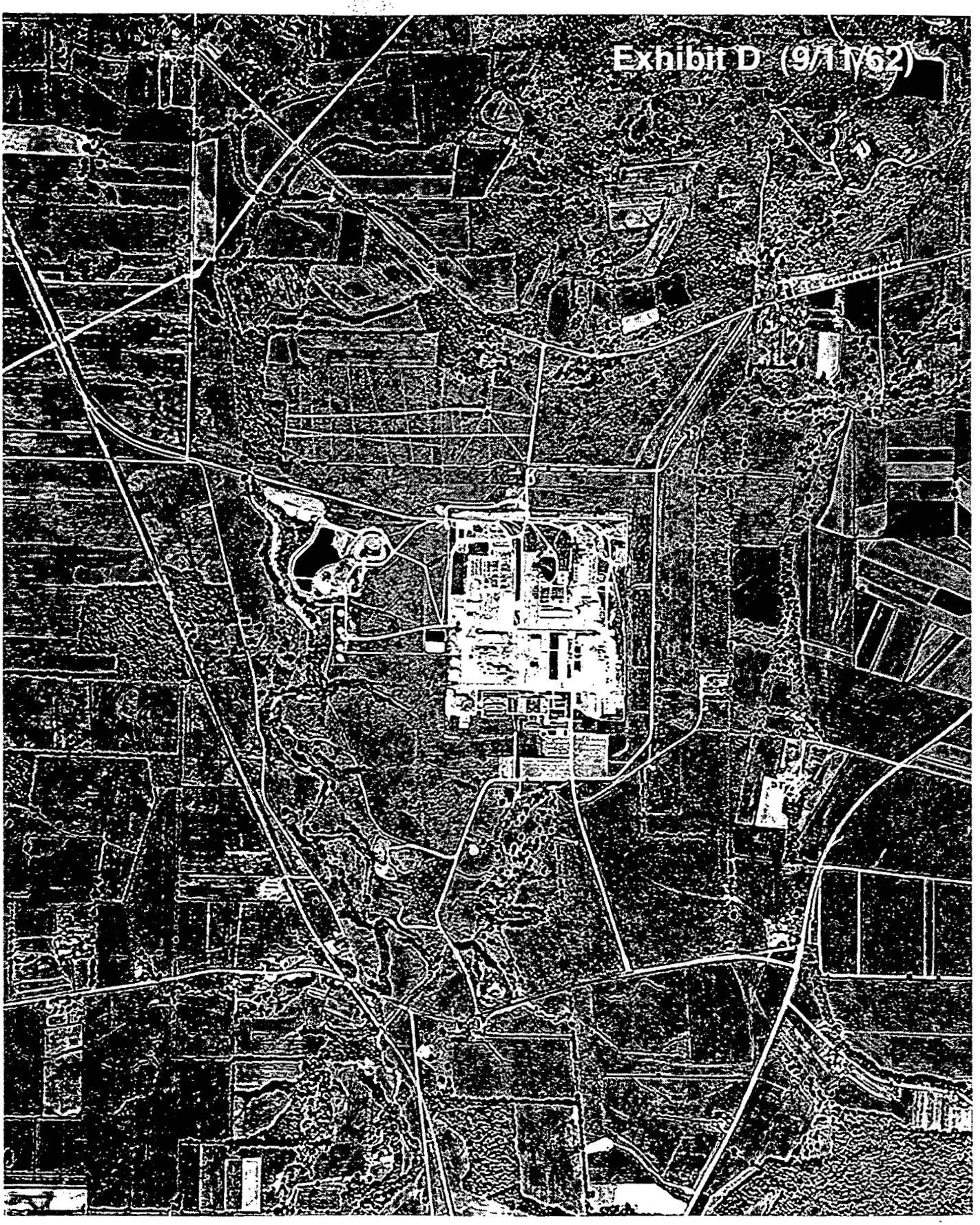


Exhibit D (9/11/62)

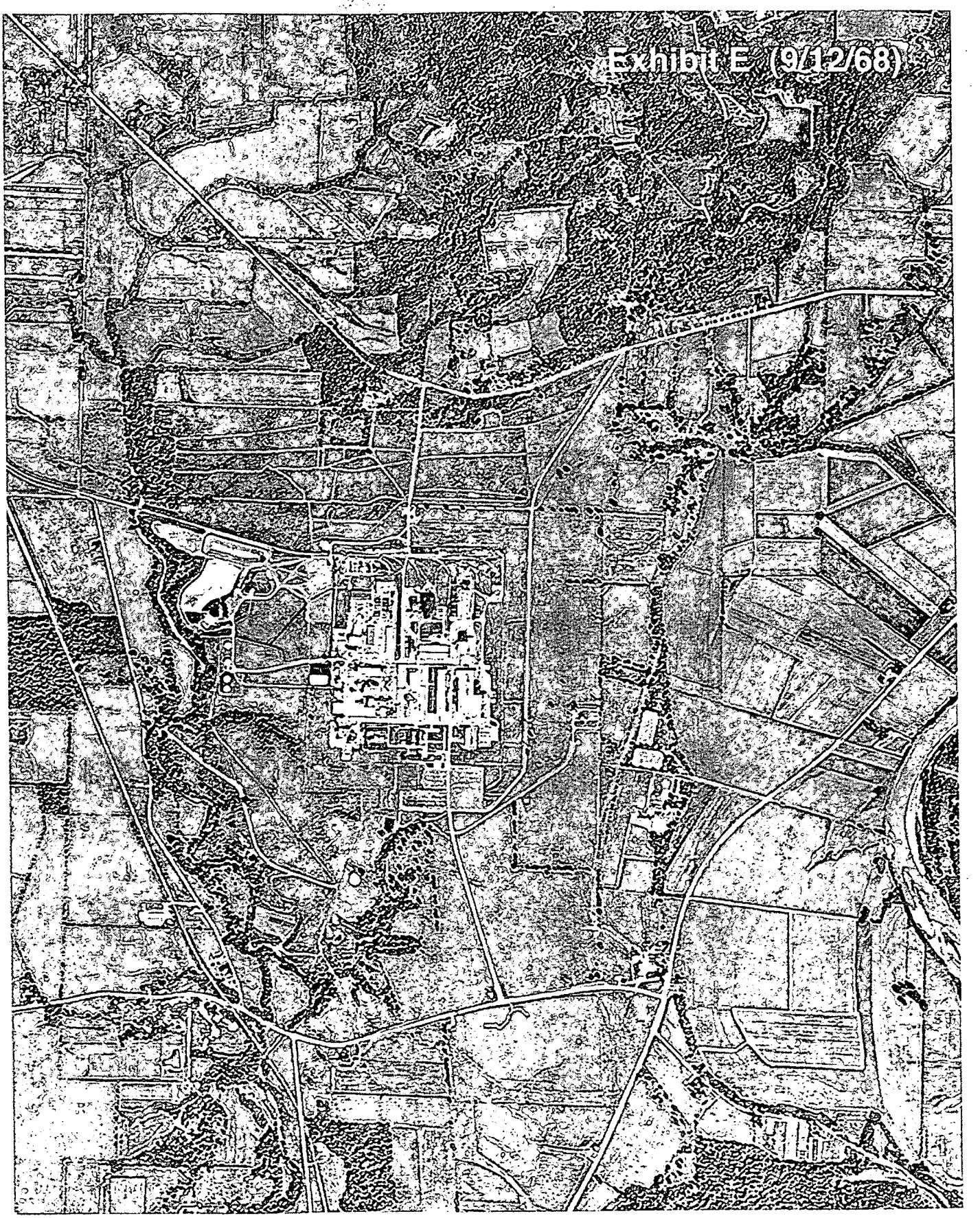


Exhibit E (9/12/68)

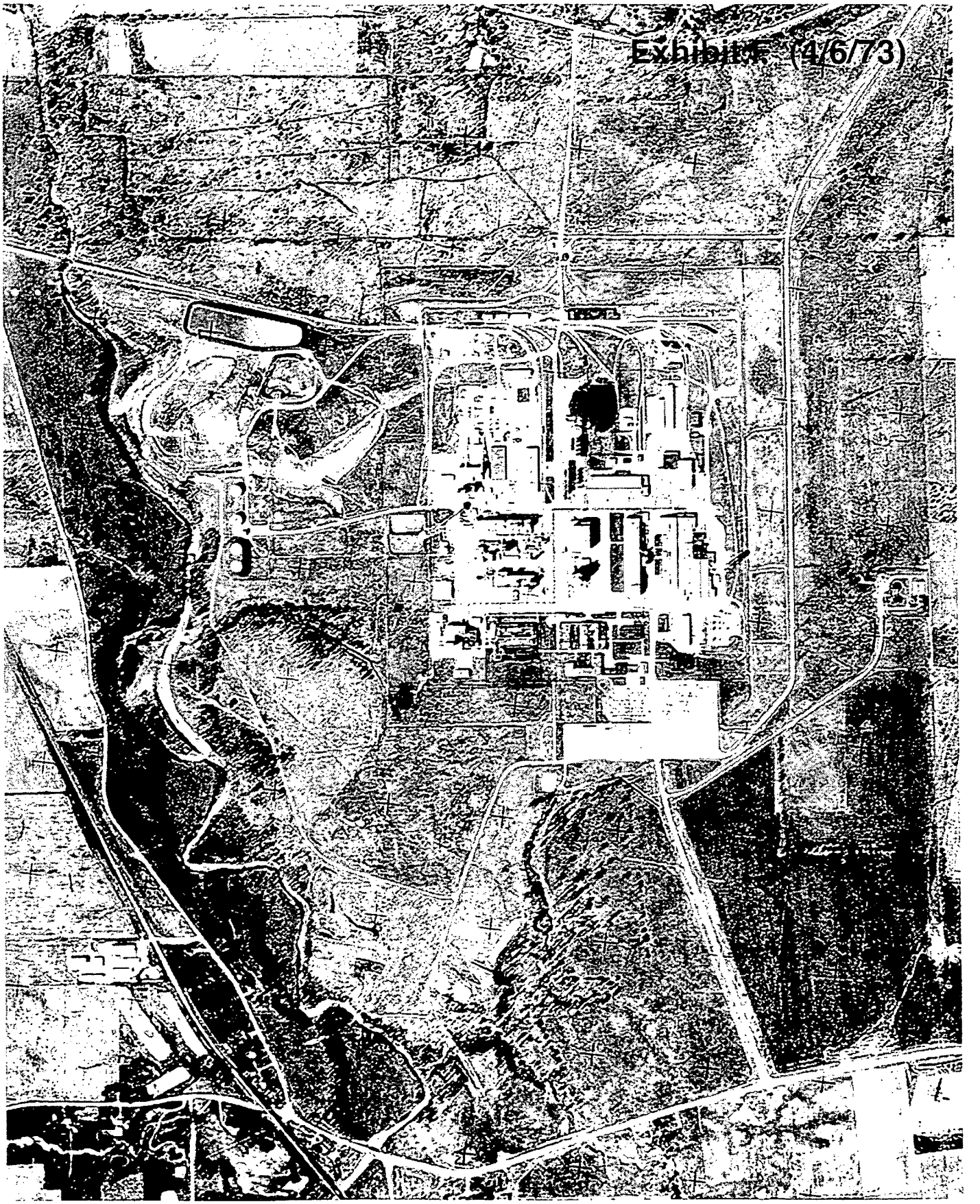


Exhibit F (4/6/73)

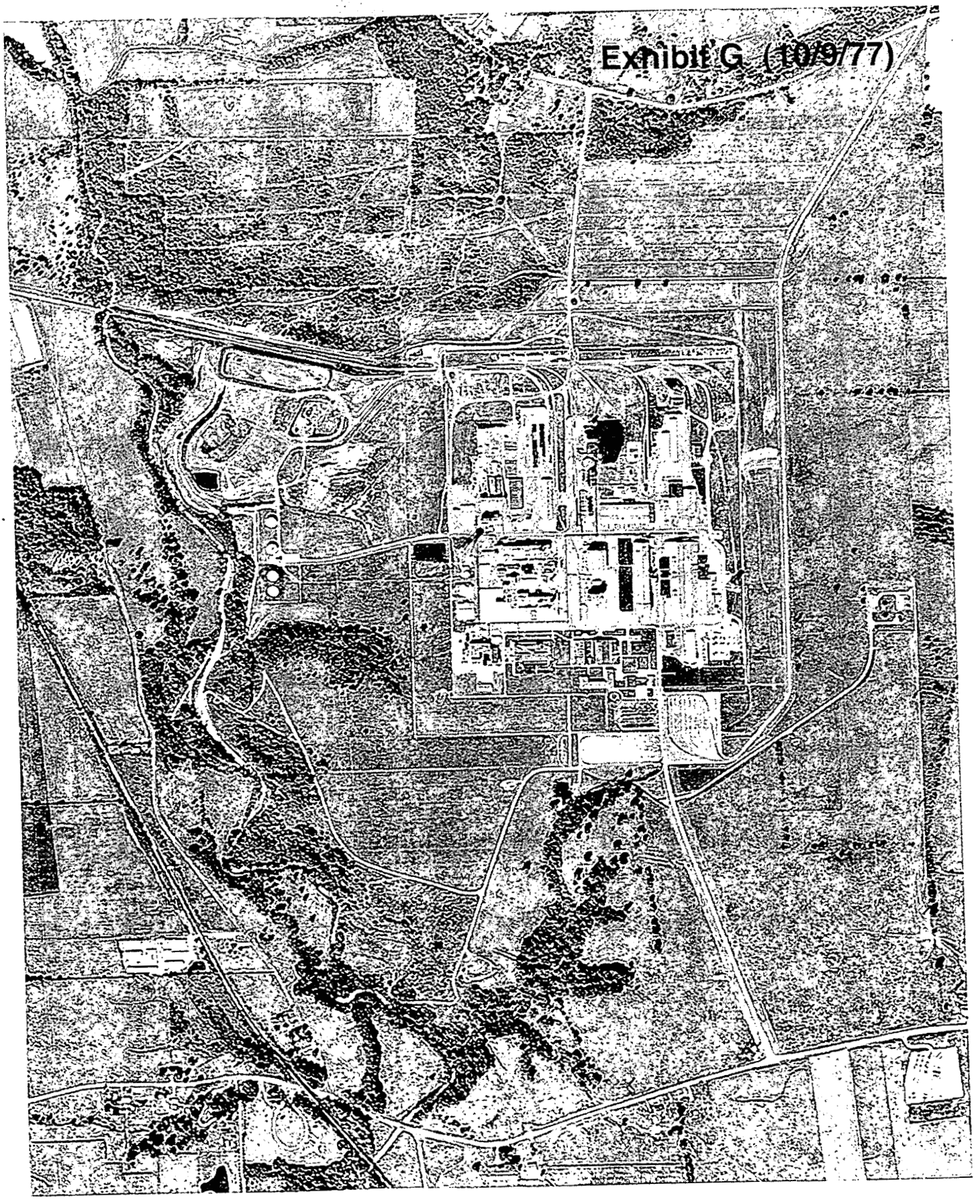


Exhibit G (10/9/77)

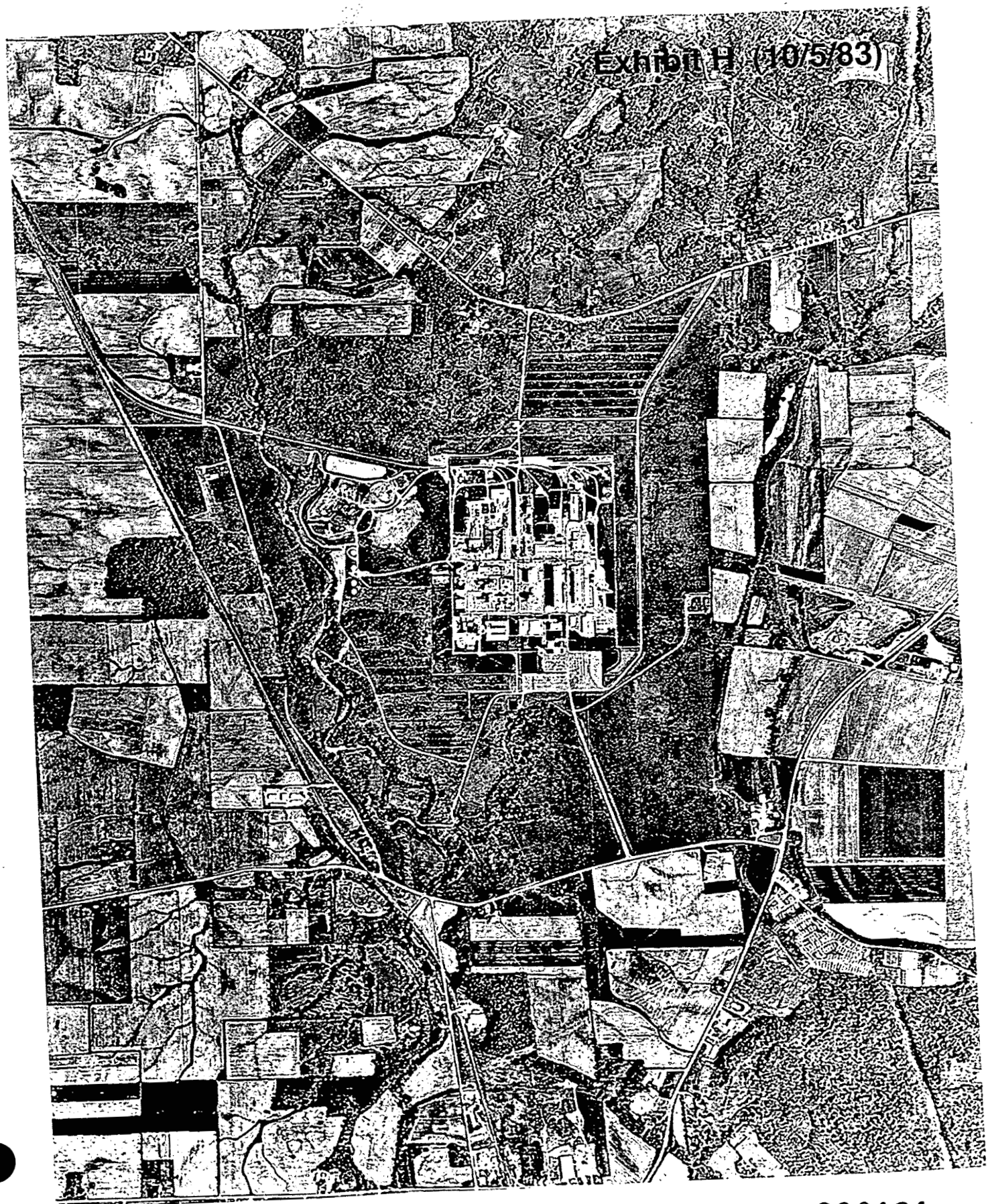
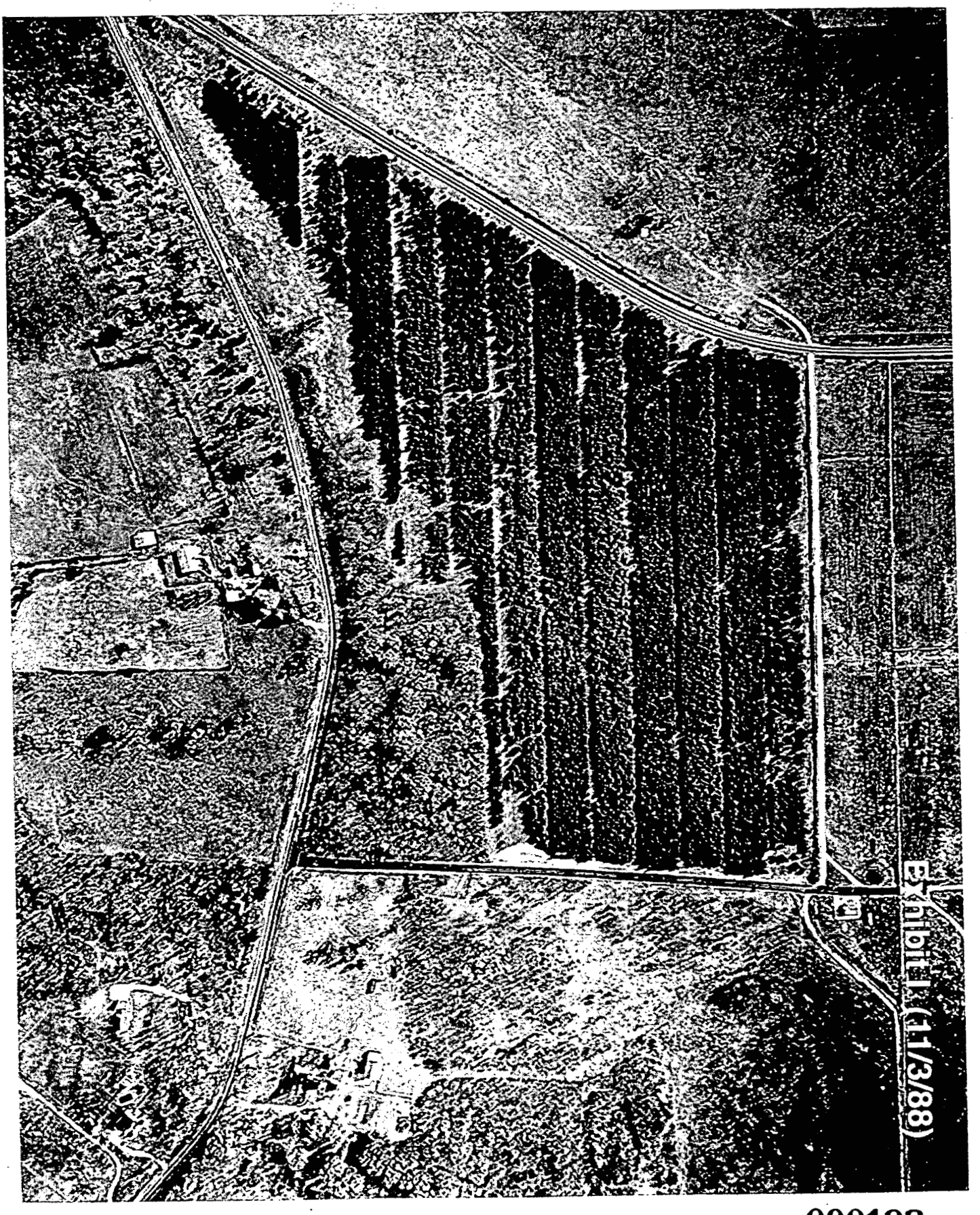


Exhibit H (10/5/83)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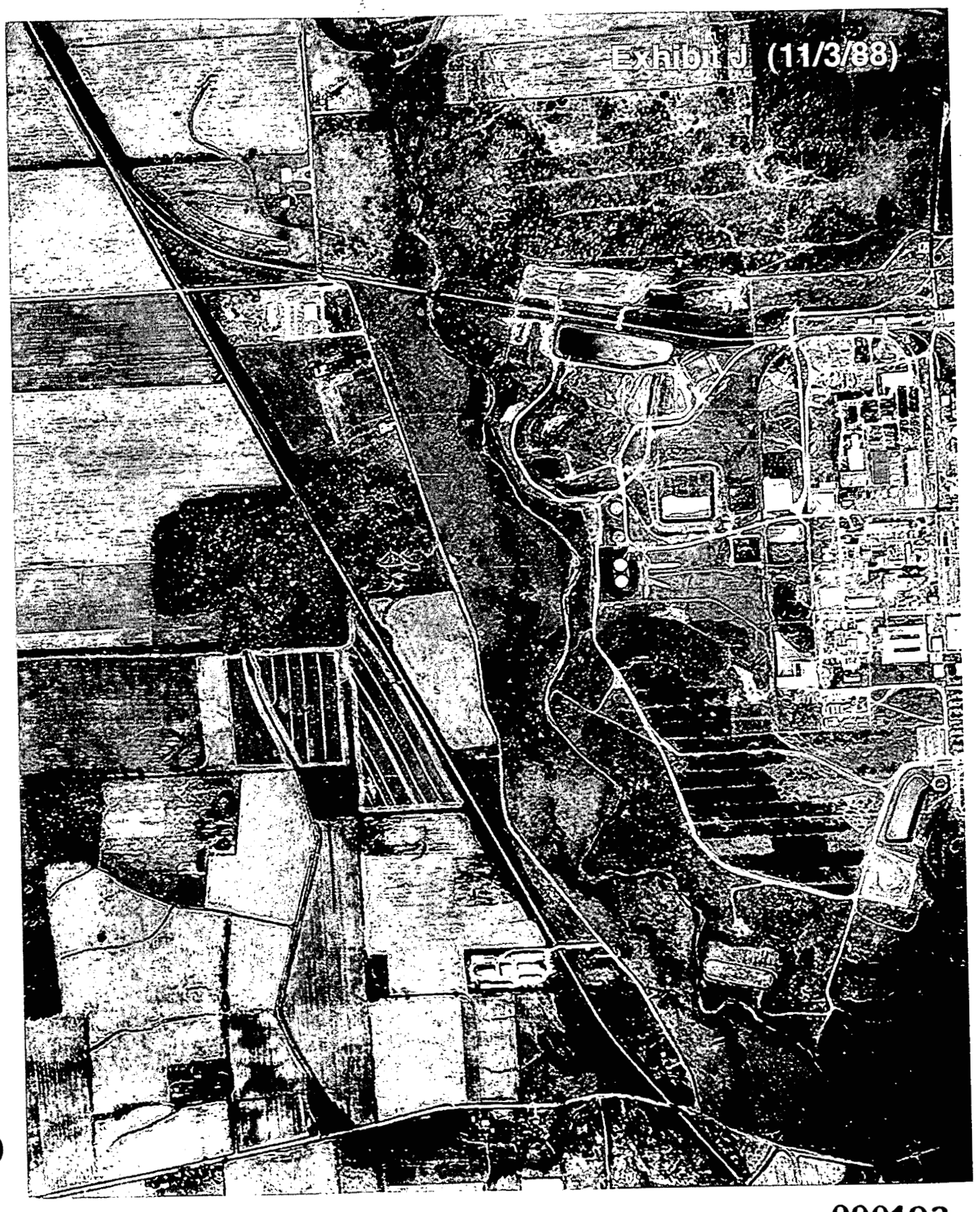
Exhibit J (11/3/88)

Appendix C

APPENDIX C

WATER AVAILABILITY STUDY

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WATER AVAILABILITY STUDY

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

PREPARED BY

BROWN & ROOT ENVIRONMENTAL

661 Andersen Drive

Pittsburgh, PA 15220

JULY 1, 1997

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EXECUTIVE SUMMARY

This study is intended to provide quantitative modeling results regarding the surface water routing for the four ponds under post-remediation conditions at Fernald Environmental Management Project (FEMP) site. The modeling results support the goal for natural resources restoration in the context of on-property open water/wetland habitats. As part of the site-wide restoration plan, four on-property open water areas are to be established in the former production area and its vicinity as a result of soil excavation activities. The integration of the ponds will provide open water areas for surface water habitats, and will provide sediment detention from activities such as remediation, construction, and excavation.

To ensure the engineering control and suitability of the ponds, storage routing modeling must be performed to assist understanding of the relationship of storage-stage-discharge of ponds. This engineering analysis is required to be analyzed under both normal conditions and extreme conditions. The normal conditions can be represented by considering the monthly average meteorological record, while the extreme conditions can be simulated by a storm event. The peak inflow rates generated by a storm event were modeled by using the TR55 method that is suitable for a small watershed. The characteristic storm typically considered in the TR55 method is a storm with 25-year return period and 24-hour duration.

Prior to the formulation of the routing model, the subbasin areas and drainage areas were first established. The storage routing model was then implemented secondly based on the conservation of mass, assuming that the rate of change of storage equals to the difference between the inflow and outflow. Water input to the ponds are rainfall and storm runoff. Outflow from the ponds are evaporation, infiltration loss through pond liner materials, and overflow from the weirs. The simulation time used was four years for normal conditions to reach an equilibrium state. In order for the model to be conservative for the extreme conditions, the initial storage of the ponds has incorporated the maximum storage volume predicted under normal conditions.

The routing modeling results indicated that the maximum and average depths of the ponds are constantly below the top edge of the ponds under both normal and extreme conditions. These results are based on allowing overflow when the pool level exceeds the designed overflow bottom elevation. Normally, the pool level in Pond 1 is the highest since it has a larger drainage area. Excess runoff from Pond 1 is allowed to be discharged to the Storm Sewer Outfall Ditch (SSOD). Excess water is also allowed to be drained from Pond 2 to Pond 4 through an open channel. The final outfall point for stormwater runoff routing through

Pond 1, Pond 3, and Pond 4 are the SSOD, which drains to Paddy's Run and eventually to the Great Miami River.

The maximum water depths estimated for the four ponds, when the peak inflow rates appear under the extreme conditions are approximately 19.1, 17.7, 14.1, and 25.5 feet respectively. At the same time, the average water depths estimated for the four ponds are 8.4, 10.7, 4.2, and 14.9 feet respectively. The corresponding maximum water surface acreage computed for the four ponds are 13.34, 14.0, 12.9, and 4.12 acres respectively. Also, the average water surface acreage computed for the four ponds are 13.03, 13.85, 12.0, and 4.02 acres respectively.

Based on the modeling results, it is suggested that an underground pipe be connected between Pond 1 and Pond 2. This connection will greatly improve the regulation of water storage between Pond 1 and Pond 2. This is because Pond 2 has a much larger capacity with approximately seven feet of freeboard under all conditions considered.

1.0 INTRODUCTION

This study is intended is to provide quantitative modeling results concerning the surface water routing for the four ponds under post-remediation conditions at Fernald Environmental Management Project (FEMP) site. The modeling results support the goal for natural resources restoration in the context of on-property open water/wetland habitats. These ponds are established as a result of soil remediation activities in the former production area and its vicinities within the FEMP site. The hydrologic conditions of ponds were modeled under normal climate conditions as well as storm event conditions. To achieve the goal of restoring natural resources, a comprehensive site-wide restoration plan is in the process of being implemented when excavation of contaminated soil at FEMP site is completed. As part of the restoration plan, four on-property ponds are to be established in the southern portion of the former production area. The integration of ponds will provide open water areas for surface water habitats, and will provide sediment detention from activities such as remediation, construction, and excavation.

1.1 SITE BACKGROUND

The U.S. Department of Energy's (DOE) FEMP site occupies 1,050 acres in rural southwestern Ohio, approximately 18 miles northwest of downtown Cincinnati, Ohio. The DOE's Fernald facility produced high-purity uranium metal products in support of the U.S. defense program from 1953 to 1989. Production was ceased in 1989, after the United States Environmental Protection Agency (USEPA) placed the sites on the National Priority List for remediation. Subsequently, the remedial efforts were initiated under the Comprehensive Environmental Response Compensation, and Liabilities Act (CERCLA).

The FEMP site is bounded by Paddys Run on the west, Willey Road to the south, and route 126 to the north. It is located at approximately 39°18' 06 " north latitude and 84°42' 30" west longitude. The site lies within the Great Miami River Drainage basin, with the Great Miami River flowing approximately 1.5 miles to the east.

For the remediation of contaminated soil in the shallow subsurface, it will be necessary to conduct site-wide soil excavation. This excavation plan will require the removal of approximately 20 feet of the contaminated soil delineated in the former production area and adjacent areas. The soils designated for remediation are mainly the gray clay at the base of the glacial overburden layer.

1.2 OBJECTIVES AND SCOPE

The primary purpose of the four on-property ponds is to restore the natural resources of surface water, and promote the land use for a natural park. To ensure the proper engineering control, storage routing modeling must be performed in assisting the understanding of the relationship of storage-stage-discharge of ponds. This engineering analysis is required for analyzing under both normal conditions and storm event conditions.

As indicated in the conceptual final land use, the developed park will be composed of a portion of open water surface areas, enhanced forest, and vegetated woodland adjacent to the open water areas (Figure 1-2). Based on the post-excavation site-wide grading map, the ponds will serve the purposes of runoff control through storage and routing the excess peak flow (Figure 1-1). The ponds will also provide open water space for surface water habitats. More specific objectives of the open water areas are:

- Controlling and storage of surface water runoff for the post-remediation conditions.
- Regulate the excess runoff during a storm event.
- Provide detention basins of sediment from soil remediation activities.
- Collecting the excess perched water near the former production area

1.3 OVERVIEW OF THE TECHNICAL PROCEDURES

The general technical steps for this pond modeling are briefly outlined as below:

- Investigation of the surface features for the post-excavation conditions.
- Delineation of the pond boundaries
- Delineation of outline of the pond water surface at 5-foot contour increments.
- Determination of subbasins that contribute surface runoff to the four pond areas.
- Estimation of drainage area for each individual pond.
- Determination of stage and storage relationship.

<u>Under Normal Conditions</u>

- Estimation of monthly mean rainfall depth.
- Estimation of monthly mean stormwater runoff depth.
- Estimation of monthly mean infiltration rates.
- Estimation of monthly mean evaporation rates.
- Assembling the reservoir routing model based on one month interval.

- Implementing the reservoir routing model with the four ponds linked together.

Under Extreme Conditions

Technical Release 55 (TR55) method was used to calculate the peak rate of discharge and hydrographs for floodwater ponds at FEMP site.

- Implementation of a conceptual model for subbasins and channels in relation to the watershed drainage path.
- Computation of peak inflow to the ponds generated by a 25-year frequency and 24-hour duration storm event.
- Generation of tabular hydrograph.
- Assembling the reservoir routing model based on six minutes time interval.
- Designing the hydraulic connections (discharging channel, and overflow weirs) between the ponds.
- Implementing the flood routing model with the four ponds linked together.
- Sizing of the discharging channel.
- Determination of the adequacy in hydraulic design and planning based on the modeling results.

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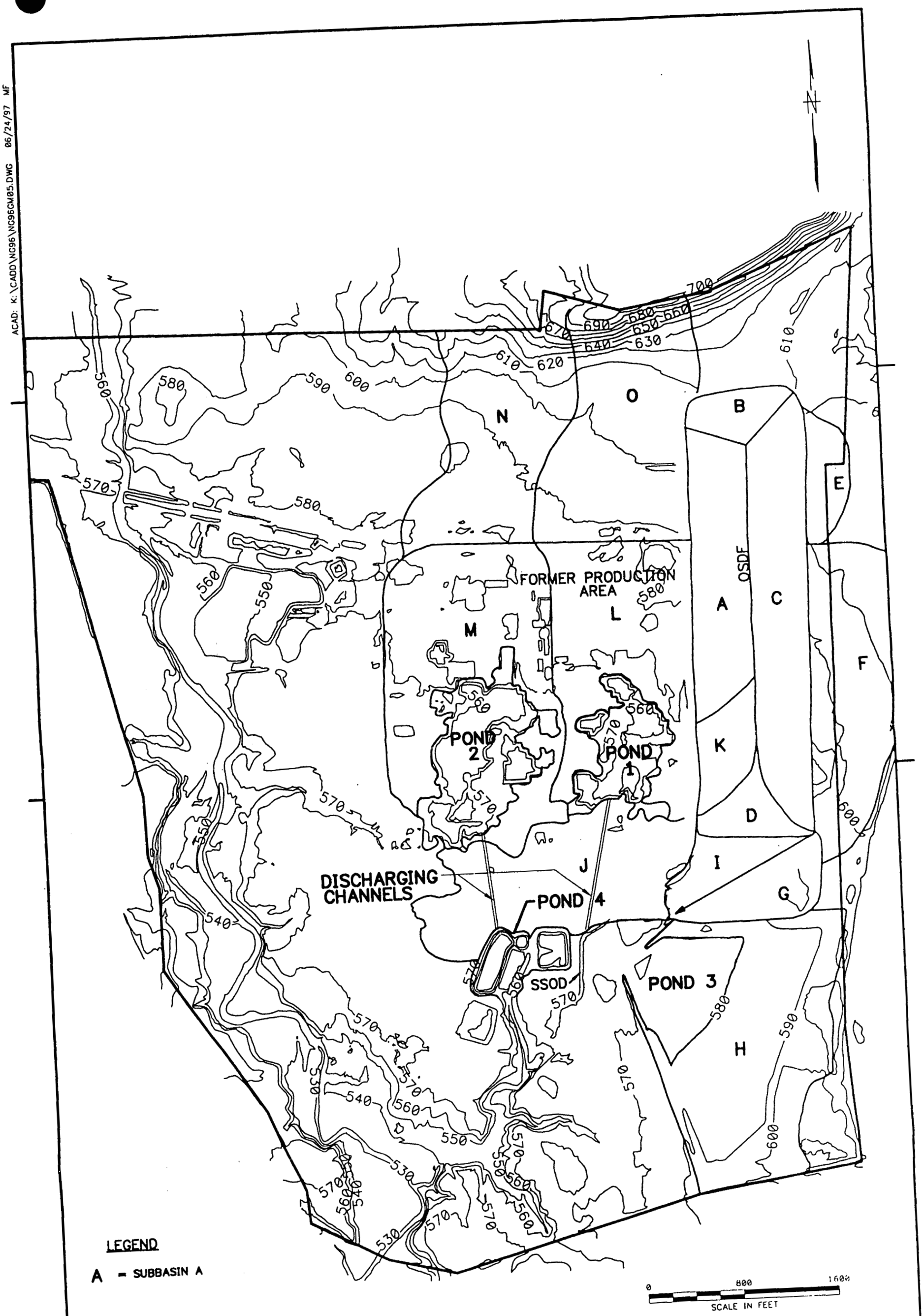

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CHECKED BY DATE	PROJECTED POST-EXCAVATED TOPOGRAPHIC FEATURES, POND BOUNDARY, AND SUBBASINS FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 1-1	REV. 0

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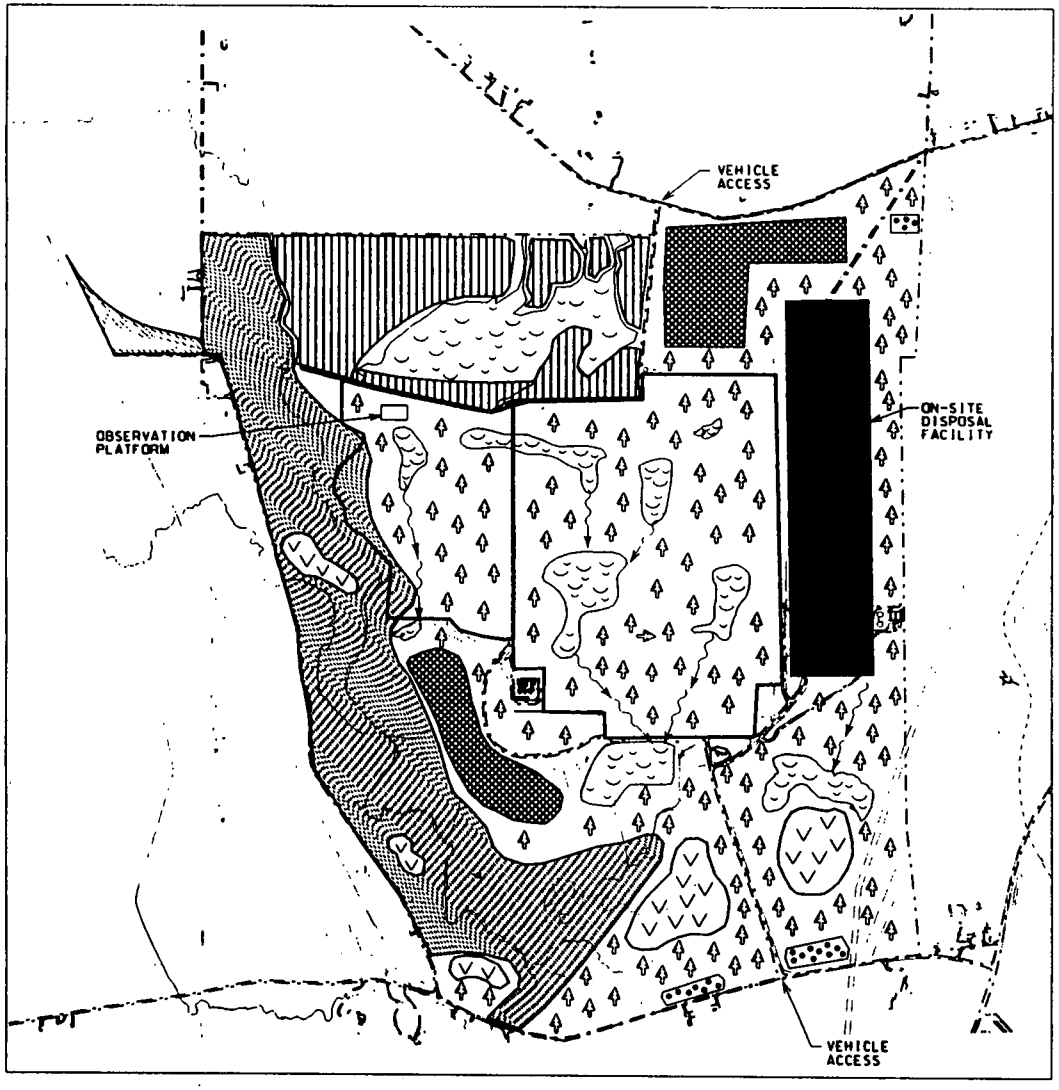

DRAFT

LEGEND:

ACREAGE:

- AESTHETIC BARRIER
- PRAIRIE
- ENHANCED PINE FOREST
- ENHANCED OAK-HICKORY FOREST
- RIPARIAN / BEECH-MAPLE FOREST
- OPEN WATER/WETLAND
- WOODLAND
- PARKING
- DRAINAGE

SCALE

0 800 1600 FEET

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FIGURE 1-2. CONCEPTUAL FINAL LAND-USE

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2.0 CONCEPTUAL MODEL DEVELOPMENT

This section presents the conceptual model and technical approach used for developing pond routing, in relation to pond storage and pond stage.

2.1 SURFACE FEATURES AT POST-EXCAVATION CONDITIONS

In developing the pond routing model, the post-remediation site surface conditions are used. Figure 1-1 presents the projected post-excavation topographic map. The existing topography is mainly level in the former production area with the remainder of the site gently sloping throughout. The elevations range from a high point of approximately 700 feet MSL within the northeastern reaches of the site, to a low point of 550 feet MSL within the Paddys Run corridor at the southwestern corner of the site. Surface slopes associated with on-site stream channels are severe.

For the projected post-excavation conditions, Pond 1 is established in the northeast of FEMP, and also east of the former production area. Pond 2 is developed west of Pond 1. Pond 3 is at the south side of FEMP, and was designated as the soil borrow area for the construction of On Site Disposal Facility (OSDF) and other structures. Pond 3 lies on a steep hills, therefore, its storage capacity is quite limited. However, Pond 3 is for temporary runoff storage purpose. Stormwater in Pond 3 can be freely overflowed to the SSOD. Pond 4 is also designated as a stormwater retention pond, and is west of Pond 3.

<u>Soil Excavation Zones</u>

The proposed soil excavation areas are mainly within the on-property areas, excluding the northern portion of the FEMP site, these areas include:

- The Former Production Area
- Waste Storage/management Areas
- Existing Stockpiles
- Shallow excavation of Impacted, On-property Areas
- Pipeline excavation outside of the Former Production Area

In addition to the soil excavation, OSDF will be constructed at the eastern border for containing the processed low-level radionuclide waste. Construction of the OSDF will require some road and traffic changes. Hence, only the existing topography in the northern portion of the FEMP site remains unchanged since this area is not designated in the boundary of soil remediation.

The excavation of the soil during remediation will change the runoff characteristics of some of the remediated areas. As indicated in figure 1-1, the soil excavation activities occur mainly in the former production area and its vicinities. The change of runoff characteristics in this area are a result of the remediation activities. Prior to the remediation, much of the production area is covered with buildings and pavement. During remediation these structures will be removed, followed by soil excavation, interim grading, establishment of vegetation, and other necessary restoration requirements. Therefore, the surface features at the post-remediation condition will be altered, when compared to the current conditions. The post-remediation site surface conditions are used for reflecting the changes such as runoff curve numbers, and drainage paths.

Subsurface Features in the Excavation Zones

The subsurface soils designated for remediation at the vicinity of FEMP consist of mainly impermeable gray clay at the base of the glacial overburden. Within this shallow excavation zone, the perched groundwater table elevation is generally high. It ranges from 574 to 576 feet in the area of Pond 1 and 2, and is approximately 570 feet in the vicinity of Pond 4 (retention pond) and Pond 3 (borrow area). The contaminated perched groundwater is located in the weathered portion of the overburden which contains fractures.

2.2 SUBBASIN AND DRAINAGE AREAS

The FEMP property can be divided into several subbasins based on drainage divides to allow for the analysis of separate areas of the FEMP containing different surface conditions and stormwater drainage systems. As shown in Figures 1-1, the drainage basin that contributes to each individual pond consists of multiple subbasins. The physical configuration of these subbasins are important in the estimation of runoff volume as well as the routing of inflow hydrograph. Since the configuration and location of the subbasins will directly affect the time of concentration and also the travel time, and subsequently determine the peak inflow rates for a storm event.

Table 2-1 presents the areas of the subbasins that contribute runoff to each individual pond. The total drainage area is also calculated in Table 2-1. As indicated in Table 2-1, the drainage area of Pond 1 consists of subbasins A, B, O, and L. The drainage area of Pond 2 is composed of subbasins N and M. The drainage area of Pond 3 encompasses subbasins C, E, F, and H. Pond 3 will collect runoff generated from the east portion of the OSDF (subbasin C) along with runoff from adjacent subbasin areas E and F, and finally drains through a culvert pipe to Pond 3. Runoff collected in subbasins K and J discharges to

Pond 4. Based on the post-excavation topographic map, the runoff collected from subbasins D, I, and G, which are located south of the OSDF, drains to SSOD.

The subbasin configurations in the OSDF area that are referred to in this study compared the peak discharge for pre-development conditions with the post-development conditions (Parsons, 1997). As stated in this study, a rerouting of drainage from the north and west areas of the OSDF draining into the OU1 Railyard channels has been considered.

2.3 STAGE AND STORAGE RELATIONSHIP

In general, the stage-storage relationship depends on the local topography at the site of the storage structures. At the FEMP site, the stage-storage relationship was derived as a discrete function (i.e. a set of points). The water surface areas within contour lines of the site can be plannimetered with five feet contours. Thus, the storage in a depth increment of five feet can be calculated by the product of the average area and the depth increment. Then, the total volume of storage is the summation of all the storage increments. The data presented in Table 2-2 were used to generate the stage-storage relationship for the routing modeling. Figure 2-2 presents the surface water area at stages for every five feet of increment of elevation. Figure 2-3 presents the stage-storage relationship of the four ponds. As indicated in Figure 2-3, Pond 2 has the highest storage, while Pond 3 has the lowest storage when compared at the same stage among the four ponds.

2.4 CONTROLLING FACTORS

The peak inflow rates and the maximum depths of the ponds are controlled by factors such as meteorological data, hydrological parameters as well as the surface features and subsurface soil stratum properties of the watersheds. These three major controlling factors are summarized in this section.

Meteorological data

The Meteorological data that affect the modeling results are:

- Monthly mean rainfall depth under the normal conditions
- Rainfall depth from a 25-year and 24-hour storm, and storm type under extreme conditions
- Air and water surface Temperature that will affect the saturated vapor pressure
- Relative humidity
- Wind speed
- Percentage of possible sunshine
- Net radiation

Hydrological data

The hydrological data that affect the modeling results are:

- Subbasin configuration in the watershed.
- Natural drainage channel length and size.
- Vegetation cover conditions upstream of the ponds
- Curve number corresponding to site soil group
- Drainage path slope.
- Time of concentration

Surface and subsurface features

The surface and subsurface features that affect the modeling results are:

- Final site-wide grading features.
- Thickness of pond liner
- Hydraulic conductivity of pond liner materials.
- Stage-storage relationship of individual pond.

2.5 STORAGE ROUTING MODEL

When planning pond development conditions, the routing process considerations take precedence. Storage routing refers to the process of estimating the passage of a storm or flood hydrograph through a pond or reservoir. The routing model is based on conservation of mass, which assumes that the rates of change of storage equals to the difference between the inflow and outflow. In comparison to other hydrological problems, storage routing is relatively complex. There are a number of variables involved, including :

- Input hydrograph (monthly mean rainfall and runoff depth)
- Output hydrograph (monthly mean pond evaporation and leakage from the pond liner)
- The stage-storage volume relationship
- The storage-water surface area relationship
- The stage-discharge relationship
- The designed peak discharge rates allowed through the pond

The drainage area is determined from the topographic map. It is assumed that the change of pond area will not change the drainage area for the routing process. The detailed storage routing equations are presented in Section 3.0.

2.6 POND INFLOW MODEL

As shown in Figure 2-1, the inflow term consists of two terms: runoff from the drainage area and rainfall directly into the pond. The monthly mean rainfall depth and runoff depth were used in the calculation under the normal conditions. The peak inflow rates were estimated using the TR55 method for extreme conditions. A brief overview of the TR55 method is provided in Section 5.0.

2.6.1 Monthly Average Rainfall and Runoff

The monthly mean precipitation was taken from database of National Oceanic and Atmospheric Administration (NOAA) (NOAA, 1986). The data are statistics from hourly precipitation data for Cincinnati, Ohio. The monthly runoff was calculated by using Hydrologic Evaluation of Landfill Performance (HELP) model based on the monthly mean precipitation data from NOAA. In HELP calculations, it is assumed that the ground surface will be compacted during the interim grading operation. Appendix A presents the monthly runoff depth calculations (HELP model).

2.7 POND OUTFLOW MODEL

The outflow components considered in the model were evaporation from the open water surface, infiltration loss from the pond liner materials, and overflow rates from the weirs when the stage exceeds the overflow bottom elevation (Figure 2-1).

2.7.1 Monthly Evaporation Model

The evaporation rate was estimated using Penman equation based on meteorological data from climate station within the study region, since direct evaporation data is not available. The Penman equation was developed for estimating evaporation from open water surface (McCUEN, 1989). In Penman's model, the following parameters are considered: air and water surface temperature, relative humidity, saturated vapor pressure, wind velocity, amount of radiation absorbed, outward flow of long-wave radiation, percent of possible sunshine etc. The detailed evaporation model equations are presented in Section 3.0.

2.7.2 Monthly Infiltration Model

The amount of infiltration through the pond liner material has incorporated the data presented in the infiltration zone model in the Feasibility Study Report (FS Report) (DOE, 1995). Based on Figures 2-4 and 2-5 originally presented in Appendix F of FS, bottom liner material is mainly the gray clay located at the base of the glacial overburden layer. Part of the Pond 1 liner materials consist of the unsaturated Great Miami Aquifer material. The gray clay is a clay-rich glacial till deposit, with an average porosity of 0.20. The reported hydraulic conductivity for gray clay is 7.23×10^{-7} cm/sec. The thickness of the liner was assumed to be 3 feet. The infiltration rates were estimated by Darcy's Law , which states that the infiltrated velocity is the product of the hydraulic conductivity of the pond liner and the vertical gradient of water depth inside the pond through the bottom liner. The infiltration equation is presented in Section 3.0.

2.8 POND LINER MATERIAL

As indicated in figures 2-4 and 2-5, the soil excavation in the Pond 2 area is in Infiltration Zone V, and will reach the formation of gray clay layer near the bottom of the overburden layer. This means the liner material for Pond 2 will be a natural gray clay material with a permeability of about 10^{-7} cm/sec. However, the soil excavation in the pond 1 area is in Infiltration Zone II & III, which reaches the unsaturated Great Miami Aquifer. The unsaturated Great Miami Aquifer is generally sandy material with a permeability range 10^{-2} to 10^{-3} cm/sec. Therefore, the liner material for Pond 1 requires replacement with either a lower permeability clay soil or a synthetic liner. Replacing the sandy soil will facilitate the minimum leakage of water through the liner materials.

2.9 HYDRAULIC CONNECTION PLAN

The hydraulic connections are necessary for regulating the storage in the ponds and to maintain open water space for surface water habitats. This design plan utilizes outlet facilities such as weirs and open channels for the conveyance of water between ponds or discharging to SSOD. In the hydraulic connection plan, excessive water from Pond 1 can be drained through an open channel to SSOD. Excessive water from Pond 2 will first be conveyed through an open channel to Pond 4 (retention pond), and then either store in Pond 4 or overflow to SSOD when the pool level in Pond 4 exceeds the weir bottom elevation. The excessive water in Pond 3 will simply overflow through a weir to SSOD.

2.10 POND DAILY OVERFLOW AND OUTFLOW DISCHARGE

It is assumed that overflow will take place in a pond when the surface water elevation in the pond is higher than a certain elevation (pond overflow elevation). Therefore, in the routing process, if the pond surface water is higher than the pond overflow elevation, the pond water will overflow until the pond surface water is just at or below the pond overflow elevation. Also, the daily overflow rate was estimated by dividing the total amount of overflow in a month by 30 days.

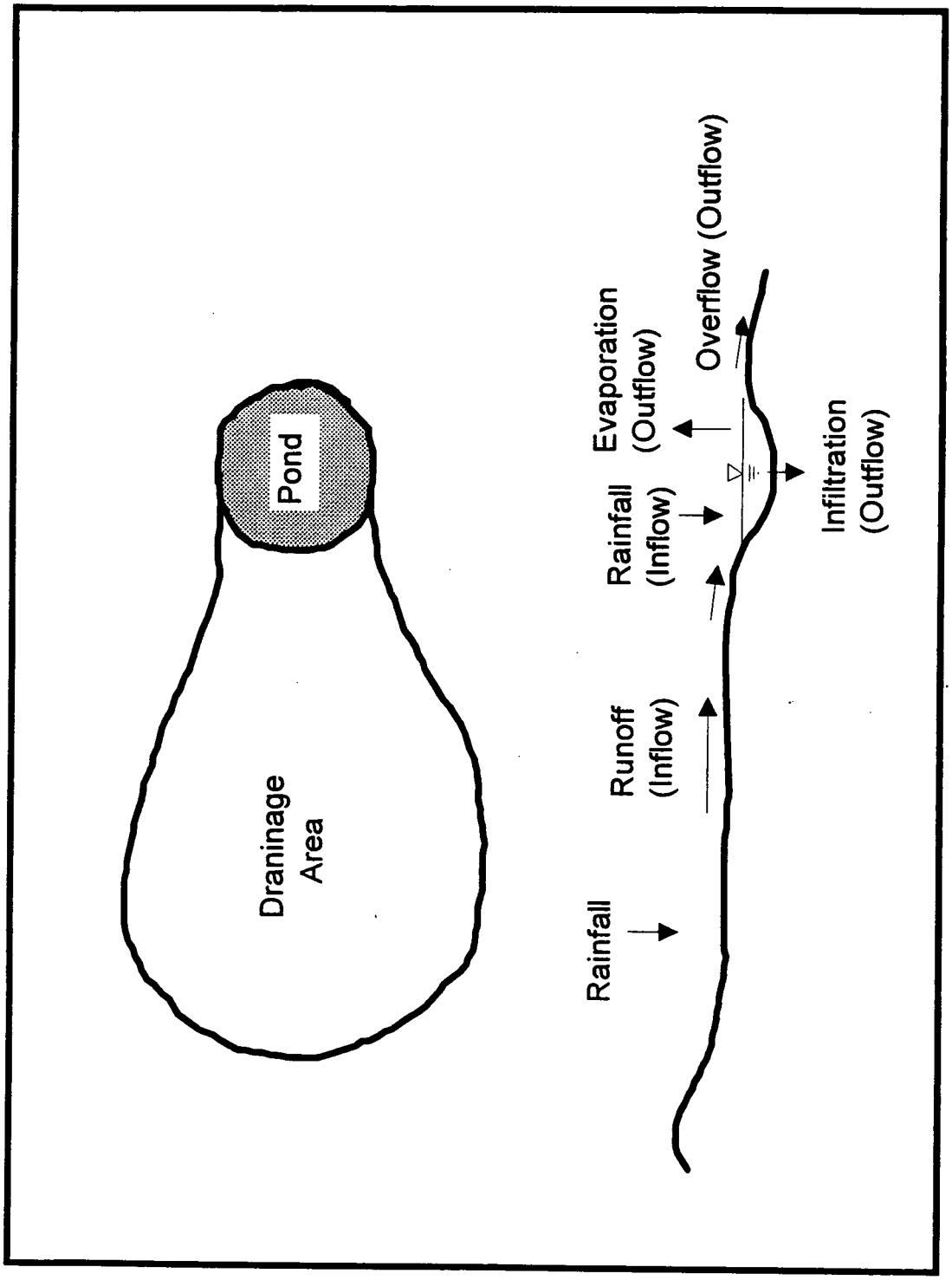

Figure 2-1 Conceptual Pond Routing Model

FIG2-2 Chart 1

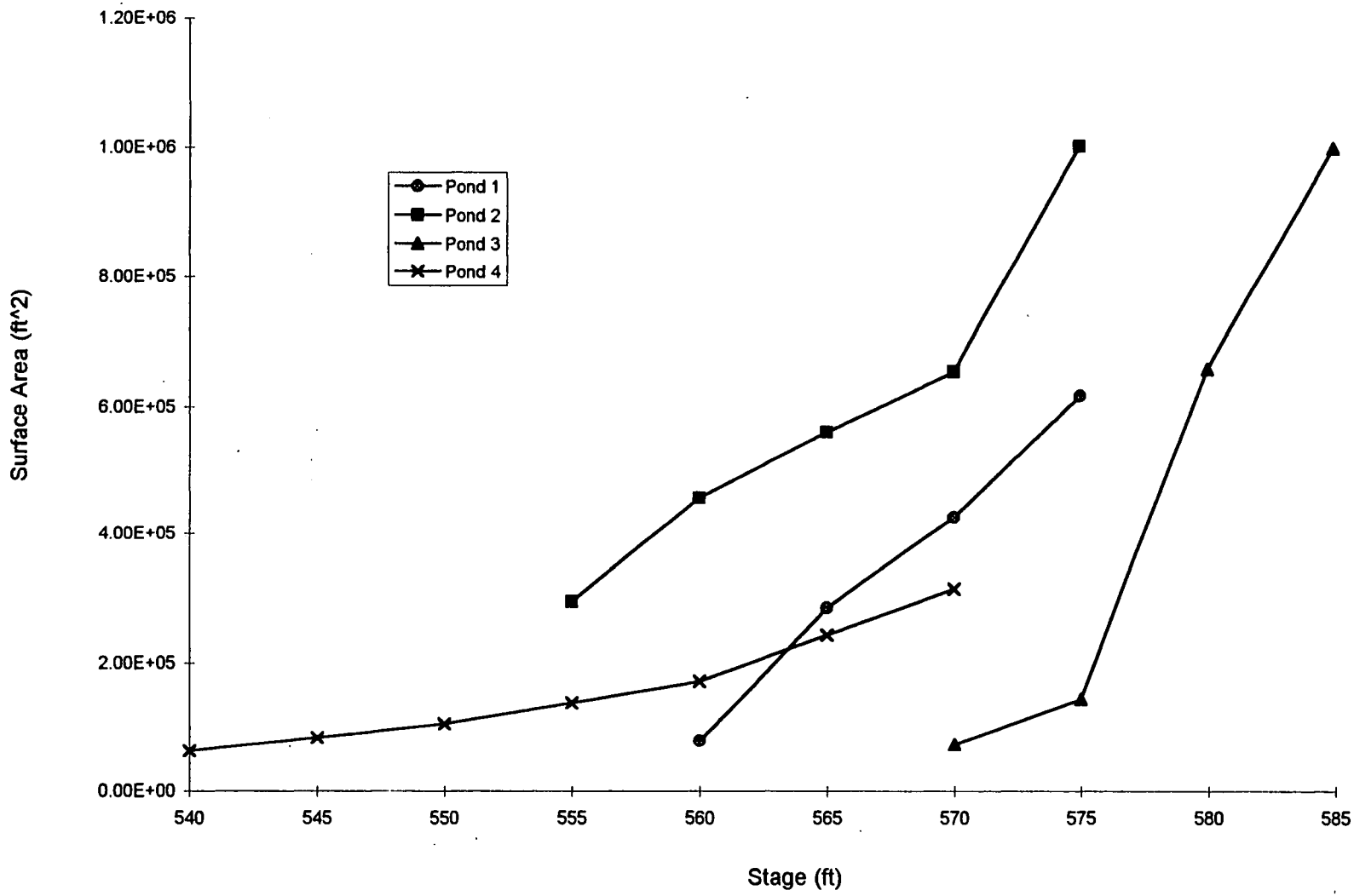

Figure 2-2 Stage and Water Surface Area Relationships

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FIG2-2 Chart 9

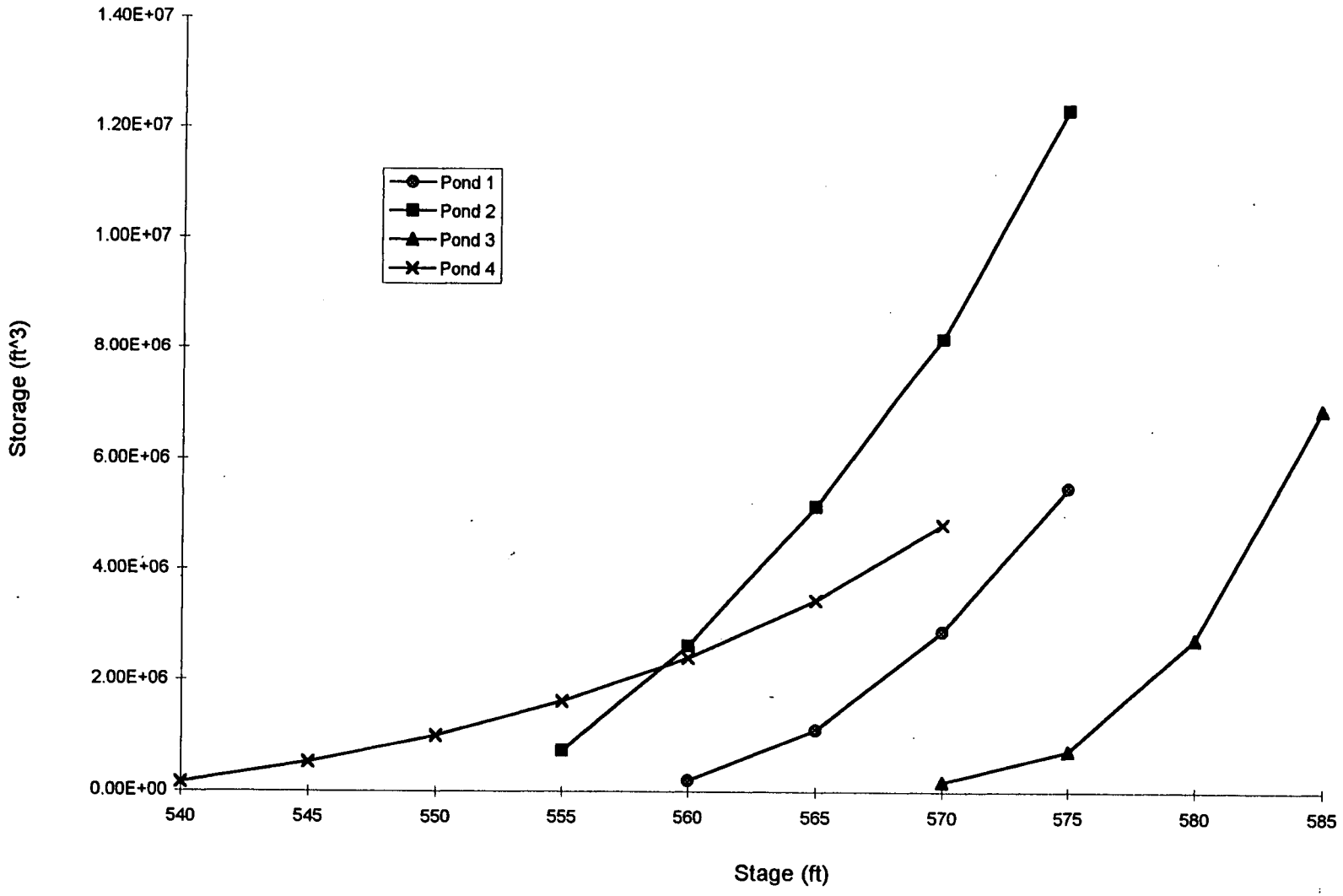

Figure 2-3 Stage and Storage Relationships

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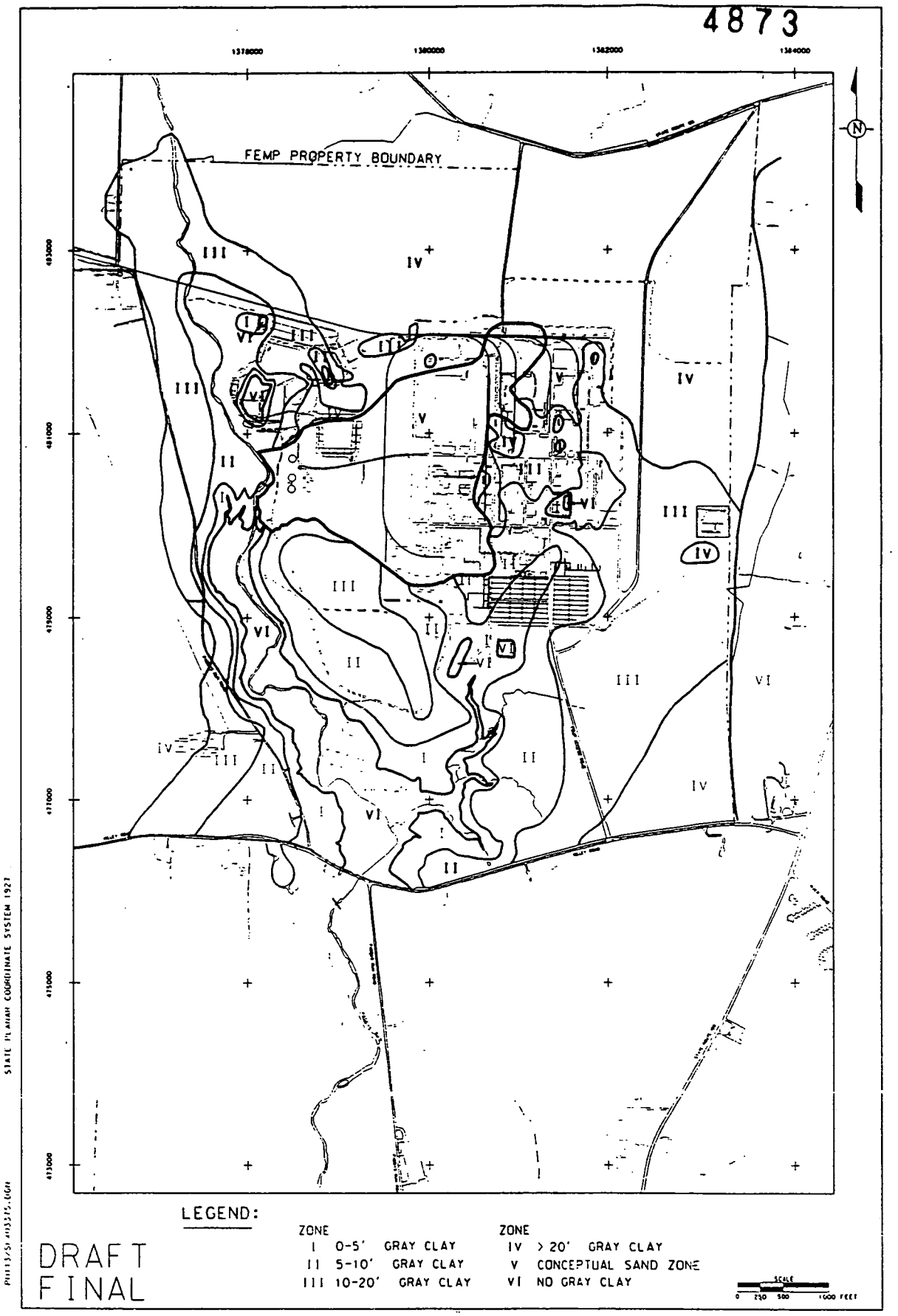

FIGURE 2-4 INFILTRATION ZONES

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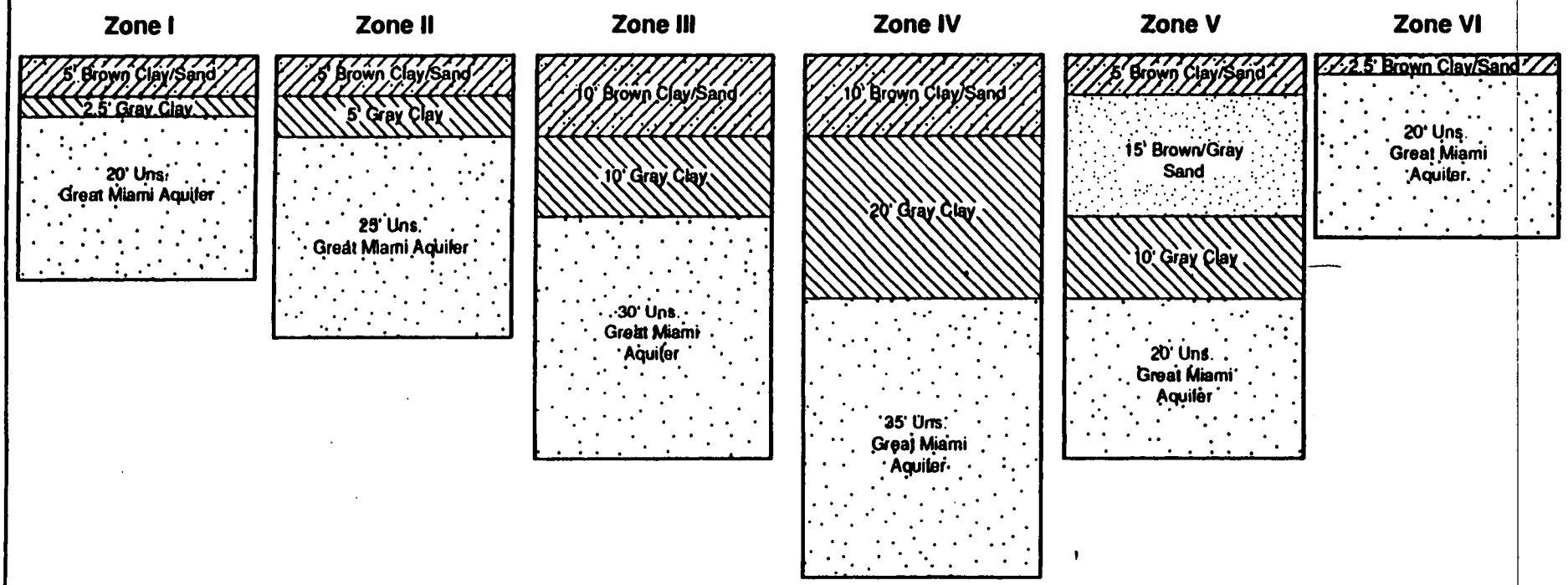

FORMATION	Kv (cm/sec)	POROSITY	DATA SOURCE
Gray Clay	7.23E -07	0.20	Kv from GO/UGMAS model calibration, ≈ 0.4 of geometric mean of slug test results
Brown/Gray Sand	1.10E -04	0.30	Harmonic mean of Kh from slug tests divided by 10
Brown Clay/Sand	7.04E -05	0.30	Harmonic mean of Kh from slug tests
Uns. GMA	1.59E -02	0.30	Kv from SWIFT Model Calibration

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FIGURE 2- 5 GENERALIZED CROSS SECTIONS

TABLE 2-1
POND SUBBASIN AREAS AND DRAINAGE AREAS
FEMP - POST EXCAVATION CONDITION

	Subbasin			Drainage Area
	Subareas	ft^2	acres	acres
POND 1 (Northeast of FEMP)	A	1150200	26.4	127.4
	B	310500	7.1	
	O	2236500	51.3	
	L	1853100	42.5	
POND 2 (Northwest of FEMP)	N	2255400	51.8	109.1
	M	2498400	57.4	
POND 3 (Southeast of FEMP)	C	1588500	36.5	104.0
	E	311850	7.2	
	F	1003500	23.0	
	H	1624500	37.3	
POND 4 Retention Pond	K	378000	8.7	49.3
	J	1768500	40.6	
		Total Drainage Area for Pond		389.8

Note: Based on the post-excavation topographic map, the runoff collected from subbasins D, I, and G that are located south of the OSDF drains to SSOD.

TABLE 2-2

POND WATER SURFACE AREA AT DIFFERENT STAGES

Surface Elevation (ft) / Pond Surface Area (ft^2) / Pond	540	550	555	560	565	570	575	580	585	Pond Drainage Area (ft^2)
POND 1 (southeast side)				7.88E+04	2.85E+05	4.25E+05	6.17E+05			5.55E+06
POND 2 (south side)			2.94E+05	4.56E+05	5.59E+05	6.54E+05	1.00E+06			4.75E+06
POND 3 (south end)						7.32E+04	1.45E+05	6.58E+05	9.99E+05	4.53E+06
POND 4 (Retention POND)	6.30E+04	1.06E+05	1.39E+05	1.72E+05	2.43E+05	3.14E+05				2.15E+06

Note: 1 arce = 43560 ft^2

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TABLE 2-3

STAGE AND STORAGE RELATIONSHIPS

Pond Storage (ft^3) / Pond \ Surface Elevation (ft)	540	550	555	560	565	570	575	580	585
POND 1 (southeast side)				1.97E+05	1.11E+06	2.88E+06	5.49E+06		
POND 2 (south side)			7.36E+05	2.61E+06	5.15E+06	8.18E+06	1.23E+07		
POND 3 (south end)						1.83E+05	7.28E+05	2.74E+06	6.88E+06
POND 4 (Retention POND)	1.58E+05	1.00E+06	1.61E+06	2.39E+06	3.43E+06	4.82E+06			

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Checked by:
Date :

TABLE 2-4
MONTHLY AVERAGE EVAPORATION RATES
POND ROUTING MODELING - FEMP

Input parameters

Sigma = 1.2E-07
Latitude = N 39.1 °
Reflection
Coeff r = 0.12
Empirical r (0.05-0.12)

Psychrometric Const.
(alpha) = 0.485 mm Hg/°C
Delta = $(e_o - e_a^*)/(To-Ta)$

Month	Temp °F	Temp °C	Temp T	Relative Humidity R_h %	Saturation Vapor Pressure e_s mm Hg (1)	Actual Vapor Pressure e mm Hg (2)	Wind Speed at 2m V m/s	Short Wave Radiation Flux Ra g-cal/cm²/day (3)	% of Possible Sunshine n/D	Radiation Absorbed Ri g-cal/cm²/day	Outward flow of Longwave Radiation Rb g-cal/cm²/day	Net Radiation Rn=Ri-Rb g-cal/cm²/day	Hv g-cal/cm³ (4)	Evaporation Rates E mm/day (5)	Water Surface Temp Tw °C (6)	Delta	Evaporation in Air Eao mm/day	Evaporation at Water Surface Hw mm/day	Evaporation at Water Surface Hw in/month
Jan.	28.9	-1.72	271.28	0.725	4.046	2.93	4.78	370.29	0.38	127	109	18	596.9	0.31	-2.20	2.33	1.10	0.45	0.527
Feb.	32.1	0.06	273.06	0.7025	4.562	3.20	4.65	549.57	0.42	198	116	82	596.0	1.37	0.00	24.43	1.31	1.37	1.620
Mar.	41.8	5.44	278.44	0.6725	6.74	4.53	4.96	670.11	0.49	262	128	134	593.2	2.26	0.00	0.41	2.26	2.26	2.673
Apr.	53.5	11.94	284.94	0.64	10.478	6.71	4.78	850.02	0.56	359	136	223	589.8	3.78	2.00	0.38	3.74	3.76	4.437
May.	63	17.22	290.22	0.675	14.728	9.94	3.89	929.19	0.6	409	129	280	587.0	4.77	5.00	0.39	3.92	4.30	5.076
June	71.4	21.89	294.89	0.6925	19.688	13.63	3.53	998.57	0.65	461	119	342	584.6	5.86	8.00	0.44	4.54	5.16	6.098
July	75.4	24.11	297.11	0.715	22.513	16.10	3.17	939.69	0.67	442	109	334	583.5	5.72	9.00	0.42	4.37	5.00	5.905
Aug.	74.1	23.39	296.39	0.73	21.567	15.74	3.04	844.98	0.65	390	108	283	583.8	4.84	8.00	0.38	3.82	4.27	5.039
Sept.	67.5	19.72	292.72	0.7325	17.232	12.62	3.31	725.17	0.66	338	124	215	585.7	3.66	5.00	0.31	3.26	3.42	4.036
Oct.	55.3	12.94	285.94	0.7025	11.182	7.86	3.62	537.54	0.5	213	120	93	589.3	1.58	1.00	0.28	2.55	2.20	2.593
Nov.	43.4	6.33	279.33	0.7175	7.172	5.15	4.29	409.11	0.36	137	103	34	592.7	0.57	0.00	0.32	1.82	1.32	1.558
Dec.	33.8	1.00	274.00	0.7425	4.92	3.65	4.56	330.65	0.32	105	98	7	595.5	0.12	0.00	1.27	1.20	0.42	0.494

Annual total (in) 40.05

Notes:
Weather data are mean monthly data for Cincinnati, Ohio, National Oceanic and Atmospheric Administration (NOAA), Part I Eastern Region, 1987.
The amount of evaporation from open water surface was computed with Penman equation presented in McCUEN, 1989.
(1) From Table 14-1, Mc CUEN, 1989.
(2) $e = e_s * R_h$
(3) From Table 14-3, Mc CUEN, 1989.
(4) Hv = 596 - 0.52*Tc
(5) E = 1-*Rn/Hv
(6) Water surface temperature was estimated based on the ambient temperature

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3.0 CONCEPTUAL MODEL FORMULATIONS

The analytical implementations of the conceptual model presented in Section 2.0 are described in this section. The general technical rational and basic equations that account for the routing processes is presented first. Then, the inflow and outflow components such as rainfall, runoff, evaporation, and infiltration are described based on site-specific information. Finally, the pond overflow equation and sizing of the discharging channels are described.

3.1 STORAGE ROUTING MODEL EQUATION

As described in the conceptual model, storage routing is the process of estimating the passage of a storm or flood hydrograph through a retention facility. For the purpose of developing routing model through the retention pond, the mass balance which states the difference between inflow and outflow equals to the pond storage change can be expressed as (see Figure 2-1)

$$I(t) - O(t) = \frac{dS_P(t)}{dt} \tag{1}$$

where

I(t) is the inflow into the pond per unit time,
O(t) is the outflow from the pond per unit time,
$S_p(t)$ is the pond storage at time t, and
t is the time.

If the month is used as the unit time, and finite difference is applied to Eq. (1), The mass balance equation can be written as:

$$I(i) - O(i) = S_P(i+1) - S_P(i) \tag{2}$$

Or

$$S_P(i+1) = S_P(i) + I(i) - O(i) \tag{3}$$

where

I(i) is the total inflow into the pond in the month i,

O(i) is the total outflow from the pond in the month i,

$S_p(i+1)$ is the pond storage at the end of month i+1, and

$S_p(i)$ is the pond storage at the end of month i.

The pond storage at the end of month i+1 can be calculated from Eq. (3) by assigning the pond storage at the end of month i (initial pond storage) and inflow and outflow in month i.

3.2 INLOW COMPONENTS : RAINFALL AND RUNOFF

As shown in Figure 2-1, the inflow term I(i) consists of two terms: runoff from the drainage area and rainfall directly into the pond. It can be expressed as:

$$I(i) = ROF(i) \times A_d + RAIN(i) \times A_p \quad (4)$$

where

ROF (i) is the runoff per unit area in month i,

RAIN (i) is the rainfall per unit area in month i,

A_d is drainage area, and

A_p is the pond surface water area at stage of H.

The monthly average rainfall depth and runoff were used in the calculations.

It is also assumed that the change of pond surface water area will not change the drainage area. Surface water area of pond (A_p) is the function of the stage for a specific pond:

$$A_p = f_{Ap}(H(i)) \quad (5)$$

Where H(i) is the pond surface water elevation in month i.

Substituting equation (5) into equation (4) will yield the following equation

$$I(i) = ROF(i) \times A_d + RAIN(i) \times f_{Ap}(H) \quad (6)$$

The monthly average rainfall was obtained from the database of the National Oceanic and Atmospheric Administration (NOAA). The recorded length obtained for the monthly mean rainfall from NOAA is approximately 30 years.

The monthly runoff was calculated by using HELP model based on the monthly rainfall data from NOAA. Appendix A presents the monthly runoff depth calculations (HELP model). The drainage area (Ad) is determined from the topographic map.

3.3 OUTFLOW COMPONENTS :EVAPORATION, INFILTRATION AND OVERFLOW

The outflow components considered in the model were evaporation from the open water surface and infiltration (see Figure 2-1). Equation (7) describes their relationship.

$$O(i) = Hw(i) \times A_p + Inf(i) \times A_p + \text{Pond Overflow} \quad (7)$$

where

O(i) is the total loss of the water in the month (i)

Hw(i) is the evaporation rate (per unit area) in month i, and

Inf(i) is the infiltration rate (per unit area) to subsurface in month i.

Evaporation rate E will be directly incorporated into Equation (7), if pan evaporation data are available. The evaporation rate was estimated using the Penman equation based on meteorological data from the climate station of Cincinnati, Ohio, since pan evaporation data is not available. The following two subsections present the evaporation and infiltration model.

3.3.1 Evaporation Simulation

The Penman equation was used for estimating evaporation from open water surface. Penman proposed the following simplified energy balance equation (McCUEN, 1989):

$$H_W = \frac{\Delta E + \alpha\ E_{a0}}{\Delta + \alpha} \quad (8)$$

Where

Hw = evaporation from water surface (mm/day),

E_{a0} =0.35 (e_s-e) (0.2+0.55V),

e=e_sxR_h,

R_h is the relative humidity,,

e is the vapor pressure at air temperature,

e_s is the saturated vapor pressure, and is a function of temperature,

V is the wind velocity at 2 meter high, and

α is the psychometric constant, the typical value is 0.485 mm Hg/°C

$$\Delta = \frac{e_0 - e_a^*}{T_0 - T_a} \tag{9}$$

Δ is the slope of the saturated vapor pressure curve at mean temperature,

T_0 and T_a are temperature of the water surface and air, respectively,

e_0 is the vapor pressure of the water surface, and e_a^* is the saturation vapor pressure at T_a.

$$E = 10\frac{R_n}{H_v} \tag{10a}$$

$$R_n = R_I - R_B \tag{10b}$$

R_n is the net radiation in units of g-cal/cm^2-day,

R_I is the amount of radiation absorbed, and is a function of short-wave radiation function,

R_B is the outward flow of long-wave radiation.

R_I and R_B can be expressed as below:

$$R_I = R_A(1-r)(a+b\frac{n}{D}) \tag{10c}$$

$$R_B = \sigma T_a^4(0.47-0.077\sqrt{e})(0.2+0.8\frac{n}{D}) \tag{10d}$$

$$H_V = 596 - 0.52T \tag{10e}$$

Where

r is the reflection coefficient,

a and b are empirical coefficients that are location dependent,

n/D is the fraction of possible sunshine,

R_A is the Angot's values of short-wave radiation flux in units of g-cal/cm^2/day, and is a function of the latitude and the month of the year,

σ =117.7 x 10^9 g-cal/cm^2/day

H_V is in unit of g-cal/cm^3,

T is the temperature, in ^{0}C.

3.3.2 Infiltration Simulation

The amount of infiltration through the pond liner material has incorporated the data presented in the infiltration zone model in the Feasibility Study Report (FS Report) (DOE, 1995). Based on the Figures F-1 and F-2 in Appendix F of FS, bottom liner material is mainly the gray clay located at the base of the glacial overburden layer. Part of Pond 1 liner materials is the unsaturated Great Miami Aquifer material. The gray clay is a clay-rich glacial till deposit, with an average porosity of 0.20. The reported hydraulic conductivity for gray clay is 7.23 x 10^{-7} cm/sec. The thickness of the liner was assumed to be 3 feet.

The infiltration rates will follow Darcy's Law, and can be described as below:

$$Inf(i) = K\frac{H(i) - H_{GW}(i)}{TH} \qquad (11)$$

where

K is the hydraulic conductivity of the pond liner,

H (i) is the water surface elevation of the pond in month I,

H_{GW}(i) is the higher value between liner bottom elevation and groundwater elevation, and

TH is the pond liner thickness.

Eq.(11) indicates that if Inf(i) is positive, flow is from surface water in the pond to groundwater, if Inf(i) is negative, flow is from groundwater to surface water.

3.3.3 Pond Overflow

It is assumed that overflow will take place in a pond when the surface water elevation in the pond is higher than a certain elevation (pond overflow elevation). For normal conditions, the daily overflow rates were estimated by dividing the total amount of overflow in a month by 30 days. For extreme conditions, if the pond surface water is higher than the pond overflow elevation, then water will overflow until the pond stage is just at or below the pond overflow elevation. The overflow equation is stated as follow:

$$Q = 3.3LH^{1.5} \tag{12}$$

where

Q is the flow rates in ft^3/sec.

L is the weir width in feet.

H is the water depth above the weir bottom in feet.

3.4 STORAGE ROUTING COMPUTATION PROCEDURES

Substituting the Equations of (6), (7), (8) and (11) into Equation (3) will yield following routing equation:

$$\begin{aligned} S_P(i+1) &= S_P(i) + ROF(i) \times A_d + RAIN \times f_{Ap}(H(i)) \\ &\quad - Hw(i) \times f_{Ap}(H(i)) - K\frac{H(i) - H_{GW(i)}}{TH} f_{Ap}(H(i)) - Overflow \end{aligned} \tag{13}$$

Equation (13) can be used to calculate the pond storage $S_p(i+1)$ starting from month i. For example, the computation starts from month 0 (i=0) to calculate the pond storage term $S_p(1)$ at month 1. The $S_p(0)$ is given as the initial condition. The runoff (ROF), rainfall (RAIN), H(I), and Hw(i) in month 0 will be calculated explicitly. The pond storage Sp(1) at month 1 can then be calculated , since the terms on the right side of Equation (13) are all known.

3.5 SIZING OF CONNECTION CHANNELS

The hydraulic connections are necessary for regulation of the pond storage, maintaining minimum depth and open water space for surface water habitats. The current hydraulic connection plan utilizes outlet facilities such as weirs and open channels for the conveyance of water between ponds or discharging to SSOD. As stated in Section 2.0, the connection plan requires two discharging channels. The first channel drains excessive water from Pond 1 to SSOD. The second channel discharges the excessive water from Pond 2 to Pond 4 (the retention pond).

Sizing the discharging channel is based on outflow rates through the outlet weirs. The outflow rates were determined from the routing model under the extreme conditions. A grass lined trapezoidal channel with side slope of 1V:1H is proposed. Manning's equation is used for estimating the depth of water in the channel, assuming a width for the channel. This computation was performed using FLOWMASTER, a sizing program for channels and pipes (Haestad, 1990).

4.0 POND MODELING RESULTS UNDER NORMAL CONDITIONS

This section presents the storage routing modeling results under normal conditions. The normal conditions are represented by considering the monthly average meteorological data. As stated in Section 2.0, monthly mean data of rainfall depth, temperature, the fraction of possible sunshine, relative humidity, and wind speed were used for developing the monthly routing model. The conceptual routing model as presented in section 2.0 is the basis for calculating the storage and passage of runoff generated by a normal rainfall event. The routing equation described in Section 3.0 defines the water budget of a watershed. The water balance is a physical analysis of the drainage basin based on the conservation of mass, which assumes that the rates of change of storage is equal to the difference between the inflow and outflow. Inflow parameters considered in the normal climate conditions are monthly rainfall and runoff. The monthly mean rainfall data source is based on data available from NOAA. Runoff depths were calculated using the HELP model. Outflow parameters considered are evaporation from the pond surface and infiltration through the liner material. The simulation time selected was four years and represents the normal conditions in order to reach an equilibrium state. Tables C-1 through C-4 in Appendix C present the detailed monthly calculations for a period of four years. The following sections present the results of the routing model by considering the monthly average meteorological record.

4-1 INPUT PARAMETERS

The input data to the routing model used for the normal conditions are briefly summarized in this subsection.

Drainage Area. The drainage areas are the total of each individual subbasin, and each subbasin is plannimetered based on the enlarged scale of the post-excavation topographic map. The drainage area for the four ponds are estimated as 127.4,109.1,104, and 49.3 acres respectively. Table 2-1 presents the subbasin areas and their total drainage areas.

Pond Bottom Elevations. Bottom elevations of the four ponds are designed at 555, 550, 565, and 535 feet respectively (Appendix C).

Monthly Mean Rainfall. The monthly mean precipitation was based on the database from NOAA (NOAA, 1986). They are presented within EXCEL calculation tables in Appendix C.

Monthly Mean Runoff. The monthly mean runoff was calculated by using the HELP model based on the monthly mean precipitation data from NOAA. The monthly mean runoff depths were presented in Appendix C.

Evaporation Model Input Parameters. In Penman's model, the following monthly mean input parameters are considered: air and water surface temperature, relative humidity, saturated vapor pressure, wind velocity, short-wave radiation flux, and percent of possible sunshine. (NOAA, 1987). Other input parameters that are not time dependent are the latitude, reflection coefficient, and psychrometric constant. The input data are presented in Table 2-4.

Pond Liner Hydraulic Conductivity. A Hydraulic Conductivity of 7.23×10^{-7} cm/sec for natural gray clay as shown in Figure 2-5 was used for modeling. As discussed in Section 2.0, the liner materials for Pond 1 requires replacement with materials that have similar hydraulic conductivity in the range of 10^{-6} to 10^{-7} cm/sec.

Thickness of Pond Liner. The thickness of pond liner is proposed as three feet for the four ponds.

Pond Overflow Elevations. Overflow elevations of the four ponds are designed as 573, 573, 578, and 560 feet respectively.

Groundwater Elevation. The typical groundwater elevation in the pond areas is reported as 520 feet.

4.2 POND INFLOW AND OUTFLOW HYDROGRAPH

Figures 4-9, 4-13, 4-17, and 4-21 present inflow and outflow hydrographs for the four ponds respectively. As shown in these figures, the total inflow volume on a monthly basis are generally higher in the first part of the year, and are lower for the months between May and November for the four ponds. Table 4-1 presents the maximum inflow rates and maximum outflow rates for the four ponds. As indicated in Table 4-1 and Figures 4-9, 4-13, 4-17, and 4-21, Pond 1 will receive the highest runoff in April among the four ponds, and also has nearly the highest outflow rates.

TABLE 4-1

MAXIMUM INFLOW RATES AND MAXIMUM OUTFLOW RATES UNDER NORMAL CONDITIONS

	Maximum Inflow Rates (ft^3/month)	Maximum Outflow Rates (ft^3/month)
POND 1 (Northeast of FEMP)	1.1×10^6	8.71×10^5
POND 2 (Northwest of FEMP)	9.81×10^5	6.19×10^6
POND 3 (Southeast of FEMP)	9.06×10^5	8.13×10^5
POND 4 (Retention Pond)	4.20×10^5	2.36×10^5

4.3 POND MONTHLY STORAGE VARIATIONS

Figures 4-10, 4-14, 4-18, and 4-22 present monthly pond storage variations for the four ponds respectively. As shown in these figures, the storage volume on a monthly basis are generally higher in the first part of the year, and decrease from April or May to the end of the year for the four ponds. Also, the storage variations experienced within each pond are about the same in order of magnitude. Table 4-2 presents the maximum and minimum pond storages for each pond under normal conditions. Table 4-3 presents the monthly pond storage variations under normal conditions.

TABLE 4-2

MAXIMUM AND MINIMUM POND STORAGE UNDER NORMAL CONDITIONS

	Maximum Storage (ft^3)	Minimum Storage (ft^3)
POND 1 (Northeast of FEMP)	$4.45X10^6$	$3.05X10^6$
POND 2 (Northwest of FEMP)	$6.19X10^6$	$4.74X10^6$
POND 3 (Southeast of FEMP)	$1.93X10^6$	$1.25X10^6$
POND 4 (Retention Pond)	$2.55X10^6$	$2.12X10^6$

4.4 POND MONTHLY STAGE VARIATIONS

Figures 4-11, 4-15, 4-19, and 4-23 present monthly pond stage variations for the four ponds respectively. Figures 4-1 through 4-8 present the pond water surface outlines with maximum and minimum storage for the four ponds. As indicated in the figures, stage variations in Pond 1 is relatively high when compared to the other ponds. This is due to the relatively smaller pond storage capacity, however, Pond 1 has a higher volume of runoff generated by a larger drainage area. Table 4-4 presents the stage changes for each pond. As indicated in the table, Pond 2 has the largest freeboard (about 7 to 8 feet) below the top edge of the pond. For this reason, Pond 2 collects less runoff, and will be excavated in a relatively large area during the soil remediation. Pond 3 serves as a temporary stormwater detention basin. Stormwater in Pond 3 can be overflowed to the SSOD. Of the four ponds, Pond 4 is the smallest one. Pond 4 also has a much lower rate of inflow, and can be functioned as an intermediate retention basin. As indicated in Table 4-4, difference in pond freeboard between Pond 1 and Pond 2 is approximately 6 feet. It would be more efficient for the purpose of storage routing, if a hydraulic connection is installed between Pond 1 and Pond 2.

Table 4-5 presents the monthly stage variations for each pond. As can be seen in Table 4-5, stage variations in Pond 3 (ranged from 576.3 to 578 feet) is the greatest among the four ponds in the same month. Pond 1 (ranged from 570.3 to 573 feet) has the second highest pool level. As mentioned in

Table 4-3 Monthly Storage Variations Under Normal Conditions

Month	Pond Water Storage (ft^3)			
	Pond 1	Pond 2	Pond 3	Pond 4
Jan	3.08E+06	4.75E+06	1.31E+06	2.13E+06
Feb	3.63E+06	5.23E+06	1.80E+06	2.34E+06
Mar	4.45E+06	5.96E+06	1.93E+06	2.55E+06
Apr	4.45E+06	6.19E+06	1.60E+06	2.54E+06
May	4.01E+06	5.96E+06	1.51E+06	2.46E+06
Jun	3.83E+06	5.75E+06	1.45E+06	2.40E+06
Jul	3.64E+06	5.52E+06	1.39E+06	2.34E+06
Aug	3.63E+06	5.44E+06	1.46E+06	2.33E+06
Sep	3.43E+06	5.20E+06	1.37E+06	2.26E+06
Oct	3.26E+06	4.99E+06	1.31E+06	2.20E+06
Nov	3.11E+06	4.81E+06	1.25E+06	2.14E+06
Dec	3.05E+06	4.74E+06	1.25E+06	2.12E+06

Section 2.0, Pond 3 serves as temporary runoff control, therefore, the higher stage is maintained for a short period of time. The stages simulated for Pond 1 would remain for a certain amount of time until the pool level exceeds the outlet elevation of 573 feet, then overflows to SSOD.

TABLE 4-4

MAXIMUM AND MINIMUM POND STAGE UNDER NORMAL CONDITIONS

	Pond Stage		**Pond Top Edge Elevation** (feet)
	Maximum (feet)	Minimum (feet)	
POND 1 (Northeast of FEMP)	573.0	570.32	575
POND 2 (Northwest of FEMP)	566.71	564.19	575
POND 3 (Southeast of FEMP)	578.0	576.29	580
POND 4 (Retention Pond)	560.0	556.9	575

Note: The maximum stage occurs in April, while the minimum stage occurs in December.

4.5 POND DAILY OVERFLOW RATE

Figures 4-12, 4-16, 4-20, and 4-24 present daily overflow rates for the four ponds respectively. As shown in these figures, the daily overflow rate occurs normally in April in response to the higher inflow rates. In general, the daily overflow rates are determined by the bottom elevation of pond outlets facilities. Table 4-6 presents the maximum daily overflow rates and bottom elevations of pond outlets for each pond under normal conditions. As indicated in table 4-6, the daily overflow rate is zero for Pond 2, since the pool level in Pond 2 has never reached the designed overflow elevation of 573 feet.

Table 4-5 Monthly Stage Variations Under Normal Conditions

Month	Pond Surface Water Elevation (ft)			
	Pond 1	Pond 2	Pond 3	Pond 4
Jan	570.4	564.2	576.5	557.0
Feb	571.4	565.1	577.7	558.5
Mar	573.0	566.3	578.0	560.0
Apr	573.0	566.7	577.2	559.9
May	572.2	566.3	577.0	559.4
Jun	571.8	566.0	576.8	558.9
Jul	571.5	565.6	576.6	558.5
Aug	571.4	565.5	576.8	558.5
Sep	571.1	565.1	576.6	558.0
Oct	570.7	564.7	576.5	557.5
Nov	570.4	564.3	576.3	557.1
Dec	570.3	564.2	576.3	556.9

TABLE 4-6

MAXIMUM DAILY OVERFLOW RATE UNDER NORMAL CONDITIONS

	Daily Overflow Rate (ft^3/day)	Pond Outlet Elevations (feet)
POND 1 (Northeast of FEMP)	$7.46X10^3$	573
POND 2 (Northwest of FEMP)	0	573
POND 3 (Southeast of FEMP)	$2.09X10^4$	578
POND 4 (Retention Pond)	$4.22X10^3$	560

4.6 MAXIMUM AND AVERAGE DEPTH OF THE PONDS

The maximum depth was computed as the difference between the water surface elevation and the pond bottom elevation. The average depth was determined by dividing the storage by the surface water area. Table 4-8 presents the maximum and average water depths under normal conditions. As indicated in Table 4-8, the highest maximum and average depths generally occur in April. The highest maximum water depths estimated for the four ponds are 18, 16.7, 13, and 25 feet respectively. The highest average water depths estimated for the four ponds are 8.2, 10.5, 4.5, and 14.8 feet respectively.

Table 4-7 Maximum and Average Depth Under Normal Conditions

Month	Pond 1		Pond 2		Pond 3		Pond 4	
	Maximum Depth (ft)	Average Depth (ft)	Maximum Depth (ft)	Average Depth (ft)	Maximum Depth (ft)	Average Depth (ft)	Maximum Depth (ft)	Average Depth (ft)
Jan	15.38	7.00	14.22	8.75	11.31	4.49	20.87	13.64
Feb	16.43	7.55	15.13	9.31	12.49	4.31	22.30	14.08
Mar	18.00	8.22	16.33	10.20	13.00	4.26	24.65	14.71
Apr	18.00	8.22	16.71	10.46	12.33	4.33	25.00	14.79
May	17.16	7.88	16.34	10.20	12.07	4.36	24.00	14.55
Jun	16.82	7.73	15.99	9.95	11.87	4.39	23.44	14.40
Jul	16.46	7.57	15.60	9.67	11.67	4.42	22.89	14.25
Aug	16.43	7.55	15.47	9.57	11.81	4.40	22.79	14.22
Sep	16.06	7.37	15.08	9.27	11.57	4.44	22.21	14.06
Oct	15.73	7.19	14.69	9.03	11.38	4.47	21.68	13.90
Nov	15.43	7.03	14.33	8.82	11.20	4.51	21.18	13.74
Dec	15.32	6.96	14.19	8.73	11.18	4.52	20.92	13.65

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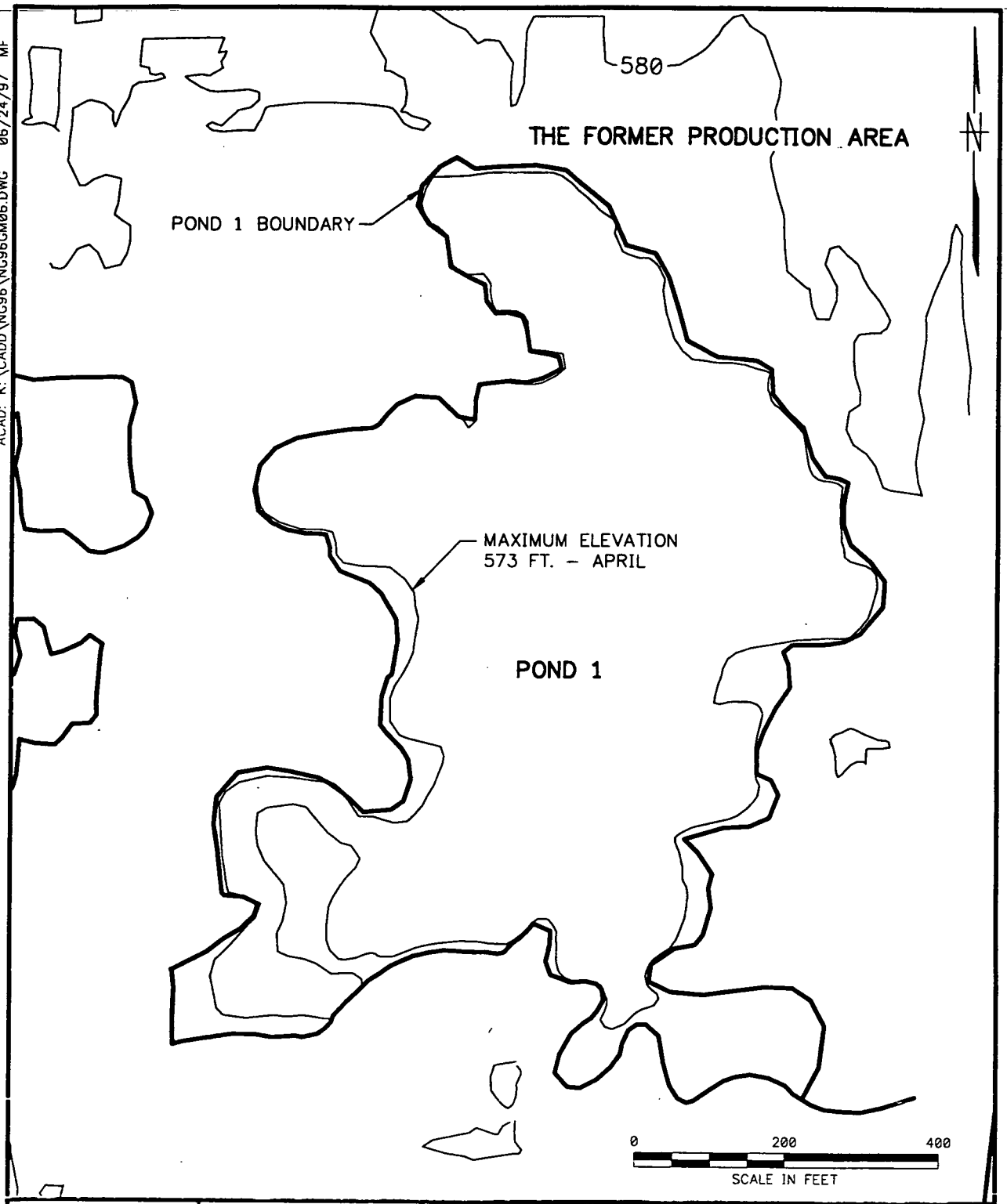

DRAWN BY DLT DATE 6/13/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 1 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MAXIMUM ELEVATION FEMP	APPROVED BY DATE	
COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 4-1	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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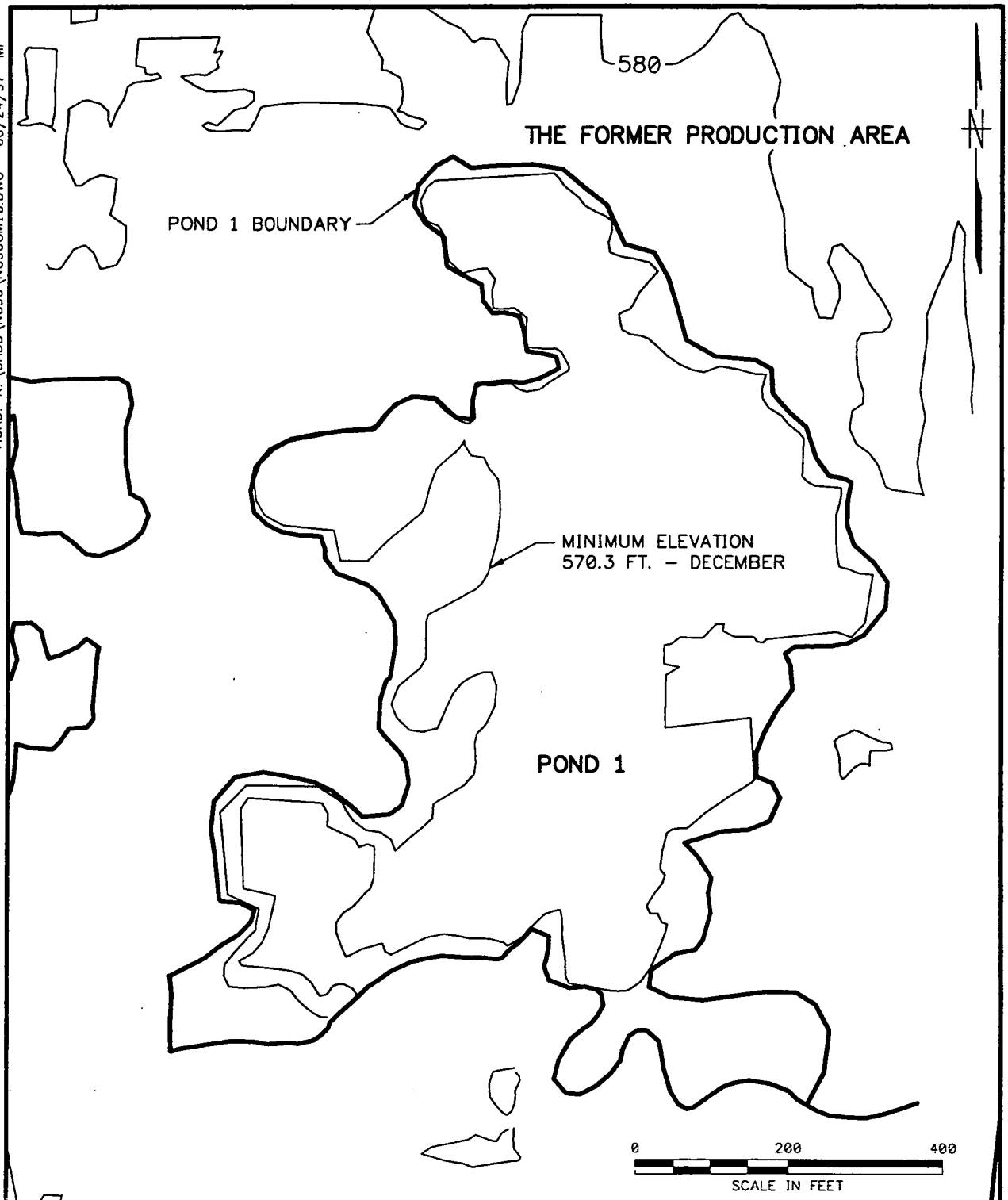

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CHECKED BY DATE	POND 1 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MINIMUM ELEVATION FEMP	APPROVED BY DATE	
COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 4-2	REV. 0

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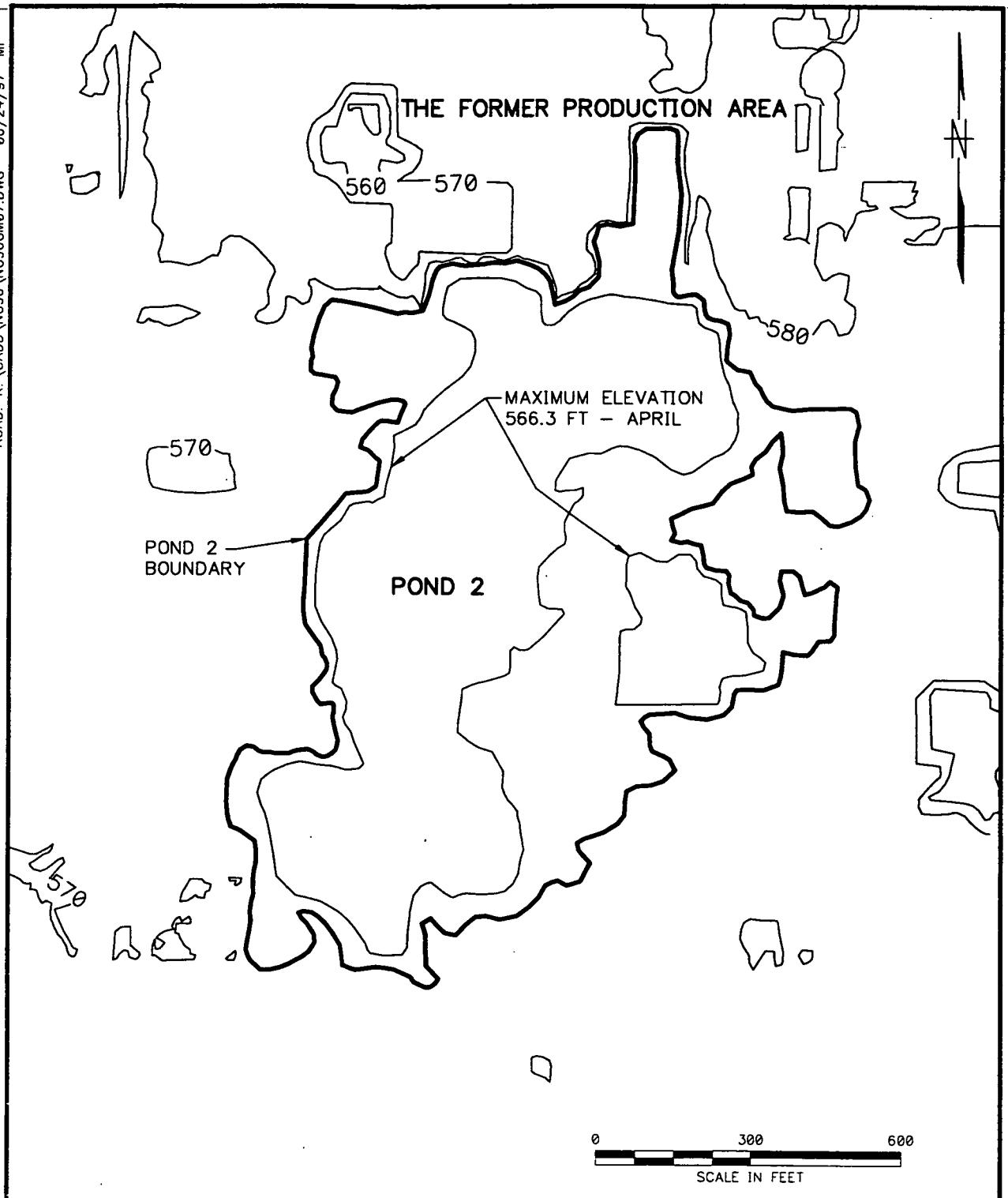

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CHECKED BY DATE	POND 2 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-3	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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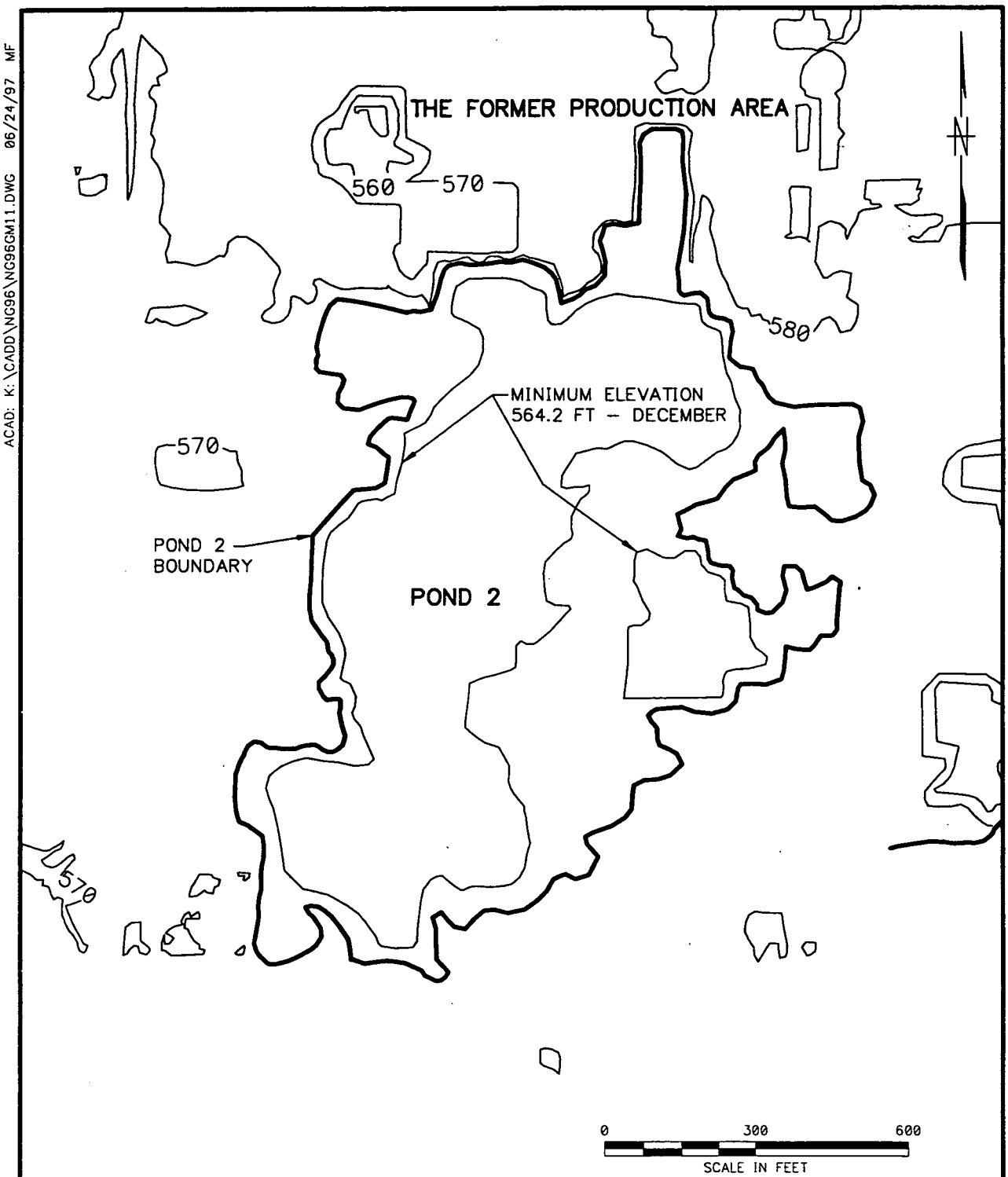

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COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 4-4	REV. 0

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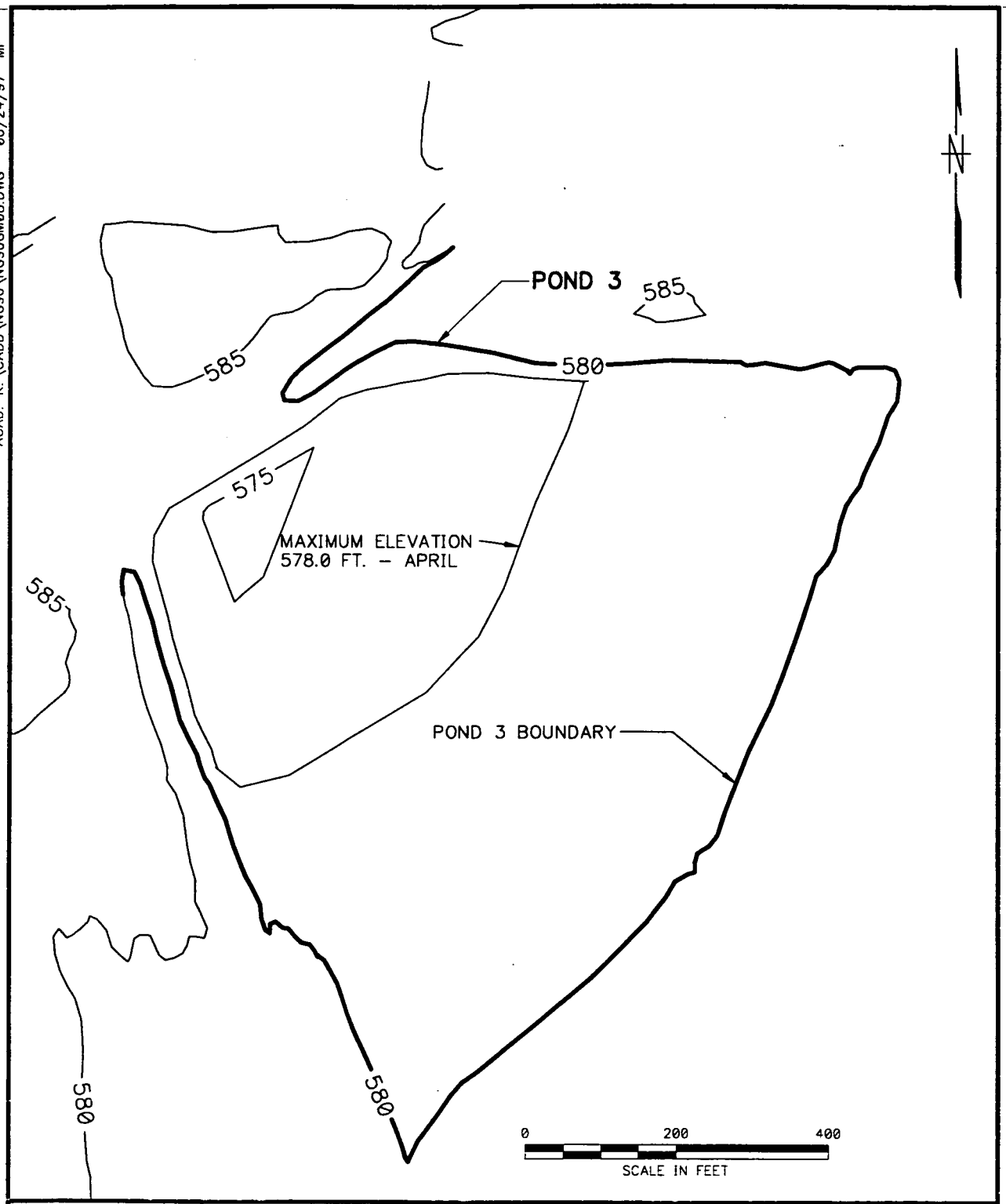

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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-5	REV. 0

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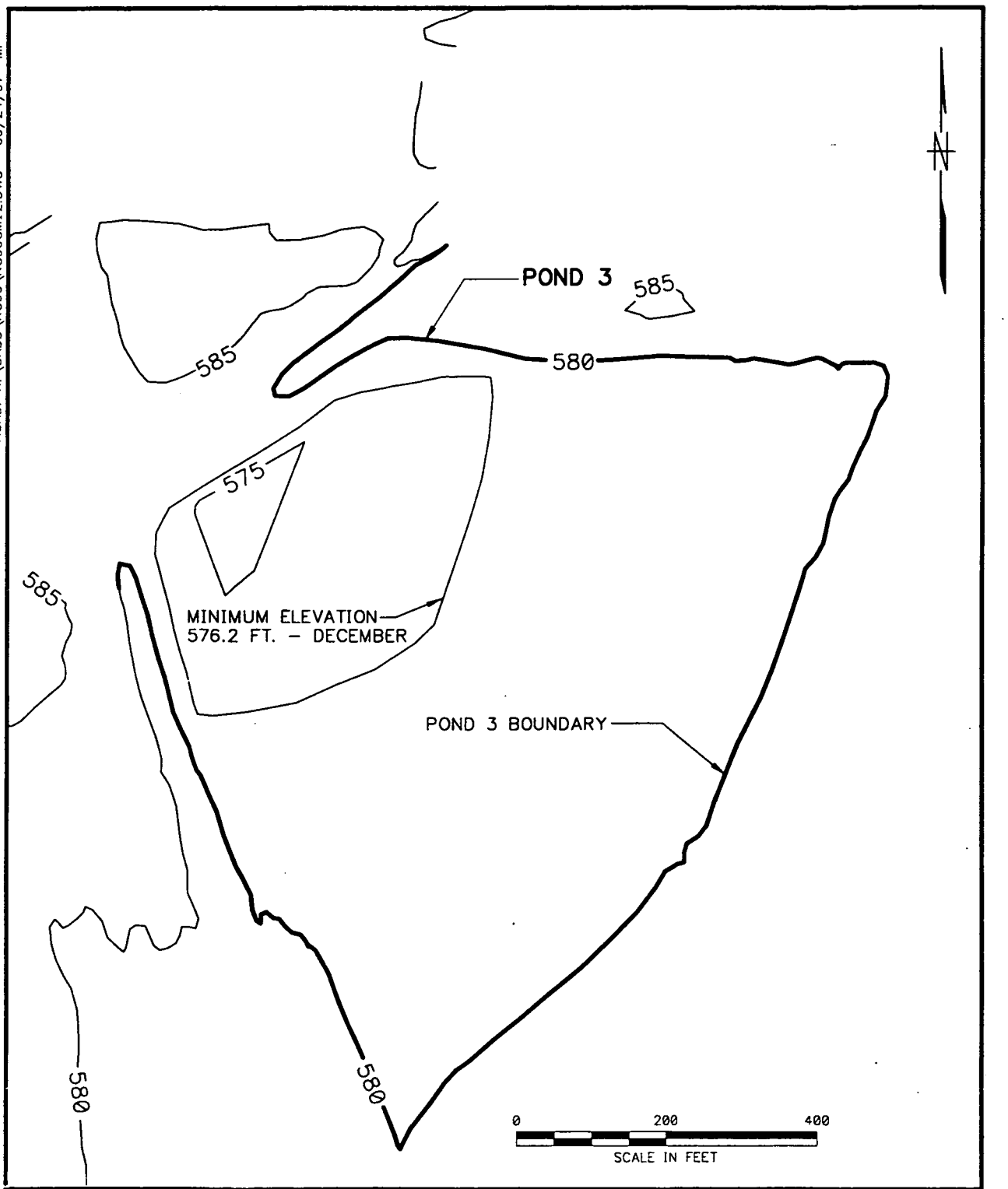

DRAWN BY GMF DATE 6/16/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 3 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MINIMUM ELEVATION FEMP	APPROVED BY DATE	
COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 4-6	REV. 0

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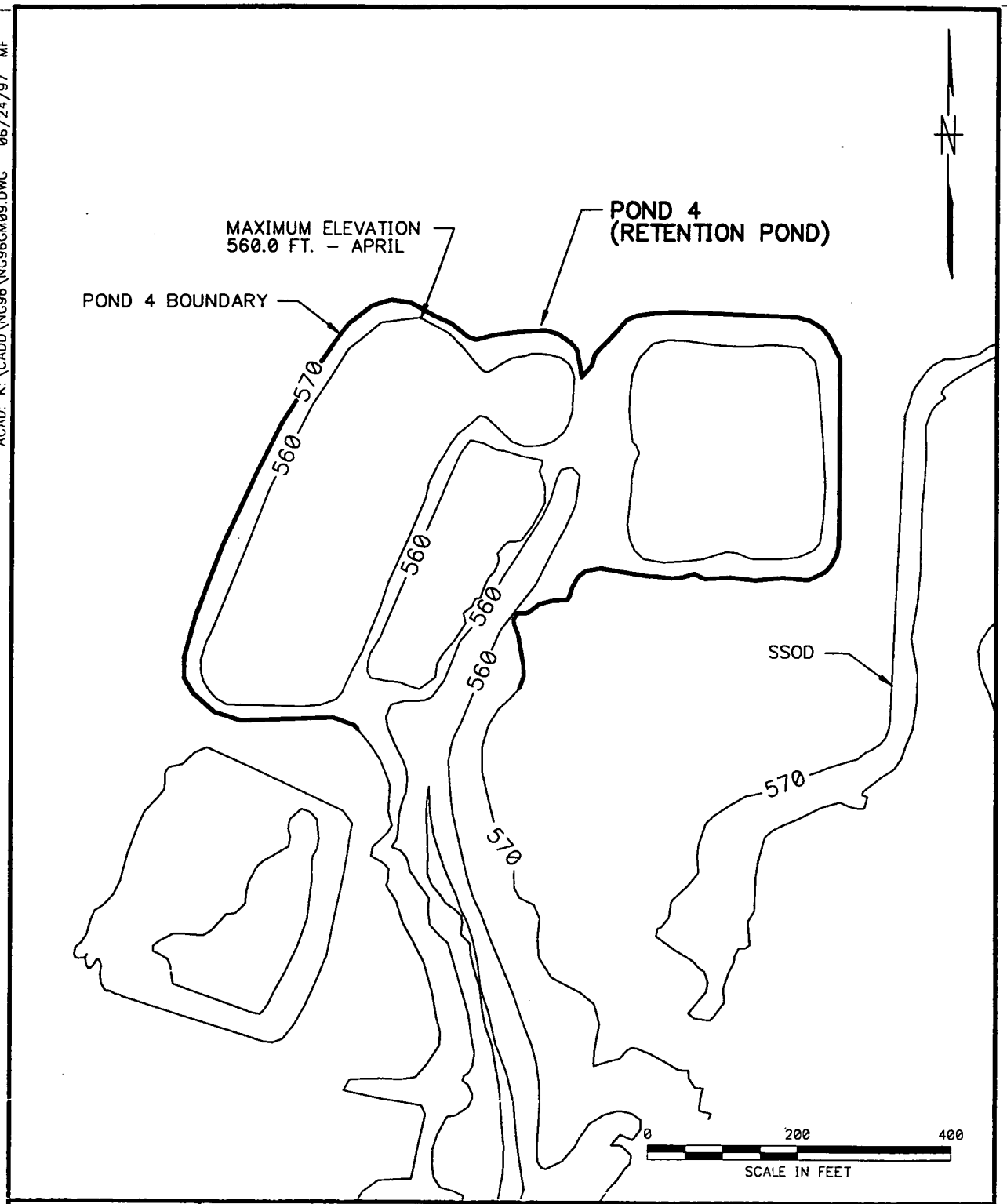

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CHECKED BY DATE	POND 4 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-7	REV. 0

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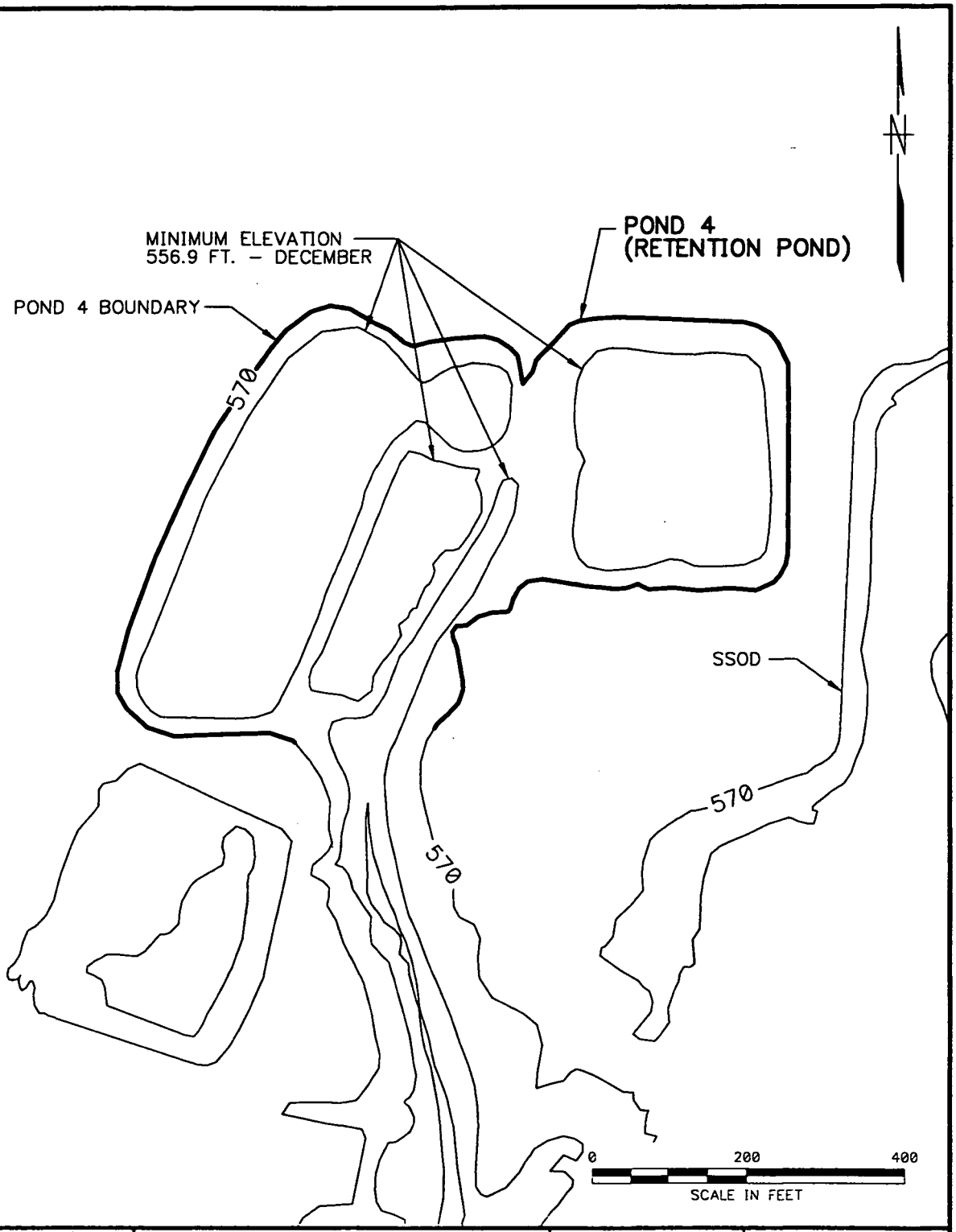

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CHECKED BY DATE	POND 4 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MIMIMUM ELEVATION FEMP	APPROVED BY DATE	
COST/SCHED–AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 4–8	REV. 0

FORM CADD NO. SOUTH_AV.DWG – REV 0 – 02/07/97

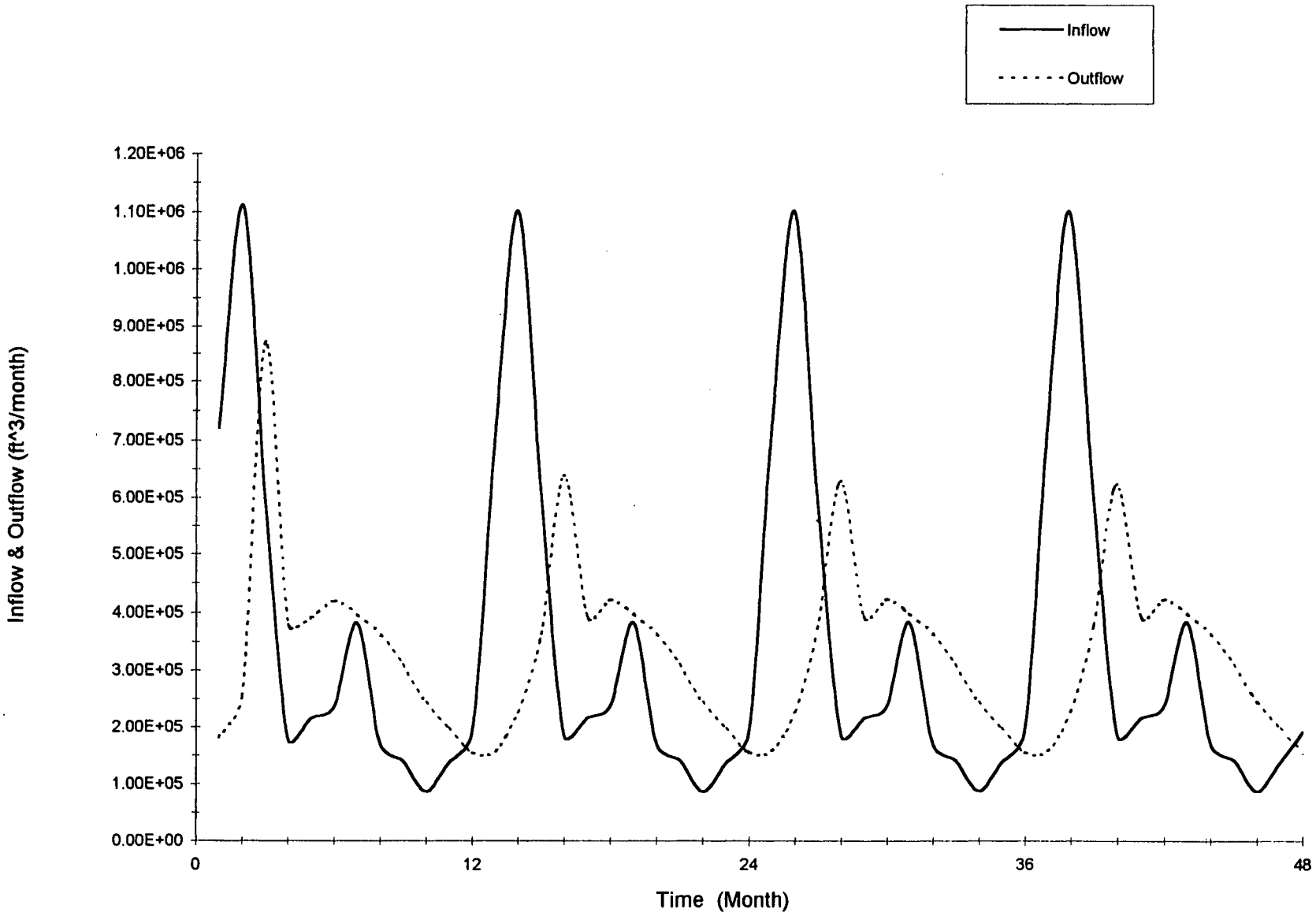

Figure 4-9 Monthly Inflow And Outflow Rates of Pond 1

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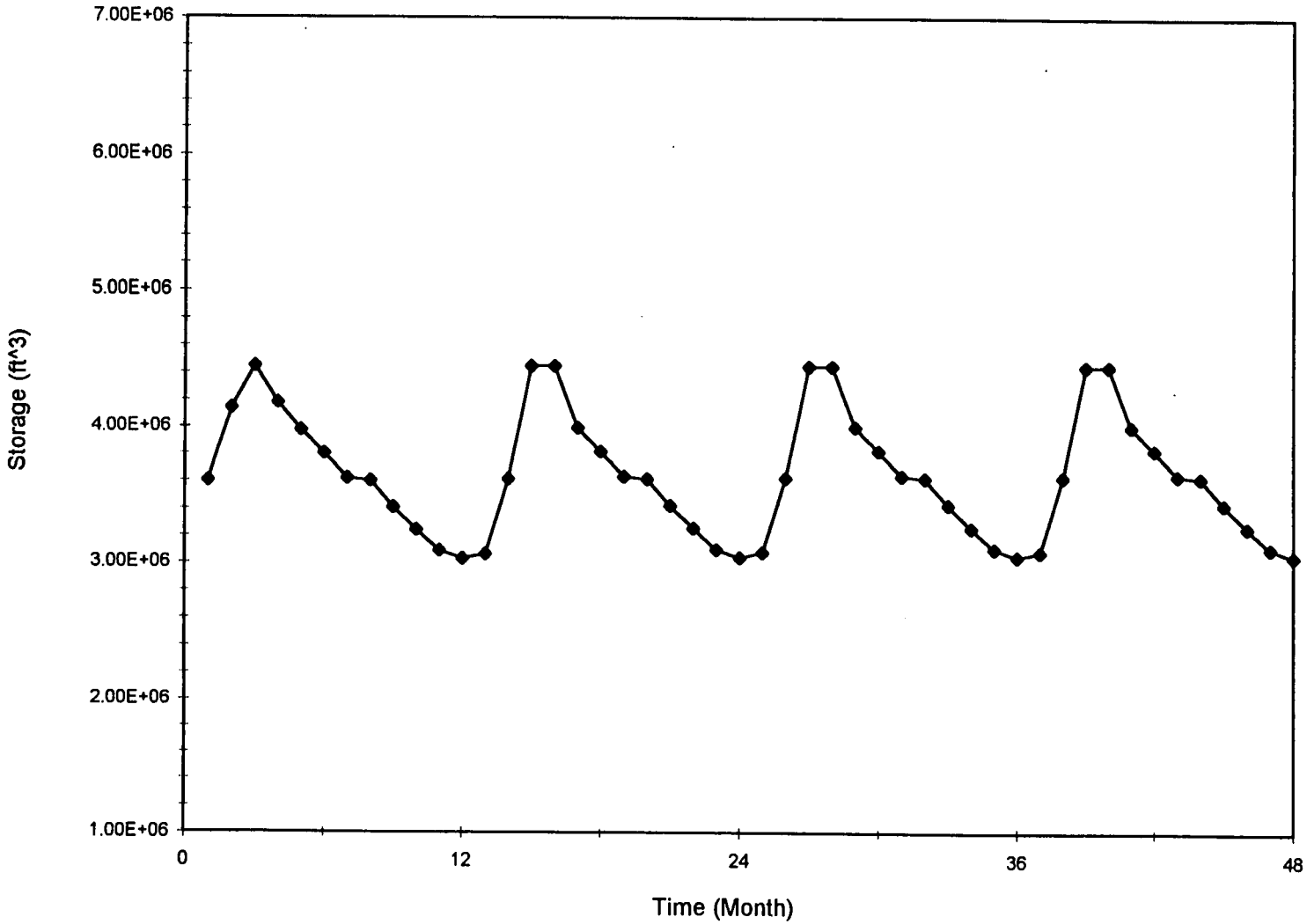

Figure 4-10 Monthly Storage Variations of Pond 1

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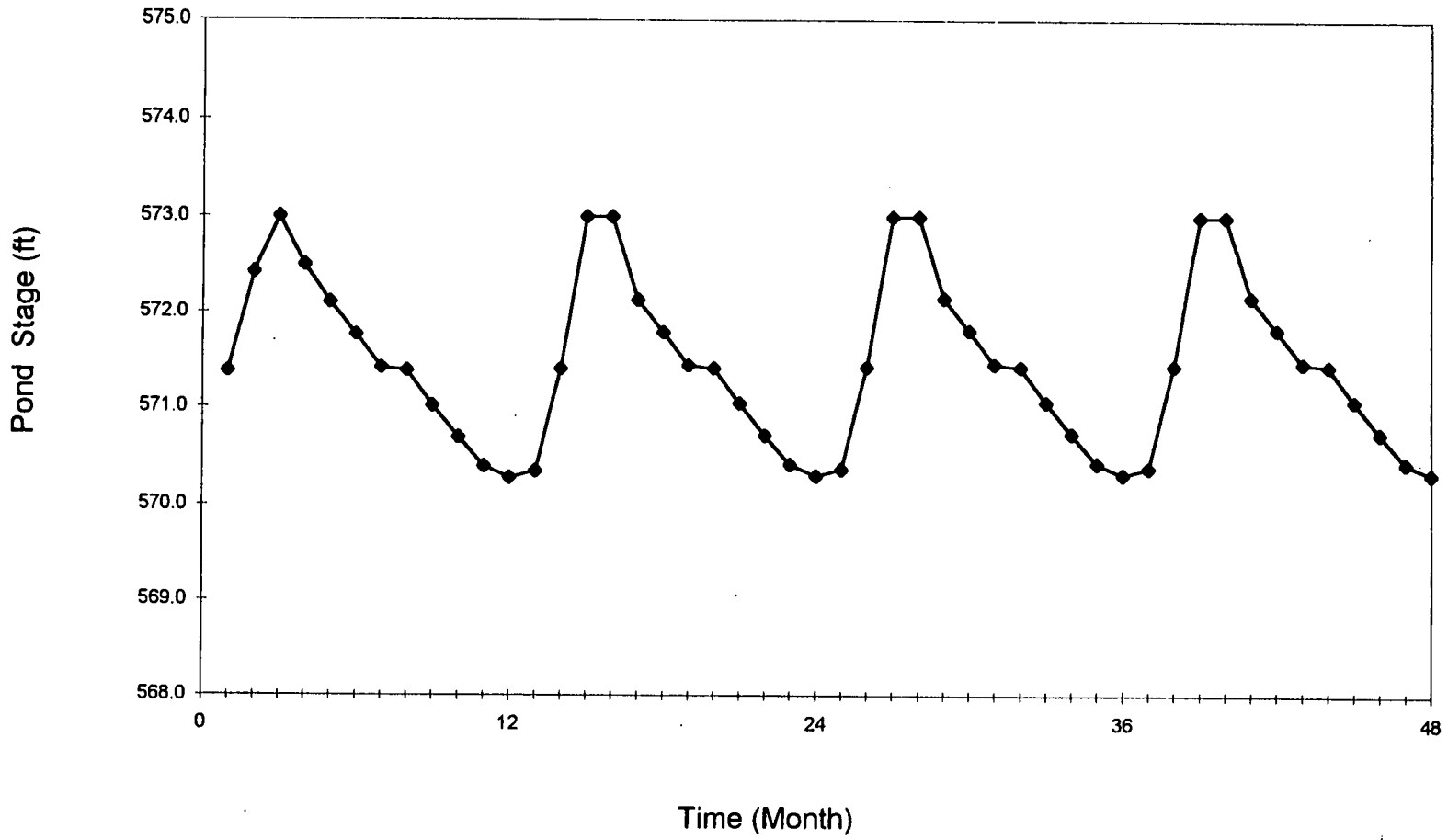

Figure 4-11 Monthly Stage Variations of Pond 1

000250

4873

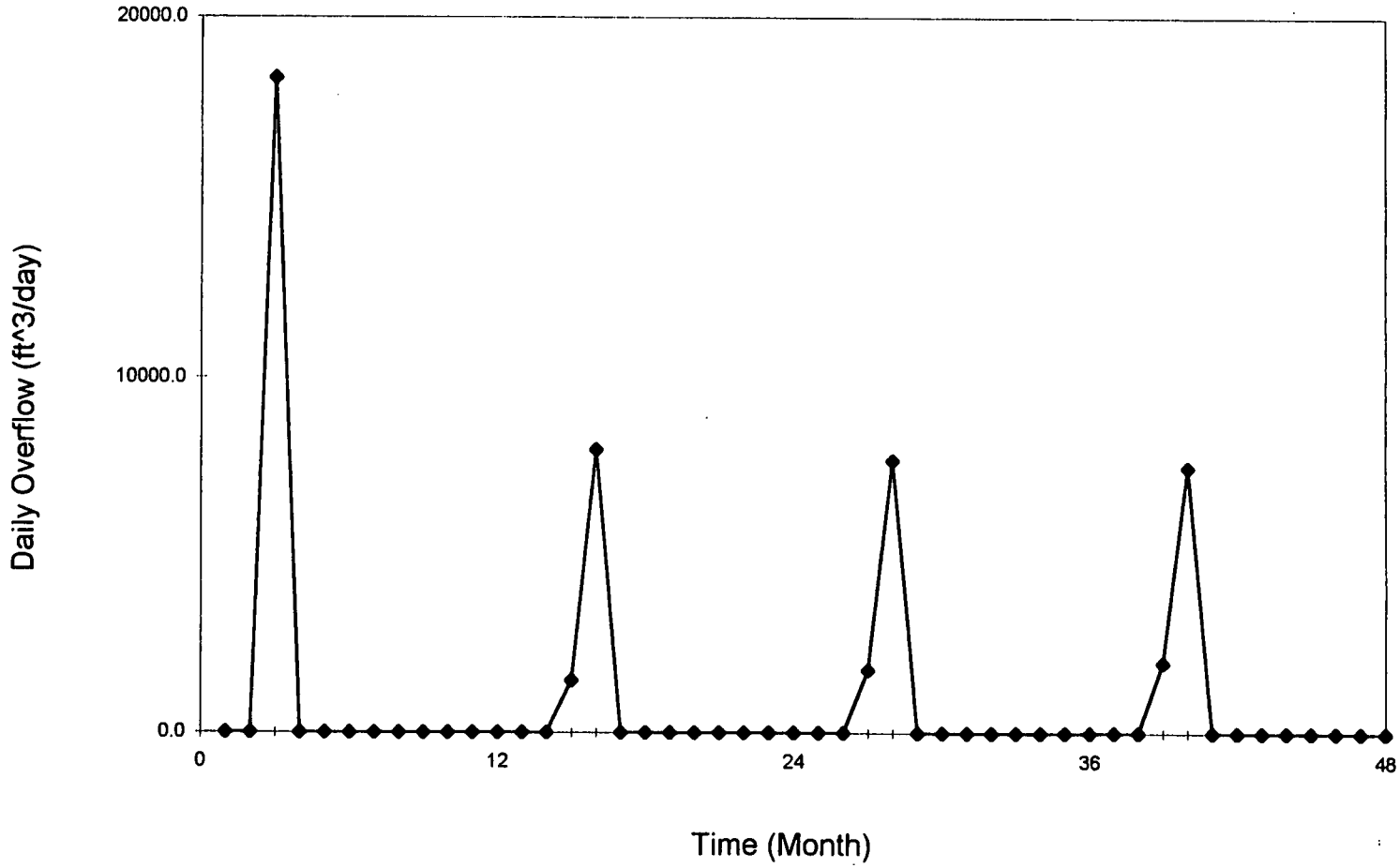

Figure 4-12 Daily Overflow Rates of Pond 1

000251

48 73

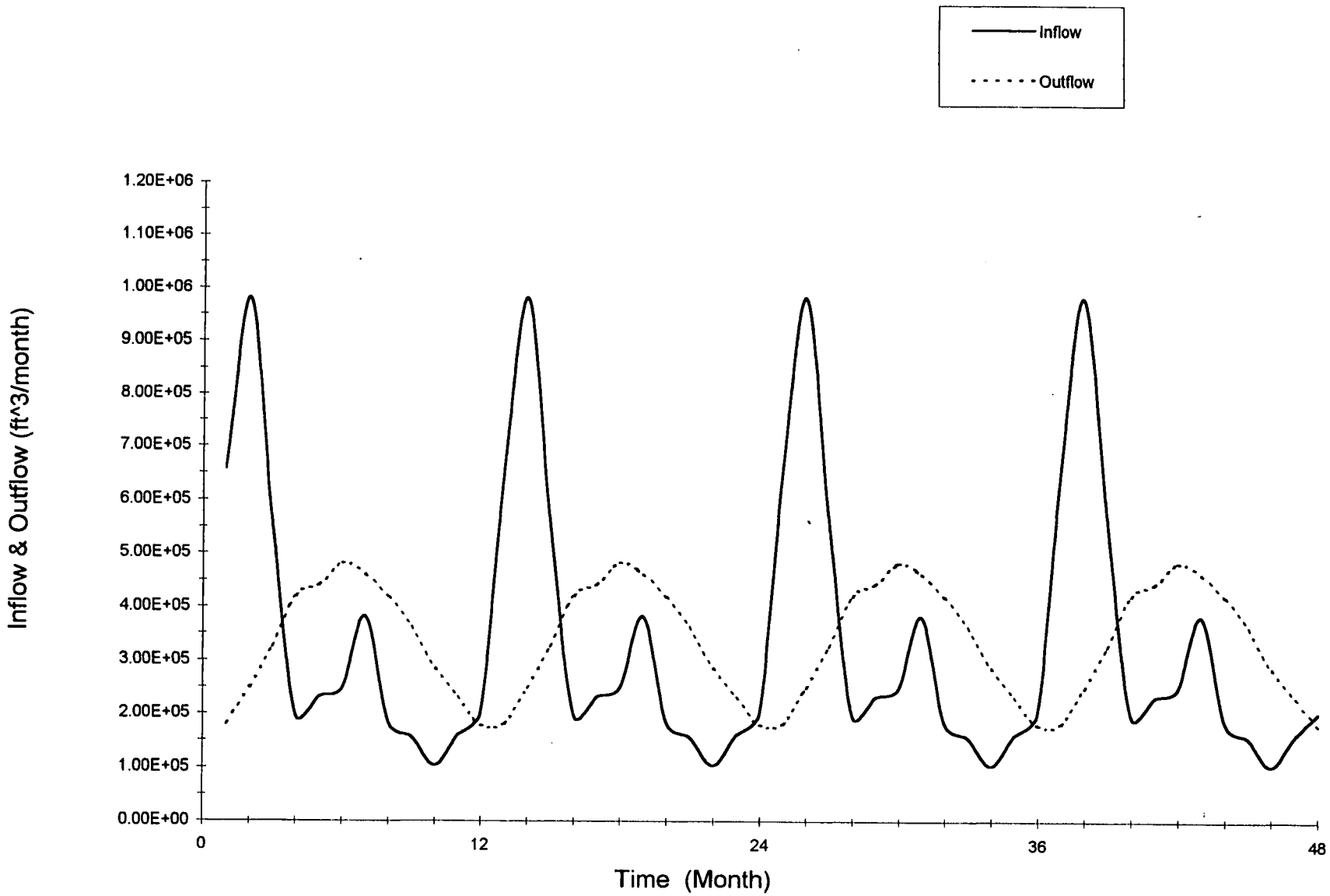

Figure 4-13 Monthly Inflow And Outflow Rates of Pond 2

000252

4873

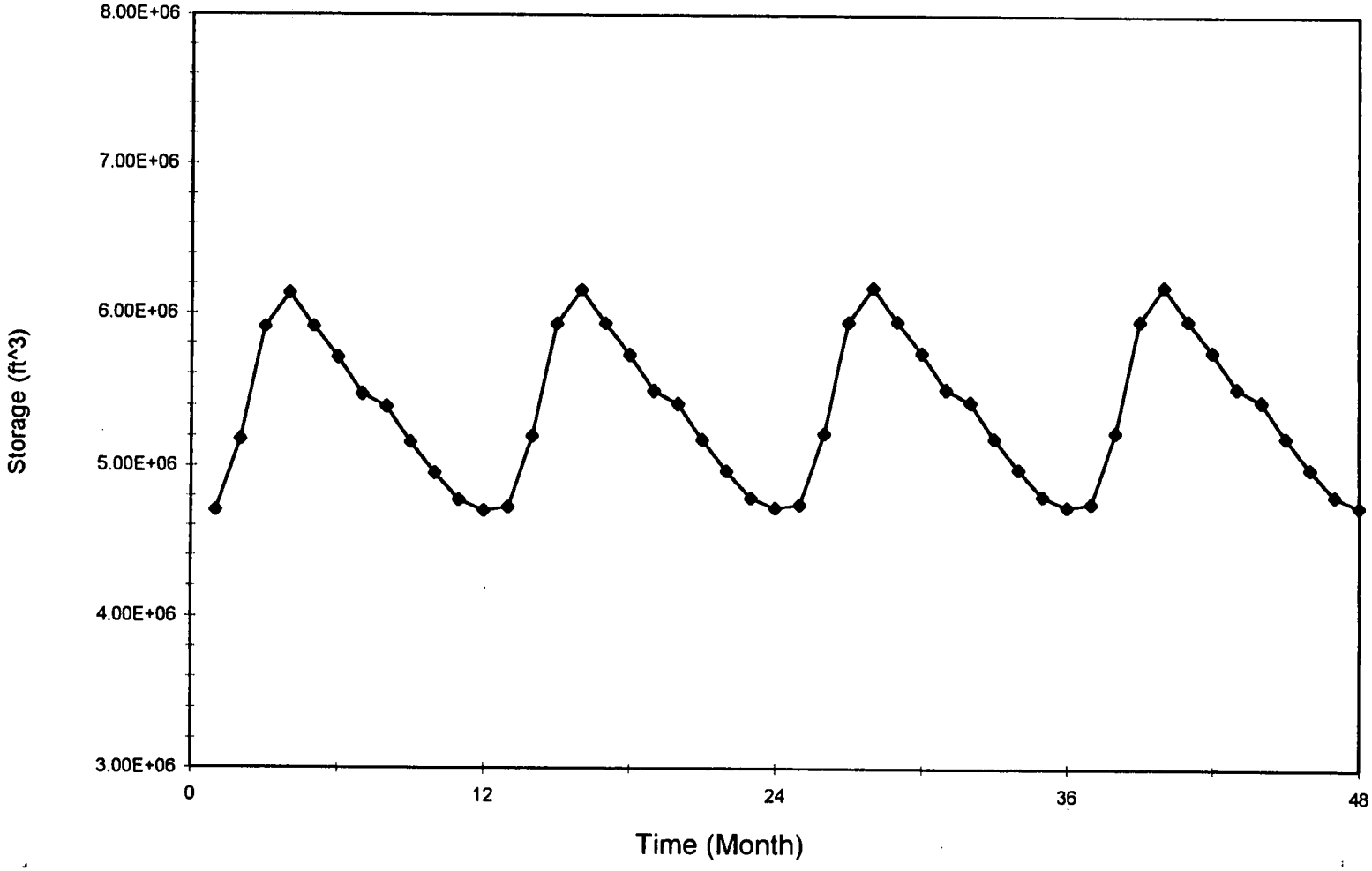

Figure 4-14 Monthly Storage Variations of Pond 2

000253

4873

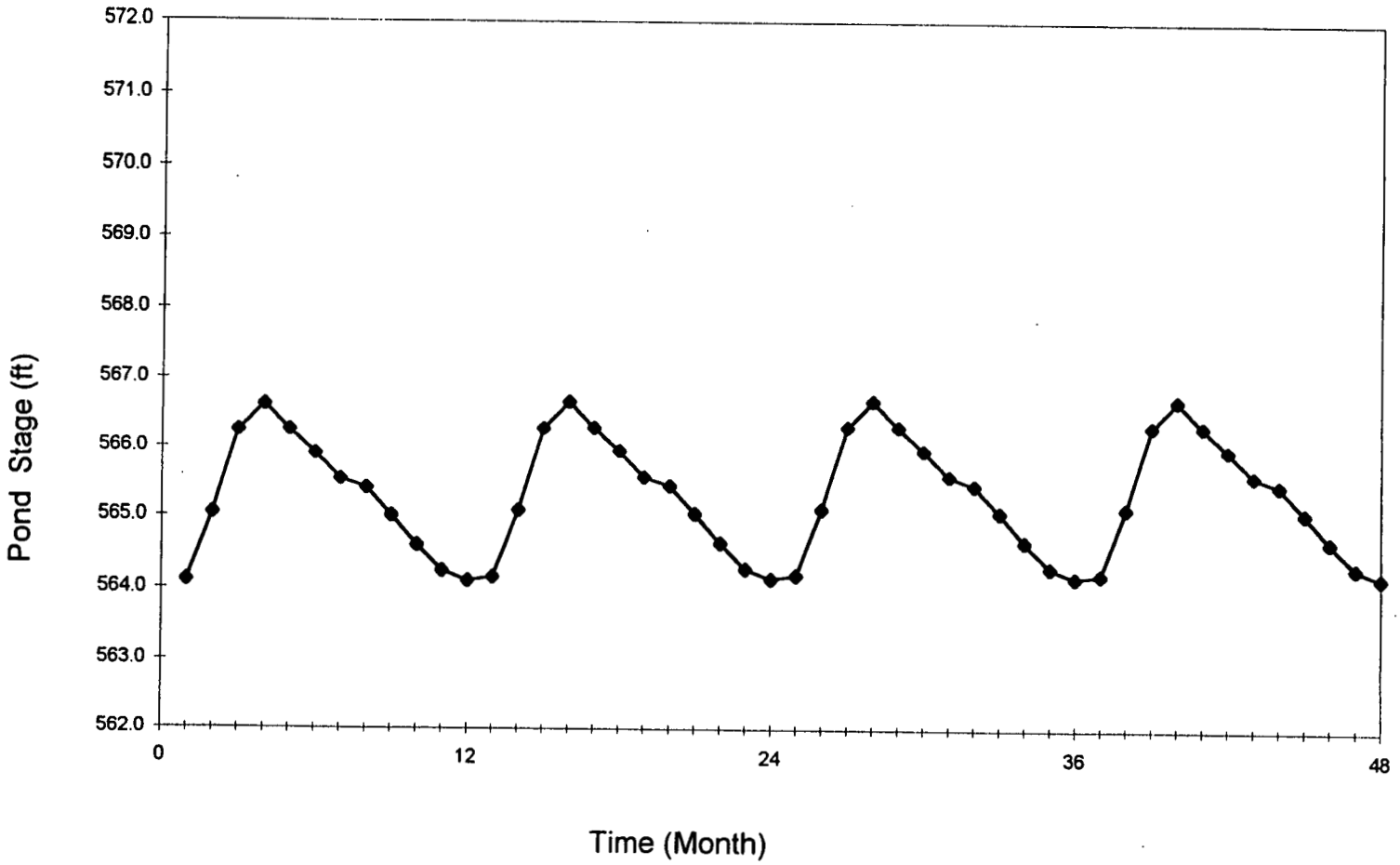

Figure 4-15 Monthly Stage Variations of Pond 2

000254

4873

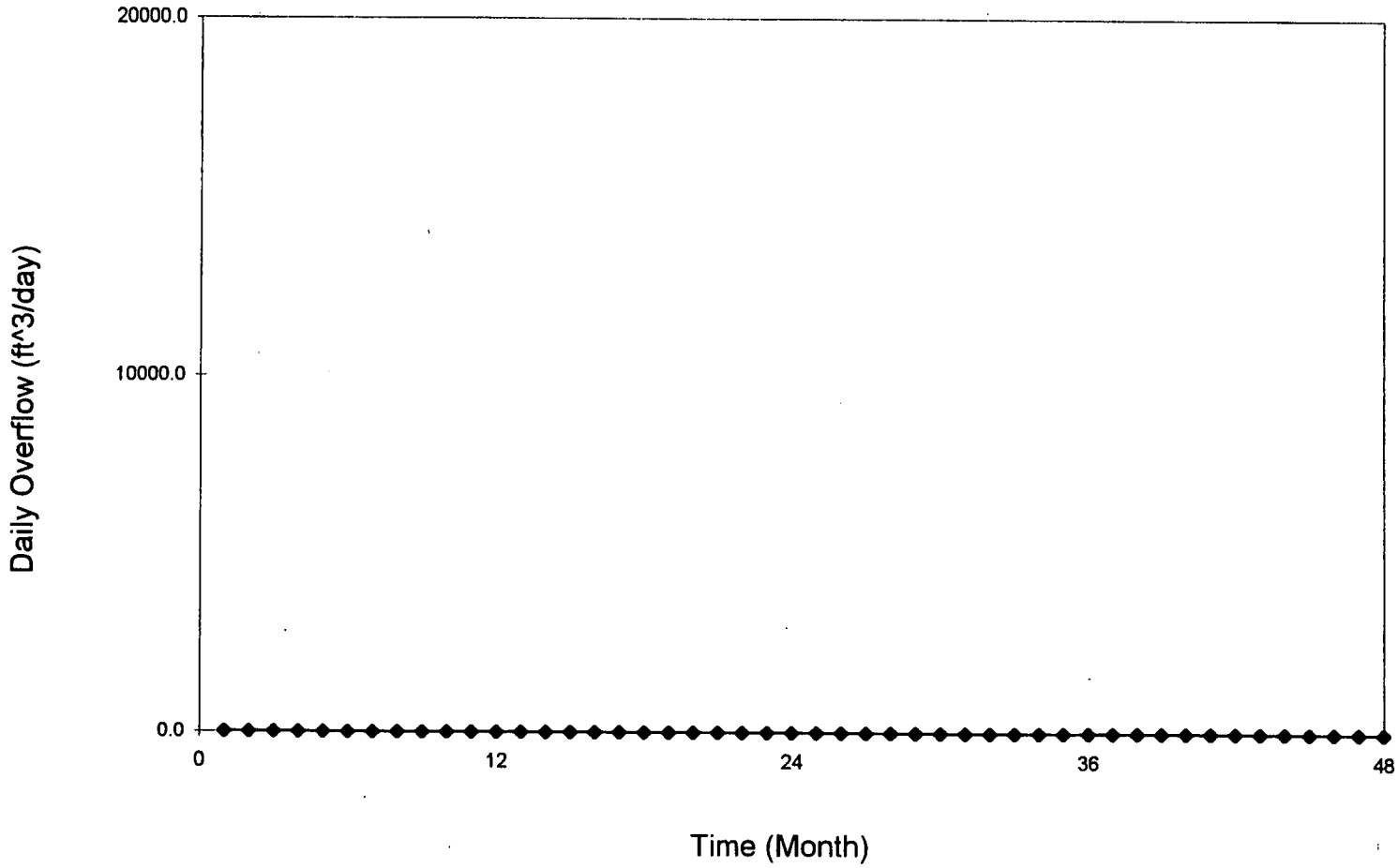

Figure 4-16 Daily Overflow Rates of Pond 2

000255

4873

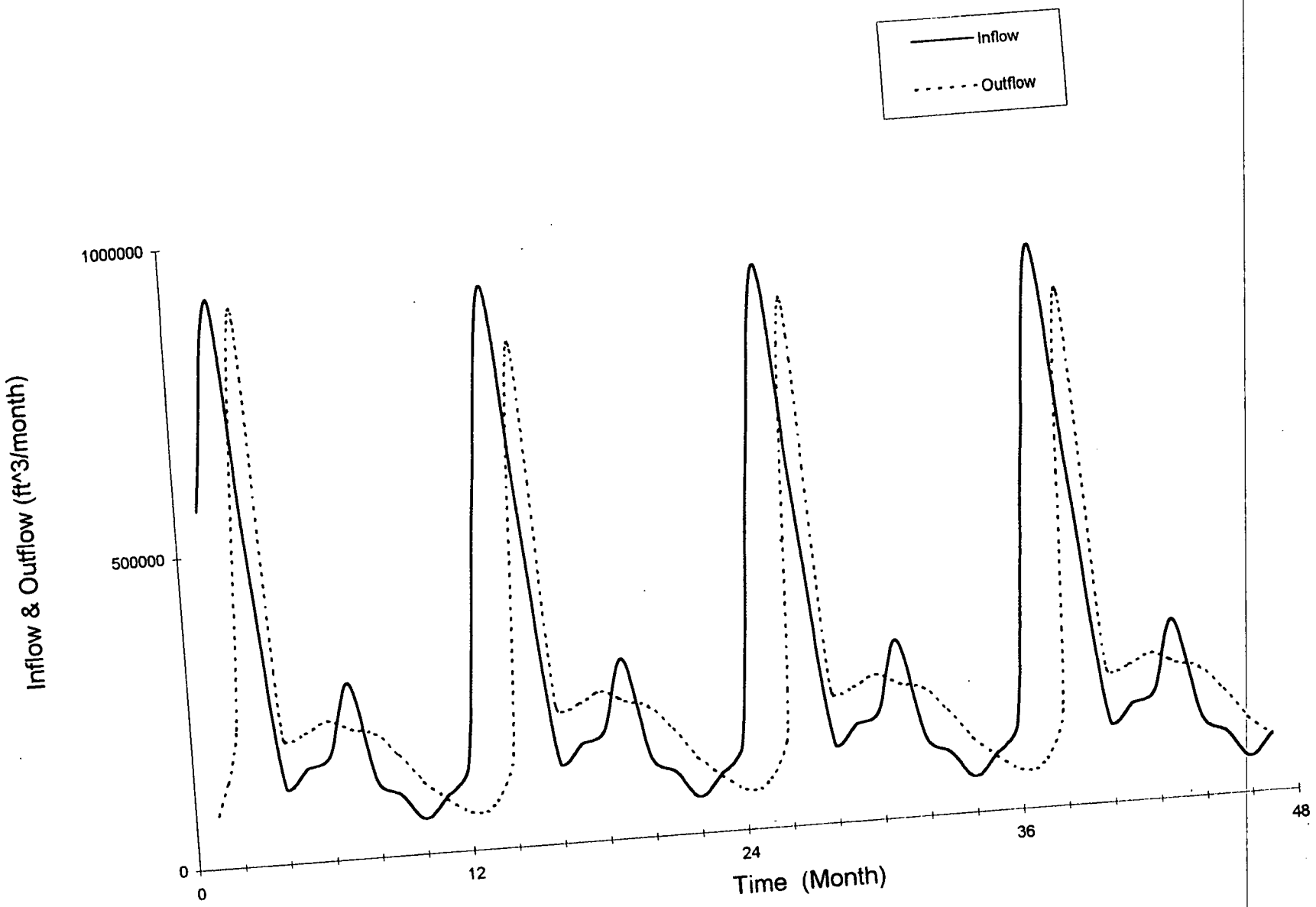

Figure 4-17 Mont[illegible] Inflow And Outflow Rates of Pond 3

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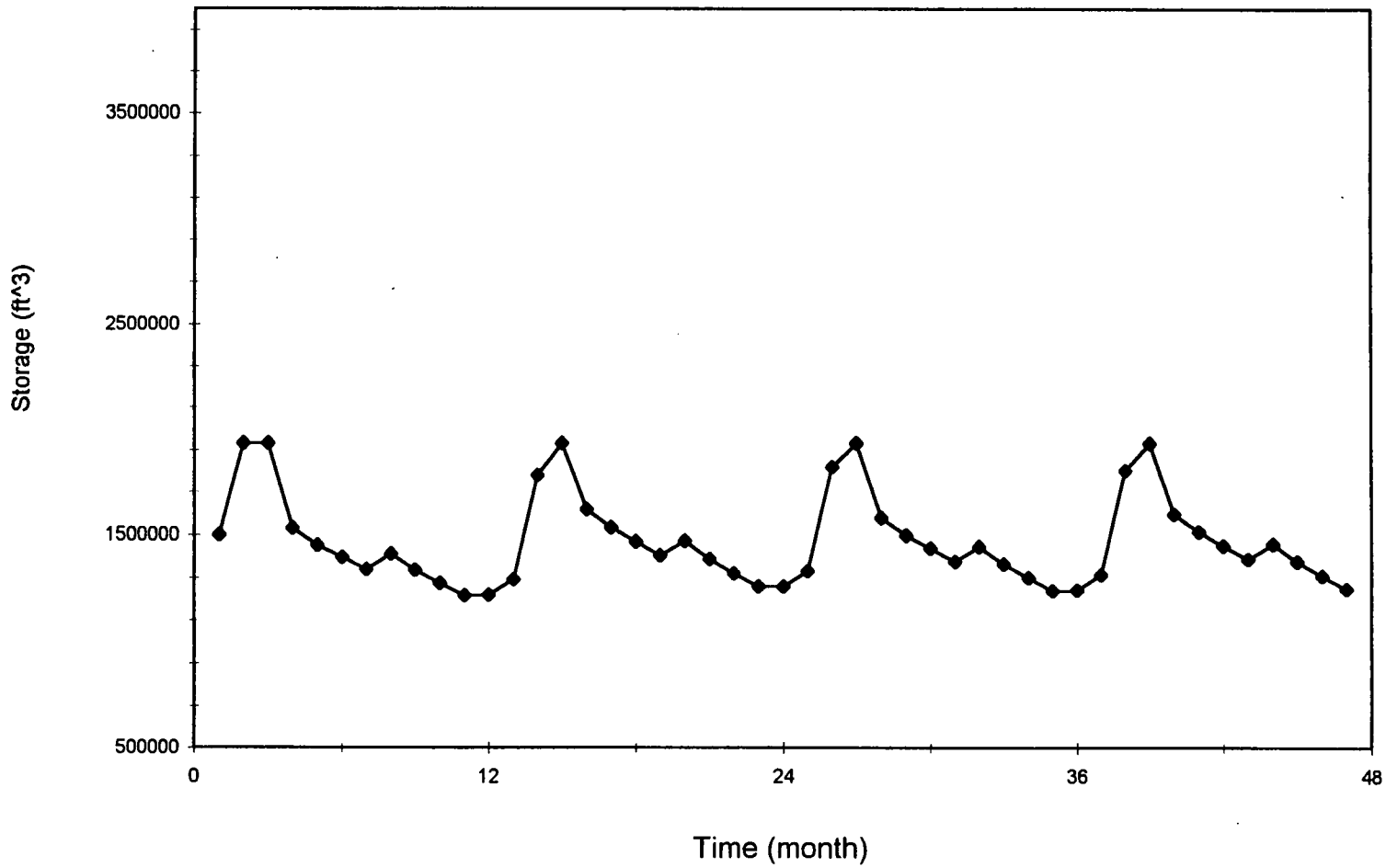

Figure 4-18 Monthly Storage Variations of Pond 3

0002257

48 73

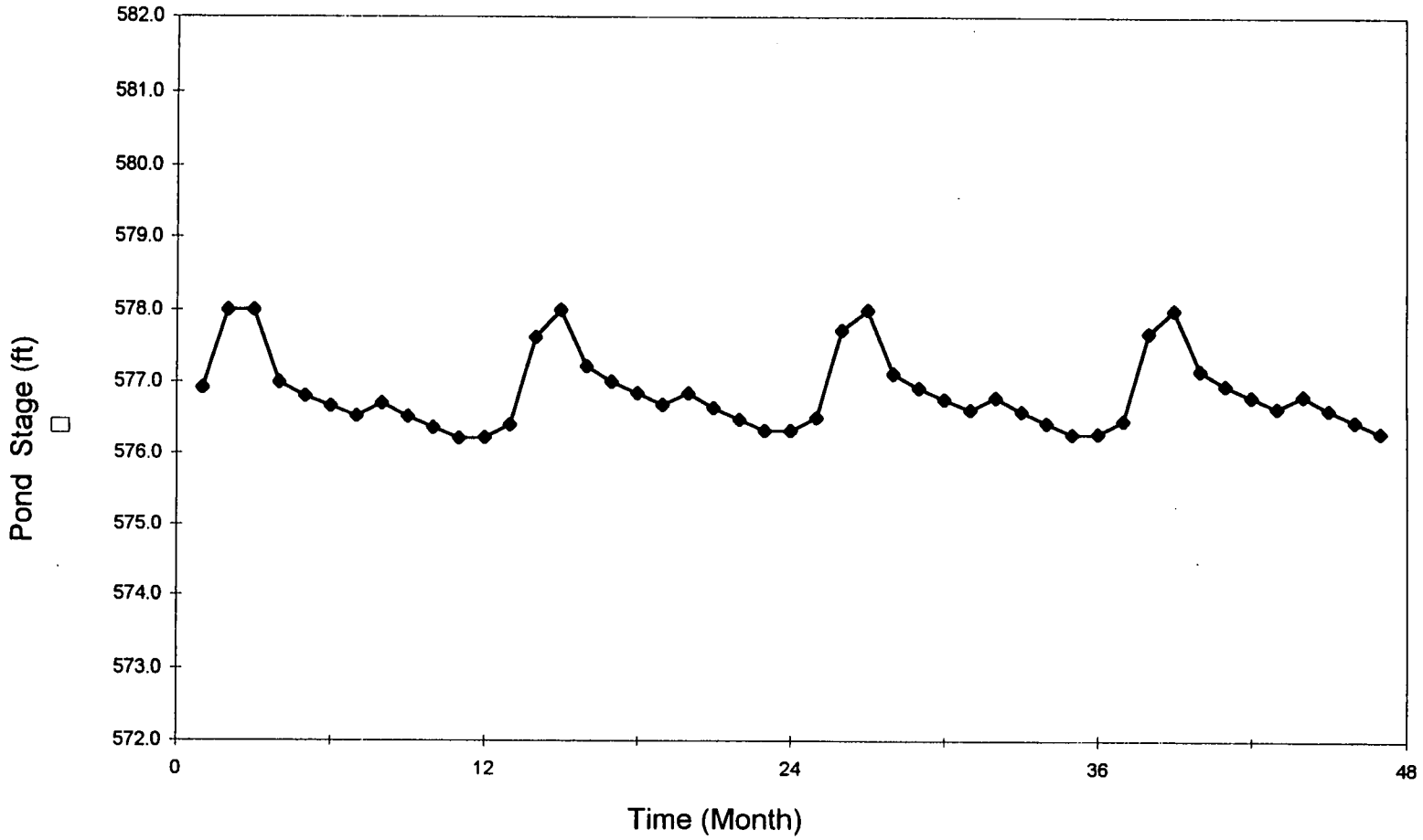

Figure 4-19 Monthly Stage Variations of Pond 3

000258

4873

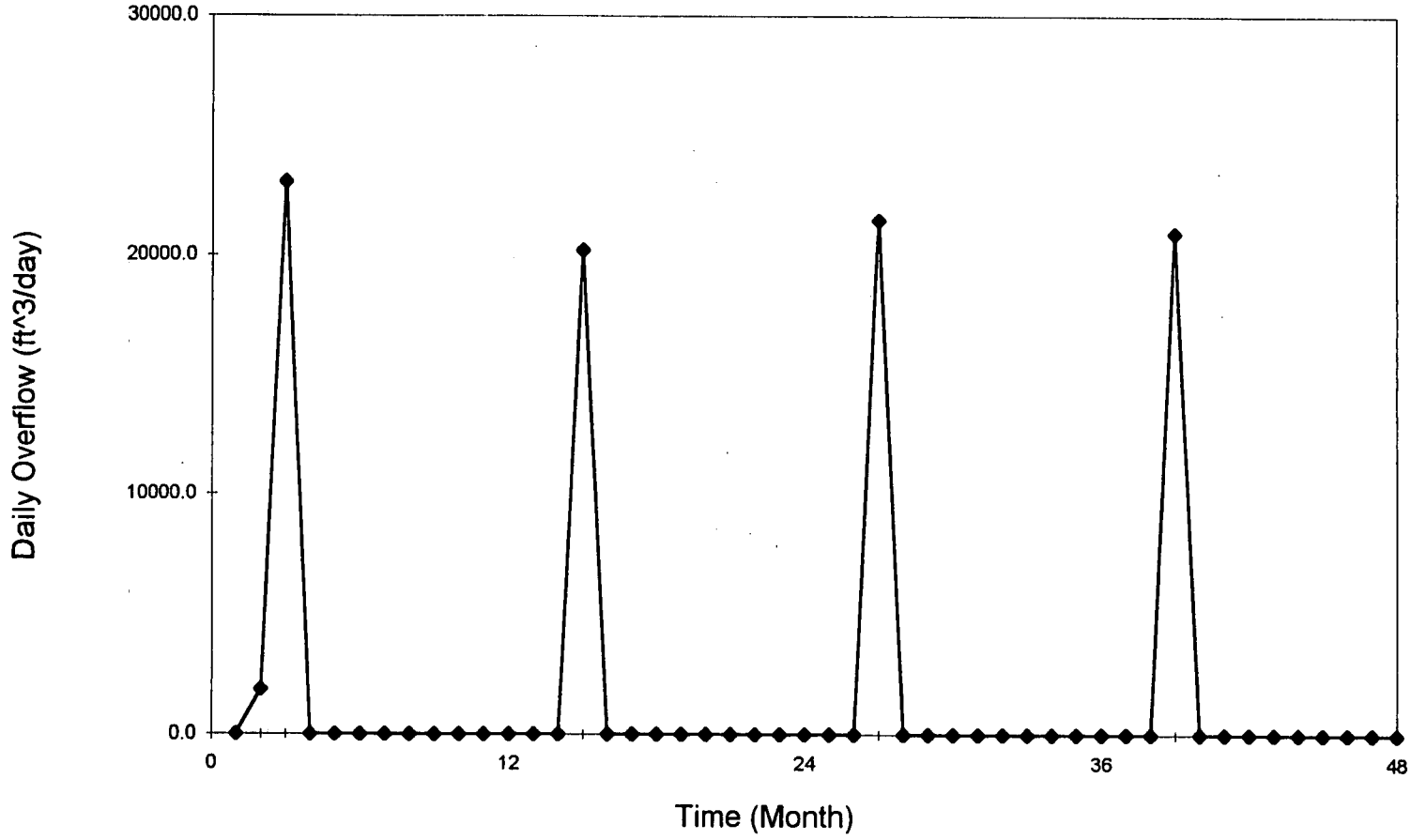

Figure 4-20 Daily Overflow Rates of Pond 3

000259

48 73

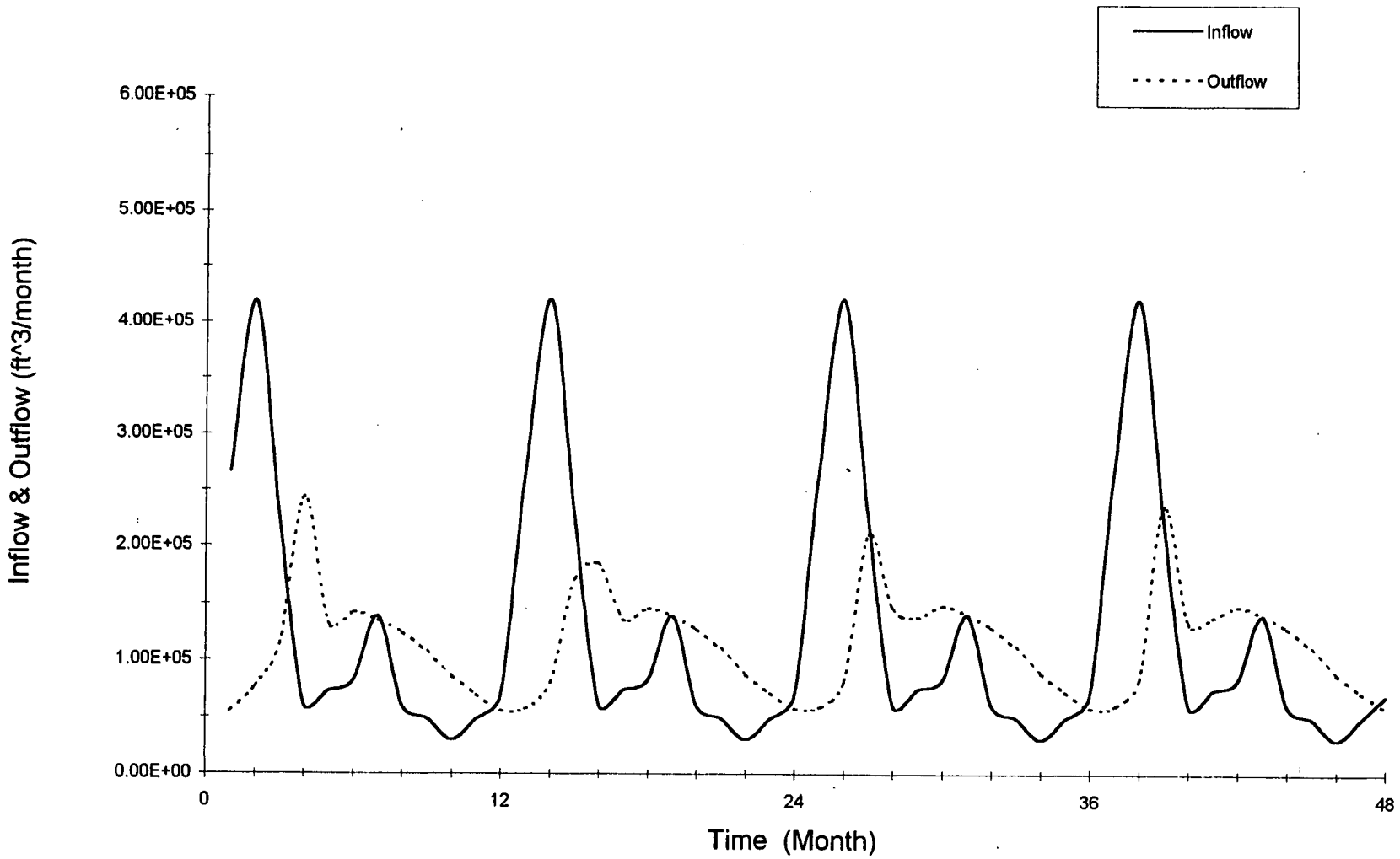

Figure 4-21 Monthly Inflow And Outflow Rates of Pond 4

000260

4873

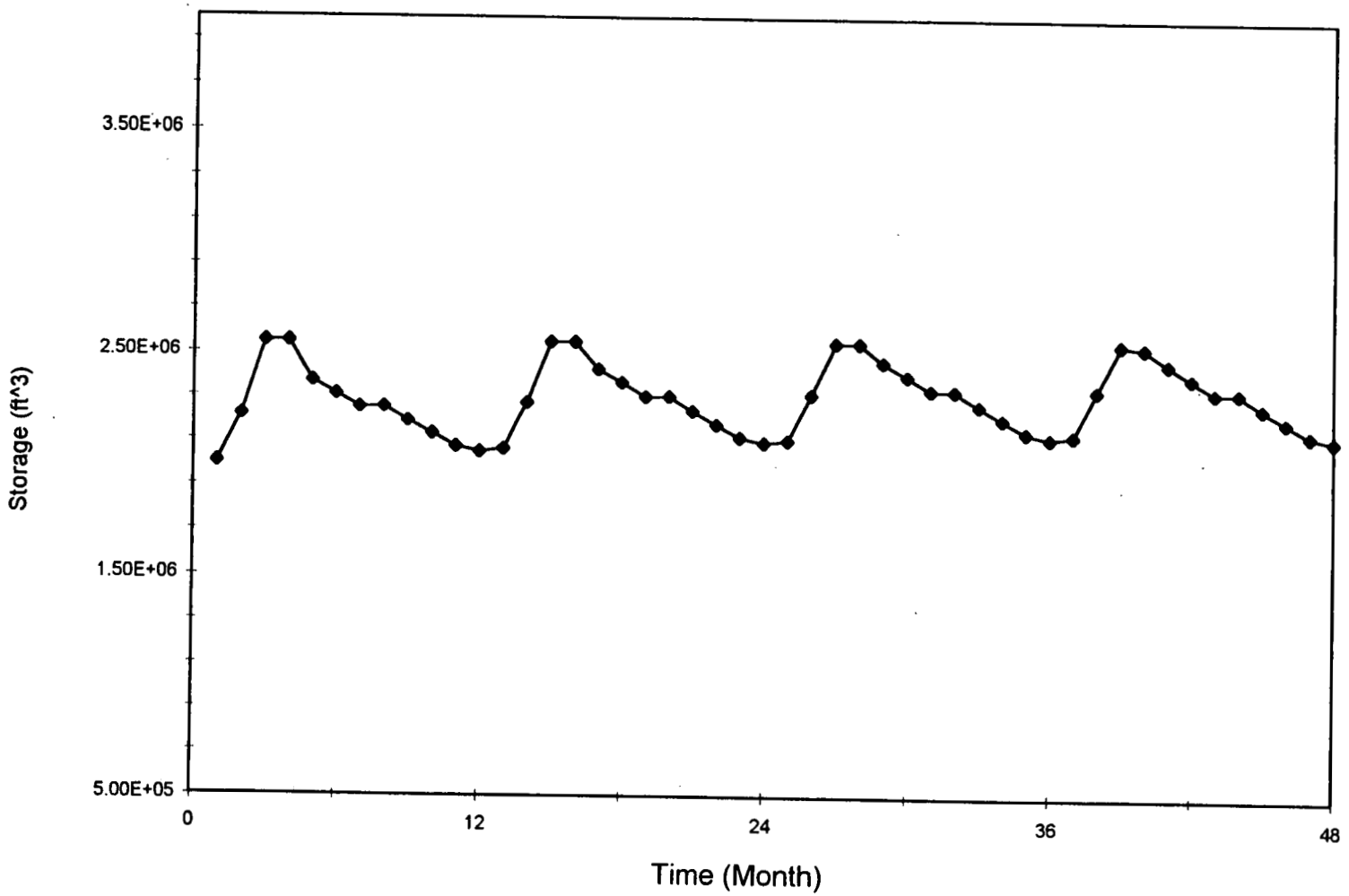

Figure 4-22 Monthly Storage Variations of Pond 4

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48 73

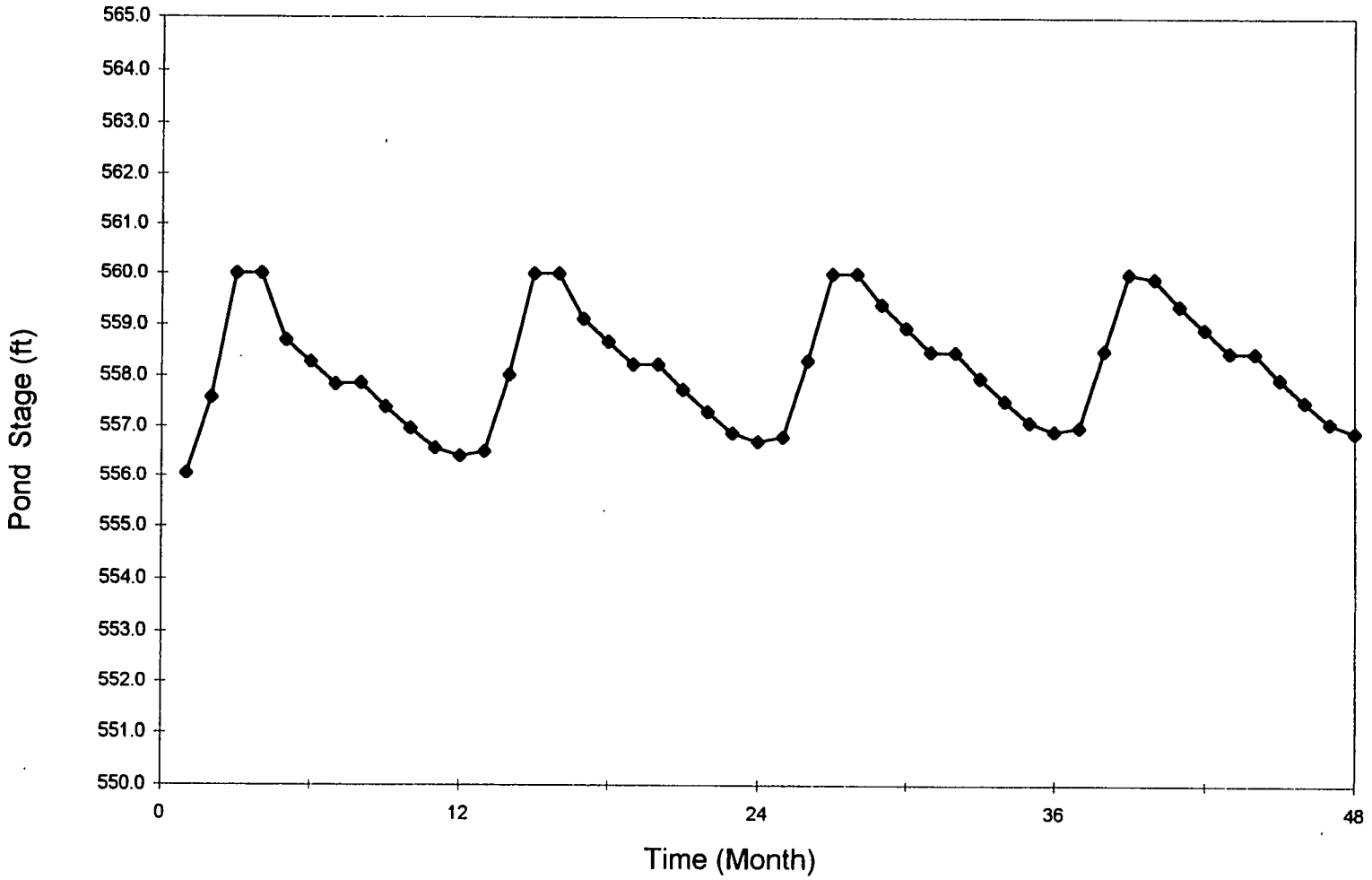

Figure 4-23 Monthly Stage Variations of Pond 4

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578A

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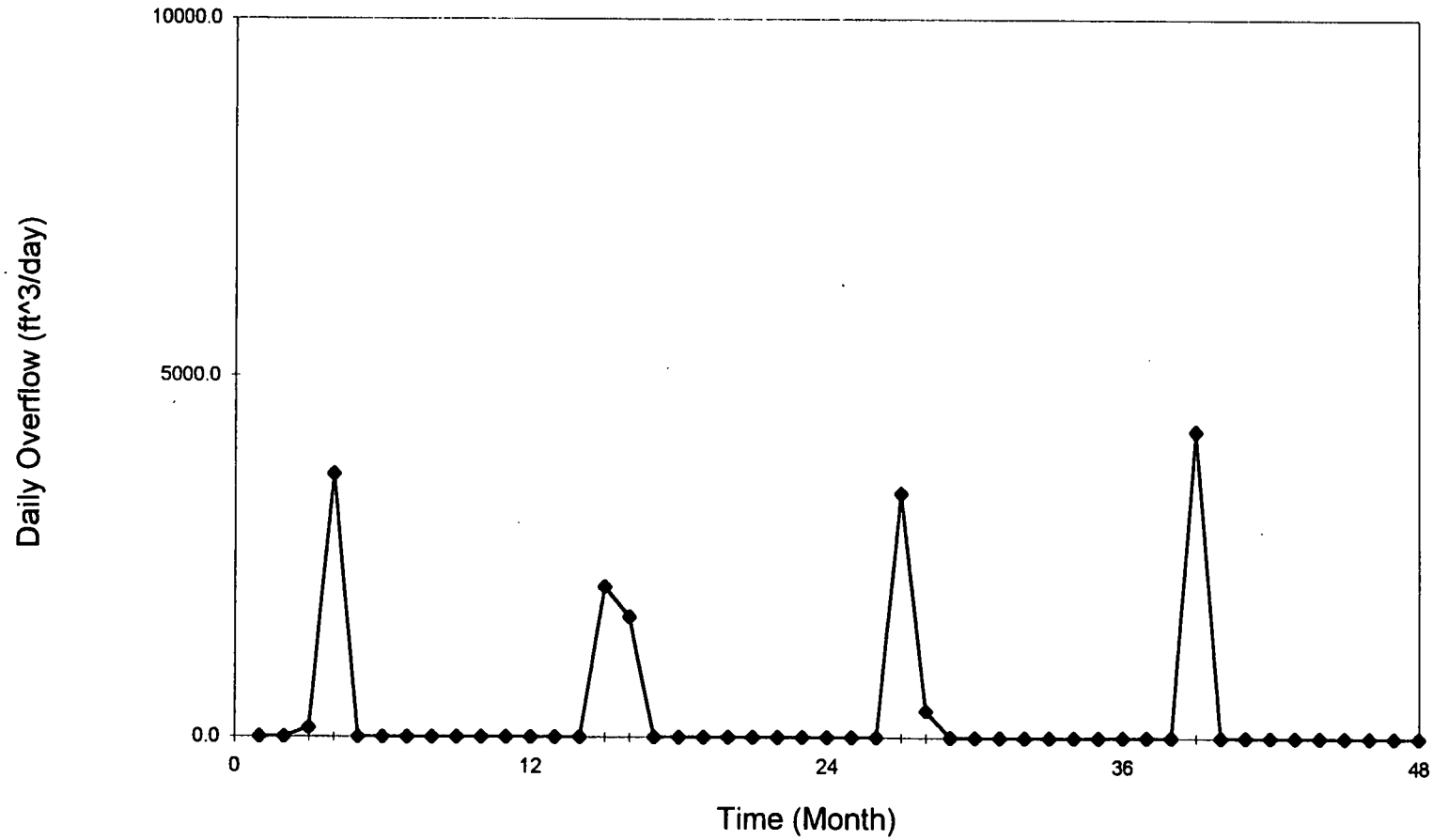

Figure 4-24 Daily Overflow Rates of Pond 4

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5.0 POND MODELING RESULTS UNDER EXTREME CONDITIONS

This section presents the storage routing modeling results under extreme conditions. The extreme conditions can be simulated by a storm event. The peak inflow rates generated by a storm event were modeled by using the TR55 method that is suitable for small watersheds. The characteristic storm typically considered in the TR55 method is a storm with a 25-year return period and a 24-hour duration. The input parameters and a brief description of inflow runoff routing using the TR55 method will be given first, then followed by the summary of modeling results generated by this characteristic storm.

5.1 INPUT PARAMETERS

The input data to the routing model used for the extreme conditions are briefly summarized in this subsection.

Drainage Area. The drainage areas are the total of their corresponding multiple subbasins. The drainage areas used in the TR55 method are the same as the normal conditions. Table 2-1 presents the areas of the subbasins that contribute runoff to each individual pond. Appendix B also presents the drainage areas and subbasin areas.

The following four parameters used for extreme conditions are the same as that for normal conditions.

- Pond Bottom Elevations.
- Pond Overflow Elevations.
- Groundwater Elevation.
- Pond Liner Hydraulic Conductivity.

The outflow components such as evaporation and infiltration through the pond liner were not considered in the routing process. The reason for this simplification is justified by the insignificant amount of loss of these two components within a relatively short period of the routing process (about three to five days).

Curve Number. A CN value of 74 was selected, based on site watershed hydrological soil groups.

25-year, 24 hour Rainfall Depth. A total of 4.7 inches of precipitation was selected from the Rainfall Frequency Atlas of the United Stated, TP No. 40.

Two-year, 24-hour Rainfall Depth. A total of 2.9 inches of precipitation was selected from the Rainfall Frequency Atlas of the United Stated, TP No. 40.

Other input parameters used in the TR55 method for characterizing the subbasins are Manning's roughness coefficient, land slope, flow length and flow width, and natural channel slope.. This data is also presented in Appendix B for each individual pond.

5.2 ROUTING HYDROGRAPH USING TR55 METHOD

Technical Release No. 55 (TR55), "Urban Hydrology for Small Watersheds," was originally developed by the United States Soil Conservation Service (SCS) in the 1970's, and was revised in 1986. TR55 was used to provide a hydrologic method for small watersheds. The Tabular Hydrograph Method is utilized for modeling multiple subareas that contribute runoff to one common design outfall point in a watershed. As a general guideline, the Tabular Hydrograph Method is applicable to a watershed with subbasin time of concentration between 0.1 and 2.0 hours, and subbasin travel time from 0.0 to 3.0 hours. For complicated watersheds, watersheds can be broken up into multiple subbasins such as the one shown in Figure 1-1. The effects of ground cover, time of concentration, reach routing times, drainage area, and precipitation for each subbasin can be taken into account independently first. Subsequently, it generates each subarea's runoff hydrograph and individually routes it to the watershed's outfall all in one step. All of the subarea's routed hydrographs are then summed directly at the watershed's outfall to obtain a composite hydrograph. Table 2-1 and Figure 1-1 presents the multiple subbasins that are related to their drainage areas.

5.3 POND INITIAL STAGES AND STORAGE

In order for the model to be conservative, the maximum storage volume predicted under normal conditions was used as the initial storage of the ponds, in addition to the peak discharge generated by a 25-year and 24-hour storm event. Table 5-1 presents the initial stage and corresponding storage of the four open water areas.

TABLE 5-1
POND INITIAL STAGES AND STORAGE
UNDER EXTREME CONDITIONS

	Stages (feet)	Storage (ft^3)
POND 1 (Northeast of FEMP)	573	4.45×10^6
POND 2 (Northwest of FEMP)	566.33	5.96×10^6
POND 3 (Southeast of FEMP)	578	1.93×10^6
POND 4 Retention Pond	560	2.55×10^6

As indicated in the above table, the initial stage of the four ponds are also the maximum stages designed for the normal conditions, since the weirs will facilitate outflow control. With the exception of Pond 2, the weir bottom elevations have set the maximum pool levels within the ponds.

Tables D-1 through D-4 in Appendix D present the storage routing calculations for a 25-year frequency and 24-hour duration storm.

5.4 POND INFLOW AND OUTFLOW HYDROGRAPH

TR55 method will generate a composite hydrograph for each pond given the physical and hydrologic parameters for the subbasins. The time step used in storage routing computation is six minutes. The input parameters used in TR55 method such as CN value and Mannings value for grassy condition are consistent with the OSDF surface water management study prepared by Parsons. A CN value of 74 was also selected, based on site watershed hydrological soil groups. The soil groups were classified as type B and C, for Dana Eden, Fincastle, Miamian-Russel, Ragsdale, and Xenia soils. A Mannings number of 0.3 was used for a dense bermude grass.

The results indicated that Pond 1 has the highest peak inflow rates of 129 cubic feet per second (cfs), while Pond 4 (retention pond) has a lowest inflow rates given the same characteristic storm event. This

difference in peak inflow rates is directly affected by the size of their drainage areas. Table 5-2 presents the peak inflow rates and the time it takes to reach the peak inflow rates.

TABLE 5-2
PEAK INFLOW RATES AND TIME TO PEAK DISCHARGE UNDER EXTREME CONDITIONS

	Peak Inflow Rates (cfs)	Time to Peak Inflow Rates (hours)
POND 1 (Northeast of FEMP)	129	13
POND 2 (Northwest of FEMP)	117	13
POND 3 (Southeast of FEMP)	95	12.8
POND 4 (Retention Pond)	43	13.2

Figures 5-9, 5-13, 5-17, and 5-21 present inflow and outflow hydrographs for the four ponds respectively. As indicated in the hydrographs, outflow generated by this characteristic storm will generally takes 130 hours or about five days to be dissipated through the weirs. The weirs width were designed as five feet for Pond 1, 2, and 3. The weir bottom width for retention pond is 20 feet, based on the exiting configurations.

5.5 POND STORAGE VARIATION WITH TIME

Figures 5-10, 5-14, 5-18, and 5-22 present pond storage variations with respect to time for the four ponds respectively. Time to reach the peak inflow rates ranged from 12.8 to 13.2 hours (also see Table 5-2). As indicated in the hydrograph, storage variations experienced within each pond are in the same order of magnitude. This is the result of regulation through the weirs. Table 5-3 presents the storage changes for each pond.

TABLE 5-3

MAXIMUM AND MINIMUM POND STORAGE UNDER EXTREME CONDITIONS

	Maximum Storage (ft^3)	Minimum Storage (ft^3)
POND 1 (Northeast of FEMP)	4.99×10^6	4.45×10^6
POND 2 (Northwest of FEMP)	6.77×10^6	5.96×10^6
POND 3 (Southeast of FEMP)	2.36×10^6	1.93×10^6
POND 4 (Retention Pond)	2.67×10^6	2.55×10^6

5.6 POND STAGE VARIATIONS WITH TIME

Figures 5-11, 5-15, 5-19, and 5-23 present stage variations with respect to time for the four ponds respectively. The time required to reach the peak stage are the same as that for the storage cases (Table 5-2). Figures 5-1, through 5-8 present the pond water surface outline for the four ponds. As indicated in the figures, stage variations experienced in Pond 1 is wider when compared to the other three ponds. This is due to the relatively smaller water storage, but with larger drainage area. Table 5-4 presents the stage changes for each pond. Pond 2 has a higher storage capacity, since it has a smaller drainage area, but will be excavated more extensively during the soil remediation. The purpose of Pond 3 is for a temporary runoff storage. Stormwater can be freely overflowed through a weir to SSOD. Of the four ponds, Pond 4 is the smallest one. Pond 4 can also be functioned as an intermediate retention basin prior to being overflowed to the SSOD. As indicated in Table 5-4, a hydraulic connection between Pond 1 and Pond 2 would physically combine Pond 1 and Pond 2 into one pond with higher storage capacity .

TABLE 5-4

MAXIMUM AND MINIMUM POND STAGE UNDER EXTREME CONDITIONS

FEMP - POST EXCAVATION CONDITION

	Pond Stage		Pond Top
	Maximum (feet)	Minimum (feet)	Edge Elevation (feet)
POND 1 (Northeast of FEMP)	574.05	573.0	575
POND 2 (Northwest of FEMP)	567.67	566.3	575
POND 3 (Southeast of FEMP)	579.06	578.0	580
POND 4 Retention Pond	560.51	560.0	575

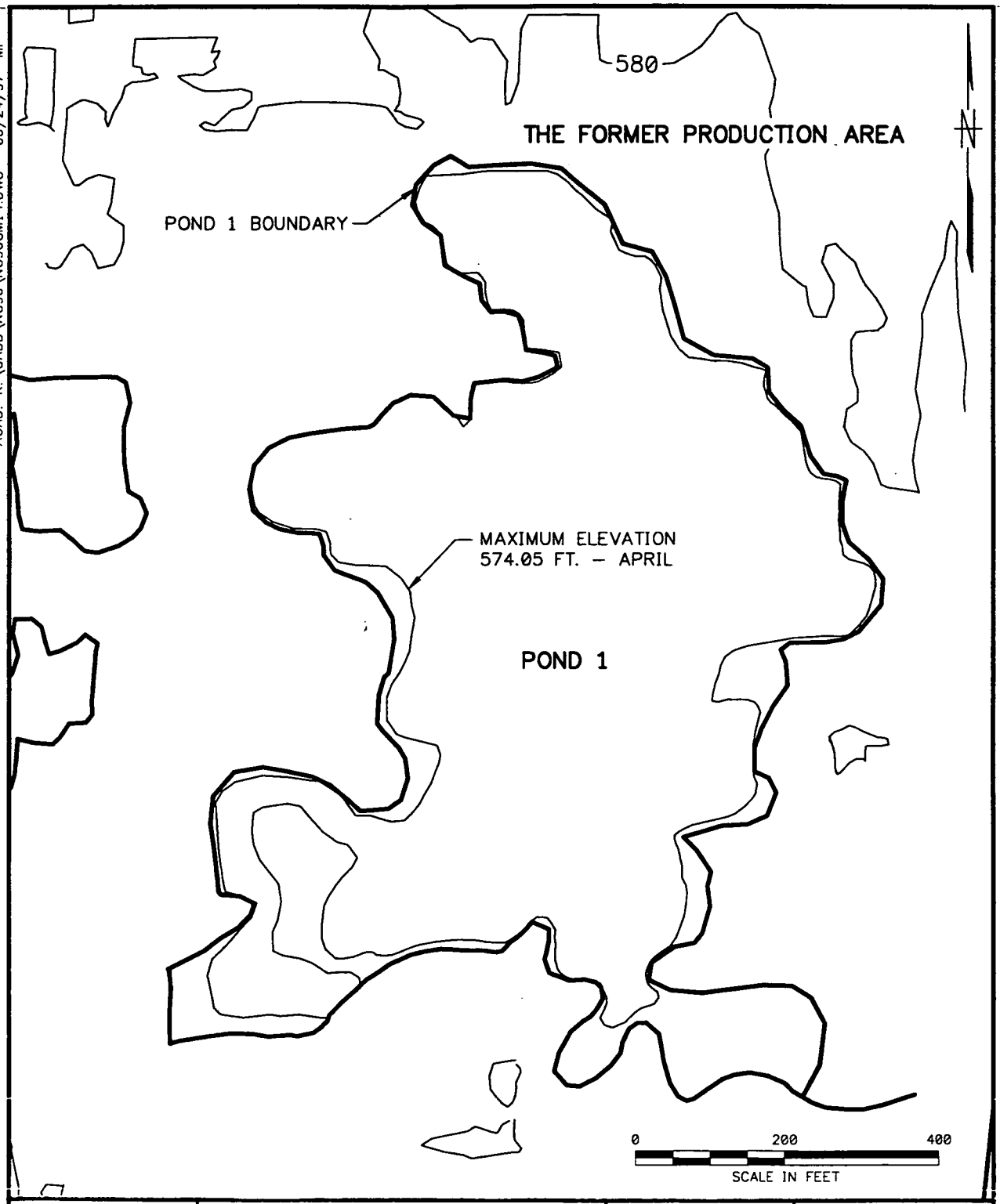
5.7 MAXIMUM AND AVERAGE DEPTH AND ACERAGE OF THE PONDS

The maximum and average depths of the ponds were estimated for each time step during the entire length of routing process. As described in Section 4.0, the maximum depth was computed as the difference between the water surface elevation and the pond bottom elevation. The average depth was determined by the ratio of the average storage and the average surface water area. Figures 5-12, 5-16, 5-20, and 5-24 present the maximum and average water depths under extreme conditions. As indicated in the figures, maximum and average water depths reach the highest when the peak inflow rates occur (about 13.0 hours). The time it takes to reach the peak inflow rates is presented in Table 5-2. The maximum water depths estimated for the four ponds, when the peak inflow rates appear are approximately 19.05, 17.67, 14.06, and 25.51 feet respectively. At the same time, the average water depths estimated for the four ponds are 8.41, 10.65, 4.24, and 14.85 feet respectively. The corresponding maximum water surface acreage computed for the four ponds are 13.34, 14.0, 12.9, and 4.12 acres respectively. Also, the average water surface acreage computed for the four ponds are 13.03, 13.85, 12.0, and 4.02 13.03, 13.85, 12.0, and 4.02 acres respectively.

5.8 CONNECTION CHANNEL DIMENSION

Trapezoidal channels with grass were proposed for the conveyance of overflowed stormwater. The channels bottom width are three feet, with side slope of 1V:1H. The Manning's roughness used was 0.3 for a natural channel with grass and stones. The slope of channel was estimated as 0.1 percent. The corresponding discharge rates and water depth in the channel were 18 cfs and 2.1 feet respectively. The calculated velocity was1.3 feet/sec, which is considered as subcritical flow.

ACAD: K:\CADD\NG96\NG96GM14.DWG 06/24/97 MF



DRAWN BY DLT DATE 6/13/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 1 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MAXIMUM ELEVATION FEMP	APPROVED BY DATE	
COST/SCHED–AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 5–1	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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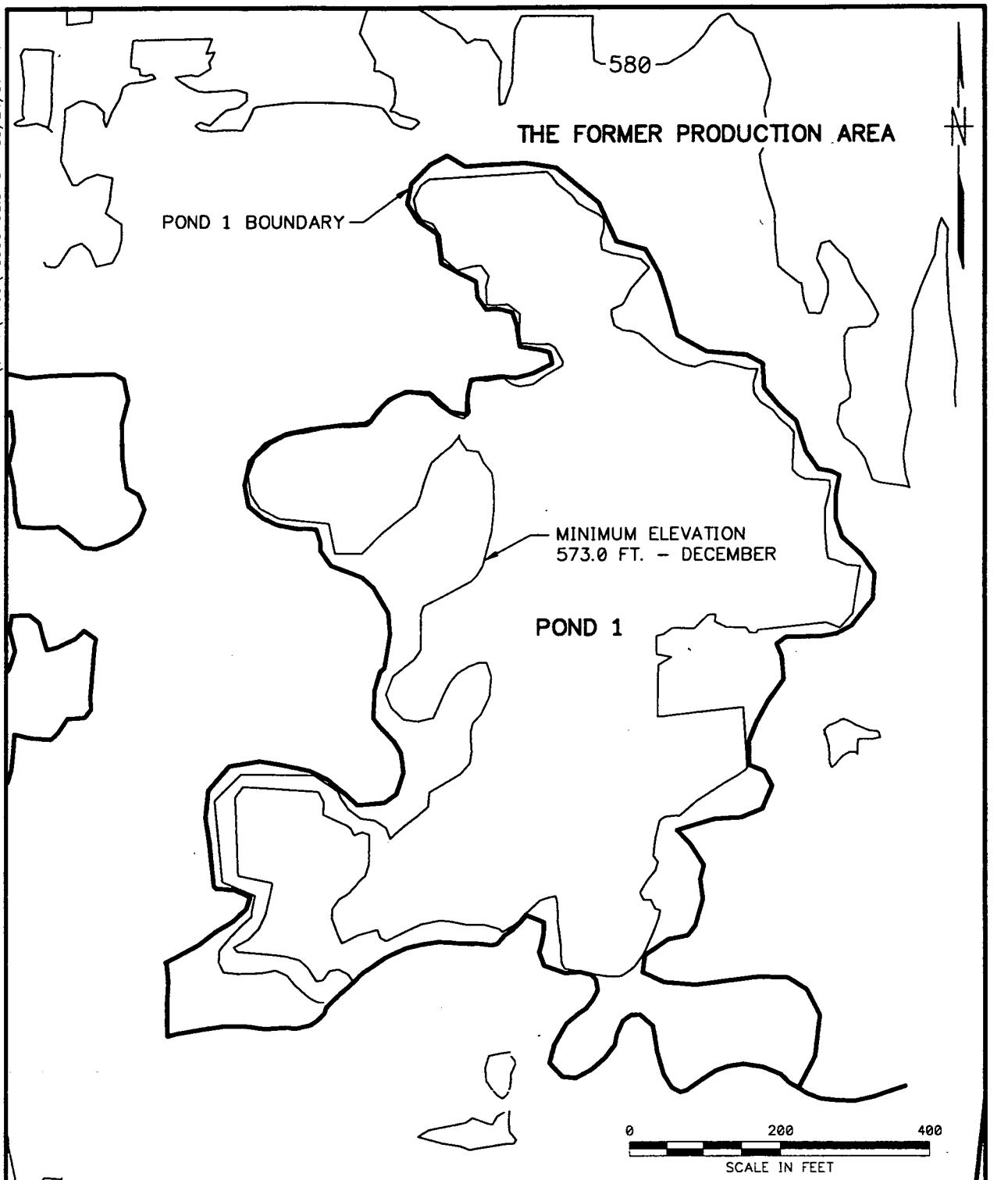

DRAWN BY DLT DATE 6/13/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 1 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MINIMUM ELEVATION FEMP	APPROVED BY DATE	
COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 5-2	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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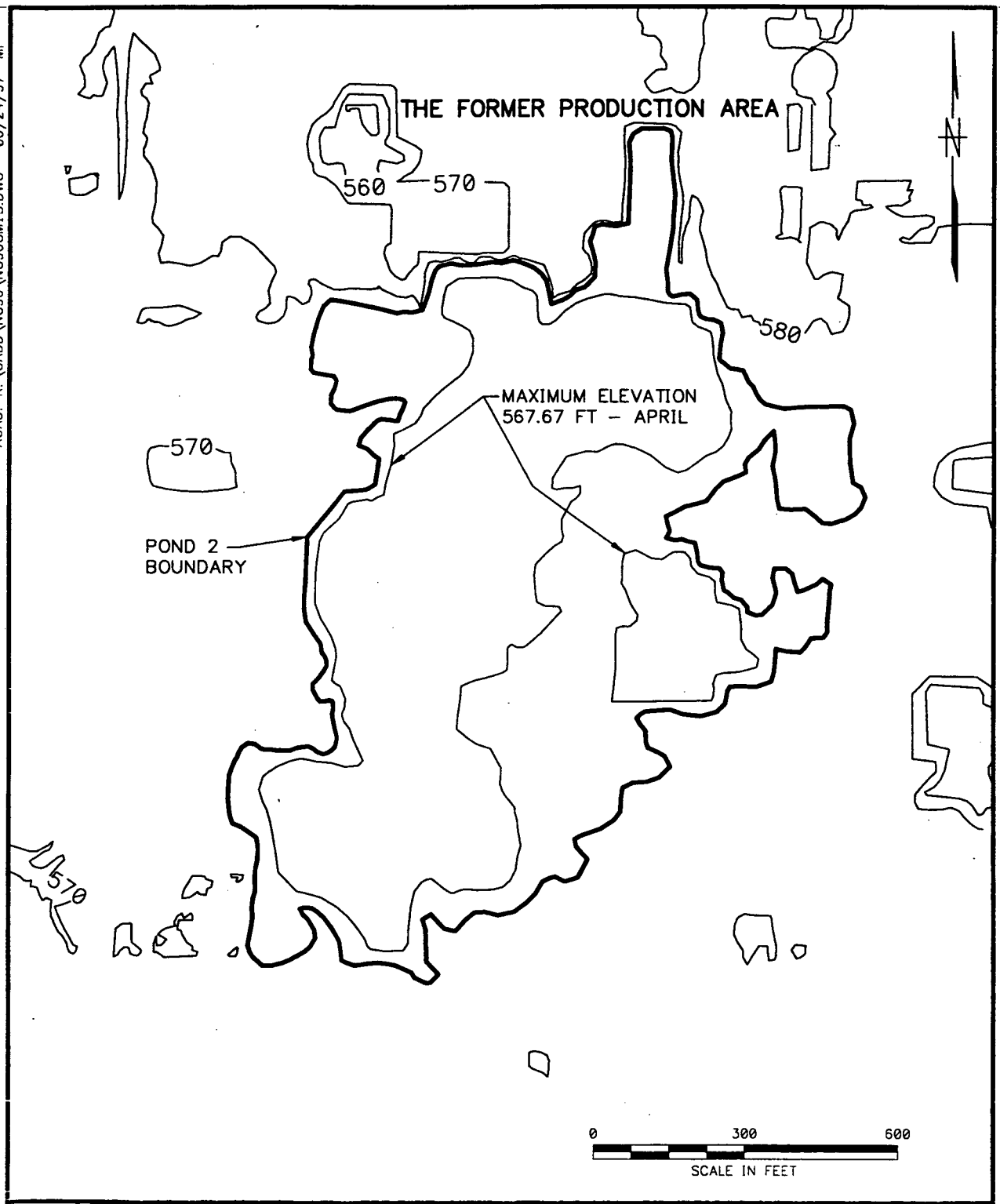

DRAWN BY DLT DATE 6/13/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 2 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED–AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5–3	REV. 0

FORM CADD NO. SOUTH_AV.DWG – REV 0 – 02/07/97

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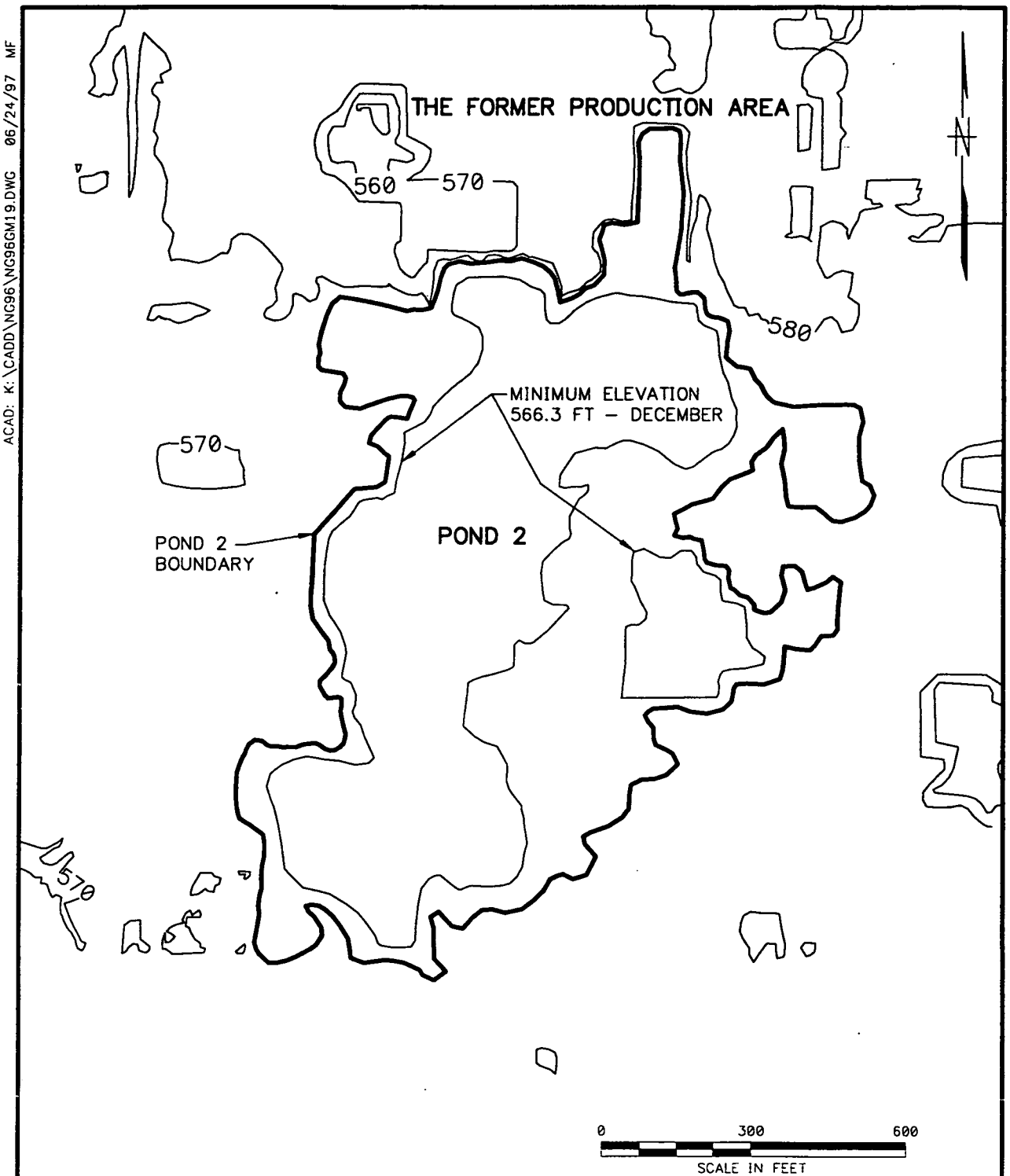

DRAWN BY DLT DATE 6/13/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 2 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MINIMUM ELEVATION FEMP	APPROVED BY DATE	
COST/SCHED–AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 5–4	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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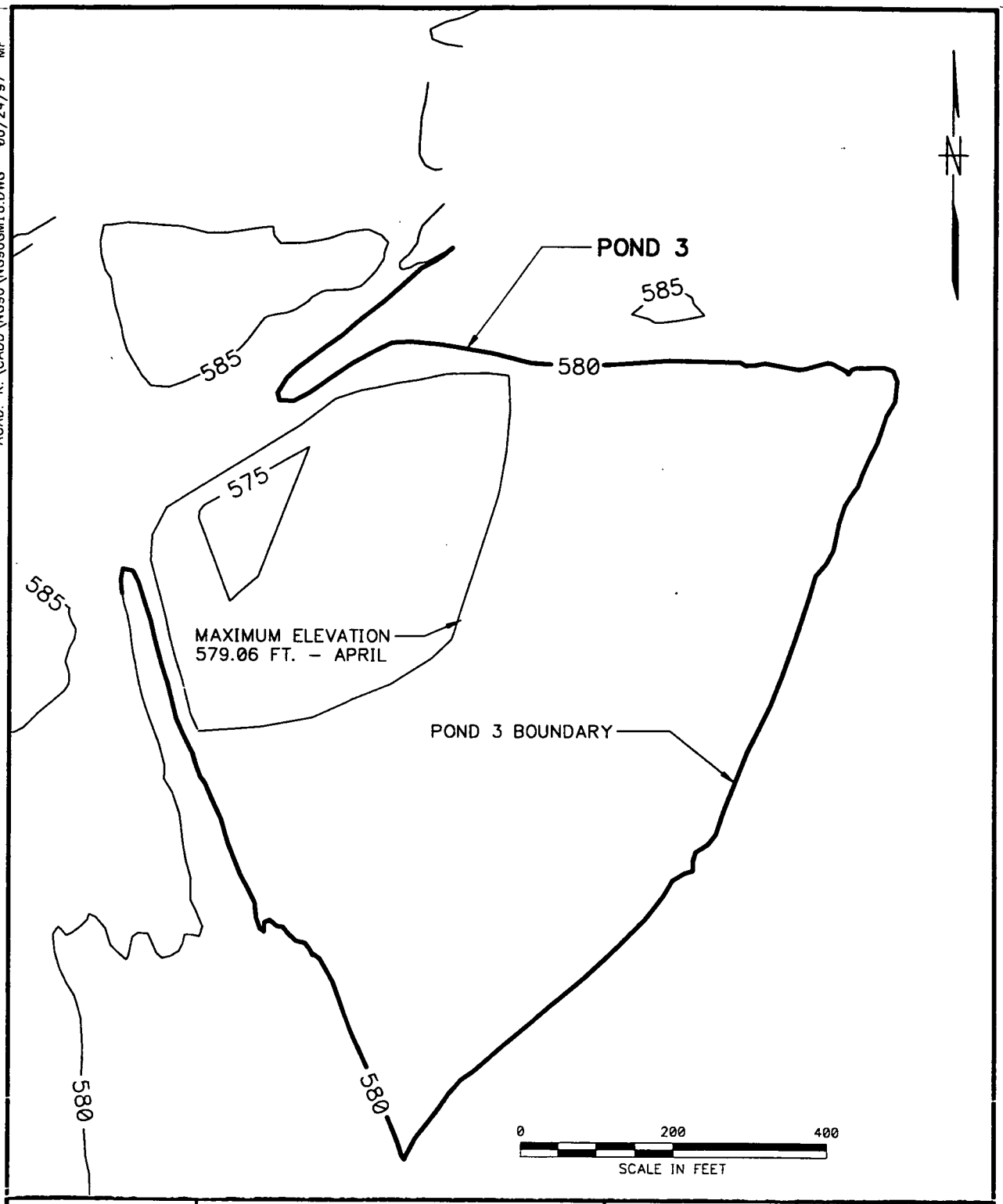

DRAWN BY GMF DATE 6/16/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 3 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MAXIMUM ELEVATION FEMP	APPROVED BY DATE	
COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 5-5	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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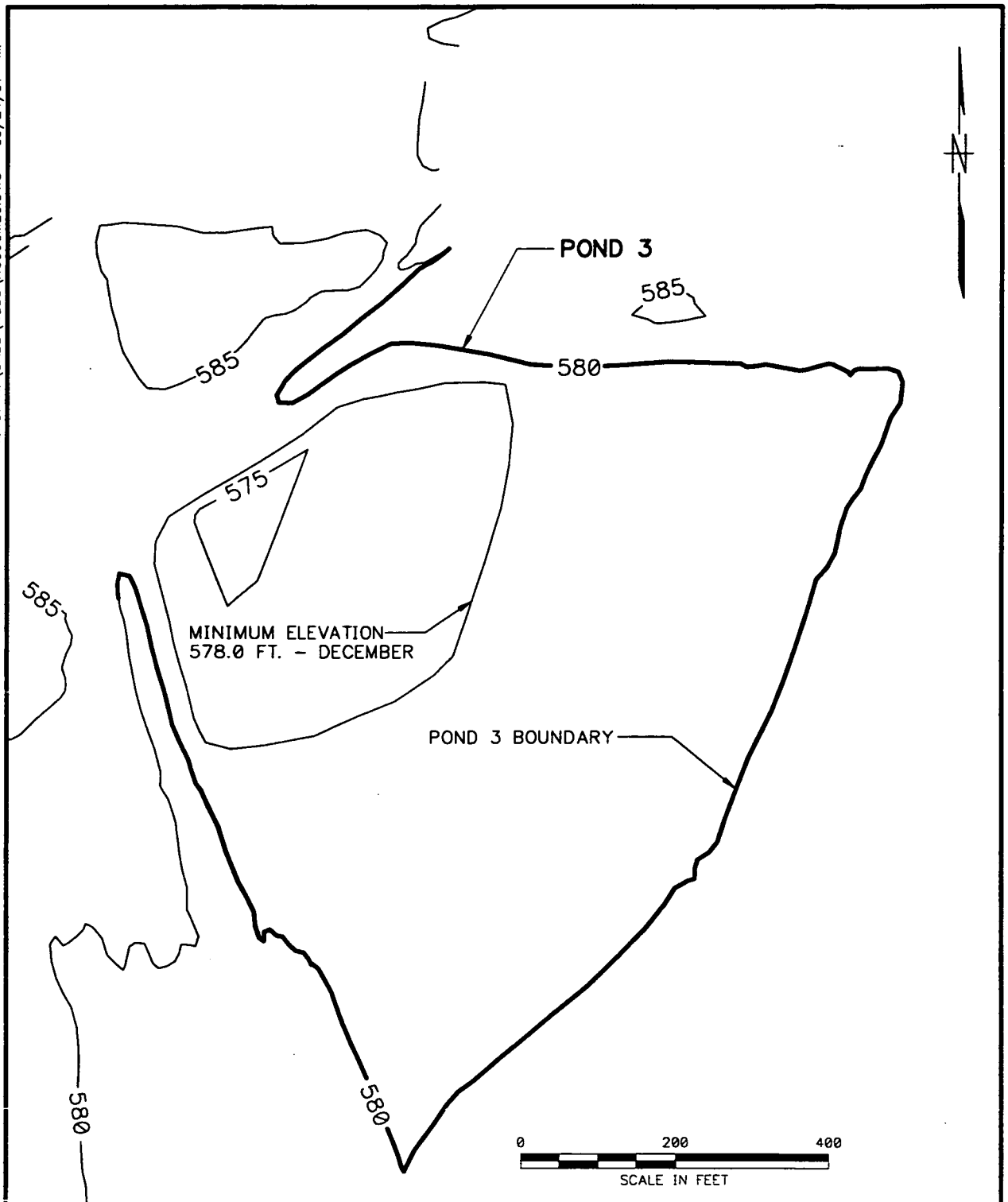

DRAWN BY GMF DATE 6/16/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 3 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MINIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-6	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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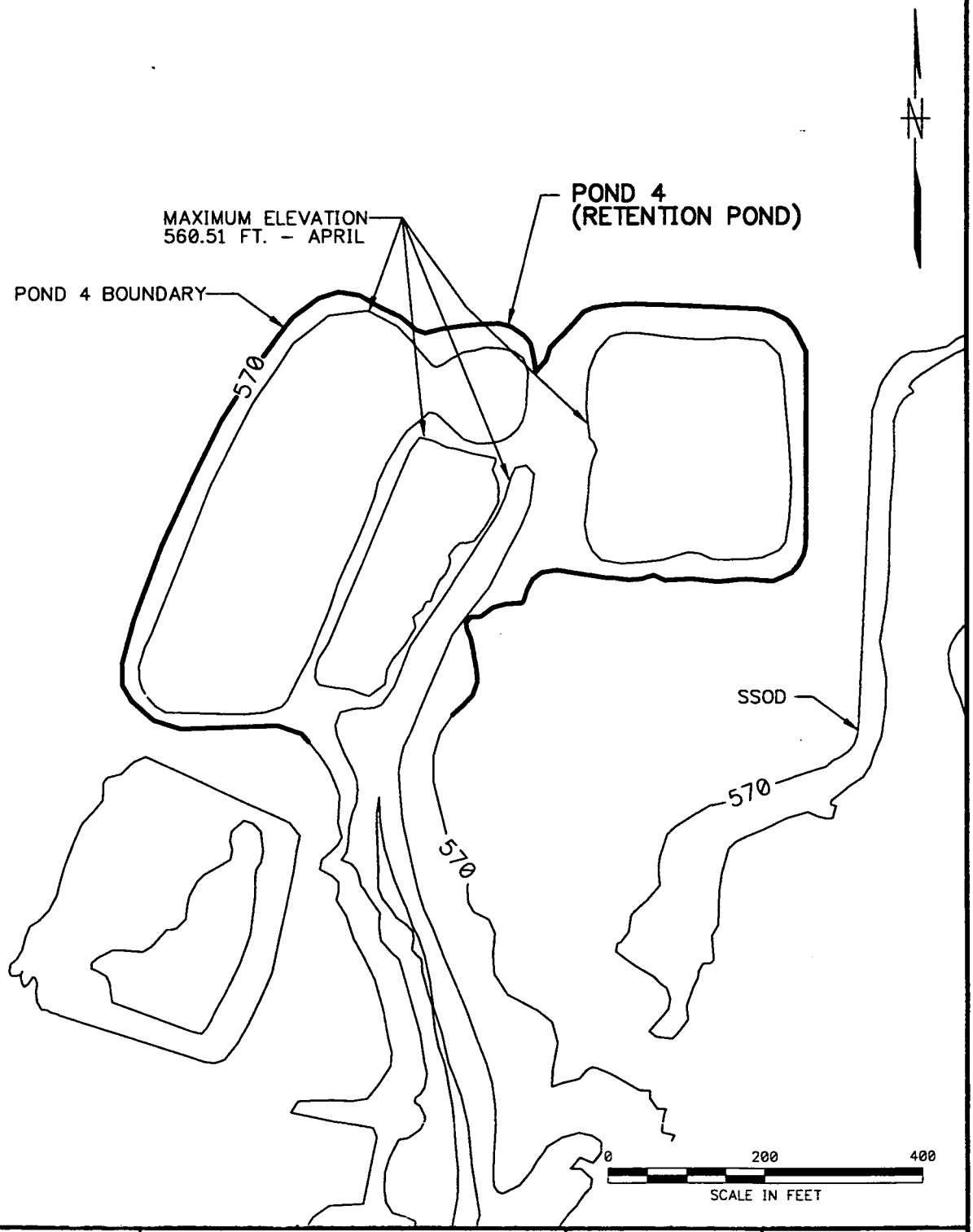

DRAWN BY GMF DATE 6/16/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 4 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-7	REV. 0

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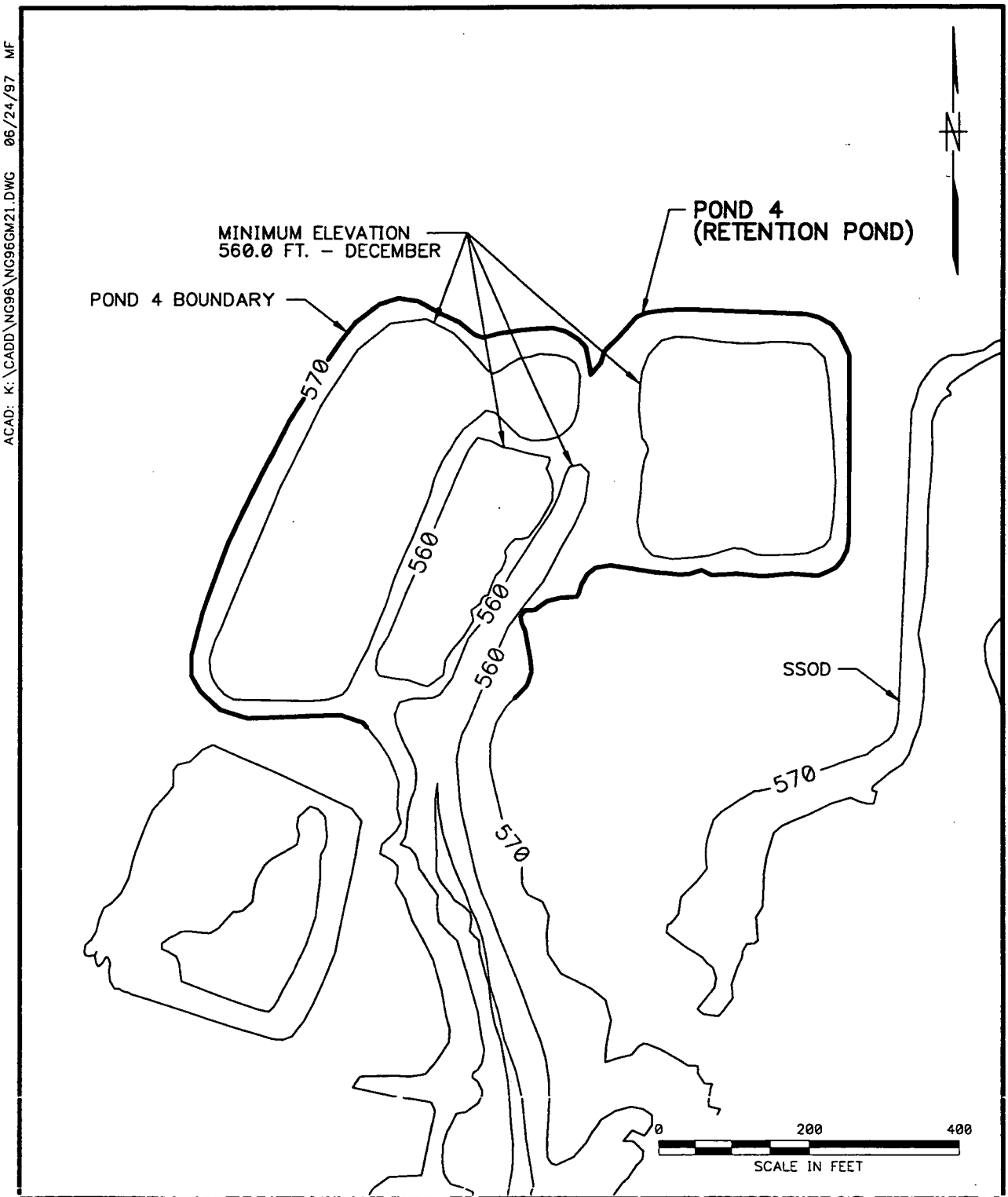

DRAWN BY GMF DATE 6/16/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 4 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MIMIMUM ELEVATION FEMP	APPROVED BY DATE	
COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 5-8	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

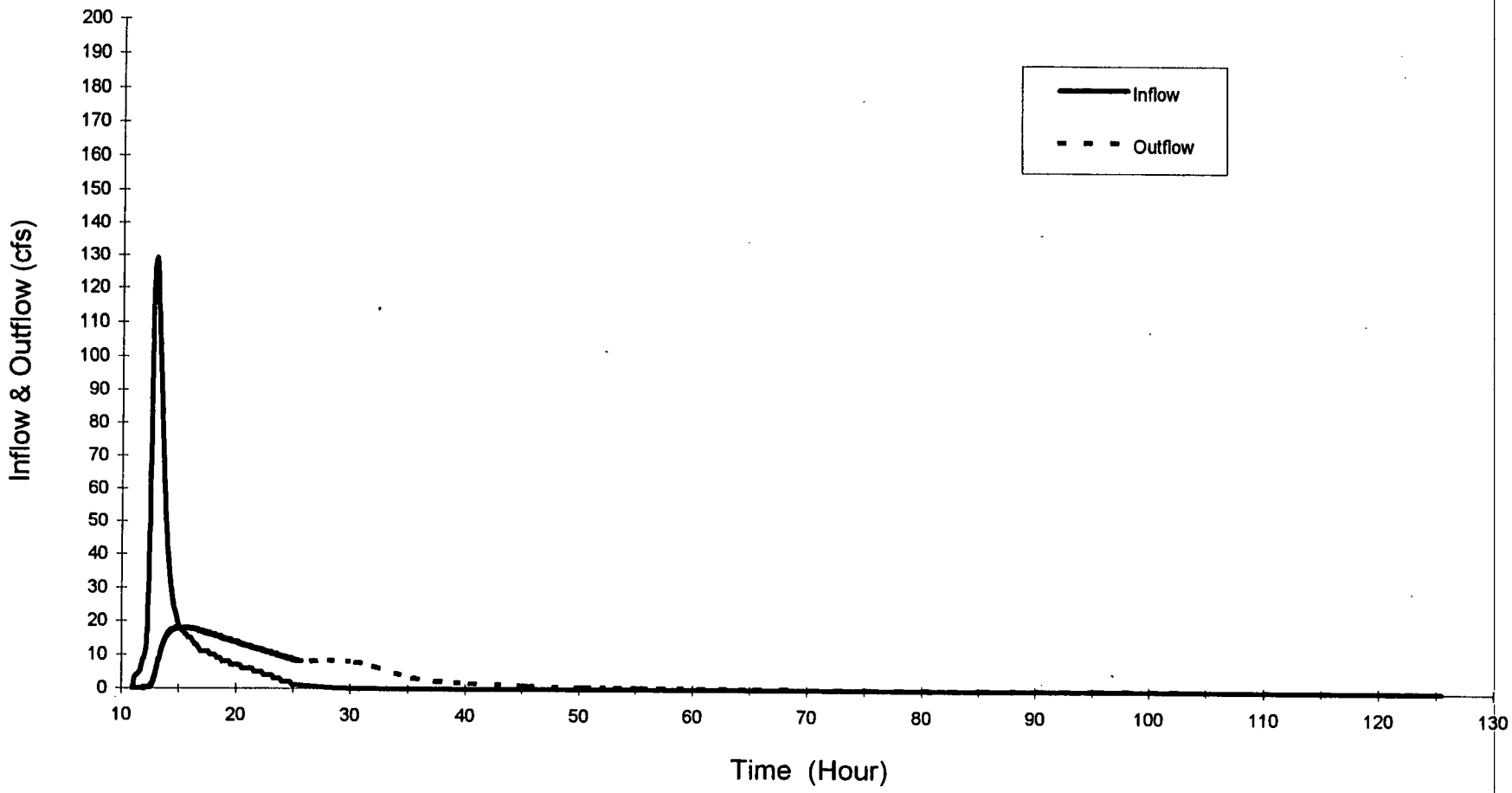

Figure 5-9 Inflow And Outflow Rates of Pond 1 Under Extreme Conditions

000279

4873

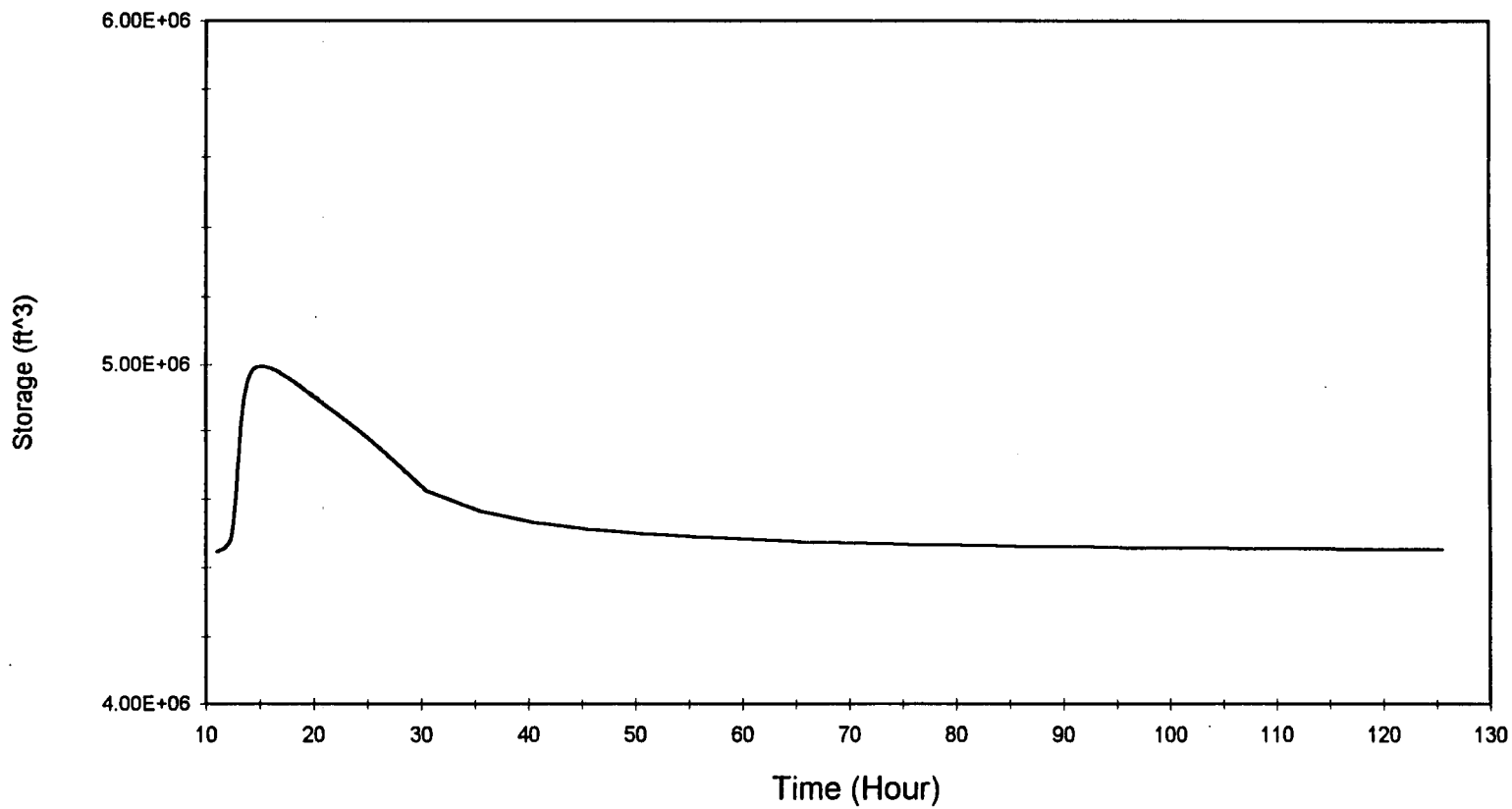

Figure 5-10 Storage Variations of Pond 1 Under Extreme Conditions

000280

48 73

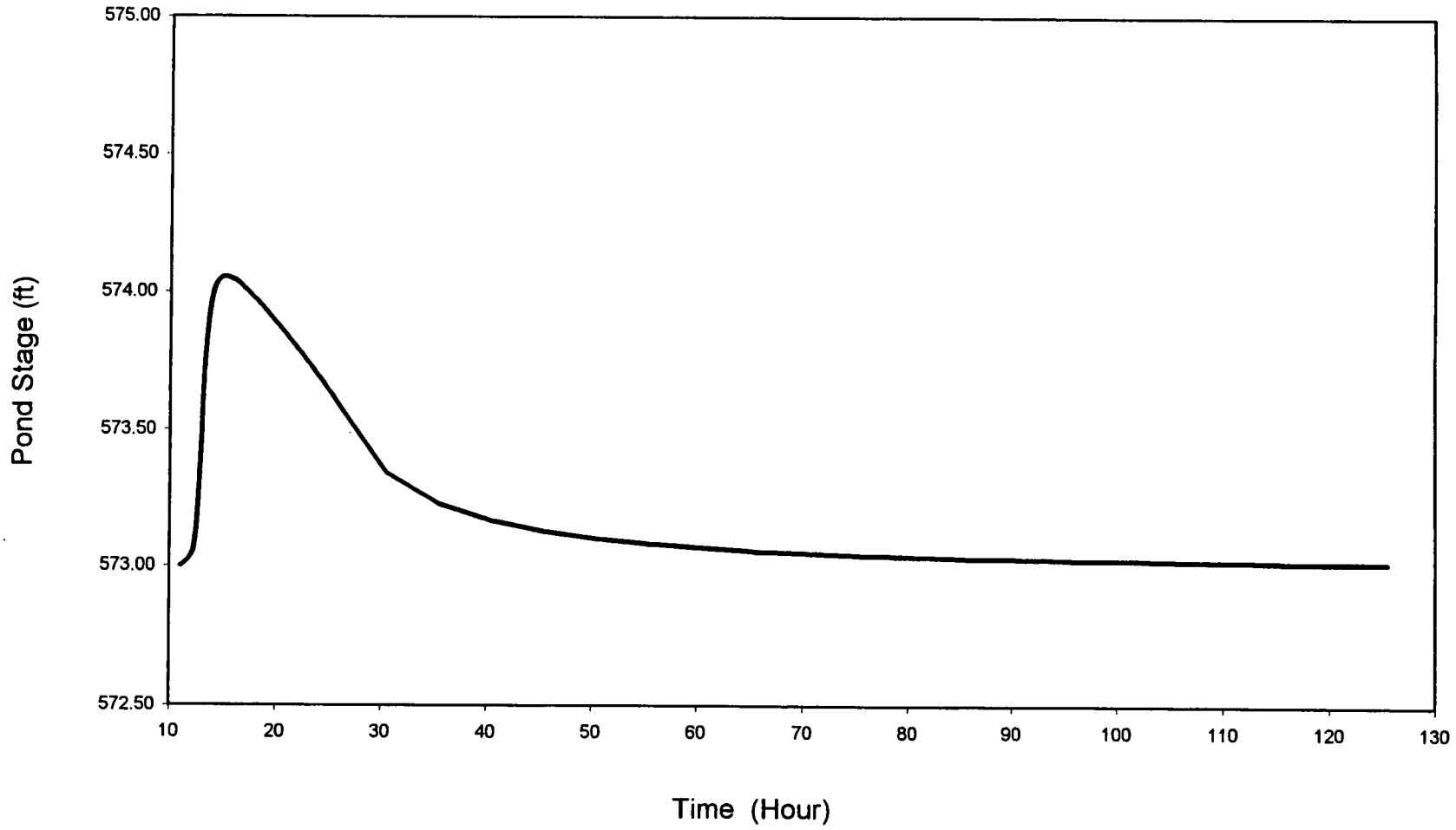

Figure 5-11 Stage Variations of Pond 1 Under Extreme Conditions

000281

F-4873

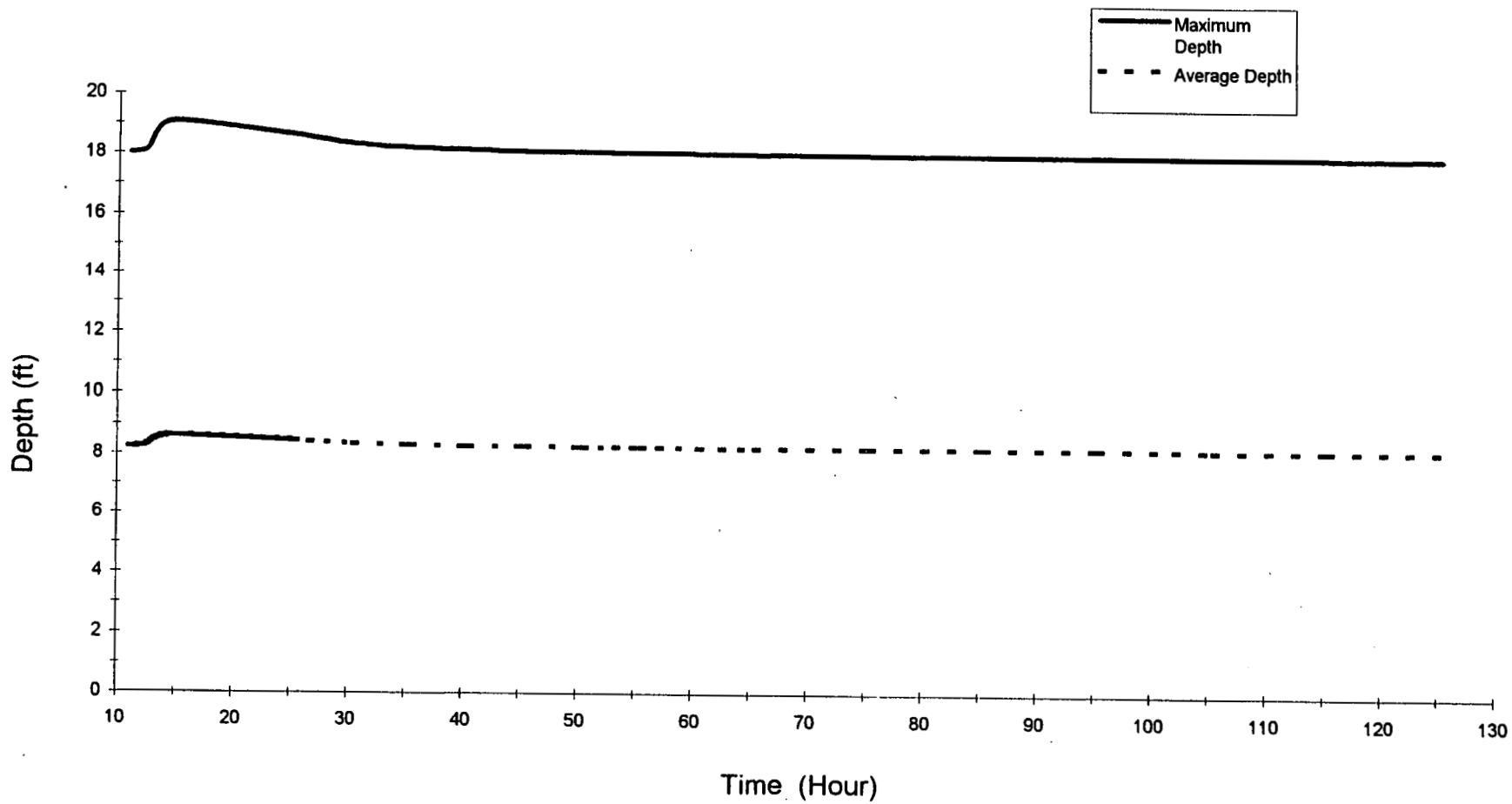

Figure 5-12 Maximum and Average Depth of Pond 1 Under Extreme Conditions

000282

48 73

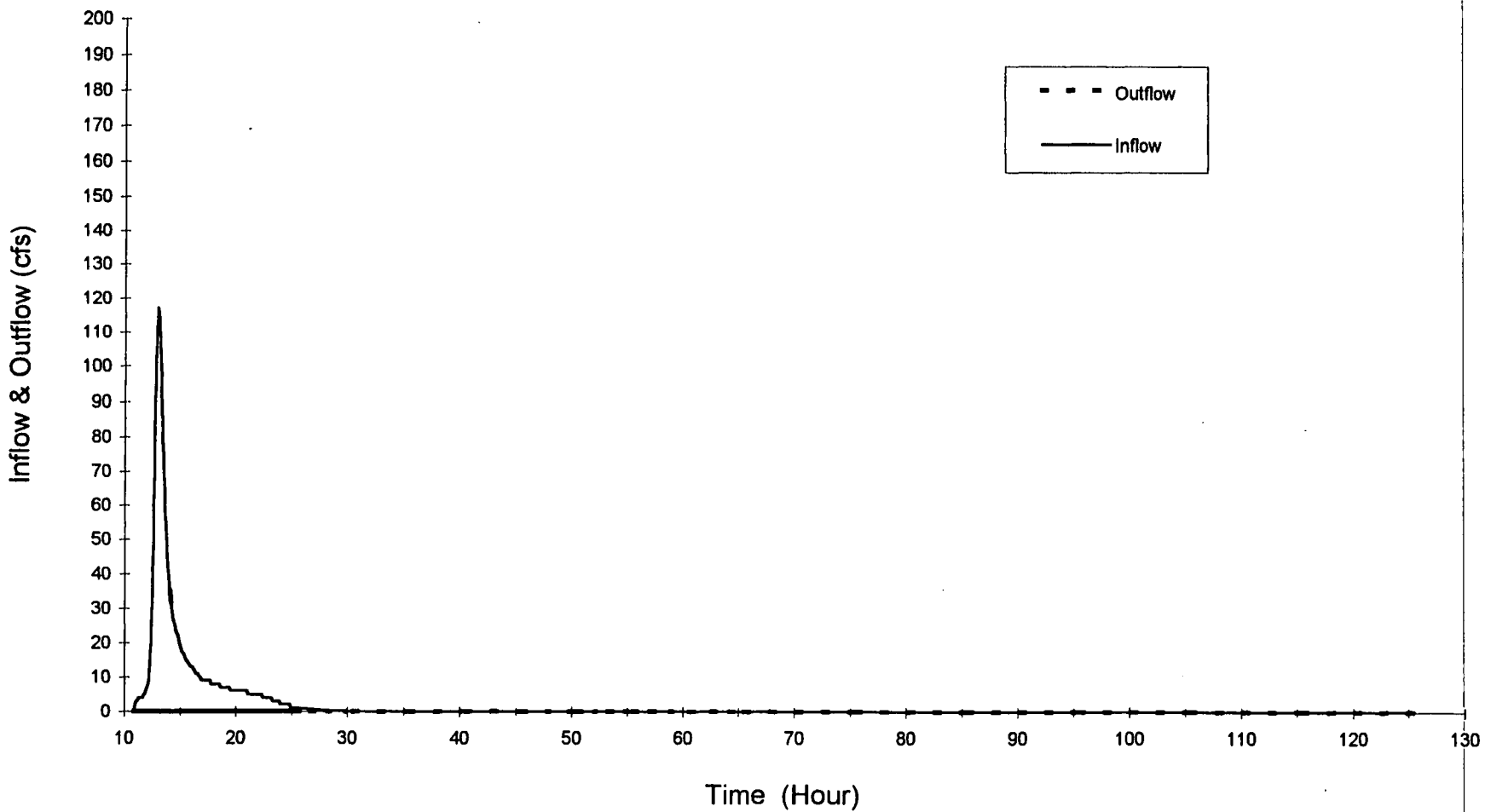

Figure 5-13 Inflow And Outflow Rates of Pond 2 Under Extreme Conditions

000083

3784

7-4873

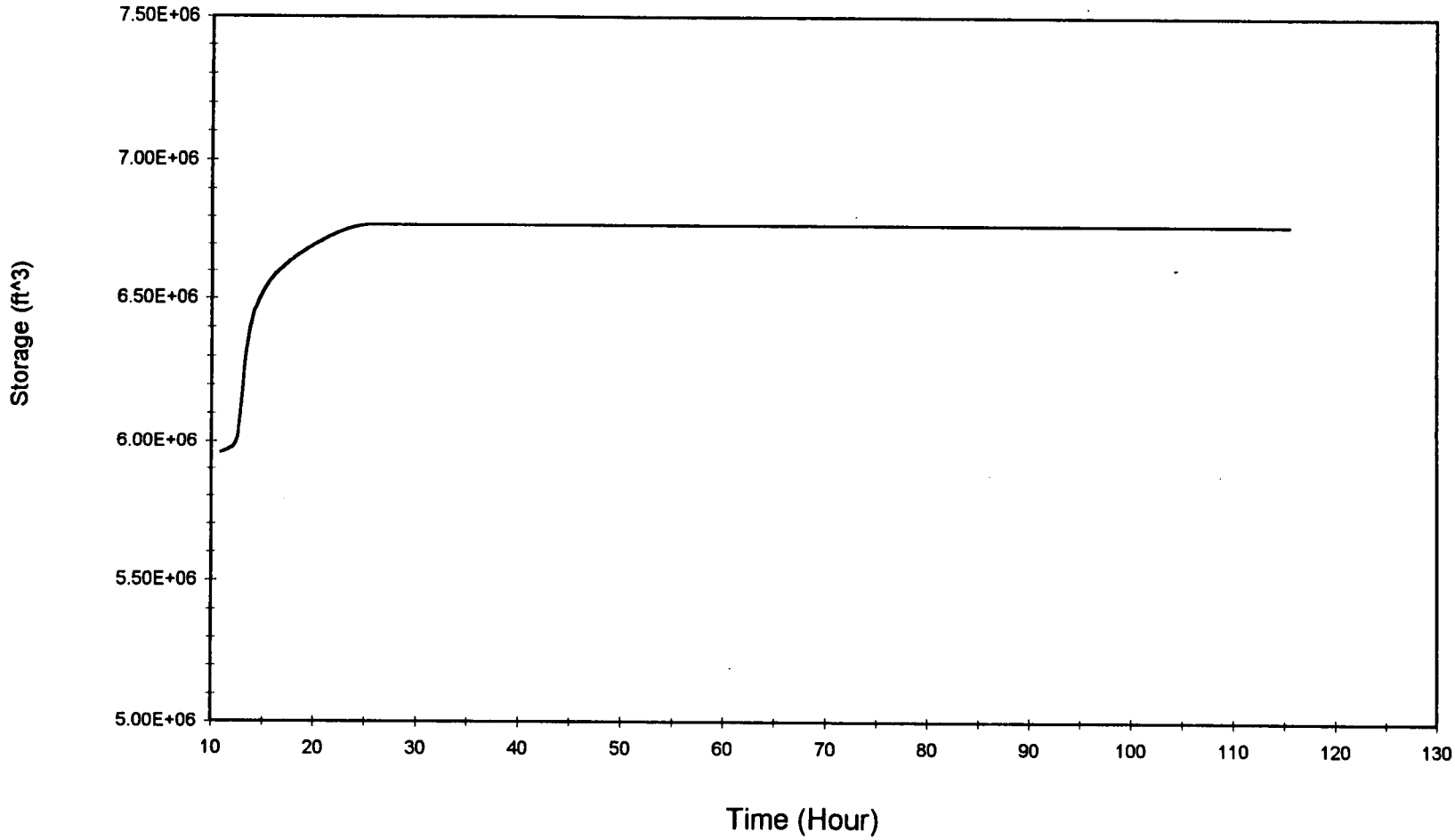

Figure 5-14 Storage Variations of Pond 2 Under Extreme Conditions

000284

48 73

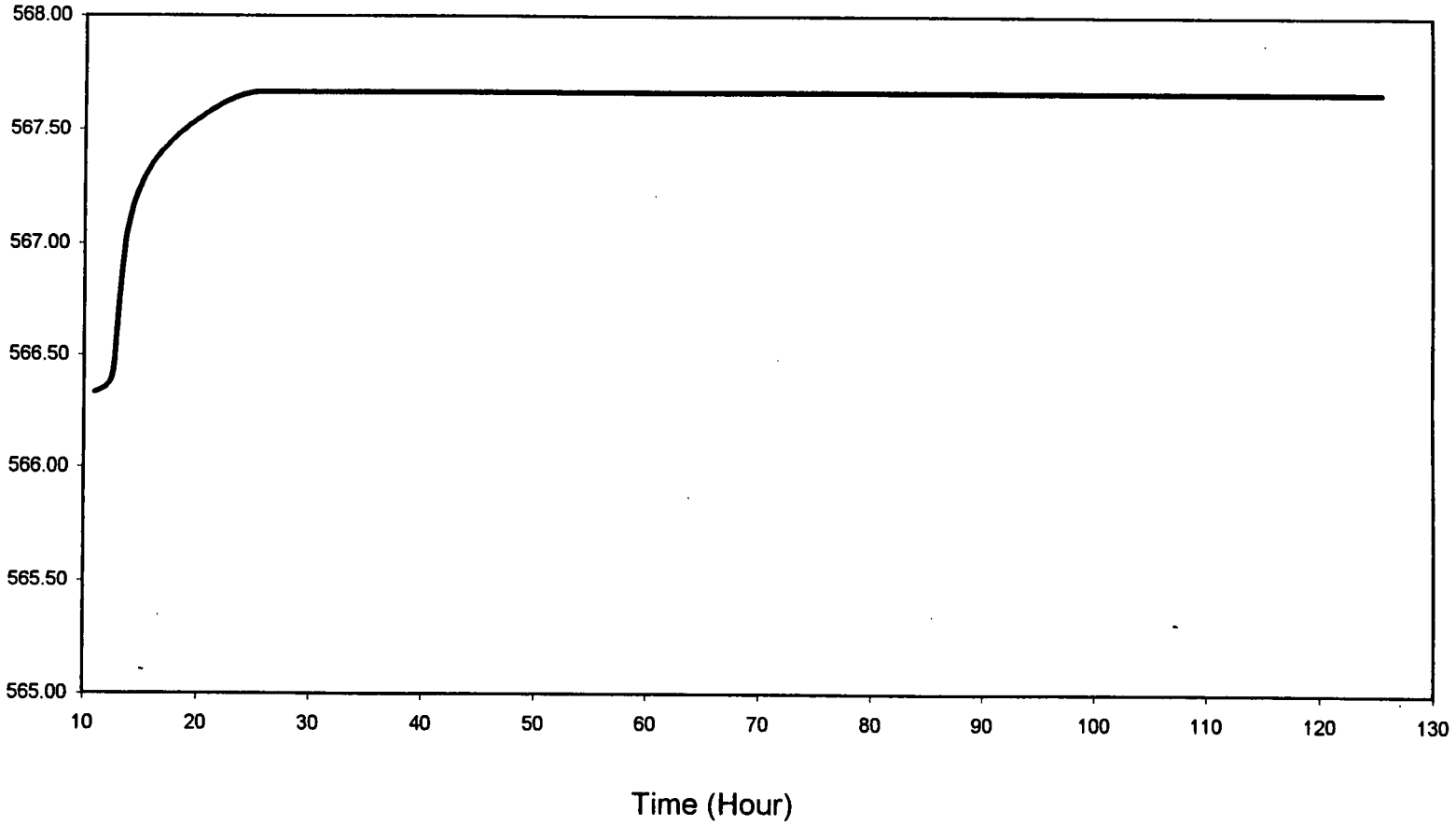

Figure 5-15 Stage Variations of Pond 2 Under Extreme Conditions

000285

48 73

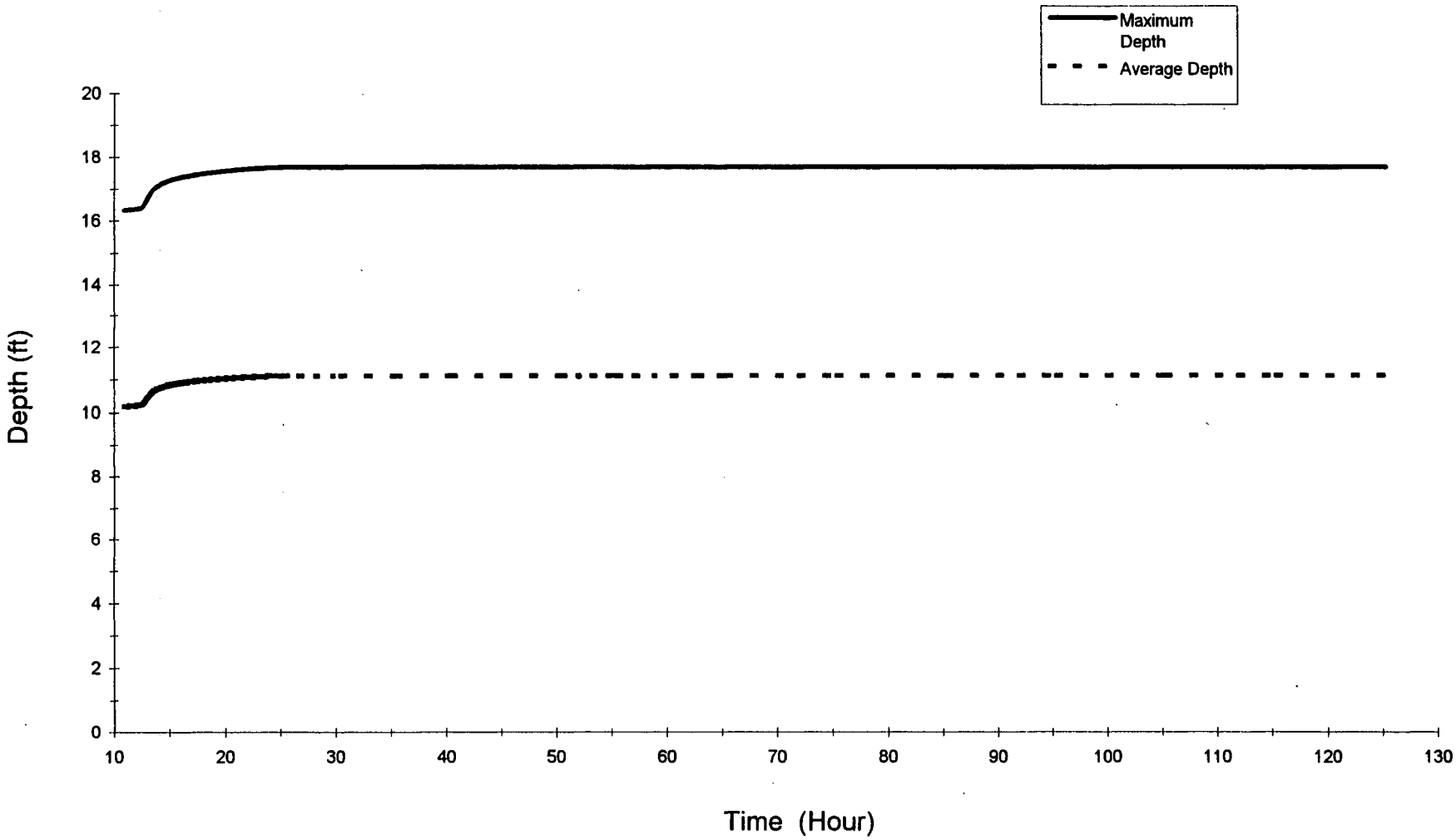

Figure 5-16 Maximum and Average Depth of Pond 2 Under Extreme Conditions

000286

4873

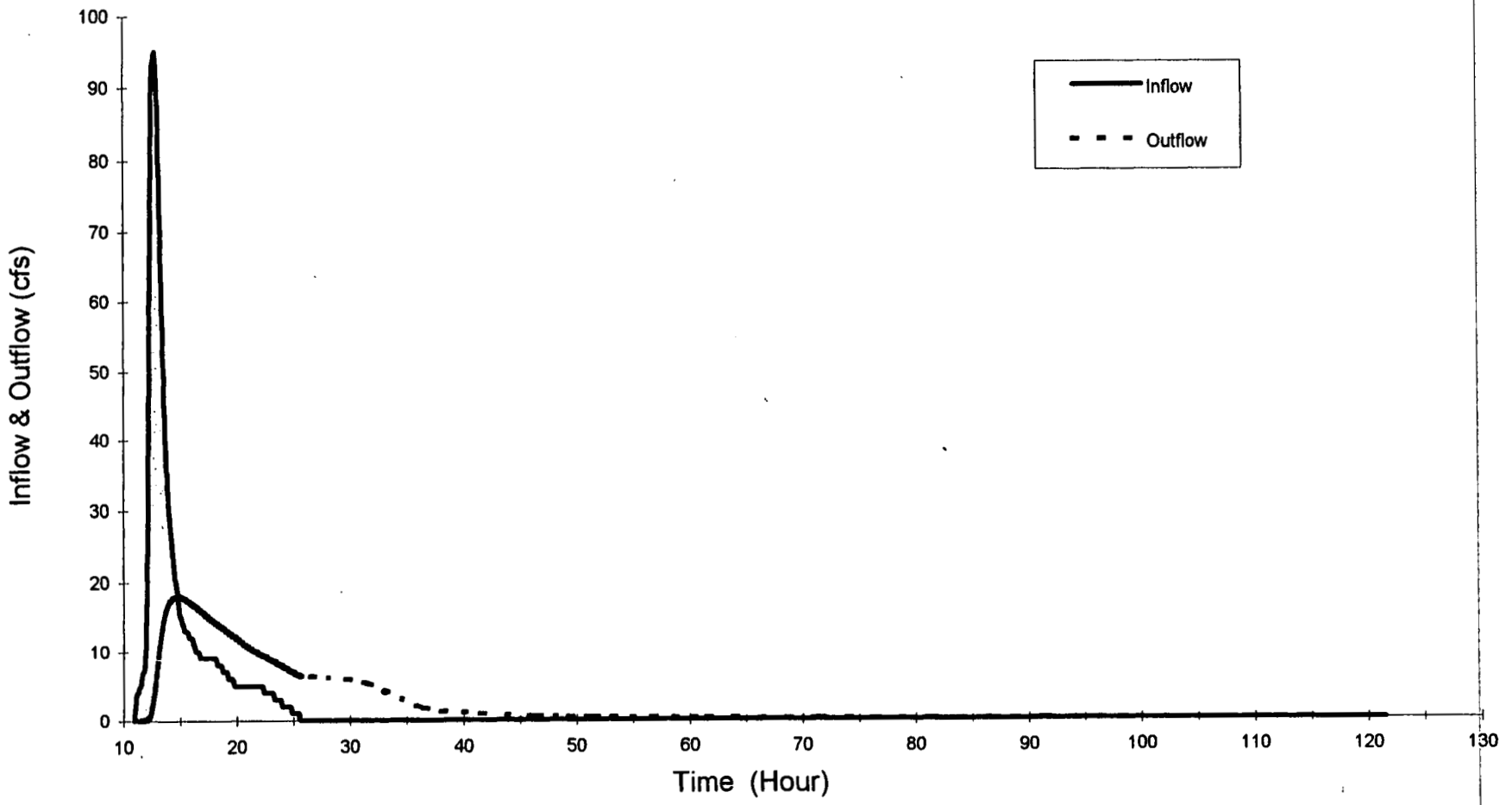

Figure 5-17 Inflow And Outflow Rates of Pond 3 Under Extreme Conditions

000287

48 73

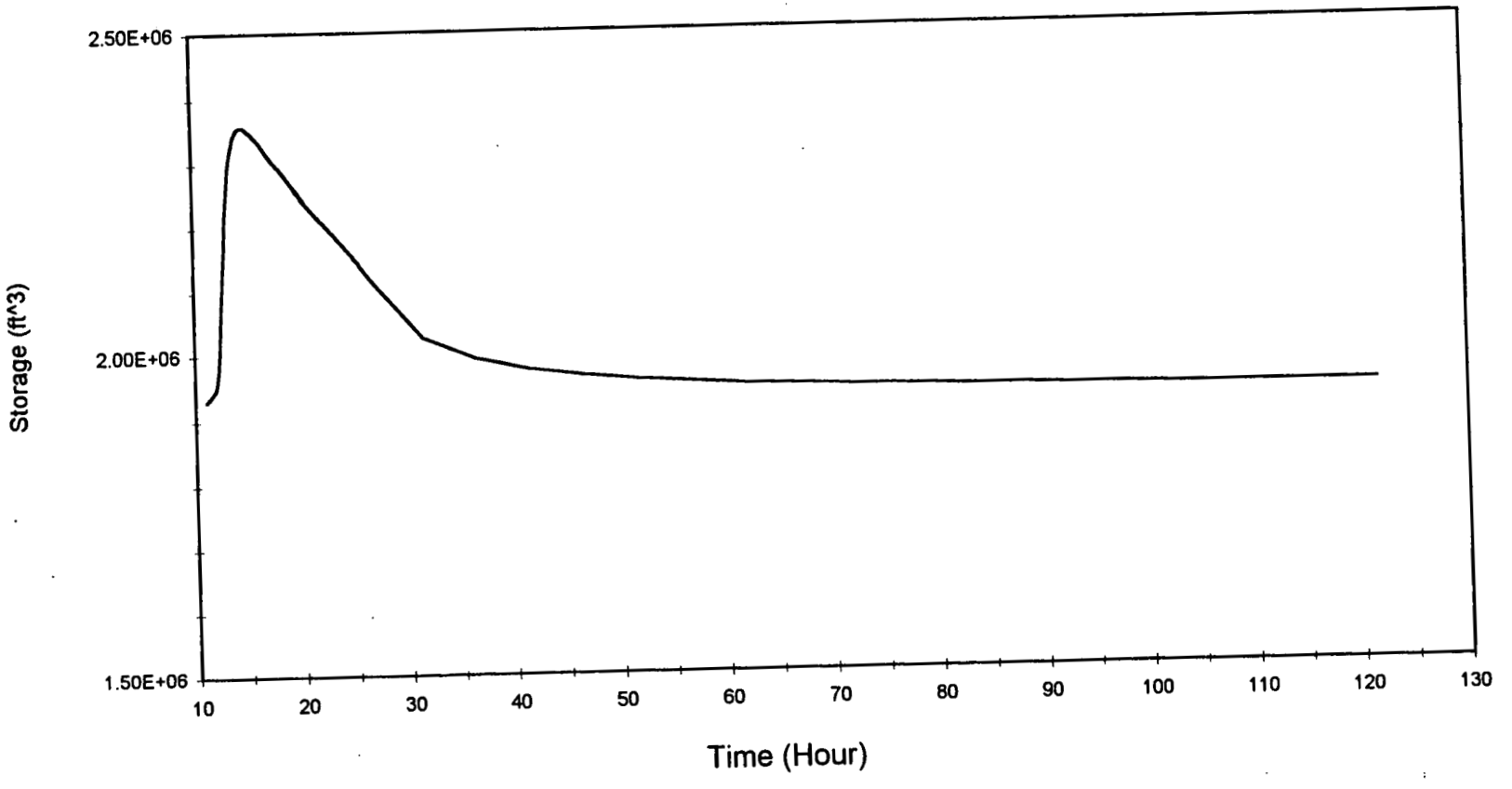

Figure 5-18 Storage Variations of Pond 3 Under Extreme Conditions

000288

48873

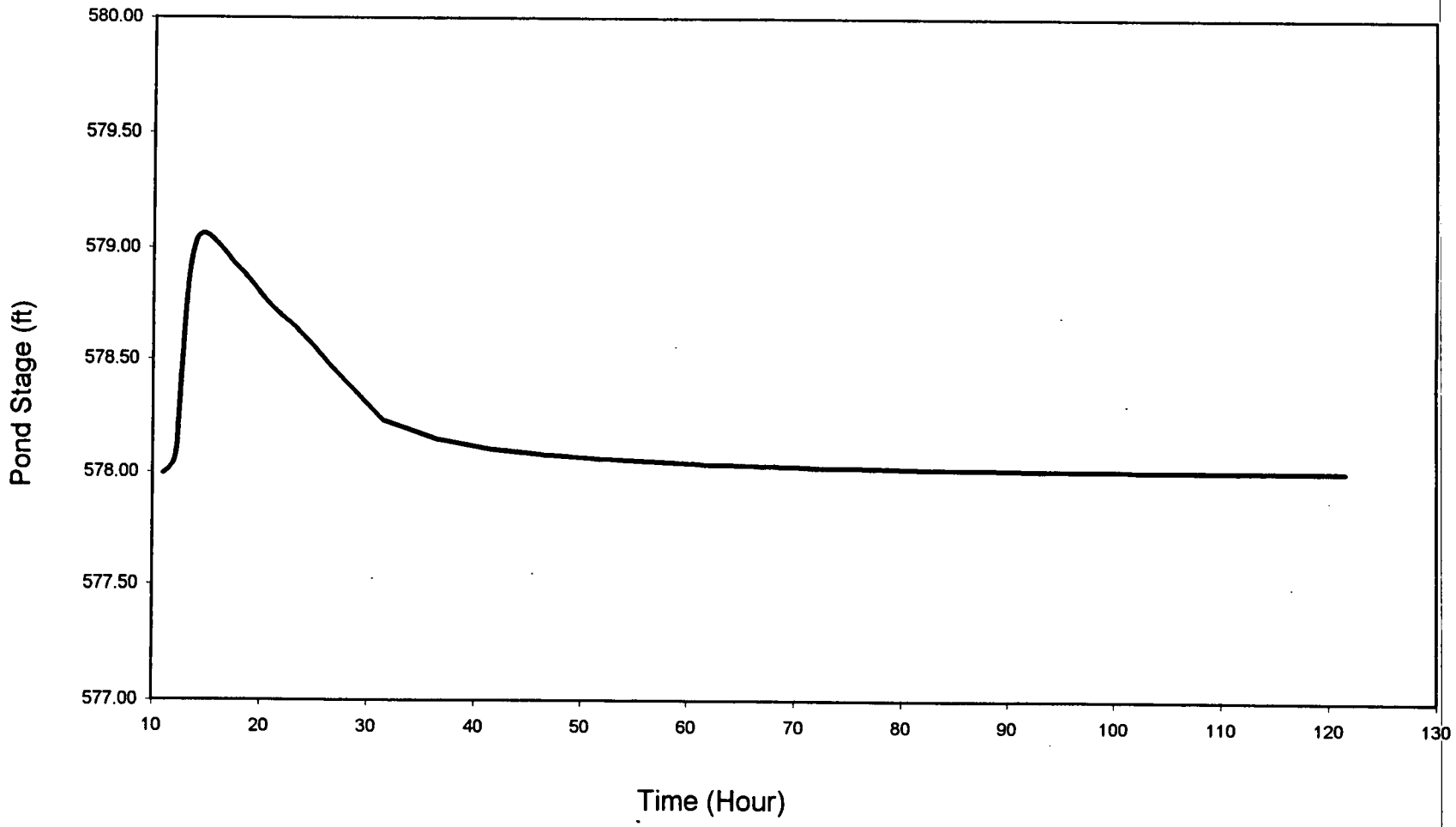

Figure 5-19 Stage Variations of Pond 3 Under Extreme Conditions

000259

5189

-- 4873

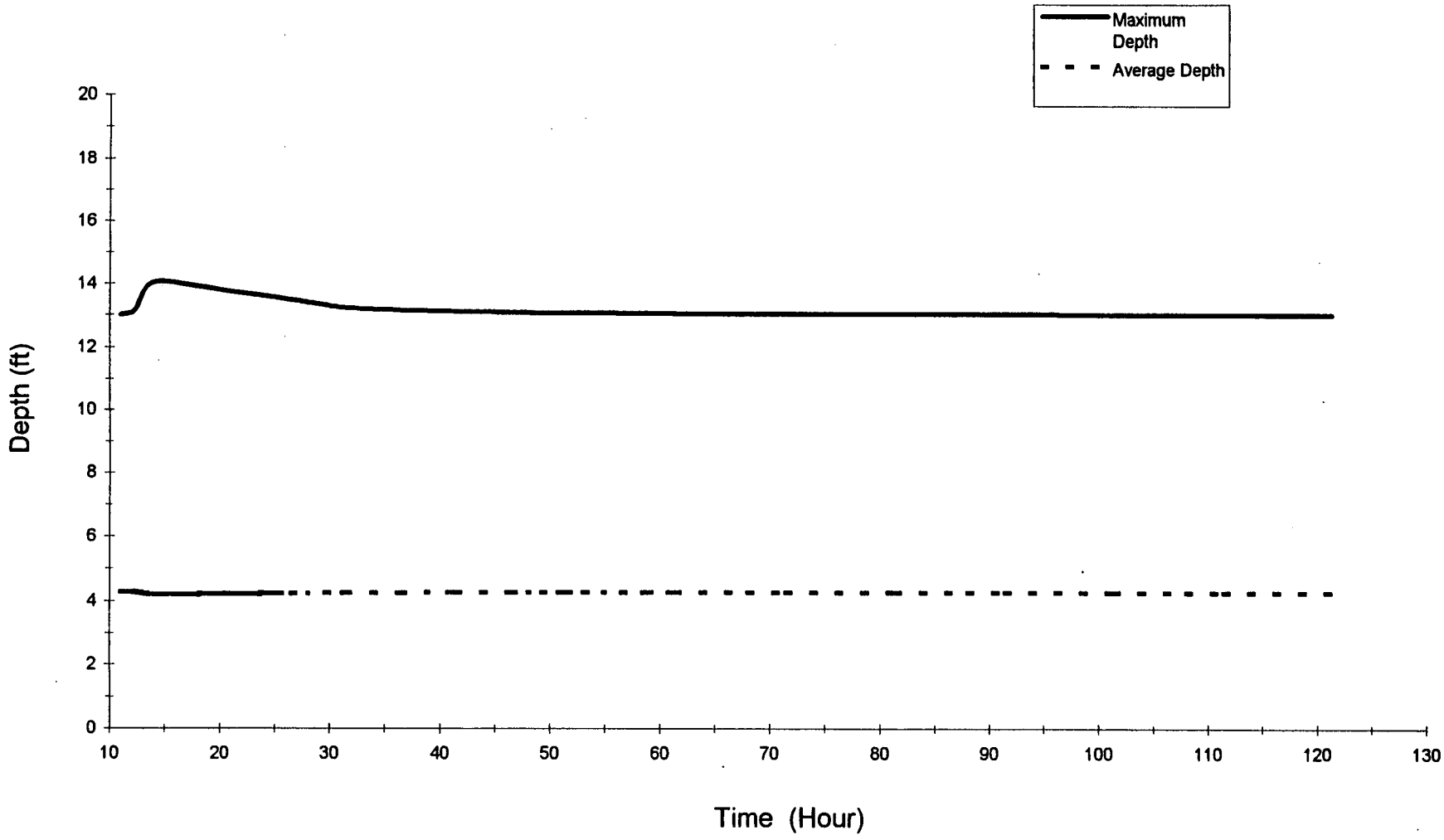

Figure 5-20 Maximum and Average Depth of Pond 3 Under Extreme Conditions

000290

48 73

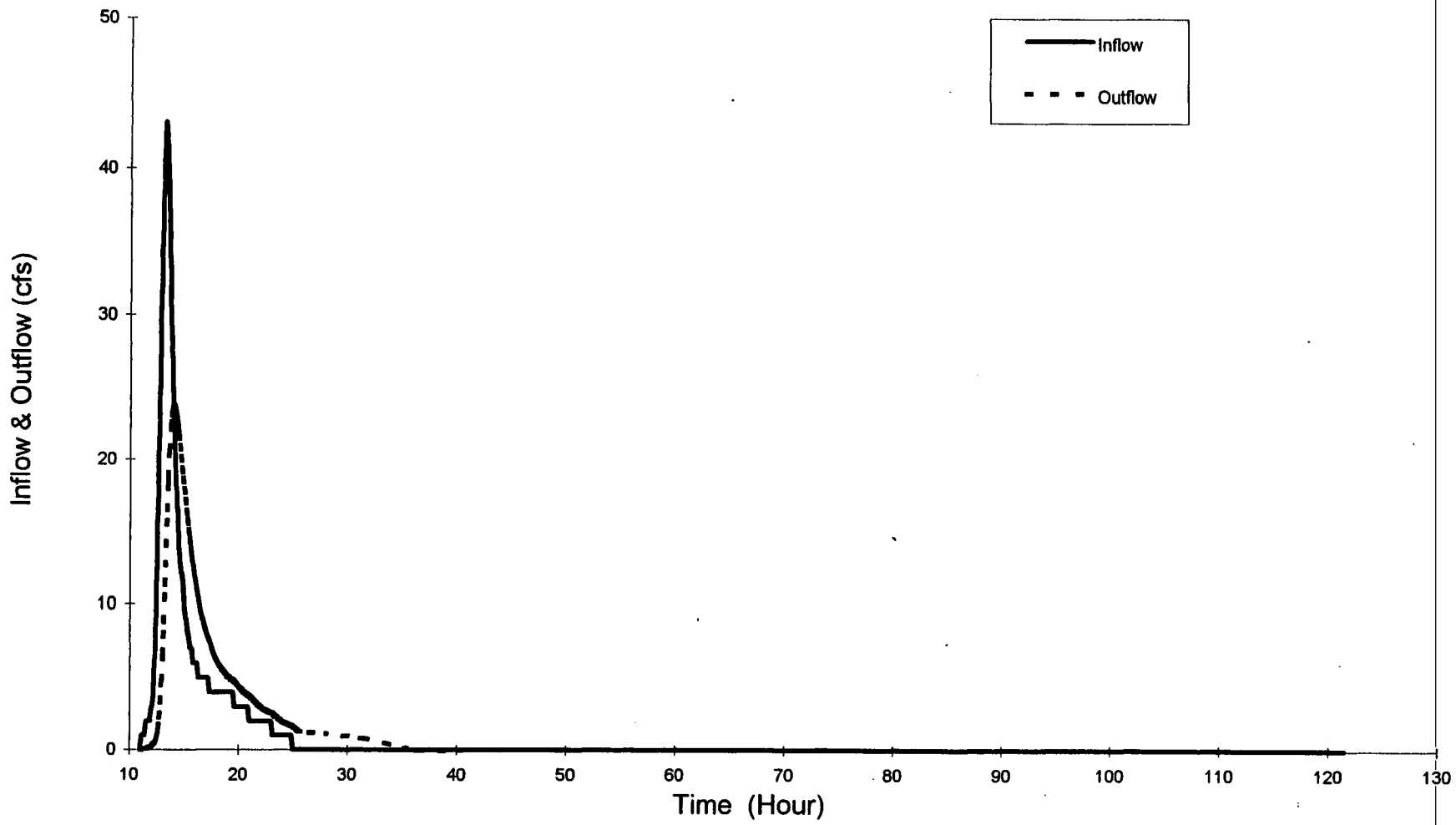

Figure 5-21 Inflow And Outflow Rates of Pond 4 Under Extreme Conditions

000291

4873

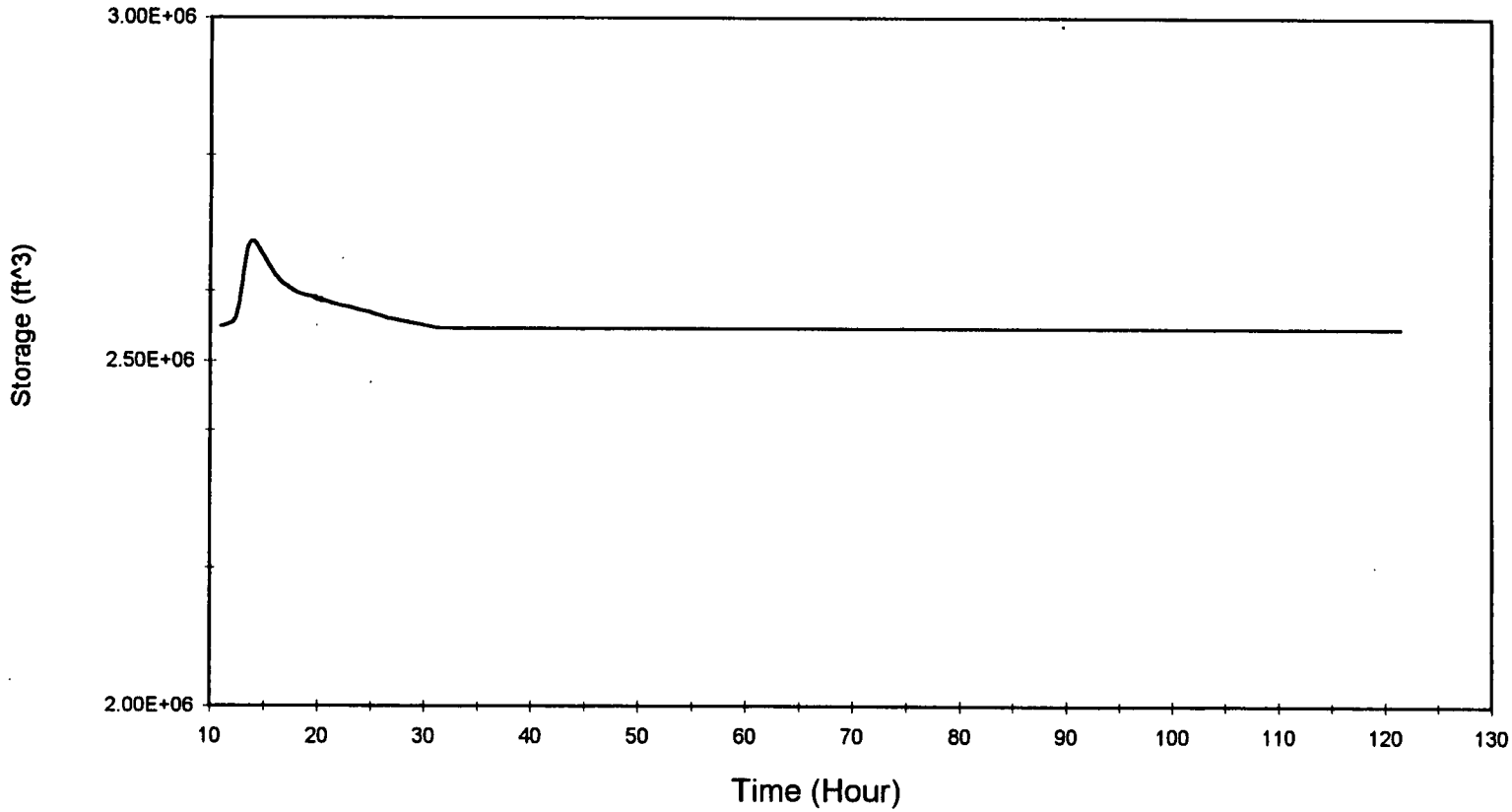

Figure 5-22 Storage Variations of Pond 4 Under Extreme Conditions

000292

4873

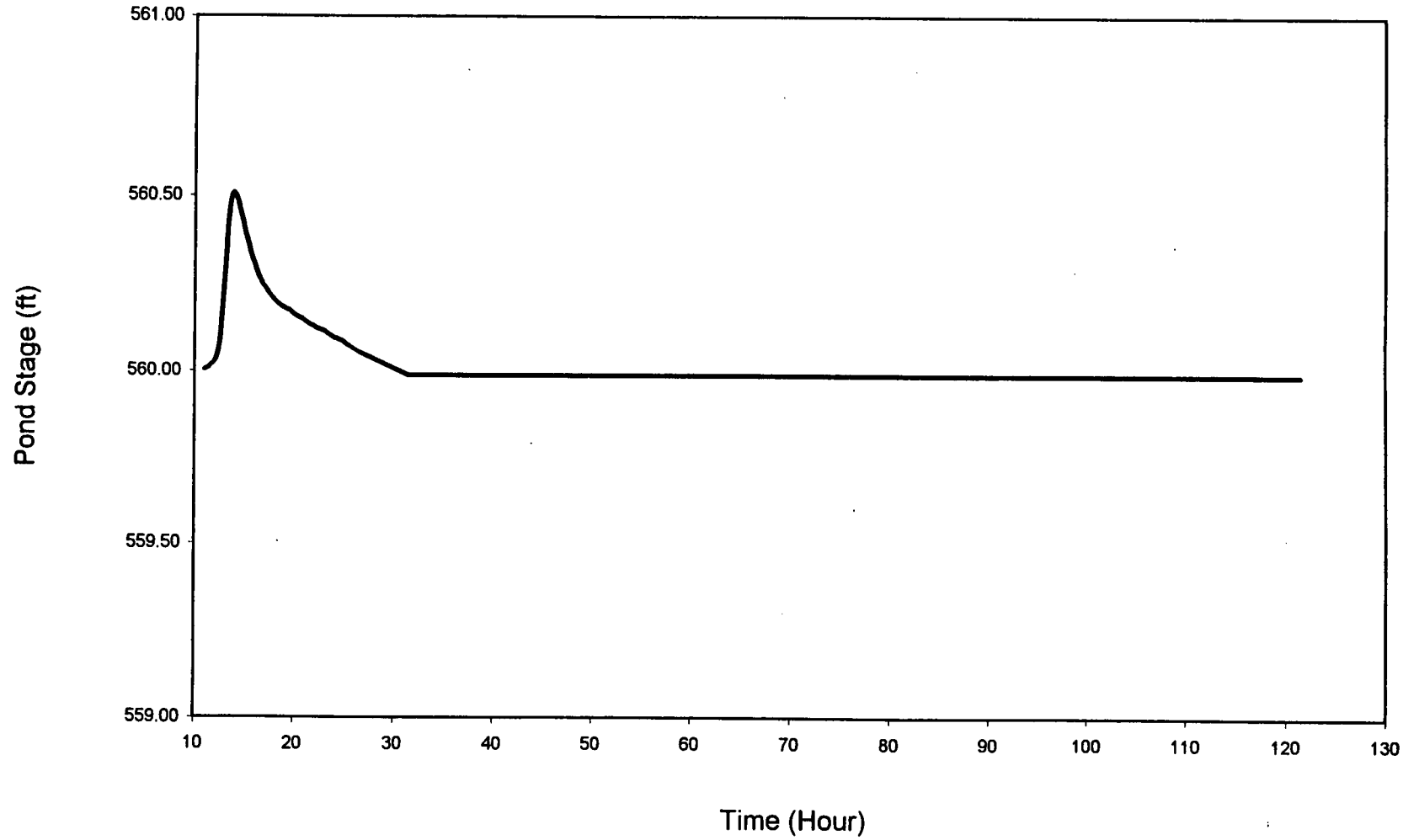

Figure 5-23 Storage Variations of Pond 4 Under Extreme Conditions

48 73

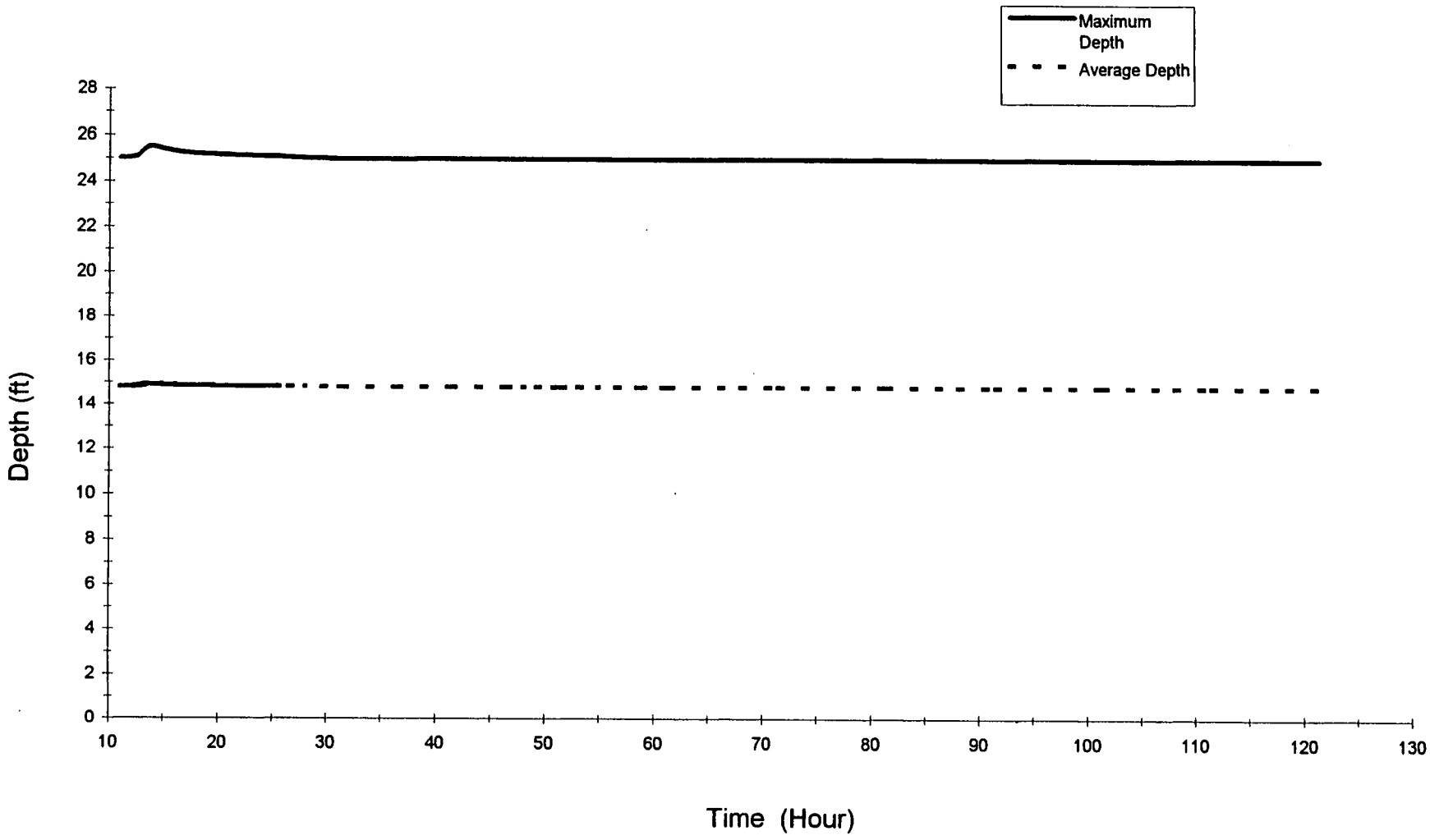

Figure 5-24 Maximum and Average Depth of Pond 4 Under Extreme Conditions

000294

4873

6.0 SUMMARY AND DISCUSSIONS

The routing modeling results indicated that the maximum pond elevations are constantly below the top edge of the ponds for both normal and extreme conditions evaluated. These results are based on allowing overflow from weirs when the pool levels exceed the outlet bottom elevations. The findings based on the storage routing modeling are briefly summarized for both modeled conditions.

Normal Conditions:

Modeling approaches for normal conditions have incorporated the monthly meteorological data, based on data available from NOAA. Any excessive storage that exceeds the designed outlet bottom elevations are overflowed to the final discharging point.

- Maximum inflow rates and maximum depth normally occur in April.
- Pond 1 has the highest stage (573 feet), if considering Pond 3 as a temporary retention pond.
- Pond 1 has the highest inflow rates (1.1×10^6 ft^3/month) among the four ponds.
- Pond 4 has the lowest inflow rates (4.2×10^5 ft^3/month) among the four ponds.
- Pond 2 has the highest storage (6.19×10^6 ft^3), and Pond 3 has the lowest storage (1.21×10^6 ft^3).
- Pond 3 has the highest daily overflow rates (2.31×10^4 ft^3/day).
- Maximum water depths estimated for the four ponds are 18, 16.7, 13, and 25 feet respectively.

Extreme Conditions:

The storm event was modeled by using the TR55 method. The Tabular Hydrograph Method is utilized for modeling multiple subareas that contribute runoff to one common design outfall point in the watershed.

- Time to peak inflow rates are approximately 13 hours.
- Pond 1 has the highest stage (574.1 feet), and Pond 4 has the lowest elevation (560 feet), if considering Pond 3 as a temporary retention pond.
- Pond 1 has the highest inflow rates (129 cfs) among the four ponds.
- Pond 4 has the lowest inflow rates (43 cfs) among the four ponds.
- Pond 2 has the highest storage (6.77×10^6 ft^3), and Pond 3 has the lowest storage (1.93×10^6 ft^3).
- Maximum and average water depths reach the highest when the peak inflow rates occur (about 13.0 hours from the beginning of storm inflow).
- Maximum water depths estimated for the four ponds, when the peak inflow appears are approximately 19, 18, 14, and 26 feet respectively

Excess runoff from Pond 1 is allowed to be discharged to the Storm Sewer Outfall Ditch (SSOD). Excess water is also allowed to be drained from Pond 2 to Pond 4 through an open channel. The final outfall point for stormwater runoff routing through Pond 1, Pond 3, and Pond 4 is the SSOD, then to Paddys Run, and eventually to the Great Miami River.

Since soil excavation in the Pond 1 area will reach the unsaturated Great Miami Aquifer, which is generally sandy material with a permeability range 10^{-2} to 10^{-3} cm/sec, the liner material for Pond 1 requires replacement with either a lower permeability clay soil or a synthetic liner. Replacing the sandy soil will facilitate minimum leakage of water through the liner materials.

Based on the modeling results, it is suggested that an underground pipe be connected between Pond 1 and Pond 2. This connection will greatly improve the regulation of water storage between Pond 1 and Pond 2, since Pond 2 has a much larger capacity with approximately seven feet of freeboard under all conditions considered.

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David R. Maidment, 1993, Handbook of Hydrology, McGraw, Inc.

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Haestad, 1990, "Flowmaster I," Haestad Method Inc., Waterbury, CT.

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U.S. Department of Energy (DOE), 1995, " Feasibility Study for Operable Unit 5, Fernald Environmental Management Project, Fernald, Ohio." volume 2, March.

APPENDIX A

MONTHLY RUNOFF CALCULATIONS (HELP MODEL)

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\POND2.D4
TEMPERATURE DATA FILE:        C:\HELP3\POND2.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\POND2.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\POND2.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\POND2.D10
OUTPUT DATA FILE:             C:\HELP3\pond2.OUT


TIME:  10:48      DATE:    6/ 3/1997


******************************************************************************

     TITLE:  RUNOFF TO PONDS OF FEMP PER UNIT ACRE (infiltration zone IV)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  22
          THICKNESS                    =    120.00   INCHES
          POROSITY                     =      0.4190 VOL/VOL
          FIELD CAPACITY               =      0.3070 VOL/VOL
          WILTING POINT                =      0.1800 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3559 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.189999992000E-04 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	120.00	INCHES
POROSITY	=	0.2000	VOL/VOL
FIELD CAPACITY	=	0.1500	VOL/VOL
WILTING POINT	=	0.1100	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1875	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.699999987000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	74.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.860	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.771	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.620	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	65.212	INCHES
TOTAL INITIAL WATER	=	65.212	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	104	
END OF GROWING SEASON (JULIAN DATE)	=	295	
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CLEVELAND OHIO

000300

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

3.66	2.98	3.67	3.55	3.78	3.59
4.09	2.80	2.59	2.11	3.01	2.86

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.10 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.57	3.10	3.75	3.30	3.52	3.55
	4.31	3.07	2.69	2.17	3.00	2.69
STD. DEVIATIONS	1.17	1.02	1.28	1.25	1.55	1.46
	2.17	1.42	1.26	1.02	1.21	1.09
RUNOFF						
TOTALS	1.242	2.125	0.954	0.053	0.121	0.191
	0.473	0.125	0.078	0.016	0.057	0.187
STD. DEVIATIONS	1.132	1.455	1.056	0.183	0.265	0.341
	0.746	0.315	0.206	0.066	0.214	0.582
EVAPOTRANSPIRATION						
TOTALS	0.913	1.116	2.543	3.052	3.048	3.073
	3.359	2.472	2.196	1.784	1.352	1.003
STD. DEVIATIONS	0.201	0.311	0.324	0.856	1.079	1.165
	1.199	0.996	0.856	0.642	0.297	0.174

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS	0.5452	0.4871	0.6067	0.6277	0.6384	0.5958
	0.6359	0.6489	0.6041	0.6430	0.5881	0.5954
STD. DEVIATIONS	0.2126	0.2022	0.1876	0.1621	0.1647	0.[illegible]7
	0.1754	0.1556	0.1739	0.1486	0.1718	0.1[illegible]3

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	38.74	(4.539)	140625.5	100.00
RUNOFF	5.621	(2.2746)	20403.37	14.509
EVAPOTRANSPIRATION	25.911	(2.7428)	94058.02	66.885
PERCOLATION/LEAKAGE THROUGH LAYER 2	7.21624	(1.50650)	26194.961	18.62746
CHANGE IN WATER STORAGE	-0.008	(2.9189)	-30.81	-0.022

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	4.24	15391.199
RUNOFF	3.420	12414.7588
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.023811	86.43263
SNOW WATER	5.69	20667.5918

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4190

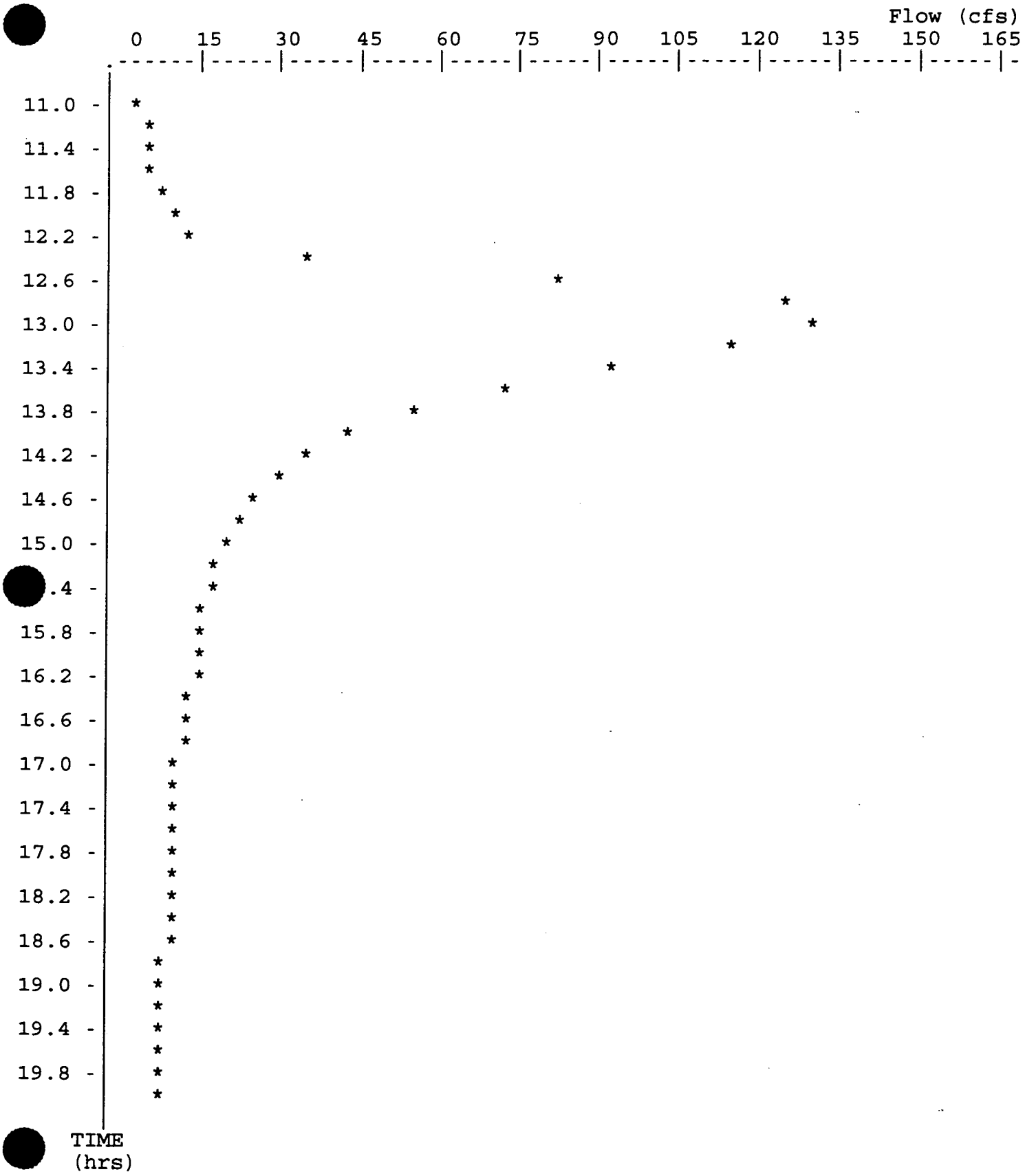
MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1297

****

APPENDIX B

PEAK DISCHARGE AND HYDROGRAPH (TR55 METHOD)

Quick TR-55 Version: 5.46 S/N:
Plotted: 06-05-1997 14:50:23



* File: c:\qtr55\POND1-25.HYD Qmax = 129.0 cfs

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: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

>>>> 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
SUBAREA A	26.40	74.0	0.40	0.50	4.70	2.13	I.15	.15
SUBAREA B	7.10	74.0	0.40	0.40	4.70	2.13	I.15	.15
SUBAREA O	51.30	74.0	0.50	0.50	4.70	2.13	I.15	.15
SUBAREA L	42.50	74.0	0.75	0.75	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 127.30 acres or 0.1989 sq.mi
Peak discharge = 129 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
SUBAREA A	0.43	0.43	0.40	0.50	Yes	--
SUBAREA B	0.39	0.39	0.40	0.40	Yes	--
SUBAREA O	0.55	0.55	0.50	0.50	Yes	--
SUBAREA L	0.74	0.74	0.75	0.75	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBAREA A	36	12.8
SUBAREA B	10	12.7
SUBAREA O	64	12.8
SUBAREA L	44	13.4
Composite Watershed	129	13.0

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

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
SUBAREA A	1	1	1	2	2	3	4	7	12
SUBAREA B	0	0	0	1	1	1	1	2	4
SUBAREA O	1	2	3	4	4	5	6	9	15
SUBAREA L	1	1	1	2	2	2	2	3	3
Total (cfs)	3	4	5	9	9	11	13	21	34

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
SUBAREA A	20	28	35	36	30	20	13	9	7
SUBAREA B	7	9	10	10	7	5	3	2	2
SUBAREA O	26	40	54	64	63	48	32	22	16
SUBAREA L	4	6	10	15	29	41	44	39	30
Total (cfs)	57	83	109	125	129	114	92	72	55

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

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
SUBAREA A	6	5	4	3	3	3	2	2	2
SUBAREA B	1	1	1	1	1	1	1	1	1
SUBAREA O	13	10	8	7	6	6	5	4	4
SUBAREA L	23	15	11	8	6	5	5	4	4
Total (cfs)	43	31	24	19	16	15	13	11	11

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBAREA A	2	2	1	1	0
SUBAREA B	1	0	0	0	0
SUBAREA O	4	3	3	2	0
SUBAREA L	3	3	3	2	0
Total (cfs)	10	8	7	5	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: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	3	14.8	22
11.1	3	14.9	20
11.2	4	15.0	19
11.3	4	15.1	18
11.4	4	15.2	18
11.5	5	15.3	17
11.6	5	15.4	17
11.7	6	15.5	16
11.8	8	15.6	16
11.9	9	15.7	16
12.0	9	15.8	15
12.1	11	15.9	15
12.2	13	16.0	15
12.3	21	16.1	15
12.4	34	16.2	14
12.5	57	16.3	14
12.6	83	16.4	13
12.7	109	16.5	13
12.8	125	16.6	13
12.9	127	16.7	12
13.0	129	16.8	12
13.1	122	16.9	11
13.2	114	17.0	11
13.3	103	17.1	11
13.4	92	17.2	11
13.5	82	17.3	11
13.6	72	17.4	11
13.7	63	17.5	11
13.8	55	17.6	11
13.9	49	17.7	11
14.0	43	17.8	10
14.1	39	17.9	10
14.2	35	18.0	10
14.3	31	18.1	10
14.4	29	18.2	10
14.5	26	18.3	9

	14.6	24	18.4	9
	14.7	23	18.5	9

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	9	22.4	4
18.7	9	22.5	4
18.8	8	22.6	4
18.9	8	22.7	4
19.0	8	22.8	4
19.1	8	22.9	4
19.2	8	23.0	4
19.3	8	23.1	4
19.4	8	23.2	4
19.5	8	23.3	3
19.6	7	23.4	3
19.7	7	23.5	3
19.8	7	23.6	3
19.9	7	23.7	3
20.0	7	23.8	3
20.1	7	23.9	3
20.2	7	24.0	2
20.3	7	24.1	2
20.4	7	24.2	2
20.5	6	24.3	2
20.6	6	24.4	2
20.7	6	24.5	2
20.8	6	24.6	2
20.9	6	24.7	2
21.0	6	24.8	2
21.1	6	24.9	1
21.2	6	25.0	1
21.3	6	25.1	1
21.4	6	25.2	1
21.5	6	25.3	1
21.6	5	25.4	1
21.7	5	25.5	1
21.8	5	25.6	0
21.9	5	25.7	0
22.0	5	25.8	0
22.1	5	25.9	0
22.2	5		
22.3	5		

Quick TR-55 Ver.5.46 S/N:
Executed: 11:29:57 06-05-1997 c:\qtr55\POND1.TCT

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

POND 1
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBAREA A	Tc	0.43
SUBBASIN B	Tc	0.39
SUBBASIN O	Tc	0.55
SUBAREA L	Tc	0.74

```
Quick-TR-55 Ver.5.46   S/N:
Executed: 11:29:57   06-05-1997     c:\qtr55\POND1.TCT

                                   POND 1
                                    FEMP


                        Tc COMPUTATIONS FOR: SUBAREA A

SHEET FLOW (Applicable to Tc only)
    Segment ID                                          A1
    Surface description                             GRASS
    Manning's roughness coeff., n                       0.3000
    Flow length, L (total < or = 300)       ft          200.0
    Two-yr 24-hr rainfall, P2               in          2.900
    Land slope, s                           ft/ft       0.1480
                           0.8
         .007 * (n*L)
    T =  -------------                      hrs         0.23           =  0.23
            0.5    0.4
          P2    *  s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                         Unpaved
    Flow length, L                          ft          380.0
    Watercourse slope, s                    ft/ft       0.1480

                             0.5
    Avg.V =  Csf *  (s)                     ft/s        6.2071
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                        hrs         0.02           =  0.02


CHANNEL FLOW
    Segment ID                                          A3
    Cross Sectional Flow Area, a            sq.ft       16.00
    Wetted perimeter, Pw                    ft          11.30
    Hydraulic radius, r = a/Pw              ft          1.416
    Channel slope, s                        ft/ft       0.0050
    Manning's roughness coeff., n                       0.0340

                        2/3    1/2
          1.49   *   r    *  s
    V =   --------------------              ft/s        3.9074
                     n

    Flow length, L                          ft          2460

    T = L / (3600*V)                        hrs         0.17           =  0.17

::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                                TOTAL TIME (hrs)        0.43
```

Quick TR-55 Ver.5.46 S/N:
Executed: 11:29:57 06-05-1997 c:\qtr55\POND1.TCT

POND 1
FEMP

Tc COMPUTATIONS FOR: SUBBASIN B

SHEET FLOW (Applicable to Tc only)

Segment ID			
Surface description		GRASS	
Manning's roughness coeff., n		0.3000	
Flow length, L (total < or = 300)	ft	300.0	
Two-yr 24-hr rainfall, P2	in	2.900	
Land slope, s	ft/ft	0.1480	
$T = \frac{.007 * (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	0.32	= 0.32

SHALLOW CONCENTRATED FLOW

Segment ID			
Surface (paved or unpaved)?		Unpaved	
Flow length, L	ft	150.0	
Watercourse slope, s	ft/ft	0.1480	
$Avg.V = Csf * (s)^{0.5}$	ft/s	6.2071	
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	16.00	
Wetted perimeter, Pw	ft	11.30	
Hydraulic radius, r = a/Pw	ft	1.416	
Channel slope, s	ft/ft	0.0050	
Manning's roughness coeff., n		0.0340	
$V = \frac{1.49 * r^{2/3} * s^{1/2}}{n}$	ft/s	3.9074	
Flow length, L	ft	810	
T = L / (3600*V)	hrs	0.06	= 0.06

::

TOTAL TIME (hrs) 0.39

```
Quick TR-55 Ver.5.46   S/N:
Executed: 11:29:57   06-05-1997    c:\qtr55\POND1.TCT

                                   POND 1
                                    FEMP


                     Tc COMPUTATIONS FOR: SUBBASIN O

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                         GRASS
    Manning's roughness coeff., n                     0.3000
    Flow length, L (total < or = 300)           ft     300.0
    Two-yr 24-hr rainfall, P2                   in     2.900
    Land slope, s                             ft/ft   0.2300
                             0.8
         .007 * (n*L)
    T =  --------------                         hrs     0.27            =  0.27
            0.5    0.4
          P2    *   s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                      Unpaved
    Flow length, L                              ft    1650.0
    Watercourse slope, s                      ft/ft   0.0100

                               0.5
    Avg.V =  Csf *  (s)                       ft/s    1.6135
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                            hrs     0.28            =  0.28


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)         0.55
```

Quick TR-55 Ver.5.46 S/N:
Executed: 11:29:57 06-05-1997 c:\qtr55\POND1.TCT

POND 1
FEMP

Tc COMPUTATIONS FOR: SUBAREA L

SHEET FLOW (Applicable to Tc only)

Segment ID			
Surface description		GRASS	
Manning's roughness coeff., n		0.3000	
Flow length, L (total < or = 300)	ft	150.0	
Two-yr 24-hr rainfall, P2	in	2.900	
Land slope, s	ft/ft	0.0100	
$T = \frac{.007 * (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	0.55	= 0.55

SHALLOW CONCENTRATED FLOW

Segment ID			
Surface (paved or unpaved)?		Unpaved	
Flow length, L	ft	950.0	
Watercourse slope, s	ft/ft	0.0070	
$Avg.V = Csf * (s)^{0.5}$	ft/s	1.3499	
where: Unpaved Csf = 16.1345			
Paved Csf = 20.3282			
T = L / (3600*V)	hrs	0.20	= 0.20

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) 0.74

Quick TR-55 Ver.5.46 S/N:
Executed: 14:18:47 06-05-1997

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using Length/Velocity)

TRAVEL TIME COMPUTATION
POND1 - NORTHEAST OF FEMP
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBAREA A	Tt	0.00
SUBAREA B	Tt	0.00
SUBAREA O	Tt	0.19
SUBAREA L	Tt	0.00

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

GRAPHICAL PEAK DISCHARGE
POND 1 -AT NORTHEAST OF FEMP

CALCULATED .GPD
DISK FILE: c:\qtr55\POND1 .GPD

Drainage Area	(acres)	127.3 --->	0.1989 sq.mi.	
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	.75		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1 --->	1.3 acres	

	Storm #1	Storm #2	Storm #3
Frequency (years)	5	25	100
Rainfall, P, 24-hr (in)	3.7	4.7	5.6
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.190	0.150	0.125
Unit Discharge, * qu (csm/in)	390	405	414
Runoff, Q (in)	1.38	2.13	2.85
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	93	149	204

Summary of Computations for qu

Ia/p	#1	0.100	0.100	0.100
C0	#1	2.553	2.553	2.553
C1	#1	-0.615	-0.615	-0.615
C2	#1	-0.164	-0.164	-0.164
qu (csm)	#1	424.152	424.152	424.152
Ia/p	#2	0.300	0.300	0.300
C0	#2	2.465	2.465	2.465
C1	#2	-0.623	-0.623	-0.623
C2	#2	-0.117	-0.117	-0.117
qu (csm)	#2	347.763	347.763	347.763
* qu (csm)		390	405	414

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$

qp (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond & Swamp Adj.)

Quick TR-55 Version: 5.46 S/N:

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND1 - NORTHEAST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND1 .DET

Drainage Area	(acres)	127.3	0.1989 sq.mi.
Rainfall Distribution	(Type)	II	

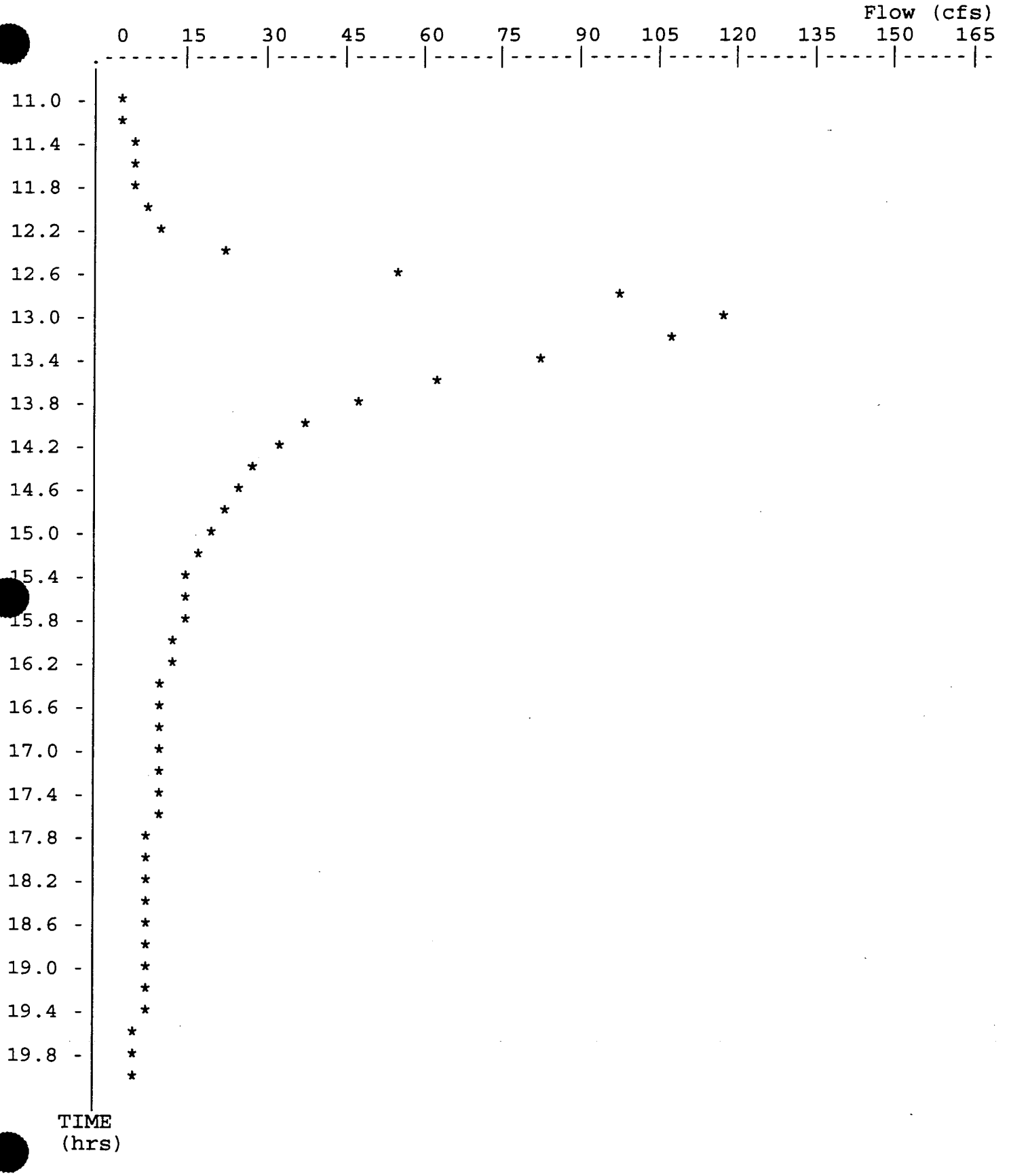
	Storm #1	Storm #2	Storm #3
Frequency (years)	5	25	100
Peak Inflow, qi (cfs)	93	149	204
Inflow Runoff, Q (in)	1.38	2.13	2.85
Peak Outflow, qo (cfs)	0	0	0
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.682	0.682
Inflow Volume, Vr (ac-ft)	14.6	22.6	30.2
STORAGE VOLUME, Vs (ac-ft)	10.0	15.4	20.6

Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.682	0.682

$$* \quad Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$$

Quick TR-55 Version: 5.46 S/N:
Plotted: 06-05-1997 15:47:36



* File: c:\qtr55\POND2-25.HYD Qmax = 117.0 cfs

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
SUBBASIN N	51.80	74.0	0.20	0.75	4.70	2.13	I.15	.15
SUBBASIN M	57.40	74.0	1.50	0.00	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 109.20 acres or 0.1706 sq.mi
Peak discharge = 117 cfs

>>>> 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
SUBBASIN N	0.29	0.65	0.20	0.75	Yes	--
SUBBASIN M	1.44	0.00	1.50	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBBASIN N	71	13.0
SUBBASIN M	50	13.2
Composite Watershed	117	13.0

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

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
SUBBASIN N	1	2	2	3	3	4	4	6	9
SUBBASIN M	1	2	2	3	4	4	6	9	13
Total (cfs)	2	4	4	6	7	8	10	15	22

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
SUBBASIN N	17	29	45	60	71	57	38	25	17
SUBBASIN M	19	25	32	38	46	50	44	37	30
Total (cfs)	36	54	77	98	117	107	82	62	47

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
SUBBASIN N	13	10	9	7	6	6	5	4	4
SUBBASIN M	25	19	15	12	9	7	6	5	5
Total (cfs)	38	29	24	19	15	13	11	9	9

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBBASIN N	4	3	3	2	0
SUBBASIN M	4	4	3	3	0

4873

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Quick TR-55 Ver.5.46   S/N:
Executed: 16:17:01   06-05-1997    c:\qtr55\POND3.TCT

                         TIME OF CONCENTRATION
                       POND 3 - SOUTHEAST FEMP
                                FEMP

                    Tc COMPUTATIONS FOR: SUBBASIN F

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                    GRASS
    Manning's roughness coeff., n                 0.3000
    Flow length, L (total < or = 300)     ft      300.0
    Two-yr 24-hr rainfall, P2             in      2.900
    Land slope, s                       ft/ft     0.0150
                          0.8
         .007 * (n*L)
    T =  --------------                  hrs       0.81           =  0.81
           0.5     0.4
          P2    *   s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                 Unpaved
    Flow length, L                        ft      510.0
    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       0.06           =  0.06

CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a       sq.ft     32.00
    Wetted perimeter, Pw                  ft     17.90
    Hydraulic radius, r = a/Pw            ft     1.788
    Channel slope, s                   ft/ft     0.0050
    Manning's roughness coeff., n                0.0340

                        2/3    1/2
         1.49   *   r    *   s
    V =  --------------------           ft/s     4.5645
                    n

    Flow length, L                        ft      2070

    T = L / (3600*V)                     hrs      0.13            =  0.13

::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                          TOTAL TIME (hrs)          1.00
```

000324

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Quick TR-55 Ver.5.46 S/N:
~~Executed: 16:17:01 06-05-1997 c:\qtr55\POND3.TCT~~

TIME OF CONCENTRATION
POND 3 - SOUTHEAST FEMP
FEMP

Tc COMPUTATIONS FOR: SUBBASIN H

SHEET FLOW (Applicable to Tc only)

Segment ID			
Surface description	GRASS		
Manning's roughness coeff., n		0.3000	
Flow length, L (total < or = 300)	ft	300.0	
Two-yr 24-hr rainfall, P2	in	2.900	
Land slope, s	ft/ft	0.0100	
$T = \dfrac{.007 * (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	0.95	= 0.95

SHALLOW CONCENTRATED FLOW

Segment ID			
Surface (paved or unpaved)?		Unpaved	
Flow length, L	ft	1400.0	
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	0.24	= 0.24

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	
$V = \dfrac{1.49 * r^{2/3} * s^{1/2}}{n}$	ft/s	0.0000	
Flow length, L	ft	0	
T = L / (3600*V)	hrs	0.00	= 0.00

::

TOTAL TIME (hrs) 1.19

000325

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

POND 2 - NORTHWEST FEMP
FEMP
25 YEAR RETURN PERIOD, 24 HOUR DURATION STORM

CALCULATED
DISK FILE: c:\qtr55\POND2 .GPD

Drainage Area	(acres)	109.2	--->	0.1706 sq.mi.
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	.95		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1	--->	1.1 acres

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Rainfall, P, 24-hr (in)	4.7		
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.150	0.000	0.000
Unit Discharge, * qu (csm/in)	352	0	0
Runoff, Q (in)	2.13	0.00	0.00
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	111	0	0

Summary of Computations for qu

Ia/p	#1	0.100	0.000	0.000
C0	#1	2.553	0.000	0.000
C1	#1	-0.615	0.000	0.000
C2	#1	-0.164	0.000	0.000
qu (csm)	#1	368.851	0.000	0.000
Ia/p	#2	0.300	0.000	0.000
C0	#2	2.465	0.000	0.000
C1	#2	-0.623	0.000	0.000
C2	#2	-0.117	0.000	0.000
qu (csm)	#2	301.391	0.000	0.000
* qu (csm)		352	0	0

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$

qp (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond & Swamp Adj.)

Quick TR-55 Version: 5.46 S/N: 4873

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND 2 - NORTHWEST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND2 .DET

Drainage Area	(acres)	109.2	0.1706 sq.mi.
Rainfall Distribution	(Type)	II	

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Peak Inflow, qi (cfs)	117		
Inflow Runoff, Q (in)	2.13		
Peak Outflow, qo (cfs)	0		
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.000	0.000
Inflow Volume, Vr (ac-ft)	19.4	0.0	0.0
STORAGE VOLUME, Vs (ac-ft)	13.2	0.0	0.0

Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.000	0.000

$$* \quad Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$$

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
SUBBASIN C	36.50	74.0	0.50	0.10	4.70	2.13	I.15	.15
SUBBASIN E	7.20	74.0	1.00	0.30	4.70	2.13	I.15	.15
SUBBASIN F	23.00	74.0	1.00	0.10	4.70	2.13	I.15	.15
SUBBASIN H	37.30	74.0	1.25	0.00	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 104.00 acres or 0.1625 sq.mi
Peak discharge = 95 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
SUBBASIN C	0.59	0.07	0.50	0.10	Yes	--
SUBBASIN E	1.02	0.24	1.00	0.30	Yes	--
SUBBASIN F	1.00	0.07	1.00	0.10	Yes	--
SUBBASIN H	1.19	0.00	1.25	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBBASIN C	57	12.5
SUBBASIN E	7	13.0
SUBBASIN F	25	13.0
SUBBASIN H	37	13.0
Composite Watershed	95	12.8

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

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
SUBBASIN C	1	2	3	5	7	13	24	40	52
SUBBASIN E	0	0	0	0	0	1	1	1	1
SUBBASIN F	1	1	1	1	2	2	2	4	6
SUBBASIN H	1	1	2	2	3	4	5	8	13
Total (cfs)	3	4	6	8	12	20	32	53	72

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
SUBBASIN C	57	52	43	34	21	14	11	9	7
SUBBASIN E	2	3	4	6	7	7	6	5	4
SUBBASIN F	10	14	18	22	25	22	17	13	10
SUBBASIN H	18	24	29	33	37	32	26	20	16
Total (cfs)	87	93	94	95	90	75	60	47	37

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

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
SUBBASIN C	7	6	5	4	4	4	3	3	3
SUBBASIN E	3	2	2	1	1	1	1	1	1
SUBBASIN F	8	6	5	4	3	3	2	2	2
SUBBASIN H	13	10	8	6	5	4	4	3	3
Total (cfs)	31	24	20	15	13	12	10	9	9

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBBASIN C	3	2	2	2	0
SUBBASIN E	1	0	0	0	0
SUBBASIN F	2	2	1	1	0
SUBBASIN H	3	3	2	2	0
Total (cfs)	9	7	5	5	0

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	3	14.8	18
11.1	3	14.9	16
11.2	4	15.0	15
11.3	4	15.1	15
11.4	5	15.2	14
11.5	5	15.3	14
11.6	6	15.4	13
11.7	7	15.5	13
11.8	7	15.6	13
11.9	8	15.7	13
12.0	12	15.8	12
12.1	20	15.9	12
12.2	32	16.0	12
12.3	53	16.1	12
12.4	72	16.2	11
12.5	87	16.3	11
12.6	93	16.4	10
12.7	94	16.5	10
12.8	95	16.6	10
12.9	92	16.7	10
13.0	90	16.8	9
13.1	82	16.9	9
13.2	75	17.0	9
13.3	67	17.1	9
13.4	60	17.2	9
13.5	54	17.3	9
13.6	47	17.4	9
13.7	42	17.5	9
13.8	37	17.6	9
13.9	34	17.7	9
14.0	31	17.8	9
14.1	29	17.9	9
14.2	26	18.0	9
14.3	24	18.1	9
14.4	23	18.2	9
14.5	21	18.3	8

	14.6	20	18.4	8
	14.7	19	18.5	8

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Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	2	14.8	22
11.1	3	14.9	20
11.2	3	15.0	19
11.3	4	15.1	18
11.4	4	15.2	17
11.5	4	15.3	17
11.6	4	15.4	16
11.7	5	15.5	15
11.8	5	15.6	15
11.9	6	15.7	14
12.0	7	15.8	14
12.1	8	15.9	13
12.2	10	16.0	13
12.3	15	16.1	13
12.4	22	16.2	12
12.5	36	16.3	12
12.6	54	16.4	11
12.7	77	16.5	11
12.8	98	16.6	11
12.9	108	16.7	10
13.0	117	16.8	10
13.1	112	16.9	9
13.2	107	17.0	9
13.3	94	17.1	9
13.4	82	17.2	9
13.5	72	17.3	9
13.6	62	17.4	9
13.7	54	17.5	9
13.8	47	17.6	9
13.9	42	17.7	9
14.0	38	17.8	8
14.1	35	17.9	8
14.2	32	18.0	8
14.3	29	18.1	8
14.4	27	18.2	8
14.5	26	18.3	8

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	7	22.4	4
18.7	7	22.5	4
18.8	7	22.6	4
18.9	7	22.7	4
19.0	7	22.8	4
19.1	7	22.9	4
19.2	7	23.0	4
19.3	7	23.1	4
19.4	7	23.2	4
19.5	6	23.3	3
19.6	6	23.4	3
19.7	6	23.5	3
19.8	6	23.6	3
19.9	6	23.7	3
20.0	6	23.8	3
20.1	6	23.9	3
20.2	6	24.0	2
20.3	6	24.1	2
20.4	6	24.2	2
20.5	6	24.3	2
20.6	6	24.4	2
20.7	6	24.5	2
20.8	6	24.6	2
20.9	6	24.7	2
21.0	6	24.8	2
21.1	5	24.9	1
21.2	5	25.0	1
21.3	5	25.1	1
21.4	5	25.2	1
21.5	5	25.3	1
21.6	5	25.4	1
21.7	5	25.5	1
21.8	5	25.6	0
21.9	5	25.7	0
22.0	5	25.8	0
22.1	5	25.9	0
22.2	5		
22.3	5		

Quick TR-55 Ver.5.46 S/N:
Executed: 16:44:51 06-05-1997

SCS RUNOFF CN NUMBER
POND 3 - SOUTHEAST FEMP
FEMP

RUNOFF CURVE NUMBER SUMMARY

Subarea Description	Area (acres)	CN (weighted)
SUBBASIN C	36.50	74
SUBBASIN E	7.20	74
SUBBASIN F	23.00	74
SUBBASIN H	37.30	74

TIME OF CONCENTRATION
POND 3 - SOUTHEAST FEMP
FEMP

Tc COMPUTATIONS FOR: SUBBASIN C

SHEET FLOW (Applicable to Tc only)

Segment ID			
Surface description		GRASS	
Manning's roughness coeff., n		0.3000	
Flow length, L (total < or = 300)	ft	300.0	
Two-yr 24-hr rainfall, P2	in	2.900	
Land slope, s	ft/ft	0.1480	
$T = \frac{.007 * (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	0.32	= 0.32

SHALLOW CONCENTRATED FLOW

Segment ID			
Surface (paved or unpaved)?		Unpaved	
Flow length, L	ft	190.0	
Watercourse slope, s	ft/ft	0.1480	
Avg.V = $Csf * (s)^{0.5}$	ft/s	6.2071	
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	40.50	
Wetted perimeter, Pw	ft	27.70	
Hydraulic radius, r = a/Pw	ft	1.462	
Channel slope, s	ft/ft	0.0050	
Manning's roughness coeff., n		0.0340	
$V = \frac{1.49 * r^{2/3} * s^{1/2}}{n}$	ft/s	3.9919	
Flow length, L	ft	3720	
T = L / (3600*V)	hrs	0.26	= 0.26

TOTAL TIME (hrs) 0.59

```
Quick TR-55 Ver.5.46   S/N:
Executed: 16:17:01   06-05-1997    c:\qtr55\POND3.TCT

                          TIME OF CONCENTRATION
                       POND 3 - SOUTHEAST FEMP
                                 FEMP

                 Tc COMPUTATIONS FOR: SUBBASIN E

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                    GRASS
    Manning's roughness coeff., n                0.3000
    Flow length, L (total < or = 300)     ft     300.0
    Two-yr 24-hr rainfall, P2             in     2.900
    Land slope, s                       ft/ft   0.0100
                        0.8
         .007 * (n*L)
    T =  -------------                    hrs     0.95              =  0.95
            0.5    0.4
          P2   *  s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                 Unpaved
    Flow length, L                        ft      60.0
    Watercourse slope, s                ft/ft   0.0100

                          0.5
    Avg.V =  Csf *  (s)                  ft/s   1.6135
    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    32.00
    Wetted perimeter, Pw                  ft     17.90
    Hydraulic radius, r = a/Pw            ft     1.788
    Channel slope, s                    ft/ft   0.0050
    Manning's roughness coeff., n               0.0340

                      2/3    1/2
         1.49  *  r    *  s
    V =  --------------------             ft/s   4.5645
                   n

    Flow length, L                        ft       980

    T = L / (3600*V)                      hrs     0.06              =  0.06

::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                             TOTAL TIME (hrs)       1.02
```

14.6	24	18.4	8
14.7	23	18.5	8

4873

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	8	22.4	4
18.7	8	22.5	4
18.8	7	22.6	4
18.9	7	22.7	4
19.0	7	22.8	4
19.1	7	22.9	4
19.2	7	23.0	4
19.3	6	23.1	4
19.4	6	23.2	4
19.5	6	23.3	3
19.6	6	23.4	3
19.7	6	23.5	3
19.8	5	23.6	3
19.9	5	23.7	3
20.0	5	23.8	3
20.1	5	23.9	3
20.2	5	24.0	2
20.3	5	24.1	2
20.4	5	24.2	2
20.5	5	24.3	2
20.6	5	24.4	2
20.7	5	24.5	2
20.8	5	24.6	2
20.9	5	24.7	2
21.0	5	24.8	2
21.1	5	24.9	1
21.2	5	25.0	1
21.3	5	25.1	1
21.4	5	25.2	1
21.5	5	25.3	1
21.6	5	25.4	1
21.7	5	25.5	1
21.8	5	25.6	0
21.9	5	25.7	0
22.0	5	25.8	0
22.1	5	25.9	0
22.2	5		
22.3	5		

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

TIME OF CONCENTRATION
POND 3 - SOUTHEAST FEMP
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBBASIN C	Tc	0.59
SUBBASIN E	Tc	1.02
SUBBASIN F	Tc	1.00
SUBBASIN H	Tc	1.19

Quick TR-55 Ver.5.46 S/N:
Executed: 16:40:59 06-05-1997

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using Length/Velocity)

TRAVEL TIME COMPUTATION
POND 3 - SOUTHEAST FEMP
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBBASIN C	Tt	0.07
SUBBASIN E	Tt	0.24
SUBBASIN F	Tt	0.07
SUBBASIN H	Tt	0.00

TRAVEL TIME COMPUTATION
POND 3 - SOUTHEAST FEMP
FEMP

Tc or Tt DATA
::

Subarea: SUBBASIN C DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		TIME hours
CHANNEL THROUGH A CULVERT TO	1200	4.54	4.4	=	0.07
		TOTAL Tt --->	minutes 4.4	=	hours 0.07

::::::::::::::::::::::::::::::::::::

Subarea: SUBBASIN E DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		TIME hours
CHANNEL THROUGH SUBAREA F	2700	4.50	10.0	=	0.17
CHANNEL THROUGH CULVERT PIPE	1200	4.50	4.4	=	0.[illegible]
		TOTAL Tt --->	minutes 14.4	=	hours 0.24

::::::::::::::::::::::::::::::::::::

Subarea: SUBBASIN F DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		TIME hours
CHANNEL THROUGH CULVERT PIPE	1200	4.50	4.4	=	0.07
		TOTAL Tt --->	minutes 4.4	=	hours 0.07

::::::::::::::::::::::::::::::::::::

Quick TR-55 Ver.5.46 S/N:
Executed: 16:40:59 06-05-1997

Subarea: SUBBASIN H DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes	TIME hours

	minutes		hours
TOTAL Tt --->	0.0	=	0.00

::::::::::::::::::::::::::::::::::::

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

GRAPHICAL PEAK DISCHARGE
POND 3 - SOUTHEAST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND3 .GPD

Drainage Area	(acres)	104	--->	0.1625 sq.mi.
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	.66		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1	--->	1.0 acres

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Rainfall, P, 24-hr (in)	4.7		
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.150	0.000	0.000
Unit Discharge, * qu (csm/in)	436	0	0
Runoff, Q (in)	2.13	0.00	0.00
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	131	0	0

Summary of Computations for qu

Ia/p	#1	0.100	0.000	0.000
C0	#1	2.553	0.000	0.000
C1	#1	-0.615	0.000	0.000
C2	#1	-0.164	0.000	0.000
qu (csm)	#1	455.922	0.000	0.000
Ia/p	#2	0.300	0.000	0.000
C0	#2	2.465	0.000	0.000
C1	#2	-0.623	0.000	0.000
C2	#2	-0.117	0.000	0.000
qu (csm)	#2	374.861	0.000	0.000
* qu (csm)		436	0	0

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$
$$qp\ (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond\ \&\ Swamp\ Adj.)$$

Quick TR-55 Version: 5.46 S/N:

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND 3 - SOUTHEAST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND3 .DET

Drainage Area	(acres)	104	0.1625 sq.mi.
Rainfall Distribution	(Type)	II	

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Peak Inflow, qi (cfs)	~~130~~ 131		
Inflow Runoff, Q (in)	2.13		
Peak Outflow, qo (cfs)	0		
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.000	0.000
Inflow Volume, Vr (ac-ft)	18.5	0.0	0.0
STORAGE VOLUME, Vs (ac-ft)	12.6	0.0	0.0

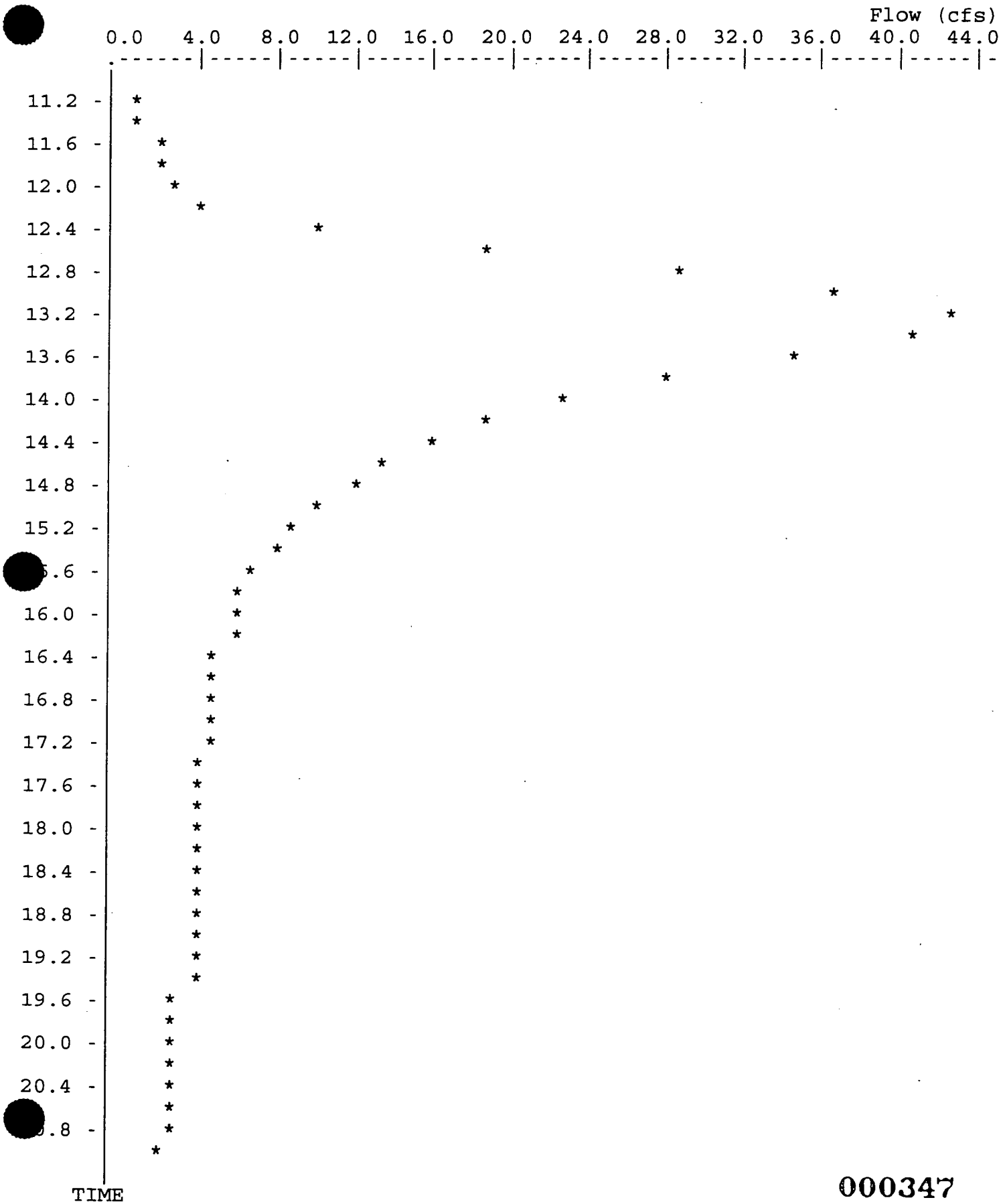
Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.000	0.000

$$* \quad Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$$

Quick TR-55 Version: 5.46 S/N:
Plotted: 06-09-1997 16:59:27

4873



000347

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
SUBBASIN K	8.70	74.0	0.50	1.00	4.70	2.13	I.15	.15
SUBBASIN J	40.60	74.0	1.50	0.00	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 49.30 acres or 0.07703 sq.mi
Peak discharge = 43 cfs

>>>> 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
SUBBASIN K	0.62	0.86	0.50	1.00	Yes	--
SUBBASIN J	1.58	0.00	1.50	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBBASIN K	10	13.4
SUBBASIN J	35	13.2
Composite Watershed	43	13.2

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

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
SUBBASIN K	0	0	0	0	0	0	0	1	1
SUBBASIN J	1	1	2	2	3	3	4	6	9
Total (cfs)	1	1	2	2	3	3	4	7	10

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
SUBBASIN K	1	1	1	2	5	8	10	9	7
SUBBASIN J	13	18	22	27	32	35	31	26	21
Total (cfs)	14	19	23	29	37	43	41	35	28

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
SUBBASIN K	5	3	2	2	1	1	1	1	1
SUBBASIN J	18	14	11	8	6	5	4	4	3
Total (cfs)	23	17	13	10	7	6	5	5	4

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBBASIN K	1	1	1	0	0
SUBBASIN J	3	3	2	2	0

Total (cfs)	4	4	3	2	0

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Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	1	14.8	12
11.1	1	14.9	11
11.2	1	15.0	10
11.3	1	15.1	9
11.4	1	15.2	9
11.5	2	15.3	8
11.6	2	15.4	8
11.7	2	15.5	7
11.8	2	15.6	7
11.9	2	15.7	7
12.0	3	15.8	6
12.1	3	15.9	6
12.2	4	16.0	6
12.3	7	16.1	6
12.4	10	16.2	6
12.5	14	16.3	5
12.6	19	16.4	5
12.7	23	16.5	5
12.8	29	16.6	5
12.9	33	16.7	5
13.0	37	16.8	5
13.1	40	16.9	5
13.2	43	17.0	5
13.3	42	17.1	5
13.4	41	17.2	5
13.5	38	17.3	4
13.6	35	17.4	4
13.7	32	17.5	4
13.8	28	17.6	4
13.9	26	17.7	4
14.0	23	17.8	4
14.1	21	17.9	4
14.2	19	18.0	4
14.3	17	18.1	4
14.4	16	18.2	4
14.5	14	18.3	4

5T3A	14.6	13	18.4	4
	14.7	12	18.5	4

4873

351-A

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	4	22.4	2
18.7	4	22.5	2
18.8	4	22.6	2
18.9	4	22.7	2
19.0	4	22.8	2
19.1	4	22.9	2
19.2	4	23.0	2
19.3	4	23.1	1
19.4	4	23.2	1
19.5	4	23.3	1
19.6	3	23.4	1
19.7	3	23.5	1
19.8	3	23.6	1
19.9	3	23.7	1
20.0	3	23.8	1
20.1	3	23.9	1
20.2	3	24.0	1
20.3	3	24.1	1
20.4	3	24.2	1
20.5	3	24.3	1
20.6	3	24.4	1
20.7	3	24.5	1
20.8	3	24.6	1
20.9	3	24.7	1
21.0	2	24.8	1
21.1	2	24.9	1
21.2	2	25.0	0
21.3	2	25.1	0
21.4	2	25.2	0
21.5	2	25.3	0
21.6	2	25.4	0
21.7	2	25.5	0
21.8	2	25.6	0
21.9	2	25.7	0
22.0	2	25.8	0
22.1	2	25.9	0
22.2	2		
22.3	2		

SCS RUNOFF CURVE NUMBER
POND 4 - RETENTION POND
FEMP

RUNOFF CURVE NUMBER SUMMARY

Subarea Description	Area (acres)	CN (weighted)
K	8.70	74
SUBBASIN J	40.60	74

Quick TR-55 Ver.5.46 S/N:
Executed: 16:32:57 06-09-1997

SCS RUNOFF CURVE NUMBER
POND 4 - RETENTION POND
FEMP

RUNOFF CURVE NUMBER DATA

::

Composite Area: K

SURFACE DESCRIPTION	AREA (acres)	CN	
GRASS	8.70	74	
COMPOSITE AREA --->	8.70	74.0	(74)

::

Composite Area: SUBBASIN J

SURFACE DESCRIPTION	AREA (acres)	CN	
GRASS	40.60	74	
COMPOSITE AREA --->	40.60	74.0	(74)

::

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

POND 4 - RETENTION POND
TIME OF CONCENTRATION
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBBASIN K	Tc	0.62
SUBBASIN J	Tc	1.58

Quick TR-55 Ver.5.46 S/N:
Executed: 16:23:41 06-09-1997 c:\qtr55\POND4.TCT

POND 4 - RETENTION POND
TIME OF CONCENTRATION
FEMP

Tc COMPUTATIONS FOR: SUBBASIN K

SHEET FLOW (Applicable to Tc only)

Segment ID			
Surface description		GRASS	
Manning's roughness coeff., n		0.3000	
Flow length, L (total < or = 300)	ft	580.0	
Two-yr 24-hr rainfall, P2	in	2.900	
Land slope, s	ft/ft	0.1480	
$T = \frac{.007 * (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	0.55	= 0.55

SHALLOW CONCENTRATED FLOW

Segment ID			
Surface (paved or unpaved)?			
Flow length, L	ft	0.0	
Watercourse slope, s	ft/ft	0.0000	
$Avg.V = Csf * (s)^{0.5}$	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	16.00	
Wetted perimeter, Pw	ft	11.30	
Hydraulic radius, r = a/Pw	ft	1.416	
Channel slope, s	ft/ft	0.0050	
Manning's roughness coeff., n		0.0340	
$V = \frac{1.49 * r^{2/3} * s^{1/2}}{n}$	ft/s	3.9074	
Flow length, L	ft	1020	
T = L / (3600*V)	hrs	0.07	= 0.07

::

TOTAL TIME (hrs) 0.62

Quick TR-55 Ver.5.46 S/N:
Executed: 16:23:41 06-09-1997 c:\qtr55\POND4.TCT

4873

POND 4 - RETENTION POND
TIME OF CONCENTRATION
FEMP

Tc COMPUTATIONS FOR: SUBBASIN J

SHEET FLOW (Applicable to Tc only)

Segment ID			
Surface description		GRASS	
Manning's roughness coeff., n		0.3000	
Flow length, L (total < or = 300)	ft	300.0	
Two-yr 24-hr rainfall, P2	in	2.900	
Land slope, s	ft/ft	0.0050	
$T = \frac{.007 * (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	1.25	= 1.25

SHALLOW CONCENTRATED FLOW

Segment ID			
Surface (paved or unpaved)?		Unpaved	
Flow length, L	ft	600.0	
Watercourse slope, s	ft/ft	0.0010	
$Avg.V = Csf * (s)^{0.5}$	ft/s	0.5102	
where: Unpaved Csf = 16.1345			
Paved Csf = 20.3282			
T = L / (3600*V)	hrs	0.33	= 0.33

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) 1.58

000357

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using Length/Velocity)

POND 4 - RETENTION POND
TRAVEL TIME
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
K	Tt	0.86
SUBBASIN J	Tt	0.00

POND 4 - RETENTION POND
TRAVEL TIME
FEMP

Tc or Tt DATA
::

Subarea: K DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		hours
CHANNEL THROUGH SUBAREA J	1580	0.51	51.6	=	0.86
			minutes		hours
		TOTAL Tt --->	51.6	=	0.86

::::::::::::::::::::::::::::::::::::

Subarea: SUBBASIN J DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		hours
OUTFALL AT RETENTION POND	0	0.00	0.0	=	0.00
			minutes		hours
		TOTAL Tt --->	0.0	=	0.00

::::::::::::::::::::::::::::::::::::

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

GRAPHICAL PEAK DISCHATGE
POND 4 -RETEMTION POND
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND4 .GPD

Drainage Area	(acres)	49.3	--->	0.0770 sq.mi.
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	1.48		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1	--->	0.5 acres

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Rainfall, P, 24-hr (in)	4.7		
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.150	0.000	0.000
Unit Discharge, * qu (csm/in)	265	0	0
Runoff, Q (in)	2.13	0.00	0.00
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	38	0	0

Summary of Computations for qu

Ia/p	#1	0.100	0.000	0.000
C0	#1	2.553	0.000	0.000
C1	#1	-0.615	0.000	0.000
C2	#1	-0.164	0.000	0.000
qu (csm)	#1	277.807	0.000	0.000
Ia/p	#2	0.300	0.000	0.000
C0	#2	2.465	0.000	0.000
C1	#2	-0.623	0.000	0.000
C2	#2	-0.117	0.000	0.000
qu (csm)	#2	226.956	0.000	0.000
* qu (csm)		265	0	0

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$

qp (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond & Swamp Adj.)

DETENTION STORAGE ESTIMATE
POND 4 - RETENTION POND
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND4 .DET

Drainage Area	(acres)	49.3	0.0770 sq.mi.
Rainfall Distribution	(Type)	II	

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Peak Inflow, qi (cfs)	4.7		
Inflow Runoff, Q (in)	2.13		
Peak Outflow, qo (cfs)	0		
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.000	0.000
Inflow Volume, Vr (ac-ft)	8.8	0.0	0.0
STORAGE VOLUME, Vs (ac-ft)	6.0	0.0	0.0

Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.000	0.000

$$* \quad Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$$

APPENDIX C

ROUTING CALCULATIONS UNDER NORMAL CONDITIONS

Table C-1
POND ROUTING UNDER NORMAL CONDITIONS
POND 1 (NORTHEAST OF FEMP)

BROWN & ROOT ENVIRONMENTAL

Hydraulic Conductivity of Pond Liner (cm/sec) = 7.23E-07
Thickness of Pond Liner (f 3
Pond Bottom Elev. (ft) = 555
Drainage Area (ft^2) 5,550,300

Pond 1 Overflow El.= 573

Pond overflow at storage (ft^3): 4445400

POND 1

Year	Month	Rainfall Depth (inch)	Rainfall Vol. into Pond (ft^3)	Runoff Depth (inch)	Runoff Vol. into Pond (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3)/day	Total Out flow O (ft^3)
1	1	3.66	1.46E+05	1.242	5.74E+05	7.20E+05	571.38	4.78E+05	520	3.60E+06	3.36E-01	1.61E+05	0.527	2.10E+04	0.00E+00	1.82E+05
1	2	2.98	1.29E+05	2.125	9.83E+05	1.11E+06	572.41	5.18E+05	520	4.14E+06	3.57E-01	1.85E+05	1.620	6.99E+04	0.00E+00	2.55E+05
1	3	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.83E+04	8.70E+05
1	4	3.55	1.54E+05	0.053	2.45E+04	1.79E+05	572.49	5.21E+05	520	4.18E+06	3.58E-01	1.87E+05	4.437	1.93E+05	0.00E+00	3.79E+05
1	5	3.78	1.59E+05	0.121	5.60E+04	2.15E+05	572.10	5.06E+05	520	3.98E+06	3.51E-01	1.77E+05	5.076	2.14E+05	0.00E+00	3.91E+05
1	6	3.59	1.48E+05	0.191	8.83E+04	2.36E+05	571.76	4.93E+05	520	3.80E+06	3.44E-01	1.69E+05	6.098	2.51E+05	0.00E+00	4.20E+05
1	7	4.09	1.63E+05	0.473	2.19E+05	3.82E+05	571.41	4.80E+05	520	3.62E+06	3.36E-01	1.61E+05	5.905	2.36E+05	0.00E+00	3.97E+05
1	8	2.8	1.12E+05	0.125	5.78E+04	1.69E+05	571.38	4.79E+05	520	3.60E+06	3.36E-01	1.61E+05	5.039	2.01E+05	0.00E+00	3.62E+05
1	9	2.59	1.00E+05	0.087	4.02E+04	1.40E+05	571.01	4.64E+05	520	3.41E+06	3.28E-01	1.52E+05	4.036	1.56E+05	0.00E+00	3.09E+05
1	10	2.11	7.95E+04	0.016	7.40E+03	8.69E+04	570.69	4.52E+05	520	3.24E+06	3.22E-01	1.45E+05	2.593	9.77E+04	0.00E+00	2.43E+05
1	11	3.01	1.10E+05	0.057	2.64E+04	1.37E+05	570.39	4.41E+05	520	3.09E+06	3.15E-01	1.39E+05	1.558	5.72E+04	0.00E+00	1.96E+05
1	12	2.86	1.04E+05	0.187	8.65E+04	1.90E+05	570.28	4.36E+05	520	3.03E+06	3.13E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05
2	13	3.66	1.34E+05	1.242	5.74E+05	7.08E+05	570.35	4.39E+05	520	3.06E+06	3.15E-01	1.38E+05	0.527	1.93E+04	0.00E+00	1.57E+05
2	14	2.98	1.19E+05	2.125	9.83E+05	1.10E+06	571.40	4.79E+05	520	3.61E+06	3.36E-01	1.61E+05	1.620	6.47E+04	0.00E+00	2.26E+05
2	15	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.46E+03	3.64E+05
2	16	3.55	1.60E+05	0.053	2.45E+04	1.84E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	4.437	2.00E+05	7.96E+03	6.38E+05
2	17	3.78	1.60E+05	0.121	5.60E+04	2.16E+05	572.13	5.07E+05	520	3.99E+06	3.51E-01	1.78E+05	5.076	2.15E+05	0.00E+00	3.93E+05
2	18	3.59	1.48E+05	0.191	8.83E+04	2.36E+05	571.79	4.94E+05	520	3.81E+06	3.44E-01	1.70E+05	6.098	2.51E+05	0.00E+00	4.21E+05
2	19	4.09	1.64E+05	0.473	2.19E+05	3.83E+05	571.44	4.81E+05	520	3.63E+06	3.37E-01	1.62E+05	5.905	2.36E+05	0.00E+00	3.98E+05
2	20	2.8	1.12E+05	0.125	5.78E+04	1.70E+05	571.41	4.79E+05	520	3.61E+06	3.36E-01	1.61E+05	5.039	2.01E+05	0.00E+00	3.62E+05
2	21	2.59	1.00E+05	0.087	4.02E+04	1.41E+05	571.04	4.65E+05	520	3.42E+06	3.29E-01	1.53E+05	4.036	1.56E+05	0.00E+00	3.09E+05
2	22	2.11	7.96E+04	0.016	7.40E+03	8.70E+04	570.71	4.53E+05	520	3.25E+06	3.22E-01	1.46E+05	2.593	9.79E+04	0.00E+00	2.44E+05
2	23	3.01	1.11E+05	0.057	2.64E+04	1.37E+05	570.41	4.41E+05	520	3.10E+06	3.16E-01	1.39E+05	1.558	5.73E+04	0.00E+00	1.97E+05
2	24	2.86	1.04E+05	0.187	8.65E+04	1.91E+05	570.30	4.37E+05	520	3.04E+06	3.14E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05
3	25	3.66	1.34E+05	1.242	5.74E+05	7.09E+05	570.37	4.40E+05	520	3.07E+06	3.15E-01	1.38E+05	0.527	1.93E+04	0.00E+00	1.58E+05
3	26	2.98	1.19E+05	2.125	9.83E+05	1.10E+06	571.42	4.80E+05	520	3.62E+06	3.37E-01	1.62E+05	1.620	6.48E+04	0.00E+00	2.26E+05

0003364

POND 1

Year	Month	Rainfall Depth (inch)	Rainfall Vol. into Pond (ft^3)	Runoff Depth (inch)	Runoff Vol. into Pond (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3)/day	Total Out flow O (ft^3)
3	27	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.77E+03	3.73E+05
3	28	3.55	1.60E+05	0.053	2.45E+04	1.84E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	4.437	2.00E+05	7.65E+03	6.29E+05
3	29	3.78	1.60E+05	0.121	5.60E+04	2.16E+05	572.15	5.08E+05	520	4.00E+06	3.51E-01	1.78E+05	5.076	2.15E+05	0.00E+00	3.93E+05
3	30	3.59	1.48E+05	0.191	8.83E+04	2.36E+05	571.81	4.95E+05	520	3.82E+06	3.44E-01	1.70E+05	6.098	2.51E+05	0.00E+00	4.22E+05
3	31	4.09	1.64E+05	0.473	2.19E+05	3.83E+05	571.45	4.81E+05	520	3.64E+06	3.37E-01	1.62E+05	5.905	2.37E+05	0.00E+00	3.99E+05
3	32	2.8	1.12E+05	0.125	5.78E+04	1.70E+05	571.42	4.80E+05	520	3.62E+06	3.37E-01	1.62E+05	5.039	2.02E+05	0.00E+00	3.63E+05
3	33	2.59	1.01E+05	0.087	4.02E+04	1.41E+05	571.05	4.66E+05	520	3.43E+06	3.29E-01	1.53E+05	4.036	1.57E+05	0.00E+00	3.10E+05
3	34	2.11	7.97E+04	0.016	7.40E+03	8.71E+04	570.73	4.53E+05	520	3.26E+06	3.22E-01	1.46E+05	2.593	9.80E+04	0.00E+00	2.44E+05
3	35	3.01	1.11E+05	0.057	2.64E+04	1.37E+05	570.42	4.42E+05	520	3.10E+06	3.16E-01	1.40E+05	1.558	5.73E+04	0.00E+00	1.97E+05
3	36	2.86	1.04E+05	0.187	8.65E+04	1.91E+05	570.31	4.37E+05	520	3.04E+06	3.14E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05
4	37	3.66	1.34E+05	1.242	5.74E+05	7.09E+05	570.38	4.40E+05	520	3.08E+06	3.15E-01	1.39E+05	0.527	1.93E+04	0.00E+00	1.58E+05
4	38	2.98	1.19E+05	2.125	9.83E+05	1.10E+06	571.43	4.81E+05	520	3.63E+06	3.37E-01	1.62E+05	1.620	6.49E+04	0.00E+00	2.27E+05
4	39	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.96E+03	3.79E+05
4	40	3.55	1.60E+05	0.053	2.45E+04	1.84E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	4.437	2.00E+05	7.46E+03	6.23E+05
4	41	3.78	1.60E+05	0.121	5.60E+04	2.16E+05	572.16	5.08E+05	520	4.01E+06	3.52E-01	1.79E+05	5.076	2.15E+05	0.00E+00	3.94E+05
4	42	3.59	1.48E+05	0.191	8.83E+04	2.37E+05	571.82	4.95E+05	520	3.83E+06	3.45E-01	1.71E+05	6.098	2.52E+05	0.00E+00	4.22E+05
4	43	4.09	1.64E+05	0.473	2.19E+05	3.83E+05	571.46	4.82E+05	520	3.64E+06	3.37E-01	1.62E+05	5.905	2.37E+05	0.00E+00	3.99E+05
4	44	2.8	1.12E+05	0.125	5.78E+04	1.70E+05	571.43	4.80E+05	520	3.63E+06	3.37E-01	1.62E+05	5.039	2.02E+05	0.00E+00	3.63E+05
4	45	2.59	1.01E+05	0.087	4.02E+04	1.41E+05	571.06	4.66E+05	520	3.43E+06	3.29E-01	1.53E+05	4.036	1.57E+05	0.00E+00	3.10E+05
4	46	2.11	7.98E+04	0.016	7.40E+03	8.72E+04	570.73	4.54E+05	520	3.26E+06	3.22E-01	1.46E+05	2.593	9.80E+04	0.00E+00	2.44E+05
4	47	3.01	1.11E+05	0.057	2.64E+04	1.37E+05	570.43	4.42E+05	520	3.11E+06	3.16E-01	1.40E+05	1.558	5.74E+04	0.00E+00	1.97E+05
4	48	2.86	1.04E+05	0.187	8.65E+04	1.91E+05	570.32	4.38E+05	520	3.05E+06	3.14E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05

7-4873

Table C-2
POND ROUTING
POND 2 (SOUTH OF PADR) - FEMP

BROWN & ROOT ENVIRONMENTAL

Hydraulic Conductivity of Pond Liner (cm/sec) = 7.23E-07
Thickness of Pond Liner (ft 3
Pond Bottom Elev. (ft) = 550
Drainage Area (ft^2) 4753800

Pond 2 Overflow El.= 573

Pond overflow at storage (ft^3): 10669000

POND 2

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft^3)	Runoff Depth (inch)	Runoff Into Pond (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3)/day	Total Out flow O (ft^3)
1	1	3.66	1.65E+05	1.242	4.92E+05	6.57E+05	564.11	5.41E+05	520	4.70E+06	2.89E-01	1.56E+05	0.527	2.37E+04	0.00E+00	1.80E+05
1	2	2.98	1.39E+05	2.125	8.42E+05	9.81E+05	565.04	5.60E+05	520	5.18E+06	3.08E-01	1.73E+05	1.620	7.56E+04	0.00E+00	2.48E+05
1	3	3.67	1.78E+05	0.945	3.74E+05	5.53E+05	566.25	5.83E+05	520	5.91E+06	3.33E-01	1.94E+05	2.673	1.30E+05	0.00E+00	3.24E+05
1	4	3.55	1.75E+05	0.053	2.10E+04	1.96E+05	566.63	5.90E+05	520	6.14E+06	3.41E-01	2.01E+05	4.437	2.18E+05	0.00E+00	4.19E+05
1	5	3.78	1.84E+05	0.121	4.79E+04	2.32E+05	566.26	5.83E+05	520	5.91E+06	3.33E-01	1.94E+05	5.076	2.47E+05	0.00E+00	4.41E+05
1	6	3.59	1.73E+05	0.191	7.57E+04	2.48E+05	565.91	5.77E+05	520	5.71E+06	3.26E-01	1.88E+05	6.098	2.93E+05	0.00E+00	4.81E+05
1	7	4.09	1.94E+05	0.473	1.87E+05	3.81E+05	565.53	5.69E+05	520	5.47E+06	3.18E-01	1.81E+05	5.905	2.80E+05	0.00E+00	4.61E+05
1	8	2.8	1.32E+05	0.125	4.95E+04	1.82E+05	565.40	5.67E+05	520	5.39E+06	3.16E-01	1.79E+05	5.039	2.38E+05	0.00E+00	4.17E+05
1	9	2.59	1.21E+05	0.087	3.45E+04	1.55E+05	565.01	5.60E+05	520	5.16E+06	3.08E-01	1.72E+05	4.036	1.88E+05	0.00E+00	3.60E+05
1	10	2.11	9.69E+04	0.016	6.34E+03	1.03E+05	564.61	5.51E+05	520	4.95E+06	2.99E-01	1.65E+05	2.593	1.19E+05	0.00E+00	2.84E+05
1	11	3.01	1.36E+05	0.057	2.26E+04	1.59E+05	564.25	5.44E+05	520	4.77E+06	2.92E-01	1.59E+05	1.558	7.06E+04	0.00E+00	2.29E+05
1	12	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.11	5.41E+05	520	4.70E+06	2.89E-01	1.57E+05	0.494	2.23E+04	0.00E+00	1.79E+05
2	13	3.66	1.65E+05	1.242	4.92E+05	6.57E+05	564.16	5.42E+05	520	4.72E+06	2.90E-01	1.57E+05	0.527	2.38E+04	0.00E+00	1.81E+05
2	14	2.98	1.39E+05	2.125	8.42E+05	9.81E+05	565.08	5.61E+05	520	5.20E+06	3.09E-01	1.73E+05	1.620	7.57E+04	0.00E+00	2.49E+05
2	15	3.67	1.79E+05	0.945	3.74E+05	5.53E+05	566.29	5.84E+05	520	5.93E+06	3.34E-01	1.95E+05	2.673	1.30E+05	0.00E+00	3.25E+05
2	16	3.55	1.75E+05	0.053	2.10E+04	1.96E+05	566.66	5.91E+05	520	6.16E+06	3.42E-01	2.02E+05	4.437	2.18E+05	0.00E+00	4.20E+05
2	17	3.78	1.84E+05	0.121	4.79E+04	2.32E+05	566.29	5.84E+05	520	5.94E+06	3.34E-01	1.95E+05	5.076	2.47E+05	0.00E+00	4.42E+05
2	18	3.59	1.73E+05	0.191	7.57E+04	2.48E+05	565.95	5.77E+05	520	5.73E+06	3.27E-01	1.89E+05	6.098	2.93E+05	0.00E+00	4.82E+05
2	19	4.09	1.94E+05	0.473	1.87E+05	3.82E+05	565.56	5.70E+05	520	5.49E+06	3.19E-01	1.82E+05	5.905	2.80E+05	0.00E+00	4.62E+05
2	20	2.8	1.32E+05	0.125	4.95E+04	1.82E+05	565.43	5.68E+05	520	5.41E+06	3.16E-01	1.79E+05	5.039	2.38E+05	0.00E+00	4.18E+05
2	21	2.59	1.21E+05	0.087	3.45E+04	1.55E+05	565.04	5.60E+05	520	5.18E+06	3.08E-01	1.73E+05	4.036	1.88E+05	0.00E+00	3.61E+05
2	22	2.11	9.71E+04	0.016	6.34E+03	1.03E+05	564.64	5.52E+05	520	4.97E+06	3.00E-01	1.66E+05	2.593	1.19E+05	0.00E+00	2.85E+05
2	23	3.01	1.37E+05	0.057	2.26E+04	1.59E+05	564.29	5.45E+05	520	4.79E+06	2.93E-01	1.59E+05	1.558	7.07E+04	0.00E+00	2.30E+05

000366

POND 2

Year	Month	Rainfall Depth (inch)	Rainfall Vol. into Pond (ft^3)	Runoff Depth (inch)	Runoff into Pond (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3)/day	Total Out flow O (ft^3)
2	24	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.15	5.42E+05	520	4.72E+06	2.90E-01	1.57E+05	0.494	2.23E+04	0.00E+00	1.79E+05
3	25	3.66	1.66E+05	1.242	4.92E+05	6.58E+05	564.19	5.43E+05	520	4.74E+06	2.91E-01	1.58E+05	0.527	2.38E+04	0.00E+00	1.82E+05
3	26	2.98	1.39E+05	2.125	8.42E+05	9.81E+05	565.11	5.61E+05	520	5.22E+06	3.10E-01	1.74E+05	1.620	7.58E+04	0.00E+00	2.50E+05
3	27	3.67	1.79E+05	0.945	3.74E+05	5.53E+05	566.32	5.84E+05	520	5.95E+06	3.34E-01	1.95E+05	2.673	1.30E+05	0.00E+00	3.25E+05
3	28	3.55	1.75E+05	0.053	2.10E+04	1.96E+05	566.69	5.91E+05	520	6.18E+06	3.42E-01	2.02E+05	4.437	2.19E+05	0.00E+00	4.21E+05
3	29	3.78	1.84E+05	0.121	4.79E+04	2.32E+05	566.32	5.84E+05	520	5.95E+06	3.34E-01	1.95E+05	5.076	2.47E+05	0.00E+00	4.43E+05
3	30	3.59	1.73E+05	0.191	7.57E+04	2.49E+05	565.97	5.78E+05	520	5.74E+06	3.27E-01	1.89E+05	6.098	2.94E+05	0.00E+00	4.83E+05
3	31	4.09	1.94E+05	0.473	1.87E+05	3.82E+05	565.59	5.70E+05	520	5.51E+06	3.19E-01	1.82E+05	5.905	2.81E+05	0.00E+00	4.63E+05
3	32	2.8	1.33E+05	0.125	4.95E+04	1.82E+05	565.45	5.68E+05	520	5.43E+06	3.17E-01	1.80E+05	5.039	2.38E+05	0.00E+00	4.18E+05
3	33	2.59	1.21E+05	0.087	3.45E+04	1.55E+05	565.06	5.61E+05	520	5.19E+06	3.09E-01	1.73E+05	4.036	1.89E+05	0.00E+00	3.62E+05
3	34	2.11	9.72E+04	0.016	6.34E+03	1.04E+05	564.67	5.53E+05	520	4.98E+06	3.01E-01	1.66E+05	2.593	1.19E+05	0.00E+00	2.86E+05
3	35	3.01	1.37E+05	0.057	2.26E+04	1.59E+05	564.31	5.45E+05	520	4.80E+06	2.93E-01	1.60E+05	1.558	7.08E+04	0.00E+00	2.31E+05
3	36	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.17	5.42E+05	520	4.73E+06	2.90E-01	1.58E+05	0.494	2.23E+04	0.00E+00	1.80E+05
4	37	3.66	1.66E+05	1.242	4.92E+05	6.58E+05	564.22	5.43E+05	520	4.75E+06	2.91E-01	1.58E+05	0.527	2.38E+04	0.00E+00	1.82E+05
4	38	2.98	1.40E+05	2.125	8.42E+05	9.81E+05	565.13	5.62E+05	520	5.23E+06	3.10E-01	1.74E+05	1.620	7.58E+04	0.00E+00	2.50E+05
4	39	3.67	1.79E+05	0.945	3.74E+05	5.53E+05	566.33	5.85E+05	520	5.96E+06	3.35E-01	1.96E+05	2.673	1.30E+05	0.00E+00	3.26E+05
4	40	3.55	1.75E+05	0.053	2.10E+04	1.96E+05	566.71	5.92E+05	520	6.19E+06	3.42E-01	2.03E+05	4.437	2.19E+05	0.00E+00	4.21E+05
4	41	3.78	1.84E+05	0.121	4.79E+04	2.32E+05	566.34	5.85E+05	520	5.96E+06	3.35E-01	1.96E+05	5.076	2.47E+05	0.00E+00	4.43E+05
4	42	3.59	1.73E+05	0.191	7.57E+04	2.49E+05	565.99	5.78E+05	520	5.75E+06	3.28E-01	1.89E+05	6.098	2.94E+05	0.00E+00	4.83E+05
4	43	4.09	1.95E+05	0.473	1.87E+05	3.82E+05	565.60	5.71E+05	520	5.52E+06	3.20E-01	1.83E+05	5.905	2.81E+05	0.00E+00	4.63E+05
4	44	2.8	1.33E+05	0.125	4.95E+04	1.82E+05	565.47	5.68E+05	520	5.44E+06	3.17E-01	1.80E+05	5.039	2.39E+05	0.00E+00	4.19E+05
4	45	2.59	1.21E+05	0.087	3.45E+04	1.56E+05	565.08	5.61E+05	520	5.20E+06	3.09E-01	1.73E+05	4.036	1.89E+05	0.00E+00	3.62E+05
4	46	2.11	9.72E+04	0.016	6.34E+03	1.04E+05	564.69	5.53E+05	520	4.99E+06	3.01E-01	1.66E+05	2.593	1.20E+05	0.00E+00	2.86E+05
4	47	3.01	1.37E+05	0.057	2.26E+04	1.59E+05	564.33	5.46E+05	520	4.81E+06	2.94E-01	1.60E+05	1.558	7.08E+04	0.00E+00	2.31E+05
4	48	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.19	5.43E+05	520	4.74E+06	2.91E-01	1.58E+05	0.494	2.24E+04	0.00E+00	1.80E+05

4873

Table C-3
POND ROUTING UNDER NORMAL CONDITIONS
POND 3 (SOUTHEAST OF FEMP, BORROWED AREA)

BROWN & ROOT ENVIRONMENTAL

Hydraulic Conductivity of Pond Liner (cm/sec) = 7.23E-07
Thickness of Pond Liner (ft 3
Pond Bottom Elev. (ft) = 565
Drainage Area (ft^2) 4528350

Pond 3 Overflow El.= 578

Pond overflow at storage (ft^3): 1931500

POND 3

Year	Month	Rainfall Depth (inch)	Rainfall Vol. into Pond (ft^3)	Runoff Depth (inch)	Runoff Vol. into Pond (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3)/Day	Total Out flow O (ft^3)
1	1	3.66	1.04E+05	1.242	4.69E+05	5.73E+05	576.93	3.42E+05	520	1.50E+06	2.44E-01	8.37E+04	0.527	1.50E+04	0.00E+00	9.87E+04
1	2	2.98	1.12E+05	2.125	8.02E+05	9.14E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	1.620	6.11E+04	1.43E+03	2.25E+05
1	3	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	2.30E+04	9.11E+05
1	4	3.55	1.02E+05	0.053	2.00E+04	1.22E+05	576.96	3.46E+05	520	1.52E+06	2.45E-01	8.49E+04	4.437	1.28E+05	0.00E+00	2.13E+05
1	5	3.78	1.02E+05	0.121	4.57E+04	1.47E+05	576.74	3.23E+05	520	1.42E+06	2.41E-01	7.77E+04	5.076	1.37E+05	0.00E+00	2.14E+05
1	6	3.59	9.15E+04	0.191	7.21E+04	1.64E+05	576.57	3.06E+05	520	1.36E+06	2.37E-01	7.26E+04	6.098	1.55E+05	0.00E+00	2.28E+05
1	7	4.09	9.87E+04	0.473	1.78E+05	2.77E+05	576.41	2.90E+05	520	1.29E+06	2.34E-01	6.77E+04	5.905	1.42E+05	0.00E+00	2.10E+05
1	8	2.8	7.16E+04	0.125	4.72E+04	1.19E+05	576.58	3.07E+05	520	1.36E+06	2.37E-01	7.28E+04	5.039	1.29E+05	0.00E+00	2.02E+05
1	9	2.59	6.16E+04	0.087	3.28E+04	9.44E+04	576.37	2.85E+05	520	1.28E+06	2.33E-01	6.65E+04	4.036	9.60E+04	0.00E+00	1.63E+05
1	10	2.11	4.71E+04	0.016	6.04E+03	5.32E+04	576.20	2.68E+05	520	1.21E+06	2.30E-01	6.15E+04	2.593	5.79E+04	0.00E+00	1.19E+05
1	11	3.01	6.30E+04	0.057	2.15E+04	8.45E+04	576.04	2.51E+05	520	1.14E+06	2.26E-01	5.68E+04	1.558	3.26E+04	0.00E+00	8.94E+04
1	12	2.86	5.95E+04	0.187	7.06E+04	1.30E+05	576.02	2.50E+05	520	1.14E+06	2.26E-01	5.64E+04	0.494	1.03E+04	0.00E+00	6.67E+04
2	13	3.66	8.11E+04	1.242	4.69E+05	5.50E+05	576.18	2.66E+05	520	1.20E+06	2.29E-01	6.10E+04	0.527	1.17E+04	0.00E+00	7.26E+04
2	14	2.98	9.64E+04	2.125	8.02E+05	8.98E+05	577.37	3.88E+05	520	1.68E+06	2.54E-01	9.84E+04	1.620	5.24E+04	0.00E+00	1.51E+05
2	15	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	1.65E+04	7.16E+05
2	16	3.55	1.17E+05	0.053	2.00E+04	1.37E+05	577.45	3.96E+05	520	1.71E+06	2.55E-01	1.01E+05	4.437	1.46E+05	0.00E+00	2.48E+05
2	17	3.78	1.16E+05	0.121	4.57E+04	1.62E+05	577.17	3.68E+05	520	1.60E+06	2.50E-01	9.18E+04	5.076	1.56E+05	0.00E+00	2.47E+05
2	18	3.59	1.03E+05	0.191	7.21E+04	1.76E+05	576.96	3.46E+05	520	1.51E+06	2.45E-01	8.48E+04	6.098	1.76E+05	0.00E+00	2.61E+05
2	19	4.09	1.10E+05	0.473	1.78E+05	2.89E+05	576.75	3.24E+05	520	1.43E+06	2.41E-01	7.81E+04	5.905	1.60E+05	0.00E+00	2.38E+05
2	20	2.8	7.87E+04	0.125	4.72E+04	1.26E+05	576.88	3.37E+05	520	1.48E+06	2.43E-01	8.21E+04	5.039	1.42E+05	0.00E+00	2.24E+05
2	21	2.59	6.74E+04	0.087	3.28E+04	1.00E+05	576.63	3.12E+05	520	1.38E+06	2.38E-01	7.45E+04	4.036	1.05E+05	0.00E+00	1.79E+05
2	22	2.11	5.13E+04	0.016	6.04E+03	5.74E+04	576.44	2.92E+05	520	1.30E+06	2.34E-01	6.84E+04	2.593	6.31E+04	0.00E+00	1.32E+05
2	23	3.01	6.85E+04	0.057	2.15E+04	9.00E+04	576.25	2.73E+05	520	1.23E+06	2.31E-01	6.29E+04	1.558	3.54E+04	0.00E+00	9.84E+04

000368

POND 3

Year	Month	Rainfall Depth (inch)	Rainfall Vol. into Pond (ft^3)	Runoff Depth (inch)	Runoff Vol. into Pond (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3)/Day	Total Out flow O (ft^3)
2	24	2.86	6.46E+04	0.187	7.06E+04	1.35E+05	576.23	2.71E+05	520	1.22E+06	2.30E-01	6.23E+04	0.494	1.12E+04	0.00E+00	7.35E+04
3	25	3.66	8.74E+04	1.242	4.69E+05	5.56E+05	576.38	2.87E+05	520	1.28E+06	2.33E-01	6.69E+04	0.527	1.26E+04	0.00E+00	7.95E+04
3	26	2.98	1.01E+05	2.125	8.02E+05	9.03E+05	577.57	4.09E+05	520	1.76E+06	2.58E-01	1.05E+05	1.620	5.52E+04	0.00E+00	1.60E+05
3	27	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	1.90E+04	7.92E+05
3	28	3.55	1.11E+05	0.053	2.00E+04	1.31E+05	577.26	3.77E+05	520	1.63E+06	2.51E-01	9.47E+04	4.437	1.39E+05	0.00E+00	2.34E+05
3	29	3.78	1.10E+05	0.121	4.57E+04	1.56E+05	577.01	3.51E+05	520	1.53E+06	2.46E-01	8.63E+04	5.076	1.48E+05	0.00E+00	2.35E+05
3	30	3.59	9.89E+04	0.191	7.21E+04	1.71E+05	576.81	3.31E+05	520	1.45E+06	2.42E-01	8.00E+04	6.098	1.68E+05	0.00E+00	2.48E+05
3	31	4.09	1.06E+05	0.473	1.78E+05	2.84E+05	576.62	3.11E+05	520	1.38E+06	2.38E-01	7.40E+04	5.905	1.53E+05	0.00E+00	2.27E+05
3	32	2.8	7.60E+04	0.125	4.72E+04	1.23E+05	576.76	3.26E+05	520	1.43E+06	2.41E-01	7.85E+04	5.039	1.37E+05	0.00E+00	2.15E+05
3	33	2.59	6.52E+04	0.087	3.28E+04	9.80E+04	576.53	3.02E+05	520	1.34E+06	2.36E-01	7.14E+04	4.036	1.02E+05	0.00E+00	1.73E+05
3	34	2.11	4.97E+04	0.016	6.04E+03	5.58E+04	576.35	2.83E+05	520	1.27E+06	2.33E-01	6.58E+04	2.593	6.11E+04	0.00E+00	1.27E+05
3	35	3.01	6.64E+04	0.057	2.15E+04	8.79E+04	576.17	2.65E+05	520	1.20E+06	2.29E-01	6.06E+04	1.558	3.43E+04	0.00E+00	9.49E+04
3	36	2.86	6.26E+04	0.187	7.06E+04	1.33E+05	576.15	2.63E+05	520	1.19E+06	2.29E-01	6.01E+04	0.494	1.08E+04	0.00E+00	7.09E+04
4	37	3.66	8.50E+04	1.242	4.69E+05	5.54E+05	576.31	2.79E+05	520	1.25E+06	2.32E-01	6.46E+04	0.527	1.22E+04	0.00E+00	7.68E+04
4	38	2.98	9.95E+04	2.125	8.02E+05	9.01E+05	577.49	4.01E+05	520	1.73E+06	2.56E-01	1.03E+05	1.620	5.41E+04	0.00E+00	1.57E+05
4	39	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	1.80E+04	7.63E+05
4	40	3.55	1.14E+05	0.053	2.00E+04	1.34E+05	577.33	3.84E+05	520	1.66E+06	2.53E-01	9.71E+04	4.437	1.42E+05	0.00E+00	2.39E+05
4	41	3.78	1.13E+05	0.121	4.57E+04	1.58E+05	577.07	3.57E+05	520	1.56E+06	2.47E-01	8.84E+04	5.076	1.51E+05	0.00E+00	2.39E+05
4	42	3.59	1.01E+05	0.191	7.21E+04	1.73E+05	576.87	3.36E+05	520	1.48E+06	2.43E-01	8.18E+04	6.098	1.71E+05	0.00E+00	2.53E+05
4	43	4.09	1.08E+05	0.473	1.78E+05	2.86E+05	576.67	3.16E+05	520	1.40E+06	2.39E-01	7.56E+04	5.905	1.55E+05	0.00E+00	2.31E+05
4	44	2.8	7.70E+04	0.125	4.72E+04	1.24E+05	576.81	3.30E+05	520	1.45E+06	2.42E-01	7.99E+04	5.039	1.39E+05	0.00E+00	2.18E+05
4	45	2.59	6.60E+04	0.087	3.28E+04	9.89E+04	576.57	3.06E+05	520	1.36E+06	2.37E-01	7.25E+04	4.036	1.03E+05	0.00E+00	1.75E+05
4	46	2.11	5.03E+04	0.016	6.04E+03	5.64E+04	576.38	2.86E+05	520	1.28E+06	2.33E-01	6.68E+04	2.593	6.19E+04	0.00E+00	1.29E+05
4	47	3.01	6.72E+04	0.057	2.15E+04	8.87E+04	576.20	2.68E+05	520	1.21E+06	2.30E-01	6.15E+04	1.558	3.48E+04	0.00E+00	9.62E+04
4	48	2.86	6.34E+04	0.187	7.06E+04	1.34E+05	576.18	2.66E+05	520	1.20E+06	2.29E-01	6.09E+04	0.494	1.10E+04	0.00E+00	7.19E+04

4873

Table C-4
POND ROUTING UNDER NORMAL CONDITIONS
POND 4 (STORMWATER RETENTION POND) - FEMP

BROWN & ROOT ENVIRONMENTAL

Hydraulic Conductivity of Pond Liner (cm/sec) = 7.23E-07
Thickness of Pond Liner (ft) = 3
Pond Bottom Elev. (ft) = 535
Drainage Area (ft^2) 2146500

Pond 4 Overflow El.= 560

Pond overflow at storage (ft^3): 2550000

POND 4

Year	Month	Rainfall Depth (inch)	Rainfall Vol. into Pond (ft^3)	Runoff Depth (inch)	Runoff Vol. into Pond (ft^3)	Inflow from Pond 2 (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3)/day	Total Out flow O (ft^3)
1	1	3.66	4.45E+04	1.242	2.22E+05	0.00E+00	2.67E+05	556.05	1.46E+05	520	2.00E+06	4.31E-01	6.30E+04	0.527	6.41E+03	0.00E+00	6.94E+04
1	2	2.98	3.86E+04	2.125	3.80E+05	0.00E+00	4.19E+05	557.47	1.55E+05	520	2.20E+06	4.60E-01	7.16E+04	1.620	2.10E+04	0.00E+00	9.26E+04
1	3	3.67	5.23E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.81	1.71E+05	520	2.52E+06	5.09E-01	8.70E+04	2.673	3.81E+04	0.00E+00	1.25E+05
1	4	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	2.32E+03	2.22E+05
1	5	3.78	5.19E+04	0.121	2.16E+04	0.00E+00	7.35E+04	558.85	1.65E+05	520	2.39E+06	4.89E-01	8.05E+04	5.076	6.96E+04	0.00E+00	1.50E+05
1	6	3.59	4.82E+04	0.191	3.42E+04	0.00E+00	8.23E+04	558.29	1.61E+05	520	2.31E+06	4.77E-01	7.69E+04	6.098	8.18E+04	0.00E+00	1.59E+05
1	7	4.09	5.36E+04	0.473	8.46E+04	0.00E+00	1.38E+05	557.75	1.57E+05	520	2.24E+06	4.66E-01	7.33E+04	5.905	7.74E+04	0.00E+00	1.51E+05
1	8	2.8	3.66E+04	0.125	2.24E+04	0.00E+00	5.89E+04	557.66	1.57E+05	520	2.22E+06	4.64E-01	7.28E+04	5.039	6.58E+04	0.00E+00	1.39E+05
1	9	2.59	3.30E+04	0.087	1.56E+04	0.00E+00	4.86E+04	557.08	1.53E+05	520	2.14E+06	4.53E-01	6.92E+04	4.036	5.14E+04	0.00E+00	1.21E+05
1	10	2.11	2.63E+04	0.016	2.86E+03	0.00E+00	2.91E+04	556.56	1.49E+05	520	2.07E+06	4.42E-01	6.61E+04	2.593	3.23E+04	0.00E+00	9.84E+04
1	11	3.01	3.67E+04	0.057	1.02E+04	0.00E+00	4.69E+04	556.07	1.46E+05	520	2.00E+06	4.32E-01	6.31E+04	1.558	1.90E+04	0.00E+00	8.21E+04
1	12	2.86	3.44E+04	0.187	3.34E+04	0.00E+00	6.79E+04	555.81	1.44E+05	520	1.97E+06	4.27E-01	6.16E+04	0.494	5.95E+03	0.00E+00	6.76E+04
2	13	3.66	4.41E+04	1.242	2.22E+05	0.00E+00	2.66E+05	555.82	1.44E+05	520	1.97E+06	4.27E-01	6.16E+04	0.527	6.34E+03	0.00E+00	6.80E+04
2	14	2.98	3.82E+04	2.125	3.80E+05	0.00E+00	4.18E+05	557.24	1.54E+05	520	2.17E+06	4.56E-01	7.02E+04	1.620	2.08E+04	0.00E+00	9.10E+04
2	15	3.67	5.19E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.60	1.70E+05	520	2.49E+06	5.04E-01	8.55E+04	2.673	3.78E+04	0.00E+00	1.23E+05
2	16	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	1.35E+03	1.93E+05
2	17	3.78	5.23E+04	0.121	2.16E+04	0.00E+00	7.40E+04	559.05	1.66E+05	520	2.42E+06	4.93E-01	8.19E+04	5.076	7.02E+04	0.00E+00	1.52E+05
2	18	3.59	4.86E+04	0.191	3.42E+04	0.00E+00	8.27E+04	558.49	1.62E+05	520	2.34E+06	4.81E-01	7.81E+04	6.098	8.25E+04	0.00E+00	1.61E+05
2	19	4.09	5.40E+04	0.473	8.46E+04	0.00E+00	1.39E+05	557.93	1.59E+05	520	2.26E+06	4.70E-01	7.45E+04	5.905	7.80E+04	0.00E+00	1.53E+05
2	20	2.8	3.68E+04	0.125	2.24E+04	0.00E+00	5.92E+04	557.83	1.58E+05	520	2.25E+06	4.68E-01	7.39E+04	5.039	6.63E+04	0.00E+00	1.40E+05
2	21	2.59	3.32E+04	0.087	1.56E+04	0.00E+00	4.88E+04	557.25	1.54E+05	520	2.17E+06	4.56E-01	7.02E+04	4.036	5.18E+04	0.00E+00	1.22E+05
2	22	2.11	2.65E+04	0.016	2.86E+03	0.00E+00	2.93E+04	556.72	1.51E+05	520	2.09E+06	4.45E-01	6.70E+04	2.593	3.25E+04	0.00E+00	9.95E+04
2	23	3.01	3.69E+04	0.057	1.02E+04	0.00E+00	4.71E+04	556.22	1.47E+05	520	2.02E+06	4.35E-01	6.40E+04	1.558	1.91E+04	0.00E+00	8.31E+04
2	24	2.86	3.47E+04	0.187	3.34E+04	0.00E+00	6.81E+04	555.96	1.45E+05	520	1.99E+06	4.30E-01	6.25E+04	0.494	5.99E+03	0.00E+00	6.85E+04
3	25	3.66	4.44E+04	1.242	2.22E+05	0.00E+00	2.67E+05	555.96	1.45E+05	520	1.99E+06	4.29E-01	6.25E+04	0.527	6.38E+03	0.00E+00	6.88E+04
3	26	2.98	3.85E+04	2.125	3.80E+05	0.00E+00	4.19E+05	557.38	1.55E+05	520	2.18E+06	4.59E-01	7.10E+04	1.620	2.09E+04	0.00E+00	9.19E+04
3	27	3.67	5.22E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.73	1.71E+05	520	2.51E+06	5.07E-01	8.64E+04	2.673	3.80E+04	0.00E+00	1.24E+05
3	28	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	1.94E+03	2.10E+05
3	29	3.78	5.20E+04	0.121	2.16E+04	0.00E+00	7.37E+04	558.93	1.65E+05	520	2.40E+06	4.90E-01	8.10E+04	5.076	6.99E+04	0.00E+00	1.51E+05

000370

POND 4

Year	Month	Rainfall Depth (inch)	Rainfall Vol. into Pond (ft^3)	Runoff Depth (inch)	Runoff Vol. into Pond (ft^3)	Inflow from Pond 2 (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3)/day	Total Out flow O (ft^3)
3	30	3.59	4.83E+04	0.191	3.42E+04	0.00E+00	8.25E+04	558.37	1.62E+05	520	2.32E+06	4.79E-01	7.74E+04	6.098	8.21E+04	0.00E+00	1.59E+05
3	31	4.09	5.38E+04	0.473	8.46E+04	0.00E+00	1.38E+05	557.82	1.58E+05	520	2.25E+06	4.68E-01	7.38E+04	5.905	7.77E+04	0.00E+00	1.51E+05
3	32	2.8	3.67E+04	0.125	2.24E+04	0.00E+00	5.90E+04	557.73	1.57E+05	520	2.23E+06	4.66E-01	7.32E+04	5.039	6.60E+04	0.00E+00	1.39E+05
3	33	2.59	3.31E+04	0.087	1.56E+04	0.00E+00	4.87E+04	557.15	1.53E+05	520	2.15E+06	4.54E-01	6.96E+04	4.036	5.16E+04	0.00E+00	1.21E+05
3	34	2.11	2.64E+04	0.016	2.86E+03	0.00E+00	2.92E+04	556.63	1.50E+05	520	2.08E+06	4.43E-01	6.64E+04	2.593	3.24E+04	0.00E+00	9.88E+04
3	35	3.01	3.68E+04	0.057	1.02E+04	0.00E+00	4.70E+04	556.13	1.47E+05	520	2.01E+06	4.33E-01	6.35E+04	1.558	1.90E+04	0.00E+00	8.25E+04
3	36	2.86	3.45E+04	0.187	3.34E+04	0.00E+00	6.80E+04	555.87	1.45E+05	520	1.98E+06	4.28E-01	6.20E+04	0.494	5.97E+03	0.00E+00	6.79E+04
4	37	3.66	4.42E+04	1.242	2.22E+05	0.00E+00	2.66E+05	555.87	1.45E+05	520	1.98E+06	4.28E-01	6.20E+04	0.527	6.36E+03	0.00E+00	6.83E+04
4	38	2.98	3.83E+04	2.125	3.80E+05	0.00E+00	4.18E+05	557.30	1.54E+05	520	2.17E+06	4.57E-01	7.05E+04	1.620	2.08E+04	0.00E+00	9.14E+04
4	39	3.67	5.20E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.65	1.70E+05	520	2.50E+06	5.05E-01	8.59E+04	2.673	3.79E+04	0.00E+00	1.24E+05
4	40	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	1.59E+03	2.00E+05
4	41	3.78	5.22E+04	0.121	2.16E+04	0.00E+00	7.38E+04	559.00	1.66E+05	520	2.41E+06	4.92E-01	8.15E+04	5.076	7.01E+04	0.00E+00	1.52E+05
4	42	3.59	4.85E+04	0.191	3.42E+04	0.00E+00	8.26E+04	558.44	1.62E+05	520	2.33E+06	4.80E-01	7.78E+04	6.098	8.23E+04	0.00E+00	1.60E+05
4	43	4.09	5.39E+04	0.473	8.46E+04	0.00E+00	1.39E+05	557.89	1.58E+05	520	2.26E+06	4.69E-01	7.42E+04	5.905	7.79E+04	0.00E+00	1.52E+05
4	44	2.8	3.68E+04	0.125	2.24E+04	0.00E+00	5.91E+04	557.79	1.58E+05	520	2.24E+06	4.67E-01	7.36E+04	5.039	6.62E+04	0.00E+00	1.40E+05
4	45	2.59	3.32E+04	0.087	1.56E+04	0.00E+00	4.87E+04	557.21	1.54E+05	520	2.16E+06	4.55E-01	7.00E+04	4.036	5.17E+04	0.00E+00	1.22E+05
4	46	2.11	2.64E+04	0.016	2.86E+03	0.00E+00	2.93E+04	556.68	1.50E+05	520	2.09E+06	4.44E-01	6.68E+04	2.593	3.25E+04	0.00E+00	9.93E+04
4	47	3.01	3.69E+04	0.057	1.02E+04	0.00E+00	4.70E+04	556.18	1.47E+05	520	2.02E+06	4.34E-01	6.38E+04	1.558	1.91E+04	0.00E+00	8.29E+04
4	48	2.86	3.46E+04	0.187	3.34E+04	0.00E+00	6.81E+04	555.92	1.45E+05	520	1.98E+06	4.29E-01	6.23E+04	0.494	5.98E+03	0.00E+00	6.82E+04

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APPENDIX D

ROUTING CALCULATIONS UNDER EXTREME CONDITIONS

TABLE D-1
POND ROUTING UNDER EXTREME CONDITIONS
POND 1 (NORTHEAST OF FEMP)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM

Initial Pond Storage 4.45E+06 ft^3 Initial Pond Elevation 573 feet
Time Step= 360 second
Pond Overflow El.= 573 feet
Weir Width = 5 feet

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
11	0	0		0.0	0	4.45E+06	573.00
11.1	6	3	1080	0.0	0	4.45E+06	573.00
11.2	6	4	1440	0.0	1	4.45E+06	573.01
11.3	6	4	1440	0.0	2	4.45E+06	573.01
11.4	6	4	1440	0.0	4	4.45E+06	573.01
11.5	6	5	1800	0.0	7	4.45E+06	573.01
11.6	6	5	1800	0.0	10	4.45E+06	573.02
11.7	6	6	2160	0.0	14	4.46E+06	573.02
11.8	6	8	2880	0.1	19	4.46E+06	573.03
11.9	6	9	3240	0.1	27	4.46E+06	573.03
12	6	9	3240	0.1	36	4.47E+06	573.04
12.1	6	11	3960	0.1	47	4.47E+06	573.05
12.2	6	13	4680	0.2	61	4.47E+06	573.06
12.3	6	21	7560	0.2	78	4.48E+06	573.07
12.4	6	34	12240	0.3	111	4.49E+06	573.09
12.5	6	57	20520	0.5	170	4.51E+06	573.13
12.6	6	83	29880	0.8	287	4.54E+06	573.19
12.7	6	109	39240	1.4	489	4.58E+06	573.26
12.8	6	125	45000	2.2	804	4.63E+06	573.35
12.9	6	127	45720	3.4	1221	4.67E+06	573.43
13	6	129	46440	4.7	1697	4.72E+06	573.52
13.1	6	122	43920	6.2	2224	4.76E+06	573.60
13.2	6	114	41040	7.7	2757	4.80E+06	573.67
13.3	6	103	37080	9.1	3279	4.83E+06	573.74
13.4	6	92	33120	10.5	3764	4.86E+06	573.79
13.5	6	82	29520	11.7	4203	4.88E+06	573.84
13.6	6	72	25920	12.8	4594	4.91E+06	573.88
13.7	6	63	22680	13.7	4933	4.92E+06	573.92
13.8	6	55	19800	14.5	5221	4.94E+06	573.95
13.9	6	49	17640	15.2	5461	4.95E+06	573.97
14	6	43	15480	15.7	5665	4.96E+06	573.99
14.1	6	39	14040	16.2	5831	4.97E+06	574.00
14.2	6	35	12600	16.6	5971	4.98E+06	574.02

POND-1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
14.3	6	31	11160	16.9	6085	4.98E+06	574.03
14.4	6	29	10440	17.1	6172	4.98E+06	574.03
14.5	6	26	9360	17.4	6246	4.99E+06	574.04
14.6	6	24	8640	17.5	6300	4.99E+06	574.04
14.7	6	23	8280	17.6	6341	4.99E+06	574.05
14.8	6	22	7920	17.7	6375	4.99E+06	574.05
14.9	6	20	7200	17.8	6402	4.99E+06	574.05
15	6	19	6840	17.8	6416	4.99E+06	574.05
15.1	6	18	6480	17.8	6424	4.99E+06	574.05
15.2	6	18	6480	17.8	6425	4.99E+06	574.05
15.3	6	17	6120	17.8	6426	4.99E+06	574.05
15.4	6	17	6120	17.8	6420	4.99E+06	574.05
15.5	6	16	5760	17.8	6415	4.99E+06	574.05
15.6	6	16	5760	17.8	6403	4.99E+06	574.05
15.7	6	16	5760	17.8	6392	4.99E+06	574.05
15.8	6	15	5400	17.7	6381	4.99E+06	574.05
15.9	6	15	5400	17.7	6364	4.99E+06	574.05
16	6	15	5400	17.6	6347	4.99E+06	574.04
16.1	6	15	5400	17.6	6331	4.99E+06	574.04
16.2	6	14	5040	17.5	6314	4.99E+06	574.04
16.3	6	14	5040	17.5	6292	4.99E+06	574.04
16.4	6	13	4680	17.4	6270	4.98E+06	574.03
16.5	6	13	4680	17.3	6243	4.98E+06	574.03
16.6	6	13	4680	17.3	6216	4.98E+06	574.03
16.7	6	12	4320	17.2	6189	4.98E+06	574.02
16.8	6	12	4320	17.1	6157	4.98E+06	574.02
16.9	6	11	3960	17.0	6125	4.98E+06	574.02
17	6	11	3960	16.9	6088	4.97E+06	574.01
17.1	6	11	3960	16.8	6051	4.97E+06	574.01
17.2	6	11	3960	16.7	6015	4.97E+06	574.00
17.3	6	11	3960	16.6	5980	4.97E+06	574.00
17.4	6	11	3960	16.5	5945	4.96E+06	574.00
17.5	6	11	3960	16.4	5911	4.96E+06	573.99
17.6	6	11	3960	16.3	5878	4.96E+06	573.99
17.7	6	10	3600	16.2	5845	4.96E+06	573.99
17.8	6	10	3600	16.1	5807	4.96E+06	573.98
17.9	6	10	3600	16.0	5770	4.95E+06	573.98
18	6	10	3600	15.9	5733	4.95E+06	573.97
18.1	6	10	3600	15.8	5697	4.95E+06	573.97
18.2	6	10	3600	15.7	5662	4.95E+06	573.96
18.3	6	9	3240	15.6	5627	4.95E+06	573.96
18.4	6	9	3240	15.5	5587	4.94E+06	573.96
18.5	6	9	3240	15.4	5548	4.94E+06	573.95
18.6	6	9	3240	15.3	5509	4.94E+06	573.95
18.7	6	9	3240	15.2	5472	4.94E+06	573.94

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.8	6	8	2880	15.1	5435	4.93E+06	573.94
18.9	6	8	2880	15.0	5392	4.93E+06	573.93
19	6	8	2880	14.9	5351	4.93E+06	573.93
19.1	6	8	2880	14.8	5310	4.93E+06	573.92
19.2	6	8	2880	14.6	5270	4.92E+06	573.92
19.3	6	8	2880	14.5	5231	4.92E+06	573.91
19.4	6	8	2880	14.4	5192	4.92E+06	573.91
19.5	6	8	2880	14.3	5155	4.92E+06	573.91
19.6	6	7	2520	14.2	5118	4.91E+06	573.90
19.7	6	7	2520	14.1	5076	4.91E+06	573.90
19.8	6	7	2520	14.0	5034	4.91E+06	573.89
19.9	6	7	2520	13.9	4994	4.91E+06	573.89
20	6	7	2520	13.8	4954	4.90E+06	573.88
20.1	6	7	2520	13.7	4915	4.90E+06	573.88
20.2	6	7	2520	13.5	4876	4.90E+06	573.87
20.3	6	7	2520	13.4	4839	4.90E+06	573.87
20.4	6	7	2520	13.3	4802	4.90E+06	573.86
20.5	6	6	2160	13.2	4765	4.89E+06	573.86
20.6	6	6	2160	13.1	4724	4.89E+06	573.85
20.7	6	6	2160	13.0	4683	4.89E+06	573.85
20.8	6	6	2160	12.9	4644	4.89E+06	573.84
20.9	6	6	2160	12.8	4605	4.88E+06	573.84
21	6	6	2160	12.7	4566	4.88E+06	573.83
21.1	6	6	2160	12.6	4529	4.88E+06	573.83
21.2	6	6	2160	12.5	4492	4.88E+06	573.83
21.3	6	6	2160	12.4	4456	4.87E+06	573.82
21.4	6	6	2160	12.3	4420	4.87E+06	573.82
21.5	6	6	2160	12.2	4385	4.87E+06	573.81
21.6	6	5	1800	12.1	4351	4.87E+06	573.81
21.7	6	5	1800	12.0	4311	4.86E+06	573.80
21.8	6	5	1800	11.9	4273	4.86E+06	573.80
21.9	6	5	1800	11.8	4235	4.86E+06	573.79
22	6	5	1800	11.7	4198	4.86E+06	573.79
22.1	6	5	1800	11.6	4162	4.85E+06	573.78
22.2	6	5	1800	11.5	4126	4.85E+06	573.78
22.3	6	5	1800	11.4	4091	4.85E+06	573.78
22.4	6	4	1440	11.3	4056	4.85E+06	573.77
22.5	6	4	1440	11.2	4017	4.84E+06	573.77
22.6	6	4	1440	11.1	3978	4.84E+06	573.76
22.7	6	4	1440	10.9	3940	4.84E+06	573.76
22.8	6	4	1440	10.8	3903	4.84E+06	573.75
22.9	6	4	1440	10.7	3867	4.83E+06	573.75
23	6	4	1440	10.6	3831	4.83E+06	573.74
23.1	6	4	1440	10.5	3795	4.83E+06	573.74
23.2	6	4	1440	10.4	3761	4.83E+06	573.73

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
23.3	6	3	1080	10.4	3727	4.82E+06	573.73
23.4	6	3	1080	10.2	3688	4.82E+06	573.72
23.5	6	3	1080	10.1	3650	4.82E+06	573.72
23.6	6	3	1080	10.0	3613	4.82E+06	573.71
23.7	6	3	1080	9.9	3576	4.81E+06	573.71
23.8	6	3	1080	9.8	3540	4.81E+06	573.70
23.9	6	3	1080	9.7	3505	4.81E+06	573.70
24	6	2	720	9.6	3470	4.81E+06	573.69
24.1	6	2	720	9.5	3431	4.80E+06	573.69
24.2	6	2	720	9.4	3393	4.80E+06	573.68
24.3	6	2	720	9.3	3355	4.80E+06	573.68
24.4	6	2	720	9.2	3318	4.80E+06	573.67
24.5	6	2	720	9.1	3281	4.79E+06	573.67
24.6	6	2	720	9.0	3245	4.79E+06	573.66
24.7	6	2	720	8.9	3210	4.79E+06	573.66
24.8	6	2	720	8.8	3175	4.79E+06	573.65
24.9	6	1	360	8.7	3141	4.78E+06	573.65
25	6	1	360	8.6	3103	4.78E+06	573.64
25.1	6	1	360	8.5	3065	4.78E+06	573.64
25.2	6	1	360	8.4	3028	4.78E+06	573.63
25.3	6	1	360	8.3	2992	4.77E+06	573.63
25.4	6	1	360	8.2	2956	4.77E+06	573.62
25.5	6	1	360	8.1	2921	4.77E+06	573.62
30.5	300	0	0	8.0	144340	4.62E+06	573.34
35.5	300	0	0	3.3	59220	4.56E+06	573.23
40.5	300	0	0	1.8	32275	4.53E+06	573.17
45.5	300	0	0	1.1	20055	4.51E+06	573.13
50.5	300	0	0	0.7	13499	4.50E+06	573.10
55.5	300	0	0	0.5	9600	4.49E+06	573.08
65.5	600	0	0	0.4	14218	4.47E+06	573.06
75.5	600	0	0	0.2	7827	4.47E+06	573.04
85.5	600	0	0	0.1	4891	4.46E+06	573.03
95.5	600	0	0	0.1	3304	4.46E+06	573.03
105.5	600	0	0	0.1	2356	4.46E+06	573.02
115.5	600	0	0	0.0	1748	4.45E+06	573.02
125.5	600	0	0	0.0	1338	4.45E+06	573.01

Total volume of flow (ft^3)= Inflow = 9.38E+05 Outflow 8.72E+05

TABLE D-2
POND ROUTING UNDER EXTREME CONDITIONS
POND 2 (NORTHWEST OF FEMP)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM

Initial Pond Storage 5.96E+06 ft^3 Initial Pond Elevation 566.33 feet
Time Step= 360 second
Pond Overflow El.= 573 feet
Weir Width = 5 feet

POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
10.9		0		0.0	0	5.96E+06	566.33
11	6	2	720	0.0	0	5.96E+06	566.33
11.1	6	3	1080	0.0	0	5.96E+06	566.34
11.2	6	3	1080	0.0	0	5.96E+06	566.34
11.3	6	4	1440	0.0	0	5.96E+06	566.34
11.4	6	4	1440	0.0	0	5.97E+06	566.34
11.5	6	4	1440	0.0	0	5.97E+06	566.34
11.6	6	4	1440	0.0	0	5.97E+06	566.35
11.7	6	5	1800	0.0	0	5.97E+06	566.35
11.8	6	5	1800	0.0	0	5.97E+06	566.35
11.9	6	6	2160	0.0	0	5.97E+06	566.36
12	6	7	2520	0.0	0	5.98E+06	566.36
12.1	6	8	2880	0.0	0	5.98E+06	566.37
12.2	6	10	3600	0.0	0	5.98E+06	566.37
12.3	6	15	5400	0.0	0	5.99E+06	566.38
12.4	6	22	7920	0.0	0	6.00E+06	566.39
12.5	6	36	12960	0.0	0	6.01E+06	566.41
12.6	6	54	19440	0.0	0	6.03E+06	566.45
12.7	6	77	27720	0.0	0	6.06E+06	566.49
12.8	6	98	35280	0.0	0	6.09E+06	566.55
12.9	6	108	38880	0.0	0	6.13E+06	566.61
13	6	117	42120	0.0	0	6.17E+06	566.68
13.1	6	112	40320	0.0	0	6.21E+06	566.75
13.2	6	107	38520	0.0	0	6.25E+06	566.81
13.3	6	94	33840	0.0	0	6.29E+06	566.87
13.4	6	82	29520	0.0	0	6.32E+06	566.92
13.5	6	72	25920	0.0	0	6.34E+06	566.96
13.6	6	62	22320	0.0	0	6.36E+06	567.00
13.7	6	54	19440	0.0	0	6.38E+06	567.03
13.8	6	47	16920	0.0	0	6.40E+06	567.06
13.9	6	42	15120	0.0	0	6.42E+06	567.08
14	6	38	13680	0.0	0	6.43E+06	567.11
14.1	6	35	12600	0.0	0	6.44E+06	567.13

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POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
14.2	6	32	11520	0.0	0	6.45E+06	567.15
14.3	6	29	10440	0.0	0	6.46E+06	567.16
14.4	6	27	9720	0.0	0	6.47E+06	567.18
14.5	6	26	9360	0.0	0	6.48E+06	567.19
14.6	6	24	8640	0.0	0	6.49E+06	567.21
14.7	6	23	8280	0.0	0	6.50E+06	567.22
14.8	6	22	7920	0.0	0	6.51E+06	567.24
14.9	6	20	7200	0.0	0	6.51E+06	567.25
15	6	19	6840	0.0	0	6.52E+06	567.26
15.1	6	18	6480	0.0	0	6.53E+06	567.27
15.2	6	17	6120	0.0	0	6.53E+06	567.28
15.3	6	17	6120	0.0	0	6.54E+06	567.29
15.4	6	16	5760	0.0	0	6.55E+06	567.30
15.5	6	15	5400	0.0	0	6.55E+06	567.31
15.6	6	15	5400	0.0	0	6.56E+06	567.32
15.7	6	14	5040	0.0	0	6.56E+06	567.32
15.8	6	14	5040	0.0	0	6.57E+06	567.33
15.9	6	13	4680	0.0	0	6.57E+06	567.34
16	6	13	4680	0.0	0	6.58E+06	567.35
16.1	6	13	4680	0.0	0	6.58E+06	567.36
16.2	6	12	4320	0.0	0	6.58E+06	567.36
16.3	6	12	4320	0.0	0	6.59E+06	567.37
16.4	6	11	3960	0.0	0	6.59E+06	567.38
16.5	6	11	3960	0.0	0	6.60E+06	567.38
16.6	6	11	3960	0.0	0	6.60E+06	567.39
16.7	6	10	3600	0.0	0	6.60E+06	567.40
16.8	6	10	3600	0.0	0	6.61E+06	567.40
16.9	6	9	3240	0.0	0	6.61E+06	567.41
17	6	9	3240	0.0	0	6.61E+06	567.41
17.1	6	9	3240	0.0	0	6.62E+06	567.42
17.2	6	9	3240	0.0	0	6.62E+06	567.42
17.3	6	9	3240	0.0	0	6.62E+06	567.43
17.4	6	9	3240	0.0	0	6.63E+06	567.43
17.5	6	9	3240	0.0	0	6.63E+06	567.44
17.6	6	9	3240	0.0	0	6.63E+06	567.44
17.7	6	9	3240	0.0	0	6.64E+06	567.45
17.8	6	8	2880	0.0	0	6.64E+06	567.45
17.9	6	8	2880	0.0	0	6.64E+06	567.46
18	6	8	2880	0.0	0	6.65E+06	567.46
18.1	6	8	2880	0.0	0	6.65E+06	567.47
18.2	6	8	2880	0.0	0	6.65E+06	567.47
18.3	6	8	2880	0.0	0	6.65E+06	567.48
18.4	6	8	2880	0.0	0	6.66E+06	567.48
18.5	6	8	2880	0.0	0	6.66E+06	567.49
18.6	6	7	2520	0.0	0	6.66E+06	567.49

POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.7	6	7	2520	0.0	0	6.67E+06	567.50
18.8	6	7	2520	0.0	0	6.67E+06	567.50
18.9	6	7	2520	0.0	0	6.67E+06	567.50
19	6	7	2520	0.0	0	6.67E+06	567.51
19.1	6	7	2520	0.0	0	6.68E+06	567.51
19.2	6	7	2520	0.0	0	6.68E+06	567.52
19.3	6	7	2520	0.0	0	6.68E+06	567.52
19.4	6	7	2520	0.0	0	6.68E+06	567.53
19.5	6	6	2160	0.0	0	6.69E+06	567.53
19.6	6	6	2160	0.0	0	6.69E+06	567.53
19.7	6	6	2160	0.0	0	6.69E+06	567.54
19.8	6	6	2160	0.0	0	6.69E+06	567.54
19.9	6	6	2160	0.0	0	6.69E+06	567.54
20	6	6	2160	0.0	0	6.70E+06	567.55
20.1	6	6	2160	0.0	0	6.70E+06	567.55
20.2	6	6	2160	0.0	0	6.70E+06	567.55
20.3	6	6	2160	0.0	0	6.70E+06	567.56
20.4	6	6	2160	0.0	0	6.70E+06	567.56
20.5	6	6	2160	0.0	0	6.71E+06	567.56
20.6	6	6	2160	0.0	0	6.71E+06	567.57
20.7	6	6	2160	0.0	0	6.71E+06	567.57
20.8	6	6	2160	0.0	0	6.71E+06	567.58
20.9	6	6	2160	0.0	0	6.72E+06	567.58
21	6	6	2160	0.0	0	6.72E+06	567.58
21.1	6	5	1800	0.0	0	6.72E+06	567.59
21.2	6	5	1800	0.0	0	6.72E+06	567.59
21.3	6	5	1800	0.0	0	6.72E+06	567.59
21.4	6	5	1800	0.0	0	6.73E+06	567.59
21.5	6	5	1800	0.0	0	6.73E+06	567.60
21.6	6	5	1800	0.0	0	6.73E+06	567.60
21.7	6	5	1800	0.0	0	6.73E+06	567.60
21.8	6	5	1800	0.0	0	6.73E+06	567.61
21.9	6	5	1800	0.0	0	6.73E+06	567.61
22	6	5	1800	0.0	0	6.74E+06	567.61
22.1	6	5	1800	0.0	0	6.74E+06	567.61
22.2	6	5	1800	0.0	0	6.74E+06	567.62
22.3	6	5	1800	0.0	0	6.74E+06	567.62
22.4	6	4	1440	0.0	0	6.74E+06	567.62
22.5	6	4	1440	0.0	0	6.74E+06	567.63
22.6	6	4	1440	0.0	0	6.75E+06	567.63
22.7	6	4	1440	0.0	0	6.75E+06	567.63
22.8	6	4	1440	0.0	0	6.75E+06	567.63
22.9	6	4	1440	0.0	0	6.75E+06	567.64
23	6	4	1440	0.0	0	6.75E+06	567.64
23.1	6	4	1440	0.0	0	6.75E+06	567.64

POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
23.2	6	4	1440	0.0	0	6.75E+06	567.64
23.3	6	3	1080	0.0	0	6.76E+06	567.64
23.4	6	3	1080	0.0	0	6.76E+06	567.65
23.5	6	3	1080	0.0	0	6.76E+06	567.65
23.6	6	3	1080	0.0	0	6.76E+06	567.65
23.7	6	3	1080	0.0	0	6.76E+06	567.65
23.8	6	3	1080	0.0	0	6.76E+06	567.65
23.9	6	3	1080	0.0	0	6.76E+06	567.65
24	6	2	720	0.0	0	6.76E+06	567.66
24.1	6	2	720	0.0	0	6.76E+06	567.66
24.2	6	2	720	0.0	0	6.76E+06	567.66
24.3	6	2	720	0.0	0	6.76E+06	567.66
24.4	6	2	720	0.0	0	6.77E+06	567.66
24.5	6	2	720	0.0	0	6.77E+06	567.66
24.6	6	2	720	0.0	0	6.77E+06	567.66
24.7	6	2	720	0.0	0	6.77E+06	567.66
24.8	6	2	720	0.0	0	6.77E+06	567.67
24.9	6	1	360	0.0	0	6.77E+06	567.67
25	6	1	360	0.0	0	6.77E+06	567.67
25.1	6	1	360	0.0	0	6.77E+06	567.67
25.2	6	1	360	0.0	0	6.77E+06	567.67
25.3	6	1	360	0.0	0	6.77E+06	567.67
25.4	6	1	360	0.0	0	6.77E+06	567.67
25.5	6	1	360	0.0	0	6.77E+06	567.67
30.5	300	0	0	0.0	0	6.77E+06	567.67
35.5	300	0	0	0.0	0	6.77E+06	567.67
40.5	300	0	0	0.0	0	6.77E+06	567.67
45.5	300	0	0	0.0	0	6.77E+06	567.67
50.5	300	0	0	0.0	0	6.77E+06	567.67
55.5	300	0	0	0.0	0	6.77E+06	567.67
65.5	600	0	0	0.0	0	6.77E+06	567.67
75.5	600	0	0	0.0	0	6.77E+06	567.67
85.5	600	0	0	0.0	0	6.77E+06	567.67
95.5	600	0	0	0.0	0	6.77E+06	567.67
105.5	600	0	0	0.0	0	6.77E+06	567.67
115.5	600	0	0	0.0	0	6.77E+06	567.67
125.5	600	0	0	0.0	0	6.77E+06	567.67

Total volume of flow (ft^3) Inflow = 8.11E+05 Outflow = 0.00E+00

TABLE D-3
POND ROUTING UNDER EXTREME CONDITIONS
POND 3 (SOUTHEAST OF FEMP, BORROWED AREA)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM

Initial Pond Storage	1.93E+06	ft^3	Initial Pond Elevation	578.00 feet
Time Step=	360	second		
Pond Overflow El.=	578	feet	Pond 3 overflow to SSOD	
Weir Width =	5	feet		

POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
11	0	0		0.0	0	1.93E+06	578.00
11.1	6	3	1080	0.0	0	1.93E+06	578.00
11.2	6	4	1440	0.0	0	1.93E+06	578.00
11.3	6	4	1440	0.0	1	1.93E+06	578.01
11.4	6	5	1800	0.0	3	1.94E+06	578.01
11.5	6	5	1800	0.0	7	1.94E+06	578.02
11.6	6	6	2160	0.0	12	1.94E+06	578.02
11.7	6	7	2520	0.1	18	1.94E+06	578.03
11.8	6	7	2520	0.1	27	1.94E+06	578.03
11.9	6	8	2880	0.1	37	1.95E+06	578.04
12	6	12	4320	0.1	49	1.95E+06	578.05
12.1	6	20	7200	0.2	69	1.96E+06	578.07
12.2	6	32	11520	0.3	108	1.97E+06	578.10
12.3	6	53	19080	0.5	181	1.99E+06	578.14
12.4	6	72	25920	0.9	327	2.01E+06	578.21
12.5	6	87	31320	1.6	565	2.05E+06	578.29
12.6	6	93	33480	2.5	904	2.08E+06	578.37
12.7	6	94	33840	3.7	1316	2.11E+06	578.45
12.8	6	95	34200	4.9	1777	2.14E+06	578.53
12.9	6	92	33120	6.3	2279	2.17E+06	578.60
13	6	90	32400	7.8	2794	2.20E+06	578.68
13.1	6	82	29520	9.2	3321	2.23E+06	578.74
13.2	6	75	27000	10.6	3811	2.25E+06	578.80
13.3	6	67	24120	11.8	4263	2.27E+06	578.85
13.4	6	60	21600	13.0	4664	2.29E+06	578.89
13.5	6	54	19440	13.9	5015	2.30E+06	578.93
13.6	6	47	16920	14.8	5321	2.32E+06	578.96
13.7	6	42	15120	15.5	5571	2.33E+06	578.98
13.8	6	37	13320	16.1	5780	2.33E+06	579.00
13.9	6	34	12240	16.5	5946	2.34E+06	579.02
14	6	31	11160	16.9	6087	2.34E+06	579.03
14.1	6	29	10440	17.2	6200	2.35E+06	579.04
14.2	6	26	9360	17.5	6296	2.35E+06	579.05

POND-3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
14.3	6	24	8640	17.7	6366	2.35E+06	579.05
14.4	6	23	8280	17.8	6417	2.36E+06	579.06
14.5	6	21	7560	17.9	6460	2.36E+06	579.06
14.6	6	20	7200	18.0	6485	2.36E+06	579.06
14.7	6	19	6840	18.1	6501	2.36E+06	579.06
14.8	6	18	6480	18.1	6509	2.36E+06	579.06
14.9	6	16	5760	18.1	6508	2.36E+06	579.06
15	6	15	5400	18.0	6491	2.36E+06	579.06
15.1	6	15	5400	18.0	6466	2.35E+06	579.06
15.2	6	14	5040	17.9	6442	2.35E+06	579.05
15.3	6	14	5040	17.8	6410	2.35E+06	579.05
15.4	6	13	4680	17.7	6379	2.35E+06	579.04
15.5	6	13	4680	17.6	6340	2.35E+06	579.04
15.6	6	13	4680	17.5	6303	2.35E+06	579.04
15.7	6	13	4680	17.4	6266	2.35E+06	579.03
15.8	6	12	4320	17.3	6230	2.34E+06	579.03
15.9	6	12	4320	17.2	6187	2.34E+06	579.02
16	6	12	4320	17.1	6145	2.34E+06	579.02
16.1	6	12	4320	17.0	6104	2.34E+06	579.01
16.2	6	11	3960	16.8	6064	2.34E+06	579.01
16.3	6	11	3960	16.7	6017	2.33E+06	579.00
16.4	6	10	3600	16.6	5972	2.33E+06	579.00
16.5	6	10	3600	16.4	5919	2.33E+06	578.99
16.6	6	10	3600	16.3	5868	2.33E+06	578.99
16.7	6	10	3600	16.2	5818	2.32E+06	578.98
16.8	6	9	3240	16.0	5769	2.32E+06	578.97
16.9	6	9	3240	15.9	5713	2.32E+06	578.97
17	6	9	3240	15.7	5659	2.32E+06	578.96
17.1	6	9	3240	15.6	5606	2.32E+06	578.96
17.2	6	9	3240	15.4	5555	2.31E+06	578.95
17.3	6	9	3240	15.3	5505	2.31E+06	578.94
17.4	6	9	3240	15.2	5456	2.31E+06	578.94
17.5	6	9	3240	15.0	5408	2.31E+06	578.93
17.6	6	9	3240	14.9	5361	2.30E+06	578.93
17.7	6	9	3240	14.8	5316	2.30E+06	578.92
17.8	6	9	3240	14.6	5272	2.30E+06	578.92
17.9	6	9	3240	14.5	5228	2.30E+06	578.91
18	6	9	3240	14.4	5186	2.30E+06	578.91
18.1	6	9	3240	14.3	5145	2.29E+06	578.90
18.2	6	9	3240	14.2	5105	2.29E+06	578.90
18.3	6	8	2880	14.1	5065	2.29E+06	578.89
18.4	6	8	2880	13.9	5019	2.29E+06	578.89
18.5	6	8	2880	13.8	4975	2.29E+06	578.88
18.6	6	8	2880	13.7	4931	2.28E+06	578.88
18.7	6	8	2880	13.6	4888	2.28E+06	578.87

POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.8	6	7	2520	13.5	4846	2.28E+06	578.87
18.9	6	7	2520	13.3	4798	2.28E+06	578.86
19	6	7	2520	13.2	4751	2.27E+06	578.86
19.1	6	7	2520	13.1	4705	2.27E+06	578.85
19.2	6	7	2520	12.9	4661	2.27E+06	578.85
19.3	6	6	2160	12.8	4617	2.27E+06	578.84
19.4	6	6	2160	12.7	4567	2.27E+06	578.83
19.5	6	6	2160	12.5	4518	2.26E+06	578.83
19.6	6	6	2160	12.4	4470	2.26E+06	578.82
19.7	6	6	2160	12.3	4424	2.26E+06	578.82
19.8	6	5	1800	12.2	4378	2.26E+06	578.81
19.9	6	5	1800	12.0	4327	2.25E+06	578.80
20	6	5	1800	11.9	4276	2.25E+06	578.80
20.1	6	5	1800	11.7	4227	2.25E+06	578.79
20.2	6	5	1800	11.6	4179	2.25E+06	578.79
20.3	6	5	1800	11.5	4132	2.24E+06	578.78
20.4	6	5	1800	11.4	4086	2.24E+06	578.77
20.5	6	5	1800	11.2	4042	2.24E+06	578.77
20.6	6	5	1800	11.1	3998	2.24E+06	578.76
20.7	6	5	1800	11.0	3955	2.24E+06	578.76
20.8	6	5	1800	10.9	3914	2.23E+06	578.75
20.9	6	5	1800	10.8	3873	2.23E+06	578.75
21	6	5	1800	10.6	3833	2.23E+06	578.74
21.1	6	5	1800	10.5	3794	2.23E+06	578.74
21.2	6	5	1800	10.4	3756	2.22E+06	578.73
21.3	6	5	1800	10.3	3719	2.22E+06	578.73
21.4	6	5	1800	10.2	3682	2.22E+06	578.72
21.5	6	5	1800	10.1	3647	2.22E+06	578.72
21.6	6	5	1800	10.0	3612	2.22E+06	578.71
21.7	6	5	1800	9.9	3578	2.22E+06	578.71
21.8	6	5	1800	9.8	3545	2.21E+06	578.70
21.9	6	5	1800	9.8	3512	2.21E+06	578.70
22	6	5	1800	9.7	3480	2.21E+06	578.70
22.1	6	5	1800	9.6	3449	2.21E+06	578.69
22.2	6	5	1800	9.5	3419	2.21E+06	578.69
22.3	6	5	1800	9.4	3389	2.21E+06	578.68
22.4	6	4	1440	9.3	3360	2.20E+06	578.68
22.5	6	4	1440	9.2	3324	2.20E+06	578.67
22.6	6	4	1440	9.1	3290	2.20E+06	578.67
22.7	6	4	1440	9.0	3256	2.20E+06	578.67
22.8	6	4	1440	9.0	3223	2.20E+06	578.66
22.9	6	4	1440	8.9	3191	2.19E+06	578.66
23	6	4	1440	8.8	3160	2.19E+06	578.65
23.1	6	4	1440	8.7	3129	2.19E+06	578.65
23.2	6	4	1440	8.6	3099	2.19E+06	578.64

POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
23.3	6	3	1080	8.5	3069	2.19E+06	578.64
23.4	6	3	1080	8.4	3034	2.19E+06	578.63
23.5	6	3	1080	8.3	2999	2.18E+06	578.63
23.6	6	3	1080	8.2	2965	2.18E+06	578.62
23.7	6	3	1080	8.1	2932	2.18E+06	578.62
23.8	6	3	1080	8.1	2900	2.18E+06	578.62
23.9	6	3	1080	8.0	2868	2.18E+06	578.61
24	6	2	720	7.9	2837	2.17E+06	578.61
24.1	6	2	720	7.8	2800	2.17E+06	578.60
24.2	6	2	720	7.7	2764	2.17E+06	578.60
24.3	6	2	720	7.6	2729	2.17E+06	578.59
24.4	6	2	720	7.5	2695	2.17E+06	578.59
24.5	6	2	720	7.4	2661	2.16E+06	578.58
24.6	6	2	720	7.3	2628	2.16E+06	578.58
24.7	6	2	720	7.2	2596	2.16E+06	578.57
24.8	6	2	720	7.1	2565	2.16E+06	578.57
24.9	6	1	360	7.0	2534	2.16E+06	578.56
25	6	1	360	6.9	2497	2.15E+06	578.56
25.1	6	1	360	6.8	2462	2.15E+06	578.55
25.2	6	1	360	6.7	2427	2.15E+06	578.55
25.3	6	1	360	6.6	2393	2.15E+06	578.54
25.4	6	1	360	6.6	2360	2.15E+06	578.54
25.5	6	1	360	6.5	2327	2.14E+06	578.53
25.6	6	0	0	6.4	2296	2.14E+06	578.52
26.5	60	0	0	6.4	22956	2.12E+06	578.47
31.5	300	0	0	5.4	96731	2.02E+06	578.23
36.5	300	0	0	1.8	33273	1.99E+06	578.15
41.5	300	0	0	1.0	17168	1.97E+06	578.11
46.5	300	0	0	0.6	10356	1.96E+06	578.08
51.5	300	0	0	0.4	6838	1.96E+06	578.06
61.5	600	0	0	0.3	9594	1.95E+06	578.04
71.5	600	0	0	0.1	4751	1.94E+06	578.03
81.5	600	0	0	0.1	2807	1.94E+06	578.02
91.5	600	0	0	0.1	1829	1.94E+06	578.02
101.5	600	0	0	0.0	1271	1.94E+06	578.01
111.5	600	0	0	0.0	926	1.94E+06	578.01
121.5	600	0	0	0.0	698	1.93E+06	578.01

Total volume of flow (ft^3) Inflow = 7.87E+05 Outflow= 7.45E+05

TABLE D-4
POND ROUTING UNDER EXTREME CONDITIONS
POND 4 (RETENTION POND- SOUTHWEST OF FEMP)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM
FEMP

Initial Pond Storage 2.55E+06 ft^3 Initial Pond Elevation 560.00 feet
Time Step= 360 second
Pond Overflow El.= 560 feet
Weir Width = 20 feet

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
11	0	0	0	0	0.0	0	2.55E+06	560.00
11.1	6	1	0	360	0.0	4	2.55E+06	560.00
11.2	6	1	0	360	0.0	7	2.55E+06	560.01
11.3	6	1	0	360	0.0	11	2.55E+06	560.01
11.4	6	1	0	360	0.0	15	2.55E+06	560.01
11.5	6	2	0	720	0.1	20	2.55E+06	560.01
11.6	6	2	0	720	0.1	30	2.55E+06	560.01
11.7	6	2	0	720	0.1	42	2.55E+06	560.02
11.8	6	2	0	720	0.2	54	2.55E+06	560.02
11.9	6	2	0	720	0.2	68	2.55E+06	560.02
12	6	3	0	1080	0.2	82	2.56E+06	560.03
12.1	6	3	0	1080	0.3	105	2.56E+06	560.03
12.2	6	4	0	1440	0.4	129	2.56E+06	560.04
12.3	6	7	0	2520	0.5	164	2.56E+06	560.05
12.4	6	10	0	3600	0.7	234	2.56E+06	560.06
12.5	6	14	0	5040	1.0	347	2.57E+06	560.08
12.6	6	19	0	6840	1.5	529	2.57E+06	560.11
12.7	6	23	0	8280	2.2	809	2.58E+06	560.14
12.8	6	29	0	10440	3.3	1189	2.59E+06	560.17
12.9	6	33	0	11880	4.8	1722	2.60E+06	560.22
13	6	37	0	13320	6.6	2378	2.61E+06	560.26
13.1	6	40	0	14400	8.8	3160	2.62E+06	560.31
13.2	6	43	0	15480	11.2	4037	2.64E+06	560.35
13.3	6	42	0	15120	13.9	5000	2.65E+06	560.40
13.4	6	41	0	14760	16.4	5908	2.65E+06	560.43
13.5	6	38	0	13680	18.7	6742	2.66E+06	560.46
13.6	6	35	0	12600	20.6	7421	2.67E+06	560.48
13.7	6	32	0	11520	22.1	7942	2.67E+06	560.50
13.8	6	28	0	10080	23.1	8308	2.67E+06	560.50
13.9	6	26	0	9360	23.6	8492	2.67E+06	560.51
14	6	23	0	8280	23.8	8582	2.67E+06	560.51
14.1	6	21	0	7560	23.8	8551	2.67E+06	560.50
14.2	6	19	0	6840	23.5	8448	2.67E+06	560.50

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pon Stag (ft)
14.3	6	17	0	6120	23.0	8281	2.67E+06	560.49
14.4	6	16	0	5760	22.4	8060	2.67E+06	560.48
14.5	6	14	0	5040	21.7	7826	2.66E+06	560.47
14.6	6	13	0	4680	21.0	7545	2.66E+06	560.45
14.7	6	12	0	4320	20.2	7261	2.66E+06	560.44
14.8	6	12	0	4320	19.4	6973	2.65E+06	560.43
14.9	6	11	0	3960	18.7	6716	2.65E+06	560.42
15	6	10	0	3600	17.9	6453	2.65E+06	560.41
15.1	6	9	0	3240	17.2	6184	2.65E+06	560.40
15.2	6	9	0	3240	16.4	5910	2.64E+06	560.38
15.3	6	8	0	2880	15.7	5666	2.64E+06	560.37
15.4	6	8	0	2880	15.0	5415	2.64E+06	560.36
15.5	6	7	0	2520	14.4	5190	2.63E+06	560.35
15.6	6	7	0	2520	13.8	4956	2.63E+06	560.34
15.7	6	7	0	2520	13.2	4746	2.63E+06	560.33
15.8	6	6	0	2160	12.7	4556	2.63E+06	560.32
15.9	6	6	0	2160	12.1	4355	2.63E+06	560.31
16	6	6	0	2160	11.6	4174	2.62E+06	560.31
16.1	6	6	0	2160	11.1	4010	2.62E+06	560.30
16.2	6	6	0	2160	10.7	3861	2.62E+06	560
16.3	6	5	0	1800	10.3	3726	2.62E+06	560.28
16.4	6	5	0	1800	9.9	3575	2.62E+06	560.28
16.5	6	5	0	1800	9.5	3437	2.61E+06	560.27
16.6	6	5	0	1800	9.2	3312	2.61E+06	560.26
16.7	6	5	0	1800	8.9	3198	2.61E+06	560.26
16.8	6	5	0	1800	8.6	3093	2.61E+06	560.25
16.9	6	5	0	1800	8.3	2998	2.61E+06	560.25
17	6	5	0	1800	8.1	2910	2.61E+06	560.24
17.1	6	5	0	1800	7.9	2830	2.61E+06	560.24
17.2	6	5	0	1800	7.7	2756	2.61E+06	560.23
17.3	6	4	0	1440	7.5	2688	2.60E+06	560.23
17.4	6	4	0	1440	7.2	2600	2.60E+06	560.22
17.5	6	4	0	1440	7.0	2519	2.60E+06	560.22
17.6	6	4	0	1440	6.8	2445	2.60E+06	560.22
17.7	6	4	0	1440	6.6	2376	2.60E+06	560.21
17.8	6	4	0	1440	6.4	2313	2.60E+06	560.21
17.9	6	4	0	1440	6.3	2254	2.60E+06	560.20
18	6	4	0	1440	6.1	2200	2.60E+06	560.20
18.1	6	4	0	1440	6.0	2150	2.60E+06	560.20
18.2	6	4	0	1440	5.8	2103	2.60E+06	560.20
18.3	6	4	0	1440	5.7	2060	2.60E+06	560.19
18.4	6	4	0	1440	5.6	2020	2.60E+06	560.19
18.5	6	4	0	1440	5.5	1983	2.60E+06	560
18.6	6	4	0	1440	5.4	1948	2.59E+06	560.19
18.7	6	4	0	1440	5.3	1916	2.59E+06	560.18

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.8	6	4	0	1440	5.2	1886	2.59E+06	560.18
18.9	6	4	0	1440	5.2	1858	2.59E+06	560.18
19	6	4	0	1440	5.1	1832	2.59E+06	560.18
19.1	6	4	0	1440	5.0	1807	2.59E+06	560.18
19.2	6	4	0	1440	5.0	1784	2.59E+06	560.18
19.3	6	4	0	1440	4.9	1763	2.59E+06	560.18
19.4	6	4	0	1440	4.8	1743	2.59E+06	560.17
19.5	6	4	0	1440	4.8	1725	2.59E+06	560.17
19.6	6	3	0	1080	4.7	1707	2.59E+06	560.17
19.7	6	3	0	1080	4.6	1669	2.59E+06	560.17
19.8	6	3	0	1080	4.5	1634	2.59E+06	560.17
19.9	6	3	0	1080	4.4	1601	2.59E+06	560.16
20	6	3	0	1080	4.4	1570	2.59E+06	560.16
20.1	6	3	0	1080	4.3	1541	2.59E+06	560.16
20.2	6	3	0	1080	4.2	1514	2.59E+06	560.16
20.3	6	3	0	1080	4.1	1488	2.59E+06	560.16
20.4	6	3	0	1080	4.1	1465	2.59E+06	560.15
20.5	6	3	0	1080	4.0	1443	2.59E+06	560.15
20.6	6	3	0	1080	3.9	1422	2.59E+06	560.15
20.7	6	3	0	1080	3.9	1402	2.59E+06	560.15
20.8	6	3	0	1080	3.8	1384	2.59E+06	560.15
20.9	6	3	0	1080	3.8	1367	2.59E+06	560.15
21	6	2	0	720	3.8	1350	2.58E+06	560.15
21.1	6	2	0	720	3.7	1315	2.58E+06	560.14
21.2	6	2	0	720	3.6	1282	2.58E+06	560.14
21.3	6	2	0	720	3.5	1251	2.58E+06	560.14
21.4	6	2	0	720	3.4	1222	2.58E+06	560.14
21.5	6	2	0	720	3.3	1195	2.58E+06	560.13
21.6	6	2	0	720	3.2	1169	2.58E+06	560.13
21.7	6	2	0	720	3.2	1145	2.58E+06	560.13
21.8	6	2	0	720	3.1	1122	2.58E+06	560.13
21.9	6	2	0	720	3.1	1101	2.58E+06	560.13
22	6	2	0	720	3.0	1081	2.58E+06	560.13
22.1	6	2	0	720	3.0	1062	2.58E+06	560.12
22.2	6	2	0	720	2.9	1045	2.58E+06	560.12
22.3	6	2	0	720	2.9	1028	2.58E+06	560.12
22.4	6	2	0	720	2.8	1012	2.58E+06	560.12
22.5	6	2	0	720	2.8	997	2.58E+06	560.12
22.6	6	2	0	720	2.7	983	2.58E+06	560.12
22.7	6	2	0	720	2.7	970	2.58E+06	560.12
22.8	6	2	0	720	2.7	957	2.58E+06	560.12
22.9	6	2	0	720	2.6	945	2.58E+06	560.12
23	6	2	0	720	2.6	934	2.58E+06	560.11
23.1	6	1	0	360	2.6	923	2.58E+06	560.11
23.2	6	1	0	360	2.5	896	2.58E+06	560.11

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pon Stag (ft)
23.3	6	1	0	360	2.4	869	2.58E+06	560.11
23.4	6	1	0	360	2.3	845	2.58E+06	560.11
23.5	6	1	0	360	2.3	822	2.57E+06	560.10
23.6	6	1	0	360	2.2	800	2.57E+06	560.10
23.7	6	1	0	360	2.2	779	2.57E+06	560.10
23.8	6	1	0	360	2.1	759	2.57E+06	560.10
23.9	6	1	0	360	2.1	741	2.57E+06	560.10
24	6	1	0	360	2.0	723	2.57E+06	560.10
24.1	6	1	0	360	2.0	707	2.57E+06	560.09
24.2	6	1	0	360	1.9	691	2.57E+06	560.09
24.3	6	1	0	360	1.9	676	2.57E+06	560.09
24.4	6	1	0	360	1.8	662	2.57E+06	560.09
24.5	6	1	0	360	1.8	649	2.57E+06	560.09
24.6	6	1	0	360	1.8	636	2.57E+06	560.09
24.7	6	1	0	360	1.7	624	2.57E+06	560.09
24.8	6	1	0	360	1.7	613	2.57E+06	560.09
24.9	6	1	0	360	1.7	602	2.57E+06	560.09
25	6	0	0	0	1.6	591	2.57E+06	560.08
25.1	6	0	0	0	1.6	566	2.57E+06	560.08
25.2	6	0	0	0	1.5	542	2.57E+06	560
25.3	6	0	0	0	1.4	520	2.57E+06	560.08
25.4	6	0	0	0	1.4	499	2.57E+06	560.07
25.5	6	0	0	0	1.3	479	2.57E+06	560.07
25.6	6	0	0	0	1.3	460	2.57E+06	560.07
26.5	54	0	0	0	1.2	3977	2.56E+06	560.05
31.5	300	0	0	0	0.8	14844	2.55E+06	559.99
36.5	300	0	0	0	0.0	0	2.55E+06	559.99
41.5	300	0	0	0	0.0	0	2.55E+06	559.99
46.5	300	0	0	0	0.0	0	2.55E+06	559.99
51.5	300	0	0	0	0.0	0	2.55E+06	559.99
61.5	600	0	0	0	0.0	0	2.55E+06	559.99
71.5	600	0	0	0	0.0	0	2.55E+06	559.99
81.5	600	0	0	0	0.0	0	2.55E+06	559.99
91.5	600	0	0	0	0.0	0	2.55E+06	559.99
101.5	600	0	0	0	0.0	0	2.55E+06	559.99
111.5	600	0	0	0	0.0	0	2.55E+06	559.99
121.5	600	0	0	0	0.0	0	2.55E+06	559.99

Total volume of flow (ft^3)= Inflow = 3.67E+05 Outflow 3.69E+05

RESPONSES TO U.S. DEPARTMENT OF INTERIOR FISH AND WILDLIFE SERVICE COMMENTS ON THE PRELIMINARY FINAL NATURAL RESOURCE RESTORATION PLAN (212E-PL-0003, REVISION 0A)

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

SPECIFIC COMMENTS

Commenting Organization: USFWS Commentator: Kurey
Section #: 1.5 Pg. #: 1-6 Line #: Last sentence
Original Comment #: 1
Comment: This sentence needs to be rewritten. There appears to be a word missing after "multi-use educational."

Response: Agree.

Action: Text will be revised to clarify the meaning of the sentence.

Commenting Organization: USFWS Commentator: Kurey
Section #: 2.2.5 Pg. #: 2-4 Line #: Second line
Original Comment #: 2
Comment: Insert an "a" between as and result.

Response: This section will be removed and text to be incorporated into project description.

Action: Section 2.2.5 will be removed and text will be incorporated into project description.

Commenting Organization: USFWS Commentator: Kurey
Section #: 3.1.4 Pg. #: 3-3 Line #: Second paragraph
Original Comment #: 3
Comment: This paragraph talks about the creation of additional floodplain. We believe that the successful sizing and design of channels and floodplain requires the attention of someone with previous experience at the task. It is as much art as science. DOE should acquire expert (experienced) advice before any design for channel or floodplain is finalized.

Response: DOE agrees that outside expertise should be consulted regarding the overall plan for increasing floodplain on Paddys Run. Section 3.1.4 discusses the option of obtaining outside expertise to assist the Natural Resource Trustees (NRTs) in assessing restoration plans for Paddys Run.

Action: No change to text. DOE will work with the NRTs to obtain appropriate outside expertise and assess plans for floodplain creation on Paddys Run.

Commenting Organization: USFWS Commentator: Kurey
Section #: 3.1.4 Pg. #: 3-3 Line #: Third paragraph, last sentence
Original Comment #: 4
Comment: The word "be" should be inserted between "will" and "designed."

Response: Agree.

~~Action: Text will be revised as noted in the comment.~~

Commenting Organization: USFWS Commentator: Kurey
Section #: 3.1.5 Pg. #: 3-3 Line #: First paragraph
Original Comment #: 5
Comment: Please assign a number to the FEMP acres that would be committed to natural resource restoration.

Response: Agree.

Action: Text will be revised to state that the Master Plan for Public Use proposed that 904 acres of the FEMP be committed to natural resource restoration.

Commenting Organization: USFWS Commentator: Kurey
Section #: 3.1.5 Pg. #: 3-4 Line #: Last paragraph
Original Comment #: 6
Comment: Please define the term "low-impact" in reference to trails.

Response: Agree.

Action: Additional text will be added to Section 3.1.5 to clarify the meaning of "low-impact" trail.

Commenting Organization: USFWS Commentator: Kurey
Section #: 3.1.5 Pg. #: 3-5 Line #: First paragraph
Original Comment #: 7
Comment: Please clarify if the Trustees, other than DOE, will have any control over the amount of paved trails for handicap access.

Response: The NRTs would collectively agree on the appropriate configuration for trails on the FEMP. For planning purposes, the maximum length of the trails will be limited by the NRRP.

Action: Text will be revised to clarify role to the Fernald NRTs in planning trails on the FEMP.

Commenting Organization: USFWS Commentator: Kurey
Section #: 3.1.6 Pg. #: 3-5 Line #: Fourth paragraph
Original Comment #: 8
Comment: Please discuss the applicability of "synthetic" topsoils to areas where mineral subsoils will be exposed. Is it feasible to bring in a trainload or two of this material from someplace like Toledo (NuSoil)? This material is composed of dredge spoil and sewage sludge.

Response: The use of "synthetic" top-soil will be evaluated as an option for soil amendment on the FEMP. The text of the NRRP will be clarified to allow for wood chips, compost or a suitable alternative to be used for soil amendment. If "synthetic" topsoil appears to be a viable alternative, discussions with the NRTs will be initiated as an alternative to wood chips or compost.

Action: Clarify text as noted above. Evaluate use of "synthetic" topsoil as a soil amendment at the FEMP.

Commenting Organization: USFWS Commentator: Kurey
Section #: 3.1.8 Pg. #: 3-6 Line #: NA
Original Comment #: 9

Comment: We were a little concerned that DOE has reserved for itself all decisions about maintenance and management of restored areas. We believe that a burn plan and other aspects of maintenance/management should be vetted by the Trustees as part of the NRD settlement. Any steward of the DOE land would be responsible for carrying out the maintenance plans already in affect at the time they take over.

Response: Agree.

Action: The text regarding maintenance and management of restored areas will be revised to clarify that the NRTs collectively will determine appropriate maintenance and management of restored areas on the FEMP.

Commenting Organization: USFWS Commentator: Kurey
Section #: 4.2.2.1 Pg. #: 4-8 Line #: Last paragraph
Original Comment #: 10

Comment: Coir and Jute matting were mentioned as appropriate for areas where erosion needs to be controlled. We would also like to add that synthetic matting should not be allowed. At a recent natural channel restoration workshop we learned that such synthetic materials are highly prone to catch and kill snakes. The presenter of this report said much of his time was spent releasing snakes and recommended against the use of synthetic matting in the future.

Response: Agree.

Action: Text will specify that coir and jute matting will be installed in erosion-prone areas and that synthetic matting will not be used for erosion control at the FEMP.

Commenting Organization: USFWS Commentator: Kurey
Section #: 4.2.2.3 Pg. #: 4-11 Line #: Last paragraph
Original Comment #: 11

Comment: This section mentions that soil amended with wood chips could be applied to four depressions that would be created. If these depressions are intended to hold water, we question the wisdom of using wood chips, which would immediately float when inundated.

Response: Any wood chips used in wetland areas would be incorporated into the surface layer of soil and would remain in the soil after inundation.

Action: No action.

Commenting Organization: USFWS Commentator: Kurey
Section #: 4.2.2.3 Pg. #: 4-12 Line #: Near bottom
Original Comment #: 12

Comment: Here again the use of wood chips is mentioned as an amendment to wetland soils. Wouldn't the wood chips float?

Response: See response to Comment No. 11.

Action: No action.

Commenting Organization: USFWS Commentator: Kurey
Section #: 4.2.2.3 Pg. #: 4-13 Line #: First section
Original Comment #: 13
Comment: The use of 20 wildlife structures is mentioned. Here and elsewhere, please describe the wildlife structures and their intended use. How was the number of structures determined?

Response: The number of wildlife structures was determined based on past project experience. The types of structures include duck boxes, various bird boxes and bat boxes.

Action: Text will be clarified to provide examples of the types of boxes to be used in restoration projects.

Commenting Organization: USFWS Commentator: Kurey
Section #: General Pg. #: NA Line #: NA
Original Comment #: 14
Comment: Although there will be numerous bodies of standing water, no mention was made of the need for stocking fish. The stocking of fish needs to be addressed in the NRRP.

Response: Agree.

Action: Text will be added to the NRRP that does not proclude stocking of fish in open water areas of the FEMP and that specific plans for stocking will be developed during NRRDP development (e.g., the Production Area).

RESPONSES TO OHIO ENVIRONMENTAL PROTECTION AGENCY COMMENTS ON THE PRELIMINARY FINAL NATURAL RESOURCE RESTORATION PLAN (212E-PL-0003, REVISION 0A)

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: General Pg. #: Line #: NA Code: C
Original Comment #: 1

Comment: In reviewing the document two specific areas were not apparent in where they are addressed. Specifically, the former STP and the pasture area west of the 23 acres set aside (A2P3) are not evident. Please clarify where these are addressed

Response: The Pasture west of the 23 acres set aside are is covered in the Paddys Run Corridor Restoration Project (Section 4.2.3). The former Sewage Treatment Plant (STP) is covered in the Borrow Area Restoration Project (Section 4.2.4).

Action: Text will added to the sections listed above to clarify the restoration plans for these areas.

Commenting Organization: Ohio EPA Commentator: OFFO/DSW
Section #: 1.0 Pg. #: NA Line #: NA Code: C
Original Comment #: 2

Comment: The introduction should include some mention of the goal of revegetation with native plants towards a pre-European settlement condition. Potentially, inclusion of the goals from Section 2.0 could provide more specifics in the Introduction. Additionally, some mention of the goal to provide accessibility to the site including educational opportunities for the public is needed.

Response: Agree in part. To avoid making the Introduction to lengthy, DOE would prefer to keep the Ecological Restoration Goals in Section 2.0.

Action: Text will be added to the Introduction to stress the goal of using vegetation native during pre-European settlement. Providing public access to the site for educational opportunities will also be added to the Introduction.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 1.0 Pg. #: 1-1 Line #: NA Code: C
Original Comment #: 3

Comment: The sentence beginning, "Final decisions on public...." is problematic. The intent should be to integrate the NRRP and Public Use EA not separate them. This document does make specific comments with regard to public use, i.e., no camping, no off-road vehicles, etc. Decisions regarding public use are integral to settlement. It was Ohio EPA's understanding that DOE had agreed that public access in the form of paths, overlooks, etc. was to be incorporated into the settlement. Therefore, the NRRP must be more fully integrated with the Public Use EA.

Response: Agree.

Action: The text in the Introduction will be clarified to reflect the current proposal for public use of the FEMP including public education and trails.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 1.0 Pg. #: 1-1 Line #: NA Code: C
Original Comment #: 4
Comment: The sentence beginning, "Groundwater impacts.." is a bit confusing and out of place. If this is meant to be a reference to the HEA calculations then reference to the Addendum should be included. Additionally, state that groundwater was excluded from the calculations and was evaluated under a separate methodology.

Response: Agree.

Action: This discussion will be removed from the Introduction. The Habitat Equivalency Analysis (HEA) methodology and approach to settling groundwater issues is discussed in Sections 1.4 and 1.5, respectively.

Commenting Organization: Ohio EPA Commentator: ODH
Section #: 1.0 Pg. #: 1-2 Line #: NA Code: C
Original Comment #: 5
Comment: First Bullet. The trustees are not willing to consider "any" future public use. Actually, specific prohibitions are included in this document. The latter portion of the bullet should be revised to state that the trustees have and continue to consider stakeholder desires with regard to public use.

Response: Agree.

Action: Text will be revised to reflect the Natural Resource Trustees (NRTs) current position regarding public use of the FEMP.

Commenting Organization: Ohio EPA Commentator: OFFO/DSW
Section #: 1.4 Pg. #: 1-4 Line #: NA Code: C
Original Comment #: 6
Comment: This section should be revised to provide a bit more detail regarding the HEA process. Most importantly replace the "order of magnitude" reference with a discussion of the fact that calculated acreage sufficiently approximated the available acreage on-site to support an on-site restoration agreement.

Response: Agree.

Action: Additional detail will be added to Section 1.4 to describe the HEA process more completely.

Commenting Organization: Ohio EPA Commentator: OFFO/DSW
Section #: 1.5 Pg. #: 1-4 Line #: last Code: C
Original Comment #: 7
Comment: It would be preferred to refer to the 20-ppb value as simply based on the proposed MCL. Risks were considered in the development of MCL based cleanup numbers though the proposed MCL was found to be protective as was the final MCL.

Response: Agree.

Action: Text will be revised as recommended in the comment.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 1.5 Pg. #: 1-5 Line #: NA Code: C
Original Comment #: 8
Comment: The statement that "DOE provided $6.4 million to install the public water supply..." leads the reader to believe that the entirety of the cost was shouldered by DOE. Phrasing like "contributed towards" or "assisted with funding in the amount of" and including the total cost of providing water would be more appropriate.

Response: Agree.

Action: Text in Section 1.5 will be revised to clarify that DOE contributed to the installation of the public water supply, but did not fully fund it.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 1.5 Pg. #: 1-5 Line #: NA Code: C
Original Comment #: 9
Comment: The statement is made that all of the restoration projects (listed in section 4) contribute in some way to the protection of groundwater, yet the first project listed (the aesthetic barrier) would not seem to contribute to the protection of groundwater in any significant way. Perhaps many, or most, of the projects do, but not all of them.

Response: Agree.

Action: Text will be clarified to state that most of the restoration projects contribute to the protection of groundwater resources.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 1.5 Pg. #: 1-5 Line #: NA Code: C
Original Comment #: 10
Comment: Recommend replacement of the last sentence with the following: "The NRTs expect the $5 million will be used to support development of an on-site multi-use educational facility and associated environmental education activities. Should for some reason such an on-site facility not be possible, the NRTs shall determine alternative applications for the settlement funds that will similarly meet the goals outlined above."

Response: Agree.

Action: Text will be revised as noted in the comment.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: Figure 1-1 Pg. #: NA Line #: NA Code: C
Original Comment #: 11
Comment: An updated and more readable figure should be provided. For example the parking lot is still located on this figure, 23-acre parcel and other features should be consistent with EA.

Response: Agree.

Action: The figure will be updated for inclusion in the final NRRP.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 2.1.3 Pg. #: 2-2 Line #: NA Code: C
Original Comment #: 12
Comment: Since wildlife structures have already been set up in different areas of the site, the last sentence in this section should read: "Wildlife structures and cover (i.e., bird boxes, brush piles) will continue to be included in ecological restoration designs."

Response: Agree.

Action: Text will be revised as noted in the comment.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 2.2.5 Pg. #: 2-4 Line #: NA Code: C
Original Comment #: 13
Comment: Recommend replacing the last sentence with the following: "Stabilization including seeding, matting, and other erosion control measures may be implemented as part of interim restoration."

Response: This section will be removed and text to be incorporated into project description.

Action: Section 2.2.5 will be removed and text will be incorporated into project description.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 3.1.1 Pg. #: 3-1 Line #: NA Code: C
Original Comment #: 14
Comment: The first paragraph in this section needs clarification. First, it states that "every effort will be made" to restore the site back to conditions prior to the construction of Fernald. The site is not actually being restored back to its original topography, considering all the reconstruction that's been done through excavation in order to reach the FRLs and from removing the contamination. Second, it states that "every effort will be made to reestablish original drainage patterns by restoring pre-site topography and elevations." Due to the numerous deviations taken during excavation and reconstruction, this has not been possible. Please correct the wording by removing the sentences that mention "restoring the site to its pre-site topography." In addition, make corrections so it will read and end on "original drainage patterns will be re-established." Obviously the goal is to re-establish drainage patterns and directions rather than original topography.

Response: Agree.

Action: Text will be clarified to state that goal will be to re-establish original drainage patterns utilizing the topography remaining after remediation is complete and not to restore pre-site topography.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 3.1.3 Pg. #: 3-2 Line #: NA Code: C
Original Comment #: 15
Comment: As this section (3.1) describes sitewide considerations, the available watershed for not only the production area, but all areas should be included (e.g., A1PI wetlands, enhanced wetland in the northern woodlot, where water budgets have been done; STP excavations, A8PIII wetland, A8PII wetland, etc., where anecdotal evidence of sufficient water for excavations remaining could be discussed).

Response: Agree.

Action: A paragraph will be added to Section 3.1.3 outlining available watershed considerations for other restoration areas across the site.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 3.1.4 Pg. #: 3-3 Line #: Last sentence Code: E
Original Comment #: 16
Comment: "...measures will designed and implemented." should read "...measures will be designed and implemented."

Response: Agree.

Action: Text will be revised as noted in comment.

Commenting Organization: Ohio EPA Commentator: OFFO/DSW
Section #: 3.1.5 Pg. #: 3-4 Line #: NA Code: C
Original Comment #: 17
Comment: The limitation on the length of trails, boardwalks, number of interpretive signs, and overlooks should be reworded to reflect the concept that the NRTs believe these numbers to be appropriate but not limiting. Also include about 1 mile of improved trail and increase boardwalk to about 1 mile.

Response: The length of the trails and boardwalks can be increased as noted in the comment. But the agreed upon lengths must be finalized in order to define the requirements of the final natural resource settlement and to plan project funding in future years.

Action: The NRRP will be revised to increase the trail lengths as noted in the comment with the stipulation that these are not expected to increase in the future.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 3.1.5 Pg. #: 3-5 Line #: NA Code: C
Original Comment #: 18
Comment: Replace the first sentence in the last paragraph of this section with that provided in the comment above regarding the proposed education facility.

Response: Agree.

Action: The paragraph outlined in Comment No. 10 will added to the end of Section 3.1.5.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 3.1.6 Pg. #: 3-5 Line #: NA Code: C
Original Comment #: 19

Comment: There is no mention of testing the soil for pH, however pH is discussed throughout the document. Shouldn't pH be included with the other soil tests listed here?

Response: Agree.

Action: The inclusion of pH testing as part of the soil analysis described in this section will added to the text.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 3.1.8 Pg. #: 3-6 Line #: NA Code: C
Original Comment #: 20

Comment: The trustees agreed that long-term maintenance and monitoring could be conducted under stewardship. We did not, however, agree it was outside the scope of this document nor that DOE would be the sole decision maker. This section and all subsequent ones referring to monitoring as "outside the scope" should be revised to include a brief discussion of long-term maintenance and monitoring. The Site Stewardship Plan, in which DOE plans to address long-term monitoring and maintenance, must be a submittal for approval under the NRRP. Include date for submittal within the NRRP long-term maintenance and monitoring will need to be addressed to finalize settlement.

Response: All required implementation and functional monitoring during restoration will be included in the NRRP and the final natural resource settlement agreement(s). Clarification will be provided in the NRRP that monitoring during restoration is within the scope of the plan and the schedule for implementation will be added to the document. Stewardship planning will address decisions regarding any long-term monitoring. All commitments to reach final settlement will be included in the NRRP.

Action: The NRRP will be revised to include all requirements for implementation and functional monitoring in restored areas in order to finalize settlement.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 3.2.1 Pg. #: 3-7 Line #: NA Code: C
Original Comment #: 21

Comment: This section appears to deviate from previous practices of looking at trees and shrubs based upon the contribution to wildife in terms of cover, diversity and forage. These classifications were utilized in the prior projects within A1PI and A8PII. The evaluation of woody stock based upon successional stage appears to be a change. Additionally, Ohio EPA was under the impression that we were going to utilize existing templates from A8PII and A1PI to the extent practical and reasonable in future projects. Neither of these projects utilized species such as black locust and honey locust.

Response: This section was not intended to suggest a deviation from previous practices of designing projects with a focus on contribution to wildlife or to propose the use of templates other than those used in A8PII and A1PI. The templates used in previous restoration work will be used in the future with some minor changes in individual species.

Action: Text will be clarified to eliminate suggestion that we are deviating from past practices as noted in the response. Table 3-1 will also be revised to include a column showing contribution to wildlife habitat.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 3.2.3 Pg. #: 3-8 Line #: NA Code: C
Original Comment #: 22
Comment: Please include within the first paragraph reference to the original Crosby Township land survey which documents numerous small prairies in the area.

Response: Agree.

Action: Reference will added as suggested in comment.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 3.2.3 Pg. #: 3-8 Line #: NA Code: C
Original Comment #: 23
Comment: The reference to specific grasses and seed rates within the text is probably not appropriate. These are subject to change based upon our adaptive management approach. If specific references are needed then attachment of the site seeding spec for upland and wetland areas would be appropriate along with caveats that changes are possible. The reference to interseeding of forbs is confusing relative to standard site practice. It might be best to include a list of species of forbs/grasses/sedges currently used as appropriate on site.

Response: Agree.

Action: Text on specific grasses and seed rates will be removed from the text of Section 3.2.3. Tables will be added to providing a listing of grass species to be used in restoration.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: Table 3-1 Pg. #: NA Line #: NA Code: C
Original Comment #: 24
Comment: See previous comment regarding the classification of woody species. Is this a comprehensive list of species proposed for usage? Some species that have not previously been used are included (black locust) and some species used are not included (prickly ash). Please clarify.

Response: Table 3-1 is intended to be a comprehensive list of woody species to be used on restoration projects at the FEMP. The table will be revised to reflect only species agreed upon by the NRTs.

Action: Table 3-1 will be revised as noted above.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.0 Pg. #: 7 of 7 Line #: NA Code: C
Original Comment #: 25
Comment: The footnote for UPL states obligate wetland. Please revise.

Response: Table 3-1 will be revised as noted in Comment No. 24 and, therefore, the designations in the footnotes will no longer be necessary.

Action: Table 3-1 will be revised as noted in the action to Comment No. 24.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.0 Pg. #: Figures Line #: NA Code: E
Original Comment #: 26
Comment: Suggest placing Figures 4-1 and 4-4 adjacent to one another to make it easier to compare what has been done and what will be done (e.g., moving 4-4 to 4-2). Note that in the text Figure 4-4 is the second figure listed and should be renamed to 4-2.

Response: Figures 4-1 and 4-4 will be included together at the end of Section 4.0.

Action: No action.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.1 Pg. #: NA Line #: NA Code: C
Original Comment #: 27
Comment: Recommend formatting each of the descriptions in this section the same as those in Section 4.2, that is included subsections describing the restoration objective, required construction activities, planting and special features, and monitoring and maintenance. In particular, include a monitoring and maintenance section for 4.1.1.

Response: The formatting of the restoration projects completed to date (Section 4.1) is different than future restoration projects (Section 4.2) due to the differences in describing projects already designed and completed versus projects that have not yet been designed. There is a need for more detail to document planned activities Section 4.2 so that all commitments can be documented for future design work. Projects already complete have existing NRRDPs, and project completion reports and monitoring reports to document details of the projects. DOE proposes to leave format as is to help distinguish between completed versus planned projects.

Action: No action.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.1.2 Pg. #: 4-1 Line #: NA Code: C
Original Comment #: 28
Comment: Please revise the reference from 10 acres of required mitigation to 11 acres. This change was made some time ago as a result of the Trap Range remediation.

Response: Agree.

Action: Text will be revised as noted.
Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.1.2 Pg. #: 4-2 Line #: NA Code: C
Original Comment #: 29
Comment: This paragraph should include in A1PI's construction description, along with the topsoil and supplemental sludge/wood chips, the different amendments used in each individual basin.

Response: Agree.

Action: Information on the soil amendments used in each basin will be added to Section 4.1.2.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.1.2 Pg. #: 4-2 Line #: NA Code: C
Original Comment #: 30
Comment: It is explained in this section that various wildlife habitats' were included in A1P1's construction. However, no examples of a habitat or structures are provided which is also noted throughout the document. It would be clearer, if a few examples could be provided here and other sections of the text.

Response: Agree.

Action: Examples of wildlife structures will be included in the description of each restoration project in Section 4.2.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.1.3 Pg. #: 4-3 Line #: NA Code: C
Original Comment #: 31
Comment: In the first paragraph of this section, it's stated that the flood storage capacity of Paddys Run may be increased, yet it didn't seem as though this was done during the construction of this project. It appears as though some of this text came from an earlier document and is no longer relevant. Suggest deleting this sentence and revising section to reflect what occurred (e.g., in the third paragraph, it is stated that the drainage channels lead to a small basin when in fact there are now two basins.)

Response: Agree.

Action: The text in Section 4.1.3 will be revised to accurately reflect the results of the completed project.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.1.3 Pg. #: 4-3 Line #: 3rd paragraph Code: C
Original Comment #: 32
Comment: Does the drainage from the material handling area feed both basins? Perhaps "basin" should read "basins." The last sentence of this paragraph appears as though it should be in the previous section describing the riparian corridor.

Response: Agree.

Action: Text will be revised as noted in the comment.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.1.3 Pg. #: General Line #: NA Code: C
Original Comment #: 33
Comment: There is a discussion of the planting of grasses for the savanna but not for the other prairie areas. Include the planting of grasses and forbs in other areas.

Response: Agree.

Action: Section 4.0 of the NRRP will be revised to include seeding as appropriate in all restoration projects.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.1 Pg. #: 4-6 Line #: NA Code: C
Original Comment #: 34
Comment: Reference is made to the installation of standard outfall structures, however outfall structures consistent with the restoration goals of maintaining a more natural environment (coir and/or jute matting interplanted heavily with native vegetation) would be preferred over concrete and/or stone structures where control of water levels are not needed. However, where control of water levels would be desirable, structures suitable for such control, but as unobtrusive as practical are desirable (e.g., the structure used at the Southdown constructed wetland in which removable stops are placed under ground but remain easily accessible).

Response: Agree.

Action: Text will be revised to emphasize the use of bioengineering techniques for outfall and drainage features to the degree practicable.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.1 Pg. #: 4-6 Line #: NA Code: C
Original Comment #: 35
Comment: The second paragraph discusses restoration of the contingency borrow area. Which area is being referenced here? It is not included on the Figure 4-5.

Response: The reference to the Contingency Borrow Area is outdated and should be removed.

Action: The sentence referenced in the comment will be removed from the NRRP.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.1 Pg. #: 4-6 Line #: NA Code: C
Original Comment #: 36
Comment: Next to last paragraph. The sentence describing the Carolina Area confuses the paragraph. Possible revision would be to move the Carolina Area discussion to the construction section and discuss what has been completed along with proposed future actions in the area.

Response: Agree.

Action: Text in Section 4.2.1 will be revised to more clearly reflect restoration plans for the area.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.2 Pg. #: 4-7 Line #: NA Code: C
Original Comment #: 37
Comment: A figure is needed to delineate each of these specific areas discussed, the Northern Pine Plantation Enhancement, the Northern Woodlot, and the Wetland Mitigation Plan II.

Response: Agree.

Action: A figure will be added to the NRRP to clearly identify each portion of the Northern Woodlot Restoration Project.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.2.1 Pg. #: 4-8 Line #: NA Code: C
Original Comment #: 38
Comment: This section should include a reference to the concept of maintaining a tree free buffer around the OSDF to limit migration of seeds onto the cell. Also this section only references the use of seedlings and not other size woody plants. The section should be revised to be consistent with the SOW and include a discussion of saplings, shrubs and seedlings.

Response: Agree.

Action: This section will be updated to include reference to the goal of maintaining a tree free buffer around the On-Site Disposal Facility (OSDF). The text will also be clarified regarding the use of saplings, shrubs and seedlings.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.2 Pg. #: 4-8 Line #: NA Code: C
Original Comment #: 39
Comment: Ohio EPA was under the impression this work was expected to be completed substantially before 2004. Please clarify.

Response: Depending on funding, chipping of the Northern Pines may be accelerated in 2002. Planting activities would only be accelerated if funding permits in 2002 or 2003. The current schedule is based on the planned availability of site funding as outlined in the Closure Plan Baseline.

Action: Accelerate chipping in the Northern Pines in 2002 if funding permits.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.2.1 Pg. #: 4-8 Line #: NA Code: C
Original Comment #: 40
Comment: The proposed clearing seems substantially less than that discussed in meetings between the NRTs. Additional confusion comes from the fact that the SOW states that 60-80% of the pines will be removed while the Northern Pine Conceptual Design Response to Comments suggest 40% removal. The figure included in the Conceptual Design is significantly different from that provided in the NRRP. As stated in Ohio EPA's comments on both documents we believe a majority of the pines should be removed leaving islands of trees as winter cover. The NRRP figure leaves behind significant numbers of the infected and dying Norway Spruce trees. Ohio EPA was under the impression all these would be removed. This is obviously a subject of necessary early and clearer communication since we understand DOE plans to initiate pine removal yet this calendar year.

Response: The appropriate acreage to be cleared in the Northern Pine Plantation was the subject of discussion at numerous NRT meetings. The conceptual design for the Northern Pines Restoration Project submitted November 20, 2000 proposed the chipping of 40% of the pine plantation. Comment responses submitted to the NRTs on April 18, 2001 and

approved by OEPA on May 21, 2001 finalized the agreement on this point. The current plan is to chip 40% of both Pine Plantations. The plan, as discussed in past meetings, was to leave islands of pines to provide winter cover and dead trees as snags for habitat. The idea of plant dense shrub patches within existing trees along the edges of the pine plantations was also discussed as part of the design to minimize the establishment of invasives.

Action: No action.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.2.1 Pg. #: 4-8 Line #: NA Code: C
Original Comment #: 41
Comment: Reference is made to the stockpiling of organic material for later use. Any stockpiles must be located and managed in a manner such that organic runoff from the piles does not degrade water quality.

Response: Agree.

Action: Any wood chip stockpile created will be managed appropriately to minimize impacts to water quality and the risk of fire. Text will be added to Section 4.2.2.1 to clarify this point.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.2.2 Pg. #: 4-10 Line #: NA Code: C
Original Comment #: 42
Comment: A number of places in the document discuss planting of prairie grasses along with reforestation work etc. In order to clarify future management issues and objectives, it is recommended that we use two different terminologies in the NRRP. When we refer to planting a "prairie" or "savanna", it is an area we intend to keep in this state and move to a stable ecosystem type including a diversity of plant and associated animal species associated with a praire/savanna. When we refer planting "upland grasses", it is an area we intend to let move in a successional trajectory toward forest or other habitat type. In these areas management and objectives would not be for prairie-associated diversity and animals but the objective of obtaining forest cover would be foremost. The goal of planting "upland grasses" would be to replace alien grasses and to provide soil cover and forage while establishing upland or riparian forests. This is proposed wording to allow the trustees and others to better set objectives for our specific restoration areas and to focus on the appropriate objectives and actions for each area. It would seem the plantings in the Northern Woodlot would be more along the "upland grasses" concept allowing the surrounding forests to naturally migrate into the meadow setting.

Response: The NRRP does identify seeding activities within the description of each restoration project. It is agreed that clarification is needed to distinguish between prairies and savannas that will be managed during restoration. Any decisions regarding long-term maintenance and management will be made as part of Stewardship planning for the FEMP.

Action: A discussion will be added to Section 3.2.3 to clarify the planned management of prairies. A figure will be also be added to Section 3.0 of the NRRP to further clarify this point.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.2.2 Pg. #: 4-10 Line #: NA Code: C
Original Comment #: 43

Comment: The statement is made that part of this project will contribute to the required restoration of the Great Miami River, but it is not clear how. Please explain.

Response: The general description of each restoration project includes a reference back to the NRIA to identify the specific impact that the restoration project is intended to compensate for. The acres restored in the Northern Woodlot will compensate for the Great Miami River impacts identified in the NRIA.

Action: No action.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.2.2 Pg. #: 4-10 Line #: NA Code: C
Original Comment #: 44

Comment: Construction Activities. At one point we had discussed taking actions to back water up into the woodlot allowing for expansion of the wetland area there. It is unclear where this action falls within the document or if it has been dropped. It would seem with a little effort along the site fence boundary, we could substantially increase the area of inundation in the Northern Woodlot and subsequently expand this wetland area.

Response: Consideration will be given to expanding the existing wetland acreage in the Northern Woodlot during design of the Wetland Mitigation – Phase II Project by reducing the rate of flow out of the area.

Action: Text will be added to Section 4.2.2.2 to clarify this goal of the project.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.2.2 Pg. #: 4-10 Line #: NA Code: C
Original Comment #: 45

Comment: Planting. It would seem appropriate to include shrub planting within the scope of this project. A significant effort will be required to remove the invasive understory in this area. It will be necessary to fill those niches with native species to reduce re-invasion. This should be considered in the final design for the area. A focused effort might be needed to at least provide a shrub seed source in the area while limiting the amount of deer management necessary.

Response: Shrub planting in the Northern Woodlot has not been discussed in past NRT meetings or proposed in past versions of the NRRP. The current plan for the restoration of the Northern Woodlot as outlined in the Closure Plan Baseline is to convert pasture areas to prairie and remove invasives to help accelerate ongoing succession of the woodlot.

Action: No action.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.2.3 Pg. #: 4-13 Line #: NA Code: C
Original Comment #: 46
Comment: Monitoring. In order to comply with wetland mitigation requirements a period of monitoring for 5 years needs to be conducted. A monitoring and reporting program similar to that for the A1PI wetland mitigation project is necessary. This will also be required in any other wetlands intended specifically to meet the 11 acres of mitigation wetlands.

Response: Agree.

Action: Monitoring requirements will be clarified in Section 4.2.2.3 and Section 5.0 of the NRRP.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.3.1 Pg. #: 4-15 Line #: NA Code: C
Original Comment #: 47
Comment: The SOW states that 60-80% of the pines will be removed. Please revise.

Response: See response to Comment No. 40.

Action: No action.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.3.1 Pg. #: 4-15 Line #: NA Code: C
Original Comment #: 48
Comment: See comment about stockpiles of organic material.

Response: Agree.

Action: See action statement in Comment No. 41.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.3.2 Pg. #: 4-16 Line #: NA Code: C
Original Comment #: 49
Comment: Is it possible to develop a figure to conceptually display the proposed areas of forest, prairie and savanna? This would help clarify the project.

Response: Figures 1-1 and 4-6 do identify area of prairie and savanna planned for area west of Paddys Run Stream. All other areas west of Paddys Run will be restored to Forests.

Action: Reference will be made to figures in the NRRP showing proposed prairie and savanna restoration west of Paddys Run.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.3.2 Pg. #: 4-16 Line #: NA Code: C
Original Comment #: 50
Comment: Although the document states that no excavation is expected, the area across from the Pilot Plant Drainage Ditch may need some excavation.

Response: Agree.

Action: Text will be added to Section 4.2.3.2 to identify the potential for excavation across from the Pilot Plant Drainage Ditch.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.3.2 Pg. #: 4-17, 4-18 Line #: NA Code: C
Original Comment #: 51
Comment: There are some springs in this area that have currently been "developed" for watering cattle. These areas should be considered special features that could be enhanced as wetland areas. Enhancement may require some grading as well as special planting considerations.

Response: Agree.

Action: Text will added to Section 4.2.3.2 to acknowledge that minor grading to enhance or create new wetland features may be implemented as opportunities allow.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.3.2 Pg. #: 4-17 Line #: NA Code: C
Original Comment #: 52
Comment: Why is this project delayed so late in the process? It would seem this is a project DOE could undertake early with minimal cost.

Response: The schedule of restoration projects has been developed based on the availability of site funding through the Closure Plan Baseline development process. The schedule in the NRRP reflects the schedule contained in the Closure Plan Baseline. Restoration work will be accelerated as site funding permits.

Action: No action.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.4 Pg. #: 4-19 Line #: NA Code: C
Original Comment #: 53
Comment: Based upon our success in previous wetland projects using plugged plants, the NRTs had agreed they would be good for all future wetland projects. The SOW discusses the use of plugs in the Borrow pit as well. Ohio EPA recommends the inclusion of plugged plants within the restoration approach for this area. Additionally, it is recommended that this plugging be completed prior to final restoration. Early installation of the plugs will help reduce invasive plants and thus lower maintenance requirements. Hopefully, plugs could be installed at the first appropriate planting season following the completion of interim restoration in a given borrow pit subarea.

Response: Agree.

Action: Text will be added to Section 4.2.4 to acknowledge the use of plant plugs in the Borrow Area. Text will also discuss the desire to accelerate planting in the Borrow Area as funding allows.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.4 Pg. #: 4-20 Line #: NA Code: E
Original Comment #: 54
Comment: "after planted" should read "after being planted."

Response: Agree.

Action: Text will be revised as noted.

Commenting Organization: Ohio EPA Commentator: OFFO/DSW
Section #: 4.2.4 Pg. #: 4-20 Line #: NA Code: C
Original Comment #: 55
Comment: Under "Monitoring and Maintenance", it should be made clear that the time frame for spraying shrubs and seedlings with deer repellants must be coordinated with the Deer Management Plan. Additionally, all maintenance sections should include reference to implementing actions called out in the Deer Management Plan.

Response: Agree.

Action: Text will be revised as noted in the comment.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.5 Pg. #: 4-20 Line #: NA Code: C
Original Comment #: 56
Comment: How will the apparent paradox of planting trees as a visual buffer but not as seed source to the OSDF be resolved? No figure was included with this section.

Response: It is agreed that the goals of visual buffer and minimizing seed source around the OSDF may be incompatible goals.

Action: The planting of trees and shrubs around the OSDF perimeter will be removed from the NRRP.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.6 Pg. #: 4-22 Line #: NA Code: E
Original Comment #: 57
Comment: "after planted" should read "after being planted."

Response: Agree.

Action: Text will be revised as noted.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.7.1 Pg. #: 4-23 Line #: NA Code: C
Original Comment #: 58
Comment: This is the only section that specifies the depth of the wood chip amendment and clay. Will different thicknesses be used in the other areas?

Response: In areas requiring soil amendment, a minimum of one inch of wood chips (or suitable alternative) will be used as a soil amendment.

Action: Text of the NRRP will be modified to clarify plan for soil amendment.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.7.1 Pg. #: 4-24 Line #: NA Code: E
Original Comment #: 59
Comment: "after planted" should read "after being planted."

Response: Agree.

Action: Text will be modified as noted.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.2.7.2 Pg. #: 4-25 Line #: NA Code: C
Original Comment #: 60
Comment: Will the side slopes here be graded to a 5:1 as in the production area?

Response: Interim restoration in the Production Area will be designed to achieve approximately 5:1 slopes for safety and slope stability.

Action: Text of Section 4.2.7.2 will be revised to clarify grading goal for Production Area.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.2.7.1 Pg. #: 4-25 Line #: NA Code: C
Original Comment #: 61
Comment: Include reference to the use of herbaceous plugs in the wetland plantings.

Response: Agree.

Action: Text will be modified as noted.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 4.3 Pg. #: 4-26 Line #: NA Code: C
Original Comment #: 62
Comment: Earlier this year the NRTs had discussed delaying projects due to DOE's expected budget shortfalls at that time. These shortfalls were not as expected however. The proposed schedules tend to back load projects creating a substantial workload at the end of the overall project. Ohio EPA believes that presents many problems for successful implementation and sufficient follow through to ensure success. Additionally, those discussions included the concept of early projects to start work such as pasture conversion, etc. This discussion is not included in the document. DOE should re-evaluate the schedule based upon the current view of remediation funding and schedule and propose appropriate revisions and detail including early projects.

Response: Agree.

Action: The NRRP will be revised to identify design schedules based on new projected funding levels.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 4.3 Pg. #: 4-26 Line #: NA Code: C
Original Comment #: 63

Comment: It does not seem necessary to delay submittal of NRRDPs. They could be submitted significantly before remediation is completed. It is prudent to avoid, as much as possible, delays in approval of the design as time for ordering and planting vegetation approach. It is understood that final implementation will be dependent on the final grading. Earlier of review of design plans with that understanding can expedite execution of the design at time of planting.

Response: The schedule for the development and submittal of the NRRDPs is timed so that a reasonable understanding of postremediaton conditions is available to support the design. It is anticipated that certain aspects of the NRRDPs can be outlined and agreed upon in conceptual design documents such as general planting approaches, conceptual drainage patterns, etc., ahead of the scheduled submittal dates. The proposed submittal dates were selected so that as much information as possible is available about postexcavation conditions, while still allowing adequate time for review and approval of the NRRDP.

Action: No action.

Commenting Organization: Ohio EPA Commentator: OFFO/DSW
Section #: 5.0 Pg. #: 5-1 Line #: NA Code: C
Original Comment #: 64

Comment: All monitoring requirements should be identified in the NRRP, even if some of those monitoring activities will be carried out after closures and be further delineated in the stewardship plan yet to be developed. Habitat monitoring will need to be carried out beyond "project completion" due to the majority of the restoration work not being completed much before "project completion." The current schedule proposed in the document puts the vast majority of restoration work finalized in the last two years of the project. This doesn't allow time for "Implementation Monitoring" much less "Functional Monitoring" prior to "project completion." Obviously this work will need to be carried forward into the stewardship phase of the site.

A date should be included for submittal of a Natural Resource Restoration Monitoring Plan. This plan would further detail the monitoring being conducted under the Implementation Monitoring and Habitat Functional Success Monitoring, including methods and data to be collected.

Response: All requirements and schedules regarding the monitoring of restored areas will be included in the NRRP. A summary of the methodology for restoration is also included in Section 5.0 of the NRRP. More detail on the methodology and monitoring results collected to date of all implementation and functional monitoring will be provided in the Consolidated Annual Restoration Monitoring Report (CARMR) that will be submitted to the NRTs and Agencies by December 15, 2001.

Action: DOE will submit the CARMR to the NRTs and Agencies by December 15, 2001.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 5.0 Pg. #: 5-1 Line #: NA Code: C
Original Comment #: 65

Comment: In order to better understand actions taken and required management, Ohio EPA recommends the development of project logbooks for each project. These books should include detail on construction (e.g., seeding mix/rate, amendments, dates, etc) and any management actions taken (e.g., mowing, re-seeding, water management, etc). This should help alleviate current confusion regarding seeding rates in areas and amendment types. A better tracking system is needed if we are to improve our construction and management efforts over time.

Response: Logbooks are kept for each restoration project and for all maintenance actions carried out in Restored Areas. Detailed information such on plant installation, timing of mowing, seeding rates, etc., is currently available. This practice will continue throughout restoration of the FEMP.

Action: Continue compilation of logbooks documenting project information and maintenance actions.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 5.0 Pg. #: 5-1 Line #: NA Code: C
Original Comment #: 66

Comment: Is it possible to have a table or tables showing the two phases of monitoring along with habitats and schedules?

Response: A table showing the planned monitoring schedule will be added to the NRRP.

Action: A table will be added to the NRRP with the planned monitoring schedule and habitat type.

Commenting Organization: Ohio EPA Commentator: OFFO/DSW
Section #: 7.0 Pg. #: 7-2 Line #: NA Code: C
Original Comment #: 67

Comment: The statement is made that DOE will work with the local communities during remedial design on establishing "Addendum D." Please include the name of the document in Addendum D here as well as in the table of contents. This paragraph and reference to a "remedial design" is confusing. Clarification is needed.

Response: Addendum D will not be included in the NRRDP.

Action: Text referencing to Addendum D will be removed from the NRRP.

Commenting Organization: Ohio EPA Commentator: DSW
Section #: 7.0 Pg. #: 7-2 Line #: NA Code: C
Original Comment #: 68

Comment: As noted above, monitoring beyond final closure needs to be identified in the NRRP. The potential for omission of additional monitoring in the long-term documents is exemplified in the bullets on this page where there is no identification of monitoring for any of the NRRP functions.

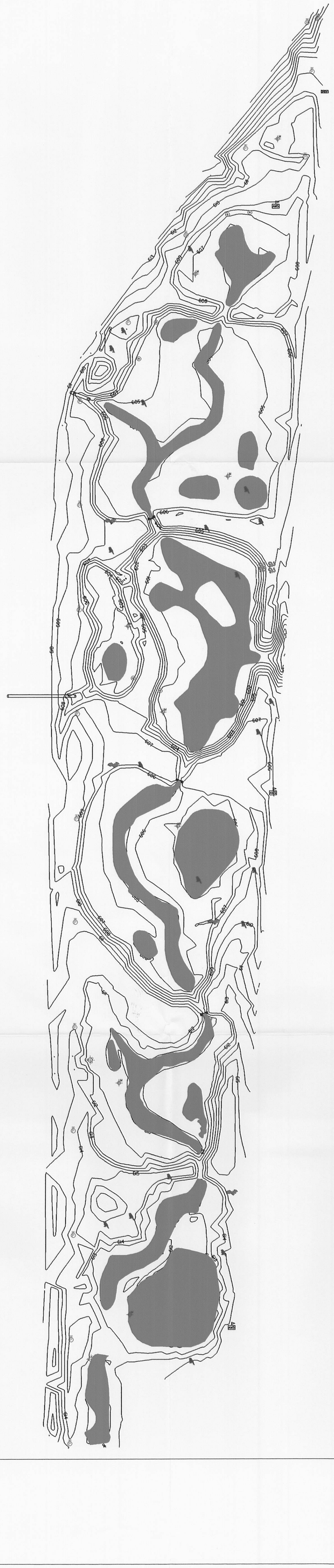
Response: Any decisions regarding the monitoring of restored areas will be addressed by Stewardship planning. Monitoring requirements outlined in the NRRP will be limited to those conducted during restoration of the FEMP.

Action: Include monitoring requirements in Section 7.0 of the NRRP to be carried out during restoration of the FEMP.

Commenting Organization: Ohio EPA Commentator: OFFO
Section #: 7.0 Pg. #: 7-2 Line #: NA Code: C
Original Comment #: 69
Comment: Inclusion of a conservation easement or similar restriction will need to be included as part of the final settlement document to ensure protection of the restored areas.

Response: Agree that the identification of proper restrictions to protect restored areas will need to be included as part of final settlement agreements.

Action: Identify restrictions as noted as part of final settlement agreements.



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Legend

- Bat House
- Bird House
- Snake Hole
- Telephone Pole
- Air Monitoring Station
- Well
- Ballard
- Concrete Weir
- Fence Post
- Circuit Box
- Culvert
- Basin Monitoring Well
- Pole Drain
- Pipe Invert

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FIGURE 4-2. WETLAND MITIGATION - PHASE I

STATE PLANAR COORDINATE SYSTEM 1983

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