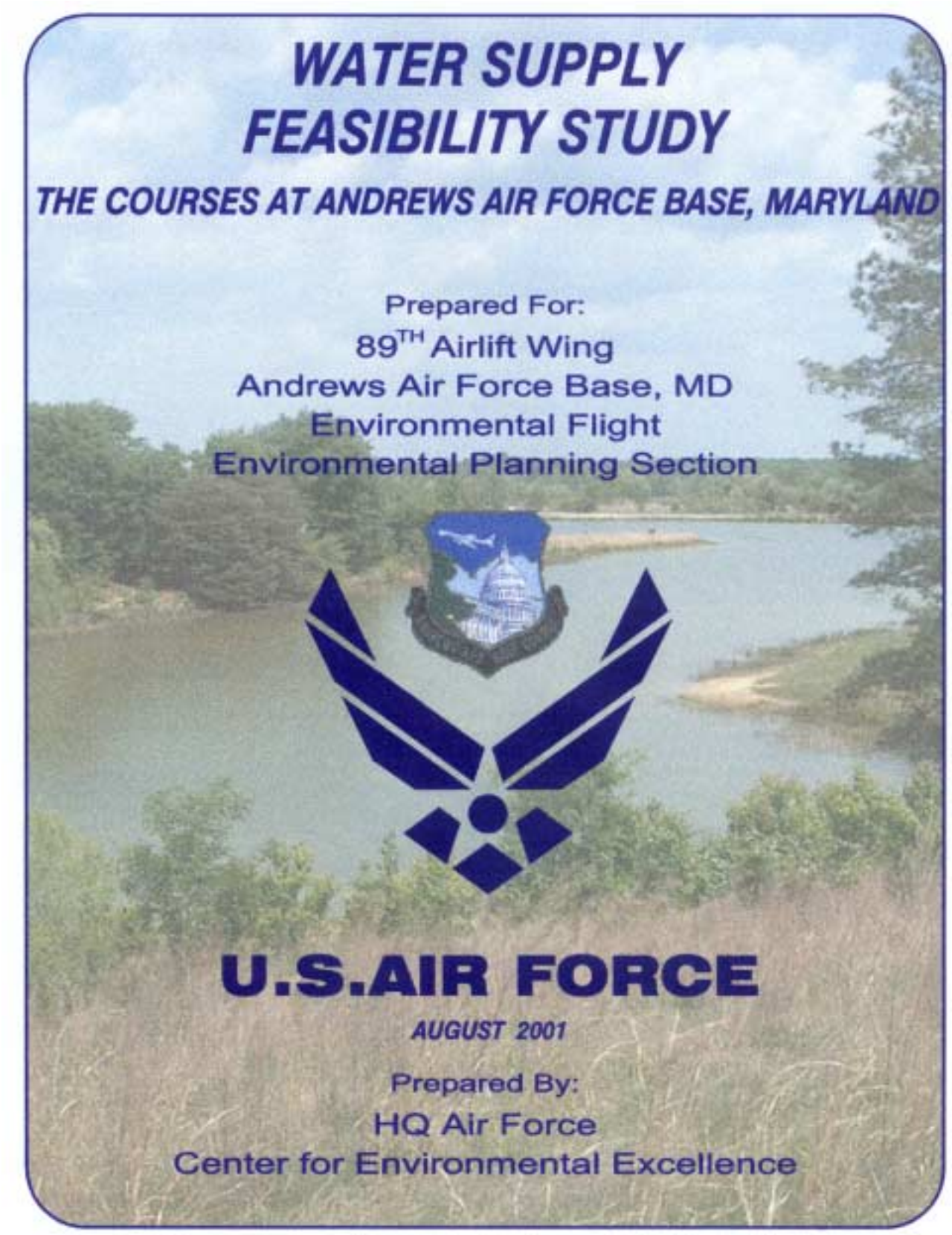

WATER SUPPLY
FEASIBILITY STUDY
THE COURSES AT ANDREWS AIR FORCE BASE, MARYLAND
Prepared For:
89TH Airlift Wing
Andrews Air Force Base, MD
Environmental Flight
Environmental Planning Section
U.S.AIR FORCE
AUGUST 2001
Prepared By:
HQ Air Force
Center for Environmental Excellence

# WATER SUPPLY
# FEASIBILITY STUDY
**for**
# GOLF COURSE IRRIGATION
**at**
# THE COURSES AT ANDREWS AIR FORCE BASE
# PRINCE GEORGES COUNTY, MARYLAND

**Department of the Air Force**
**Center for Environmental Excellence**
**BROOKS AIR FORCE BASE, TEXAS**

## TABLE OF CONTENTS

# 1.0 INTRODUCTION

The Courses at Andrews Air Force Base comprise a premier golf facility, less than 10 miles from the Pentagon (Figure 1). Located in the western portion of Prince George's County, Maryland, the facility includes three 18-hole golf courses, a practice area, and a clubhouse located entirely within Andrews Air Force Base (AFB) (Figure 2).

The Courses at Andrews AFB constructed an additional 18-hole golf course in 1997 to complement the two existing courses. The course construction project included the proposed development of a second storage and supply pond. Site limitations prohibited completion of this water source. As a result, the facility was left without additional irrigation supply.

## 1.1 Permits

Andrews AFB is currently permitted to irrigate the golf courses and practice areas using water from Base Lake under the Maryland Department of the Environment (MDE), Water Management Administration (WMA), Water Appropriation and Use Permit PG96G005/01. A well located adjacent to Base Lake withdraws water from the Magothy Formation and discharges into the lake under the Water Appropriation and Use Permit PG79G002/02.

## 1.2 Goals and Objectives

In order to adequately irrigate the golf courses a supplemental water supply needs to be developed. This Water Supply Feasibility Study (WSFS) was performed to assess alternative supplies and develop a work plan for irrigation source improvements for Andrews AFB. The goal is to identify the most cost-effective and reliable supply alternatives while providing the basis for an Environmental Assessment and required permits.

## 2.0 HYDROGEOLOGIC ANALYSES

The hydrogeologic analysis follows guidelines used by the MDE, provides the framework for source alternative selection, and evaluates groundwater and surface water resources in the Andrews AFB area.

### 2.1 General Hydrogeologic Framework

**Methods** - The groundwater/geologic analyses includes the following steps:

- Published and unpublished hydrogeologic reports and information pertinent to the project were reviewed and summarized.
- The subsurface stratigraphy and formations beneath the site were identified and local geologic formation materials were verified in the field.
- The driller's log, geophysical log, and well construction information for the existing supply well located adjacent to Base Lake were interpreted and compared to the published geology for the area.

Andrews AFB is entirely within the Coastal Plain physiographic province. The geologic formations of the Coastal Plain are inclined to the southeast at approximately one degree and thicken seaward. A generalized stratigraphy cross section illustrating the geology in the Andrews AFB area is shown in Figure 3. As shown, in the Andrews AFB area the total thickness of these sedimentary layers is approximately 1,300 feet (ft) (Hansen, 1972). The surface materials are Upland Deposits, comprised mainly of sand and gravel with minor amounts of silt and clay. These surficial deposits are underlain by various layers, of which the Magothy, Patapsco, and Patuxent Formations are the primary aquifers.

### 2.2 Shallow Aquifer

The Upland Deposits form a relatively shallow, unconfined aquifer zone underlying the Base Lake area. This shallow aquifer is recharged primarily by local precipitation that infiltrates

through the on-site soils. Base Lake is excavated into the top of this aquifer. As a result, drawing water out of Base Lake draws the lake level down and induces groundwater flow from this shallow aquifer. The amount of groundwater available in this way is proportional to the level of lake drawdown and can be greatly affected by natural, seasonal fluctuations in water table depth.

### 2.3 Deep Aquifers

The Magothy, Patapsco and Patuxent Formations each have the capability of providing significant quantities of water to a properly constructed well. The Patapsco and Patuxent both contain multiple aquifer zones. Each of these aquifers is located between clay layers. In general, these clays form upper and lower hydraulic boundaries through which there is little groundwater flow.

The estimated depths to the tops of the major aquifers beneath the site are as follows (Hanson, 1968 and existing well geophysical log):

- Magothy - approximately 300 ft
- Patapsco - approximately 400 ft
- Patuxent - approximately 900 ft

### 2.4 Surface Water Resources

**Methods** - The analyses of surface water resources included the following**:**

- Regional topography and drainage patterns were analyzed using United States Geological Survey (USGS) and site plan topography; significant hydrogeologic features such as watersheds, sub-watersheds and perennial streams were delineated; the area of the contributing watershed at Stormwater Outfall C on Piscataway Creek was obtained from the Andrews AFB Final Stormwater Management Plan, April 2001.

- The USGS gauging station for Piscataway Creek at Piscataway, Maryland provided the data for analyses of daily mean flow data for water years 1965 through 2000, using the Maryland Method.
- Monthly 85 percent exceedance flow rates for Piscataway Creek at Andrews AFB were calculated by watershed area proportionment, using a ratio of 6.4 percent, and the average monthly volume of water potentially available for use by Andrews AFB was estimated.

The Base Lake area is located within the Piscataway Creek watershed (USGS, 1993)(Figure 2). The headwaters of Piscataway Creek originate in the southern portion of Andrews AFB and flow nearly 12 miles to the Potomac River. Piscataway Creek itself is approximately 1,200 ft to the northeast of Base Lake. Stormwater Outfall C consists of a weir located in the creek just north of South Perimeter Road and has a drainage area of 1,610 acres, the largest catchment on Andrews AFB and the headwaters of Piscataway Creek. This area includes the airfield and other base structures, which results in a relatively high 35 percent imperviousness (USAF, 2001).

The monthly flows for Outfall C are analyzed in frequency distributions in Appendix A. The surface water available at Outfall C during normal conditions, allowing flow-by, is summarized in Table 4. As shown, the statistical monthly 85 percent exceedance flow rates vary considerably from zero gallons per day (gpd) in September to 1,235,000 gpd in March. Assuming the drought flows as flow-by, the monthly average volume of water potentially available ranges from 165,000 gpd in September to 947,000 gpd in March.

## 3.0 WATER SUPPLY REQUIREMENTS

The additional water supply requirements for the Courses at Andrews AFB are based on the turf irrigation needs and the supply already available. This provides the basis for the development of a work plan for making irrigation source improvements.

### 3.1 Irrigation Needs Analysis

The turf irrigation needs are estimated using the method required by the MDE.

**Methods** – The analyses included the following steps:

- The acreage of tees, greens, and fairways on each of the three courses along with the area of the practice facility, were estimated using the site plan and current aerial photography.
- The application rates required to irrigate the courses were determined using water management guidelines established by the MDE for various turf types and irrigation systems.
- An appropriate factor was used to account for overspray (based on single- or double-row layouts), to estimate the actual area being irrigated.
- Each course surface area (tees, greens, fairways, and practice facility) was multiplied by applicable irrigation rates to determine the usage rates on an average annual basis and during the month of maximum use.

Table 1 lists the areas of tees, greens, and fairways for each of the three courses. The area of the practice facility was added to the fairway areas since they are typically irrigated at the same rate. The overspray factors are based on the irrigation spray-head layouts for each course and are consistent with MDE guidelines.

The total irrigation rates for the courses represent daily averages over the year and during the month of maximum use. As shown, the total irrigation need for the course is about 190,000 gpd as an annual average, and about 748,000 gpd during the month of maximum use.

### 3.2 Flow-Mass Analyses

The Courses at Andrews AFB are currently permitted to use water from two sources. Base Lake, which is groundwater fed from shallow sediments, and an irrigation well adjacent to the lake that withdraws water from the Magothy aquifer. These two sources are not hydraulically capable of meeting the total irrigation demand established in Section 3.1. Flow-mass analyses were performed to determine the additional supply required to adequately irrigate the facility during both normal and drought conditions.

Flow-mass analyses account for all water entering and exiting the storage facility (Base Lake) through natural and engineered means. The inputs to Base Lake include direct precipitation, groundwater pumping (well), groundwater infiltration (due to pond drawdown), and storm water runoff. The outputs include irrigation and evaporation.

**Methods** – The flow-mass analyses include the following steps:

- Average monthly evaporation rates during normal (50 percent exceedance) and drought conditions (85 percent exceedance) are determined using frequency analyses of monthly pan evaporation rates recorded at the Beltsville, Maryland weather observation station during the period of 1960 through 1999 and obtained from the National Climatic Data Center; these rates are applied to the surface area of Base Lake to account for evaporative losses (January, February, and December evaporation rates were estimated).

- Average monthly precipitation rates during normal and drought conditions are determined using frequency analyses of daily precipitation amounts recorded at the Beltsville, Maryland weather observation station during the period of 1960 through 1999 and obtained from the National Climatic Data Center; these rates are applied to the surface area of Base Lake to account for supply from direct precipitation.

- The volume of water held by Base Lake was determined by actual depth measurements (bathymetric study) and by digital surface area analyses; to protect the aquatic habitat in the lake, reduce potential environmental effects, minimize bank erosion, and avoid

impacting the multi-purpose recreational uses of the lake, a maximum one-half foot drawdown of the lake is assumed.

- The existing well is conservatively assumed to provide the permitted volume (38,325,000 gallons), distributed across the irrigation season based on 1997 through 2000 pumping records (actual use has been less—the reported annual use during the 1997 through 2000 seasons averaged approximately 28,500,000 gallons).
- Groundwater infiltration from the shallow aquifer into the lake is estimated by taking a third of the difference between the monthly total irrigation amounts and the well withdrawals reported during the period 1997 through 2000.
- Normal and drought-level monthly storm water runoff rates are based on a 27-acre watershed (excluding lake area), type B soils, weighted runoff curve number that equals 62.4, and the assumption that runoff occurs during and/or after precipitation events equal to or greater than 0.5 inches. Of this, the actual volume stored is based on estimated lake stage/storage capacity.
- The irrigation needs (Section 3.1) are distributed across the growing season, varying from zero percent of the annual use between December and March up to 33 percent of the annual use in July on a sliding scale which parallels evapo-transpiration rates and 1997-2000 irrigation records.
- The total volume of water required from supplemental sources is calculated on a monthly and annual basis for both normal and drought conditions.

Tables 2 and 3 summarize the monthly volumes of water lost, gained, and required to irrigate the golf courses and maintain lake water levels during normal and drought conditions, respectively.

- During normal conditions, Base Lake receives approximately 42.1 inches of precipitation and loses approximately 50.5 inches of water due to evaporation annually. During drought conditions, these amounts are approximately 16.8 and 60.4 inches, respectively.

- The surface area of Base Lake at full capacity is approximately 17-acres; therefore, one half foot of usable lake storage is equivalent to approximately 2 million gallons of water.
- The monthly groundwater infiltration rates vary between 0 and 510,000 gallons, with the highest infiltration occurring during the summer months when the lake water level is drawn down.
- During normal conditions, the monthly storm water runoff in the Base Lake area varies between 308,000 and 743,000 gallons with total annual runoff of nearly 6.9 million gallons. Stormwater runoff during drought conditions contributes approximately 2.7 million gallons annually to Base Lake.

The estimated average annual deficit of 103,000 gpd (37.5 million gallons) is shown on Table 2 and the month of maximum use deficit of approximately 649,000 gpd is shown on Table 3. The identification, development, and permitting of a supplemental source(s) capable of producing these volumes of water is necessary in order to adequately irrigate the golf course and maintain Base Lake water levels during normal and drought conditions.

## 4.0 INVENTORY OF OTHER USERS

The inventory provides information critical to assessment of the potential impacts to other wells and groundwater users and surface water users in the area. It also facilitates planning of a test well location, target depth(s), and the identification of potential monitoring points.

**Methods -** The well inventory work consisted of the following steps:

- A database query of MDE-Water Management Administration files for all wells and water appropriation permits within 10,000 ft and 25,000 ft of Base Lake, respectively, was requested and reviewed.
- Current digital aerial photography (Y2000) covering the region was examined and compared to the query results.
- A field reconnaissance included wellhead inspections, and interview of owners (where available) for wells within 2,000 ft of Base Lake (exceeds the MDE requirement to identify all wells within 1,500 ft of a potential source location).

### 4.1 Other Wells

No water supply wells were found within 2,000 ft of Base Lake with the exception of the existing course irrigation well. The MDE well database query resulted in no water supply wells and approximately 22 ‘test’ wells (all less than 50 ft deep) within 2,000 ft of Base Lake (MDE, 2001a). The MDE defines ‘test’ wells as test, observation, or monitoring wells. Typically, ‘test’ wells are associated with environmental investigations, and most of the queried wells are on Andrews AFB itself.

### 4.2 Other Users

According to the MDE appropriation and use permit database search, there are no other appropriation permits within one mile of Base Lake (MDE, 2001b)(Figure 4). Three appropriation permits are located within 1 to 2 miles of Base Lake; however, these permits are

for groundwater remediation systems that withdrawal from the shallow aquifer. The largest nearby user is the Norbourne Mobile Home Court, located approximately 2.8 miles northeast of Base Lake, which is appropriated for an annual average of 10,000 gpd from the Magothy Aquifer. No other users within three miles of Base Lake are permitted for greater than 10,000 gpd on an annual average basis.

## 5.0 WATER SOURCE ALTERNATIVES

Based on the levels of irrigation pumping required and the number of sprinkler heads on the courses, a peak pumping capacity of approximately 1 million gallons per day (mgd) is required. Based on the acreages of tees, greens, and fairways using irrigation application rates developed for this region, the estimated average daily demand during the course of an irrigation season is approximately 190,000 gpd, with peak monthly averages of up to approximately 750,000 gpd. In order to adequately irrigate the course and maintain Base Lake, an annual average of approximately 100,000 gpd and maximum month use of 750,000 gpd is required.

**Use of groundwater from the Patuxent Formation –** Andrews AFB is located in the Coastal Plain physiographic province. The geologic formations of the Coastal Plain are inclined to the southeast at approximately one degree and thicken seaward. In the Andrews AFB area the total thickness of these sedimentary layers is approximately 1,000 ft (Hansen, 1972). The Patuxent aquifer of the Coastal Plain has the capability of providing significant quantities of water to a properly constructed well. Based on geologic logs of other wells in the region the Patuxent aquifer is located approximately 600 to 1,000 ft below the ground surface, beneath multiple confining clay layers. It is a multi-layer aquifer that consists of interbedded clay, silt, sand, and gravel. The Patuxent is the deepest of the Coastal Plain aquifers.

This alternative requires a Maryland Department of the Environment (MDE), Water Appropriation and Use Permit and Well Construction Permit, Prince George's County Well Permit, and modification to Prince George's County Water and Sewer Master Plan. The well would be drilled, geophysically logged, constructed, and developed in the Patuxent Aquifer. Drilling fluids will be contained in a mud pit located within 100 ft of the well site. An appropriate pump would be selected and installed in the well with the groundwater discharged to Base Lake.

**Use of Groundwater from the Patapsco Formation** - The Patapsco Formation of the Coastal Plain physiographic province is also a multi-layer aquifer consisting of interbedded clay, silt, sand, and gravel. In the western Prince George's County region the Patapsco aquifer is located

approximately 400 to 800 ft below the ground surface. This aquifer has the capability of providing significant quantities of water to a properly constructed well.

This alternative would require a Maryland Department of the Environment, Water Appropriation and Use Permit and a Prince George's County Well Permit would be obtained. A well would be located adjacent to Base Lake near the existing pumping stations. The well would be drilled, geophysically logged, constructed, and developed in the Patapsco Aquifer. The drilling fluids would be contained in a mud pit located within 100 ft of the well. An appropriate pump would be selected and installed in the well with the groundwater discharged to Base Lake.

**Use of Groundwater from the Magothy Formation -** The Magothy Formation of the Coastal Plain physiographic province consists of medium to coarse-grained sand and fine gravel interbedded with silt and clay. In the Andrews AFB area the Magothy aquifer is located within 300 ft of the ground surface. The existing golf course irrigation well currently withdraws approximately 165 gpm of groundwater from this aquifer.

This alternative would require a Maryland Department of the Environment, Water Appropriation and Use Permit and a Prince George's County Well Permit would be obtained. A well would be located adjacent to Base Lake near the existing pumping stations. The well would be drilled, geophysically logged, constructed, and developed in the Magothy Aquifer. The drilling fluids would be contained in a mud pit located within 100 ft of the well. An appropriate pump would be selected and installed in the well with the groundwater discharged to Base Lake.

**Increasing the Yield of the Existing Well** - According to available information, the existing well located on the northwest side of Base Lake was drilled around 1978, is screened in the Magothy aquifer, and had an initial yield of approximately 190 gallons per minute. Currently the well is being pumped at a rate of approximately 165 gpm. No information is readily available regarding the age of the existing submersible pump or if the well has been rehabilitated since construction. Over time the efficiency (and yield) of many screened wells will decrease due to chemical incrustation, biofouling, and/or collapse of well screen, formation plugging

adjacent to the well, pump impeller and or shaft deterioration due to pumping sand, or lower water table.

In many cases, the efficiency of a well can be restored using various methods depending on the condition diagnosed. Likewise, a pump replacement can allow higher rates of pumping if the decrease in yield is only mechanical.

**Lateral Expansion of Base Lake -** The existing Base Lake covers approximately 17 acres and has a maximum depth of 12 ft based on a June 2001 bathymetric study. Due to the multi-purpose recreational uses of the lake and for aesthetic reasons, withdrawals for course irrigation are carefully managed in order to maintain the water level within a few ft of full capacity. The usable storage volume of the lake is therefore approximately 12 million gallons (50 percent of lake capacity). Therefore, the lateral expansion of the lake would create additional surface area and an equivalent increase in the usable storage volume. Assuming a 60-day supply is required, approximately 300,000 cubic yards of material would need to be removed, affecting about 50 acres of land.

This alternative would be accomplished by dredging and excavation in selected areas of the lake. The water level in Base Lake would likely be lowered significantly during expansion to facilitate removal of material. A spoils site, likely the former borrow pits to the south, would receive the removed materials.

**Deepening of Base Lake** - Based on SAIC's bathymetric study the maximum depth of the lake is 12 ft. The capacity of the lake is estimated to be 24 million gallons. The deepening of the Base Lake would increase the storage capacity of the lake without affecting the existing land use surrounding the lake. To use this storage, however, the lake would be routinely drawn down more than is allowable in current operations. This alternative would likely require the complete draining of Base Lake to allow for the dredging and removal of material.

**Use of Borrow Pits as a Seasonal Groundwater Supply** - Two former sand and gravel borrow pits exist within 1,000 ft of Base Lake. The pits currently have standing water up to six ft deep and are groundwater fed. There is little surface water inflow or recharge area to these ponds. However, the permeable nature of the sand and gravel aquifer, which they intercept, may allow groundwater influx in significant quantities. The seasonal shallow water table fluctuations on site would, however, limit the reliable supply from this source. The viability of this option is uncertain and may be retained for further study.

This alternative would involve connecting the two pits with a buried pipe (approximately 100 ft long by 6 inches in diameter. This system would render the bottom of the borrow pits essentially dry during the growing season. A low head pumping system would be installed in a dewatering sump in the deepest portion of the borrow pit and water would be discharged to Base Lake via buried pipe.

**Use of Piscataway Creek as a Surface Water Supply** - The headwaters of Piscataway Creek are located approximately 1,200 ft to the northeast of Base Lake. Stormwater Outfall C consists of a weir located in the creek just north of South Perimeter Road and has a drainage area of 1,610 acres, the largest catchment on Andrews AFB. A significant quantity of water may be available at this location during and subsequent to precipitation events due to the 35% impervious area within the drainage basin (Whitman, Requardt and Associates, LLP, April 2001, Andrews AFB Final Stormwater Management Plan).

This alternative would require the installation of an underground pipe to hydraulically connect the two borrow pits. A low head pumping system would be installed in the deepest portion of the borrow pits. Pumped water would be discharged to Base Lake via aboveground pipe.

**Re-route Storm Water Flow** - An irrigation pond was planned along South Perimeter Road, to be installed in parallel with new course construction. This area is underlain by a clay cap and now forms a depression. This area receives runoff from local fairway areas and ponds during rainfall events. Discharge is routed through a pipe beneath a landscaped portion of the course, which daylights along South Perimeter Road. Runoff flows through this ditch until it reaches a

36-inch-diameter pipe culvert beneath a cart path and flows towards the access road to Base Lake. Before reaching the access road, an approximate 12-inch diameter pipe receives a portion of the storm flow; the remainder runs over land and across Base Lake Road.

This supply option would involve re-routing the runoff from the pond area through an improved grassed swale, beneath the existing cart part, and into a pipe and/or culvert routed to Base Lake. The diameter and size of the culvert or pipe would be commensurate with anticipated storm flows such that no ponding or backwaters would occur. This supply would be viable at any time when there is enough rainfall to create runoff in the catchment.

**Waste Water Reuse -** The facilities at Andrews AFB generate considerable wastewater flows. Wastewater reuse has been used successfully in many areas of the country for non-potable water supplies. Wastewater at Andrews AFB is currently routed to pumping stations throughout the base, which transmit waste flows into the Washington Suburban Sanitary Commission (WSSC) collection system, eventually reaching the Blue Plains Wastewater Treatment Plant.

Reuse of a portion of these waste flows at Andrews AFB would involve construction of a wastewater treatment plant on site. This would include primary and secondary treatment as well as tertiary treatment systems. Such a plant would likely be located and permitted on Piscataway Creek, with the discharge routed to Base Lake.

**Connection to Existing Water System** - This alternative would use potable water for irrigation. The connection to the potable water supply would be constructed and metered by WSSC, probably through an “agricultural” connection with a discharge pipe directly to Base Lake.

## 6.0 WORK PLAN

In accordance with the findings of this study, there is a significant water supply deficit at the Courses at Andrews AFB. Few of the alternatives studied could provide the amount of water needed alone or provide water management flexibility or safety back-up supply. Some of the alternatives provide added environmental benefits and reduce the impacts of single options. This study recommends the combination of a well completed in the Patapsco Formation, use of stormflow from Piscataway Creek, and capture of stormwater on the course itself.

### 6.1 Development of a Well in the Patapsco Formation

This proposed action will require a MDE, Water Appropriation and Use Permit and Well Construction Permit, Prince George's County Well Permit, and modification to Prince George's County Water and Sewer Master Plan. The well will be drilled, geophysically logged, constructed, and developed in the Patapsco Aquifer. An appropriate pump will be selected and installed in the well with the groundwater discharged to Base Lake.

**Test Well Drilling and Construction** – A test well will be drilled in the open area between East Course hole 9 and South Course hole 4, (Figure 5). The drilling and construction procedure will include the following:

- Approximately 50 ft of large-diameter surface casing will be set and a 10-inch diameter test hole will be drilled approximately 620 ft by mud-rotary methods into the Patapsco Formation.
- The well cuttings will be sampled during drilling every ten ft and geologically described.
- The test well will be geophysically logged, using natural gamma, spontaneous potential, and resistivity tools.
- The test well will be reamed to a 15- to 16-inch diameter and 10-inch diameter steel casing will be installed to approximately 400 ft.

- Approximately 80 ft of 6-inch diameter stainless steel screen and 120 ft of 6-inch steel pipe will be installed and gravel-packed at various depths between approximately 400 and 600 ft based on the logging results.
- The well screen will be developed by a combination of airlift and water jetting until an efficiency of at least 75% is achieved.

**Test Pumping** - Testing will be done in accordance with MDE requirements, and will include the following:

- Continuously recording water level monitoring devices will be installed in the test well and the existing water supply well. Other wells identified during the well inventory process may be monitored pending access.
- The well will be test-pumped by step-drawdown methods to assess maximum pumping rates and efficiencies.
- A 24-hour constant-rate-pumping test will be conducted at a rate equivalent to the projected maximum pumping rate based on the step-drawdown test.
- Electrical conductivity, salinity, pH, temperature, and hardness will be measured periodically with field equipment.
- A water sample will be collected and delivered to a Maryland-certified laboratory for analyses of the required parameters.
- The pumped water will be discharged directly to Base Lake to prevent soil erosion.

**Pump Selection and Installation** – The constant rate pumping test results will be evaluated to determine the projected long-term yield and pumping water level of the well. Using this information an appropriate submersible pump, motor, and electric wire will be selected. The pump assembly will be suspended on 6-inch diameter galvanized steel riser pipe and a pitless adapter at a depth based on the pumping test results. The discharge pipe will be routed underground from the pitless adapter to the depression between East Course holes 9 and 10.

### 6.2 Use of Piscataway Creek

This proposed action will require a MDE Water Appropriation and Use Permit for surface water withdrawal. An intake structure will be constructed on the west side of Piscataway Creek, upstream from Stormwater Outfall C (Figure 5). At this location, the weir produces a large pool from which water will be withdrawn. Construction of the pumping system will include the following:

- Installation of a low-head, electric powered, centrifugal pumping system along with appropriate flow controls, and flow metering to the pool above the weir at Stormwater Outfall C.
- Installation of a water level switch to allow the pump to operate automatically when the pool is overflowing the weir during the course of the summer. The pump water level switch will be adjusted to maintain the flow-by requirement established by the MDE Water Appropriation and Use Permit.
- Installation of discharge pipe from the pump to Base Lake, following the route illustrated on Figure 5.
- Modification of the outlet structure to enable accurate measurement of streamflow released and automatic control of the pumping system.

### 6.3 Capture of Stormwater Runoff

During heavy rainfall events, the swale along the southern side of South Perimeter Road overflows and water runs across the entrance road to Base Lake. This phase of the proposed work plan will consist of the improvement of the swale to route stormwater runoff into Base Lake (Figure 5). In addition, a pipe installed beneath the swale will transmit water from the catchment between East Course holes 9 and 10 directly to Base Lake. The construction activities will include the following:

- Installation of a drain box to capture water discharged via the existing underground pipe from the existing depression located between East Course holes 9 and 10 (Figure 5).
- Installation of an approximately 8- to 10-inch diameter pipeline under the swale along South Perimeter Road to transmit water from the drain box to Base Lake. The pipe will be designed to transmit the water to be pumped from the Patapsco Well by gravity into Base Lake. Excess runoff during precipitation events will be discharged into the swale.
- The swale will be improved above the pipeline and rerouted to discharge directly to Base Lake.

## 7.0 SELECTED REFERENCES

Freeze, R.A., and Cherry, J.A., 1979, Groundwater; Prentice-Hall, Englewood Cliffs, New Jersey.

Hanson III, H.J., 1968, R.I. No. 7, Geophysical log cross-section network of the Cretaceous sediments of southern Maryland, Maryland Geological Survey, Annapolis, Maryland.

Hanson III, H.J., 1972, A user's guide for the artesian aquifers of the Maryland Coastal Plain, Maryland Geological Survey, Annapolis, Maryland.

Maryland Department of the Environment, 2001a, Results of database search of wells, Well Permits Division, Dundalk, Maryland.

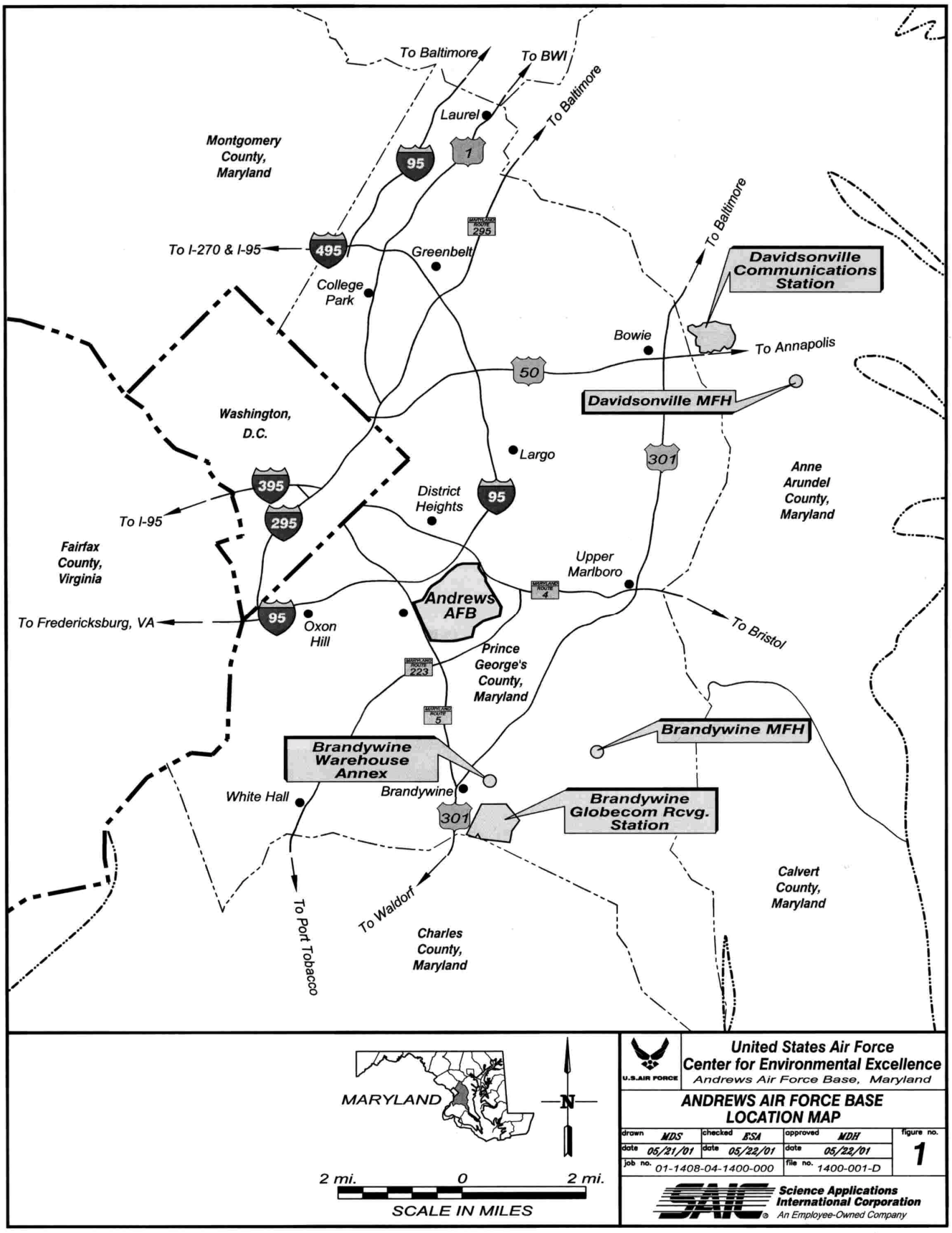
Maryland Department of the Environment, 2001b, Results of database search of water appropriation and use permits, Water Rights Division, Dundalk, Maryland.

US Geological Survey, 1993, 7 ½ Topographic Quadrangle of the Anacostia Quadrangle.

US Geological Survey, 1993, 7 ½ Topographic Quadrangle of the Upper Marlboro Quadrangle.

USAF, 2001, Final Stormwater Management Plan, 89th Airlift Wing, Andrews Air Force Base, Maryland, Prepared by Whitman, Requardt and Associates, LLP.

## 8.0 FIGURES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Largo
301
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395
District Heights
95
To I-95
295
Fairfax County, Virginia
Upper Marlboro
Andrews AFB
MARYLAND ROUTE 4
To Fredericksburg, VA
95
Oxon Hill
To Bristol
Prince George's County, Maryland
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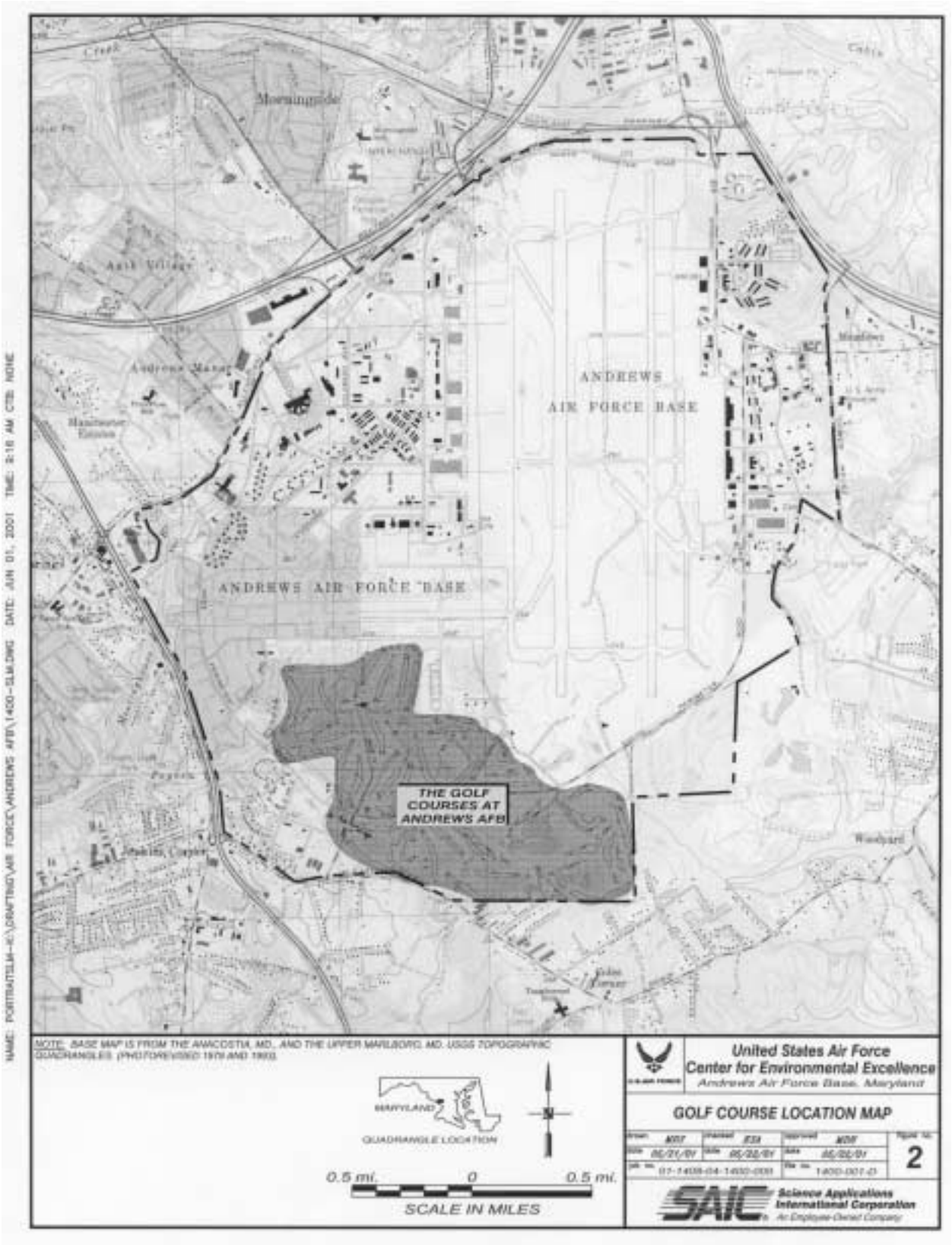
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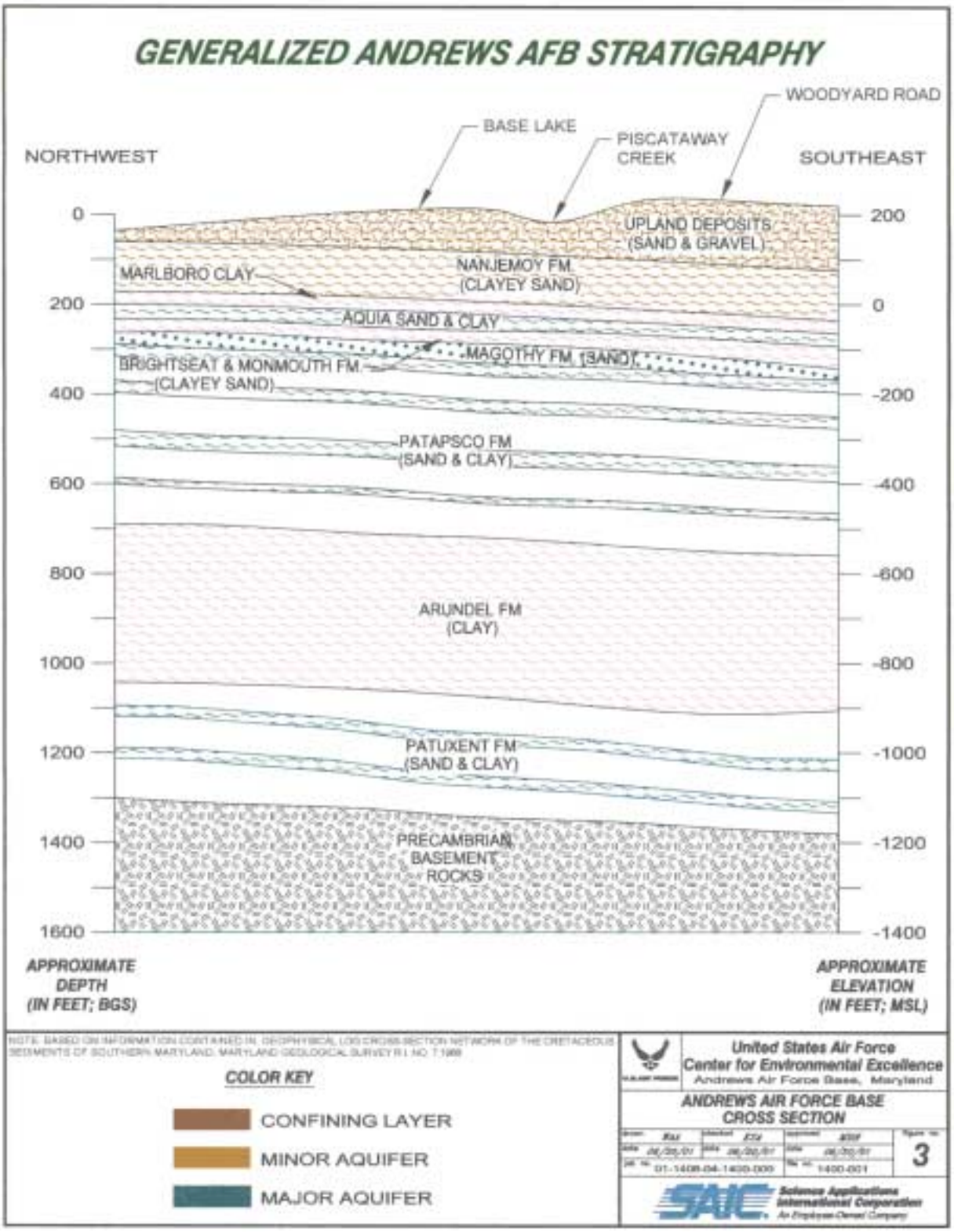
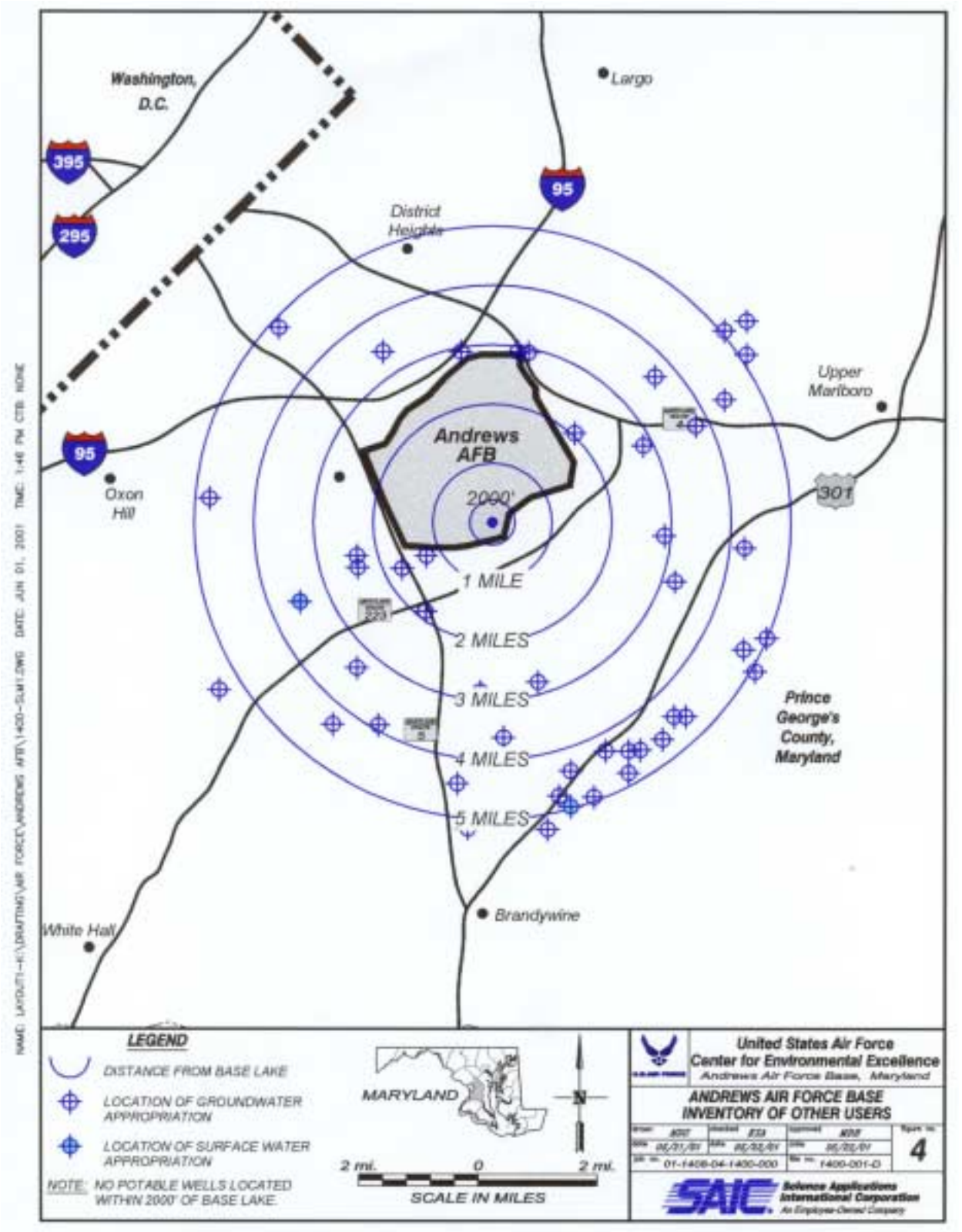
ANDREWS AIR FORCE BASE
THE GOLF COURSES AT ANDREWS AFB
NOTE: BASE MAP IS FROM THE ANACOSTIA, MD., AND THE UPPER MARLBORO, MD. USGS TOPOGRAPHIC QUADRANGLES. (PHOTOREVISED 1979 AND 1993).
MARYLAND
QUADRANGLE LOCATION
N
0.5 mi. 0 0.5 mi.
SCALE IN MILES
United States Air Force
Center for Environmental Excellence
Andrews Air Force Base, Maryland
GOLF COURSE LOCATION MAP
Figure No.
2
Science Applications International Corporation
An Employee-Owned Company


GENERALIZED ANDREWS AFB STRATIGRAPHY
NORTHWEST
SOUTHEAST
BASE LAKE
PISCATAWAY CREEK
WOODYARD ROAD
UPLAND DEPOSITS (SAND & GRAVEL)
NANJEMOY FM (CLAYEY SAND)
MARLBORO CLAY
AQUIA SAND & CLAY
MAGOTHY FM (SAND)
BRIGHTSEAT & MONMOUTH FM (CLAYEY SAND)
PATAPSCO FM (SAND & CLAY)
ARUNDEL FM (CLAY)
PATUXENT FM (SAND & CLAY)
PRECAMBRIAN BASEMENT ROCKS
0
200
400
600
800
1000
1200
1400
1600
200
0
-200
-400
-600
-800
-1000
-1200
-1400
APPROXIMATE DEPTH (IN FEET; BGS)
APPROXIMATE ELEVATION (IN FEET; MSL)
COLOR KEY
CONFINING LAYER
MINOR AQUIFER
MAJOR AQUIFER
United States Air Force
Center for Environmental Excellence
Andrews Air Force Base, Maryland
ANDREWS AIR FORCE BASE
CROSS SECTION
3
Science Applications International Corporation


Washington, D.C.
Largo
District Heights
Upper Marlboro
Andrews AFB
2000'
Oxon Hill
1 MILE
2 MILES
3 MILES
4 MILES
5 MILES
Prince George's County, Maryland
Brandywine
White Hall
395
295
95
301
LEGEND
DISTANCE FROM BASE LAKE
LOCATION OF GROUNDWATER APPROPRIATION
LOCATION OF SURFACE WATER APPROPRIATION
NOTE: NO POTABLE WELLS LOCATED WITHIN 2000' OF BASE LAKE.
MARYLAND
N
2 mi.
0
2 mi.
SCALE IN MILES
United States Air Force
Center for Environmental Excellence
Andrews Air Force Base, Maryland
ANDREWS AIR FORCE BASE
INVENTORY OF OTHER USERS
4
01-1408-04-1400-000
1400-001-D
SAIC
Science Applications International Corporation

## 9.0 TABLES

## Table 1 - Irrigation Demand Analysis The Courses at Andrews Air Force Base

| Annual Average | | | | | | |
|---|---|---|---|---|---|---|
| Golf Course Parameters | | | Irrigation Rates | | Overspray | Demand |
| Course | Surface | Area (acres) | (inches) | (gpd/acre) | Factor | (gpd) |
| East | Tees & Greens | 4.2 | 21 | 1,562 | 2.0 | 13,124 |
| | Fairways | 32.3 | 14 | 1,042 | 1.1 | 37,008 |
| West | Tees & Greens | 4.2 | 21 | 1,562 | 2.0 | 13,124 |
| | Fairways | 29.7 | 14 | 1,042 | 1.1 | 34,029 |
| South | Tees & Greens | 6.3 | 21 | 1,562 | 2.0 | 19,686 |
| | Fairways | 30.8 | 14 | 1,042 | 2.0 | 64,187 |
| Practice Area | | 7.4 | 14 | 1,042 | 1.1 | 8,482 |
| | | | | | **Total** | **189,641** |

| Month of Maximum Use | | | | | | |
|---|---|---|---|---|---|---|
| Golf Course Parameters | | | Irrigation Rates | | Overspray | Demand |
| Course | Surface | Area (acres) | (inches) | (gpd/acre) | Factor | (gpd) |
| East | Tees & Greens | 4.2 | 6.9 | 6,162 | 2.0 | 51,758 |
| | Fairways | 32.3 | 4.6 | 4,108 | 1.1 | 145,950 |
| West | Tees & Greens | 4.2 | 6.9 | 6,162 | 2.0 | 51,758 |
| | Fairways | 29.7 | 4.6 | 4,108 | 1.1 | 134,202 |
| South | Tees & Greens | 6.3 | 6.9 | 6,162 | 2.0 | 77,637 |
| | Fairways | 30.8 | 4.6 | 4,108 | 2.0 | 253,040 |
| Practice Area | | 7.4 | 4.6 | 4,108 | 1.1 | 33,437 |
| | | | | | **Total** | **747,784** |

Notes:
The Courses at Andrews AFB consist of three 18-hole golf courses
Based on rates of use developed by the MDE's Water Management Administration
Rates are for rye and bent grasses irrigated with automated systems
Method accounts for 10% irrigation overlap of fairways* and 100% irrigation overlap of tees and greens
*The South Course has a double row irrigation system on the fairways, hence the 2x overspray factor
One inch of water = 74.4 gpd/acre (annual average) or 893 gpd/acre (maximum month)
gpd = gallons per day

## Table 2 - Flow Mass Analysis - Normal conditions (50% exceedance)

| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | | | | | | | |
| | days | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 365 |
| Base Lake | **Evaporation** | | | | | | | | | | | | | |
| | inches | (1.00) | (2.00) | (3.67) | (5.03) | (5.85) | (6.99) | (7.65) | (6.48) | (4.97) | (3.58) | (2.36) | (1.00) | (50.57) |
| | gallons | (461,591) | (923,182) | (1,693,269) | (2,322,933) | (2,699,917) | (3,224,636) | (3,532,233) | (2,989,145) | (2,292,691) | (1,652,866) | (1,088,431) | (461,591) | (23,342,485) |
| | **Direct Precipitation** | | | | | | | | | | | | | |
| | inches | 3.03 | 2.63 | 3.71 | 3.25 | 4.23 | 3.39 | 3.90 | 3.99 | 4.01 | 3.38 | 3.27 | 3.33 | 42.13 |
| | gallons | 1,397,066 | 1,215,733 | 1,712,829 | 1,501,552 | 1,953,416 | 1,564,793 | 1,798,468 | 1,843,878 | 1,850,237 | 1,558,357 | 1,509,757 | 1,538,728 | 19,444,814 |
| | **Storm Water Runoff** | | | | | | | | | | | | | |
| | gallons | 339,813 | 308,260 | 574,879 | 444,874 | 640,947 | 543,925 | 705,303 | 742,989 | 858,438 | 644,795 | 577,460 | 525,849 | 6,907,533 |
| | **Groundwater Infiltration** | | | | | | | | | | | | | |
| | gallons | 0 | 0 | 0 | 0 | 87,630 | 509,685 | 469,395 | 445,600 | 114,804 | 0 | 0 | 0 | 1,627,115 |
| | **Supply Well** | | | | | | | | | | | | | |
| | days in use | 0 | 0 | 0 | 15 | 31 | 30 | 31 | 31 | 30 | 31 | 6 | 0 | 205 |
| | gallons | 0 | 0 | 0 | 2,808,000 | 5,803,200 | 5,616,000 | 5,803,200 | 5,803,200 | 5,616,000 | 5,803,200 | 1,123,200 | 0 | 38,376,000 |
| Demand | **Irrigation Demand** | | | | | | | | | | | | | |
| | percent | 0% | 0% | 0% | 2% | 7% | 22% | 33% | 25% | 7% | 3% | 1% | 0% | 100% |
| | gallons | 0 | 0 | 0 | (1,384,378) | (4,845,321) | (15,228,153) | (23,181,402) | (17,304,719) | (4,845,321) | (2,076,566) | (692,189) | 0 | (69,218,877) |
| | gpd | 0 | 0 | 0 | (46,146) | (156,301) | (507,605) | (747,787) | (558,217) | (161,511) | (66,986) | (23,073) | 0 | 189,641 |
| Storage | **Lake Drawdown** | | | | | | | | | | | | | |
| | Inflow/Outflow | 1,275,289 | 600,812 | 594,439 | 1,047,115 | 939,955 | (10,218,386) | (17,937,269) | (11,458,198) | 1,301,467 | 4,276,920 | 1,429,797 | 1,602,986 | |
| | Storage Avail. | 2,077,159 | 2,077,159 | 2,077,159 | 2,077,159 | 2,077,159 | 0 | 0 | 0 | 1,301,467 | 2,077,159 | 2,077,159 | 2,077,159 | |
| | Storage Used | 0 | 0 | 0 | 0 | 0 | 2,077,159 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Deficit | **Additional Supply Required** | | | | | | | | | | | | | |
| | gallons | 0 | 0 | 0 | 0 | 0 | 8,141,227 | 17,937,269 | 11,458,198 | 0 | 0 | 0 | 0 | **37,536,694** |
| | gpd | 0 | 0 | 0 | 0 | 0 | 271,374 | 578,622 | 369,619 | 0 | 0 | 0 | 0 | **102,840** |

**Notes:** Supplemental supply required is shown in bold

Base Lake area = 17 acres (740,520 sq ft) - is based on current aerial photography

Evaporation and precipitation rates are based on 1960-1999 daily measurements from NCDC's Beltsville, MD weather station (January, February, and December evaporation rates are estimated)

The well supplies approximately 130 gallons per minute to the lake when operating (MDE-WMA permit limit = 38,325,000 gallons/year)

Base Lake infiltration rates determined using irrigation and well pumping records

Stormwater runoff rates are based on; 27-acre watershed (excluding Base Lake area), type B soils, weighted runoff curve # = 62.4, and the assumption that runoff results from precipitation events greater than 0.5 inches

Monthly irrigation rates, shown as a percentage of annual use, are based on golf course irrigation records

Due to environmental considerations the maximum amount of lake drawdown is 6 inches or 2,077,159 gallons

gpd = gallons per day

## Table 3 - Flow Mass Analysis - Drought conditions (85% exceedance)

| | Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | days | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 365 |
| Base Lake | **Evaporation** | | | | | | | | | | | | | |
| | inches | (1.20) | (2.40) | (4.40) | (6.51) | (6.82) | (7.75) | (8.68) | (7.75) | (6.51) | (4.34) | (2.83) | (1.20) | (60.39) |
| | gallons | (553,909) | (1,107,818) | (2,031,923) | (3,004,956) | (3,148,049) | (3,577,329) | (4,006,608) | (3,577,329) | (3,004,956) | (2,003,304) | (1,306,117) | (553,909) | (27,876,207) |
| | **Direct Precipitation** | | | | | | | | | | | | | |
| | inches | 1.47 | 0.97 | 1.78 | 1.43 | 1.88 | 1.36 | 1.25 | 1.74 | 1.05 | 1.43 | 1.16 | 1.32 | 16.84 |
| | gallons | 678,538 | 447,743 | 821,632 | 660,075 | 867,791 | 627,763 | 576,989 | 803,168 | 484,670 | 660,075 | 535,445 | 609,300 | 7,773,189 |
| | **Storm Water Runoff** | | | | | | | | | | | | | |
| | gallons | 165,043 | 113,529 | 275,765 | 195,564 | 284,736 | 218,212 | 226,277 | 323,636 | 224,868 | 273,116 | 204,800 | 208,224 | 2,713,771 |
| | **Groundwater Infiltration** | | | | | | | | | | | | | |
| | gallons | 0 | 0 | 0 | 0 | 87,630 | 509,685 | 469,395 | 445,600 | 114,804 | 0 | 0 | 0 | 1,627,115 |
| | **Supply Well** | | | | | | | | | | | | | |
| | days in use | 0 | 0 | 0 | 15 | 31 | 30 | 31 | 31 | 30 | 31 | 6 | 0 | 205 |
| | gallons | 0 | 0 | 0 | 2,808,000 | 5,803,200 | 5,616,000 | 5,803,200 | 5,803,200 | 5,616,000 | 5,803,200 | 1,123,200 | 0 | 38,376,000 |
| Demand | **Irrigation Demand** | | | | | | | | | | | | | |
| | percent | 0% | 0% | 0% | 2% | 7% | 22% | 33% | 25% | 7% | 3% | 1% | 0% | 100% |
| | gallons | 0 | 0 | 0 | (1,384,378) | (4,845,321) | (15,228,153) | (23,181,402) | (17,304,719) | (4,845,321) | (2,076,566) | (692,189) | 0 | (69,218,877) |
| | gpd | 0 | 0 | 0 | (46,146) | (156,301) | (507,605) | (747,787) | (558,217) | (161,511) | (66,986) | (23,073) | 0 | 189,641 |
| Storage | **Lake Drawdown** | | | | | | | | | | | | | |
| | Inflow/Outflow | 289,673 | (546,546) | (934,526) | (725,695) | (950,014) | (11,833,821) | (20,112,150) | (13,506,444) | (1,409,935) | 2,656,521 | (134,861) | 263,614 | |
| | Storage Avail. | 2,077,159 | 1,530,613 | 596,087 | 0 | 0 | 0 | 0 | 0 | 0 | 2,077,159 | 1,942,298 | 2,077,159 | |
| | Storage Used | 0 | 546,546 | 934,526 | 596,087 | 0 | 0 | 0 | 0 | 0 | 0 | 134,861 | 0 | |
| Deficit | **Additional Supply Required** | | | | | | | | | | | | | |
| | gallons | 0 | 0 | 0 | 129,607 | 950,014 | 11,833,821 | 20,112,150 | 13,506,444 | 1,409,935 | 0 | 0 | 0 | **47,941,971** |
| | gpd | 0 | 0 | 0 | 4,320 | 30,646 | 394,461 | 648,779 | 435,692 | 46,998 | 0 | 0 | 0 | **131,348** |

**Notes:** Supplemental supply required is shown in bold

Base Lake area = 17 acres (740,520 sq ft) - is based on current aerial photography

Evaporation and precipitation rates are based on 1960-1999 daily measurements from NCDC's Beltsville, MD weather station (January, February, and December evaporation rates are estimated)

The well supplies approximately 130 gallons per minute to the lake when operating (MDE-WMA permit limit = 38,325,000 gallons/year)

Base Lake infiltration rates determined using irrigation and well pumping records

Stormwater runoff rates are based on; 27-acre watershed (excluding Base Lake area), type B soils, weighted runoff curve # = 62.4, and the assumption that runoff results from precipitation events greater than 0.5 inches

Monthly irrigation rates, shown as a percentage of annual use, are based on golf course irrigation records

Due to environmental considerations the maximum amount of lake drawdown is 6 inches or 2,077,159 gallons

gpd = gallons per day

**Table 4 - Piscataway Creek Flow-by Analyses The Courses at Andrews AFB**

| Exceedance Flow Rates for Piscataway Creek at Piscataway, MD<br>Using Daily Flow Data for 1965-2000 Water Years<br>Watershed = 39.5 sq mi | | |
|---|---|---|
| Month | 85% Exceedance Drought Conditions flow (cfs) | 50% Exceedance Normal Conditions flow (cfs) |
| January | 17 | 40 |
| February | 25 | 47 |
| March | 30 | 53 |
| April | 26 | 47 |
| May | 12 | 30 |
| June | 3.5 | 13 |
| July | 0.45 | 6.2 |
| August | 0.1 | 4.5 |
| September | 0 | 4 |
| October | 1.1 | 6.8 |
| November | 5.1 | 16 |
| December | 12 | 28 |

| Exceedance Flow Rates for Piscataway Creek at Stormwater Outfall C<br>Projected using watershed proportioning method<br>Watershed = 2.52 sq mi (1,610 acres) | | | | |
|---|---|---|---|---|
| Month | 85% Exceedance Drought Conditions flow (cfs) | 50% Exceedance Normal Conditions flow (cfs) | Available During Normal Conditions (cfs) | Available During Normal Conditions (gallons) |
| January | 1.08 | 2.55 | 1.47 | 946,853 |
| February | 1.59 | 2.99 | 1.40 | 905,686 |
| March | 1.91 | 3.38 | 1.47 | 946,853 |
| April | 1.66 | 2.99 | 1.34 | 864,518 |
| May | 0.76 | 1.91 | 1.15 | 741,015 |
| June | 0.22 | 0.83 | 0.61 | 391,092 |
| July | 0.03 | 0.39 | 0.37 | 236,713 |
| August | 0.01 | 0.29 | 0.28 | 181,137 |
| September | 0.00 | 0.25 | 0.25 | 164,670 |
| October | 0.07 | 0.43 | 0.36 | 234,655 |
| November | 0.32 | 1.02 | 0.69 | 448,726 |
| December | 0.76 | 1.78 | 1.02 | 658,680 |
| Average | 0.70 | 1.57 | 0.87 | 560,050 |

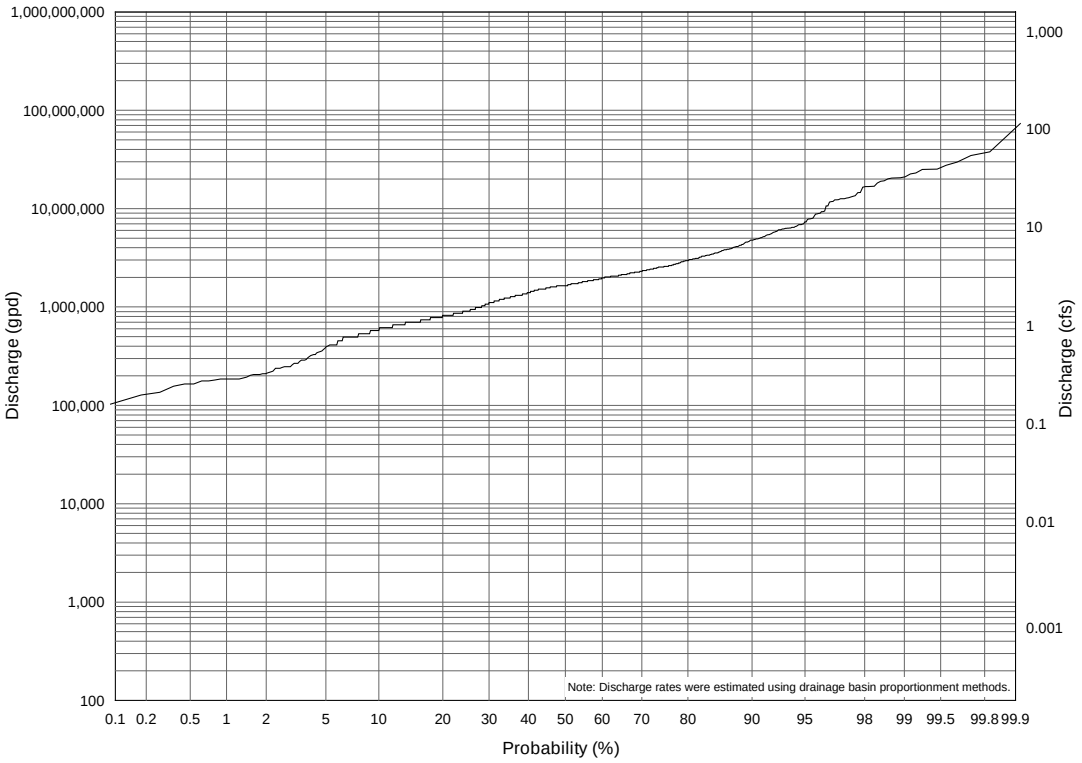
**Maryland Method Flow-by:**

**Nov-Apr 85% Exceedance = 1.22 cfs (788,452 gpd)**
**May-Oct 85% Exceedance = 0.18 cfs (116,329 gpd)**

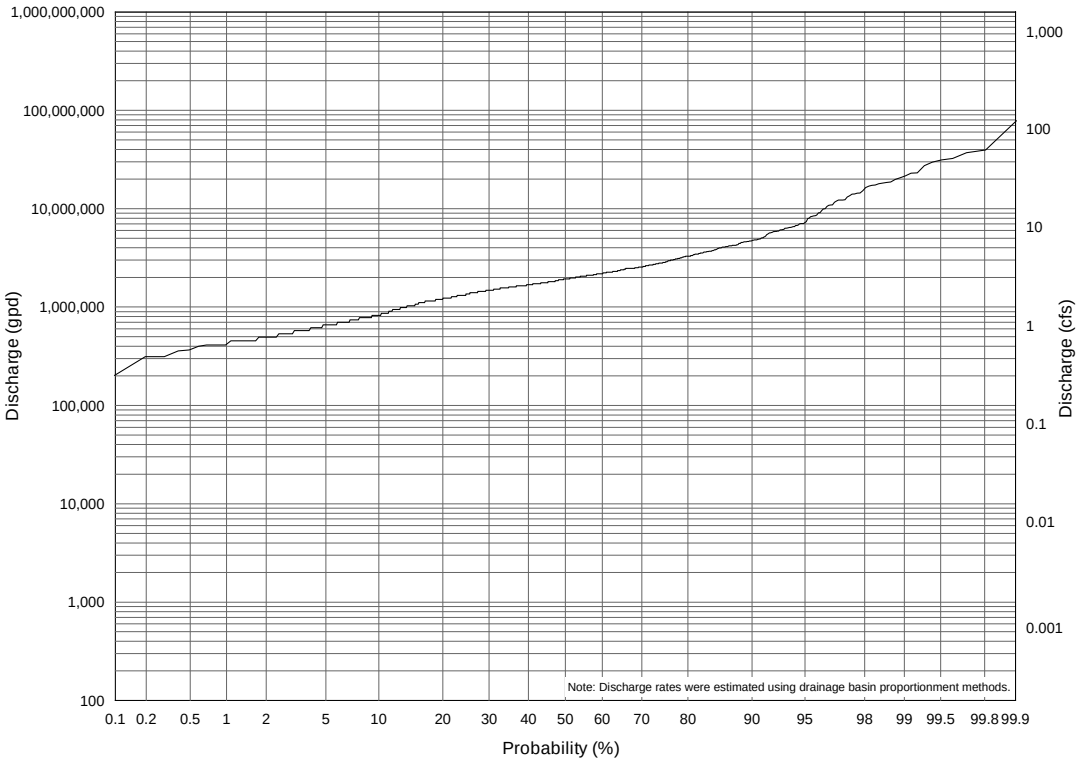
## APPENDIX A

- Piscataway Creek at Stormwater Outfall C – January Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – February Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – March Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – April Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – May Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – June Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – July Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – August Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – September Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – October Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – November Flow Duration Curve
- Piscataway Creek at Stormwater Outfall C – December Flow Duration Curve

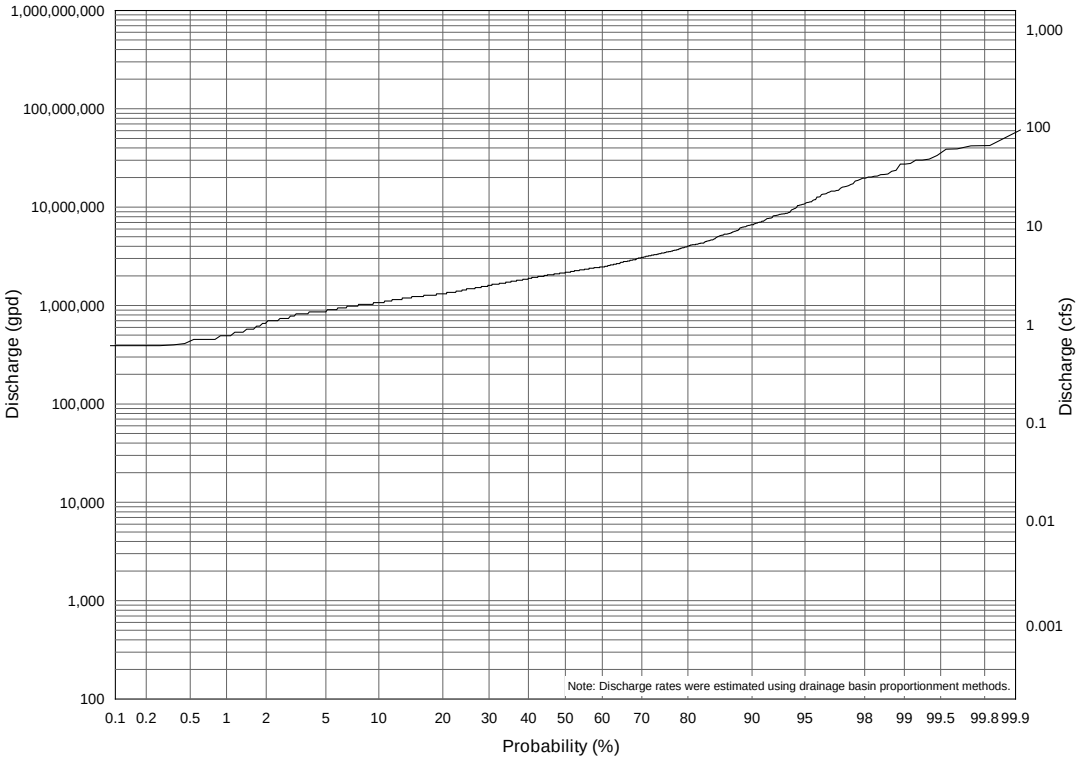
Piscataway Creek at Stormwater Outfall C
January Flow Duration Curve



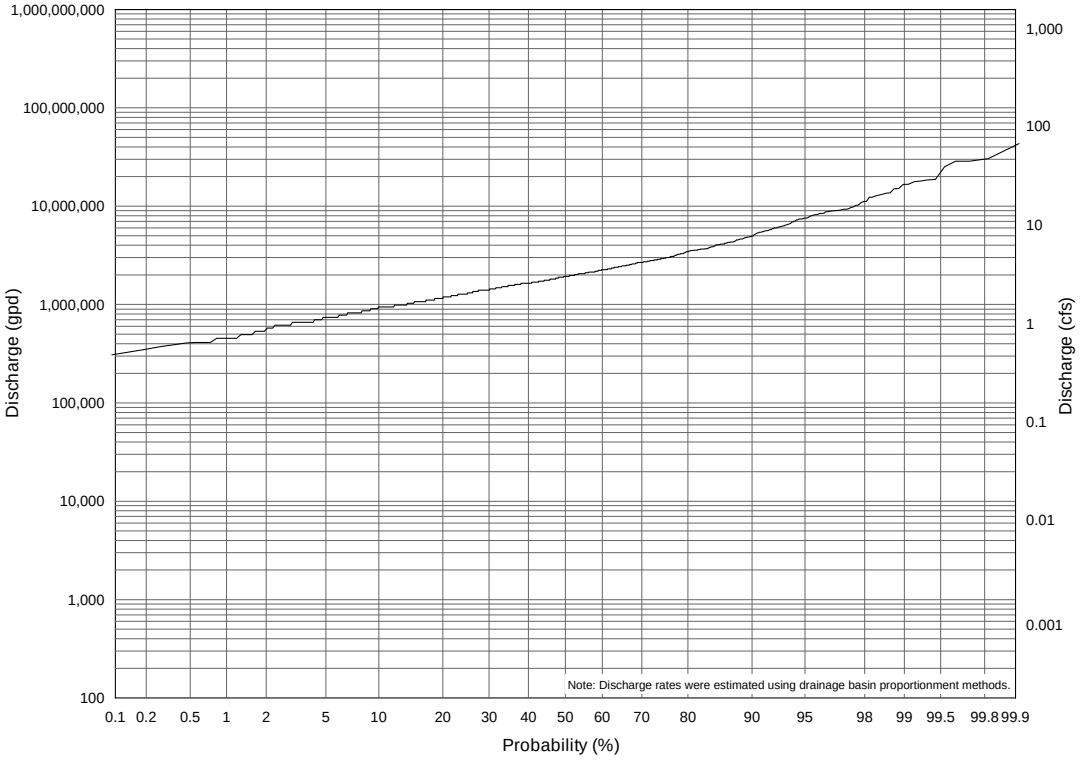

Piscataway Creek at Stormwater Outfall C
February Flow Duration Curve



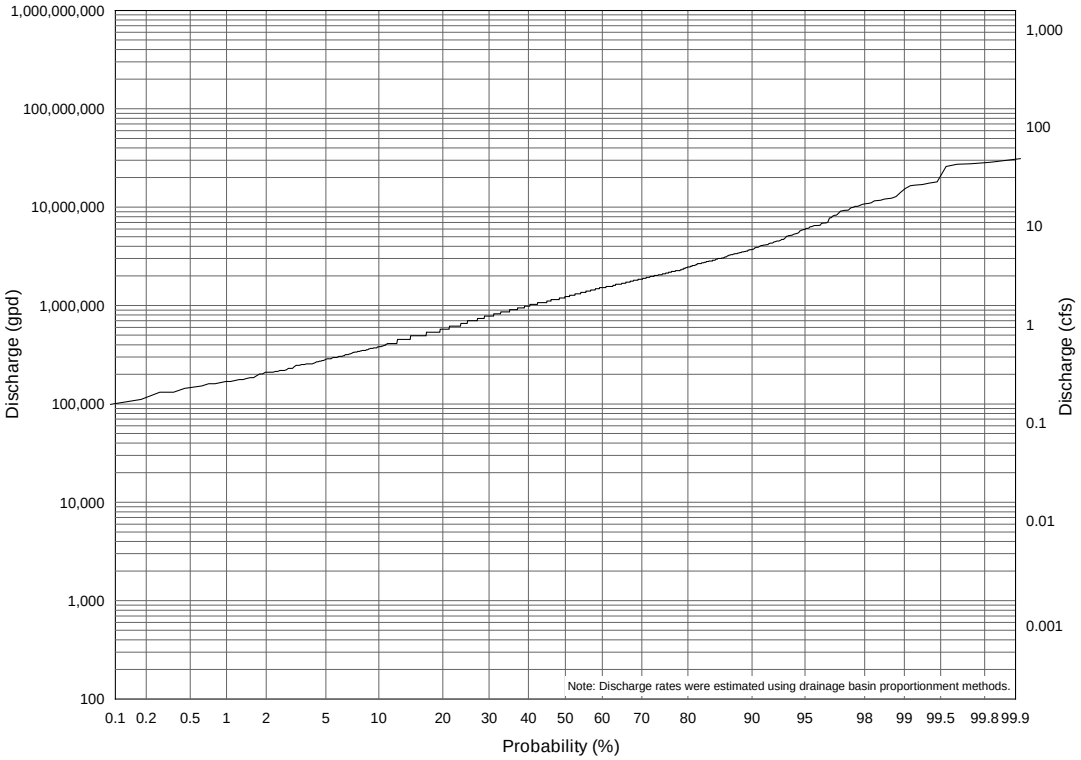
Piscataway Creek at Stormwater Outfall C
March Flow Duration Curve



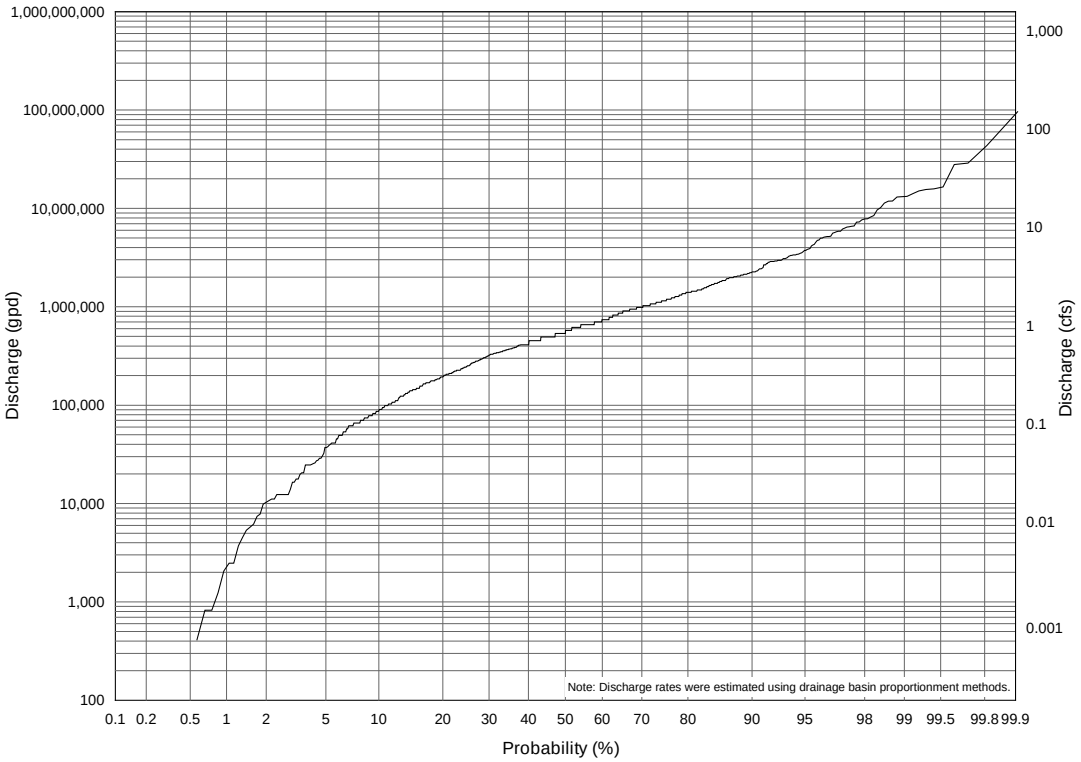

Piscataway Creek at Stormwater Outfall C
April Flow Duration Curve



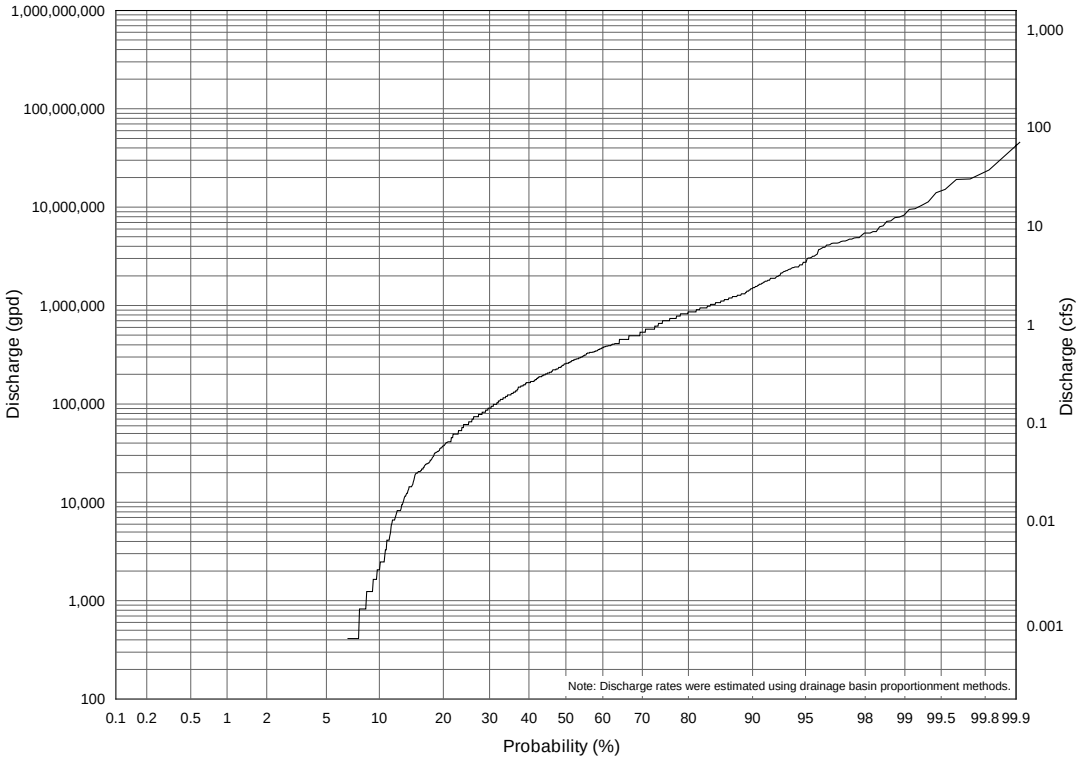
Piscataway Creek at Stormwater Outfall C
May Flow Duration Curve



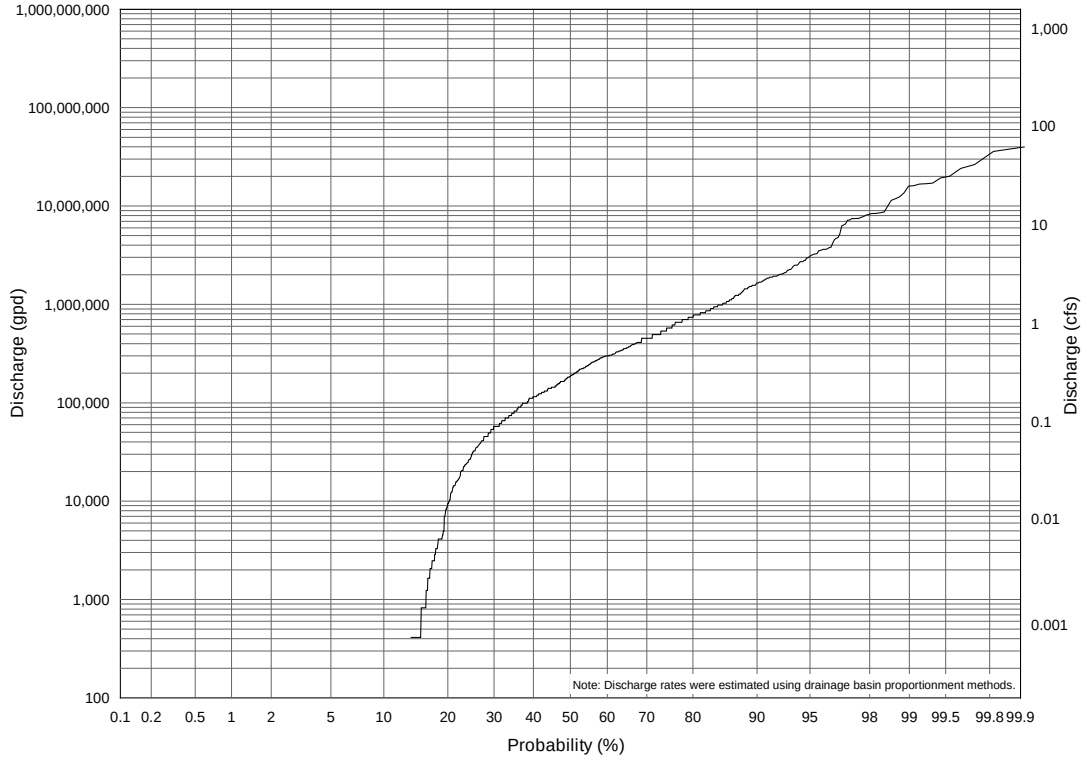

Piscataway Creek at Stormwater Outfall C
June Flow Duration Curve



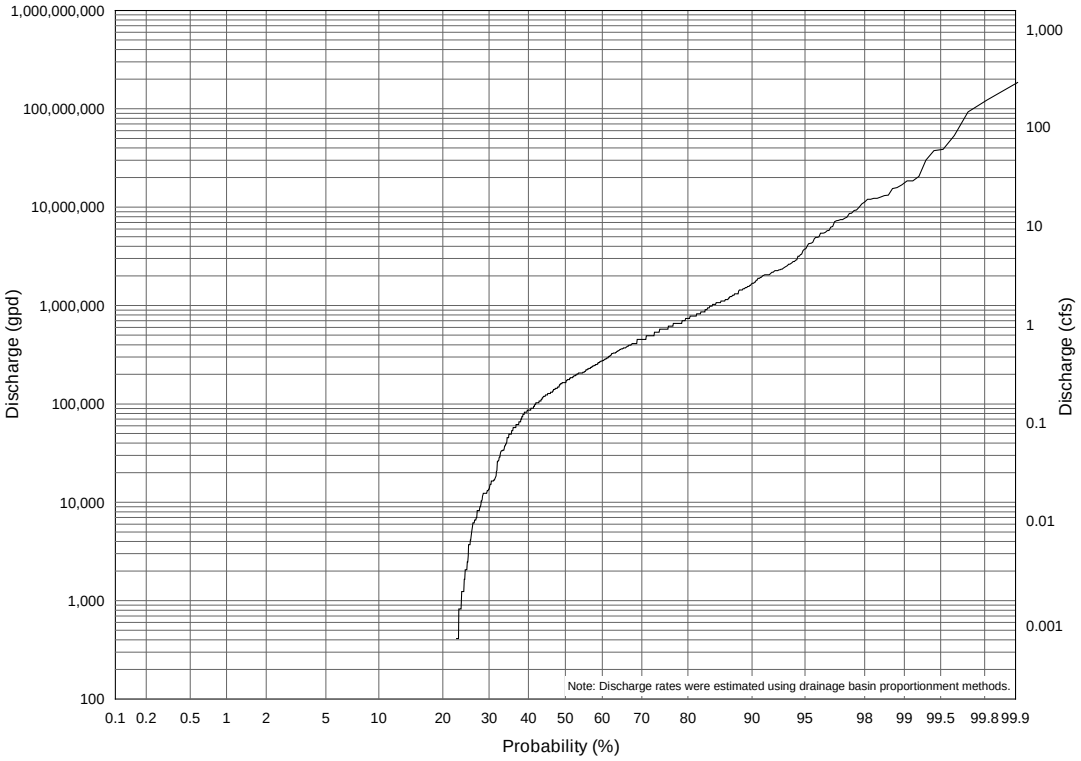
Piscataway Creek at Stormwater Outfall C
July Flow Duration Curve



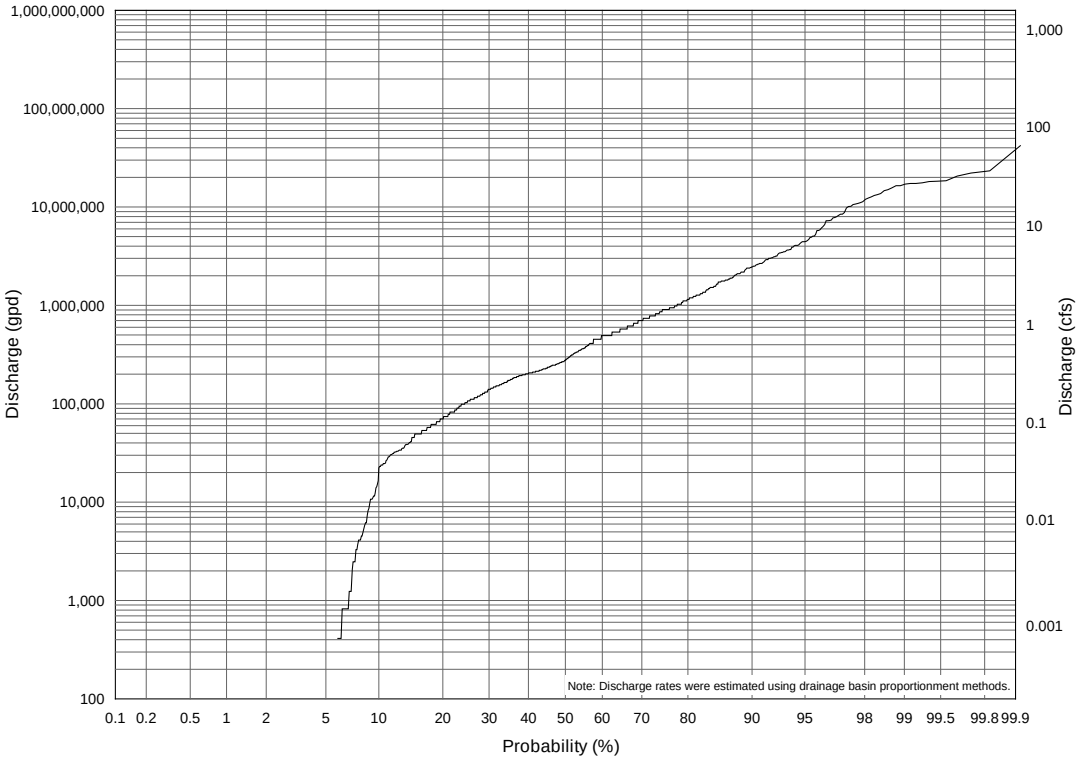

Piscataway Creek at Stormwater Outfall C
August Flow Duration Curve



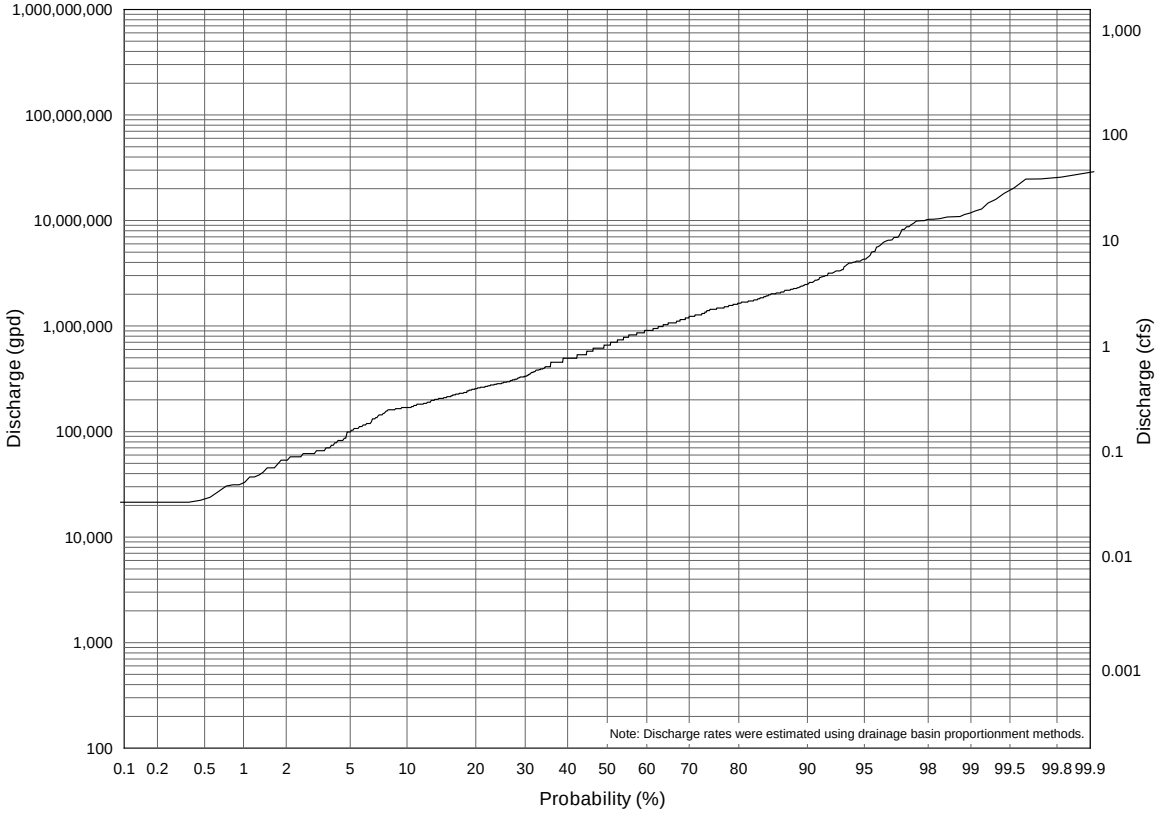
Piscataway Creek at Stormwater Outfall C
September Flow Duration Curve



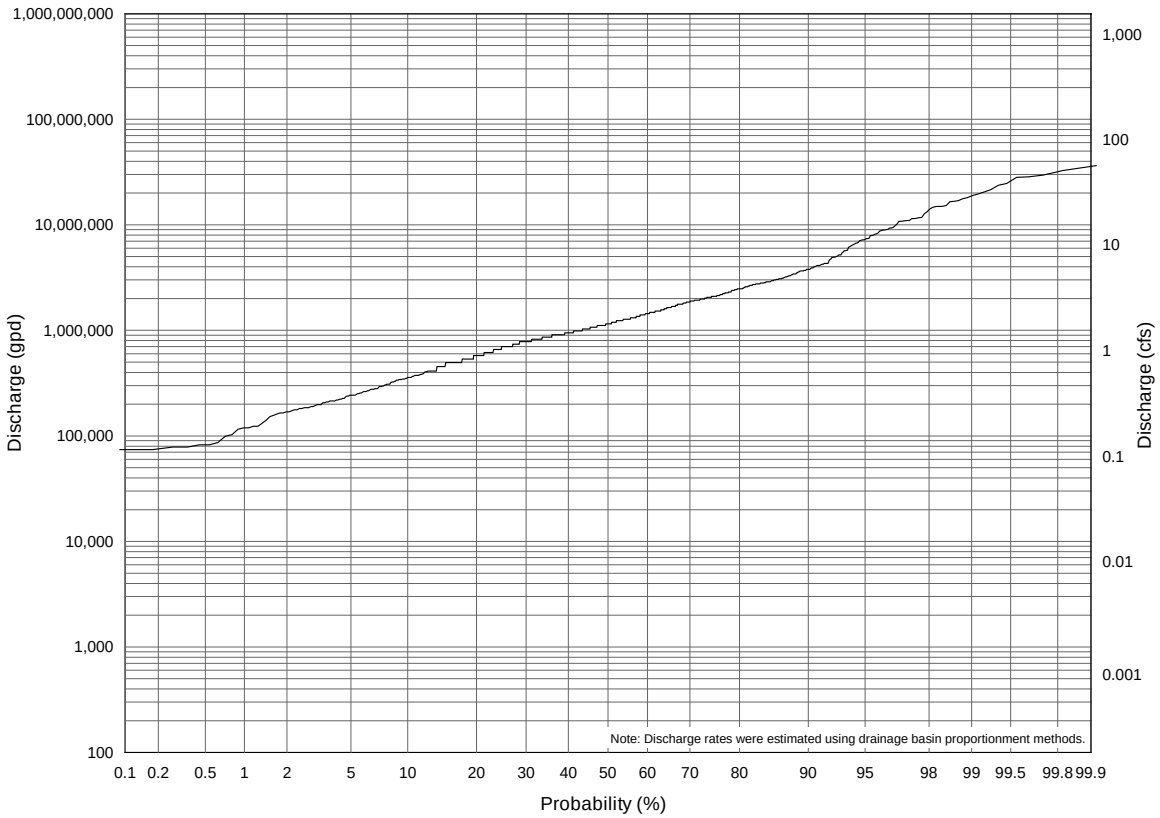

Piscataway Creek at Stormwater Outfall C
October Flow Duration Curve

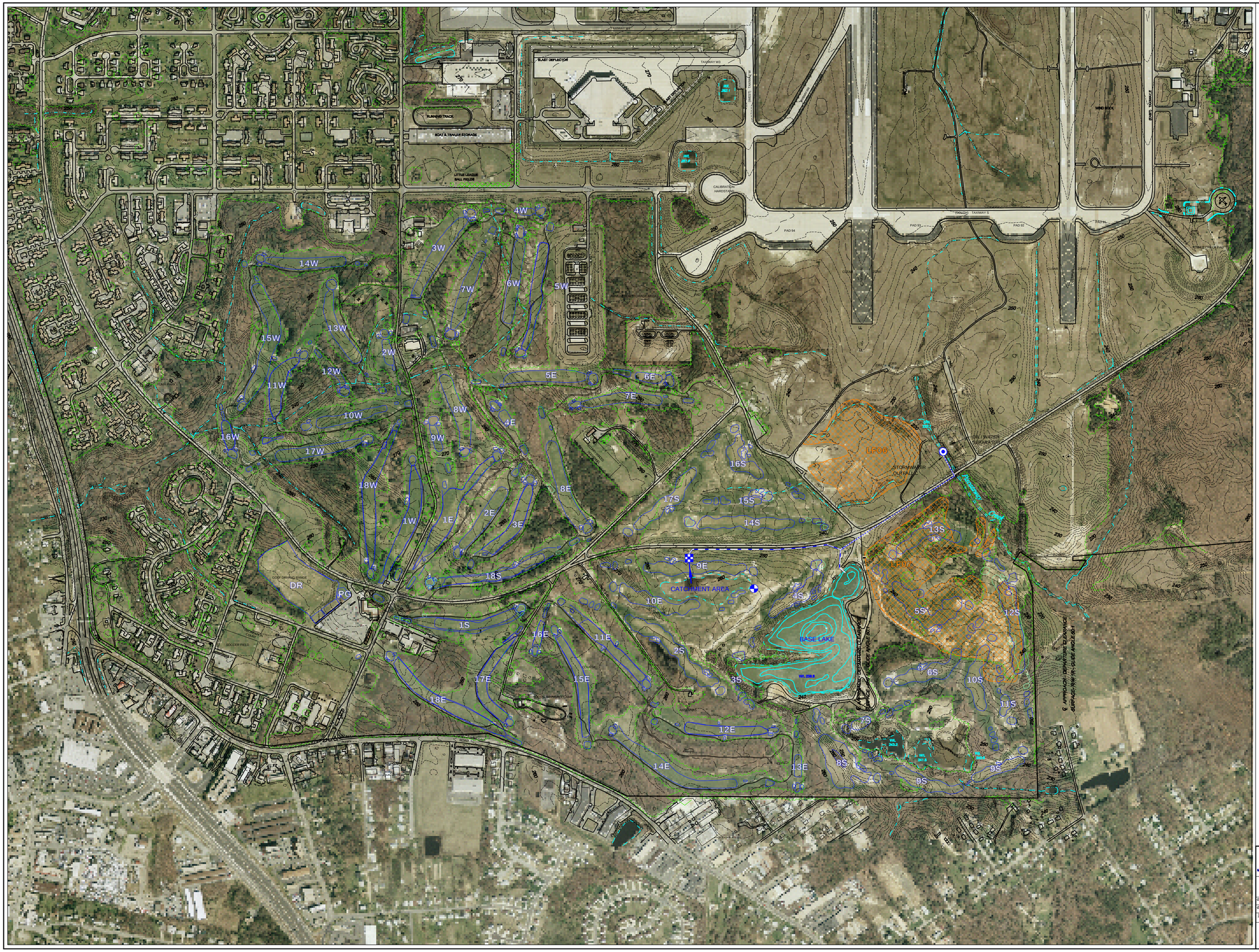


Piscataway Creek at Stormwater Outfall C
November Flow Duration Curve




Piscataway Creek at Stormwater Outfall C
December Flow Duration Curve






NAME: GOLF COURSE-A1\DRAWINGS\AR FORCE\WORKS AFB\BASE.DWG DATE: AUG 07, 2001 TIME: 2:56 PM CTB: NONE

United States Air Force
Center for Environmental Excellence
Andrews Air Force Base, Maryland

**GOLF COURSE AREA**

| drawn | checked | approved | figure no. |
|---|---|---|---|
| MDS | ESA | MDS | 5 |
| date 08/21/01 | date 08/22/01 | date 08/22/01 | |
| job no. 01-1408-04-1400-000 | | file no. 1400-001-D | |

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