**FINAL REPORT**

# ACP Purchase Order No.SAA107926FGP

## REVIEW AND MODIFICATION OF THE PANAMA CANAL HEC-5 MODELS

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August 25, 2003

# 1 INTRODUCTION

This report has been prepared in accordance work required under Autoridad del Canal de Panama Purchase Order N0. SAA107926FGP and associated SOW titled *Terms of Reference for the Review and Modification of the Panama Canal HEC-5 Model. Canal.* Engineering review, development of HEC-5 models, and report preparation have been performed by Richard J. Hayes, P.E (Contractor). Modifications to the HEC-5 FORTRAN code (HEC-5A, dated 17 August 2003) to provide enhancements necessary for the development of the "Water Saving Basins" (using HEC-5 diversion type –4), improvements to the HEC-5 tandem operation code, and enhancements to the program's water supply analysis capability (CP.5) were developed by the Contractor. It is anticipated that these modifications will included in the next official release of HEC-5.

# 2 BACKGROUND

The ACP is conducting feasibility studies and analyses in preparation of a Master Plan that includes the evaluation of alternatives to augment the water yield of the Canal Watershed to meet long-term needs for potable water as well as the water requirements for future traffic of vessels in the Panama Canal. A key element in the development of the Panama Canal Master Plan is the use of the *HEC-5, Simulation of Flood Control and Conservation Systems,* computer program developed by the US Army Corps of Engineers, Hydrologic Engineering Center (HEC) in 1998 to evaluate water yields and reservoir behavior of different alternatives. It is necessary to review the previously developed HEC-5 Models in order to determine the need to modify them and add new features and other variables not previously considered. Simulation results will used to evaluate system performance. This report, along with the attached HEC-5 executable, input, output and DSS files, documents those findings.

# 3 REQUIREMENTS

Under this ACP Purchase Order, the Contractor shall review, diagnose, analyze to meet ACP HEC-5 output requirements, test, validate and modify the existing Panama Canal System HEC-5 models as follows:

Review, analyze and diagnose the existing HEC-5 models to identify shortcomings and insufficiencies that prevent them from providing the output needed to meet ACP Study Plan requirements. Modify and update the models as required to enable them to provide the output needed to meet ACP Study Plan requirements, specifically, but not limited to the following**:**

3.1.1 The option of water consumption per lockage.

3.1.2 Outputs from the simulation shall include the power generation and printing of codes.

3.1.3 Option of a temporary percentage reduction in lockage water consumption as reservoirs reach minimum levels, to simulate water saving basins.

3.1.4 Option to separate the lockage water used for navigation and M&I supply and print them separately.

3.1.5 Option of having the same end-of-month percentage use of all reservoirs in the system.

3.1.6 Option of priority use for any month.

3.1.7 Option to print intermediate computations.

3.1.8 Review up to six different reservoir system alternatives incorporating the requested modifications

3.1.9 Prepare a detailed presentation agenda and program. The agenda must be submitted to ACP COR for review and approval at least seven (7) working days in advance of the date of the presentation. The agenda shall include as a minimum: (1) presentation program, time and duration, (2) objectives, (3) deliverables and results, (4) issues to be discussed and presented and (5) list of presenters and (6) any media slides to be used, such as PowerPoint;

3.1.10 Prepare presentation documentation, handouts and support materials, including computer media presentations and other visual aids as needed to execute the training sessions.

# 4 COORDINATION

An initial meeting between the Contractor and ACP personnel was held in Panama during May 6-7, 2003 to coordinate the work to be performed, exchange information and review the criteria used in the model runs. Subsequently, the ACP revised the contact completion schedule from June 11, 2003 to July 11, 2003.

The Contractor presented an Executive Briefing and Training Session in Panama during 9 and 10 July 2003. Subsequent to reviewing the initial modeling results, the ACP requested an additional HEC-5 modification to simplify the procedure for determining the water supply reliability. The requested capability along, with additional tandem operation enhancements, is included in the 17 August 2003 version of HEC5A.
The 17 August 2003 version was provided to the ACP electronically on 17 August and is included with the CD-ROM, which accompanies this report. Contract Modification No. 2 change the final date to 29 August 2003.

# 5 DEVELOPMENT OF ACP HEC-5 MODELS and EXAMPLE DATA SETS

HEC-5 models which were developed to satisfy the requirements of section 3 (Requirements) are described in the following section and are listed in the respective appendixes at the end of this report. Significant model features are discussed in this section and are also identified in

bold print in the appendix listings that follow. These models are also provided on the CD-ROM that accompanies this report.

**Tasks 3.1.1 & 3.1.4, Water Consumption Per Lockage & Separate Water Used for Navigation and M&I Supply.**

The HEC-5 model developed to satisfy both of these tasks is GAT-RJH.DAT. This model was developed from the ACP provided base HEC-5 model GAT785.DAT. The ACP provided model (GAT785.DAT) represented navigation required flows as a single combined navigation and M & I diversion, which varied only by month (not as a function of lake elevation).

The goal of task 3.1.1 was to provide for the simulation of the effects of Lake Gatun elevation on lockage flows. ACP provided an Excel spreadsheet, *"Lockage water use Equation according trendline.xls"* which computes lockage flow, by month and elevation, as a function of monthly lockages. The provided spreadsheet was modified to directly develop HEC-5 input record images. The modified spreadsheet, *"HEC-5 Data for Gatun Lockages.xls"* is included on the accompanying CD-ROM. This spreadsheet can be used to develop revised HEC-5 data records to reflect Panama Canal planning scenarios. In anticipation of an eventual shift from a monthly simulation interval to a weekly interval, the HEC-5 data is created in a form (25 seasons rather than 12) to provide the necessary weekly detail.

The applicable HEC-5 input records required to implement the desired Lake Gatun Lockage navigation release are CS, CG and QM records. These records are added to the Gatun data set at HEC-5 control points 40 (Gatun Lake) and 39 (Gatun Locks). To facilitate water supply reliability determinations, the QMDRAT (CP.5), minimum flow multiplier, can be used in conjunction with the CS, CG, and QM records. This capability is available in the 17 August 2003 version of HEC5A. These records and the additional diversion modifications described in the following paragraphs change Gatun's navigation flow from a diversion requirement to a reservoir release requirement. The CS records define time periods as the days of the year (e.g. July 1 is 182, Dec 31 is 365). CG and QM records relate Lake elevations to required lockage water use (releases from Lake Gatun).

As an example, consider January: the ACP spreadsheet indicates the average number of January transits is 1025; correspondingly at a Lake Gatun elevation of 88 ft. the water usage would be 3,186 cfs over the month, while at an elevation of 79 feet the water usage would be 2,398 cfs. The CG and QM records for January describe this as a straight line function defined by 3,500 cfs at 91.59 ft. and 2,200 cfs at 76.74 ft., these data are highlighted in Table 1.

**Table 1, Lake Gatun Lockage Water Use Data (from the GAT-RJH.DAT)**

```
C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
```

```
CP    40   99999                    1.50
IDGAT-LAKE
RT    40      39
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30   May 1
CS    25       1      31      32      59      60      90      91     120     121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30   Oct 1
CS   151     152     181     182     212     213     243     244     273     274
C Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46   76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33   77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57   90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12   92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500
```

To implement the desired elevation related lockage release option, it was necessary to also separate the combined navigation and M&I diversion into distinct model components, thereby also satisfying the goals of task 3.1.4. To do this the M&I diversion was separated from the combined Lake Gatun diversion, which was defined as an HEC-DSS time series diversion (input by a ZR=QD40 record). Two additional control points were added to the model immediately upstream of Lake Gatun (CP 40). The added control points are, CP 42 (GAT-M&I) and CP 41 (GAT-LEAK). At CP 42, the M&I diversion was represented as a monthly varying diversion (DR and QD records) from the system.

Since task item 3.1.2 also required improvement to the display of power related flow data, a control point was also created to define the Lake Gatun leakage function. The diversion specification at CP 41 directs a constant 27 cfs to a point downstream of the Lake Gatun power plant. Since, both of these diversions conceptually with draw water from upstream of Lake Gatun, the time series inflow for Lake Gatun was shifted to control point 42 (ZR=IN42). Additionally, Lake Madden was directed to consider CP 42 diversion requirements when making it's downstream release determination (RO 2, 40, 42).

The GAT-RJH.DAT model is listed in Appendix A, major modifications to the model are noted with bold print. The model also provided together with HEC-5 output (GAT-RJH.OUT) and HEC-DSS files on the accompanying CD-ROM.

**<u>Tasks 3.1.2</u> Outputs from the Simulation shall also include the power generation and printing of all codes.**

The HEC-5 model developed to satisfy this task is GAT-POWR.DAT. This model was developed from the ACP provided base HEC-5 model GAT785.DAT. The GAT785.DAT model utilized a diversion for navigation water requirements and represented Lake Gatun's power facility as a run-of-river plant releasing from Lake Gatun outlet directly to the river downstream. Although, HEC-5 does not provide direct output of power releases, it possible

to print power releases in the HEC-5 output by employing the program's J8 record subtraction feature. To accomplish this a J8 record is configured from left to right, with the reservoir release variable (.10), the power spill variable (.32), and the subtraction directive (.00) as shown in the following J8 record, which is configured to output data for both Madden (50) and Gatun (40) : **J8 40.10 40.32 40.00 50.10 50.32 50.00**.

Normally, the reservoir release variable also includes the amount flow for reservoir leakage. To improve the computation of the requested power release, the reservoir leakage flows were removed from the power input (P2 records) and the model was modified to account for leakages as a diversion around the reservoir. In the case of Lake Madden (50), control points were added just above (51) and just below (49) the Madden reservoir input data.

To model the Navigation Lockage feature required for task 3.1.1, the Lake Gatun power model was changed from a direct release from the dam to a diversion from Gatun to a power plant at control point 38. This was accomplished using the HEC-5 "headwater reservoir" feature (see P1 record field 6). The Gatun leakage was modeled in manner similar to the Lake Madden input, control points were added above Lake Gatun, (41) and below (37). These allowed Gatun's leakage to be configured as a diversion.

Additionally, to assist in the understanding of HEC-5 power output the following J8 records were added to the GAT-POWR.DAT model:

```
C ------------------- Madden's Hydropower Parameters ---------------------------
C Madden   Total   Power Turbine  Energy  Plant    Rated   Power  Madden    Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation  Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case    feet
J8 51.03   50.10   50.32   50.00   50.16   50.35   50.25   50.33   50.12   50.22C
C -------------------------------------------------------------------------------
C -------------------- Gatun's Hydropower Parameters ---------------------------
C Gatun  Non-Lock  Power Turbine  Energy  Plant    Rated   Power   Gatun    Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation  Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case    feet
J8 41.03   40.03   38.32   38.00   38.16   38.35   38.25   38.33   40.12   40.22
C -------------------------------------------------------------------------------
```

Since the release of the latest HEC-5 program, Version 8.0, October 1998, several new hydropower output features have been added which may help program users better understand the program's hydropower input. They are the **Hydropower Data* and **Hydropower Operation* summaries shown below:

***Hydropower Data (P1 & P2)**

| Power Plant | Installed Cap.(kW) | OverLoad Ratio | Efficiency Gen*Turb | PenQ CFS | Leakage CFS | TailWater Elev (Ft) | H-Loss Feet | Reservoir Name |
|---|---|---|---|---|---|---|---|---|
| 50 | 36000 | 1.10 | 0.83 | 3625 | 0.0 | 89.00 | 0.0 | MAD-LAKE |
| 38 | 24000 | 1.10 | 0.85 | 4550 | 0.0 | 9.00 | 0.0 | GAT-POWER |

***Hydropower Operation Summary**

| Power Plant | System Power | Pumped Storage | Peaking Power | Run of River | Reservoir Name |
|---|---|---|---|---|---|
| 50 | --- | --- | --- | YES | MAD-LAKE |
| 38 | --- | --- | --- | YES | GAT-POWER |

Both of these summary reports are a part of the standard HEC-5 output, they are located following the reservoir data summary (*RESERVOIR DATA). They can be located in the output with the MENU5 output viewing program "LIST" by searching for "*H".

The HEC-5 option, which may be used for the printing of HEC-5 operation codes and associated discharges is the program's trace feature. This option is implemented by adding TC, TP and TS records to an HEC-5 data set. They are placed in an HEC-5 data set following the last J8 or JZ record.

The following is an excerpt from the GAT-POWR.DAT showing the placement of trace records TC, TP, and TS:

```
T1    Panama Canal Capacity Study: Period - of Record Analysis (GAT-POWR.DAT)
T2    Model: Existing System with Deepening (GAT785.DAT & GAT-LOCK.DAT)
T3    DRAFT Model developed by RJHayes, June 2003 for ACP, (PO#SAA107926BGP)
J1     0       1       5       3       4       2              10
J2    24     1.0               4                               0
J3     5                                      -1                      0
J8 51.03   50.10   50.32   50.00   50.16   50.35   50.25   50.33   50.12   50.22
J8 41.03   40.03   38.32   38.00   38.16   38.35   38.25   38.33   40.12   40.22
J8 40.10   40.13   50.13   50.10   50.12   50.12   40.14   50.22   50.11
TC     1      50
TP     1       8
TS   117
C ---- Madden's Inflow
RL    52
RO
RS     2       1      10
RQ     2   99999      -1
CP    52   99999
IDMAD-INFLOW
RT    52      51
```

The TRACE feature is discussed in more detail under the Task 3.1.7 section. The GAT-POWR.DAT model is listed in Appendix B, major modifications to the model are noted with bold print. The model also provided together with HEC-5 output (GAT-POWR.OUT) and HEC-DSS files on the accompanying CD-ROM.

**Tasks 3.1.3 & 3.1.8, Water Saving Basins & Recycling of Water at Gatun**.

The HEC-5 model developed to satisfy both of these tasks is GAT-WSB.DAT. This model was developed from the above described HEC-5 model GAT-RJH.DAT. The essential elements of the Water Saving Basin scheme in the GAT-WSB.DAT model are; an efficiency rate, a conditional pump configured to only return water when Gatun Lake stages are low and a seasonally based maximum pump rate.

To develop the water saving basins capability the following model modifications were made:

1) A stream flow based diversion (DR.7= –1) was added immediately downstream (CP 39, GAT-WSB) of Lake Gatun (CP 40, GAT-LAKE), this diversion establishes the efficiency of the water saving system, for this example data set a percent efficiency of 50% was modeled. The lost water is diverted to control point 37, (GAT-SUM). The remaining water, which is the potential saved water, continues downstream to location 38.
2) A second pump based diversion location was added just downstream of 39 at CP 38 (GAT-PUMP). To establish this type of diversion requires the specification of a NEGATIVE flow specification at the up stream end of the pumped diversion, in this case, at Lake Gatun (CP 40).
3) The pumped diversion (DR.7= -4 and QD records with NEGATIVE flows) was input at Lake Gatun.
4) The conditional aspect of the Water Saving Basins scheme is specified by the input of an additional reservoir level in the reservoirs of the system (both Madden and Gatun). At Gatun the added level represents the top of the pump-back pool. In this instance the top of the Lake Gatun pump-back pool was specified as 80 feet (storage =3,681,600 ac. ft.).
5) Changes were also required for the job control records, J1 and J2. The J1 record was modified to permit 6 levels in place of the original 5 (J1.3-J1.6), the pump back level was specified as level 3 (J1.7=3) and the programs automatic level interpolation procedure for monthly interval simulations was turned off by adding a 10 to field of the J1 record (J1.8=10). To enhance the computation related to the reverse pump back scheme, the HEC-5 "recycle" option was turned on by adding a 32 to the sum of the "operational priority" variable (J2.4). To further enhance the computations the recycle option variable for the number of recalculations was set to 3 (J2.8=3).

Excerpts from the GAT-WSB.DAT model, which show the above changes, follow:

Modification to Job Control Records, J1 and J2

```
T1    Panama Canal Capacity Study: Period - of Record Analysis (GAT-WSB.DAT)
T2    Model: Existing System with Deepening (GAT785.DAT & GAT-LOCK.DAT)
T3    DRAFT Model developed by RJHayes, June 2003 for ACP, (PO#SAA107926BGP)
C === Modify Job Control Records for 6 Levels & RECYCLE Option ===
C   === Intended for Application with HEC-5A Dated 23June 03 ===
C      0       1       5       3       4       2
C     24     1.0              132                                    0
C ------------------------------------------------------------------
J1     0       1       6       4       5       2       3      10
```

```
J2    24     1.0             164                                3
C ------------------------------------------------------------
J3     5                                      -1                        0
```

## Modification to Lake Gatun Reservoir Levels

```
C ============== Lake Gatun ====================================================
C  6.  Top-of-dam      = Elev. 105.0
C  5.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  4.  Top-of-conserv. = Monthly varying, Elevations from Fig 5.1
C  3   ADDED Level for Water Saving Basins Option
C  2.  Top-of-buffer   = Elev.  78.5
C  1.  Top-of-inactive = Elev.  78.5 (3830250 ACFT) to determine DIV Shortages
C
RL    40  -87.75
C                          Elev = 78.5 ft
RL     1      40      -1          3536150
RL     2      40      -1          3536150
C ================= Water Saving Basins Upper Limit for Pump Back ==========
C                          Elev = 80.0 ft
RL     3      40      -1          3681612
C ================================================================================
C                                  Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31
C        ELEV:                        87    87.0    87.0    86.3    86.3    85.4
RL     4      40      25          4453580 4399800 4399800 4325160 4325160 4230070
```

## Specification of Pump Back Diversion at Lake Gatun

```
CP    40  999999
IDGAT-LAKE
RT    40      39
C ---- Div Type -4 Uses Level 3 to Limit Pump Back from Water Saving Basins ----
DR    40      38                                          -4
QD    12       0   -2000   -2000   -2000   -2000   -2000       0       0       0
QD     0        0       0
C --------------------------------------------------------------------------------
```

## Specification of Water Saving Basins Below Lake Gatun

```
C  Lake Gatun Water Saving Basins 50% Returned if Gatun is Lower Than 80 ft
CP    39  999999
IDGAT-WSB
RT    39      38
DR    39      37                                      -1
QS     3       2    1000   10000
QD     3       1     500    5000

C === From this Location Water Saving Basin Flow is Returned to Lake Gatun ====
CP    38   99999
IDGAT-PUMP
```

```
RT    38      37
```

## Tasks 3.1.5, 3.3.6 & 3.1.7, HEC-5 Options for Operation Specification and Output..

The HEC-5 model developed to satisfy these tasks is GAT-OPTS.DAT. This model was developed from the above described HEC-5 model GAT-LOCK.DAT. The HEC-5 program options shown in this HEC-5 model include: 1) printing of intermediate computations; 2) specifying end of period reservoir levels; and 3) specifying reservoir priority use in any period.

The HEC-5 Trace records TC, TP and TS are required to direct the program to print intermediate computations. The HEC-5 Trace output is usually used by program developers to assist in developing new program options or for use in correcting program deficiencies.
The following is an excerpt from the GAT-OPTS.DAT model, which shows the application of the Trace specification, to print out computations for two reservoirs (40 & 50) for fourth time period. Control point locations to be traced are specified on the TC record. Time period numbers are specified on the TP record. Detailed information regarding the TRACE option is available in the HEC-5 User's Manual on pages G-27 through G-31. To review the HEC-5 decision process it is useful to review Trace output from HEC-5's executive subroutine RESREL. The TS record is used to specify which subroutine computations are to be output (noted by 117 for RESREL on the TS record).

```
J8 50.31   42.31   40.31   40.06   40.13   50.13   40.22   50.22
JZ 50.13   50.22   50.03   50.10   50.32   51.03   50.16   49.04   40.03   42.31
JZ 40.13   40.22   42.03   40.10   38.32   38.16   37.04   42.31   42.30   40.30
C
C ============ Option for Printing Intermediate Computations (TRACES) =========
C Reservoir Release Computations for 2 Locations (50 & 40) for the  4th Period
C  Locations 50 (Madden) & 40 (Gatun)
TC     2      50      40
C  Period #4
TP     1       4
C  Sub-Routine 117 (RESREL, Determines which Release will be Made))
TS   117
C
```

To understand the variable names and computations printed in the Trace output it is advisable to have a listing of the HEC-5 FORTRAN source code. The HEC-5 source code is included in the accompanying CD-ROM.

Program users may direct the program to cause a reservoir go to a particular level at the end of a specified period or to make a specified release by using QA records. When applying this user override feature (QA records) all operational rules are ignored. The only limits to the user specified release directive are availability of water and the capacity of a reservoir's outlet. The use of the QA record is shown on pages G-96 and G-97 of the HEC-5 User's Manual. The following is an excerpt from the GAT-OPTS.DAT model, which shows the application of this option.

```
ED
C ===== OBSERVED DATA SPECIFIED FOR JAN 1948 TO DEC 1999 ========================
BF     2      36                97010100             720                      1900
C === Option for Specified Reservoir Levels (periods 5,6,7, & 8) ==============
QA    40      -5                              270.43  260.43  250.43  240.43
QA    50      -5                              270.43  260.43  250.43  240.43
C ------------------------------------------------------------------------------
C ========== Option for Reservoir Priority Use for any Period ===================
C  Reservoir 50 to Release 333 cfs in Period 10 & Maximum Release in Period 11
QA    50     -10                              333    0.25
```

**Task 3.1.9 Review Reservoir Systems Incorporating Requested Modifications.**

The ACP supplied 6 HEC-5 models to be revised to incorporate the above requested modifications. The projects included; Upper Chagres, Case 8; Cocle del Norte; Gatun, Existing with deepening; Indio; Toabre-Indio; and Lower Trinidad.

The revised ACP models were presented to ACP staff members during the July 9 and 10, 2003 training session in Balboa. They are included following this report in the appendices as shown below;

| Appendix | ACP Model | Revised Model |
|---|---|---|
| E – Upper Chagres | CHAG8NEW.DAT | CH2-RJH.DAT |
| F Cocle del Norte | COC10090.DAT | COC-RJH.DAT |
| G Gatun + Deepening | GAT785.DAT | GAT-RJH.DAT |
| H Indio | IND8040.DAT | IND-RJH.DAT |
| I Toabre-Indio | TOAB9550.dat | TOA-RJH.DAT |
| J Lower Trinidad | TRIN75R4.DAT | TRI-RJH.DAT |

The revised models, as well as the ACP supplied original models, are included on the accompanying CD-ROM.

**Task 3.2 Verification of Panama Canal Reservoir System HEC-5 Model.**

This task was originally done in 1998 by the HEC. In discussions during the contractor's July 9-10, 2003 visit to the ACP office, it was concluded that this task was sufficiently well documented by HEC to make it unnecessary to redo.

**Task 3.5 Demonstration and Training Session on the Modified Model for Selected ACP Staff.**

The contractor demonstrated the revised models and trained ACP staff in the use and application of the requested options and modifications.

**Task 3.6 Executive Presentation to ACP Senior Staff on the Modified Model.**

The contractor delivered an executive presentation to ACP senior staff prior to the beginning of the training session on 9 July 2003.

**Task 3.7 Modeling Support and Review.**

The contractor will provide ACP staff using the HEC-5 program and models developed under this purchase order, modeling support. The primary means of communication will be through the exchange of files and messages via the internet. The contractors contact information is as follows:

| | |
|---|---|
| Internet Address: | RandKHayes@aol.com |
| FAX Number | (530) 759-0722 |
| Phone Number | (530) 758-2375 |
| Mailing Address | 1814 Alicante Street,<br>Davis, CA 95616<br>USA |

# 5 CONCLUSIONS AND RECOMMENDATIONS

Upon review of the six ACP provided HEC-5 models, as revised, and listed in Appendices E through J, it is the Contractor's conclusion that these HEC-5 models are adequate and appropriate to determine and compare water supply reliability among these selected water supply system alternatives. Also, it should be noted that, the modeling techniques applied in these models, can be adapted to other reservoir system alternatives that may be considered later.

As a general recommendation, I encourage the development and use of weekly time series data for simulation studies after these initial screening studies are completed. As studies transition from an emphasis on planning to more of an operational analysis with concerns about flood control and hydropower the shorter time interval will become more important.

# 6 SIGNATURE

It has been a great honor to once again assist the staff of Authoridad del Canal de Panama in these interesting and important analyses for the Panama Canal.

Sincerely,

Richard J. Hayes, P.E.

# APPENDIX A

# OPTION FOR LOCKAGE CONSUMPTION, Task 3.1.1

## HEC-5 Model Developed for Lockage Consumption Simulation

**GAT-LOCK.DAT**

```
T1    Panama Canal Capacity Study: Period - of Record Analysis (GAT-LOCK.DAT)
T2    Model: Existing System with Deepening (GAT785.DAT)
T3    DRAFT Model developed by RJHayes, June 2003 for ACP, (PO#SAA107926BGP)
J1     0       1       5       3       4       2
J2    24     1.0             132                                0
J3     5                                      -1                        0
J8 50.13   40.13   40.00   50.10   40.10   50.12   40.12   50.22   40.22
42.31
J8 50.10   50.32   50.00   50.35   51.03   50.10   49.04   50.12   50.13
50.22
J8 52.09   50.03   50.10   50.12   50.13   50.22   50.16   50.35
J8 42.04   41.03   40.09   40.10   41.03   38.10    3.99   38.10   38.32
38.00
J8 41.04   40.03   40.10   40.12   40.13   40.22   38.16   38.35   38.32
38.10
J8 50.31   42.31   40.31   40.06   40.13   50.13   40.22   50.22
JZ 50.13   50.22   50.03   50.10   50.32   51.03   50.16   49.04   40.03
42.31
JZ 40.13   40.22   42.03   40.10   38.32   38.16   37.04   42.31   42.30
40.30
C  ----- Madden's Inflow
RL    52
RO
RS     2       1      10
RQ     2   99999      -1
CP    52   99999
IDMAD-INFLOW
RT    52      51

C        Seperate Madden Power Leakage from Madden Releases to:
C          Provide HEC-5 Output Computation of Power Discharge
C           via J8 40.10   40.32   40.00 for Printout
C           and DSS Computations
```

```
C
CP    51   99999
IDMAD-LEAK
RT    51      50
C  ----- Madden's Leakage Routed to Base of Dam (CP 49)
DR    51      49                                          0      20

C ============== Lake Madden
================================================
C  5.  Top-of-dam      = Elev. 270
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevations from Fig 5.1
C  2.  Top-of-buffer   = Elev. 190 (M&I only)
C  1.  Top-of-inactive = Elev. 190
RL    50 -252.00
C                                   190
RL     1      50      -1          127250
C                                   190
RL     2      50      -1          127250
C        ELEV:                      249     243     233     221     217
215
RL     3      50       0          611478  541116  434890  324950  292650
277430
C        ELEV:                      217     222     228     236     247
252
RL                                292650  333360  386640  465290  587580
648140
C   Madden Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C                                   252     252     252     245     245
245
RL     4      50       0          648140  648140  648140  564096  564096
564096
C                                   245     245     245     248     251
252
RL                                564096  564096  564096  599470  635790
648140
C                                   270
RL     5      50      -1          886754
C  Operate for:
C              Gatun Inflow & M&I Diversion Point (CP 42)
C              Lake Gatun (CP 40)
RO     2      42      40
C  Reservoir storage from path = /PCC/MAD/ELEV-CAPAC(ACFT)///OBS/
C  Reservoir areas from path =  /PCC/MAD/ELEV-AREA(ACRES)///OBS/
C  Storage & area values below Elev. = 190 are extrapolated
C  Areas above Elev = 264.0 are extrapolated
C  Reservoir maximum outflow from Tables 5-2 + 5-3 + 6-2 PCC FC MANUAL
(9/1992)
RS   -54       0    16.0    54.4  127.25  136.89  146.51  156.70  167.29
178.35
RS184.07 189.992 195.914 202.066 208.356 214.761 221.281 227.916 234.665
241.529
RS248.51 255.579 262.764 270.041 277.433 284.963 292.654 300.505 308.517
316.667
```

```
RS333.36 350.573 368.297 386.639 405.556 425.000 444.904 465.289 486.226
507.782
RS529.87 552.525 575.781 599.472 623.577 648.140 673.255 698.852 724.908
751.400
RS778.33 805.624 832.668 859.711 886.754
RQ    54    1000   10000   15000   20000   22000   23000   24000   25000
26000
RQ 26150   26300   26400   26500   26750   27000   27150   27300   27400
27500
RQ 27650   27800   27900   28000   28150   28300   28400   28500   28650
28800
RQ 29000   29300   29500   29800   30000   30100   34100   41100   50400
60700
RQ 74000   88000  103700  120800  139300  159200  180600  203500  227700
253600
RQ281000  310000  340700  373100  407100
RA    54       0    1600    3840    4608    4800    4992    5184    5376
5568
RA  5792    6016    6144    6272    6400    6528    6624    6720    6784
6848
RA  6976    7104    7168    7296    7488    7616    7744    7936    8064
8198.4
RA  8480  8761.6  9043.2  9318.4  9587.2    9856 10124.8 10393.6 10630.4
10912
RA 11168   11424   11680   11936 12179.2 12422.4 12665.6 12908.8 13145.6
13376
RA 13606   13837   14080   14304   14528
RE    54     140     160     180     190     192     194     196     198
200
RE   201     202     203     204     205     206     207     208     209
210
RE   211     212     213     214     215     216     217     218     219
220
RE   222     224     226     228     230     232     234     236     238
240
RE   242     244     246     248     250     252     254     256     258
260
RE   262     264     266     268     270
C R2               1.08
C  4.944   5.135   5.850   5.031   3.369   2.878   3.244   3.214   2.889
2.997
C  2.583   3.673
C   Evaporation rates are read from DSS file for Madden
=======================
P1    50   36000    1.10              89             .83
C   Penstock Capacity Based on Hydro-Met data for Maximum Discharge @ elev =
252
C   Leakage Diverted to Base of Dam (CP 51 to CP 49)
P2          3625
PR
PR
C  = Channel Capacity Based on Limiting Non-spill Releases to Power Operation
==
C  = Lake Gatun Balancing Releases Are ALSO LIMITED to Penstock Capacity
=======
```

```
C  = Minimum flow set to 500 (480+20) cfs based on historic minimum
============
CP    50    3625     480
IDMAD-LAKE
RT    50      49

C ============== Municipal Diversion from Lake Madden
========================
C   Diversions are M&I 5 yr average (1993 - 1997)
C                                                                    Demand
DR    50                                                1           2.60
C                                                                   =======
QD    12     185     188     190     190     191     188     188     187
187
QD   180     182     183

C    Outlet Sum Madden Leakage and Power/Spillway Flows
CP    49  999999
IDMAD-SUM
RT    49      42
C        Control Points 42 and 41 Added to Seperate Diversions
C  --- Gatun Local Inflow + Madden Rlease - Gatun M&I ---
CP    42  999999      27
IDGAT-M&I
RT    42      41
C ============== Divert Lockage + Municipal Water Supply Flows
=================
C                                                                    Demand
DR    42                                                1           2.6
C                                                                    ======
C   Water supply is M&I 5 yr average (1993 - 1997)
QD    12     123     126     123     127     117     127     121     124
115
QD   124     123     119
C  --- - Gatun Power LEAKAGE ---
CP    41  999999
IDGAT-LEAK
RT    41      40
DR    41      37                                          0      27
C ============== Lake Gatun
=================================================
C  5.  Top-of-dam      = Elev. 105.0
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevaions from Fig 5.1
C  2.  Top-of-buffer   = Elev.  78.5
C  1.  Top-of-inactive = Elev.  78.5 (3830250 ACFT) to determine DIV
Shortages
C
RL    40  -87.75
C                         Elev = 78.5 ft
RL     1      40      -1         3536150
RL     2      40      -1         3536150
C                                  Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
```

```
C        ELEV:                          87    87.0    87.0    86.3    86.3
85.4
RL     3      40      25          4453580 4399800 4399800 4325160 4325160
4230070
C                                    Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                        85.4    84.7    84.7    84.7    84.7
84.7
RL                                  4230070 4156820 4156820 4156820 4156820
4156820
C                                    Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                        84.7    84.7    84.7    84.7    84.7
85.0
RL                                  4156820 4156820 4156820 4156820 4156820
4188100
C                                    Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                        85.0    85.9    85.9    87.3    87.3
87.75
RL                                  4188100 4282800 4282800 4432050 4432050
4480570
C                                    Dec31
C        ELEV:                         87.5
RL                                  4453580
C   Gatun Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C                                    Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                       87.75   87.75   87.75  87.75    87.75
87.75
RL     4      40      25          4480570 4480570 4480570 4480570 4480570
4480570
C                                    Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                       87.75   87.75   87.75    86.5    86.5
86.5
RL                                  4480570 4480570 4480570 4346420 4346420
4346420
C                                    Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                        86.5    86.5    86.5    86.5    86.5
86.5
RL                                  4346420 4346420 4346420 4346420 4346420
4346420
C                                    Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                        86.5    86.8    86.8    87.4   87.75
88.00
RL                                  4346420 4378440 4378440 4442800 4480570
4507600
C                                    Dec31
C        ELEV:                       87.75
RL                                  4480570
RL     5      40      -1          6384700
RO
```

```
C   Reservoir storage from path = /PCC/GAT/ELEV-CAPAC(ACFT)///OBS/
C   Reservoir maximum outflow from StoneyGAT.xls, data for 14 gates ELEV=78'-
92'
C   Reservoir areas from path =   /PCC/GAT/ELEV-AREA(ACRES)///OBS/
C   data below elev. 77 and above 90 was extrapolated
RS   -21       0   833.7  1781.7  2729.7  3393.3  3488.1  3584.2  3681.6
3780.3
RS3880.2  3981.6  4084.2  4188.1  4293.3  4399.8  4507.6  4616.7  4727.2
5279.7
RS5832.2  6384.7
RQ    21       0       0       0    1890   42790   58878   69463   80672
92479
RQ104860  117796  131268  145260  159756  174743  190208  206139  222525
300000
RQ350000  400000
RA    21       0   56544   70404   84264   93966   95353   96740   98127
99414
RA100702  101990  103277  104566  105853  107141  108382  109670  110957
117392
RA123827  130262
RE    21      40      50      60      70      77      78      79      80
81
RE    82      83      84      85      86      87      88      89      90
95
RE   100     105
RD    -1     .01     .01     .01     .01     .01     .01     .01     .01
.01
RD   .01    4550    4550    4550    4550    4550  190208  206139  222525
300000
RD350000  400000
C   Evaporation rates are 5 yr. average for Gatun
C R2                1.10
C  4.240   4.589   5.372   5.251   3.304   2.896   3.037   3.132   2.882
2.869
C  2.666   3.349
```

```
CP    40  999999                    1.15
IDGAT-LAKE
RT    40      39
DR    40      38                                      -2
```

```
C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
```

```
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Lockage Releases
CP    39  999999                    1.15
IDGAT-LOCKS
RT    39      37
C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500


C  Lake Gatun Flood (Power) Release
RL    38  -87.75 3536150 3536150 4453580 4480570 6384700
RO
RS     5       0 3536150 4453580 4480570 6384700
RQ     5    9999   99999   99999   99999      -1
RE     5      50    78.5    87.5   87.75     105
P1    38   24000    1.10               9     -40     .85
C   Penstock Capacity Estimated from Operation Data Sheets
P2          4550
PR
PR
CP    38  999999
```

```
IDGAT-POWER
RT    38      37

C  SUM of Lake Gatun LOCKAGE, LEAKAGE, and FLOOD (Power) Releases
CP    37  999999
IDGAT-SUM
RT    37     999
CP   999  999999
IDEND
RT   999

ED
C ===== OBSERVED DATA SPECIFIED FOR JAN 1948 TO DEC 1999
======================
BF     2     624                48010100             720
1900
C ===== PCC EVAPORATION INPUT IN INCHES
ZR=EV40 A=PCC B=GAT C=EVAP F=OBS
ZR=EV50 A=PCC B=MAD C=EVAP F=OBS
C --------- Observed Inflows ---------------
ZR=IN52 A=PCC B=MAD C=FLOW-IN  F=OBS1477+DP7898
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC  F=OBS1477+DP7898
ZW   A=ACP-RJH   F=GAT-LOCK-1.15
EJ
ER
```

# APPENDIX C

# OPTION FOR LOCKAGE CONSUMPTION, Task 3.1.3

## HEC-5 Model Developed for Water Saving Basins Simulation
### GAT-WSB.DAT

```
T1    Panama Canal Capacity Study: Period - of Record Analysis (GAT-WSB.DAT)
T2    Model: Existing System with Deepening (GAT785.DAT & GAT-LOCK.DAT)
T3    DRAFT Model developed by RJHayes, June 2003 for ACP, (PO#SAA107926BGP)
C === Modify Job Control Records for 6 Levels & RECYCLE Option ===
C   === Intended for Application with HEC-5A Dated 23June 03 ===
C      0       1       5       3       4       2
C     24     1.0             132                              0
C ---------------------------------------------------------------
J1     0       1       6       4       5       2       3      10
J2    24     1.0             164                              3
C ---------------------------------------------------------------
J3     5                                          -1                      0
J8 40.10   39.04   38.03   40.03   40.13   40.22
J8 40.10   40.22   40.41   40.03   40.13   40.11   50.13
J8 40.10   40.13   40.22   38.03   50.13   39.04   39.03   37.04
J8 50.13   40.13   40.00   50.10   40.10   50.12   40.12   50.22   40.22
42.31
J8 50.10   50.32   50.00   50.35   51.03   50.10   49.04   50.12   50.13
50.22
J8 52.09   50.03   50.10   50.12   50.13   50.22   50.16   50.35
J8 42.04   41.03   40.09   40.10   41.03   38.03    3.99
J8 41.04   40.03   40.10   40.12   40.13   40.22
J8 50.31   42.31   40.31   40.06   40.13   50.13   40.22   50.22
JZ 40.13   40.22   38.03   40.10
C  ----- Madden's Inflow
RL    52
RO
RS     2       1      10
RQ     2   99999      -1
CP    52   99999
IDMAD-INFLOW
RT    52      51

C        Seperate Madden Power Leakage from Madden Releases to:
C          Provide HEC-5 Output Computation of Power Discharge
C           via J8 40.10   40.32   40.00 for Printout
C           and DSS Computations
C
CP    51   99999
IDMAD-LEAK
RT    51      50
```

```
C  ----- Madden's Leakage Routed to Base of Dam (CP 49)
DR    51      49                                        0      20



C ============== Lake Madden
================================================
C  6.  Top-of-dam      = Elev. 270
C  5.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  4.  Top-of-conserv. = Monthly varying, Elevations from Fig 5.1
C  3   ADDED Level for Water Saving Basins Option
C  2.  Top-of-buffer   = Elev. 190 (M&I only)
C  1.  Top-of-inactive = Elev. 190
RL    50 -252.00
C                                    190
RL     1      50      -1          127250
C                                    190
RL     2      50      -1          127250
RL     3      50      -1          127300
C        ELEV:                       249     243     233     221     217
215
RL     4      50       0          611478  541116  434890  324950  292650
277430
C        ELEV:                       217     222     228     236     247
252
RL                                 292650  333360  386640  465290  587580
648000
C   Madden Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C                                    252     252     252     245     245
245
RL     5      50       0          648140  648140  648140  564096  564096
564096
C                                    245     245     245     248     251
252
RL                                 564096  564096  564096  599470  635790
648140
C                                    270
RL     6      50      -1          886754
C  Operate for:
C              Gatun Inflow & M&I Diversion Point (CP 42)
C              Lake Gatun (CP 40)
RO     2      42      40
C  Reservoir storage from path = /PCC/MAD/ELEV-CAPAC(ACFT)///OBS/
C  Reservoir areas from path =  /PCC/MAD/ELEV-AREA(ACRES)///OBS/
C  Storage & area values below Elev. = 190 are extrapolated
C  Areas above Elev = 264.0 are extrapolated
C  Reservoir maximum outflow from Tables 5-2 + 5-3 + 6-2 PCC FC MANUAL
(9/1992)
RS   -54       0    16.0    54.4  127.25  136.89  146.51  156.70  167.29
178.35
RS184.07 189.992 195.914 202.066 208.356 214.761 221.281 227.916 234.665
241.529
RS248.51 255.579 262.764 270.041 277.433 284.963 292.654 300.505 308.517
316.667
```

```
RS333.36 350.573 368.297 386.639 405.556 425.000 444.904 465.289 486.226
507.782
RS529.87 552.525 575.781 599.472 623.577 648.140 673.255 698.852 724.908
751.400
RS778.33 805.624 832.668 859.711 886.754
RQ    54    1000   10000   15000   20000   22000   23000   24000   25000
26000
RQ 26150   26300   26400   26500   26750   27000   27150   27300   27400
27500
RQ 27650   27800   27900   28000   28150   28300   28400   28500   28650
28800
RQ 29000   29300   29500   29800   30000   30100   34100   41100   50400
60700
RQ 74000   88000  103700  120800  139300  159200  180600  203500  227700
253600
RQ281000  310000  340700  373100  407100
RA    54       0    1600    3840    4608    4800    4992    5184    5376
5568
RA  5792    6016    6144    6272    6400    6528    6624    6720    6784
6848
RA  6976    7104    7168    7296    7488    7616    7744    7936    8064
8198.4
RA  8480  8761.6  9043.2  9318.4  9587.2    9856 10124.8 10393.6 10630.4
10912
RA 11168   11424   11680   11936 12179.2 12422.4 12665.6 12908.8 13145.6
13376
RA 13606   13837   14080   14304   14528
RE    54     140     160     180     190     192     194     196     198
200
RE   201     202     203     204     205     206     207     208     209
210
RE   211     212     213     214     215     216     217     218     219
220
RE   222     224     226     228     230     232     234     236     238
240
RE   242     244     246     248     250     252     254     256     258
260
RE   262     264     266     268     270
C R2               1.08
C  4.944   5.135   5.850   5.031   3.369   2.878   3.244   3.214   2.889
2.997
C  2.583   3.673
C   Evaporation rates are read from DSS file for Madden
=======================
P1    50   36000    1.10              89             .83
C   Penstock Capacity Based on Hydro-Met data for Maximum Discharge @ elev =
252
C   Leakage Diverted to Base of Dam (CP 51 to CP 49)
P2          3625
PR
PR
C  = Channel Capacity Based on Limiting Non-spill Releases to Power Operation
==
C  = Lake Gatun Balancing Releases Are ALSO LIMITED to Penstock Capacity
=======
```

```
C  = Minimum flow set to 500 (480+20) cfs based on historic minimum
============
CP    50    3625     480
IDMAD-LAKE
RT    50      49

C ============== Municipal Diversion from Lake Madden
========================
C   Diversions are M&I 5 yr average (1993 - 1997)
C                                                                    Demand
DR    50                                                1           2.60
C                                                                   =======
QD    12     185     188     190     190     191     188     188     187
187
QD   180     182     183

C    Outlet Sum Madden Leakage and Power/Spillway Flows
CP    49  999999
IDMAD-SUM
RT    49      42

C        Control Points 42 and 41 Added to Seperate Diversions

C  --- Gatun Local Inflow + Madden Rlease - Gatun M&I ---
CP    42  999999      27
IDGAT-M&I
RT    42      41
C ============== Divert Lockage + Municipal Water Supply Flows
=================
C                                                                    Demand
DR    42                                                1           2.6
C                                                                    ======
C   Water supply is M&I 5 yr average (1993 - 1997)
QD    12     123     126     123     127     117     127     121     124
115
QD   124     123     119

C  --- - Gatun Power LEAKAGE ---
CP    41  999999
IDGAT-LEAK
RT    41      40
DR    41      37                                          0      27

C ============== Lake Gatun
==================================================
C  6.  Top-of-dam      = Elev. 105.0
C  5.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  4.  Top-of-conserv. = Monthly varying, Elevaions from Fig 5.1
C  3   ADDED Level for Water Saving Basins Option
C  2.  Top-of-buffer   = Elev.  78.5
C  1.  Top-of-inactive = Elev.  78.5 (3830250 ACFT) to determine DIV
Shortages
C
RL    40  -87.75
C                         Elev = 78.5 ft
```

```
RL     1      40      -1          3536150
RL     2      40      -1          3536150
C ================= Water Saving Basins Upper Limit for Pump Back
==============
C                          Elev = 80.0 ft
RL     3      40      -1          3681612
C
================================================================================
=
C                                  Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                       87    87.0    87.0    86.3    86.3
85.4
RL     4      40      25          4453580 4399800 4399800 4325160 4325160
4230070
C                                  Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                      85.4    84.7    84.7    84.7    84.7
84.7
RL                                4230070 4156820 4156820 4156820 4156820
4156820
C                                  Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                      84.7    84.7    84.7    84.7    84.7
85.0
RL                                4156820 4156820 4156820 4156820 4156820
4188100
C                                  Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                      85.0    85.9    85.9    87.3    87.3
87.75
RL                                4188100 4282800 4282800 4432050 4432050
4480570
C                                  Dec31
C        ELEV:                      87.5
RL                                4453580

C   Gatun Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C                                  Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                     87.75   87.75   87.75   87.75    87.75
87.75
RL     5      40      25          4480570 4480570 4480570 4480570 4480570
4480570
C                                  Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                     87.75   87.75   87.75    86.5    86.5
86.5
RL                                4480570 4480570 4480570 4346420 4346420
4346420
C                                  Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                      86.5    86.5    86.5    86.5    86.5
86.5
```

```
RL                                4346420 4346420 4346420 4346420 4346420
4346420
C                                   Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                       86.5    86.8    86.8    87.4   87.75
88.00
RL                                4346420 4378440 4378440 4442800 4480570
4507600
C                                   Dec31
C        ELEV:                      87.75
RL                                4480570

RL     6      40      -1          6384700
RO
C   Reservoir storage from path = /PCC/GAT/ELEV-CAPAC(ACFT)///OBS/
C   Reservoir maximum outflow from StoneyGAT.xls, data for 14 gates ELEV=78'-
92'
C   Reservoir areas from path =   /PCC/GAT/ELEV-AREA(ACRES)///OBS/
C   data below elev. 77 and above 90 was extrapolated
RS   -21       0   833.7  1781.7  2729.7  3393.3  3488.1  3584.2  3681.6
3780.3
RS3880.2  3981.6  4084.2  4188.1  4293.3  4399.8  4507.6  4616.7  4727.2
5279.7
RS5832.2  6384.7
RQ    21       0       0       0    1890   42790   58878   69463   80672
92479
RQ104860  117796  131268  145260  159756  174743  190208  206139  222525
300000
RQ350000  400000
RA    21       0   56544   70404   84264   93966   95353   96740   98127
99414
RA100702  101990  103277  104566  105853  107141  108382  109670  110957
117392
RA123827  130262
RE    21      40      50      60      70      77      78      79      80
81
RE    82      83      84      85      86      87      88      89      90
95
RE   100     105

C   Evaporation rates are 5 yr. average for Gatun
C R2               1.10
C  4.240   4.589   5.372   5.251   3.304   2.896   3.037   3.132   2.882
2.869
C  2.666   3.349
CP    40  999999
IDGAT-LAKE
RT    40      39

C ---- Div Type -4 Uses Level 3 to Limit Pump Back from Water Saving Basins -
---
DR   40      38                                      -4
QD    12       0   -2000   -2000   -2000   -2000   -2000       0       0
0
QD     0       0       0
```

```
C ------------------------------------------------------------------------
---

C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C
==========
C  Lake Gatun Water Saving Basins 50% Returned if Gatun is Lower Than 80 ft
CP    39  999999
IDGAT-WSB
RT    39      38
DR    39      37                                        -1
QS     3       2    1000   10000
QD     3       1     500    5000

C === From this Location Water Saving Basin Flow is Returned to Lake Gatun
====
CP    38   99999
IDGAT-PUMP
RT    38      37

C  SUM of Lake Gatun LOCKAGE, LEAKAGE, and FLOOD (Power) Releases
CP    37  999999
IDGAT-SUM
RT    37     999

CP   999  999999
IDEND
RT   999

ED
C ===== OBSERVED DATA SPECIFIED FOR JAN 1948 TO DEC 1999
======================
```

```
BF     2     624                48010100             720
1900
C ===== PCC EVAPORATION INPUT IN INCHES
ZR=EV40 A=PCC B=GAT C=EVAP F=OBS
ZR=EV50 A=PCC B=MAD C=EVAP F=OBS
C --------- Observed Inflows ---------------
ZR=IN52 A=PCC B=MAD C=FLOW-IN  F=OBS1477+DP7898
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC  F=OBS1477+DP7898
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C   ZR=QD40  A=PCC B=GAT C=FLOW-DIV  F=AVE CURRENT DEMANDS
ZW   A=ACP-RJH   F=TEST-WSB
EJ
ER
```

# APPENDIX E

# UPPER CHAGRES RIVER CASE 8

## HEC-5 Model Developed for Water Supply Reliability Analysis
**CH2-RJH.DAT**

```
T1    Panama Canal Capacity Study: Period for analysis:1948-1999
(Chag8new.dat)
T2    Based on POR Model: Existing System with Average Lockage & Municipal Qs
T3    Upper Chagres Model developed by A.Bal, July, 1999. Modified by Modesto
E.
C ------------------------------------------------------------------------
-
C     Model (Final) developed by RJHayes, Aug 2003 for ACP, (PO#SAA107926BGP)
C     Analysis should be made with HEC5A Dated 17 Aug 2003 or Later
C     HEC-5 Model CH2-RJH.DAT, based on CH210155.DAT
C ------------------------------------------------------------------------
-
C  THIS IS UPPER CHAGRES LAKE CASE 8 MODEL.
C  NORMAL POOL ELEVATION = 210 M (689.01 FEET) (MONTH OF DECEMBER)
C  MINIMUM POOL ELEVATION = 155 M (508.56 FEET)
C  IT IS BUILT AROUND THE EXISTING WATERSHED MODEL AS DEVELOPED BY RICHARD
HAYES
C  OF HEC ON JANUARY 1999 (PCCBASE.DAT).  THAT MODE
C  Existing System with Average Lockage & Municipal Qs.
C  INFLOWS ARE READ FROM FILE PCCMONQ.DSS.
C  FLOWS WERE OBSERVED AT CHICO STATION.  MISSING FLOWS WERE DERIVED BY A
C  CORRELATION WITH BOQUERON RIVER.
C  I=CHAGRES1.DAT O=CHAGRES1.OUT DSSI=PCCMONSS.DSS  DSSO=CHAGRES1.DSS
C
J1     0       1       5       3       4       2
J2    24     1.0             140                             0
J3     5                                      1                       0
C
C  BASIN MONTHLY NET EVAPORATION (INCHES) FOR LAKE CHAGRES IS ASSUMED TO BE
THE
C  SAME AS THE HISTORICAL EVAPORATION FROM MADDEN LAKE.  EVAPORATION FROM PCC
C  COMPUTED VALUES ARE INPUT AS EV DATA.
J6 4.406   4.615   5.226   4.858   3.586   3.128   3.293   3.148   3.075
3.133
J6 2.827   3.307
J8 39.06   40.13   42.04   50.10   50.13   60.13   50.12   60.12   40.03
J8 39.06   40.13   50.13   60.13   50.10   60.10   50.17   60.17   40.10
J8 60.01   60.10   51.01   50.10   42.01   40.10
J8 60.10   60.16   50.10   50.16   38.09   38.16
C ------------------- Upper Chagres' Power Parameters ----------------------
--
```

```
C Chagres  Total   Power Turbine  Energy  Plant    Rated   Power  Chagres
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 61.03   60.10   60.32   60.00   60.16   60.35   60.25   60.33   60.12
60.22
C ------------------------------------------------------------------------
---
C ------------------- Madden's Hydropower Parameters -----------------------
---
C Madden   Total   Power Turbine  Energy  Plant    Rated   Power  Madden
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 51.03   50.10   50.32   50.00   50.16   50.35   50.25   50.33   50.12
50.22
C ------------------------------------------------------------------------
---

C -------------------- Gatun's Hydropower Parameters -----------------------
---
C Gatun  Non-Lock  Power Turbine  Energy  Plant    Rated   Power   Gatun
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 41.03   40.03   38.32   38.00   38.16   38.35   38.25   38.33   40.12
40.22
C ------------------------------------------------------------------------
---
C  OPTIMIZE THE DIVERSION SCHEDULE ON QD RECORDS BASED ON TOP OF BUFFER LEVEL
C  (LEVEL 2)
C  J7 200.4                                 0                                6
J8 60.09   60.10   60.11   60.12   60.13   60.21   60.22
J8 40.03   40.30   40.31   40.22   40.10   40.09   40.13
J8 50.10   50.12   50.13   50.22   50.09   50.31   50.32
J8200.04  200.01
JZ 40.31   40.10   40.22   50.22   50.10   50.31   40.03   50.03   50.30
40.30
JZ 40.21   50.21   40.13   50.13   40.11   50.16   40.16   50.33   50.35
40.35
JZ 60.09   60.10   60.12   60.13   60.16   60.21   60.22   60.32   60.33
60.35

C  ----- Upper Chagres's Inflow
RL    62
RO
RS     2       1      10
RQ     2   99999      -1
CP    62   99999
```

```
IDCHA-INFLOW
RT    62      61

CP    61   99999
IDCHA-LEAK
RT    61      60
C  ----- Upper Chagres' Leakage Routed to Base of Dam (CP 59)
DR    61      59                                        0      10
C        Seperate Chagres Power Leakage from Chagres Releases to:
C          Provide HEC-5 Output Computation of Power Discharge
C           via J8 60.10   60.32   60.00 for Printout
C

C ============== LAKE UPPER CHAGRES ======================================
C  CONTROL POINT TITLES
C  60 UPPER CHAGRES DAM.  OUTFLOWS GO TO MADDEN LAKE.
C  50 MADDEN DAM.  OUTFLOWS GO TO GATUN LAKE.  M&I DIV. GOES TO DUMMY NODE
99.
C  40 GATUN DAM.  FLOWS GO TO DUMMY NODE 99.
C  99 DOWNSTREAM OF GATUN DAM.  M&I DIVERSION FROM MADDEN GO TO THIS POINT.
C 200 END NODE OF THE RUN
C
C  RESERVOIR LEVELS
C  5.  Top-of-dam                 = Elev. 215.0 m (705.42 ft)
C  LEVELS 3 AND 4 HAVE A RESERVOIR RULE CURVE ASSOCIATED TO THEM.
C  THE LEVEL INDICATED CORRESPONDS TO THE MONTH OF DECEMBER.
C  4.  Top-of-flood (spill curve)  = Elev. 210.0 m (689.01 ft)
C  3.  Top-of-conservation        = Elev. 210.0 m (689.01 ft)
C  2.  Top-of-buffer                  = Elev. 155.10 m (508.88 ft) (No M&I
demand)
C  1.  Top-of-inactive               = Elev. 155.0 m (508.56 ft)
C
C  THE RULE CURVES WERE DERIVED USING MADDEN DAM'S RULE CURVE AS A GUIDE.
C  DEPENDING ON THE RESERVOIR SIZE AND ELEVATION, THEY WERE PLACED IN THE
C  RIGHT ELEVATION AND FLATTENED ACCORDINGLY.  THE RULE CURVES WERE OBTAINED
C  FROM THE BASE MODEL ON THE PANAMA CANAL DEVELOPED BY HEC IN FEBRUARY 1999.
C
C  STARTING STORAGE IN RESERVOIR (1000 ACRE-FEET) IS IN TOP OF CONSERVATION
C  LEVEL (210 METERS OR 689.01 FEET IN THE MONTH OF JANUARY)
C  CUMMULATIVE RESERVOIR CAPACITIES FOR EACH RESERVOIR LEVEL (acre-feet)
C
C  CASE OF VARIABLE RULE CURVES IN UPPER CHAGRES
RL    60  420000
C        ELEVATION (TOP OF INACTIVE):  155 METERS OR 508.56 FEET
RL     1      60      -1           64380
C        ELEVATION (TOP OF BUFFER):  155.10 METERS OR 508.88 FEET
RL     2      60      -1           64714
C Level 3 shape based on reducing to 1/4 of the active storage from January
to June (linearly distributed)
C July is the same as June. Then, recovering to full conservation storage
from July to December.
C        ELEVATION (METERS):      207.50  205.00  202.50  200.00  197.5
195.00
C        ELEVATION (FEET):         680.8   672.6   664.4   656.2   648.0
639.8
```

```
RL     3      60       0          399468  372439  347980  323522  259993
279980
C        ELEVATION (METERS):      195.00  198.00  201.00  204.00  207.00
210.00
C        ELEVATION (FEET):         639.8   649.6   659.5   669.3   679.2  ?
RL                                279980  306105  333305  362656  394063
420000
C RJH
======
C  Level 4 shape based on reducing to 1/8 of the active storage in June and
July similar to Level 3.
C        ELEVATION (METERS):      208.75  207.50  206.25  205.00  203.75
202.50
C        ELEVATION (FEET):         684.9   680.8   676.7   672.6   668.5
664.4
RL     4      60       0          412983  399468  385954  372439  360210
347980
C        ELEVATION (METERS):      202.50  204.00  205.50  207.00  208.50
210.00
C        ELEVATION (FEET):         664.4   669.3   674.2   679.2   684.1
689.0
RL                                347980  362656  377845  394063  410280
426498
C        ELEVATION:  215 METERS OR 705.42 FEET
RL     5      60      -1          485307
C  OPERATE FOR ONE DOWNSTREAM POINT:  MADDEN LAKE.
RO     1      50
C  RESERVOIR STORAGE IN 1000 ACRE-FEET.
RS   -21    .211    .803   1.395   2.919   6.892   9.730  15.025  20.960
29.190
RS 49.46  81.083  122.44  174.33  240.00  323.52 426.498 438.260 450.021
461.783
RS473.54 485.307
C  RESERVOIR OUTLET CAPACITIES. MINIMUM RELEASE IS 10% AVERAGE FLOW (1055
CFS)
C  MINIMUM FLOW, SLUICEWAY CONDUIT AND SPILLWAY ARE CONSIDERED.  THE SLUICE
C  CONDUIT IS 4 FEET BY 4 FEET, LOCATED AT ELEVATION 90 METERS.  THE SPILLWAY
C  IS 286.5 METERS LONG, LOCATED AT ELEVATION 184 METERS.  MINIMUM FLOW IS
105 CFS.
RQ    21     310     439     537     620     760     820     877     930
981
RQ  1074    1160    1240    1316    1387    1454    1519   21134   56880
103167
RQ159469  221647
C  RESERVOIR AREAS IN ACRES.
RA    21      22      30      52      82     189     247     314     413
529
RA   791    1082    1413    1794    2258    2814    3432    3501    3570
3638
RA  3707    3776
C  RESERVOIR ELEVATIONS IN FEET.
C  (METERS) 95   100      105     110     120      125      130      135
140
RE    21   311.7   328.1   344.5   360.9   393.7   410.1   426.5   442.9
459.3
```

```
C     150      160      170     180     190      200      210      211
212      213
RE 492.2   525.0   557.8   590.6   623.4   656.2   689.0   692.3   695.6
698.8
C     214      215
RE 702.1   705.4
C ************************POWER CARDS - UPPER CHAGRES DAM
*************************
C  RATED CAPACITY OF THE POWERPLANT IN KW.  OVERLOAD RATIO.  POWER PEAKING
C  CAPABILITY FUNCTION WILL NOT BE USED.  TAILWATER ELEVATION.  EFFICIENCY.
C  FIXED HEAD LOSS OF 1 FT.
C  USE TAILWATER BLOCK LOADING ELEVATION of 100m (328.1 ft)
P1    60   34500     1.0       0   328.1       0    0.86       1
C  CONSTANT LEAKAGE OF 10 CFS.  THERE IS NO PENSTOCK DISCHARGE LIMITATION.
C  Leakage of 10 cfs Diverted from 61 to 59
P2     0       0
C  THERE ARE NO MONTHLY AT-SITE ENERGY REQUIREMENTS.
PR
PR
C  = Minimum flow set to 500 cfs based 10% of average ====================
C  CHANNEL CAPACITY.  MINIMUM DESIRED FLOW.  MINIMUM REQUIRED FLOW.
CP    60    3500     250     105
IDCHA
C  OUTFLOW FROM RESERVOIR 60 GOES TO CONTROL POINT 50. NO ROUTING WILL BE
PERFOR
RT    60      59
C CL   8     1.0     2.3     2.4     2.8     2.9     3.0    3.01     4.0
C CC60.4    1300    1300    1000    1000    1200    1500    3500    3500

CP    59   99999
IDCHA-SUM
RT    59      51

CP    51   99999
IDMAD-LEAK
RT    51      50
C  ----- Madden's Leakage Routed to Base of Dam (CP 49)
DR    51      49                                        0      20

C ============== Lake Madden
================================================
C  5.  Top-of-dam      = Elev. 270
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevations from Fig 5.1
C  2.  Top-of-buffer   = Elev. 190 (M&I only)
C  1.  Top-of-inactive = Elev. 190
RL    50 -252.00
C                                  190
RL     1      50      -1          127250
C                                  190
RL     2      50      -1          127250
C        ELEV:                       249     243     233     221     217
215
RL     3      50       0          611478  541116  434890  324950  292650
277430
```

```
C        ELEV:                          217     222     228     236     247
252
RL                                   292650  333360  386640  465290  587580
648140
C ------------------------------------------------------------------------
-
C   Madden Spill Curve Modified for Dec-Mar 255 Spill Elevation
C                                      255     255     255     245     245
245
RL     4      50       0          686100  686100  686100  564096  564096
564096
C                                      245     245     245     248     251
255
RL                                   564096  564096  564096  599470  635790
686100
C ------------------------------------------------------------------------
--
C   Madden Spill Curve from PCC OPERDATA.BAS dated 6-23-94 252 Spill
Elevation
C                                      252     252     252     245     245
245
C RL   4      50       0          648140  648140  648140  564096  564096
564096
C                                      245     245     245     248     251
252
C RL                                 564096  564096  564096  599470  635790
648140
C ------------------------------------------------------------------------
--
C                                      270
RL     5      50      -1          886754
C  Operate for:
C              Gatun Inflow & M&I Diversion Point (CP 42)
C              Lake Gatun (CP 40)
RO     2      42      40
C  Reservoir storage from path = /PCC/MAD/ELEV-CAPAC(ACFT)///OBS/
C  Reservoir areas from path =  /PCC/MAD/ELEV-AREA(ACRES)///OBS/
C  Storage & area values below Elev. = 190 are extrapolated
C  Areas above Elev = 264.0 are extrapolated
C  Reservoir maximum outflow from Tables 5-2 + 5-3 + 6-2 PCC FC MANUAL
(9/1992)
RS   -54       0    16.0    54.4  127.25  136.89  146.51  156.70  167.29
178.35
RS184.07 189.992 195.914 202.066 208.356 214.761 221.281 227.916 234.665
241.529
RS248.51 255.579 262.764 270.041 277.433 284.963 292.654 300.505 308.517
316.667
RS333.36 350.573 368.297 386.639 405.556 425.000 444.904 465.289 486.226
507.782
RS529.87 552.525 575.781 599.472 623.577 648.140 673.255 698.852 724.908
751.400
RS778.33 805.624 832.668 859.711 886.754
RQ    54    1000   10000   15000   20000   22000   23000   24000   25000
26000
```

```
RQ 26150   26300   26400   26500   26750   27000   27150   27300   27400
27500
RQ 27650   27800   27900   28000   28150   28300   28400   28500   28650
28800
RQ 29000   29300   29500   29800   30000   30100   34100   41100   50400
60700
RQ 74000   88000  103700  120800  139300  159200  180600  203500  227700
253600
RQ281000  310000  340700  373100  407100
RA    54       0    1600    3840    4608    4800    4992    5184    5376
5568
RA  5792    6016    6144    6272    6400    6528    6624    6720    6784
6848
RA  6976    7104    7168    7296    7488    7616    7744    7936    8064
8198.4
RA  8480  8761.6  9043.2  9318.4  9587.2    9856 10124.8 10393.6 10630.4
10912
RA 11168   11424   11680   11936 12179.2 12422.4 12665.6 12908.8 13145.6
13376
RA 13606   13837   14080   14304   14528
RE    54     140     160     180     190     192     194     196     198
200
RE   201     202     203     204     205     206     207     208     209
210
RE   211     212     213     214     215     216     217     218     219
220
RE   222     224     226     228     230     232     234     236     238
240
RE   242     244     246     248     250     252     254     256     258
260
RE   262     264     266     268     270
C R2                1.08
C  4.944   5.135   5.850   5.031   3.369   2.878   3.244   3.214   2.889
2.997
C  2.583   3.673
C   Evaporation rates are read from DSS file for Madden
=======================
P1    50   36000    1.10              89             .83
C   Penstock Capacity Based on Hydro-Met data for Maximum Discharge @ elev =
252
C   Leakage Diverted to Base of Dam (CP 51 to CP 49)
P2          3625
PR
PR
C  = Channel Capacity Based on Limiting Non-spill Releases to Power Operation
==
C  = Lake Gatun Balancing Releases Are ALSO LIMITED to Penstock Capacity
=======
C  = Minimum flow set to 500 (480+20) cfs based on historic minimum
============
CP    50    3625     480
IDMAD-LAKE
RT    50      49
```

```
C ============== Municipal Diversion from Lake Madden
=========================
C   Diversions are M&I 5 yr average (1993 - 1997)
C                                                                       Demand
DR    50                                                  1            2.60
C                                                                      =======
QD    12     185     188     190     190     191     188     188     187
187
QD   180     182     183
C CL   8     1.0     2.0     2.2     2.8     2.9     3.0    3.01     4.0
C CC50.4    2500    2500    2400    2400    2700    2900    3625    3625

C    Outlet Sum Madden Leakage and Power/Spillway Flows
CP    49  999999
IDMAD-SUM
RT    49      42

C ============== Lake Gatun
==================================================

C        Control Points 42 and 41 Added to Seperate Diversions

C  --- Gatun Local Inflow + Madden Rlease - Gatun M&I ---
CP    42    6000     400      27
IDGAT-M&I
RT    42      41
C ============== Divert Lockage + Municipal Water Supply Flows
=================
C                                                                       Demand
DR    42                                                  1            2.6
C                                                                       ======
C   Water supply is M&I 5 yr average (1993 - 1997)
QD    12     123     126     123     127     117     127     121     124
115
QD   124     123     119
C RJH  Upsteram Reservoirs to Operate for Min Flow Requirement
C RJH  To Reduce Effect of Negative Local Flow Into Lake Gatun
QM   400     400     400     400     400     400     400     400     400
400
QM   400     400

C  --- - Gatun Power LEAKAGE ---
CP    41  999999
IDGAT-LEAK
RT    41      40
DR    41      37                                          0      27


C ============== Lake Gatun
==================================================
C  5.  Top-of-dam      = Elev. 105.0
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevaions from Fig 5.1
C  2.  Top-of-buffer   = Elev.  78.5
```

```
C  1.  Top-of-inactive = Elev.  78.5 (3830250 ACFT) to determine DIV
Shortages
C
RL    40  -87.75
C                          Elev = 78.5 ft
RL     1      40      -1          3536150
RL     2      40      -1          3536150

C                                   Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                         87    87.0    87.0    86.3    86.3
85.4
RL     3      40      25          4453580 4399800 4399800 4325160 4325160
4230070
C                                   Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                        85.4    84.7    84.7    84.7    84.7
84.7
RL                                 4230070 4156820 4156820 4156820 4156820
4156820
C                                   Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                        84.7    84.7    84.7    84.7    84.7
85.0
RL                                 4156820 4156820 4156820 4156820 4156820
4188100
C                                   Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                        85.0    85.9    85.9    87.3    87.3
87.75
RL                                 4188100 4282800 4282800 4432050 4432050
4480570
C                                   Dec31
C        ELEV:                       87.5
RL                                 4453580

C   Gatun Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C                                   Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                      87.75   87.75   87.75  87.75    87.75
87.75
RL     4      40      25          4480570 4480570 4480570 4480570 4480570
4480570
C                                   Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                      87.75   87.75   87.75    86.5    86.5
86.5
RL                                 4480570 4480570 4480570 4346420 4346420
4346420
C                                   Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                       86.5    86.5    86.5    86.5    86.5
86.5
RL                                 4346420 4346420 4346420 4346420 4346420
4346420
```

```
C                                    Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                        86.5    86.8    86.8    87.4   87.75
88.00
RL                                  4346420 4378440 4378440 4442800 4480570
4507600
C                                    Dec31
C        ELEV:                       87.75
RL                                  4480570

RL     5      40      -1          6384700
RO     1      39
C   Reservoir storage from path = /PCC/GAT/ELEV-CAPAC(ACFT)///OBS/
C   Reservoir maximum outflow from StoneyGAT.xls, data for 14 gates ELEV=78'-
92'
C   Reservoir areas from path =   /PCC/GAT/ELEV-AREA(ACRES)///OBS/
C   data below elev. 77 and above 90 was extrapolated
RS   -21       0   833.7  1781.7  2729.7  3393.3  3488.1  3584.2  3681.6
3780.3
RS3880.2  3981.6  4084.2  4188.1  4293.3  4399.8  4507.6  4616.7  4727.2
5279.7
RS5832.2  6384.7
RQ    21       0       0       0    1890   42790   58878   69463   80672
92479
RQ104860  117796  131268  145260  159756  174743  190208  206139  222525
300000
RQ350000  400000
RA    21       0   56544   70404   84264   93966   95353   96740   98127
99414
RA100702  101990  103277  104566  105853  107141  108382  109670  110957
117392
RA123827  130262
RE    21      40      50      60      70      77      78      79      80
81
RE    82      83      84      85      86      87      88      89      90
95
RE   100     105
RD    -1     .01     .01     .01     .01     .01     .01     .01     .01
.01
RD   .01   99999   99999   99999   99999   99999  190208  206139  222525
300000
RD350000  400000
C   Evaporation rates are 5 yr. average for Gatun
C R2                1.10
C  4.240   4.589   5.372   5.251   3.304   2.896   3.037   3.132   2.882
2.869
C  2.666   3.349
CP    40  999999                   1.20
IDGAT-LAKE
RT    40      39
DR    40      38                                    -2

C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
```

```
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Lockage Releases
CP    39  999999                  1.20
IDGAT-LOCKS
RT    39      37
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Flood (Power) Release
RL    38  -87.75 3536150 3536150 4453580 4480570 6384700
RO
RS     5       0 3536150 4453580 4480570 6384700
RQ     5    9999   99999   99999   99999      -1
RE     5      50    78.5    87.5   87.75     105
P1    38   24000    1.10               9     -40     .85
```

```
C   Penstock Capacity Estimated from Operation Data Sheets
P2          4550
PR
PR
CP    38  999999
IDGAT-POWER
RT    38      37

C  SUM of Lake Gatun LOCKAGE, LEAKAGE, and FLOOD (Power) Releases
CP    37  999999
IDGAT-SUM
RT    37     200

CP   200  999999
IDEND
RT   200

ED
C ===== OBSERVED DATA SPECIFIED FOR JAN 1948 TO DEC 1999
=======================
BF     2     624                48010100             720
1900
NOLIST
C ===== PCC EVAPORATION INPUT IN INCHES
ZR=EV40 A=PCC B=GAT C=EVAP F=OBS
ZR=EV50 A=PCC B=MAD C=EVAP F=OBS
ZR=EV60 A=PCC B=MAD C=EVAP F=OBS
C --------- Observed Inflows ---------------
C  ZR=IN51 A=PCC B=MAD C=FLOW-IN  F=OBS1477+DP7898
ZR=IN51 A=PCC B=MAD C=FLOW-IN-INC  F=CHICO SUBTRACTED
C  UPPER CHAGRES FLOWS WERE SUBTRACTED FROM GATUN INFLOW DATA WITH
C  F PART OBS1477+DP7898
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC  F=OBS1477+DP7898
C      ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC  F=CHAGRES SUBTRACTED
C
ZR=IN62 A=CHAGRES B=CHICO C=FLOW-IN E=1MON F=COMP
C
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C ZR=QD40  A=PCC B=GAT C=FLOW-DIV  F=AVE CURRENT DEMANDS
C ===== Write to DSS File for use with HEC-DSS Vue
============================
ZW   A=RJH-17AUG03 F=CH2-RJH-1.20
EJ
ER
```

# APPENDIX F

# COCLE DEL NORTE

## HEC-5 Model Developed for Water Supply Reliability Analysis

**COC-RJH.DAT**

```
T1    Panama Canal Capacity Study:   Based on TOAB9550.DAT    (COC-RJH.DAT)
T2    Model: Toabre, Indio linked to Gatun with Average Lockage & Municipal
Qs
T3    Model (Final) developed by RJHayes, Aug 2003 for ACP, (PO#SAA107926BGP)
C     Analysis should be made with HEC5A Dated 17 Aug 2003 or Later
C ------------------------------------------------------------------------
-
C  RIO INDIO AT LIMON, PANAMA CANAL
C  NORMAL POOL=80M MIN POOL=40M; 1 TUNNELS OF 4.5  METER OF DIAMETER AND 8.4
KMS OF LENGTH
C  COCLE DEL NORTE DAM, PANAMA CANAL
C  NORMAL POOL=100M MIN POOL=90M; TUNNELS OF 5 M OF DIAMETER AND 2.7 KMS OF
LENGTH
C
J1     0       1       5       3       4       2
C     24     1.0             172                                0
J2    24     1.0             140                                0
J3     5                                      -1                          0
J8 39.06   40.13   50.13  200.13  300.13   50.10  200.10  300.10  300.03
200.03
J8 39.06   40.13   50.13   50.12   50.10  200.13  200.12  200.10  300.10
39.05
C
C ------------------------------------------------------------------------
---
C ------------------- Cocle's PRIMARY Hydropower Plant ---------------------
-----
C Madden   Total   Power Turbine  Energy  Plant    Rated   Power  Madden
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8300.03  300.10  300.32  300.00  300.16  300.35  300.25  300.33  300.12
300.22
C ------------------------------------------------------------------------
---
C ------------------- Cocle's SECOND Hydropower Plant ----------------------
---
```

```
C Madden   Total   Power Turbine  Energy  Plant    Rated   Power  Madden
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8290.03  290.10  290.32  290.00  290.16  290.35  290.25  290.33  290.12
300.22
C ------------------------------------------------------------------------
---
C ------------------- Madden's Hydropower Parameters -----------------------
---
C Madden   Total   Power Turbine  Energy  Plant    Rated   Power  Madden
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 51.03   50.10   50.32   50.00   50.16   50.35   50.25   50.33   50.12
50.22
C ------------------------------------------------------------------------
---
C -------------------- Gatun's Hydropower Parameters -----------------------
---
C Gatun  Non-Lock  Power Turbine  Energy  Plant    Rated   Power   Gatun
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 41.03   40.03   38.32   38.00   38.16   38.35   38.25   38.33   40.12
40.22
C ------------------------------------------------------------------------
---
J8300.22  300.12  300.13  200.22  200.12  200.13   40.22   40.13   50.22
50.13
JZ-40.03   40.30   40.31   40.22   50.22  300.22  200.22
JZ300.22  300.10  300.12  300.13  200.22  200.10  200.12  200.13   50.22
50.13
JZ 40.03   40.30   40.31   40.22   40.24   40.02   40.09   40.10   40.21
40.32
JZ 50.24   50.02   50.03   50.09   50.10   50.21   50.32   50.22
JZ300.22  300.24  300.03  300.09  300.10  300.21  300.13  300.11  300.16
300.32
JZ301.03  301.09  301.10  290.32  290.09  290.10  290.16
JZ200.22  200.02  200.24  200.03  200.09  200.10  200.21  200.13  200.12
200.11
JZ199.10  199.03
C  DATA SAVED TO DSS
C   .03=FLOW-DIV           .04=FLOW-REG         .12=CASE         .13=LEVEL
C   .09=FLOW-RES IN        .10=FLOW-RES OUT     .22=ELEV         .30=DIV
REQUIRED
C   .32=FLOW-SPILL         .16=ENERGY-GEN       .35=PLANT FACTOR .33=POWER
HEAD
C   .21=EVAPORATION        .32=FLOW-POWER SPILL .31=DIV SHORTAGE .11=STORGE
```

```
C  ----- Cocle del Norte's Inflow
RL   302
RO
RS     2       1      10
RQ     2   99999      -1
CP   302   99999
IDCOC-INFLOW
RT   302     301

CP   301   99999
IDCOC-TO-290
RT   301     300
C  ----- Cocle Flow (386 cfs) Routed to 2nd Power Plant (CP 290)
DR   301     290                                        0     386

C   *************  COCLE DEL NORTE DAM AT EL TORNO  **************
C  RESERVOIR LEVELS
C  LEVEL 1 = INACTIVE STORAGE     (BELOW ELEV 90M)
C  LEVEL 2 = MINIMUM POOL ELEV    (ELEV 90M)
C  LEVEL 3 = TOP OF CONSERVATION  (ELEV 100M)
C  LEVEL 4 = MAXIMUM POOL ELEV    (ELEV 102.5M)
C  LEVEL 5 = TOP OF DAM           (ELEV 105M)
RL   300 -328.10 8149890 814990011138100119997061289476 5
RL     1     300      -1         8149890
RL     2     300      -1         8149890
RL     3     300      -1        11138100
  RL   3     300       0        106600001042000010180000 9940000 9700000
9460000
C RL
111381001113810011138100111381001113810011138100
RL     4     300      -1        11999706
RL     5     300      -1        12894765


RO     1     200
RS   -20   723.9  2432.9  5798.7  6888.2  8149.9  8421.1  8698.5  8982.1
9272.0
RS9568.4  9871.1 10180.3 10496.1 10818.5 11138.1 11438.0 11483.3 11825.9
12175.3
C                                              ======
RS12895.
C Multiple outlet capacity from a tunnel of 5 meters diameter and 2.7 kms
length
QQ   200       9  262.48
RQ131.24       0       0       0       0    4893    5014    5132    5247
5360
RQ  5471    5579    5686    5790    5892    5993    6079    6092    6190
6286
C                                                  ====
RQ  6473
RQ147.64       0       0       0       0    4893    5014    5132    5247
5360
RQ  5471    5579    5686    5790    5892    5993    6079    6092    6190
6286
```

```
RQ  6473
RQ164.05       0       0       0       0    4893    5014    5132    5247
5360
RQ  5471    5579    5686    5790    5892    5993    6079    6092    6190
6286
RQ  6473
RQ180.46       0       0       0       0    4893    5014    5132    5247
5360
RQ  5471    5579    5686    5790    5892    5993    6079    6092    6190
6286
RQ  6473
RQ196.86       0       0       0       0    4893    5014    5132    5247
5360
RQ  5471    5579    5686    5790    5892    5993    6079    6092    6190
6286
RQ  6473
RQ213.26       0       0       0       0    4893    5014    5132    5247
5360
RQ  5471    5579    5686    5790    5892    5993    6079    6092    6190
6286
RQ  6473
RQ229.67       0       0       0       0    4893    5014    5132    5247
5360
RQ  5471    5579    5686    5790    5892    5993    6079    6092    6190
6286
RQ  6473
RQ246.08       0       0       0       0    4238    4377    4511    4642
4769
RQ  4893    5014    5132    5247    5360    5471    5565    5579    5686
5790
C                                           ====
RQ  5993
RQ262.48       0       0       0       0    3460    3629    3790    3945
4094
RQ  4238    4377    4511    4642    4769    4893    4998    5014    5132
5247
C                                           ====
RQ  5471

RA    20   15488   38347   65539   72777   81111   82859   84634   86438
88270
RA 90130   92017   93931   95872   97840   99692  101570  101854  103900
105972
C                                          ======
RA110191
RE    20  131.24  196.86  262.48  278.89  295.29  298.57  301.85  305.13
308.41
RE311.70  314.98  318.26  321.54  324.82  328.10   331.0  331.38  334.66
337.94
C                                          ======
RE344.51
C Divert all flood waters to power plant and spillway, values from spillway
rati
RD    -1     .01     .01     .01     .01     .01     .01     .01     .01
.01
```

```
RD   .01     .01     .01     .01     .01     .01     1.0   18598   61745
122619
C                                                   =====   =====   =====
RD263833
C  AVERAGE EVAPORATION RATES PROVIDED BY PCC, BASED ON GATUN AVERAGE FROM
1993-1
R3 4.406   4.615   5.226   4.858   3.586   3.128   3.293   3.148   3.075
3.133
R3 2.827   3.307
C   ************** POWER RECORDS **************
C Indio pool tailwater elevation to compute head
P1   300   20000     1.0       0       0     200    0.86       1
P2     0       0
PR
PR
C   ****************************************
CP   300   99999
IDCOCLE DAM
RT   300     299
C   Flood Flows are Diverted to 2nd Cocle Power Plant
DR   300     290                                        -2


CP   299   99999
ID CP299
RT   299     200
C RJH Revised Please Check
C   DR   299     290                                                386

C ================= COCLE DAM & POWER PLANT (THIRD of 3 Parts) ==============
C  ============== COCLE Hydro Power Reservoir
==================================
RL   290 -328.10 8149890 814990011138100119997061289476 5
RO
RS   -19   723.9  2432.9  5798.7  6888.2  8149.9  8421.1  8698.5  8982.1
9272.0
RS9568.4  9871.1 10180.3 10496.1 10818.5 11138.1 11483.3 11825.9 12175.3
12894.8
RQ    19      -1      -1      -1      -1      -1      -1      -1      -1
-1
RQ    -1      -1      -1      -1      -1      -1      -1      -1      -1
-1
RA    19   15488   38347   65539   72777   81111   82859   84634   86438
88270
RA 90130   92017   93931   95872   97840   99692  101854  103900  105972
110191
RE    19  131.24  196.86  262.48  278.89  295.29  298.57  301.85  305.13
308.41
RE311.70  314.98  318.26  321.54  324.82  328.10  331.38  334.66  337.94
344.51
C   ************** POWER RECORDS **************
C Tailwater block loading at 20 m (65.6 ft)
P1   290    7500     1.0       0    65.6    -300    0.86       1
C                                  ====
C No leakage; minimum flow pass thru small unit, ? MW
```

```
P2     0       0
PR
PR
C   ****************************************
CP   290  999999
IDCOCLE PP         POWER PLANT
RT   290     999

C  ============== RIO INDIO DAM AT LIMON
=====================================
C  RESERVOIR LEVELS
C  LEVEL 1 = INACTIVE STORAGE     (BELOW ELEV 40M)
C  LEVEL 2 = MINIMUM POOL ELEV    (ELEV 40.01M)
C  LEVEL 3 = TOP OF CONSERVATION  (ELEV 80M)
C  LEVEL 4 = MAXIMUM POOL ELEV    (ELEV 82.5M)
C  LEVEL 5 = TOP OF DAM           (ELEV 85M)

RL   200 -262.48
RL     1     200      -1          229600
RL     2     200      -1          229649
RL     3     200      -1         1278900
C RL     3     200       0          1278900 1226400 1174000 1121500 1069100
1016600
C RL                               1016600 1069100 1121500 1174000 1226400
1278900
RL     4     200      -1         1384200
RL     5     200      -1         1489530
RO     2      42      40
RS   -20  33.544 229.649 318.191 406.733 528.932 651.131 708.070 765.009
821.947
RS878.89 935.825 1004.44 1073.04 1141.66 1210.27 1278.88 1384.00 1384.20
1489.53
RS1700.2
C Discharges for a tunnel of 4.25 m of diameter (HORSESHOE)
C RQ    19       0    1754    2044    2296    2525    2733    2813    2890
29
C RQ  3038    3109    3179    3248    3315    3380    3444    3523    3600
37
C Discharges for a tunnel of 4.5 m of diameter (HORSESHOE)
C RQ    19       0    2021    2355    2646    2909    3150    3241    3330
3416
C RQ  3501    3583    3663    3742    3820    3895    3969    4060    4149
4321
C Discharges for 2 tunnels of 4.5 m of diameter (HORSESHOE)
RQ    20       0    4042    4710    5292    5818    6300    6482    6660
6832
RQ  7002    7166    3663    7326    7640    7790    7938    8100    8120
8298
RQ  8642
C Discharges for a tunnel of 5m of diameter (HORSESHOE)
C RQ    19       0    2623    3056    3435    3776    4088    4207    4322
44
C RQ  4544    4651    4755    4858    4958    5056    5152    5270    5386
56
C Discharges for a tunnel of 6 m of diameter (HORSESHOE)
```

```
C RQ    19       0    4118    4797    5391    5926    6417    6603    6784
6960
C RQ  7132    7300    7464    7624    7782    7936    8087    8272    8453
9141
RA    20    1573    4371    5401    6425    7026    7624    8014    8404
8794
RA  9185    9575    9915   10255   10595   10935   11275   11670   11671
12059
RA 12842
RE    20   65.62  131.24  147.65  164.05  180.46  196.86  203.42  209.98
216.55
RE223.11  229.67  236.23  242.79  249.36  255.92  262.48  270.63  270.68
278.88
RE295.29
RD    -1    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
0.01
RD  0.01    0.01    0.01    0.01    0.01    0.01    0.01       1   32362
91535
RD258900
C                                                          =====
C RD0.01    0.01    0.01    0.01    0.01    0.01    0.01   32362   91535
258900
C  AVERAGE EVAPORATION RATES PROVIDED BY PCC, BASED ON GATUN AVERAGE FROM
1993-1
R3 4.406   4.615   5.226   4.858   3.586   3.128   3.293   3.148   3.075
3.133
R3 2.827   3.307
C ******************* POWER CARDS ************************
C P1   200   25000     1.0       0       0      40    0.86       1
C Set leakage to 81.2 cfs which will be diverted from 199 to 20
C P2  81.2       0
C PR
C PR
C  ******************************************************

CP   200   12000            91.2
ID INDIO DAM       NR LIMON
RT   200     199
DR   200     999                                        -2
QM  2000    2000    2000    2000    2000    2000     500     500     500
500
QM   500     500

CP   199  999999
ID CP199
RT   199      42
DR   199     999                                         0    91.2

C  ----- Madden's Inflow
RL    52
RO
RS     2       1      10
RQ     2   99999      -1
CP    52   99999
IDMAD-INFLOW
```

```
RT    52      51

C        Seperate Madden Power Leakage from Madden Releases to:
C          Provide HEC-5 Output Computation of Power Discharge
C           via J8 50.10   40.32   50.00 for Printout
C           and DSS Computations
C
CP    51   99999
IDMAD-LEAK
RT    51      50
C  ----- Madden's Leakage Routed to Base of Dam (CP 49)
DR    51      49                                          0      20


RL    50 -252.00
C                                   190
RL     1      50      -1          127250
C                                   190
RL     2      50      -1          127250
C        ELEV:                      249     243     233     221     217
215
RL     3      50       0          611478  541116  434890  324950  292650
277430
C        ELEV:                      217     222     228     236     247
252
RL                                 292650  333360  386640  465290  587580
648140
C ------------------------------------------------------------------------
-
C   Madden Spill Curve Modified for Dec-Mar 255 Spill Elevation
C                                   255     255     255     245     245
245
RL     4      50       0          686100  686100  686100  564096  564096
564096
C                                   245     245     245     248     251
255
RL                                 564096  564096  564096  599470  635790
686100
C ------------------------------------------------------------------------
--
C   Madden Spill Curve from PCC OPERDATA.BAS dated 6-23-94 252 Spill
Elevation
C                                   252     252     252     245     245
245
C RL   4      50       0          648140  648140  648140  564096  564096
564096
C                                   245     245     245     248     251
252
C RL                               564096  564096  564096  599470  635790
648140
C ------------------------------------------------------------------------
--
C                                   270
RL     5      50      -1          886754
C  Operate for:
```

```
C              Gatun Inflow & M&I Diversion Point (CP 42)
C              Lake Gatun (CP 40)
RO     2      42      40
C  Reservoir storage from path = /PCC/MAD/ELEV-CAPAC(ACFT)///OBS/
C  Reservoir areas from path =  /PCC/MAD/ELEV-AREA(ACRES)///OBS/
C  Storage & area values below Elev. = 190 are extrapolated
C  Areas above Elev = 264.0 are extrapolated
C  Reservoir maximum outflow from Tables 5-2 + 5-3 + 6-2 PCC FC MANUAL
(9/1992)
RS   -54       0    16.0    54.4  127.25  136.89  146.51  156.70  167.29
178.35
RS184.07 189.992 195.914 202.066 208.356 214.761 221.281 227.916 234.665
241.529
RS248.51 255.579 262.764 270.041 277.433 284.963 292.654 300.505 308.517
316.667
RS333.36 350.573 368.297 386.639 405.556 425.000 444.904 465.289 486.226
507.782
RS529.87 552.525 575.781 599.472 623.577 648.140 673.255 698.852 724.908
751.400
RS778.33 805.624 832.668 859.711 886.754
RQ    54    1000   10000   15000   20000   22000   23000   24000   25000
26000
RQ 26150   26300   26400   26500   26750   27000   27150   27300   27400
27500
RQ 27650   27800   27900   28000   28150   28300   28400   28500   28650
28800
RQ 29000   29300   29500   29800   30000   30100   34100   41100   50400
60700
RQ 74000   88000  103700  120800  139300  159200  180600  203500  227700
253600
RQ281000  310000  340700  373100  407100
RA    54       0    1600    3840    4608    4800    4992    5184    5376
5568
RA  5792    6016    6144    6272    6400    6528    6624    6720    6784
6848
RA  6976    7104    7168    7296    7488    7616    7744    7936    8064
8198.4
RA  8480  8761.6  9043.2  9318.4  9587.2    9856 10124.8 10393.6 10630.4
10912
RA 11168   11424   11680   11936 12179.2 12422.4 12665.6 12908.8 13145.6
13376
RA 13606   13837   14080   14304   14528
RE    54     140     160     180     190     192     194     196     198
200
RE   201     202     203     204     205     206     207     208     209
210
RE   211     212     213     214     215     216     217     218     219
220
RE   222     224     226     228     230     232     234     236     238
240
RE   242     244     246     248     250     252     254     256     258
260
RE   262     264     266     268     270
C R2               1.08
```

```
C  4.944   5.135   5.850   5.031   3.369   2.878   3.244   3.214   2.889
2.997
C  2.583   3.673
C   Evaporation rates are read from DSS file for Madden
=======================
P1    50   36000    1.10              89             .83
C   Penstock Capacity Based on Hydro-Met data for Maximum Discharge @ elev =
252
C   Leakage Diverted to Base of Dam (CP 51 to CP 49)
P2          3625
PR
PR
C  = Channel Capacity Based on Limiting Non-spill Releases to Power Operation
==
C  = Lake Gatun Balancing Releases Are ALSO LIMITED to Penstock Capacity
=======
C  = Minimum flow set to 500 (480+20) cfs based on historic minimum
============
CP    50    3625     480     480
IDMAD-LAKE
RT    50      49

C ============== Municipal Diversion from Lake Madden
=========================
C   Diversions are M&I 5 yr average (1993 - 1997)
C                                                                      Demand
DR    50                                                 1            2.60
C                                                                     =======
QD    12     185     188     190     190     191     188     188     187
187
QD   180     182     183
CL     4     1.0     2.0     2.5     3.0     4.0
CC  50.4    2000    2000    2000    3625    3625

C    Outlet Sum Madden Leakage and Power/Spillway Flows
CP    49  999999
IDMAD-SUM
RT    49      42

C        Control Points 42 and 41 Added to Seperate Diversions

C  --- Gatun Local Inflow + Madden Rlease - Gatun M&I ---
CP    42    8000    1000      27
IDGAT-M&I
RT    42      41
C ============== Divert Lockage + Municipal Water Supply Flows
=================
C                                                                      Demand
DR    42                                                 1            2.6
C                                                                      ======
C   Water supply is M&I 5 yr average (1993 - 1997)
QD    12     123     126     123     127     117     127     121     124
115
QD   124     123     119
```

```
QM  4000    4000    4000    4000    4000    4000     500     500     500
500
QM   500     500
C  --- - Gatun Power LEAKAGE ---
CP    41  999999
IDGAT-LEAK
RT    41      40
DR    41      37                                        0      27

C ============== Lake Gatun
================================================
C  5.  Top-of-dam      = Elev. 105.0
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevaions from Fig 5.1
C  2.  Top-of-buffer   = Elev.  78.5
C  1.  Top-of-inactive = Elev.  78.5 (3830250 ACFT) to determine DIV
Shortages
C
RL    40  -87.75
C                          Elev = 78.5 ft
RL     1      40      -1         3536150
RL     2      40      -1         3536150

C                                  Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                        87    87.0    87.0    86.3    86.3
85.4
RL     3      40      25         4453580 4399800 4399800 4325160 4325160
4230070
C                                  Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                       85.4    84.7    84.7    84.7    84.7
84.7
RL                                4230070 4156820 4156820 4156820 4156820
4156820
C                                  Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                       84.7    84.7    84.7    84.7    84.7
85.0
RL                                4156820 4156820 4156820 4156820 4156820
4188100
C                                  Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                       85.0    85.9    85.9    87.3    87.3
87.75
RL                                4188100 4282800 4282800 4432050 4432050
4480570
C                                  Dec31
C        ELEV:                      87.5
RL                                4453580

C   Gatun Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C                                  Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
```

```
C        ELEV:                      87.75   87.75   87.75  87.75    87.75
87.75
RL     4      40      25          4480570 4480570 4480570 4480570 4480570
4480570
C                                   Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                      87.75   87.75   87.75    86.5    86.5
86.5
RL                                 4480570 4480570 4480570 4346420 4346420
4346420
C                                   Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                       86.5    86.5    86.5    86.5    86.5
86.5
RL                                 4346420 4346420 4346420 4346420 4346420
4346420
C                                   Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                       86.5    86.8    86.8    87.4   87.75
88.00
RL                                 4346420 4378440 4378440 4442800 4480570
4507600
C                                   Dec31
C        ELEV:                      87.75
RL                                 4480570

RL     5      40      -1          6384700
RO     1      39
C   Reservoir storage from path = /PCC/GAT/ELEV-CAPAC(ACFT)///OBS/
C   Reservoir maximum outflow from StoneyGAT.xls, data for 14 gates ELEV=78'-
92'
C   Reservoir areas from path =   /PCC/GAT/ELEV-AREA(ACRES)///OBS/
C   data below elev. 77 and above 90 was extrapolated
RS   -21       0   833.7  1781.7  2729.7  3393.3  3488.1  3584.2  3681.6
3780.3
RS3880.2  3981.6  4084.2  4188.1  4293.3  4399.8  4507.6  4616.7  4727.2
5279.7
RS5832.2  6384.7
RQ    21       0       0       0    1890   42790   58878   69463   80672
92479
RQ104860  117796  131268  145260  159756  174743  190208  206139  222525
300000
RQ350000  400000
RA    21       0   56544   70404   84264   93966   95353   96740   98127
99414
RA100702  101990  103277  104566  105853  107141  108382  109670  110957
117392
RA123827  130262
RE    21      40      50      60      70      77      78      79      80
81
RE    82      83      84      85      86      87      88      89      90
95
RE   100     105
RD    -1     .01     .01     .01     .01     .01     .01     .01     .01
.01
```

```
RD   .01    4550    4550    4550    4550    4550  190208  206139  222525
300000
RD350000  400000
C   Evaporation rates are 5 yr. average for Gatun
C R2                1.10
C  4.240   4.589   5.372   5.251   3.304   2.896   3.037   3.132   2.882
2.869
C  2.666   3.349
CP    40  999999                   2.600
IDGAT-LAKE
RT    40      39
DR    40      38                                    -2

C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Lockage Releases
CP    39  999999                   2.600
IDGAT-LOCKS
RT    39      37
C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
```

```
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Flood (Power) Release
RL    38  -87.75 3536150 3536150 4453580 4480570 6384700
RO
RS     5       0 3536150 4453580 4480570 6384700
RQ     5    9999   99999   99999   99999      -1
RE     5      50    78.5    87.5   87.75     105
P1    38   24000    1.10               9     -40     .85
C   Penstock Capacity Estimated from Operation Data Sheets
P2          4550
PR
PR
CP    38  999999
IDGAT-POWER
RT    38      37

C  SUM of Lake Gatun LOCKAGE, LEAKAGE, and FLOOD (Power) Releases
CP    37  999999
IDGAT-SUM
RT    37     999

CP   999  999999
IDEND
RT   999

ED
C ===== OBSERVED DATA SPECIFIED FOR JAN 1958 TO DEC 1996
=======================
BF     2     624                48010100             720
1900
QA    50    -472                                1158
C      2     624                48010100             720
1900
NOLIST
C ===== PCC EVAPORATION INPUT IN INCHES
ZR=EV40 A=PCC B=GAT C=EVAP F=OBS
ZR=EV50 A=PCC B=MAD C=EVAP F=OBS
C --------- Observed Inflows ---------------
ZR=IN52 A=PCC B=MAD C=FLOW-IN  F=OBS1477+DP7898
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC  F=OBS1477+DP7898
ZR=IN302 A=COCLE-SUCIO B=DAMSITE C=FLOW E=1MON F=COMP
ZR=IN200 A=INDIO B=DAMSITE C=FLOW E=1MON F=COMP
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C  ZR=QD40  A=PCC B=GAT C=FLOW-DIV E=1MON F=AVE CURRENT DEMANDS
C  ZW   A=ALT-COC  F=COCLED2.634 H5AEM
```

```
C ===== Write to DSS File for use with HEC-DSS Vue
============================
ZW   A=RJH-17AUG03 F=COC-RJH-2.600
EJ
ER
```

# APPENDIX G

# EXISTING SYSTEM WITH DEEPENING

## HEC-5 Model Developed for Water Supply Reliability Analysis

**GAT-RJH.DAT**

```
T1    Panama Canal Capacity Study: Period - of Record Analysis (GAT-RJH.DAT)
T2    Model Based on Existing System with Deepening (GAT785.DAT)
T3    Model (Final) developed by RJHayes, Aug 2003 for ACP, (PO#SAA107926BGP)
C     Analysis should be made with HEC5A Dated 17 Aug 2003 or Later
J1     0       1       5       3       4       2
J2    24     1.0             140                             0
J3     5                                     -1                          0
J8 39.05   39.06   40.13   50.13   50.12   50.10   49.04   40.01   41.04
J8 50.22   50.13   50.10   50.12   50.16   50.32
J8 40.22   40.13   40.10   40.12   40.03   38.16   38.32   40.05   39.05
39.06
C ------------------- Madden's Hydropower Parameters ------------------------
---
C Madden   Total   Power Turbine  Energy  Plant    Rated   Power  Madden
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 51.03   50.10   50.32   50.00   50.16   50.35   50.25   50.33   50.12
50.22
C ------------------------------------------------------------------------
---
C -------------------- Gatun's Hydropower Parameters ------------------------
---
C Gatun  Non-Lock  Power Turbine  Energy  Plant    Rated   Power   Gatun
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 41.03   40.03   38.32   38.00   38.16   38.35   38.25   38.33   40.12
40.22
C ------------------------------------------------------------------------
---
J8 50.12   50.10   50.13   40.13   40.00   40.10   40.03   50.32   50.22
40.22
J8 51.03   50.03   42.03   41.03   40.03
JZ-41.03   40.03   38.32   38.16   38.35   38.33   40.12   40.22   39.06
39.05
```

```
JZ 50.13   40.13   50.10   40.10   50.12   40.12   50.22   40.22   42.31

C  ----- Madden's Inflow
RL    52
RO
RS     2       1      10
RQ     2   99999      -1
CP    52   99999
IDMAD-INFLOW
RT    52      51

C        Seperate Madden Power Leakage from Madden Releases to:
C          Provide HEC-5 Output Computation of Power Discharge
C           via J8 50.10   50.32   50.00 for Printout
C           and DSS Computations
C
CP    51   99999
IDMAD-LEAK
RT    51      50
C  ----- Madden's Leakage Routed to Base of Dam (CP 49)
DR    51      49                                        0      20

C ============== Lake Madden
================================================
C  5.  Top-of-dam      = Elev. 270
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevations from Fig 5.1
C  2.  Top-of-buffer   = Elev. 190 (M&I only)
C  1.  Top-of-inactive = Elev. 190
RL    50 -252.00
C                                   190
RL     1      50      -1          127250
C                                   190
RL     2      50      -1          127250
C        ELEV:                        249     243     233     221     217
215
RL     3      50       0          611478  541116  434890  324950  292650
277430
C        ELEV:                        217     222     228     236     247
252
RL                                 292650  333360  386640  465290  587580
648140
C ------------------------------------------------------------------------
-
C   Madden Spill Curve Modified for Dec-Mar 255 Spill Elevation
C                                   255     255     255     245     245
245
RL     4      50       0          686100  686100  686100  564096  564096
564096
C                                   245     245     245     248     251
255
RL                                 564096  564096  564096  599470  635790
686100
C ------------------------------------------------------------------------
--
```

```
C   Madden Spill Curve from PCC OPERDATA.BAS dated 6-23-94 252 Spill
Elevation
C                                    252     252     252     245     245
245
C RL   4      50       0          648140  648140  648140  564096  564096
564096
C                                    245     245     245     248     251
252
C RL                                564096  564096  564096  599470  635790
648140
C ------------------------------------------------------------------------
--
C                                    270
RL     5      50      -1          886754
C  Operate for:
C              Gatun Inflow & M&I Diversion Point (CP 42)
C              Lake Gatun (CP 40)
RO     2      40      42
C  Reservoir storage from path = /PCC/MAD/ELEV-CAPAC(ACFT)///OBS/
C  Reservoir areas from path =  /PCC/MAD/ELEV-AREA(ACRES)///OBS/
C  Storage & area values below Elev. = 190 are extrapolated
C  Areas above Elev = 264.0 are extrapolated
C  Reservoir maximum outflow from Tables 5-2 + 5-3 + 6-2 PCC FC MANUAL
(9/1992)
RS   -54       0    16.0    54.4  127.25  136.89  146.51  156.70  167.29
178.35
RS184.07 189.992 195.914 202.066 208.356 214.761 221.281 227.916 234.665
241.529
RS248.51 255.579 262.764 270.041 277.433 284.963 292.654 300.505 308.517
316.667
RS333.36 350.573 368.297 386.639 405.556 425.000 444.904 465.289 486.226
507.782
RS529.87 552.525 575.781 599.472 623.577 648.140 673.255 698.852 724.908
751.400
RS778.33 805.624 832.668 859.711 886.754
RQ    54    1000   10000   15000   20000   22000   23000   24000   25000
26000
RQ 26150   26300   26400   26500   26750   27000   27150   27300   27400
27500
RQ 27650   27800   27900   28000   28150   28300   28400   28500   28650
28800
RQ 29000   29300   29500   29800   30000   30100   34100   41100   50400
60700
RQ 74000   88000  103700  120800  139300  159200  180600  203500  227700
253600
RQ281000  310000  340700  373100  407100
RA    54       0    1600    3840    4608    4800    4992    5184    5376
5568
RA  5792    6016    6144    6272    6400    6528    6624    6720    6784
6848
RA  6976    7104    7168    7296    7488    7616    7744    7936    8064
8198.4
RA  8480  8761.6  9043.2  9318.4  9587.2    9856 10124.8 10393.6 10630.4
10912
```

```
RA 11168   11424   11680   11936 12179.2 12422.4 12665.6 12908.8 13145.6
13376
RA 13606   13837   14080   14304   14528
RE    54     140     160     180     190     192     194     196     198
200
RE   201     202     203     204     205     206     207     208     209
210
RE   211     212     213     214     215     216     217     218     219
220
RE   222     224     226     228     230     232     234     236     238
240
RE   242     244     246     248     250     252     254     256     258
260
RE   262     264     266     268     270
C R2               1.08
C  4.944   5.135   5.850   5.031   3.369   2.878   3.244   3.214   2.889
2.997
C  2.583   3.673
C   Evaporation rates are read from DSS file for Madden
========================
P1    50   36000    1.10              89             .83
C   Penstock Capacity Based on Hydro-Met data for Maximum Discharge @ elev =
252
C   Leakage Diverted to Base of Dam (CP 51 to CP 49)
P2          3625
PR
PR
C  = Channel Capacity Based on Limiting Non-spill Releases to Power Operation
==
C  = Lake Gatun Balancing Releases Are ALSO LIMITED to Penstock Capacity
=======
C  = Minimum flow set to 500 (480+20) cfs based on historic minimum
============
CP    50    3625     480
IDMAD-LAKE
RT    50      49

C ============== Municipal Diversion from Lake Madden
=========================
C   Diversions are M&I 5 yr average (1993 - 1997)
C                                                                    Demand
DR    50                                              1             2.60
C                                                                   =======
QD    12     185     188     190     190     191     188     188     187
187
QD   180     182     183
CL     9     1.0     2.0     2.2     2.7     2.8     3.0    3.01     4.0
CC  50.4    2000    2000    1000    1000    1500    2000    3625    3625

C    Outlet Sum Madden Leakage and Power/Spillway Flows
CP    49  999999
IDMAD-SUM
RT    49      42
```

**C Control Points 42 and 41 Added to Seperate Diversions**

```
C  --- Gatun Local Inflow + Madden Rlease - Gatun M&I ---
CP    42    6000     400
IDGAT-M&I
RT    42      41
C ============== Divert Lockage + Municipal Water Supply Flows
=================
C                                                                    Demand
DR    42                                                  1           2.6
C                                                                    ======
C   Water supply is M&I 5 yr average (1993 - 1997)
QD    12     123     126     123     127     117     127     121     124
115
QD   124     123     119


C  --- - Gatun Power LEAKAGE ---
CP    41  999999
IDGAT-LEAK
RT    41      40
DR    41      37                                          0      27

C ============== Lake Gatun
================================================
C  5.  Top-of-dam      = Elev. 105.0
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevaions from Fig 5.1
C  2.  Top-of-buffer   = Elev.  78.5
C  1.  Top-of-inactive = Elev.  78.5 (3830250 ACFT) to determine DIV
Shortages
C
RL    40  -87.75
C                         Elev = 78.5 ft
RL     1      40      -1         3536150
RL     2      40      -1         3536150

C                                  Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                        87    87.0    87.0    86.3    86.3
85.4
RL     3      40      25         4453580 4399800 4399800 4325160 4325160
4230070
C                                  Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                       85.4    84.7    84.7    84.7    84.7
84.7
RL                                4230070 4156820 4156820 4156820 4156820
4156820
C                                  Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                       84.7    84.7    84.7    84.7    84.7
85.0
RL                                4156820 4156820 4156820 4156820 4156820
4188100
```

```
C                                  Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                      85.0    85.9    85.9    87.3    87.3
87.75
RL                                4188100 4282800 4282800 4432050 4432050
4480570
C                                  Dec31
C        ELEV:                      87.5
RL                                4453580

C   Gatun Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C                                  Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                     87.75   87.75   87.75  87.75    87.75
87.75
RL     4      40      25         4480570 4480570 4480570 4480570 4480570
4480570
C                                  Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                     87.75   87.75   87.75    86.5    86.5
86.5
RL                                4480570 4480570 4480570 4346420 4346420
4346420
C                                  Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                      86.5    86.5    86.5    86.5    86.5
86.5
RL                                4346420 4346420 4346420 4346420 4346420
4346420
C                                  Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                      86.5    86.8    86.8    87.4   87.75
88.00
RL                                4346420 4378440 4378440 4442800 4480570
4507600
C                                  Dec31
C        ELEV:                     87.75
RL                                4480570

RL     5      40      -1         6384700
RO     1      39
C   Reservoir storage from path = /PCC/GAT/ELEV-CAPAC(ACFT)///OBS/
C   Reservoir maximum outflow from StoneyGAT.xls, data for 14 gates ELEV=78'-
92'
C   Reservoir areas from path =   /PCC/GAT/ELEV-AREA(ACRES)///OBS/
C   data below elev. 77 and above 90 was extrapolated
RS   -21       0   833.7  1781.7  2729.7  3393.3  3488.1  3584.2  3681.6
3780.3
RS3880.2  3981.6  4084.2  4188.1  4293.3  4399.8  4507.6  4616.7  4727.2
5279.7
RS5832.2  6384.7
RQ    21       0       0       0    1890   42790   58878   69463   80672
92479
RQ104860  117796  131268  145260  159756  174743  190208  206139  222525
300000
```

```
RQ350000  400000
RA    21       0   56544   70404   84264   93966   95353   96740   98127
99414
RA100702  101990  103277  104566  105853  107141  108382  109670  110957
117392
RA123827  130262
RE    21      40      50      60      70      77      78      79      80
81
RE    82      83      84      85      86      87      88      89      90
95
RE   100     105
RD    -1     .01     .01     .01     .01     .01     .01     .01     .01
.01
RD   .01   99999   99999   99999   99999   99999  190208  206139  222525
300000
RD350000  400000
C   Evaporation rates are 5 yr. average for Gatun
C R2                1.10
C  4.240   4.589   5.372   5.251   3.304   2.896   3.037   3.132   2.882
2.869
C  2.666   3.349
CP    40  999999                    1.15
IDGAT-LAKE
RT    40      39
DR    40      38                                    -2

C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Lockage Releases
CP    39  999999                    1.15
IDGAT-LOCKS
RT    39      37
```

```
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Flood (Power) Release
RL    38  -87.75 3536150 3536150 4453580 4480570 6384700
RO
RS     5       0 3536150 4453580 4480570 6384700
RQ     5    9999   99999   99999   99999      -1
RE     5      50    78.5    87.5   87.75     105
P1    38   24000    1.10               9     -40     .85
C   Penstock Capacity Estimated from Operation Data Sheets
P2          4550
PR
PR
CP    38  999999
IDGAT-POWER
RT    38      37

C  SUM of Lake Gatun LOCKAGE, LEAKAGE, and FLOOD (Power) Releases
CP    37  999999
IDGAT-SUM
RT    37     999

CP   999  999999
IDEND
RT   999

ED
C ===== OBSERVED DATA SPECIFIED FOR JAN 1948 TO DEC 1999
=======================
BF     2     624                48010100             720
1900
NOLIST
C ===== PCC EVAPORATION INPUT IN INCHES
ZR=EV40 A=PCC B=GAT C=EVAP F=OBS
ZR=EV50 A=PCC B=MAD C=EVAP F=OBS
```

```
C --------- Observed Inflows ---------------
ZR=IN52 A=PCC B=MAD C=FLOW-IN  F=OBS1477+DP7898
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC  F=OBS1477+DP7898
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C   ZR=QD40  A=PCC B=GAT C=FLOW-DIV  F=AVE CURRENT DEMANDS
C ===== Write to DSS File for use with HEC-DSS Vue
============================
ZW   A=RJH-17AUG03 F=GAT-RJH-1.15
EJ
ER
```

1

# APPENDIX H

# RIO INDIO

## HEC-5 Model Developed for Water Supply Reliability Analysis

**IND-RJH.DAT**

```
T1    Panama Canal Capacity Study: Period - of Record Analysis  (IND-RJH.DAT)
T2    Model: Indio linked to Gatun, Ave. Lockage & Municipal Qs (IND8040.DAT
T3    Model (Final) developed by RJHayes, Aug 2003 for ACP, (PO#SAA107926BGP)
C     Analysis should be made with HEC5A Dated 17 Aug 2003 or Later
C ------------------------------------------------------------------------
-
C  RIO INDIO AT LIMON, PANAMA CANAL
C  NORMAL POOL=80M MIN POOL=40M
C  HYDROPOWER, EVAPORATION AND MINIMUM FLOW INCLUDED
J1     0       1       5       3       4       2
J2    24     1.0             140                             0
J3     5                                      -1                      0
C ======================Revisions March 2001 RJH for
PCA======================
C Alternative Rio Indio operating between 80m to 40m acting
C   as a single reservoir addition (Gatun operates between 87.75 & 78.5)
C =>Indio Diversion Revised for Flood Control Releases (19 RS,RQ,RA,RE & RD)

J8 39.05   39.06   40.10   40.22   40.13  200.13   50.13  200.10   50.10
C ------------------- Indio's Hydropower Parameters ------------------------
--
C Total   Power Turbine  Energy  Plant    Rated   Power   Indio    Lake
C Release Spill   Flow  Produced Factor  Capacity  Head Operation  Elev
C   cfs     cfs     cfs     MWH      %       kW     feet    Case    feet
J8200.10  200.32  200.00  200.16  200.35  200.25  200.33  200.12  200.22
C ------------------------------------------------------------------------
---
C ------------------- Indio's Second Hydropower Plant ----------------------
---
C  Power   Total   Power Turbine  Energy  Plant    Rated   Power  Indio
Lake
C Inflow  Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 20.09   20.10   20.32   20.00   20.16   20.35   20.25   20.33  200.12
200.22
C ------------------------------------------------------------------------
---
C ------------------- Madden's Hydropower Parameters -----------------------
---
```

```
C Madden   Total   Power Turbine  Energy  Plant    Rated   Power  Madden
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 51.03   50.10   50.32   50.00   50.16   50.35   50.25   50.33   50.12
50.22
C ------------------------------------------------------------------------
---
C -------------------- Gatun's Hydropower Parameters ----------------------
---
C Gatun  Non-Lock  Power Turbine  Energy  Plant    Rated   Power   Gatun
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 41.03   40.03   38.32   38.00   38.16   38.35   38.25   38.33   40.12
40.22
C ------------------------------------------------------------------------
---

J8200.12  200.10  200.13   40.13  200.03   40.10   40.03   50.10
JZ-41.03   40.03   38.32   38.16   38.35   38.33   40.22   39.06   39.05
JZ 50.13   40.13   50.10   40.10   50.22   40.22   42.31
JZ200.13  200.10  200.13  200.22  200.03   20.10   20.28  200.28   38.28
50.28

C ===== Rio Indio Inflow =====
RL   202
RO
RS     2       1      10
RQ     2   99999      -1
CP   202   99999
IDIND-INFLOW
RT   202     201

C ---- Divert to Indio'S Second Power Plant (CP 20) ----
C ---- Constant Release of 91.2 cfs to Rio Indio ----
CP   201   99999
IDIND-PP2
RT   201     200
DR   201      20                                              91.2

C  ============== RIO INDIO DAM AT LIMON
=====================================
C  RESERVOIR LEVELS
C  LEVEL 1 = INACTIVE STORAGE     (BELOW ELEV 40M)
C  LEVEL 2 = MINIMUM POOL ELEV    (ELEV 40.01M)
C  LEVEL 3 = TOP OF CONSERVATION  (ELEV 80M)
C  LEVEL 4 = MAXIMUM POOL ELEV    (ELEV 82.5M)
C  LEVEL 5 = TOP OF DAM           (ELEV 85M)
RL   200 -262.48
RL     1     200      -1          229649
```

```
RL     2     200      -1          229649
C Using 25% of active storage
RL     3     200       0         1278900 1226400 1174000 1121500 1069100
1016600
RL                               1016600 1069100 1121500 1174000 1226400
1278900
RL     4     200      -1         1384200
RL     5     200      -1         1489530
RO     2      40      42
RS   -19  33.544 229.649 318.191 406.733 528.932 651.131 708.070 765.009
821.947
RS878.89 935.825 1004.44 1073.04 1141.66 1210.27 1278.88 1384.20 1489.53
1700.19
C Discharges for a tunnel of 4.5 m of diameter (HORSESHOE)
RQ    19       0    2021    2355    2646    2909    3150    3241    3330
3416
RQ  3501    3583    3663    3742    3820    3895    3969    4060    4149
4321
RA    19    1573    4371    5401    6425    7026    7624    8014    8404
8794
RA  9185    9575    9915   10255   10595   10935   11275   11671   12059
12842
RE    19   65.62  131.24  147.65  164.05  180.46  196.86  203.42  209.98
216.55
RE223.11  229.67  236.23  242.79  249.36  255.92  262.48  270.68  278.88
295.29
RD    -1    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
0.01
RD  0.01    0.01    0.01    0.01    0.01    0.01    0.01   32362   91535
258900
C  AVERAGE EVAPORATION RATES PROVIDED BY PCC, BASED ON GATUN AVERAGE FROM
1993-1
R3 4.406   4.615   5.226   4.858   3.586   3.128   3.293   3.148   3.075
3.133
R3 2.827   3.307
C ******************* POWER CARDS ************************
P1   200   25000     1.0       0       0      40    0.86       1
C ---------------- ORIGINAL-------------------------------------
C Set leakage to 91.2 cfs which will be diverted from 199 to 20
C P2  91.2       0
C ------------------REVISED-----------------
C RJH 91.2 Diverted from 201 to 20
C RJH Check Power Assumptions with ACP Staff
P2     0       0
PR
PR
C  ******************************************************
CP   200   12500
ID INDIO DAM       NR LIMON
RT   200     199
DR   200      20                                        -2
CL     9     1.0     2.0     2.3     2.4     2.7     3.0    3.01     4.0
CC 200.4    3000    3000    3000    2000    2000    2600   12500   12500
QM  1000    1000    1000    1000    1000    1000       0       0       0
0
```

```
QM     0       0

CP   199  999999
ID CP199
RT   199      42

C  ============== Indio Hydro Power ================================
C  ------------ 91.2 cfs Diverted from CP 201 ------------------------------
-
C
RL    20 1278876 1278876 1278876 1278876 1278876 1278876
RO
RS   -18 229.649 318.191 406.733 528.932 651.131 708.070 765.009 821.947
878.886
RS935.82 1004.44 1073.04 1141.66 1210.27 1278.88 1384.20 1489.53 1700.19
RQ    18      -1      -1      -1      -1      -1      -1      -1      -1
-1
RQ    -1      -1      -1      -1      -1      -1      -1      -1      -1
RE    18  131.24  147.65  164.05  180.46  196.86  203.42  209.98  216.55
223.11
RE229.67  236.23  242.79  249.36  255.92  262.48  270.68  278.88  295.29
C ******************* POWER CARDS ************************
P1    20    5000     1.0       0    32.8    -200    0.86       1
P2     0       0
PR
PR
C  ****************************************************
CP    20  999999
ID INDIO PP       POWER PLANT
RT    20     999

C  ----- Madden's Inflow
RL    52
RO
RS     2       1      10
RQ     2   99999      -1
CP    52   99999
IDMAD-INFLOW
RT    52      51

C        Seperate Madden Power Leakage from Madden Releases to:
C          Provide HEC-5 Output Computation of Power Discharge
C           via J8 50.10   50.32   50.00 for Printout
C           and DSS Computations
C
CP    51   99999
IDMAD-LEAK
RT    51      50
C  ----- Madden's Leakage Routed to Base of Dam (CP 49)
DR    51      49                                        0      20

C ============== Lake Madden
================================================
C  5.  Top-of-dam      = Elev. 270
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
```

```
C  3.  Top-of-conserv. = Monthly varying, Elevations from Fig 5.1
C  2.  Top-of-buffer   = Elev. 190 (M&I only)
C  1.  Top-of-inactive = Elev. 190
RL    50 -252.00
C                                   190
RL     1      50      -1          127250
C                                   190
RL     2      50      -1          127250
C        ELEV:                      249     243     233     221     217
215
RL     3      50       0          611478  541116  434890  324950  292650
277430
C        ELEV:                      217     222     228     236     247
252
RL                                 292650  333360  386640  465290  587580
648140
C ------------------------------------------------------------------------
-
C   Madden Spill Curve Modified for Dec-Mar 255 Spill Elevation
C                                   255     255     255     245     245
245
RL     4      50       0          686100  686100  686100  564096  564096
564096
C                                   245     245     245     248     251
255
RL                                 564096  564096  564096  599470  635790
686100
C ------------------------------------------------------------------------
--
C   Madden Spill Curve from PCC OPERDATA.BAS dated 6-23-94 252 Spill
Elevation
C                                   252     252     252     245     245
245
C RL   4      50       0          648140  648140  648140  564096  564096
564096
C                                   245     245     245     248     251
252
C RL                               564096  564096  564096  599470  635790
648140
C ------------------------------------------------------------------------
--
C                                   270
RL     5      50      -1          886754
C  Operate for:
C             Gatun Inflow & M&I Diversion Point (CP 42)
C             Gatun Leakage (CP 41) and Lake Gatun (CP 40)
RO     2      40      42
C  Reservoir storage from path = /PCC/MAD/ELEV-CAPAC(ACFT)///OBS/
C  Reservoir areas from path =  /PCC/MAD/ELEV-AREA(ACRES)///OBS/
C  Storage & area values below Elev. = 190 are extrapolated
C  Areas above Elev = 264.0 are extrapolated
C  Reservoir maximum outflow from Tables 5-2 + 5-3 + 6-2 PCC FC MANUAL
(9/1992)
RS   -54       0    16.0    54.4  127.25  136.89  146.51  156.70  167.29
178.35
```

```
RS184.07 189.992 195.914 202.066 208.356 214.761 221.281 227.916 234.665
241.529
RS248.51 255.579 262.764 270.041 277.433 284.963 292.654 300.505 308.517
316.667
RS333.36 350.573 368.297 386.639 405.556 425.000 444.904 465.289 486.226
507.782
RS529.87 552.525 575.781 599.472 623.577 648.140 673.255 698.852 724.908
751.400
RS778.33 805.624 832.668 859.711 886.754
RQ    54    1000   10000   15000   20000   22000   23000   24000   25000
26000
RQ 26150   26300   26400   26500   26750   27000   27150   27300   27400
27500
RQ 27650   27800   27900   28000   28150   28300   28400   28500   28650
28800
RQ 29000   29300   29500   29800   30000   30100   34100   41100   50400
60700
RQ 74000   88000  103700  120800  139300  159200  180600  203500  227700
253600
RQ281000  310000  340700  373100  407100
RA    54       0    1600    3840    4608    4800    4992    5184    5376
5568
RA  5792    6016    6144    6272    6400    6528    6624    6720    6784
6848
RA  6976    7104    7168    7296    7488    7616    7744    7936    8064
8198.4
RA  8480  8761.6  9043.2  9318.4  9587.2    9856 10124.8 10393.6 10630.4
10912
RA 11168   11424   11680   11936 12179.2 12422.4 12665.6 12908.8 13145.6
13376
RA 13606   13837   14080   14304   14528
RE    54     140     160     180     190     192     194     196     198
200
RE   201     202     203     204     205     206     207     208     209
210
RE   211     212     213     214     215     216     217     218     219
220
RE   222     224     226     228     230     232     234     236     238
240
RE   242     244     246     248     250     252     254     256     258
260
RE   262     264     266     268     270
C R2               1.08
C  4.944   5.135   5.850   5.031   3.369   2.878   3.244   3.214   2.889
2.997
C  2.583   3.673
C   Evaporation rates are read from DSS file for Madden
=======================
P1    50   36000    1.10              89             .83
C   Penstock Capacity Based on Hydro-Met data for Maximum Discharge @ elev =
252
C   Leakage Diverted to Base of Dam (CP 51 to CP 49)
P2          3625
PR
PR
```

```
C  = Channel Capacity Based on Limiting Non-spill Releases to Power Operation
==
C  = Lake Gatun Balancing Releases Are ALSO LIMITED to Penstock Capacity
=======
C  = Minimum flow set to 500 (480+20) cfs based on historic minimum
============
CP    50    3625     480
IDMAD-LAKE
RT    50      49

C ============== Municipal Diversion from Lake Madden
=========================
C   Diversions are M&I 5 yr average (1993 - 1997)
C                                                                      Demand
DR    50                                                  1             2.60
C                                                                     =======
QD    12     185     188     190     190     191     188     188     187
187
QD   180     182     183
CL     9     1.0     2.0     2.2     2.7     2.8     3.0    3.01     4.0
CC  50.4    2000    2000    1200    1200    1500    2500    3625    3625

C    Outlet Sum Madden Leakage and Power/Spillway Flows
CP    49  999999
IDMAD-SUM
RT    49      42


C        Control Points 42 and 41 Added to Seperate Diversions

C  --- Gatun Local Inflow + Madden Rlease - Gatun M&I ---
CP    42    6000     400
IDGAT-M&I
RT    42      41
C ============== Divert Lockage + Municipal Water Supply Flows
=================
C                                                                      Demand
DR    42                                                    1           2.6
C                                                                      ======
C   Water supply is M&I 5 yr average (1993 - 1997)
QD    12     123     126     123     127     117     127     121     124
115
QD   124     123     119

C  --- - Gatun Power LEAKAGE ---
CP    41  999999
IDGAT-LEAK
RT    41      40
DR    41      37                                          0      27

C ============== Lake Gatun
================================================
C  5.  Top-of-dam      = Elev. 105.0
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevaions from Fig 5.1
```

```
C  2.  Top-of-buffer   = Elev.  78.5
C  1.  Top-of-inactive = Elev.  78.5 (3830250 ACFT) to determine DIV
Shortages
C
RL    40  -87.75
C                          Elev = 78.5 ft
RL     1      40      -1          3536150
RL     2      40      -1          3536150

C                                  Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                        87    87.0    87.0    86.3    86.3
85.4
RL     3      40      25         4453580 4399800 4399800 4325160 4325160
4230070
C                                  Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                      85.4    84.7    84.7    84.7    84.7
84.7
RL                                4230070 4156820 4156820 4156820 4156820
4156820
C                                  Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                      84.7    84.7    84.7    84.7    84.7
85.0
RL                                4156820 4156820 4156820 4156820 4156820
4188100
C                                  Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                      85.0    85.9    85.9    87.3    87.3
87.75
RL                                4188100 4282800 4282800 4432050 4432050
4480570
C                                  Dec31
C        ELEV:                      87.5
RL                                4453580

C   Gatun Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C                                  Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                     87.75   87.75   87.75  87.75    87.75
87.75
RL     4      40      25         4480570 4480570 4480570 4480570 4480570
4480570
C                                  Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                     87.75   87.75   87.75    86.5    86.5
86.5
RL                                4480570 4480570 4480570 4346420 4346420
4346420
C                                  Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                      86.5    86.5    86.5    86.5    86.5
86.5
```

```
RL                                4346420 4346420 4346420 4346420 4346420
4346420
C                                   Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                       86.5    86.8    86.8    87.4   87.75
88.00
RL                                4346420 4378440 4378440 4442800 4480570
4507600
C                                   Dec31
C        ELEV:                      87.75
RL                                4480570

RL     5      40      -1         6384700
RO     1      39
C   Reservoir storage from path = /PCC/GAT/ELEV-CAPAC(ACFT)///OBS/
C   Reservoir maximum outflow from StoneyGAT.xls, data for 14 gates ELEV=78'-
92'
C   Reservoir areas from path =   /PCC/GAT/ELEV-AREA(ACRES)///OBS/
C   data below elev. 77 and above 90 was extrapolated
RS   -21       0   833.7  1781.7  2729.7  3393.3  3488.1  3584.2  3681.6
3780.3
RS3880.2  3981.6  4084.2  4188.1  4293.3  4399.8  4507.6  4616.7  4727.2
5279.7
RS5832.2  6384.7
RQ    21       0       0       0    1890   42790   58878   69463   80672
92479
RQ104860  117796  131268  145260  159756  174743  190208  206139  222525
300000
RQ350000  400000
RA    21       0   56544   70404   84264   93966   95353   96740   98127
99414
RA100702  101990  103277  104566  105853  107141  108382  109670  110957
117392
RA123827  130262
RE    21      40      50      60      70      77      78      79      80
81
RE    82      83      84      85      86      87      88      89      90
95
RE   100     105
RD    -1     .01     .01     .01     .01     .01     .01     .01     .01
.01
RD   .01   99999   99999   99999   99999   99999  190208  206139  222525
300000
RD350000  400000
C   Evaporation rates are 5 yr. average for Gatun
C R2                1.10
C  4.240   4.589   5.372   5.251   3.304   2.896   3.037   3.132   2.882
2.869
C  2.666   3.349
CP    40  999999                   1.50
IDGAT-LAKE
RT    40      39
DR    40      38                                    -2

C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
```

```
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Lockage Releases
CP    39  999999                    1.50
IDGAT-LOCKS
RT    39      37
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500


C  Lake Gatun Flood (Power) Release
RL    38  -87.75 3536150 3536150 4453580 4480570 6384700
RO
RS     5       0 3536150 4453580 4480570 6384700
RQ     5    9999   99999   99999   99999      -1
```

```
RE     5      50    78.5    87.5   87.75     105
P1    38   24000    1.10               9     -40     .85
C   Penstock Capacity Estimated from Operation Data Sheets
P2          4550
PR
PR
CP    38  999999
IDGAT-POWER
RT    38      37

C  SUM of Lake Gatun LOCKAGE, LEAKAGE, and FLOOD (Power) Releases
CP    37  999999
IDGAT-SUM
RT    37     999

CP   999  999999
IDEND
RT   999

ED

BF     2     624                48010100             720
1900
NOLIST
C
C Initial Conditions for Indio
C SS   200 -242.39
C QA   200      -1       0       0       0    1530
C
C ===== PCC EVAPORATION INPUT IN INCHES
ZR=EV40 A=PCC B=GAT C=EVAP F=OBS
ZR=EV50 A=PCC B=MAD C=EVAP F=OBS
C --------- Observed Inflows ---------------
ZR=IN52 A=PCC B=MAD C=FLOW-IN  F=OBS1477+DP7898
ZR=IN40 A=PCC B=GAT C=FLOW-IN-INC  F=OBS1477+DP7898
ZR=IN202 A=INDIO B=DAMSITE C=FLOW E=1MON F=COMP
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
ZR=QD40  A=PCC B=GAT C=FLOW-DIV  F=AVE CURRENT DEMANDS
ZW   A=ALT-IND   F=A2-DIV*1.56 H5AEM
EJ
ER
```

# APPENDIX I

# TOABRE - INDIO

## HEC-5 Model Developed for Water Supply Reliability Analysis

**TOA-RJH.DAT**

```
T1    Panama Canal Capacity Study: Period - of Record Analysis (TOA-RJH.DAT)
T2    Model: Toabre, Indio linked to Gatun with Average Lockage & Municipal
Qs
T3    Model (Final) developed by RJHayes, Aug 2003 for ACP, (PO#SAA107926BGP)
C     Analysis should be made with HEC5A Dated 17 Aug 2003 or Later
C ------------------------------------------------------------------------
-
C  TOABRE DAM, PANAMA CANAL
C  NORMAL POOL=95M MIN POOL=50M;
C TUNNEL OF 5 M OF DIAMETER AND 16 KMS OF LENGTH FROM TOABRE TO INDIO
C
C  RIO INDIO AT LIMON, PANAMA CANAL
C  NORMAL POOL=80M MIN POOL=40M;
C TUNNEL OF 4.5 M OF DIAMETER AND 8.4 KMS OF LENGTH FROM INDIO TO GATUN
J1     0       1       5       3       4       2
J2    24     1.0             140                                0
J3     5                                      -1                          0
J8400.13  400.22  400.10  400.12  400.03  400.22  200.22  200.00
J8 40.13   40.22   40.03   38.03   39.05   39.06
J8 39.06   42.04   40.13   50.13   50.10   50.12  200.13  200.10  200.12
400.10
J8 39.06   40.13   50.13   50.10   50.12  200.13  200.10  200.12  400.13
400.10
J8 39.06   39.05   42.04   50.10  200.10  400.10  200.10  400.03  200.03
4
C ------------------- Toabre's Hydropower Parameters ------------------------
---
C Toabre   Total   Power Turbine  Energy  Plant    Rated   Power  Madden
Lake
C  Div    Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8400.03  390.10  390.32  390.00  390.16  390.35  390.25  390.33  400.12
400.22
C ------------------------------------------------------------------------
---
C ------------------- Madden's Hydropower Parameters ------------------------
---
C Madden   Total   Power Turbine  Energy  Plant    Rated   Power  Madden
Lake
```

```
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 51.03   50.10   50.32   50.00   50.16   50.35   50.25   50.33   50.12
50.22
C ------------------------------------------------------------------------
---
C -------------------- Gatun's Hydropower Parameters ----------------------
---
C Gatun  Non-Lock  Power Turbine  Energy  Plant    Rated   Power   Gatun
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
J8 41.03   40.03   38.32   38.00   38.16   38.35   38.25   38.33   40.12
40.22
C ------------------------------------------------------------------------
---
J8400.13  400.03  200.13  400.12  400.22   40.13   50.13
J8200.13  200.03   40.13  200.12  200.22   50.13   50.12   50.10
C 400.13  400.03  200.13  200.03   40.13  400.22  200.22   40.22   50.13
50.22
C 400.22  200.22   40.22  400.10  200.10   50.10
C  40.13  200.13  200.10  200.03
C 200.13  400.13  400.10  400.03  400.11  400.22  400.12   40.13
C JZ400.13  200.13   40.13   50.13  400.22  200.22   40.22   50.22
C JZ400.10  400.03  200.10  200.03   40.10   40.03   50.10
C 400.13  400.12  400.37  200.13  200.12  200.37   50.13   50.12   50.37
40.13
C 400.38  400.41  200.38  200.41   50.38   50.41   40.38   40.41
C  40.03   40.30   40.31   40.22   50.22  400.22  200.22
C 400.22  400.10  400.12  400.13  200.22  200.10  200.12  200.13   50.22
50.13
C  40.03   40.30   40.31   40.22   40.24   40.02   40.09   40.10   40.21
40.32
C  50.24   50.02   50.03   50.09   50.10   50.21   50.32   50.22
C 400.22  400.24  400.03  400.09  400.10  400.21  400.13  400.11  400.16
400.32
C 401.03  401.09  401.10  390.32  390.09  390.10  390.16
C 200.22  200.02  200.24  200.03  200.09  200.10  200.21  200.13  200.12
200.11
C 199.10  199.03
C  DATA SAVED TO DSS
C   .03=FLOW-DIV           .04=FLOW-REG         .12=CASE         .13=LEVEL
C   .09=FLOW-RES IN        .10=FLOW-RES OUT     .22=ELEV         .30=DIV
REQUIRED
C   .32=FLOW-SPILL         .16=ENERGY-GEN       .35=PLANT FACTOR .33=POWER
HEAD
C   .21=EVAPORATION        .32=FLOW-POWER SPILL .31=DIV SHORTAGE .11=STORGE

C   ********************  TOABRE DAM  **************
C  RESERVOIR LEVELS
C  LEVEL 1 = INACTIVE STORAGE     (BELOW ELEV 50M)
```

```
C  LEVEL 2 = MINIMUM POOL ELEV    (ELEV 50M)
C  LEVEL 3 = TOP OF CONSERVATION  (ELEV 95M)
C  LEVEL 4 = MAXIMUM POOL ELEV    (ELEV 100M)
C  LEVEL 5 = TOP OF DAM           (ELEV 105M)

RL   400 -311.70   53710   53720  777350  777400 1144260
C RL   400 -311.70
C RL     1     400      -1           53710
C RL     2     400      -1           53720
C RL     3     400       0          777400  741200  705000  668800  632600
596400
C RL                                596400  632600  668800  705000  741200
777400
C   Madden Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C RL     4     400      -1          948760
C RL     5     400      -1         1144260

C  STOR AT   90M    <50M     50M     90M     95M    100M
C        295.29F 164.05F 164.05F 295.29F 311.70F 328.10F
RO     1     200
C Toabre Storage and Area
RS   -18   21.98   34.90   53.72   80.57  122.49  164.81  225.41  300.46
386.70
RS500.36  628.42  777.35  860.15  948.76 1043.40 1144.26 1251.55 1365.45
C Multiple outlet capacity from a tunnel of 5 meters diameter and 16 kms
length
QQ   200       9  262.48
RQ131.24       0    1040    1471    1801    2080    2326    2548    2752
2942
RQ  3120    3289    3449    3527    3603    3677    3750    3821    3891
RQ147.64       0       0    1040    1471    1801    2080    2326    2548
2752
RQ  2942    3120    3289    3449    3527    3603    3677    3750    3821
RQ164.05       0       0       0    1040    1471    1801    2080    2326
2548
RQ  2752    2942    3120    3289    3449    3527    3603    3677    3750
RQ180.46       0       0       0       0    1040    1471    1801    2080
2326
RQ  2548    2752    2942    3120    3289    3449    3527    3603    3677
RQ196.86       0       0       0       0       0    1040    1471    1801
2080
RQ  2326    2548    2752    2942    3120    3289    3449    3527    3603
RQ213.26       0       0       0       0       0       0    1040    1471
1801
RQ  2080    2326    2548    2752    2942    3120    3289    3449    3527
RQ229.67       0       0       0       0       0       0       0    1040
1471
RQ  1801    2080    2326    2548    2752    2942    3120    3289    3449
RQ246.08       0       0       0       0       0       0       0       0
1040
RQ  1471    1801    2080    2326    2548    2752    2942    3120    3289
RQ262.48       0       0       0       0       0       0       0       0
0
RQ  1040    1471    1801    2080    2326    2548    2752    2942    3120
```

```
RA    18     650    1031    1501    2043    2640    3286    3979    4738
5604
RA  6642    7953    9673   10741   11984   13429   15111   17067   19338
RE    18  131.24  147.65  164.05  180.46  196.86  213.27  229.67  246.08
262.48
RE278.89  295.29  311.70  319.90  328.10  336.30  344.51  352.71  360.91
C Divert all floodwater to power plant and spillway
RD    -1     .01     .01     .01     .01     .01     .01     .01     .01
.01
RD   .01     .01    4000   59200  167442  307611  473598  661873  870055
C    .01     .01     .01   59200  167442  307611  473598  661873  870055
C  AVERAGE EVAPORATION RATES COMPUTED BY COYNE ET BELLIER
R3 4.129   3.573   4.121   0.217  -5.403  -3.175  -2.330  -1.492   0.603
0.204
R3 0.273   2.4055
C   ***************POWER CARDS*****************
C Use Indio pool for Tail Water
C P1   400   21300     1.0       0     200       0    0.86       1
C P2   141       0
C PR
C PR
C   ******************************************

CP   400   10000     141     141
ID TOABRE DAM
RT   400     401
DR   400     390                                          -2
QM  1330    1330    1330    1330    1330    1330    1330    1330    1330
1330
QM  1330    1330

CP   401   10000
ID CP401
RT   401     200
DR   401     390                                           0     141

C  ============== TOABRE Hydro Power Reservoir
====================================
RL   390  777350  777350  777350  777350  777350  777350
C  STOR AT   95M     95M     95M     95M     95M     95M
C           328F
RO
RS   -18   21.98   34.90   53.72   80.57  122.49  164.81  225.41  300.46
386.70
RS500.36  628.42  777.35  860.15  948.76 1043.40 1144.26 1251.55 1365.45
RQ    18      -1      -1      -1      -1      -1      -1      -1      -1
-1
RQ    -1      -1      -1      -1      -1      -1      -1      -1      -1
RE    18  131.24  147.65  164.05  180.46  196.86  213.27  229.67  246.08
262.48
RE278.89  295.29  311.70  319.90  328.10  336.30  344.51  352.71  360.91
C   ***************POWER CARDS*****************
C Tailwater block loading at 25 m (82.02ft)
P1   390    4000     1.0      0    82.0  -400    0.86       1
C No leakage; minimum flow pass thru small unit, 4 mw
```

```
P2     0       0
PR
PR
C   ****************************************
CP   390    6500
ID TOABRE PP         POWER PLANT
RT   390     999
C Minimum flow diverted from main dam
C DR   390     999                                        0     141

C ============== Lake Madden
================================================
C  ----- Madden's Inflow
RL    52
RO
RS     2       1      10
RQ     2   99999      -1
CP    52   99999
IDMAD-INFLOW
RT    52      51

C        Seperate Madden Power Leakage from Madden Releases to:
C          Provide HEC-5 Output Computation of Power Discharge
C           via J8 50.10   50.32   50.00 for Printout
C           and DSS Computations
C
CP    51   99999
IDMAD-LEAK
RT    51      50
C  ----- Madden's Leakage Routed to Base of Dam (CP 49)
DR    51      49                                          0      20


RL    50 -252.00
C                                    190
RL     1      50      -1          127250
C                                    190
RL     2      50      -1          127250
C        ELEV:                       249     243     233     221     217
215
RL     3      50       0          611478  541116  434890  324950  292650
277430
C        ELEV:                       217     222     228     236     247
252
RL                                  292650  333360  386640  465290  587580
648140
C ------------------------------------------------------------------------
-
C   Madden Spill Curve Modified for Dec-Mar 255 Spill Elevation
C                                    255     255     255     245     245
245
RL     4      50       0          686100  686100  686100  564096  564096
564096
C                                    245     245     245     248     251
255
```

```
RL                                  564096  564096  564096  599470  635790
686100
C ------------------------------------------------------------------------
--
C   Madden Spill Curve from PCC OPERDATA.BAS dated 6-23-94 252 Spill
Elevation
C                                      252     252     252     245     245
245
C RL   4      50       0          648140  648140  648140  564096  564096
564096
C                                      245     245     245     248     251
252
C RL                                564096  564096  564096  599470  635790
648140
C ------------------------------------------------------------------------
--
C                                      270
RL     5      50      -1          886754
C  Operate for:
C              Gatun Inflow & M&I Diversion Point (CP 42)
C              Lake Gatun (CP 40)
RO     2      40      42
C  Reservoir storage from path = /PCC/MAD/ELEV-CAPAC(ACFT)///OBS/
C  Reservoir areas from path =  /PCC/MAD/ELEV-AREA(ACRES)///OBS/
C  Storage & area values below Elev. = 190 are extrapolated
C  Areas above Elev = 264.0 are extrapolated
C  Reservoir maximum outflow from Tables 5-2 + 5-3 + 6-2 PCC FC MANUAL
(9/1992)
RS   -54       0    16.0    54.4  127.25  136.89  146.51  156.70  167.29
178.35
RS184.07 189.992 195.914 202.066 208.356 214.761 221.281 227.916 234.665
241.529
RS248.51 255.579 262.764 270.041 277.433 284.963 292.654 300.505 308.517
316.667
RS333.36 350.573 368.297 386.639 405.556 425.000 444.904 465.289 486.226
507.782
RS529.87 552.525 575.781 599.472 623.577 648.140 673.255 698.852 724.908
751.400
RS778.33 805.624 832.668 859.711 886.754
RQ    54    1000   10000   15000   20000   22000   23000   24000   25000
26000
RQ 26150   26300   26400   26500   26750   27000   27150   27300   27400
27500
RQ 27650   27800   27900   28000   28150   28300   28400   28500   28650
28800
RQ 29000   29300   29500   29800   30000   30100   34100   41100   50400
60700
RQ 74000   88000  103700  120800  139300  159200  180600  203500  227700
253600
RQ281000  310000  340700  373100  407100
RA    54       0    1600    3840    4608    4800    4992    5184    5376
5568
RA  5792    6016    6144    6272    6400    6528    6624    6720    6784
6848
```

```
RA  6976    7104    7168    7296    7488    7616    7744    7936    8064
8198.4
RA  8480  8761.6  9043.2  9318.4  9587.2    9856 10124.8 10393.6 10630.4
10912
RA 11168   11424   11680   11936 12179.2 12422.4 12665.6 12908.8 13145.6
13376
RA 13606   13837   14080   14304   14528
RE    54     140     160     180     190     192     194     196     198
200
RE   201     202     203     204     205     206     207     208     209
210
RE   211     212     213     214     215     216     217     218     219
220
RE   222     224     226     228     230     232     234     236     238
240
RE   242     244     246     248     250     252     254     256     258
260
RE   262     264     266     268     270
C R2                1.08
C  4.944   5.135   5.850   5.031   3.369   2.878   3.244   3.214   2.889
2.997
C  2.583   3.673
C   Evaporation rates are read from DSS file for Madden
========================
P1    50   36000    1.10              89             .83
C   Penstock Capacity Based on Hydro-Met data for Maximum Discharge @ elev =
252
C   Leakage Diverted to Base of Dam (CP 51 to CP 49)
P2          3625
PR
PR
C  = Channel Capacity Based on Limiting Non-spill Releases to Power Operation
==
C  = Lake Gatun Balancing Releases Are ALSO LIMITED to Penstock Capacity
=======
C  = Minimum flow set to 500 (480+20) cfs based on historic minimum
============
CP    50    3625     480
IDMAD-LAKE
RT    50      49

C ============== Municipal Diversion from Lake Madden
=========================
C   Diversions are M&I 5 yr average (1993 - 1997)
C                                                                    Demand
DR    50                                                1           2.60
C                                                                   =======
QD    12     185     188     190     190     191     188     188     187
187
QD   180     182     183
C L    9     1.0     2.0     2.2     2.7     2.8     3.0    3.01     4.0
C C 50.4    2000    2000    1000    1000    1500    2000    3625    3625

C    Outlet Sum Madden Leakage and Power/Spillway Flows
CP    49  999999
```

```
IDMAD-SUM
RT    49      42

C  ============== RIO INDIO DAM AT LIMON
=====================================
C  RESERVOIR LEVELS
C  LEVEL 1 = INACTIVE STORAGE     (BELOW ELEV 40M)
C  LEVEL 2 = MINIMUM POOL ELEV    (ELEV 40.01M)
C  LEVEL 3 = TOP OF CONSERVATION  (ELEV 80M)
C  LEVEL 4 = MAXIMUM POOL ELEV    (ELEV 82.5M)
C  LEVEL 5 = TOP OF DAM           (ELEV 85M)

RL   200 -262.48
RL     1     200      -1          229600
RL     2     200      -1          229649
RL     3     200      -1         1278900
C RL     3     200       0          1278900 1226400 1174000 1121500 1069100
1016600
C RL                                1016600 1069100 1121500 1174000 1226400
1278900
RL     4     200      -1         1384200
RL     5     200      -1         1489530
RO     2      40      42
RS   -19  33.544 229.649 318.191 406.733 528.932 651.131 708.070 765.009
821.947
RS878.89 935.825 1004.44 1073.04 1141.66 1210.27 1278.88 1384.20 1489.53
1700.19
C Discharges for a tunnel of 4.5 m of diameter (HORSESHOE)
RQ    19       0    2021    2355    2646    2909    3150    3241    3330
3416
RQ  3501    3583    3663    3742    3820    3895    3969    4060    4149
4321
RA    19    1573    4371    5401    6425    7026    7624    8014    8404
8794
RA  9185    9575    9915   10255   10595   10935   11275   11671   12059
12842
RE    19   65.62  131.24  147.65  164.05  180.46  196.86  203.42  209.98
216.55
RE223.11  229.67  236.23  242.79  249.36  255.92  262.48  270.68  278.88
295.29
RD    -1    0.01    0.01    0.01    0.01    0.01    0.01    0.01    0.01
0.01
RD  0.01    0.01    0.01    0.01    0.01    0.01    4000   32362   91535
258900
C   0.01    0.01    0.01    0.01    0.01    0.01    0.01   32362   91535
258900
C AVERAGE EVAPORATION RATES PROVIDED BY PCC, BASED ON GATUN AVERAGE FROM
1993-97
R3 4.406   4.615   5.226   4.858   3.586   3.128   3.293   3.148   3.075
3.133
R3 2.827   3.307
C ****************** POWER CARDS ************************
C P1   200   25000     1.0       0       0      40    0.86       1
C Set leakage to 81.2 cfs which will be diverted from 199 to 20
C P2  91.2       0
```

```
C PR
C PR
C  ****************************************************

CP   200   12000    91.2    91.2
ID INDIO DAM       NR LIMON
RT   200     199
DR   200     999                                        -2
QM  2000    2000    2000    2000    2000    2000       0       0       0
QM     0       0       0       0

CP   199  999999
ID CP199
RT   199      42
DR   199     999                                         0    91.2


C        Control Points 42 and 41 Added to Seperate Diversions

C  --- Gatun Local Inflow + Madden Rlease - Gatun M&I ---
CP    42    6000     400
IDGAT-M&I
RT    42      41
C ============== Divert Lockage + Municipal Water Supply Flows
=================
C                                                                    Demand
DR    42                                                1           2.6
C                                                                    ======
C   Water supply is M&I 5 yr average (1993 - 1997)
QD    12     123     126     123     127     117     127     121     124
115
QD   124     123     119

C  --- - Gatun Power LEAKAGE ---
CP    41  999999
IDGAT-LEAK
RT    41      40
DR    41      37                                        0      27

C ============== Lake Gatun
==================================================
C  5.  Top-of-dam      = Elev. 105.0
C  4.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  3.  Top-of-conserv. = Monthly varying, Elevaions from Fig 5.1
C  2.  Top-of-buffer   = Elev.  78.5
C  1.  Top-of-inactive = Elev.  78.5 (3830250 ACFT) to determine DIV
Shortages
C
RL    40  -87.75
C                         Elev = 78.5 ft
RL     1      40      -1         3536150
RL     2      40      -1         3536150

C                                 Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
```

```
C        ELEV:                          87    87.0    87.0    86.3    86.3
85.4
RL     3      40      25          4453580 4399800 4399800 4325160 4325160
4230070
C                                   Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                        85.4    84.7    84.7    84.7    84.7
84.7
RL                                 4230070 4156820 4156820 4156820 4156820
4156820
C                                   Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                        84.7    84.7    84.7    84.7    84.7
85.0
RL                                 4156820 4156820 4156820 4156820 4156820
4188100
C                                   Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                        85.0    85.9    85.9    87.3    87.3
87.75
RL                                 4188100 4282800 4282800 4432050 4432050
4480570
C                                   Dec31
C        ELEV:                        87.5
RL                                 4453580
C   Gatun Spill Curve from PCC OPERDATA.BAS dated 6-23-94
C                                   Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                      87.75   87.75   87.75  87.75    87.75
87.75
RL     4      40      25          4480570 4480570 4480570 4480570 4480570
4480570
C                                   Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                      87.75   87.75   87.75    86.5    86.5
86.5
RL                                 4480570 4480570 4480570 4346420 4346420
4346420
C                                   Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                        86.5    86.5    86.5    86.5    86.5
86.5
RL                                 4346420 4346420 4346420 4346420 4346420
4346420
C                                   Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                        86.5    86.8    86.8    87.4   87.75
88.00
RL                                 4346420 4378440 4378440 4442800 4480570
4507600
C                                   Dec31
C        ELEV:                      87.75
RL                                 4480570

RL     5      40      -1          6384700
```

```
RO     1      39
C   Reservoir storage from path = /PCC/GAT/ELEV-CAPAC(ACFT)///OBS/
C   Reservoir maximum outflow from StoneyGAT.xls, data for 14 gates ELEV=78'-
92'
C   Reservoir areas from path =   /PCC/GAT/ELEV-AREA(ACRES)///OBS/
C   data below elev. 77 and above 90 was extrapolated
RS   -21       0   833.7  1781.7  2729.7  3393.3  3488.1  3584.2  3681.6
3780.3
RS3880.2  3981.6  4084.2  4188.1  4293.3  4399.8  4507.6  4616.7  4727.2
5279.7
RS5832.2  6384.7
RQ    21       0       0       0    1890   42790   58878   69463   80672
92479
RQ104860  117796  131268  145260  159756  174743  190208  206139  222525
300000
RQ350000  400000
RA    21       0   56544   70404   84264   93966   95353   96740   98127
99414
RA100702  101990  103277  104566  105853  107141  108382  109670  110957
117392
RA123827  130262
RE    21      40      50      60      70      77      78      79      80
81
RE    82      83      84      85      86      87      88      89      90
95
RE   100     105
RD    -1     .01     .01     .01     .01     .01     .01     .01     .01
.01
RD   .01     .01     .01     .01     .01    1000    4550  206139  222525
300000
C                                                 ======
C    .01    4550    4550    4550    4550    4550  190208  206139  222525
300000
RD350000  400000
C   Evaporation rates are 5 yr. average for Gatun
C R2                1.10
C  4.240   4.589   5.372   5.251   3.304   2.896   3.037   3.132   2.882
2.869
C  2.666   3.349
CP    40  999999                    2.0
IDGAT-LAKE
RT    40      39
DR    40      38                                    -2

C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
```

```
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Lockage Releases
CP    39  999999                    2.0
IDGAT-LOCKS
RT    39      37
C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Flood (Power) Release
RL    38  -87.75 3536150 3536150 4453580 4480570 6384700
RO
RS     5       0 3536150 4453580 4480570 6384700
RQ     5    9999   99999   99999   99999      -1
RE     5      50    78.5    87.5   87.75     105
P1    38   24000    1.10               9     -40     .85
C   Penstock Capacity Estimated from Operation Data Sheets
P2          4550
PR
PR
CP    38  999999
IDGAT-POWER
RT    38      37
```

```
C  SUM of Lake Gatun LOCKAGE, LEAKAGE, and FLOOD (Power) Releases
CP    37  999999
IDGAT-SUM
RT    37     999

CP   999  999999
IDEND
RT   999

ED
C ===== OBSERVED DATA SPECIFIED FOR JAN 1958 TO DEC 1996
=======================
BF     2    2714                47122700            168
1900
NOLIST
C ===== PCC EVAPORATION INPUT IN INCHES
ZR=EV40 A=PCC B=GAT C=EVAP-WEEK F=OBS-RJH
ZR=EV50 A=PCC B=MAD C=EVAP-WEEK F=OBS-RJH
C --------- Observed Inflows ---------------
ZR=IN52 A=PCC B=MAD C=FLOW-IN  F=OBS+DP-RJH
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC  F=OBS+DP-RJH
C Toabre's Inflow to 401
ZR=IN400 A=TOABRE B=DAMSITE C=FLOW E=1WEEK F=COMP
ZR=IN200 A=INDIO B=DAMSITE C=FLOW E=1WEEK F=COMP
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C ZR=QD40  A=PCC B=GAT C=FLOW-DIV E=1WEEK F=AVE CURRENT DEMANDS
C ===== Write to DSS File for use with HEC-DSS Vue
============================
ZW   A=RJH-17AUG03 F=TOA-RJH-1.00
EJ
ER


BF     2     730                86010400             720
1900
C ===== PCC EVAPORATION INPUT IN INCHES
ZR=EV40 A=PCC B=GAT C=EVAP F=OBS
C ZR=EV50 A=PCC B=MAD C=EVAP F=OBS
C --------- Observed Inflows ---------------
ZR=IN52 A=PCC B=MAD C=FLOW-IN  F=OBS1477+DP7898
C ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC  F=OBS1477+DP7898
ZR=IN400 A=TOABRE B=DAMSITE C=FLOW E=1MON F=COMP
C Toabre's Inflow to 401
ZR=IN200 A=INDIO B=DAMSITE C=FLOW E=1MON F=COMP
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
ZR=QD40  A=PCC B=GAT C=FLOW-DIV E=1MON F=AVE CURRENT DEMANDS
ZR=QD40  A=PCC B=GAT C=FLOW-DIV E=1WEEK F=AVE CURRENT DEMANDS
ZW   A=PCA-RJH5 F=TOBR3D1.975
EJ
ER
```

# APPENDIX J

# LOWER TRINIDAD

## HEC-5 Model Developed for Water Supply Reliability Analysis
**TRI-RJH.DAT**

```
T1    Panama Canal Capacity Study: Period - of Record Analysis (TRI-RJH.DAT)
T2    Lower Trinidad Dam, Average Lockage & Municipal Qs (TRIN75R4.DAT)
T3    Model developed by HEC,SAM  June 1999 and modified by CCW may 2001
PUMP CAPACITY variable CFS
C     Model (Final) developed by RJHayes, Aug 2003 for ACP, (PO#SAA107926BGP)
C ------------------------------------------------------------------------
--
C     Analysis should be made with HEC5A Dated 17 Aug 2003 or Later
C     Daily pumpback option - (Conservation pool 75.0 to 100 ft. msl,
GENERATION @GATUN limited to 240kw)
C     PERCENTAGE OF LOWER MADDEN WATERSHED ACCORDING TO DRAWING SK-6121-183
C ------------------------------------------------------------------------
-
C
J1     0       1       6       4       5       2       4
J2    24     1.0             140                             0
J3     4                      -1              -1                      0
J8 39.06   40.13   50.13   50.10   45.10   42.04   50.01   45.01   40.01
J8 40.13   45.13   45.10   45.22   46.10   39.06   40.03   40.22   45.11
45.38
J8 39.06   40.03   46.03   45.13   40.13   45.10   45.01   45.12
J8 52.24   45.24   42.24    3.99   39.05   39.06   40.03   46.03
C ------------------- Madden's Hydropower Parameters ----------------------
---
C Madden   Total   Power Turbine  Energy  Plant    Rated   Power  Madden
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
C J51.03   50.10   50.32   50.00   50.16   50.35   50.25   50.33   50.12
50.22
C ------------------------------------------------------------------------
---
C -------------------- Gatun's Hydropower Parameters ----------------------
---
C Gatun  Non-Lock  Power Turbine  Energy  Plant    Rated   Power   Gatun
Lake
C  Leak   Release  Spill   Flow  Produced Factor  Capacity  Head Operation
Elev
```

```
C   cfs     cfs     cfs     cfs     MWH      %       kW     feet    Case
feet
C J41.03   40.03   38.32   38.00   38.16   38.35   38.25   38.33   40.12
40.22
C -------------------------------------------------------------------------
---
C -------------------- Lower Trinidad's Pump Parameters --------------------
--
C  Pump   Release Energy  Plant    Rated   Power  Trinidad Gatun
C  Back  To Gatun  Used    Factor  Capacity Head n  Elev    Elev
C    cfs     cfs     MWH      %       kW     fee    feet    feet
C J45.09   45.10   46.16   46.35   46.25   46.33   46.12   46.22
C -------------------------------------------------------------------------
---
C +++++++ Write Diversion Shortages To DSS File (Madden and Gatun Sum)
+++++++++
C  MADDEN RESERVOIR
C JZ 50.22   50.13   50.21   50.09   50.10   50.32   50.12   50.30   50.03
50.31
C
C  UPSTREAM DUMMY RESERVOIR
C  46.15   46.16   50.22   45.22   40.22   30.32   46.09   40.31   30.22
30.10
C
C  TRINIDAD RESERVOIR
C JZ 45.22   45.13   45.21   45.09   45.10   30.03   45.41   40.31   40.22
40.13
C
C  GATUN RESERVOIR AND DUMMY RESERVOIR FOR LOCKAGES DEMANDS
C  40.22   40.13   40.21   40.09   40.10   30.32   40.03   40.30   40.31
30.10
C
C  SUMMARY OF LAKES
C  50.22   45.22   45.10   40.22   46.09   30.32   40.03   40.30   40.31
30.10
C
C 46.154  46.164  45.223  50.223  40.223  40.222  40.034  40.304  40.314
30.324
C
JZ 50.22   45.22   40.22   50.13   45.13   40.13   50.11   45.11   40.11
JZ 50.10   45.10   40.10   46.10   50.16   38.16   46.16
JZ 39.06   39.05   50.03   42.03   40.03   46.03
C  ----- Madden's Inflow
RL    52
RO
RS     2       1      10
RQ     2   99999      -1
CP    52   99999
IDMAD-INFLOW
RT    52      51

C        Seperate Madden Power Leakage from Madden Releases to:
C          Provide HEC-5 Output Computation of Power Discharge
C           via J8 50.10   50.32   50.00 for Printout
C           and DSS Computations
```

```
C
CP    51   99999
IDMAD-LEAK
RT    51      50
C  ----- Madden's Leakage Routed to Base of Dam (CP 49)
DR    51      49                                          0      20

RL    50 -252.00
C                                    190
RL     1      50      -1          127250
C                                    190
RL     2      50      -1          127250
C        ELEV:                       249     243     233     221     217
215
RL     3      50       0          611478  541116  434890  324950  292650
277430
C        ELEV:                       217     222     228     236     247
252
RL                                  292650  333360  386640  465290  587580
648140
C        ELEV:                       249     243     233     221     217
215
RL     4      50       0          611478  541116  434890  324950  292650
277430
C        ELEV:                       217     222     228     236     247
252
RL                                  292650  333360  386640  465290  587580
648140
C ------------------------------------------------------------------------
-
C   Madden Spill Curve Modified for Dec-Mar 255 Spill Elevation
C                                    255     255     255     245     245
245
RL     5      50       0          686100  686100  686100  564096  564096
564096
C                                    245     245     245     248     251
255
RL                                  564096  564096  564096  599470  635790
686100
C ------------------------------------------------------------------------
--
C   Madden Spill Curve from PCC OPERDATA.BAS dated 6-23-94 252 Spill
Elevation
C                                    252     252     252     245     245
245
C RL   5      50       0          648140  648140  648140  564096  564096
564096
C                                    245     245     245     248     251
252
C RL                                564096  564096  564096  599470  635790
648140
C ------------------------------------------------------------------------
--
C                                    270
RL     6      50      -1          886754
```

```
C  Operate for:
C              Gatun Inflow & M&I Diversion Point (CP 42)
C              Lake Gatun (CP 40)
RO     2      40      42
C  Reservoir storage from path = /PCC/MAD/ELEV-CAPAC(ACFT)///OBS/
C  Reservoir areas from path =  /PCC/MAD/ELEV-AREA(ACRES)///OBS/
C  Storage & area values below Elev. = 190 are extrapolated
C  Areas above Elev = 264.0 are extrapolated
C  Reservoir maximum outflow from Tables 5-2 + 5-3 + 6-2 PCC FC MANUAL
(9/1992)
RS   -54       0    16.0    54.4  127.25  136.89  146.51  156.70  167.29
178.35
RS184.07 189.992 195.914 202.066 208.356 214.761 221.281 227.916 234.665
241.529
RS248.51 255.579 262.764 270.041 277.433 284.963 292.654 300.505 308.517
316.667
RS333.36 350.573 368.297 386.639 405.556 425.000 444.904 465.289 486.226
507.782
RS529.87 552.525 575.781 599.472 623.577 648.140 673.255 698.852 724.908
751.400
RS778.33 805.624 832.668 859.711 886.754
RQ    54    1000   10000   15000   20000   22000   23000   24000   25000
26000
RQ 26150   26300   26400   26500   26750   27000   27150   27300   27400
27500
RQ 27650   27800   27900   28000   28150   28300   28400   28500   28650
28800
RQ 29000   29300   29500   29800   30000   30100   34100   41100   50400
60700
RQ 74000   88000  103700  120800  139300  159200  180600  203500  227700
253600
RQ281000  310000  340700  373100  407100
RA    54       0    1600    3840    4608    4800    4992    5184    5376
5568
RA  5792    6016    6144    6272    6400    6528    6624    6720    6784
6848
RA  6976    7104    7168    7296    7488    7616    7744    7936    8064
8198.4
RA  8480  8761.6  9043.2  9318.4  9587.2    9856 10124.8 10393.6 10630.4
10912
RA 11168   11424   11680   11936 12179.2 12422.4 12665.6 12908.8 13145.6
13376
RA 13606   13837   14080   14304   14528
RE    54     140     160     180     190     192     194     196     198
200
RE   201     202     203     204     205     206     207     208     209
210
RE   211     212     213     214     215     216     217     218     219
220
RE   222     224     226     228     230     232     234     236     238
240
RE   242     244     246     248     250     252     254     256     258
260
RE   262     264     266     268     270
C R2               1.08
```

```
C  4.944   5.135   5.850   5.031   3.369   2.878   3.244   3.214   2.889
2.997
C  2.583   3.673
C   Evaporation rates are read from DSS file for Madden
=======================
P1    50   36000    1.10              89             .83
C   Penstock Capacity Based on Hydro-Met data for Maximum Discharge @ elev =
252
C   Leakage Diverted to Base of Dam (CP 51 to CP 49)
P2          3625
PR
PR
C  = Channel Capacity Based on Limiting Non-spill Releases to Power Operation
==
C  = Lake Gatun Balancing Releases Are ALSO LIMITED to Penstock Capacity
=======
C  = Minimum flow set to 500 (480+20) cfs based on historic minimum
============
CP    50    3625     480
IDMAD-LAKE
RT    50      49

C ============== Municipal Diversion from Lake Madden
=========================
C   Diversions are M&I 5 yr average (1993 - 1997)
C                                                                      Demand
DR    50                                              -5              2.60
C                                                                     =======
C Use Time Series of Diversions (ZR=QD50) in BF-EJ Data Set
C QD  12     185     188     190     190     191     188     188     187
187
C QD 180     182     183
CL     9     1.0     2.0     2.3     2.4     2.8     3.0    3.01     4.0
CC  50.4    3000    3000    3000    2500    2500    2500    3625    3625

C    Outlet Sum Madden Leakage and Power/Spillway Flows
CP    49  999999
IDMAD-SUM
RT    49      42

C ==================== DUMMY RESERVOIR FOR PUMPED STORAGE DATA
==================
C == PUMPBACK AT GATUN RESERVOIR TO TRINIDAD LAKE
==============================
RL    46
RO
RS     2       1     100
RQ     2     100      -1
RE     2       1      10
C
C ** UPPER DUMMY RESERVOIR TO BE FEED BY GATUN LAKE
#30**********************
C  =======TRINIDAD RESERVOIR PUMPBACK ==  1   12 MW PUMP UNIT
===================
C    LOC     PWRMX    OVLDr           TLWEL   DWNRES    EFFCY     HLPO
```

```
P1    46  -12000       1                        40    0.75    2.10
C  LEAKAGE  PENSTOCK CAPACITY
C   RJH P2     0    9000
P2     0    4000
C  ENERGY AVAILABLE TO PUMP AS MONTHLY PLANT FACTOR
PR
PR  -0.5    -0.5
C      0       0       0       0       0       0       0       0    -0.5    -
0.5
C   -0.5    -0.5
C  ENERGY AVAILABLE 12 HRS/DAY  FORM SUNDAY TO SATURDAY  7 DAYS A WEEK
C PD 0.142    .143    .143    .143    .143    .143    .143
C PH     4    0.50    0000    0000    0.50
CP    46   99999
IDPUMPBACK
C  DUMMY RESERVOIR FEEDS TRINIDAD LAKE
RT    46      45
C  DIVERSION FROM DUMMY RESERVOIR TO THE DOWNSTREAM OF WATER SOURCE
DR    46      40                                          -3
C ** UPPER DUMMY RESERVOIR TO BE FEED BY GATUN LAKE
#30**********************
C
================================================================================
===
C
C LOWER TRINIDAD DAM ..... TOP OF DAM ELEV AT 105 FT.
C
================================================================================
=
C ============== Lower Trinidad Dam
==========================================
C  6.  Top-of-dam      = Elev. 105
C  5.  Top-of-flood    = Elev. 100.
C  4.  Top-of-conserv. = Monthly varying,
C  3.  Tandem Operation= Monthly varying
C  2.  Top-of-buffer   = Elev. 75.0  Using 36-  6 ft. diameter pipes
C  1.  Top-of-inactive = Elev. 75.0  Minimum level of TRINIDAD Lake during
normal cond.
C
RL    45 1528000
C      STORAGE IN ACRE-FT AT ELEV.  75.0
RL     1      45      -1          648600
C                                  75.0
C RL   2      45      -1          648600
RL     2      45       0          648600  648600  648600  648600  648600
648600
RL                               648600  648600  648600  648600 1440000
1440000
C   TANDEM RULE CURVE SET TO 1 FOOT BELOW TOP OF CONSERVATION MJ 6/15/99
C    ELEVATIONS                    097.    096.    095.    094.    094.
094.
RL     3      45       0         1435000 1389300 1344600 1300900 1300900
1300900
C  ELEV                             094.    095.    096.    097.    098.
099.
```

```
RL                                1300900 1344600 1389300 1435000 1450000
1450000
C  ELEV                               099     098     098     098     098
098
RL     4      45       0         1529300 1481700 1481700 1481700 1481700
1481700
C  ELEV                               098     098     098     098     099
100
RL                                1481700 1481700 1481700 1481700 1529300
1578000
C                                   100.0
RL     5      45      -1         1578100
C                                   105.0
RL     6      45      -1         1836600
RO     1      40
C             75      78       STORAGE IN 1000's OF ACRE-FT
85
RS   -29   648.6   730.9   759.2   788.4   818.7   850.0   882.1   920.0
949.4
RS 984.5  1025.0  1057.6  1095.7  1134.7  1174.7  1215.7  1257.6  1300.6
1344.5
RS1389.4  1435.2  1482.1  1529.3  1578.0  1627.7  1678.4  1730.1  1782.8
1836.6
C
C             75      78       RESERVOIR OUTLET CAPACITY
85
RQ    29    4000    4000    4000    4000    4000    4000    4000    4000
4000
RQ  5000    5000    5000    5000    6000    6000    6000    6000    6000
6000
RQ  7000    7000    7000   45950   85500  188580  230400  346400 5490000
6800000
C
C             75      78       AREA OF LAKE IN ACRES
85
RA    29   22300   26000   27000   28000   29000   30000   31000   32000
33000
RA 34000   35000   35744   36488   37231   37975   38719   39463   40207
40951
RA 41694   42438   43182   44097   45000   45710   46541   47393   48267
49545
C
RE    29      75      78      79      80      81      82      83      84
85
RE    86      87      88      89      90      91      92      93      94
95
RE    96      97      98      99     100     101     102     103     104
105
C
C
C     Reliability optimized with d/s channel limit max at 7500 cfs
CP    45   99999
IDTRN
C ======= INFLOWS FROM PORTION OF GATUN WATERSHED ========================
C ========== ESTIMATED BY JORGE============================================
```

```
C1    42   0.334
RT    45      42
CL     5     2.0     3.0     4.0     4.1     5.0
CC  45.4    1500    1600    1700    3000    3000
C ======== FORCING MIN FLOW DURING DRY SEASSON ============================
C *************  DR    45      44                                        -2
C ************** QM  5500    5500    5500    5500    3500    3500    3500
3500    3000    2000
C ************** QM  0000    5500
C ===========================================================================
C        Control Points 42 and 41 Added to Seperate Diversions

C  --- Gatun Local Inflow + Madden Rlease - Gatun M&I ---
CP    42  999999      27
IDGAT-M&I
C ========== ESTIMATED IN MOBILE,
ALA=========================================
C1    42   0.666
RT    42      41
C ============== Divert Municipal Water Supply Flows =================
C                                                                  Demand
DR    42     999                                          1          2.60
C                                                                  ======
C   Water supply is M&I 5 yr average (1993 - 1997)
QD    12     123     126     123     127     117     127     121     124
115
QD   124     123     119

C  --- - Gatun Power LEAKAGE ---
CP    41  999999
IDGAT-LEAK
RT    41      40
DR    41      37                                           0      27
C
=============================================================================
C
C
C ============== Lake Gatun
==================================================
C  6.  Top-of-dam      = Elev. 105.0
C  5.  Top-of-flood    = Monthly varying, Based on Spill Curve
C  4.  Top-of-conserv. = Monthly varying, Elevations
C  3.  Tandem Operation= Monthly varying, Based on Previous Operations
C  2.  Top-of-buffer   = Elev.  85.50
C
C  1.  Top-of-inactive = Elev.  85 (ACFT real watershed) to determine DIV
Shortages
C
RL    40 3411000
C                          Elev= 85.0 ft of equivalent Gatun-Trinidad
watershed
RL     1      40      -1         3238750
C                          Elev= 85.01 ft
RL     2      40      -1         3239000
```

```
C ------------------------ Levels 3, 4, & 5 Revised to 25 Seasons -----------
--
C        ELEV:                        87.3    87.0    86.5    86.5    86.5
86.5
C RL   3      40       0         3397350 3374800 3341820 3341820 3341820
3341820
C        ELEV:                        86.5    86.5    86.5    86.5    87.0
87.5
C RL                              3341820 3341820 3341820 3341820 3374800
3412385
C                                    87.5    87.3    87.0    87.0    87.0
87.0
C RL   4     40       0           3412385 3397350 3374800 3374800 3374800
3374800
C                                    87.0    87.0    87.0    87.0    87.3
87.5
C RL                              3374800 3374800 3374800 3374800 3397350
3412385
C   NEW Gatun Spill Curve
C        ELEV:                      87.75   87.50   87.40   87.30    87.3
87.3
C RL   5      40       0         3431180 3412390 3404870 3397350 3397350
3397350
C        ELEV:                        87.3    87.3    87.3    87.3    87.4
87.75
C RL                              3397350 3397350 3397350 3397350 3404870
3431180
C ========= Revised Level 3-5 (25 Seasons for CS, CG and QM application)
=========
C  Revised Level 3 (25 Seasons)    Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                        87.5    87.3    87.3    87.0    87.0
86.5
RL     3      40      25         3412000 3397350 3397350 3374800 3374800
3341820
C                                   Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                        86.5    86.5    86.5    86.5    86.5
86.5
RL                                3341820 3341820 3341820 3341820 3341820
3341820
C                                   Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                        86.5    86.5    86.5    86.5    86.5
86.5
RL                                3341820 3341820 3341820 3341820 3341820
3341820
C                                   Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                        86.5    86.5    86.5    87.0    87.0
87.5
RL                                3341820 3341820 3341820 3374800 3374800
3412385
C                                   Dec31
C        ELEV:                       87.5
```

```
RL                                3412000
C  Revised Level 4 (25 Seasons)    Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                      87.5    87.5    87.5    87.3    87.3
87.0
RL     4      40      25         3412835 3412385 3412385 3397350 3397350
3374800
C                                   Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                      87.0    87.0    87.0    87.0    87.0
87.0
RL                                3374800 3374800 3374800 3374800 3374800
3374800
C                                   Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                      87.0    87.0    87.0    87.0    87.0
87.0
RL                                3374800 3374800 3374800 3374800 3374800
3374800
C                                   Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                      87.0    87.0    87.0    87.3    87.3
87.75
RL                                3374800 3374800 3374800 3397350 3397350
3431180
C                                   Dec31
C        ELEV:                      87.5
RL                                3412835
C   NEW Gatun Spill Curve
C
C  Revised Level 5 (25 Seasons)    Jan 1   Jan31   Feb 1   Feb28   Mar 1
Mar31
C        ELEV:                      87.75   87.75   87.75    87.5    87.5
87.4
RL     5      40      25         3431300 3431180 3431180 3412390 3412390
3404870
C                                   Apr 1   Apr30   May 1   May31   Jun 1
Jun30
C        ELEV:                      87.4    87.3    87.3    87.3    87.3
87.3
RL                                3404870 3397350 3397350 3397350 3397350
3397350
C                                   Jul 1   Jul31   Aug 1   Aug31   Sep 1
Sep30
C        ELEV:                      87.3    87.3    87.3    87.3    87.3
87.3
RL                                3397350 3397350 3397350 3397350 3397350
3397350
C                                   Oct 1   Oct31   Nov 1   Nov30   Dec 1
Dec15
C        ELEV:                      87.3    87.3    87.3    87.4    87.4
87.75
RL                                3397350 3397350 3397350 3404870 3404870
3431200
C                                   Dec31
```

```
C        ELEV:                     87.75
RL                                3431300

RL     6      40      -1         4547370
RO
C   data below elev. 77 and above 90 was extrapolated

C   Reservoir storages and areas were reduced by the amount in Lower Trinidad

RS   -21       0   833.7  1781.7  2317.9  2693.3  2757.2  2825.0  2893.2
2961.7
RS3030.2  3099.6  3164.2  3238.8  3308.8  3374.8  3450.0  3521.0  3592.5
3935.1
RS4253.5  4547.4
RQ    21       0       0       0    1890   42790   58878   69463   80672
92479
RQ104860  117796  131268  145260  159756  174743  190208  206139  222525
300000
RQ350000  400000
RA    21       0   49853   57023   64192   69211   69436   69707   70020
70272
RA 70562   70887   71242   71627   72036   72470   72877   73349   73836
76398
RA 78931   81095
RE    21      40      50      60      70      77      78      79      80
81
RE    82      83      84      85      86      87      88      89      90
95
RE   100     105
C
================================================================================
RD    -1     .01     .01     .01     .01     .01     .01     .01     .01
.01
RD   .01     .01     .01     .01     .01     .01     200  206139  222525
300000
RD350000  400000
C
================================================================================
C
CP    40  999999
IDGAT
RT    40      39
C
================================================================================
=
DR    40      38                                        -2
C
================================================================================
=

C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
```

```
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500

C  Lake Gatun Lockage Releases
CP    39  999999
IDGAT-LOCKS
RT    39      37
C Lake Gatun Minimum Flow Based on MONTHLY/ELEVATION Water Consumption
C  See  ACP Excel File  .xls
C          Jan 1   Jan31   Feb 1   Feb28   Mar 1   Mar31   Apr 1   Apr30
May 1
CS    25       1      31      32      59      60      90      91     120
121
C  May31   Jun 1   Jun30   Jul 1   Jul31   Aug 1   Aug31   Sep 1   Sep30
Oct 1
CS   151     152     181     182     212     213     243     244     273
274
C  Oct31   Nov 1   Nov30   Dec 1   Dec15   Dec31
CS   304     305     334     335     349     365
CG -4.22   76.74   76.74   75.48   75.48   75.11   75.11   75.46   75.46
76.21
CG 76.21   78.02   78.02   78.19   78.19   77.81   77.81   78.33   78.33
77.48
CG 77.48   77.73   77.73   78.03   78.03   78.03
CG -2.35   91.59   91.59   89.61   89.61   89.00   89.00   89.57   89.57
90.78
CG 90.78   93.62   93.62   93.92   93.92   93.30   93.30   94.12   94.12
92.78
CG 92.78   93.16   93.16   93.65   93.65   93.65
QM   -40    2200    3500


C  Lake Gatun Flood (Power) Release
RL    38  -87.75 3536150 3536150 4453580 4480570 6384700
RO
RS     5       0 3536150 4453580 4480570 6384700
RQ     5    9999   99999   99999   99999      -1
RE     5      50    78.5    87.5   87.75     105
```

```
P1    38   24000    1.10               9     -40     .85
C   Penstock Capacity Estimated from Operation Data Sheets
P2          4550
PR
PR
CP    38  999999
IDGAT-POWER
RT    38      37

C  SUM of Lake Gatun LOCKAGE, LEAKAGE, and FLOOD (Power) Releases
CP    37  999999
IDGAT-SUM
RT    37     999
C
C  ================================================================================
C
CP   999  999999
IDEND
RT   999

ED

C ===== OBSERVED DATA SPECIFIED FOR JAN 1948 TO DECEMBER 1999
=======================
C
BF     2    1461    1461        48010100              24               1
1900
NOLIST
C
C ===== PCC EVAPORATION INPUT IN INCHES
=======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
=====================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C   ZW   A=PCC   F=LWTRN_OPT2(D128%)
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        52010100              24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
=======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
=====================================
```

```
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        56010100             24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
==================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
C
BF     2    1461    1461        60010100             24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
==================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        64010100             24               1
1900
C
```

```
C ===== PCC EVAPORATION INPUT IN INCHES
=======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
=====================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
===================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        68010100              24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
=======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
=====================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
===================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        72010100              24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
=======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
=====================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
===================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
```

```
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        76010100              24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
=======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
=================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        80010100              24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
=======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
=================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        84010100              24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
=======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
=================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
```

```
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        88010100              24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
=====================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
====================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        92010100              24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
=====================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
====================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
BF     2    1461    1461        96010100              24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
=====================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
```

```
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
====================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
C ZW   A=ACP-RJH  F=LEVEL-3
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
ER
BF     2    1461    1461        96010100              24               1
1900
C
C ===== PCC EVAPORATION INPUT IN INCHES
=======================================
ZR=EV40 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV45 A=PCC B=GAT C=EVAP F=COMP-HEC
ZR=EV50 A=PCC B=MAD C=EVAP F=COMP-HEC
C ===== INFLOW INCREMENTAL COMPUTED BY HEC
====================================
ZR=IN42 A=PCC B=GAT C=FLOW-IN-INC F=COMP-HEC
ZR=IN52 A=PCC B=MAD C=FLOW-IN F=COMP-HEC
C ===== DIVERSIONS FOR MUNICIPAL AND LOCKAGE
==================================
C      ZR=QD42 A=PCC B=GAT C=FLOW-DIV F=AVE CURRENT DEMANDS_W2D
ZR=QD50 A=PCC B=MAD C=FLOW-DIV REQ F=AVE CURRENT DEMAND
C ZW   A=PCC   F=LWTRN_OPT2(D128%)
ZW   A=ACP-RJH  F=TRI-RJH-4000_PUMPBACK
EJ
ER
```