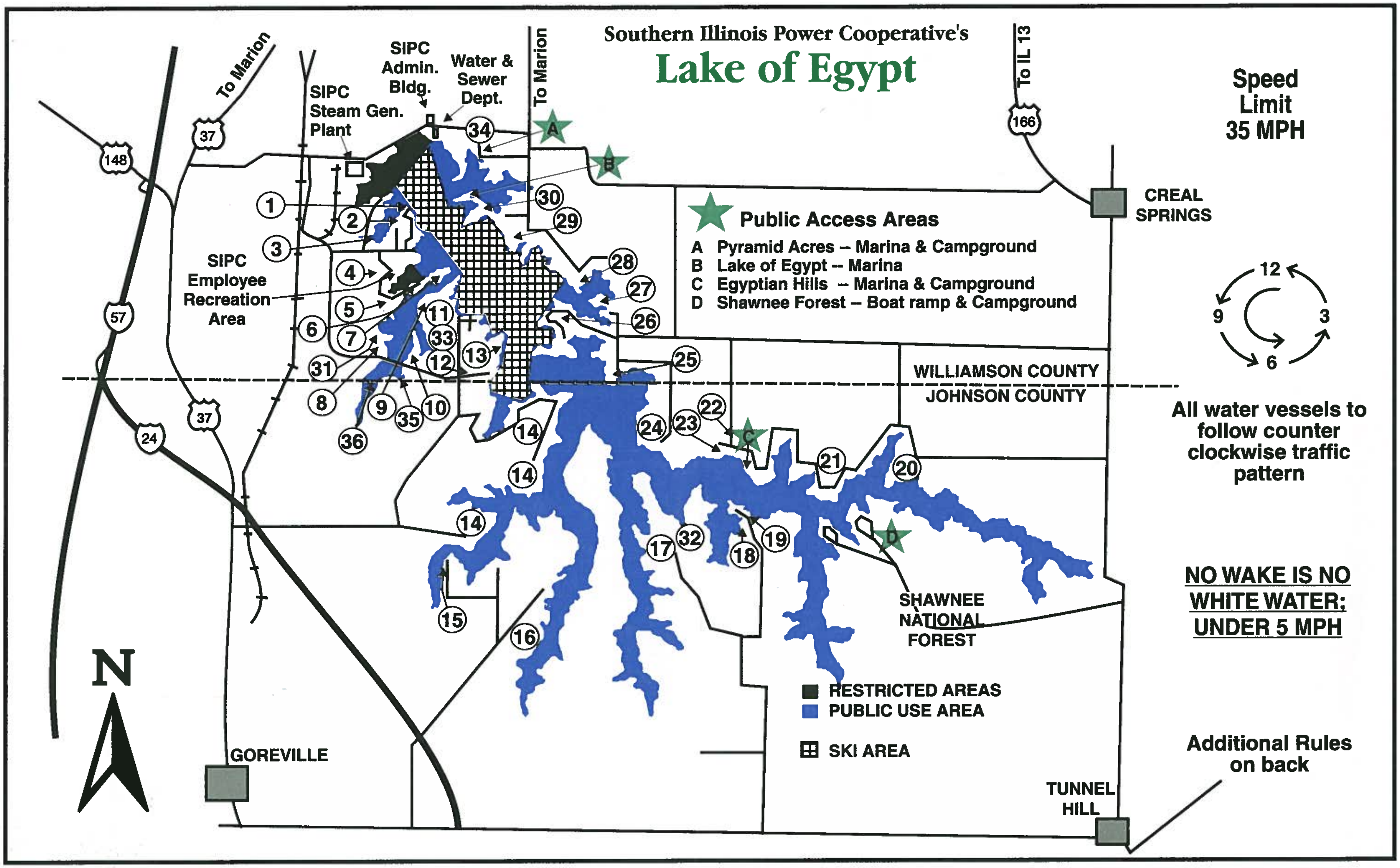
Southern Illinois Power Cooperative's

Lake of Egypt



★ **Public Access Areas**

- A Pyramid Acres -- Marina & Campground
- B Lake of Egypt -- Marina
- C Egyptian Hills -- Marina & Campground
- D Shawnee Forest -- Boat ramp & Campground

■ RESTRICTED AREAS

■ PUBLIC USE AREA

⊞ SKI AREA

Speed Limit 35 MPH

All water vessels to follow counter clockwise traffic pattern

NO WAKE IS NO WHITE WATER; UNDER 5 MPH

Additional Rules on back

○ Subdivisions

1. Howard's Lakeside
2. Westgate
3. Lake of Egypt Country Club
4. Westgate II
5. Adams Acres
6. Woodland Hills
7. Fopal
8. Sleepy Hollow
9. Cedar Hills
10. Clifty Heights
11. Crestwood
12. Cedar Ridge
13. Saline Rock
14. Eagle Point Bay
15. Deer Ridge
16. Sugar Creek Ranch
17. Robinwood
18. Cox
19. Wagon Creek Haven
20. Wagon Creek Ranch
21. Egyptian Hills
22. Hunts
23. Wagon Creek Point
24. Pharoah's Gardens
25. Egyptian Acres
26. Egypt Shores
27. Lake Crest
28. North Shoreland
29. Lake Estates
30. Sunset Harbor
31. Clifty Bay
32. Mallard's Landing
33. Three Star
34. Pyramid Acres
35. Grahams Acres
36. Luxor Landing

OFFICIAL LAKE OF EGYPT RULES AND REGULATIONS
SOUTHERN ILLINOIS POWER COOPERATIVE, MARION, IL 62959

Lake of Egypt is a private lake; its primary purpose being to furnish water for the generation of electricity. The waters and shoreline may be used for recreational purposes subject to the following rules and regulations:

1. **SHORELINE AGREEMENT**
   - A. Shoreline property owners who have a boat dock on or make use of the shoreline abutting their property shall execute a standard Southern Illinois Power Cooperative Shoreline Agreement.

2. **ZONING**
   - A. **RECREATIONAL AREA**: All areas of Lake of Egypt except "Restricted Areas" are open to boating and fishing.
   - B. **RESTRICTED AREA:** Areas marked "Restricted" are not open to recreation. Authorized boats only are permitted in these areas.
   - C. **SKIING**
     Limited to northern wide area of lake.
     Skiers shall not ski closer than 100 feet from shoreline or buoyline.
     Skiers will ski in counterclockwise direction. This applies to Jet Skis also.
     No skiing after sundown.

3. **BOATS – TYPES PROHIBITED**
   - A. Racing type boats.
   - B. Boats with loud, open or uninhibited exhaust systems.
   - C. Pontoon boats exceeding 28 feet and hull boats exceeding 20 feet.
   - D. Boats with toilet, kitchen or lodging facilities.
   - E. Boats (except when docked) that have closed sidewalls where all occupants are not visible to passing boats.

4. **BOATING REGULATIONS**
   - A. All provisions of the Illinois Boat Registration and Safety Act will be enforced on the Lake of Egypt. (See Manual).
   - B. All boats shall carry a container acceptable for holding litter and refuse and must be emptied in litter barrels, not in lake.
   - C. All boats will display anchor lights and, when moving, running lights after sundown.
   - D. Boats will not anchor within 25 feet of lake buoys or buoy line.
   - E. No one under the influence of alcohol may operate a boat on the Lake of Egypt.
   - F. Racing is prohibited
   - G. 35 miles per hour speed limit.
   - H. JET SKIS –State Law- same as for boats.
     Allowed in ski area only and only in counter clockwise direction.
     Not allowed on lake after sundown.
     May go directly to other areas for access or fuel only following counter clockwise traffic pattern.

5. **FISHING**
   - A. Bass tournaments, fish-offs or other competitive fishing events for prizes will register their events at either Egyptian Hills, Lake of Egypt, Pyramid Acres Marina and Southern Illinois Power Cooperative. No bass tournaments or fish-offs will be allowed from June 1 thru September 30 except on a catch-measure-release basis.
   - B. NO TROTLINES OR JUGS ALLOWED IN SKI AREA OR COVES OFF THE SKI AREA. ALL TROTLINES AND JUGS MUST HAVE NAME AND ADDRESS ON EACH JUG AND TROTLINE. JUGS AND TROTLINES CANNOT BE PUT IN BEFORE 5:00 P.M. AND MUST BE REMOVED BY 8:00 A.M.
   - C. Crappie limited to 30 fish per day per fisherman.
   - D. Largemouth bass-2 fish per day < 14" in length and 4 fish > 16" in length.*
   - E. Walleye 14" minimum length – 6 fish per day.
   - F. Hybrid striped bass 18" minimum length – 3 fish per day.
   - G. ABSOLUTELY NO CASTING OF LURES WITHIN 10 FEET OF DOCKS, BOATS OR BOAT HOUSES.

6. Boaters will not anchor boats for picnicking or fishing within less than 100 feet of shoreline near residence so as not to interfere with the privacy of the homeowner.
7. Swimming is prohibited except at approved beaches marked by buoys. Air mattresses are prohibited outside of beach areas.
8. Skin diving and landing of sea planes in lake are prohibited.
9. The use of kite tubes is prohibited on the lake
10. Hunting is not permitted on or over the Lake nor is the transportation or discharge of firearms or other weapons permitted on or over the Lake.
11. RULES WILL BE ENFORCED. Failure to abide by these rules will result in either arrest and/or denial or further use of the lake.
12. **Chemical Treatment of Lake.**
    WHEREAS, the lake is under the jurisdiction of State and Federal EPA Regulations, there shall be no chemicals or any foreign substances placed into, or allowed as runoff or leaching into, the water of the lake or on the property of Southern Illinois Power Cooperative.
13. These rules and regulations may be changed by the Southern Illinois Power Cooperative Board of Directors from time to time as necessary.

* (< = Less than, > = Greater than)

APPROVED: JULY 2006

Shawnee National Forest

Plant Cooling Study
Lake of Egypt
Marion Generating Station

Prepared For
Southern Illinois Power Cooperative (SIPC)

Prepared By
Sargent & Lundy, LLC

Rev 2

Project No 10401-044

SL-009090

October 3, 2011

Issue Summary Page

Revision	Date	Purpose	Prepared By	Reviewed By	Approved By
0	04/30/2007	Draft	D. Azukas		
1	05/31/2007	Final	T. Pierce	B. Barth	B. Barth
2	10/03/2011	Final	C. Kadera	A. Landry	A. Landry

Prepared By: C. Kadera \ Date: 3 Oct 2011

Reviewed By: A. Landry \ Adam Landry Date: 03 oct 2011

Approved By: A. Landry Adam Landry Date: 03 oct 2011

SIPC
Marion Generating Station
Lake of Egypt

Plant Cooling Study
Table of Contents

I. Executive Summary

Sargent & Lundy (S&L) was authorized by Southern Illinois Power Cooperative (SIPC) to perform an investigation of the water temperatures in the Lake of Egypt (LOE) in southern Illinois. Marion Generating Station, situated on the northwest shore of LOE uses the lake for once-through cooling. The purpose of this report is to study changes to the use of LOE and their subsequent impacts on Marion Generating Station, including plant generation capacity and thermal discharge limits. The following three items will be reviewed as part of this report:

1. Examine impacts of adding additional head load on LOE.
2. Explore effect of withdrawal of additional water from LOE.
3. Investigate methods to obtain additional cooling.

This study does not include the following information:

1. Permitting of the lake usage
2. Detailed design
3. Detailed cost
4. Environmental impact
5. Project schedule (defined during detailed engineering)

Key design input provided by SIPC was the daily plant discharge and intake temperatures and corresponding monthly average and maximum circulating water flow rates for several years. This information corresponds to Marion Generating Station, which consists of two coal fired units (units 123 and 4) which use once-through cooling and two additional combined cycle units (unit 5 and 6) that use a cooling tower rather than once-through cooling. Altogether, units 123 and 4 produce nominally approximately 300 MW.

Lake elevation is critical to the thermal performance of the lake and is impacted by the amount of water that is sold off to the water utility. Data showing historical water sell off rates to the local water utility were provided. Information on the lake elevation was provided.

LOE was modeled using S&L's LakeT software. Since LOE has an irregular shape and the power plant thermal plume is located in a small section of the lake, an obvious solution was not presented by the software tool. Engineering judgment and trends from the model and actual data were used to propose a solution.

With the current configuration of the lake and with the established weather data several problems are evident. The lake is operating at temperatures above NPDES permit levels during the summer months. From conversations with SIPC it was also discovered that the current units at Marion have to be derated in the summer due to high circulating water inlet temperatures causing excessive steam turbine condenser back pressures. Additionally, S&L report SL-010308 address other factors that contribute to plant derating including biofouling/scaling of the condenser tubes.

The most effective alternative for obtaining additional heat rejection from the existing units and any additional source of heat load would be to install a closed-cycle cooling tower at the site. The cooling tower proposed is a full size tower to handle the heat rejection for existing units 123 and 4. The tower would take load off of the lake in the summer months when the high temperatures become an issue. However, a cooling tower may reduce water levels depending on the design.

Based on observations and after analyzing the recorded historical temperature data it is clear that the lake currently cannot support additional heat load or water removal nor can it operate at the current thermal limits set forth in its NPDES permit without implementing alternative cooling technologies. As a minimum SIPC should seek relief from the existing permit limits to maintain operability with the lowest cost impact.

II. Introduction

Sargent & Lundy (S&L) was authorized by Southern Illinois Power Cooperative (SIPC) to perform an investigation of the water temperatures in the Lake of Egypt (LOE) in southern Illinois. Marion Generating Station, situated on the northwest shore of LOE uses the lake for once-through cooling. The purpose of this report is to study changes to the use of LOE and their subsequent impacts on Marion Generating Station, including plant generation capacity and thermal discharge limits. The following three items will be reviewed as part of this report:

1. Examine impacts of adding additional head load on LOE.
2. Explore effect of withdrawal of additional water from LOE.
3. Investigate methods to obtain additional cooling.

This study does not include the following information:

1. Permitting of the lake usage
2. Detailed design
3. Detailed cost
4. Environmental impact
5. Project schedule (defined during detailed engineering)

The Marion Generating Station is located on LOE, 6 miles south of Marion, IL at an approximate elevation of 510 ft AMSL. The lake is approximately 99,316,800 square feet, has an average depth of 18 feet and a maximum depth of 52 feet. The Marion Power Station consists of two coal fired units (units 123 and 4) which use once-through cooling on LOE and generate a combined nominal output of approximately 300 MW for the two units. Unit 123 consist of 3 similar nominal 40 MW steam turbines fed by a common CFB boiler and Unit 4 is a 173 MW steam turbine fed by a separate CFB boiler. Units 5 and 6 are combined cycle units that use a cooling tower and do not utilize once-through cooling.

LOE is constructed with a dike that provides a flow path for warm discharge water to allow for a greater duration of mixing, evaporative cooling and convective heat dissipation before being recirculated back to the plant and prevent “short-circuiting” the lake. An aerial image of the lake near the plant along with existing dike is shown in Attachment 6.

The current discharge temperature monthly average and peak limits at the edge of the 26-acre mixing zone adjacent to the plant discharge are established in the station’s NPDES permit. Those limits are shown below:

> Water temperature at representative locations in the lake shall not exceed the maximum limits in the following table during more than one (1) percent of the hours in the 12-month period ending with any month. Moreover, at no time shall the water temperature at such locations exceed the maximum limits the following table by more than 3 F (1.7 C).

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
60	60	60	90	90	90	90	90	90	90	90	90

LOE was modeled using Sargent & Lundy's LakeT software. LakeT assumes a fully mixed one-dimensional lake that progresses from the plant discharge to the plant intake. Due to its depth and configuration, LOE is stratified and the intake structure takes in water at a depth of about 25 ft, which allows the plant to take in cooler water than what is at the surface or what the temperatures would be if it were fully mixed. If the water were drawn in at a lower elevation than the current intake structure is capable of, this would help to lower the intake water temperatures. However, the water is approximately 28 feet deep near the intake so drawing water in from a lower elevation is not an option as solids would be pulled into the circulating water system. Due to the limitations of the software tool, an obvious solution was not available and an estimation of the expected lake performance was made based on the trends in the model and actual data. It was not possible to locate the stratified thermal layers of the lake. Engineering judgment was used in order to make recommendations of several alternatives for the use of LOE for additional cooling needs and water sales.

The report is organized as follows:

1. Lake of Egypt level modeling
2. Discussion of input data.
3. LakeT Model Results
4. Alternatives
5. Conclusions

III. Lake of Egypt Water Level

Various sources of water inflows and outflows into and out of the Lake of Egypt were analyzed to produce predicted lake levels for several scenarios. The LOE inflows, explained in detail below in Section III-A, include drainage runoff into the lake from the surrounding land area and direct precipitation into the lake. The LOE outflows, detailed in section III-B, include seepage from the lake, natural evaporation off the surface of the lake, forced evaporation off the surface of the lake, cooling tower make-up from the lake for both the existing and new units, Marion Plant discharge into Saline Creek, Flue Gas Desulfurization (FGD) System water usage, and sell-off water to the local water municipality.

Average monthly lake levels for the Lake of Egypt, both with and without additional heat load, were represented in two line graphs, labeled Figure 1 and Figure 2, respectively, and included with this report as part of Attachment 7.

Figures 1A and 2A, in Attachment 7, represent the average monthly level of the Lake of Egypt during a drought year, both with and without additional heat load. Data from 1988 was used for this drought case. The next set of graphs, presented as figures 1B and 2B in Attachment 7, show the average monthly level during a recovery year immediately following the drought year. In this case, average monthly values, as shown in Figures 1 and 2, were used to model the recovery of the lake after this year of drought. This was done by setting the initial lake level in January in Figures 1B and 2B equal to the lake level at the end of December during the drought year shown in Figures 1A and 2A.

Figures 1C and 2C, in Attachment 7, show an extreme two-year drought period with and without additional heat load. This drought period was modeled to closely reflect the drought that was present in 1953 and 1954 in the area that would later become the Lake of Egypt. The average lake levels during the recovery year after two years of extreme drought at the 1953-1954 levels are shown in Attachment 7 as Figures 1D and 2D, both with and without additional heat load at Marion, respectively. These recovery graphs were also calibrated by setting the initial January lake levels in Figures 1D and 2D equal to the lake levels at the end of December shown in Figures 1C and 2C.

A. Lake of Egypt Water Inflows

1) Drainage Runoff into the Lake

The Lake of Egypt has a surrounding drainage area of 34.1 square miles. This area estimation was found in the “Summary Report Southern Illinois Power Cooperative Lake of Egypt Water Yield Analysis” (Reference 3), and was used to determine the runoff flow into the lake. The drainage area is the area of land surrounding the lake upon which the rainfall will collect and flow into the lake.

Flow values for drainage runoff into the Lake of Egypt were estimated based on the U.S. Geological Survey (USGS) stream flow records for Crab Orchard Creek near Marion, Illinois. Crab Orchard Creek is located approximately nine (9) miles from the Lake of Egypt and has a drainage area of 31.7 square miles. Stream flow records were available starting in 1951 until 2006. The data obtained from the USGS was scaled by the ratio of the drainage areas of the two waterways.

Drainage runoff for the average conditions used to develop Figures 1, 1B, 1D, 2, 2B, and 2D was taken from the average values for all the years between 1951 and 2006. The drought years shown in Figures 1A and 2A used drainage runoff data from 1988, while data from 1953-1954 was used to develop the extreme two year drought models shown in Figures 1C and 2C.

2) Direct Precipitation into the Lake

Monthly total water equivalent precipitation data, in inches, was obtained from the National Oceanic and Atmospheric Administration (NOAA) for this study. The Marion Illinois Cooperative Climate Station was used as the source of precipitation data for July 1948 to December 1955. The Marion 2 W Illinois Cooperative Climate Station was the source for data from January 1956 to December 1963, and the Marion 4 NNE Illinois Cooperative Climate Station was the source from January 1964 to April 1998, with the exception of March 1997. Precipitation data for March 1997 and May 1998 to December 2005 was obtained from the Dixon Springs Illinois Cooperative Climate Station.

These monthly total water equivalent precipitation values, in inches, were then converted to millions of gallons per day (MGD). This conversion was done by assuming that the Lake of Egypt will absorb all rain falling on its surface area of 99,316,800 square feet at the maximum lake elevation of 500 feet, even when the lake is not at that elevation. This is contingent on the assumption that all precipitation falling on land exposed due only to a decreased lake level runs down into the lake without absorbing into the ground or evaporating off into the atmosphere.

Direct precipitation values for the average conditions used to develop Figures 1, 1B, 1D, 2, 2B, and 2D were taken from the average values for all the years between 1948 and 2005. Figures 1A and 2A used precipitation data from 1988, while data from 1953-1954 was used to develop the two year drought models shown in Figures 1C and 2C.

B. Lake of Egypt Water Outflows

1) Seepage from the Lake

Seepage water loss is difficult to measure, so a constant value of 7 cfs, which was found in the “Summary Report Southern Illinois Power Cooperative Lake of Egypt Water Yield Analysis” (Reference 3), was converted to 4.52 MGD and used for all Figures found in Attachment 7. This value is typical for a lake of this size and type.

2) Natural Evaporation from the Lake

Natural evaporation is the evaporation from the lake at the natural lake temperature. Natural evaporation was estimated based on pan evaporation data supplied by the Illinois State Climatologist Office for the Dixon Springs, IL area. Natural lake evaporation was taken as 75% of the pan evaporation to account for the additional heat added by the sun through the metal sides of the pan. Data was available for the years from 1983 and 2002.

Evaporation values for the average conditions used to develop Figures 1, 1B, 1D, 2, 2B, and 2D were taken from the average values for all the years between 1983 and 2002. Figures 1A, 1C, 2A, and 2C used precipitation data from 1988. Data from 1953-1954 was not available to develop the two year drought models shown in Figures 1C and 2C.

3) Forced Evaporation from the Lake

Forced evaporation is the increase in evaporation over natural levels due to the rise in water temperature from the influences of the plant. For purposes of this study, forced evaporation off the LOE was set equal to the estimated make-up water levels that would be required for a cooling tower at Marion. Based on input from cooling tower vendors, this flow rate was set at 1.5% of total cooling water flow. This was done for all Figures included as part of Attachment 7.

4) Cooling Tower Make-Up Flow

If a cooling tower was installed to provide cooling water to the existing or additional head load, water from the Lake of Egypt would be used to provide make-up water to the cooling tower to account for water losses from evaporation and drift. Cooling tower blowdown, which is defined as water discharged from the tower in order to control the concentration of solids within the circulating water, could be discharged directly back to the lake (Reference 4). This enables the evaluation to neglect the effect of cooling tower blowdown on the lake level analysis. Cooling tower make-up flow was set at 1.5% of total cooling water flow, based on input from cooling tower vendors. Cooling water flow was defined by data provided by Marion Plant on existing unit monthly operations between the years 1984 and 2006. The existing unit cooling water flow was then scaled by the ratio of the capacities of the existing and new heat load to estimate the cooling water flow and make-up water flow for the new operation.

5) Marion Plant Discharge into Saline Creek

Actual measured monthly values of the discharge flow rate from Marion Plant into the Saline Creek were provided for the years 1984 - 2006. To account for the effects of runoff from rainfall onto the Marion site, data from the month of October 1994 was multiplied by 1.5 to obtain 1.985 million gallons per day. This number was used as an average monthly value for all Figures included in Attachment 7. October 1994 was chosen because it was a month with both low precipitation and low overall discharge into Saline Creek, which would most accurately represent the actual loss of water from the plant into the creek. A margin of 50% was added for conservativeness.

6) Flue Gas Desulfurization (FGD) System Usage

FGD usage was estimated based on S&L’s previous experience on FGD Retrofit projects. A value of 0.4 million gallons per day was chosen after examination of water balances from other projects and comparison of total plant capacities. All Figures in Attachment 7 used 400,000 gallons per day as an input.

7) Sell-Off Water

A sell-off rate of one million gallons per day was used as the existing rate from the Lake of Egypt. Each Figure in Attachment 7 includes two lines, one of which represents this existing one million gallons per day sell-off rate. This value was based on monthly meter readings from water purchased by the Lake of Egypt water district between 2002 and 2006. To represent an increased sell-off rate, each Figure in Attachment 7 also includes a line which shows the lake level with a two million gallon per day sell-off rate and all other water inflows and outflows held equal.

IV. Input Data

A. Weather Data

Approximately fifty years of the historical weather data spanning from 1948 to 2005 was collected from one of the first-order weather station sites (stations with data recorded regularly and with the most detail). Observed ("raw") meteorological data were used to develop the meteorological data input file for LakeT. Raw data were purchased from the National Climatic Data Center (NCDC) for locations located near LOE. Separate digital files were obtained for surface weather observations and precipitation data. Those files are described below.

1. Surface Weather Observations

Surface weather data used for this analysis were collected at the Evansville, IN Dress Regional Airport. Evansville is approximately 80 miles east-northeast of the plant site. In terms of latitude, Evansville is approximately 25 miles north of the plant site, making temperatures at Evansville slightly cooler than those at the plant site. However, the Evansville station is also located approximately at an elevation that is 100 ft lower than the plant site, making temperatures at Evansville slightly warmer than those at the plant site. Slight temperature differences arising from differences in latitude and elevation between Evansville and the plant site are expected, on the average, to offset.

Insignificant east west-direction (longitudinal) temperature and humidity differences are expected between the plant site and Evansville due to their location in a region where east-west temperature and humidity gradients are slight. Humidity differences arising from differences in elevation between Evansville and the plant site are insignificant because both locations receive moisture from the Gulf of Mexico. Gulf moisture in the region is typically in a layer several thousand feet deep above the surface - far above the elevations of Evansville and the plant site. Therefore, Evansville temperature and humidity data were considered representative of the plant site.

The meteorological station at Evansville is located on a slight topographic rise adjacent to the Ohio River. The meteorological station is not situated in an incised valley, deep river bottom, or other terrain feature that would feature drainage (gravity-driven) airflows. The station is located in a slightly hilly area with several small lakes. The lakes are not large enough to significantly modify wind and other meteorological parameters. Similarly, the station is also not located in an incised valley, or other terrain feature, that would modify wind and other meteorological parameters. Therefore, local terrain influences are not expected to render Evansville wind data unrepresentative of winds at the plant site. Those data included the period of record 1948-2005 (Reference 1). This period was sufficiently long to capture a number of drought years, including a well-known dry period during the early 1950s.

NCDC subjects meteorological data to rigorous quality control checks before archiving it. Nevertheless, databases still typically include gaps and data values outside of valid ranges. The archived data included most of the weather parameters required by LakeT, with the following exceptions: freezing precipitation code, solar radiation, atmospheric radiation, and partial pressure of water vapor. S&L estimated those parameters using standard methods. Additionally, S&L estimated hourly wet bulb temperature and dew point temperature to ensure consistency between the following parameters: relative humidity and dry bulb temperatures. The wet bulb and dew point temperature depend on the relative humidity of the air. When the air is saturated the wet bulb and dew point temperatures are equal and the dew point temperature drops lower when air is not saturated. These two temperatures are necessary for the evaporation model in LakeT.

2. Precipitation Data

   Hourly precipitation data used for this analysis were collected at the Dixon Springs Agricultural Station in nearby Pope County, IL. The Dixon Springs Agricultural Station was selected because it was closer to the Project location and located at nearly the same elevation. There are no significant terrain features between the Dixon Agricultural Station and the Project site that would drive precipitation processes; therefore, precipitation data from the Dixon Agricultural Station are considered to be representative of the Project site. These data covered the period of record 1948 through 2006 (Reference 2).

After S&L arranges the data into a format that is useable by the LakeT software, the data is passed through a rigorous review to determine where periods of missing or bad (out of range) weather data are located. Once this is complete, the data is adjusted and corrected using linear interpolation in order to replace the bad data and fill in the gaps where there is missing data.

B. Summary of LakeT Input Values

SIPC provided daily and monthly plant intake and discharge temperature data and average/maximum circulating water flow rates for both units for several years. Recorded average discharge temperatures at the edge of the mixing zone were provided for a fifteen (15) month period between January 1984 and March 1985 (Attachment 5). Historical data for the water sales to the water utility were also provided.

A continuous lake blow down was used to model the seepage and other water losses associated with the lake other than evaporation losses (explained in section IV, B). Seepage water loss is difficult to measure, so a value of 7 cfs, which was found in the "Summary Report Southern Illinois Power Cooperative Lake of Egypt Water Yield Analysis" (Reference 3) was used. This value is typical for a lake of this size and type.

The lake capacity data for lake area and volume versus lake level were based on the Area- Capacity Curve produced by Burns & McDonnell Engineering Company 1960, provided by SIPC (Attachment 1). The minimum lake elevation is 485 ft Above Mean Sea Level (AMSL), based on the limitations of the circulating water pumps. However, due to alternate uses of the lake, the elevation should not drop below 497 ft AMSL. Based on the Water Shed Soil Association map E-127.1 provided, the lake effective length was determined by estimating the flow path through the lake from the discharge to the inlet. The lake drainage area surrounding the lake of 34.1 square miles which was found in the "Summary Report Southern Illinois Power Cooperative Lake of Egypt Water Yield Analysis" (Reference 3) was used to determine the runoff flow into the lake. The drainage area is the area upon which the rainfall will collect and flow into the lake. No additional makeup sources feed the lake; it is completely dependant upon the runoff in order to maintain elevation.

The lake area and volume effectiveness percentages were adjusted in order to calibrate the model to match the actual plant data provided. Area and volume effectiveness values are adjusted separately according to the percentages of the total area and volume that are actually effective in plant heat rejection, which is approximately 10% of the lakes surface area.

The LakeT inputs for the base case are summarized in the Table below.

Parameter	**Value**
Weather Data Range	1/1/1948 – 12/31/2005
Fresh/Salt Water	Fresh
Seepage Rate (cfs)	7.0
Approximated Lake Length (ft)	4,563
Maximum Design Lake Elevation (ft AMSL)	500
Minimum Lake Elevation (ft AMSL)	485
Preferred Minimum Lake Elevation (ft AMSL)	497
Dam elevation (ft AMSL)	510
Spillway Elevation (ft AMSL)	500
Sell off Water from Lake (cfs)	Variable
Makeup to Lake (cfs)	0
Existing Plant Flow (cfs)	450
Nominal Condenser Temperature Rise (°F)	17
Extra Precipitation Area for Drainage into Lake (sq. mile)	34.1

V. LakeT Model Results

A. Modeling the Lake and Comparison to Actual Plant Data

LOE is an existing operating cooling lake with recorded historical temperature, circulating water flow and lake elevation data, the model was adjusted in order to match this data. The first step was to measure the assumed flow path that the water takes from the plant discharge to the plant intake. This task was accomplished by measuring the distance for an approximated path out from the discharge into the lake past the end of the dike and then gradually looping back toward the intake again. A key element in the model is the digitized Area-Capacity Curve (see Attachment 1) for the area and volume along with the effective area and volume with respect to the lake elevation. The effective area and volume is adjusted in order to reduce the total area and volume to model what is actually being used for cooling the power plant.

Several variations were made to replicate the actual plant temperature data provided. As the effective area was increased, the ability of the lake to dissipate heat increased but at the same time the surface area affected by solar radiation and ambient temperatures increased causing the natural lake peak temperatures to increase in the summer and valleys decrease in the winter. As the effective volume was increased, fluctuations between warmer and cooler natural lake temperatures were reduced since the lake has more volume therefore it takes longer for the changes to occur. This trend shows that the lake is most effective at cooling the plant using the surface area while volume helps to maintain the cooling capacity in times of draught and/or hot ambient conditions.

Due to the trends seen in the recorded historical data and the model results, the lake is operating at temperatures above NPDES permit levels during the summer months with the current power plant and once-through configuration. In a conversation with SIPC, it was noted that the current units at Marion have to be derated at times due to the high circulating water temperatures which cause high steam turbine condenser back pressures. This fact is further proven by the actual measured water temperatures at the plant intake in the middle summer months. The temperatures peak out near 90°F at a depth of 25 ft below the water surface. Even though the lake is stratified, the high temperature water is migrating to the depths of the lake because of the short path through the lake to cool the water before returning to the plant. Because of the trends in the actual data and what the model showed, the most effective use of the lake would be if 40% of the lake surface area was utilized for the flow path. The limitations of the software tool did not provide an obvious solution. However, our analyses and engineering judgment allowed us propose four alternatives in order to increase the effective cooling capacity of the lake or reduce thermal load on the lake.

B. Cooling Process

The cooling tower has 3 modes of water loss, evaporation, drift and blowdown. Evaporation loss is defined as the water evaporated from the circulating water into the air stream in the cooling process within the cooling tower (Reference 4). Drift is defined as circulating water lost from the tower as liquid droplets entrained in the exhaust air stream (Reference 4). Blowdown is defined as water discharged from the tower in order to control the concentration of solids within the circulating water (Reference 4). The blowdown could possibly be returned to the lake after treatment, which would reduce the water losses to evaporation and drift only.

The lake has 3 modes of water loss, natural and forced evaporation and seepage. Natural evaporation is defined as the evaporation from the lake at the natural lake temperature. Forced evaporation is defined as the increase over natural evaporation caused by the influence of a plant. Based on the LakeT model the forced evaporation from the existing units on the lake is approximately 35% of the natural evaporation (based on the heat rejection from a 300 MW plant). Seepage is defined as the water loss through the bottom of the lake and around the dam. The amount of water coming into the lake is significantly larger than what is leaving the lake. If the lake were not used for once-through cooling, the forced evaporation would go to zero.

However, the cooling tower will require more water in terms of makeup than the lake is losing in forced evaporation so the water sales can not be increased and may need to be decreased if SIPC decides to implement a cooling tower technology. With the use of a cooling tower, solar radiation is not a factor as it is in the cooling lake. The cooling lake receives excess heating load from the solar radiation that the cooling tower does not, which shows that the cooling tower would be more effective. Even though the cooling tower would require more water than the lake is losing to forced evaporation currently, the cooling tower will be more effective at maintaining lower steam turbine backpressures in the summer months. This would allow SIPC to generate more power in the summer when it is needed most.. It is anticipating that implementing a cooling tower would allow the plant to operate at full load throughout the summer months and would avoid the need for derating.

Table showing estimated cooling tower and the estimated lake water losses based on the current 300 MW plant.

Cooling Tower	Estimate
Evaporation loss (gpm)	3,300
Drift (gpm)	100
Blowdown (gpm)	1,100
Required Makeup (gpm)	4,500
with blowdown to lake (gpm)	3,400

Lake	Estimate
Natural Pan Evaporation (gpm)	4,400
Forced Evaporation (gpm)	1,540
Seepage (gpm)	3,200
Runoff from 34.1 sq. miles (gpm)	171,000

VI. Evaluated Alternatives

Based on the available information we have concluded that the lake can not support additional heat load and/or water withdrawal without modifications. Furthermore, the plant can not maintain compliance with the existing NPDES thermal limits without derating or additional cooling technologies. We propose several alternatives and discuss the relative cost and technical feasibility of each.

A. Relocate the Intake Structure

Move the intake further south, to the end of one of the fingers on the lake to better utilize the lake. Note that the intake structure will need to be located in deep water such that the plant draws in the coolest possible water. Estimates from engineering judgment based on the results from the LakeT software show that the effective area of the lake would have to be increased roughly 40%. This could be done by relocating the intake structure roughly 17,000 feet from the plant in the 25 ft deep portion of one of the fingers (Attachment 2).

Advantages

1. More effectively use the area and volume available in the lake to cool the circulating water before it returns to the plant.
2. Help to reduce the circulating water temperatures in the summer months thus reducing the condenser back pressures and increasing power output.
3. Does not significantly alter plant O&M costs.

Disadvantages

1. This alternative would have a capital cost of approximately $17 million (2007$), as it would require long lengths of circulating water piping, a new intake structure and circulating water pumps.
2. Land purchase or right of way issues at the site of the new intake structure and easement issues in the area between the plant site and the new intake structure.
3. May not reduce temperatures at the edge of the mixing zone enough to comply with current thermal limits year round.
4. Permitting and various environmental issues could be raised with the new intake structure and additional use of the lake.

Summary

Relocating the intake structure would require a substantial amount of capital investment and present many challenges to purchase land or gain easement rights for the new intake pipeline. This approach may not effectively reduce the peak temperatures seen at the edge of the current mixing zone, and the plant could still faces issues in meeting current permit levels if the existing discharge is used with an added heat load to the lake. This proposed option has a high capital cost and although relatively no change to O&M costs, would most likely result in insufficient payback to justify implementation with the current heat load.

B. Extend the Dike further into the Lake

Extend the dike further out into the lake in order to better utilize the lake. Estimates from engineering judgment based on the results from the LakeT software show that the effective area of the lake would have to be increased roughly 40%. This could be done by extending the dike 3 miles into the lake (Attachment 3).

Advantages

1. Similar to relocating the intake structure by more effectively using the area and volume available in the lake to cool the circulating water before it returns to the plant, but without the issues of relocating the intake structure.
2. Help to reduce the circulating water temperatures in the summer months thus reducing the condenser back pressures and increasing power output.
3. No changes would be necessary for the existing intake/discharge arrangement.
4. Has negligible impact on current plant O&M costs.

Disadvantages

1. The estimated order of magnitude capital cost for this alternative is $100 million (2007$). An alternative to building the dike extension would be to use curtains suspended by floating cables. This would reduce the cost; however the other disadvantages would have to be addressed.
2. It may create issues with permitting.
3. This would be an alternative that would allow the use of the current intake/discharge configuration. Like Alternative A above, the mixing zone temperature and area limits may still be an issue with the additional heat load on the lake.
4. Will cause major issues with boaters and people who have homes on the lake. The current large open body of water would be divided by the dike, creating issues with water skiing patterns, fishermen and the general boating public. The dike will be unattractive to home owners with a view of the lake.

Summary

Extending the existing dike by means of a permanent structure requires a large capital investment and has potential thermal advantages very similar to those suggested by relocating the intake structure. The permanent dike would not provide sufficient payback to justify it’s installation and it does not provide a sufficient advantage over other technologies discussed to warrant implementation.

Using a curtain to divide the lake in a manner similar to the extended dike is another option that could present a sizable cost savings. S&L does not have experience with this technology; therefore, availability, cost and effectiveness are not known. It is foreseen that such a modification to the lake would create significant regulatory hurdles and would substantially reduce the lakes usefulness to the general public. Using a suspended curtain as a dike is relatively untested and would create permitting issues and require additional research to determine effectiveness, constructability, lifespan and capital and O&M cost.

C. Install Fountain Spray Cooling Modules

Install Fountain Spray Cooling (FSC) modules near the intake to aid in lowering the intake water temperatures.

Advantages

1. Increase the effective surface area of the cooling lake with the current arrangement.

Disadvantages

1. There is no good method to predict the performance of this system.
2. No guarantee that the temperatures will be reduced.
3. There have been failures of other similar systems in the past.
4. Generally FSC modules have a low effectiveness due to the inability to atomize the water well enough to increase the evaporative cooling.
5. Cooling performance is drastically reduced on days with little wind, high humidity and high ambient temperatures.
6. Like alternatives A and B, this may not be a good alternative if additional heat load is added to the lake using the existing intake/discharge configuration because the mixing zone temperature limits may become an issue.

Summary

No capital or O&M costs were explored for the FSC modules as this technology offers no promise of effectively reducing the lake temperatures. Generally these units have been relatively ineffective due to their inability to atomize the discharge sufficiently for evaporative cooling. Several failures of like systems have been recorded throughout the industry. Because of their unproven performance and the great uncertainty associated with their payback, installation of FSC modules to support new generation or improve existing heat load dissipation is a large economical risk with potential for no return.

D. Install a Cooling Tower

Install a cooling tower at the site to aid the cooling lake in the summer and help with additional heat load. Further study is necessary to determine the location, type and size depending on the choice of the location for the new unit. The cooling tower could be either a full size tower to handle the full heat rejection or a smaller helper tower that could be place in series with the once-through water system to help lower the water temperatures before or after passing through the lake. The tentative location of the cooling tower to handle the full heat rejection from the existing units 123 and 4 is shown in Attachment 4. Further study is required to determine the amount of load placed on the cooling tower versus what load would be placed on the cooling lake.

Advantages

1. The estimated capital cost for a full-sized cooling tower is approximately $11 million (2007$), which is less than the previously discussed alternatives that allow for use of a larger area of the lake. Note that this cost is for a mechanical draft cooling tower sized to cool the existing units 123 and 4 and would eliminate any need for the plant to derate because of NPDES limits.
2. The cooling tower could be used in the summer months to help with the high water temperatures and then shut down in the winter when the plant is operating at lower loads and cooler ambient conditions help keep the lake water temperatures lower.
3. Discharge permit levels for the cooling lake would not include the summer months when the cooling tower is in operation.
4. The cooling tower could be placed into service only when discharge temperature levels reach their maximum allowable limits to avoid derating.

Disadvantages

1. Higher auxiliary power in the summer months, due to operation of several large fans and more circulating water pumping power required to pump the water to the higher elevation in the cooling tower.
2. The cooling tower would use area at the power plant site that may be set aside for future use.
3. A cooling tower creates environmental issues such as noise and drift.
4. The water sale flow rates may have to be reduced depending on the cooling tower design.
5. Water treatment may be required for cooling tower blowdown prior to retuning it to the lake.

Summary

The addition of a cooling tower to support new generation or improve the effectiveness of the existing cooling system is the most proven technology presented. However, installation of a cooling tower will require a relatively large capital cost investment of $11 million (2007$), and it is the only technology discussed with a significant increase in O&M cost and auxiliary power consumption. During the summer months when lake temperatures reach their allowable permit limits, the cooling tower would be operational to reduce load on the lake. However, the additional auxiliary power consumption to operate the cooling tower offsets any additional savings that would result from not having to derate the unit to maintain lake temperatures. Due to its relatively high capital and O&M cost, the cooling tower is not an economically viable alternative for reducing current lake heat loads. This technology should however be explored further if new generation is desired as it could be the most practical of the options presented. (See S&L report SL-010308 for economic analysis)

E. Alternate Thermal NPDES Permit Limits

Although the current discharge arrangement is not capable of dissipating additional heat load using LOE, Marion Power Station should considering revising their thermal discharge limits to meet current plant operation. Based on plant operational data, the following revised NPDES limits would allow the plant to continue operating without derating beyond current plant limitations:

> Lake temperatures at the edge of the mixing zone shall not exceed the following maximums as a monthly average: 80°F from December through March; 95°F in April and November; 100°F in May and October and 102°F from June through September.
>
> Lake temperatures at the edge of the mixing zone shall not exceed the following maximums for more than two percent of the hours during that period: 89°F from December through March; 102°F in April and November; 108°F from May through October.

Advantages

1. Will allow the station to continue operating without derating beyond plant limitations.
2. No additional capital or O&M costs associated with revised limits.
3. Does not restrict public use of lake.
4. Will not substantially reduce water sales or lake levels.

Disadvantages

1. Does not reduce current discharge temperatures.
2. Will not allow for additional heat load on LOE.
3. Does not eliminate need to derate because of high turbine backpressure.

Summary

The proposed revised NPDES permit limits allow the plant to maintain its current operation without incurring additional O&M or capital costs. Although it is known that plant is currently forced to derate in the summer months because of high turbine backpressure, these revised limits will prevent further reduction. It is recommended that as a minimum SIPC seek relief from the existing permit limits to maintain operability with the lowest cost impact.

VII. Conclusions

Marion Generating Station currently uses LOE as a sole means for cooling a nominal 300 MW facility via a once through cooling system. With the current arrangement of the cooling lake intake, discharge and dike approximately 10% of the available lake surface area (at 500 ft. AMSL) is being used for cooling the plant. As a result the plant has experienced a loss in generation capacity in the summer months when the units are derated due to high circulating water temperatures. Assuming a lost output of 5MW for 12 hours per day over three summer months at a cost of $35/MWh, the potential economic loss due to derating the unit is approximately $226,000 per year. (SL-010308)

LOE is at capacity using the current once through cooling arrangement. If heat load is added to the lake or additional amounts of water are sold without cooling modifications, the plant will see increased lake temperatures resulting in higher circulating water temperatures thus creating higher turbine backpressure and further derating the station.

Based on the evaluation of potential modifications to the Marion Generating Station, revising the NPDES permit limits can provide the adequate relief required to operate the existing units without addition of the discussed technologies. If additional heat load beyond Units 123 and 4 is sought, further economical and engineering feasibility analyses should be completed to ensure the best possible cooling technology or combination of technologies is selected. Revising the thermal limit for LOE will accommodate generation needs without derating the existing units beyond current plant limitations.

OPTION		TECH. FEASIBLE	CAPITAL (2007$)	O&M (2007$)	OPERATE PLANT AT FULL CAPACITY	CAPACITY FOR ADDITIONAL HEAT LOAD / WATER SALES
A	Relocate Intake	Yes	$17 Million	$0	Yes	Yes / Yes
B	Extend the Dike	Yes	$100 Million	$0	Yes	Yes / Yes
C	Fountain Spray Modules	No	N/A	N/A	No	No / No
D	Cooling Tower	Yes	$11 Million	~$226k / yr	Yes	Yes / Unknown
E	Revise NPDES Limits	Yes	$0	$0	No	No / No

VIII. References

1. National Climatic Data Center (NCDC), "TD 3280 - Airways Surface Observations", Surface weather observations in TD 3280 digital format from 1948-2005, for NWS-Evansville, IN. Data purchased from NCDC, Published by NCDC, Asheville, NC, 2004.

2. National Climatic Data Center (NCDC), "TD3240 Precipitation Data, Hourly", Dixon Springs Agricultural Station, Illinois. Data purchased from NCDC, Published by NCDC, Asheville, NC, 2004.

3. Reynolds, Smith and Hills Architects. Engineers. Planner, Inc., "Summary Report Southern Illinois Power Cooperative Lake of Egypt Water Yield Analysis", AEP 79-141-003, November 12, 1979.

4. The Marley Cooling Tower Company, "Cooling Tower Fundamentals", 2nd edition, 1985.

IX. Attachment 1

Area-Capacity Curve produced by Burns & McDonnell Engineering Company 1960, provided by SIPC

REPORT ON
COOLING WATER SUPPLY
SOUTHERN ILLINOIS POWER COOPERATIVE, INC.

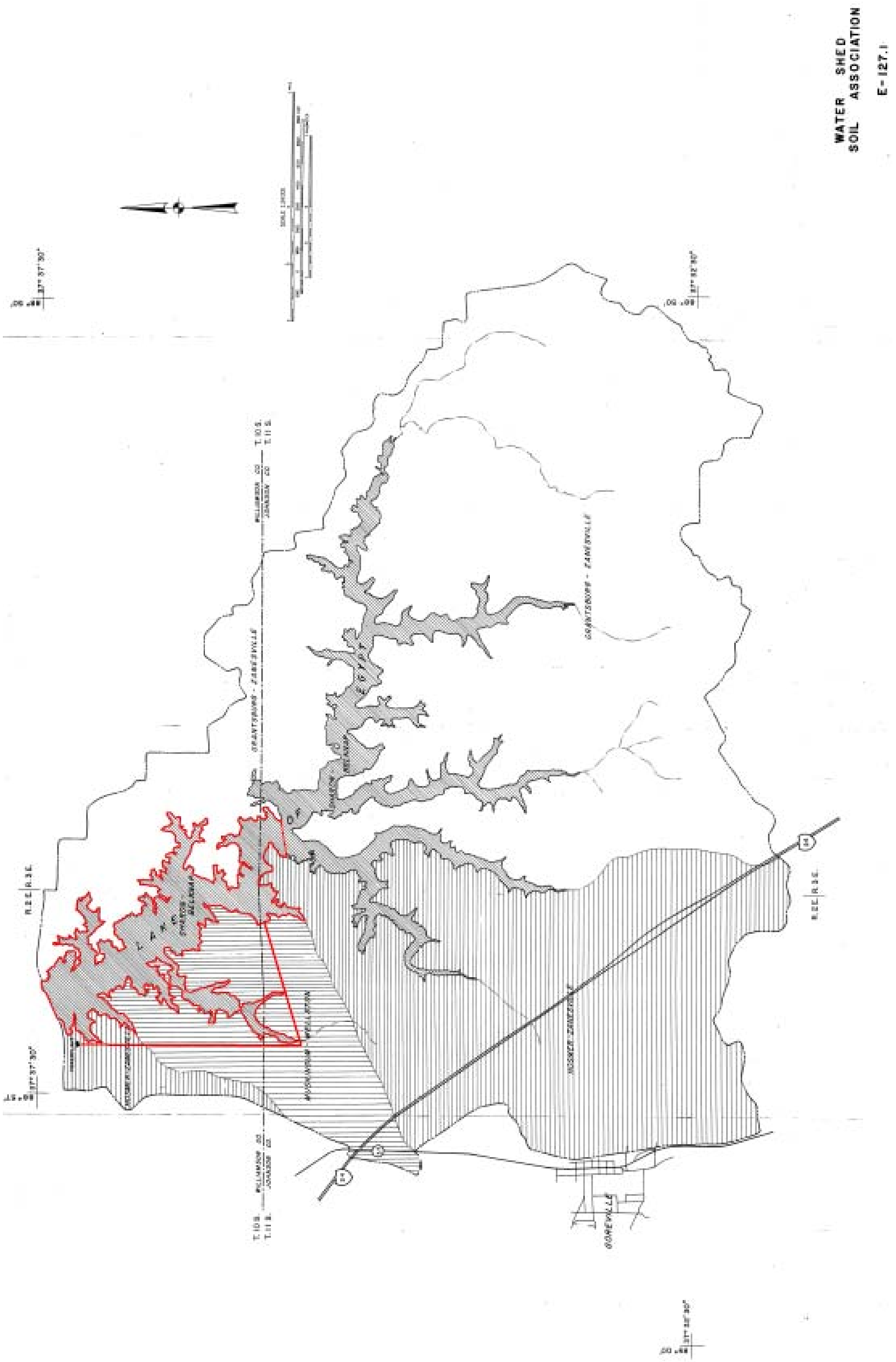
Area Capacity Curve

BURNS & McDONNELL ENGINEERING COMPANY
KANSAS CITY MISSOURI
1960

60-702 EXH. NO. 2

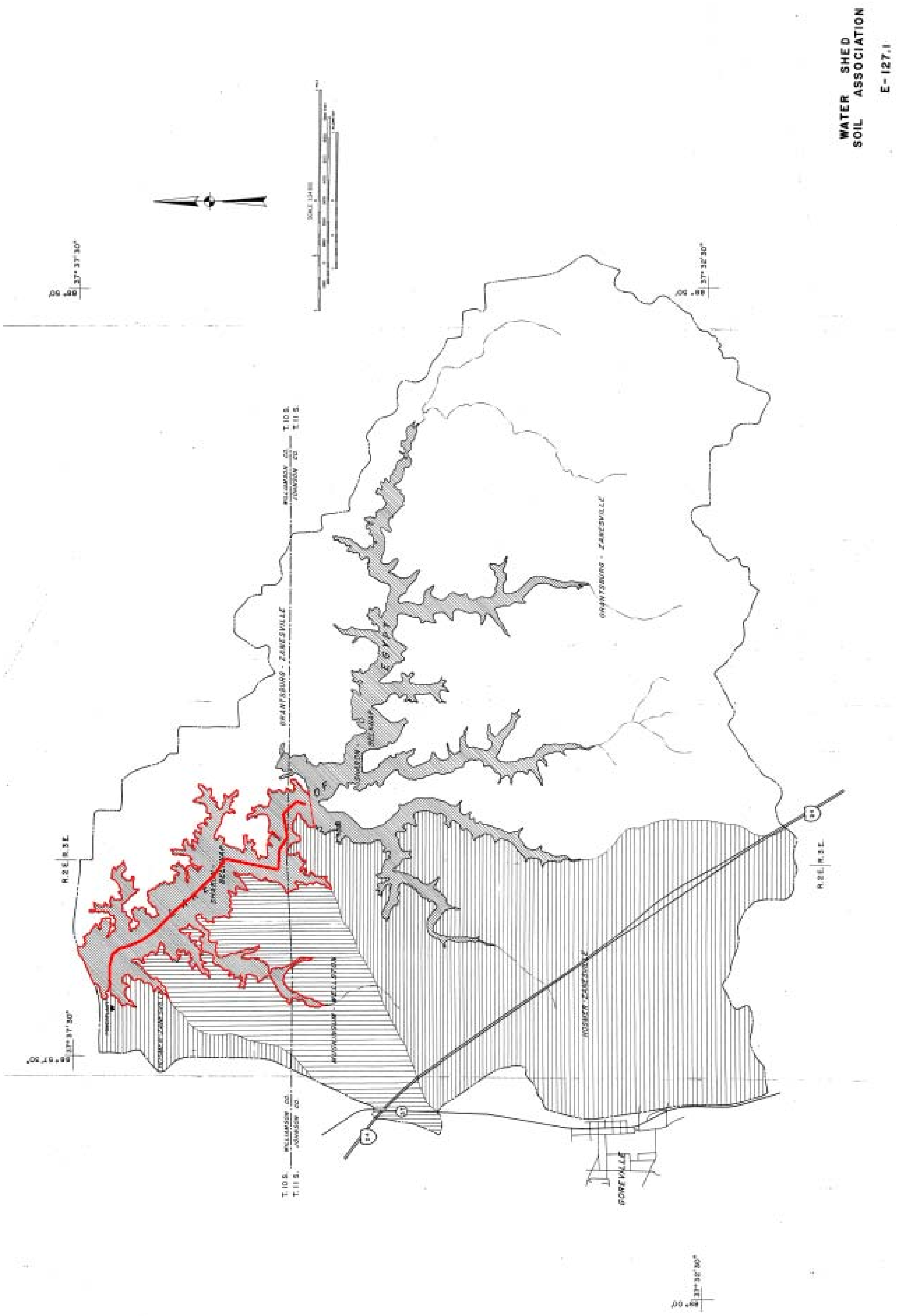
X. Attachment 2

Sketch showing the relocated intake structure location drawn on the Water Shed Soil Association Drawing E-127.1 provided by SIPC.


WATER SHED
SOIL ASSOCIATION
E-127.1
LAKE OF EGYPT
GRANTSBURG - ZANESVILLE
HOSMER - ZANESVILLE
GOREVILLE
WILLIAMSON CO.
JOHNSON CO.
T.10 S.
T.11 S.
R.2 E.
R.3 E.
37° 37' 30"
37° 32' 30"

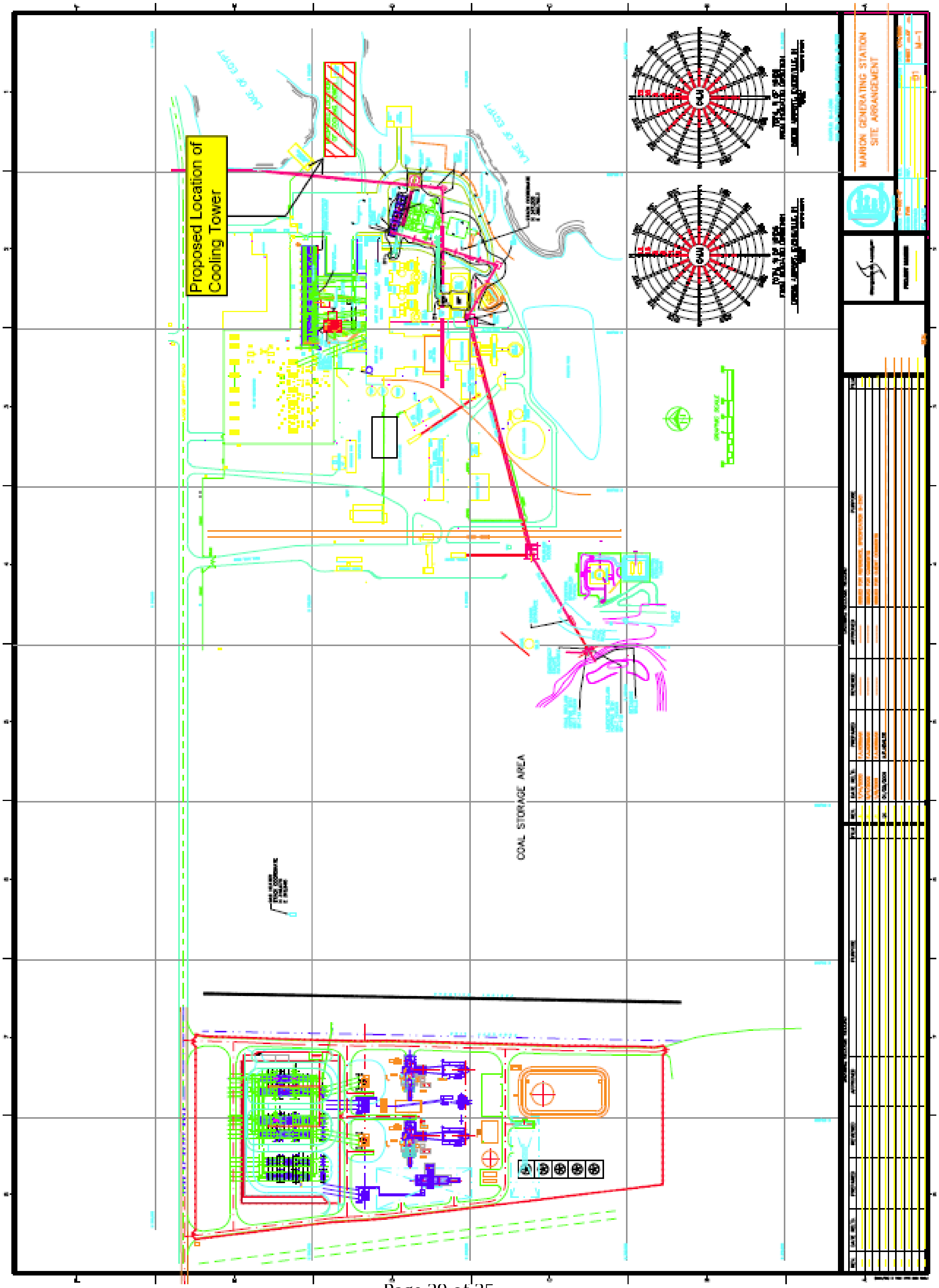
XI. Attachment 3

Sketch showing the extension of the dike drawn on the Water Shed Soil Association Drawing E-127.1 provided by SIPC.


WATER SHED
SOIL ASSOCIATION
E-127.1
GRANTSBURG - ZANESVILLE
HOSMER - ZANESVILLE
MUSKINGUM - WELLSTON
LAKE OF EGYPT
WILLIAMSON CO.
JOHNSON CO.
T.10 S.
T.11 S.
R.2 E.
R.3 E.
GOREVILLE
37°37'30"
37°32'30"
88°50'
88°57'30"

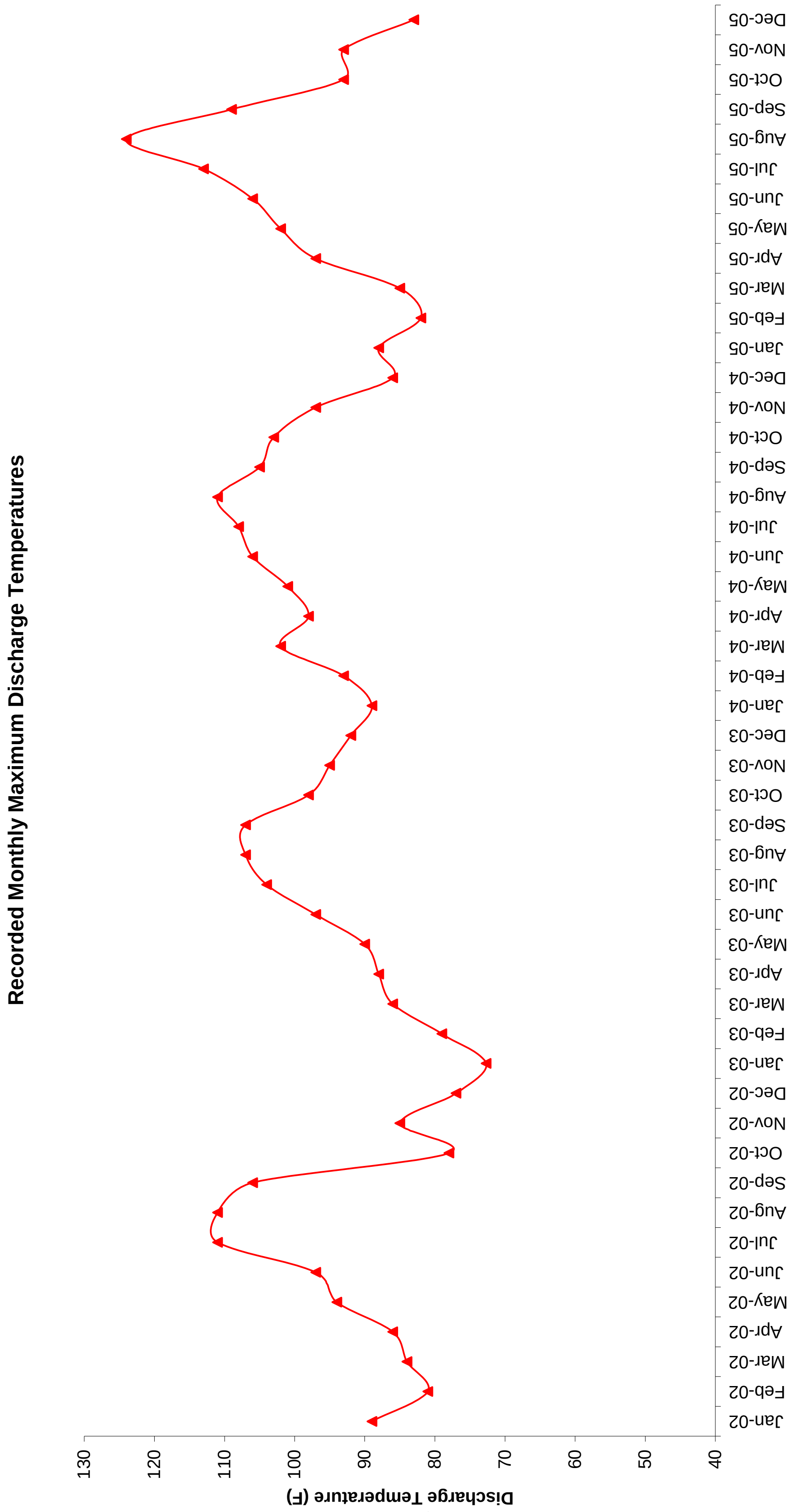
XII. Attachment 4

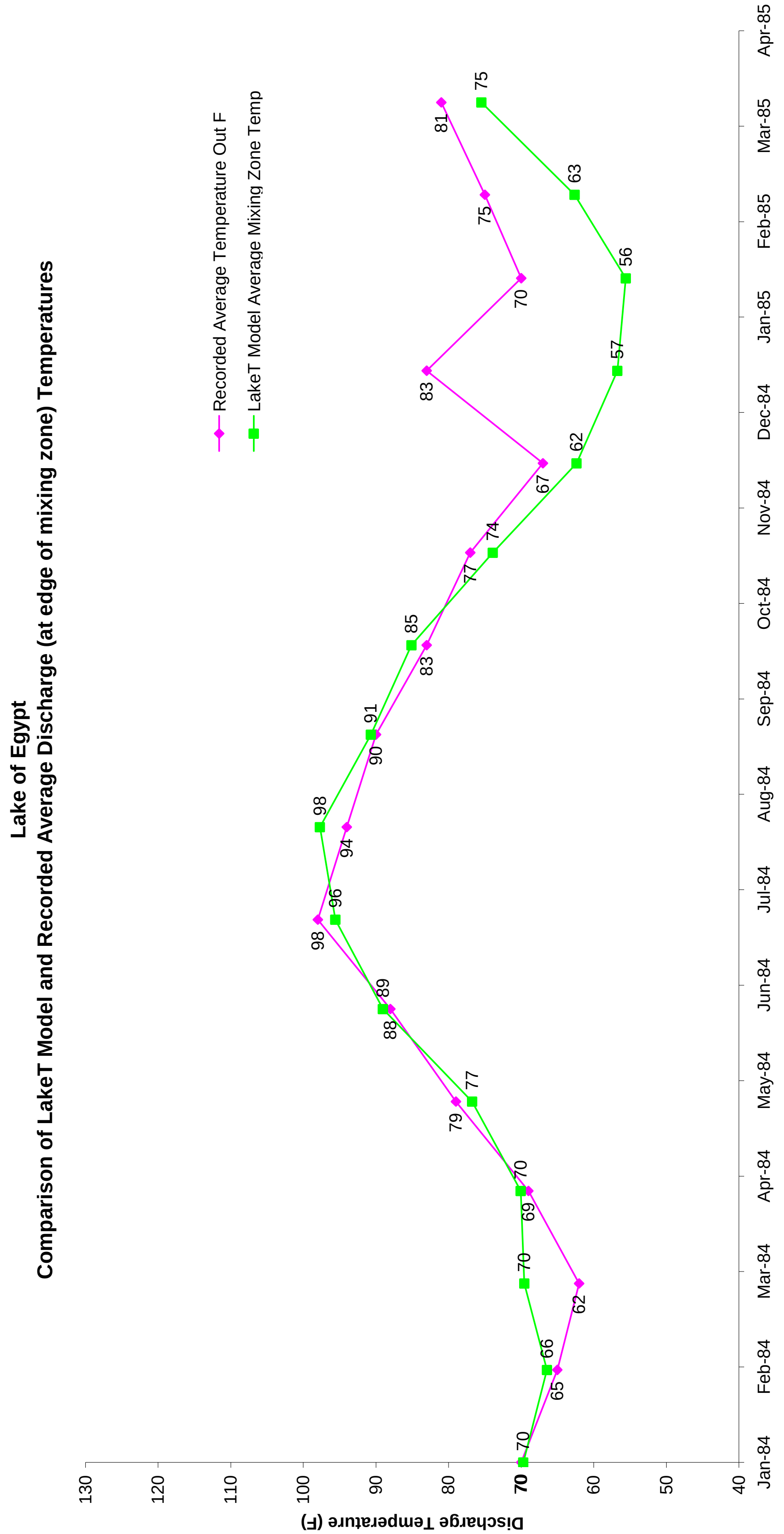
Sketch showing the location of the proposed cooling tower.


Proposed Location of Cooling Tower
LAKE OF EGYPT
LAKE OF EGYPT
COAL STORAGE AREA
MARION GENERATING STATION
SITE ARRANGEMENT
M-1

XIII. Attachment 5

Plots showing recorded monthly maximum discharge temperatures and a comparison of the average temperature at the edge of the mixing zone and the LakeT model data.


Recorded Monthly Maximum Discharge Temperatures
Discharge Temperature (F)
130
120
110
100
90
80
70
60
50
40
Jan-02
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05



Lake of Egypt
Comparison of LakeT Model and Recorded Average Discharge (at edge of mixing zone) Temperatures

XIV. Attachment 6

Aerial image of current Lake of Egypt configuration


N
Existing Dike
Power Plant Rd
Country Club Rd
Southern Illinois Power Co-Op
Nielson Crossing Rd
Lake Egypt Rd
Lake of Egypt Country Club
Fargo Ln
Hogan Dr
Nicklaus Ln
Palmer Ln
Howard Rd
Malibu Ln
Laguna Dr
Projector Place
Bahama
St Vincent Ln
Hudspeth Rd
Pyramid Acres
McBride Ct
Marina Rd
Triple E BBQ
Market Rd
N Shoreline
Lake of Egypt
©2011 Google - Imagery ©2011 DigitalGlobe, USDA Farm Service Agency, GeoEye, Map data ©2011 Google - Terms of Use - Edit in Google Map Maker

XV. Attachment 7

Lake of Egypt water level graphs

Figure 1

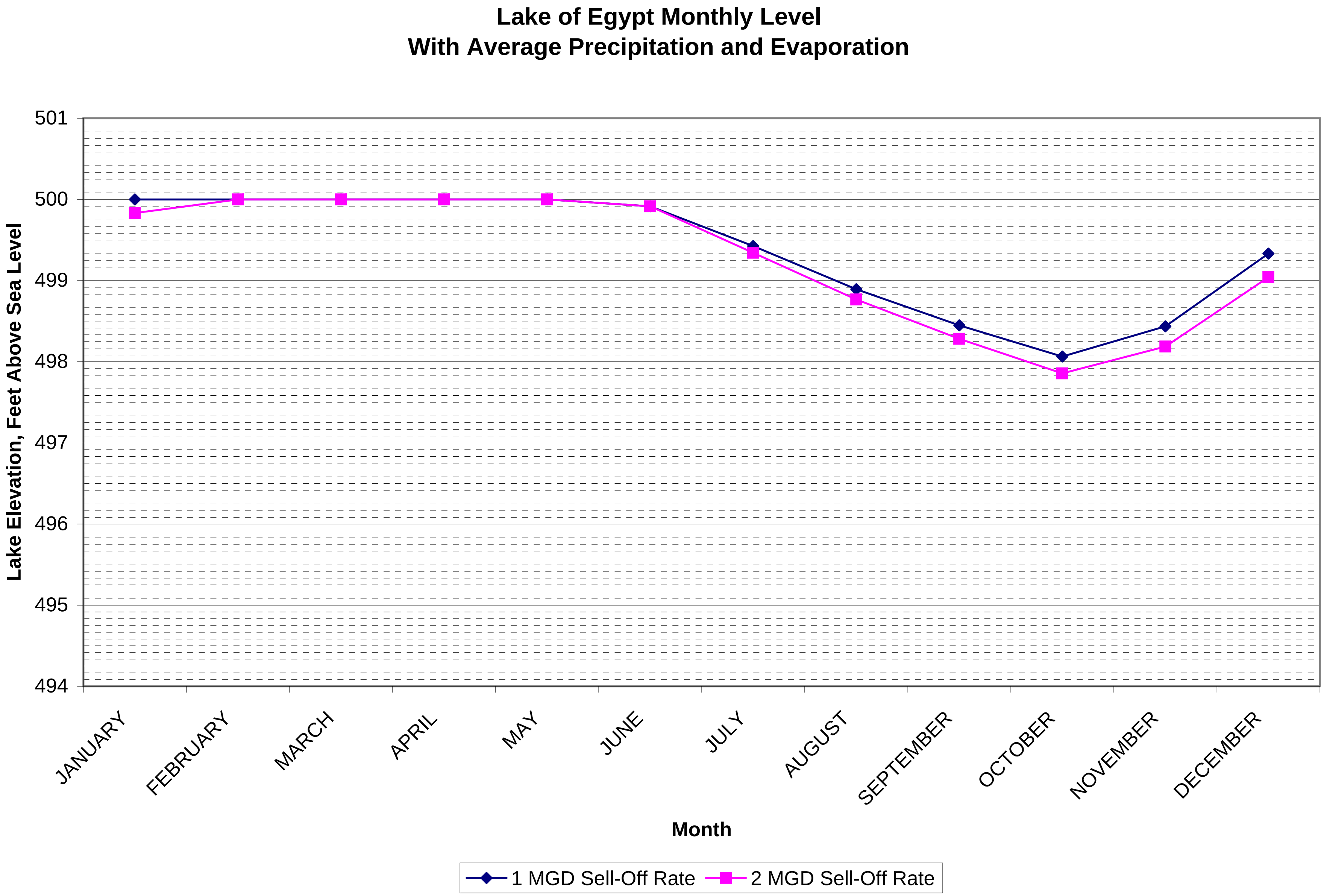

Lake of Egypt Monthly Level
With Average Precipitation and Evaporation
Lake Elevation, Feet Above Sea Level
501
500
499
498
497
496
495
494
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Month
1 MGD Sell-Off Rate
2 MGD Sell-Off Rate

Figure 2

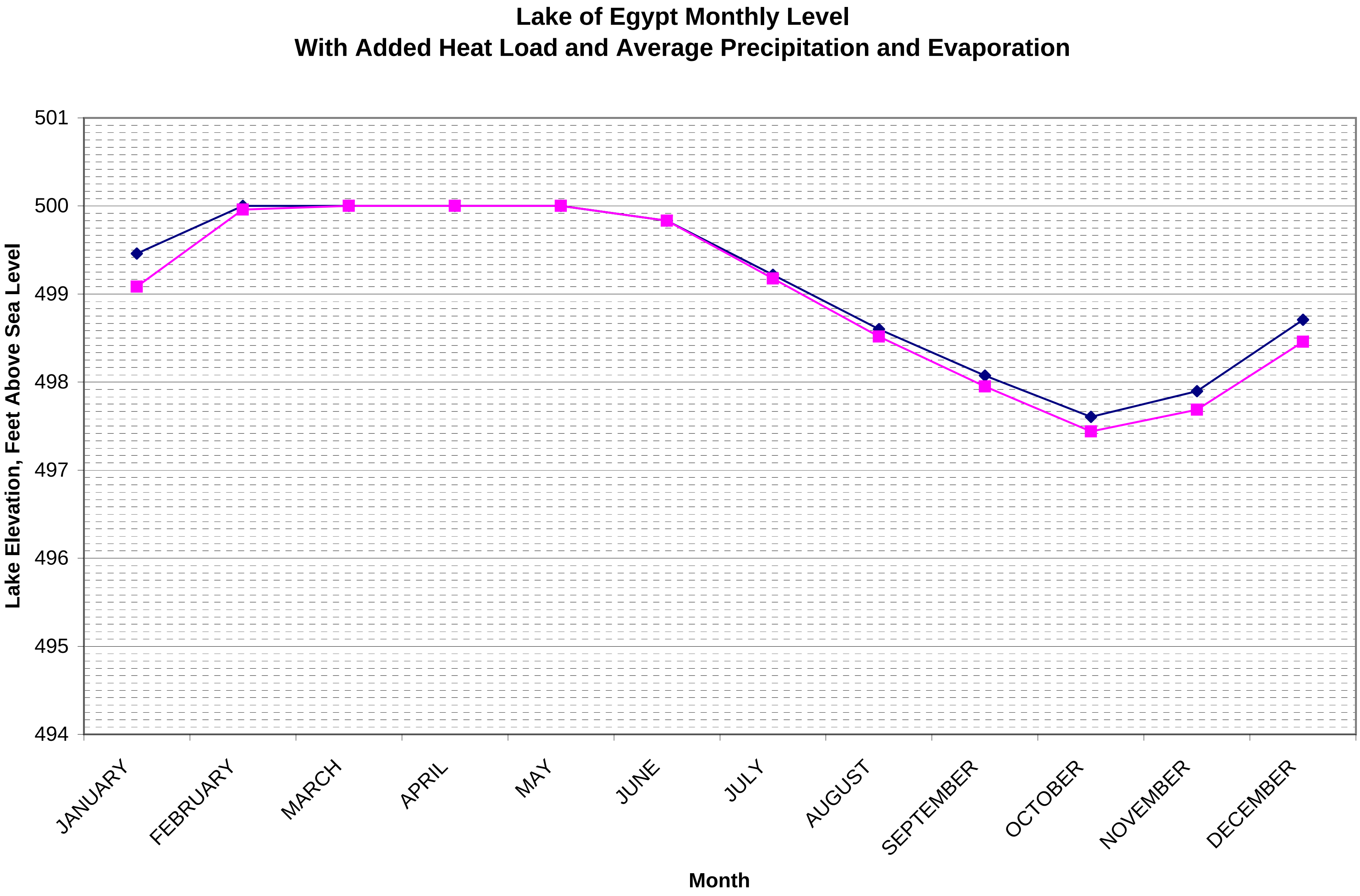

Lake of Egypt Monthly Level
With Added Heat Load and Average Precipitation and Evaporation
501
500
499
498
497
496
495
494
Lake Elevation, Feet Above Sea Level
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Month

Figure 1A

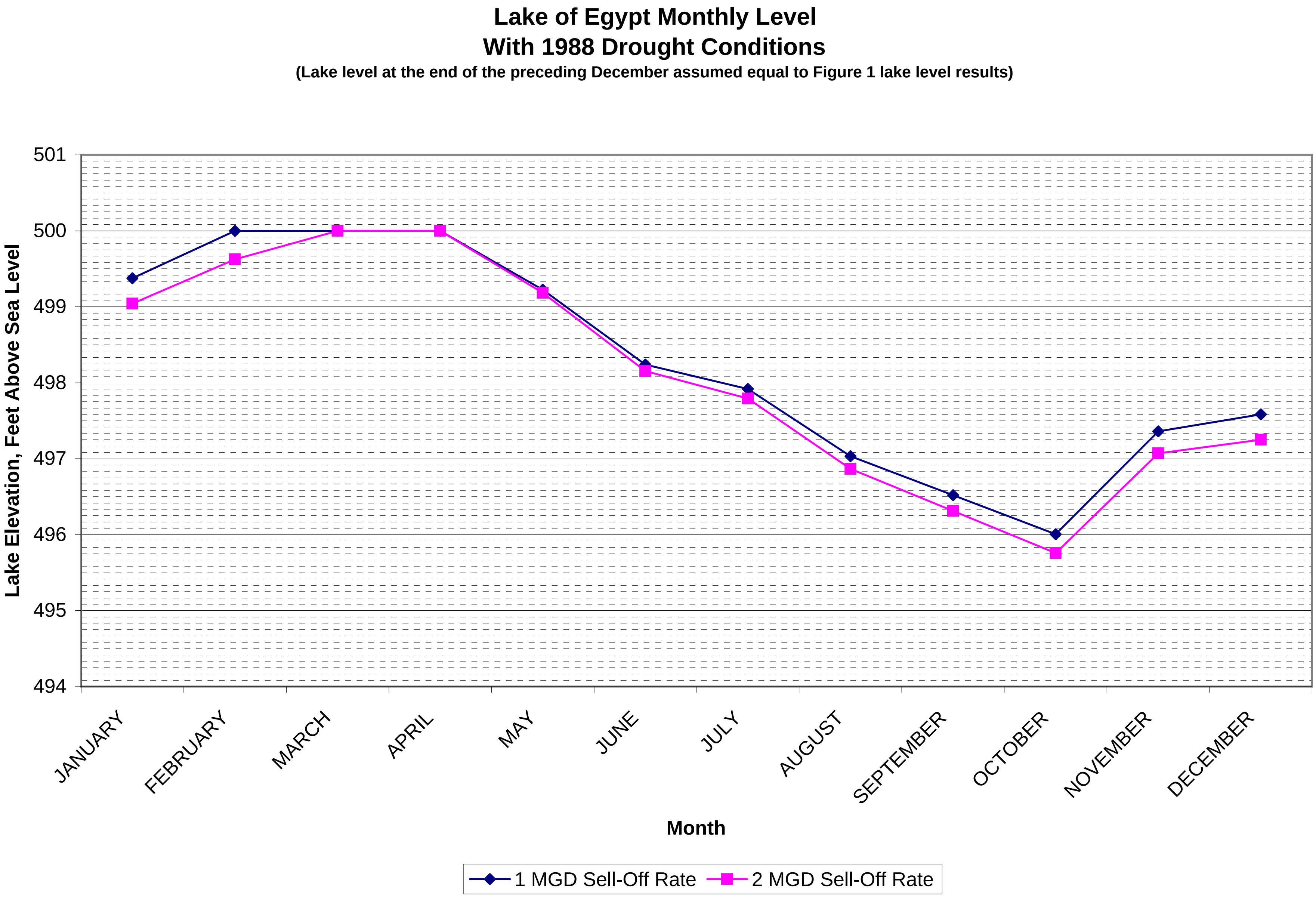

Lake of Egypt Monthly Level
With 1988 Drought Conditions
(Lake level at the end of the preceding December assumed equal to Figure 1 lake level results)
501
500
499
498
497
496
495
494
Lake Elevation, Feet Above Sea Level
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Month
1 MGD Sell-Off Rate
2 MGD Sell-Off Rate

Figure 1B

Lake of Egypt Monthly Level
Recovery Year After Year With 1988 Drought Conditions

(Lake level at the end of the preceding December assumed equal to Figure 1A lake level results)

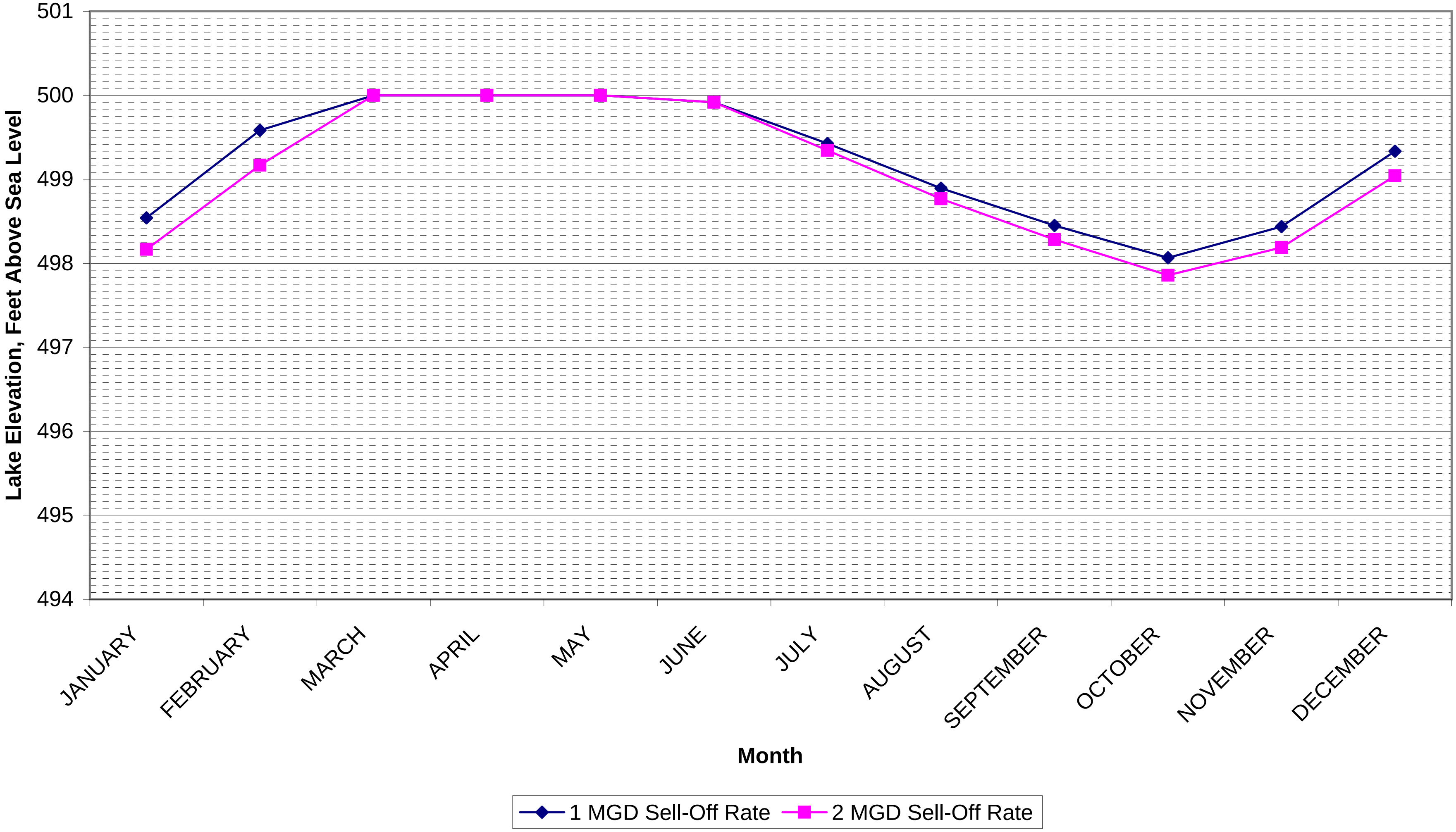
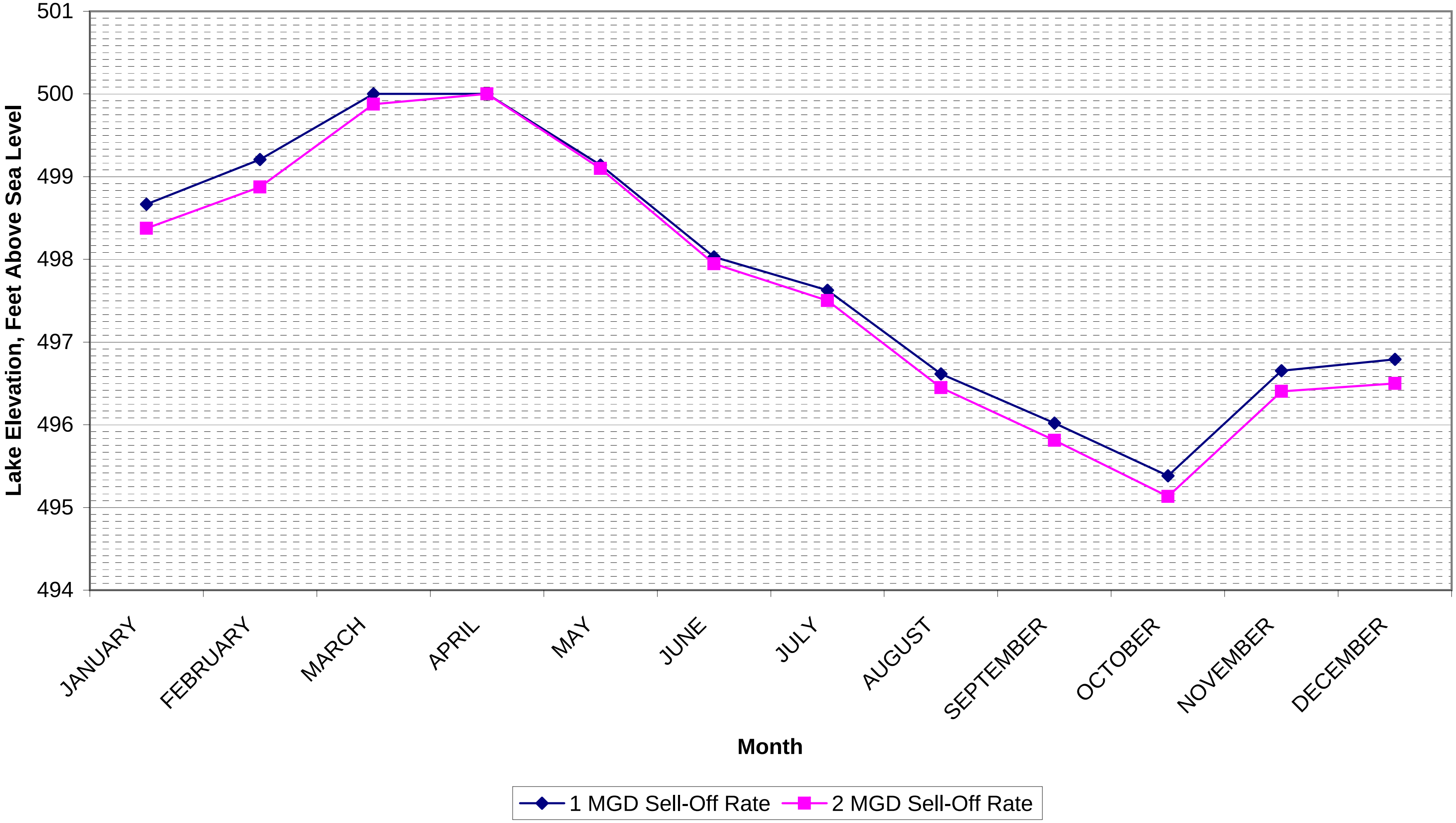


Figure 2A



Lake of Egypt Monthly Level
With Added Heat Load and 1988 Drought Conditions
(Lake level at the end of the preceding December assumed equal to Figure 2 lake level results)

Figure 2B

Lake of Egypt Monthly Level
Recovery Year After Year With Added Heat Load and 1988 Drought Conditions

(Lake level at the end of the preceding December assumed equal to Figure 2A lake level results)

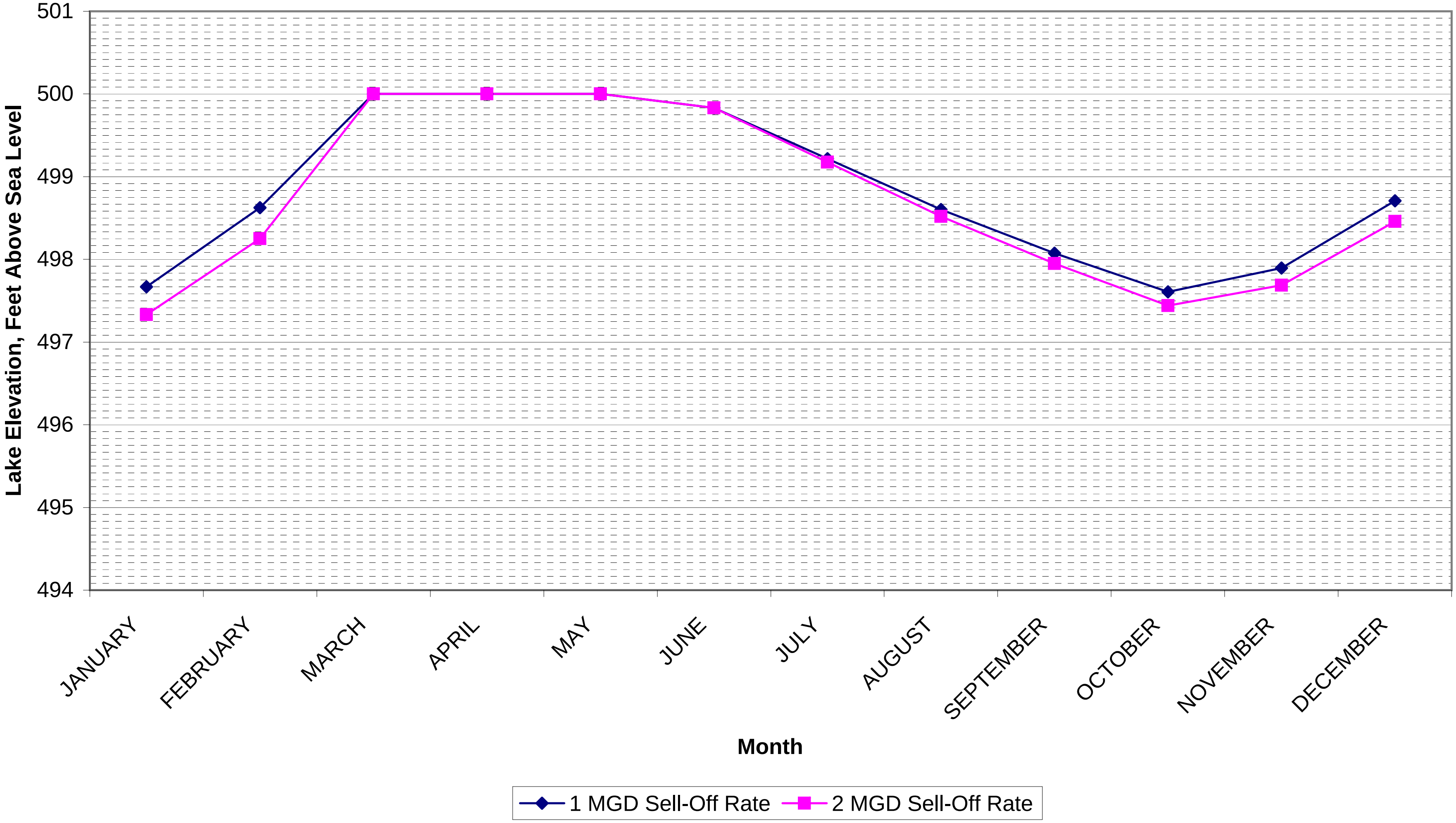


Figure 1C

Lake of Egypt Monthly Level
With 2 Year 1953-1954 Drought Conditions
(Lake level at the end of the preceding December assumed equal to Figure 1 lake level results)

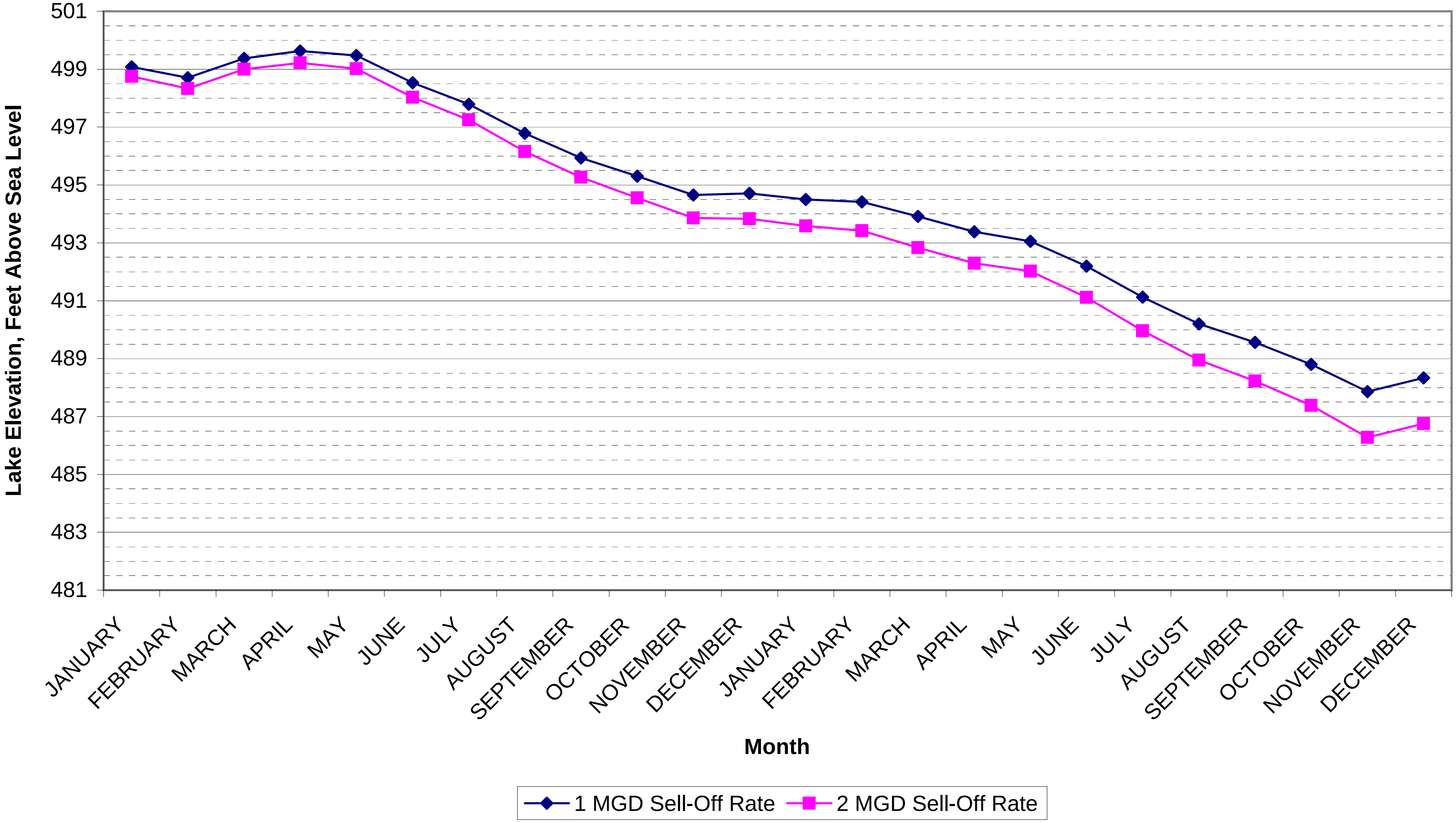


Figure 1D

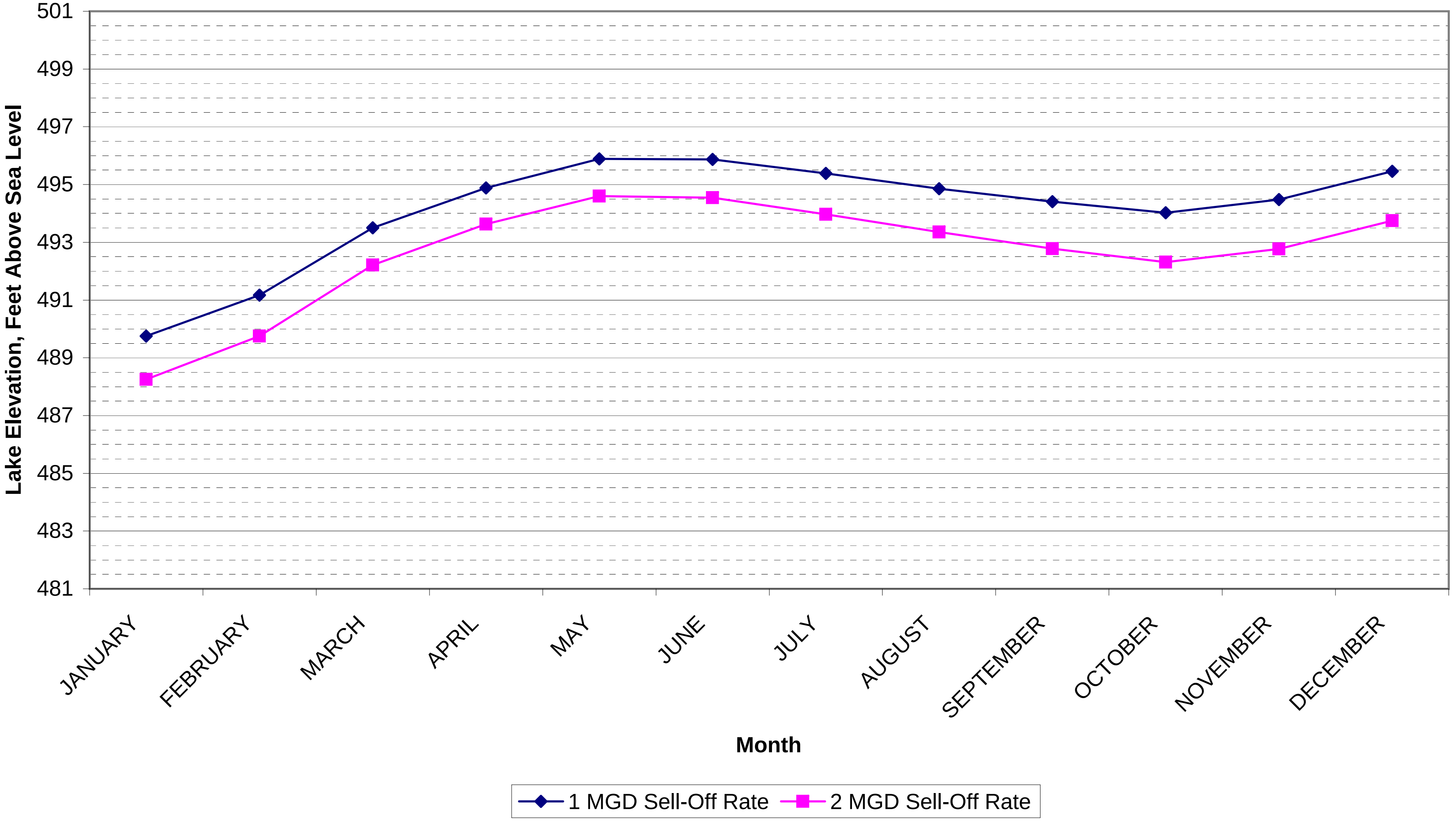

Lake of Egypt Monthly Level
Recovery Year After 2 Years With 1953-1954 Drought Conditions
(Lake level at the end of the preceding December assumed equal to Figure 1C lake level results)
501
499
497
495
493
491
489
487
485
483
481
Lake Elevation, Feet Above Sea Level
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Month
1 MGD Sell-Off Rate
2 MGD Sell-Off Rate

Figure 2C

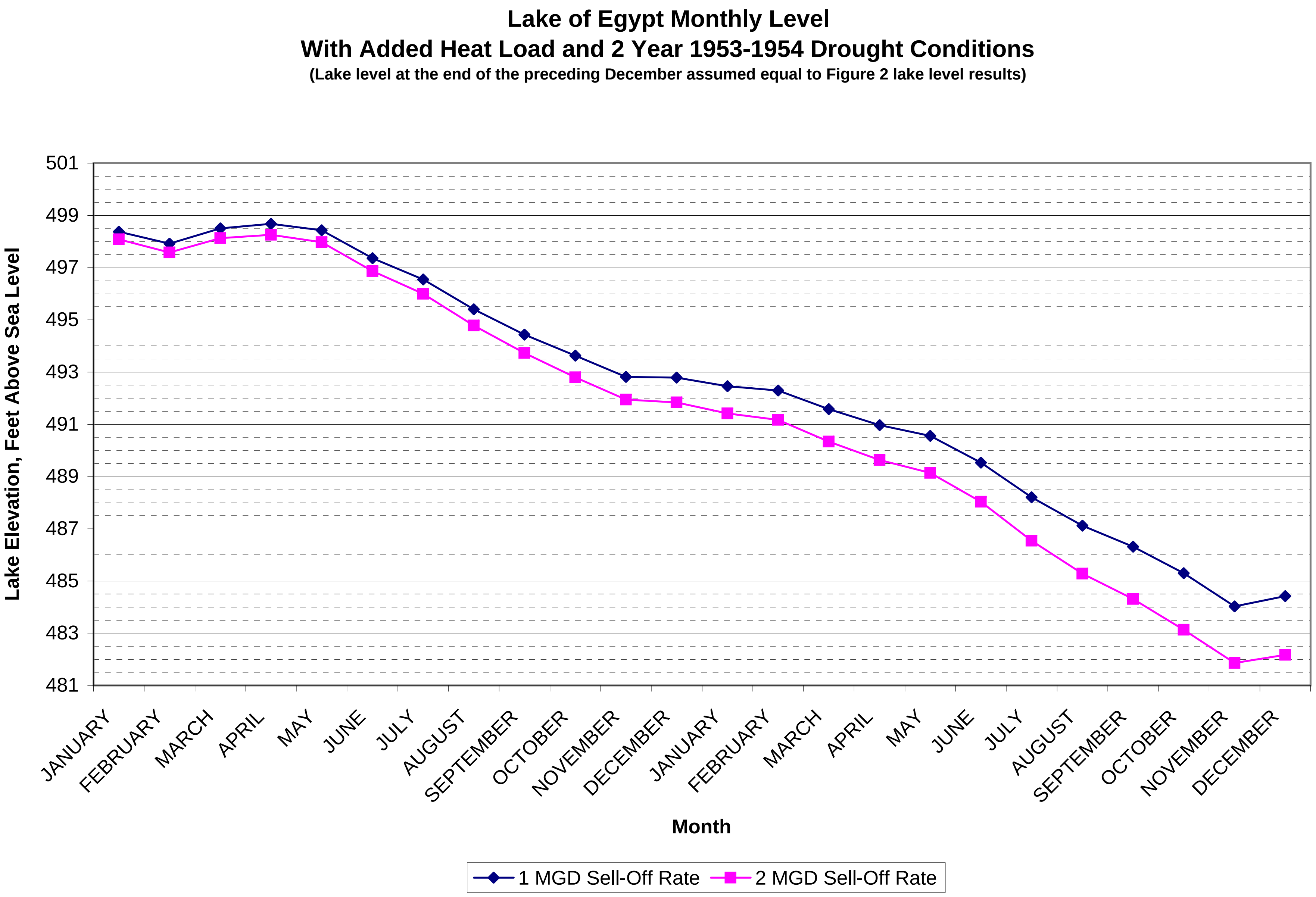
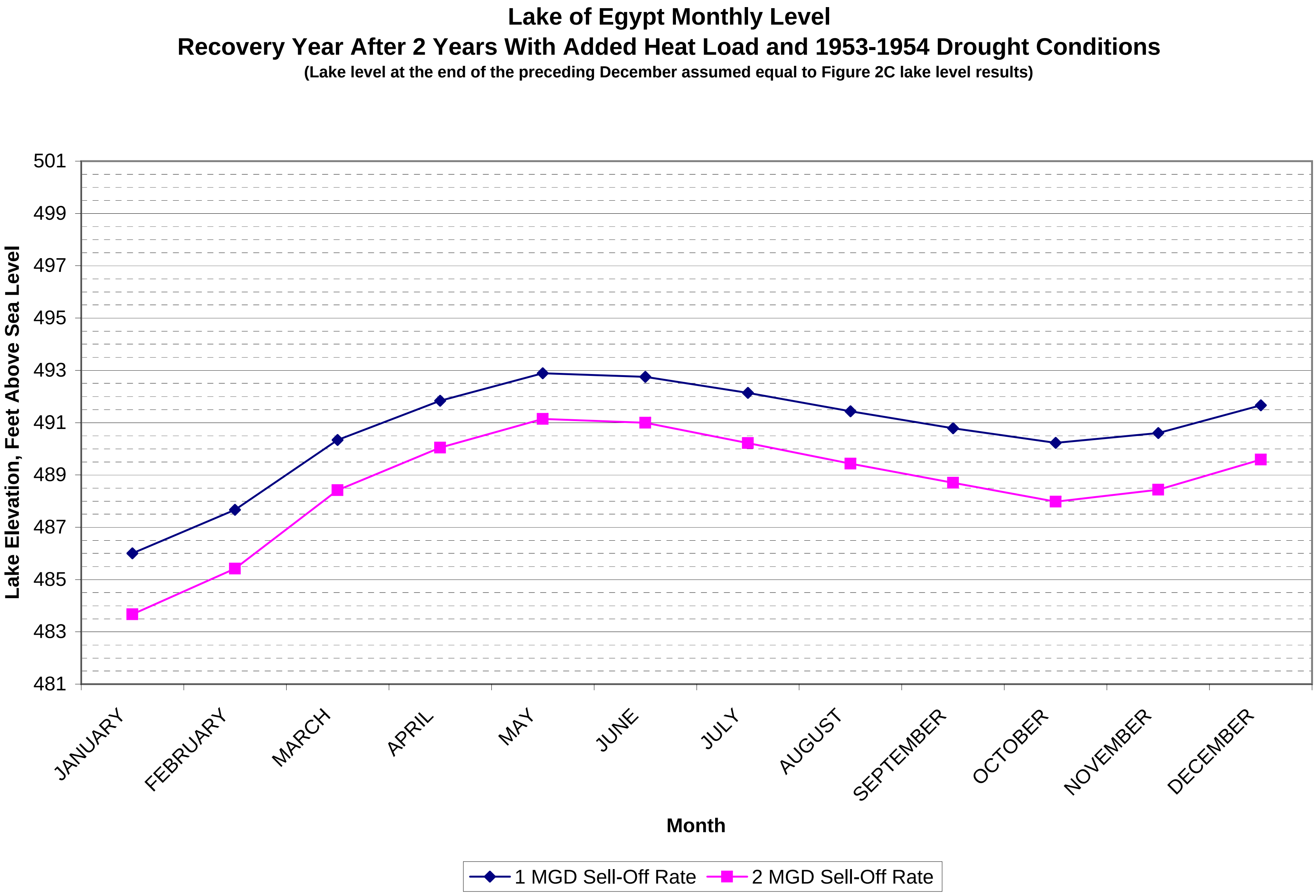

Lake of Egypt Monthly Level
With Added Heat Load and 2 Year 1953-1954 Drought Conditions
(Lake level at the end of the preceding December assumed equal to Figure 2 lake level results)
Lake Elevation, Feet Above Sea Level
501
499
497
495
493
491
489
487
485
483
481
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Month
1 MGD Sell-Off Rate
2 MGD Sell-Off Rate

Figure 2D


Lake of Egypt Monthly Level
Recovery Year After 2 Years With Added Heat Load and 1953-1954 Drought Conditions
(Lake level at the end of the preceding December assumed equal to Figure 2C lake level results)
Lake Elevation, Feet Above Sea Level
501
499
497
495
493
491
489
487
485
483
481
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Month
1 MGD Sell-Off Rate
2 MGD Sell-Off Rate