ATTACHMENT 3:
HYDROLOGIC SIMULATION PROGRAM-FORTRAN (HSPF) MODEL DEVELOPMENT

1. INTRODUCTION

Brown and Caldwell (BC) developed a Hydrologic Simulation Program–Fortran (HSPF) model to help predict stream flows in Thompson Creek. The HSPF model was subsequently coupled with a HEC-RAS hydraulic model to estimate how the proposed Thurston Highlands development could affect the frequency of flooding (prior to implementing any mitigation strategies). The HSPF modeling process consisted of the following:

1. Selecting a historical flood event for model calibration. The February 1996 flood was selected because (a) the flood generated extensive inundation and (b) WSDOT conducted an aerial mapping survey of the flooding.
2. Using a calibrated HSPF hydrologic model to estimate the flow rates that occurred during the February 1996 flood.

This memorandum summarizes BC's method of analysis, key assumptions, and results.

2. GATHER INPUT DATA

The HSPF model requires gathering several types of data including:

- topography
- soil types
- aerial photos
- tax parcels
- precipitation data
- evaporation data
- streamflow and stage data

The data listed above are used as input or to create input for the HSPF model. Below is a description of the input data necessary and how they were produced.

<u>Drainage Sub-basins</u>

Drainage sub-basins were delineated from a digital elevation model (DEM) that was created from LiDAR (Light Detection and Ranging) data (http://pugetsoundlidar.ess.washington.edu/)]. The DEM contained 6-foot by 6-foot pixels. BC used the built-in Basin tool in ESRI's ArcGIS v9.2 software to identify the portions of the Thompson Creek watershed that are tributary to five specific locations along the creek: (1) mouth of Thompson Creek, (2) upstream side of Hwy 510 culvert, (3) upstream of Anderson Lane culvert, (4) downstream of the 93rd Street culvert, and (5) at the EnviroVision Gage just downstream of the new Tahoma Terra Bridge. BC chose these sites for sub-drainage delineations because data (streamflow or stage or both) had been collected at these locations. All of the sub-basins were defined to drain into the downstream sub-basin.

After using the Basin tool, the EnviroVision gage sub-basin (defined below) was altered based on engineering judgment. The automatically-created sub-basin was contributing significantly more water to Thompson Creek (in the model) than even the largest known floods. This is likely due to the fact that most of the water from the east side of SR 507 does not travel to Thompson Creek but rather is intercepted into ponds and groundwater; therefore, the EnviroVision sub-basin was decreased in size to reflect these corrections.

Soil Types

Soil types are necessary for HSPF to describe hydrologic behavior. The soil types were acquired from the Thurston County soils maps (http://websoilsurvey.nrcs.usda.gov/app/) and then grouped into A/B and C/D soil types based on U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) hydrologic soil groups (http://websoilsurvey.nrcs.usda.gov/app/).

Land Use

Land use data is also necessary to describe hydrologic behavior. The tax parcels and right-of-way shapefiles contain land use descriptions. BC obtained these shapefiles from Thurston County. BC assigned a percent impervious area to each parcel based on its specified land use. Regionally-accepted values of percent impervious area for a given land use were used (Dinicola 1990). Tables Att. 3-1 and 3-2 show the land use categories and their associated impervious percentage. BC determined the percent of vegetation cover in each parcel based on aerial photos.

Meteorological

Meteorological data is necessary for calibrations and long-term simulations. The meteorological time-series data sets such as precipitation and evaporation were obtained, processed, and integrated into one data set using the Watershed Data Management Utility (WDMUtil) tool.

Two precipitation stations were used: the 93rd Street by Thurston County and the Olympia Airport. The 93rd Street station was installed in November 2007. This station is located in the middle of the basin and therefore has the most accurate data. Olympia Airport data were used for the period before the 93rd Street station was installed. Olympia Airport data were obtained from the National Oceanic and Atmospheric Administration (NOAA) data archive websites. Similar to the Western Washington Hydrology Model (WWHM) modeling performed in the previous phase of work, the Olympia precipitation depths were multiplied by a factor of 0.8 to account for 20 percent lower annual rainfall depths in Yelm.

Pan evaporation data were extracted from WWHM. The WWHM has data that were collected at the National Weather Service (NWS) Puyallup station over a long period. For periods simulated when there were no observed pan evaporation data, the period of record average for observed data was used. BC applied a factor of 0.76 to the pan evaporation data to convert to potential evapotranspiration, which is the input data needed by HSPF.

Streamflow and Stage

Stream data is needed for the calibration period for matching the model output. Two stream gages were installed on Thompson Creek during the period of this study. The EnviroVision Gage was installed in December 2007. EnviroVision installed a flow and depth monitoring station in Thompson Creek about 50 feet downstream of the Tahoma Terra bridge. EnviroVision developed their initial stage-discharge rating table for the station in April 2008. Based on more data the rating table was updated in August 2008. [Thurston County installed a depth monitoring station on the downstream side of 93rd street in November 2007.

3. MODEL DEVELOPMENT

To develop the HSPF model, BC started with the base model. This base model was previously created for estimating how land use changes could affect infiltration on the Thurston Highlands property. Using a base model is efficient because many of the calibration parameters are similar.

HSPF has three application modules that simulate the hydrologic/hydraulic components of the watershed: PERLND, IMPND, and RCHRES.

The PERLND (pervious land module) simulates runoff from pervious land areas in the watershed. The PERLND models the movement of water along three paths: overland flow, interflow, and groundwater flow. Each of these three paths experiences differences in time delay. A variety of storage zones are used to represent the processes that occur on the land surface and in the soil horizons.

The IMPLND (impervious land module) simulates runoff from impervious land areas in the watershed. IMPLND is used in urban areas where little or no infiltration occurs. However, some land processes do occur, and some water moves laterally downslope to a pervious area, stream channel, or reservoir.

The RCHRES (channel module) simulates the movement of runoff water simulated by PERLND and IMPLND, stream flow, and reservoirs.

PERLND

Four PERLNDs were used in the Thompson Creek model:

- Soil Type C, Land Use Type Forest, and Moderate Slope
- Soil Type C, Land Use Type Pasture, and Moderate Slope
- Soil Type A/B, Land Use Type Forest, and Moderate Slope
- Soil Type A/B, Land Use Type Pasture, and Moderate Slope

The area of the PERLNDs in each sub-basin is given in the uci file at the end of this Attachment.

IMPLND

Only one IMPLND was used in the Thompson Creek model to represent all of the impervious areas:

- Land Use Type Roads and Moderate Slope

The area of the IMPLND in each sub-basin is given in the uci file in Attachment 1.

RCHRES

Within RCHRES (the channel model), the hydraulic characteristics of each stream reach are represented by a hydraulic function table, called an FTABLE. An FTABLE characterizes a stream by defining the flow rate, surface area, and volume as a function of the water depth in the channel reach. FTABLEs were developed from available representative cross-sections from the survey. The cross-section data were used to compute the rating tables. The FTABLES are given in the uci file at the end of this Attachment.

4. CALIBRATION

After the model input preparation and the initial evaluation of parameters, the model needs to be calibrated. BC calibrated the HSPF model using streamflow data collected by EnviroVision during the winter and spring 2007/2008. However, BC was unable to obtain recent water depth data from the well/piezometer network installed near Thompson Creek.

Hydrologic calibration was performed after the initial model setup. Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. Calibration is an iterative procedure of parameter evaluation and refinement as a result of comparing simulated and observed values at a specified location. Calibration is required for parameters that cannot be deterministically and uniquely evaluated from topographic, climatic, or physical characteristics of the watershed of interest. Calibration often covers a number of years to capture a variety of climatic conditions; however, only about 6 months of streamflow data were available from the EnviroVision gage at the time the Draft Technical Report was prepared.

The hydrologic calibration process involved a comparison of observed data to modeled stream flow and an adjustment of key parameters. Modeling parameters were varied within generally accepted bounds set out in BASINS Technical Note 6 (USEPA 2000). Model parameters were adjusted after model iterations to improve model performance. The parameters that were adjusted include those that account for the partitioning of surface flow versus subsurface flow, infiltration rate, surface and subsurface storage, evapotranspiration, and surface runoff. A complete hydrologic calibration would involve a successive examination of the following four characteristics of the watershed hydrology, in the following order: (1) annual water balance, (2) seasonal and monthly flow volumes, (3) baseflow, and (4) storm events. The annual and seasonal water balances were not possible due to the limited amount of calibration data. Thompson Creek is primarily fed by groundwater, but it was difficult to match both the baseflow recession and the storm peaks. BC determined that it was more important to match the peaks than the baseflow because the purpose of this HSPF model is to simulate changes in flooding conditions due to the Thurston Highlands development; therefore, the high flows are more critical.

The hydrology calibration results are shown below. Figure Att. 3-1 shows daily simulation comparison between model and observed flow. One issue noted during the calibration period was that precipitation was reaching Thompson Creek too quickly, and the levels of the Creek were not being sustained. The area just upstream of the EnviroVision gage is a large series of wetlands. These wetlands likely buffer the inflow into the EnviroVision gage reach. To combat this problem, an additional FTABLE was added to the model to mimic this ponding in the wetland. This FTABLE was just upstream of the EnviroVision gage, and all of the flow routed to the EnvioVision gage sub-basin came from the wetland reach.

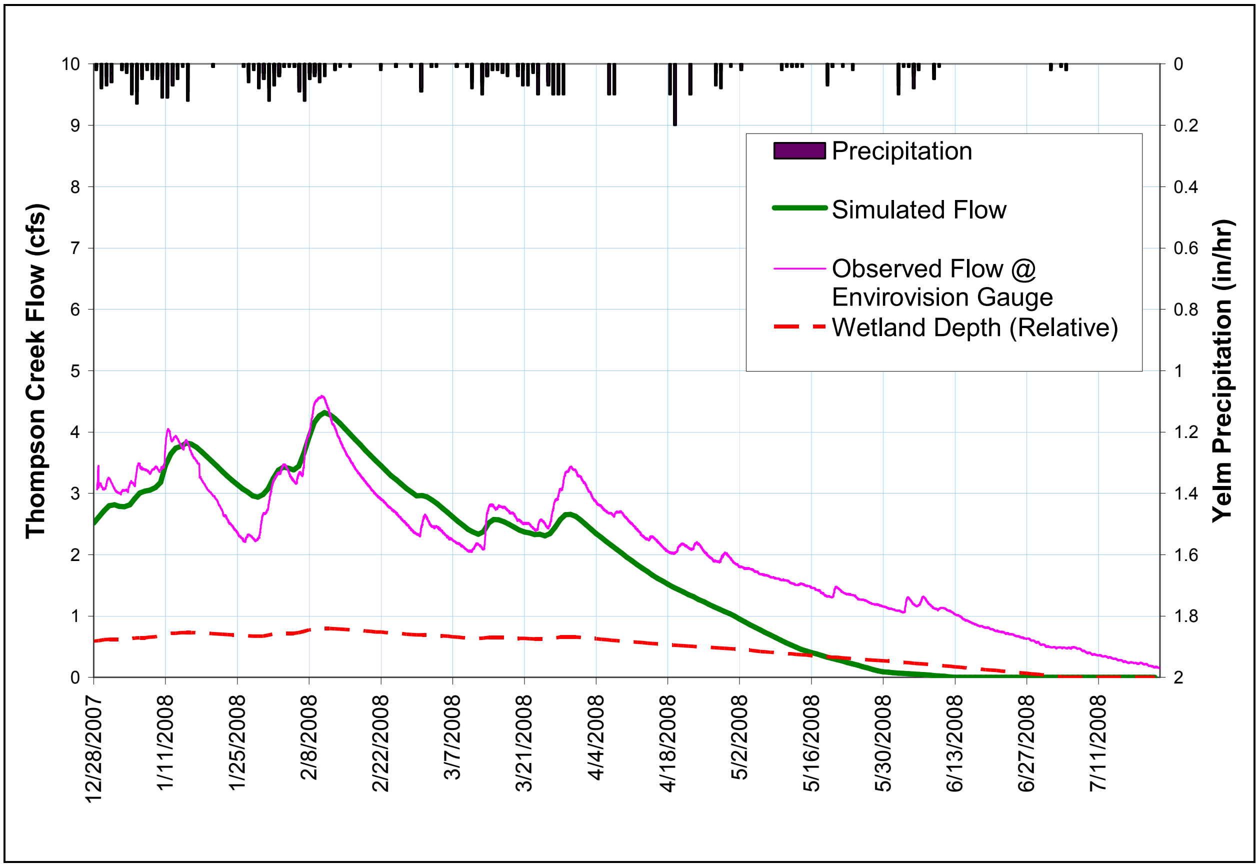

Figure Att. 3-1. Comparison of HSPF Model Output and EnviroVision Gage Measurements

5. TASK 4: LONG-TERM MODEL SIMULATIONS

Once the model was shown to reflect current streamflow conditions, BC ran a long-term HSPF model simulation. This simulation used 50 years of historical hourly precipitation data to calculate a long-term stream flow time series for the existing conditions. The long-term simulations were examined to estimate the flow rates that occurred during historically important, large events. In particular, the simulation results for the February 1996 storm event were incorporated into the assessment of how the Thurston Highlands development could impact the water surface elevation and inundation extent during large flood events, as described in Section 2 of the *Final Surface Water Technical Report* (prepared by Brown and Caldwell, 2008).

References

Dinicola, R.S. 1990. Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington. U.S. Geological Survey Water Resources Investigations Report 89-4052.

EPA BASINS Technical Note 6; Estimating Hydrology and Hydraulic Parameters for HSPF. 2000, Office of Water, United States Environmental Protection Agency.

Puget Sound LiDAR Consortium. http://pugetsoundlidar.ess.washington.edu/

US Deaprtment of Agriculture Natrural Resource Conservation Center. http://websoilsurvey.nrcs.usda.gov/app/

Tables Att. 3-1 and 3-2 give the dwelling units by land use and describe the effective impervious areas. The effective impervious areas

Table Att. 3-1. Dwelling Units by Land Use Type

Land Use Description from Parcel GIS shapefile	Category of Land Use	Dwelling Units
11 - SINGLE-UNIT	Single Residential	1
12 - 2-4-UNITS	2-4 Residential	3
13 - 5+-UNITS	5+ Residential	5
15 - MOBILE-HOME-PARK	Mobile Home Residential	10
16 - HOTEL-MOTEL	Commercial	0
17 - INST-LODGING	Commercial	0
18 - OTHER-RESID	Other Residential	2
39 - MANF-OTHER	Commercial	0
41 - TRAN-RAILROD	Commercial	0
43 - TRAN-AIRCRFT	Commercial	0
45 - TRAN-HIGHWAY	ROW	0
48 - UTILITIES	Commercial	0
49 - TRAN-OTHER	Commercial	0
52 - RETL-HARDWAR	Commercial	0
53 - RETL-GEN-MER	Commercial	0
54 - RETL-FOOD	Commercial	0
55 - RETL-AUTO	Commercial	0
57 - RETL-FURNITR	Commercial	0
61 - SRV-FINANCE	Commercial	0
62 - SRV-PERSONAL	Commercial	0
63 - SRV-BUSINESS	Commercial	0
64 - SRV-REPAIR	Commercial	0
65 - SRV-PROFSNAL	Commercial	0
67 - SRV-GOVRNMTL	Commercial	0
68 - SRV-EDUCATNL	Commercial	0
69 - SRV-MISCELNS	Commercial	0
71 - CULTRL-ACTIV	Commercial	0
72 - PUBLIC-ASSMB	Commercial	0
73 - AMUSEMENTS	Commercial	0
74 - RECREATIONAL	Commercial	0
76 - PARKS	Ag/ Open Space	0
79 - OTHER-CULTRL	Commercial	0
81 - AG-NOT-CU	Ag/ Open Space	0
83 - CUR-USE-AG	Ag/ Open Space	0
85 - MINING	Commercial	0
88 - DESIGNATED-FOREST	Forest	0
91 - UNDEVELOPED-LAND	Ag/ Open Space	0
92 - UNDEVELOPED-LAND	Ag/ Open Space	0
94 - CUR-USE-OPEN	Ag/ Open Space	0
95 - CUR-USE-TIMBER	Ag/ Open Space	0
96 - COMMRCL/INDUST-LAND	Commercial	0

Table Att. 3-1. Dwelling Units by Land Use Type		
Land Use Description from Parcel GIS shapefile	**Category of Land Use**	**Dwelling Units**
99 - OTHER-UNDEVL	Ag/ Open Space	0
blank	Commercial	0

Table Att. 3-2 Effective Impervious Area	
Category	**Effective Impervious Area**
Low Density Development*	4%
Medium Density Development*	10%
High Density Development*	48%
Commercial	86%
Ag/ Open Space	0%
Forest	0%
ROW	80%
Vacant	0%
Water	100%

** The residential density developments are based on the dwelling units per acre as defined in Table Att. 3-1.*

Thompson Creek HSPF Input File

```
RUN

GLOBAL
  Thurston Highlands Hydrology -- calibration
  START       2006 12 01        END    2008 07 22
  RUN INTERP OUTPUT LEVEL    3    0
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL

FILES
<File>  <Un#>   <-----------File Name------------------------------>***
<-ID->                                                              ***
WDM         26   TH.wdm
MESSU       25   th.MES
            31   CAL.plt
            32   WETLAND.plt
            33   THGAGE.plt
END FILES

OPN SEQUENCE
    INGRP              INDELT 00:60
      PERLND      11
      PERLND      14
      PERLND       2
      PERLND       5
      IMPLND       2
      RCHRES      34
      RCHRES      31
      RCHRES      32
      RCHRES      33
      PLTGEN       1
      PLTGEN       2
    END INGRP
END OPN SEQUENCE

COPY
  TIMESERIES
    # -  #  NPT  NMN ***
  END TIMESERIES
END COPY
GENER
  OPCODE
    #    # OPCD ***
  END OPCODE
  PARM
    #    #         K ***
  END PARM
END GENER

PERLND
  GEN-INFO
    <PLS ><-------Name------->NBLKS   Unit-systems   Printer ***
    # -  #                          User  t-series Engl Metr ***
                                          in  out            ***
   10     C, Forest, Flat         1    1    1    1   61    0
   11     C, Forest, Mod          1    1    1    1   61    0
   12     C, Forest, Steep        1    1    1    1   61    0
   13     C, Pasture, Flat        1    1    1    1   61    0
   14     C, Pasture, Mod         1    1    1    1   61    0
   15     C, Pasture, Steep       1    1    1    1   61    0
   16     C, Lawn, Flat           1    1    1    1   61    0
```

```
 17     C, Lawn, Mod           1    1    1    1   61    0
 19     SAT, Forest, Flat      1    1    1    1   61    0
 20     SAT, Forest, Mod       1    1    1    1   61    0
 22     SAT, Pasture, Flat     1    1    1    1   61    0
  1     A/B, Forest, Flat      1    1    1    1   61    0
  2     A/B, Forest, Mod       1    1    1    1   61    0
  3     A/B, Forest, Steep     1    1    1    1   61    0
  5     A/B, Pasture, Mod      1    1    1    1   61    0
  6     A/B, Pasture, Steep    1    1    1    1   61    0
  7     A/B, Lawn, Flat        1    1    1    1   61    0
  8     A/B, Lawn, Mod         1    1    1    1   61    0
END GEN-INFO
*** Section PWATER***

ACTIVITY
  <PLS > ************* Active Sections *****************************
  # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
 10         0    0    1    0    0    0    0    0    0    0    0    0
 11         0    0    1    0    0    0    0    0    0    0    0    0
 12         0    0    1    0    0    0    0    0    0    0    0    0
 13         0    0    1    0    0    0    0    0    0    0    0    0
 14         0    0    1    0    0    0    0    0    0    0    0    0
 15         0    0    1    0    0    0    0    0    0    0    0    0
 16         0    0    1    0    0    0    0    0    0    0    0    0
 17         0    0    1    0    0    0    0    0    0    0    0    0
 19         0    0    1    0    0    0    0    0    0    0    0    0
 20         0    0    1    0    0    0    0    0    0    0    0    0
 22         0    0    1    0    0    0    0    0    0    0    0    0
  1         0    0    1    0    0    0    0    0    0    0    0    0
  2         0    0    1    0    0    0    0    0    0    0    0    0
  3         0    0    1    0    0    0    0    0    0    0    0    0
  5         0    0    1    0    0    0    0    0    0    0    0    0
  6         0    0    1    0    0    0    0    0    0    0    0    0
  7         0    0    1    0    0    0    0    0    0    0    0    0
  8         0    0    1    0    0    0    0    0    0    0    0    0
END ACTIVITY

PRINT-INFO
  <PLS > ***************** Print-flags ***************************** PIVL  PYR
  # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC  *********
 10         0    0    4    0    0    0    0    0    0    0    0    0    1    9
 11         0    0    4    0    0    0    0    0    0    0    0    0    1    9
 12         0    0    4    0    0    0    0    0    0    0    0    0    1    9
 13         0    0    4    0    0    0    0    0    0    0    0    0    1    9
 14         0    0    4    0    0    0    0    0    0    0    0    0    1    9
 15         0    0    4    0    0    0    0    0    0    0    0    0    1    9
 16         0    0    4    0    0    0    0    0    0    0    0    0    1    9
 17         0    0    4    0    0    0    0    0    0    0    0    0    1    9
 19         0    0    4    0    0    0    0    0    0    0    0    0    1    9
 20         0    0    4    0    0    0    0    0    0    0    0    0    1    9
 22         0    0    4    0    0    0    0    0    0    0    0    0    1    9
  1         0    0    4    0    0    0    0    0    0    0    0    0    1    9
  2         0    0    4    0    0    0    0    0    0    0    0    0    1    9
  3         0    0    4    0    0    0    0    0    0    0    0    0    1    9
  5         0    0    4    0    0    0    0    0    0    0    0    0    1    9
  6         0    0    4    0    0    0    0    0    0    0    0    0    1    9
  7         0    0    4    0    0    0    0    0    0    0    0    0    1    9
  8         0    0    4    0    0    0    0    0    0    0    0    0    1    9
END PRINT-INFO

PWAT-PARM1
  <PLS >  PWATER variable monthly parameter value flags  ***
  # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE INFC  HWT ***
```

```
  10        0    0    0    0    0    0    0    0    0    0    0
  11        0    0    0    0    0    0    0    0    0    0    0
  12        0    0    0    0    0    0    0    0    0    0    0
  13        0    0    0    0    0    0    0    0    0    0    0
  14        0    0    0    0    0    0    0    0    0    0    0
  15        0    0    0    0    0    0    0    0    0    0    0
  16        0    0    0    0    0    0    0    0    0    0    0
  17        0    0    0    0    0    0    0    0    0    0    0
  19        0    0    0    0    0    0    0    0    0    0    0
  20        0    0    0    0    0    0    0    0    0    0    0
  22        0    0    0    0    0    0    0    0    0    0    0
   1        0    0    0    0    0    0    0    0    0    0    1
   2        0    0    0    0    0    0    0    0    0    0    0
   3        0    0    0    0    0    0    0    0    0    0    0
   5        0    0    0    0    0    0    0    0    0    0    0
   6        0    0    0    0    0    0    0    0    0    0    0
   7        0    0    0    0    0    0    0    0    0    0    0
   8        0    0    0    0    0    0    0    0    0    0    0
END PWAT-PARM1

PWAT-PARM2
  <PLS >      PWATER input info: Part 2          ***
  # -   # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
  10             0       4.5      0.08       400      0.05       0.5     0.996
  11             0       4.5      0.05       400       0.1       0.5     0.996
  12             0       4.5      0.08       400      0.15       0.5     0.996
  13             0       4.5      0.06       400      0.05       0.5     0.996
  14             0       4.5      0.01       400       0.1       0.5     0.996
  15             0       4.5      0.06       400      0.15       0.5     0.996
  16             0       4.5      0.03       400      0.05       0.5     0.996
  17             0       4.5      0.03       400       0.1       0.5     0.996
  19             0         4         2       100     0.001       0.5     0.996
  20             0         4         2       100      0.01       0.5     0.996
  22             0         4       1.8       100     0.001       0.5     0.996
   1             0         5         2       400      0.05       0.3     0.996
   2             0         5         1       400       0.1       0.3     0.996
   3             0         5         2       400      0.15       0.3     0.996
   5             0         5       0.8       400       0.1       0.3     0.996
   6             0         5       1.5       400      0.15       0.3     0.996
   7             0         5       0.8       400      0.05       0.3     0.996
   8             0         5       0.8       400       0.1       0.3     0.996
END PWAT-PARM2

PWAT-PARM3
  <PLS >      PWATER input info: Part 3          ***
  # -   # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
  10             0         0         2         2         0         0         0
  11             0         0         2         2        .2         0         0
  12             0         0         2         2         0         0         0
  13             0         0         2         2         0         0         0
  14             0         0         2         2        .2         0         0
  15             0         0         2         2         0         0         0
  16             0         0         2         2         0         0         0
  17             0         0         2         2         0         0         0
  19             0         0        10         2         0         0       0.7
  20             0         0        10         2         0         0       0.7
  22             0         0        10         2         0         0       0.5
   1             0         0         2         2         0         0         0
   2             0         0         2         2         0         0         0
   3             0         0         2         2         0         0         0
   5             0         0         2         2         0         0         0
   6             0         0         2         2         0         0         0
   7             0         0         2         2         0         0         0
```

```
    8              0         0         2         2         0         0         0
  END PWAT-PARM3
  PWAT-PARM4
    <PLS >      PWATER input info: Part 4                                  ***
    # -   #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
   10             0.2       0.5      0.35         6       0.5       0.7
   11             0.2       0.5      0.35         6       0.5       0.7
   12             0.2       0.3      0.35         6       0.3       0.7
   13            0.15       0.4       0.3         6       0.5       0.4
   14            0.15       0.4       0.3         6       0.5       0.4
   15            0.15      0.25       0.3         6       0.3       0.4
   16             0.1      0.25      0.25         6       0.5      0.25
   17             0.1      0.25      0.25         6       0.5      0.25
   19             0.2         3       0.5         1       0.7       0.8
   20             0.2         3       0.5         1       0.7       0.8
   22            0.15         3       0.5         1       0.7       0.6
    1             0.2       0.5      0.35         0       0.7       0.7
    2             0.2       0.5      0.35         0       0.7      0.7
    3             0.2       0.5      0.35         0       0.7       0.7
    5            0.15       0.5       0.3         0       0.7       0.4
    6            0.15       0.5       0.3         0       0.7       0.4
    7             0.1       0.5      0.25         0       0.7      0.25
    8             0.1       0.5      0.25         0       0.7      0.25
  END PWAT-PARM4
  PWAT-PARM6
    <PLS >       PWATER input info: Part 3          ***
    # -   # ***MELEV      BELV    GWDATM     PCW       PGW      UPGW
   10             400         0         0       0.2      0.23      0.28
   11             400         0         0       0.2      0.23      0.28
   12             400         0         0       0.2      0.23      0.28
   13             400         0         0      0.18       0.2      0.25
   14             400         0         0      0.18       0.2      0.25
   15             400         0         0      0.18       0.2      0.25
   16             400         0         0      0.15      0.17       0.2
   17             400         0         0      0.15      0.17       0.2
   19             400         0         0      0.17       0.2      0.25
   20             400         0         0      0.17       0.2      0.25
   22             400         0         0      0.15      0.17      0.22
    1             400         0         0      0.35      0.38      0.45
    2             400         0         0      0.35      0.38      0.45
    3             400         0         0      0.35      0.38      0.45
    5             400         0         0      0.33      0.35      0.42
    6             400         0         0      0.33      0.35      0.42
    7             400         0         0      0.31      0.33       0.4
    8             400         0         0      0.31      0.33       0.4
  END PWAT-PARM6
  PWAT-PARM7
    <PLS >       PWATER input info: Part 3          ***
    <PLS > ***STABNO      SRRC     SREXP     IFWSC     DELTA    UELFAC    LELFAC
   10             510       0.1         0         4       0.2         4       2.5
   11             511       0.1         0         4       0.2         4       2.5
   12             512       0.1         0         4       0.2         4       2.5
   13             513       0.1         0         4       0.2         4       2.5
   14             514       0.1         0         4       0.2         4       2.5
   15             515       0.1         0         4       0.2         4       2.5
   16             516       0.1         0         4       0.2         4       2.5
   17             517       0.1         0         4       0.2         4       2.5
   19             519       0.1         0         4       0.2         4       2.5
   20             520       0.1         0         4       0.2         4       2.5
   22             522       0.1         0         4       0.2         4       2.5
    1             501       0.1         0         4       0.2         4       2.5
    2             502       0.1         0         4       0.2         4       2.5
    3             503       0.1         0         4       0.2         4       2.5
```

```
    5            505       0.1         0         4       0.2         4       2.5
    6            506       0.1         0         4       0.2         4       2.5
    7            507       0.1         0         4       0.2         4       2.5
    8            508       0.1         0         4       0.2         4       2.5
  END PWAT-PARM7

  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
              ran from 1990 to end of 1992 (pat 1-11-95) RUN 21 ***
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
   10             0         0         0         0       2.5         1         0
   11             0         0         0         0       2.5         1         0
   12             0         0         0         0       2.5         1         0
   13             0         0         0         0       2.5         1         0
   14             0         0         0         0       2.5         1         0
   15             0         0         0         0       2.5         1         0
   16             0         0         0         0       2.5         1         0
   17             0         0         0         0       2.5         1         0
   19             0         0         0         0       4.2         1         0
   20             0         0         0         0       4.2         1         0
   22             0         0         0         0       4.2         1         0
    1             0         0         0         0         3         1         0
    2             0         0         0         0         3         1         0
    3             0         0         0         0         3         1         0
    5             0         0         0         0         3         1         0
    6             0         0         0         0         3         1         0
    7             0         0         0         0         3         1         0
    8             0         0         0         0         3         1         0
  END PWAT-STATE1

END PERLND

IMPLND
  GEN-INFO
    <PLS ><-------Name------->   Unit-systems   Printer ***
    # -  #                     User  t-series Engl Metr ***
                                     in  out            ***
    2      ROADS MOD              1    1    1   61    0
    4      ROOF TOPS FLAT         1    1    1   61    0
    6      DRIVEWAYS MOD          1    1    1   61    0
    8      SIDEWALKS FLAT         1    1    1   61    0
    9      SIDEWALKS MOD          1    1    1   61    0
   11      PARKING FLAT           1    1    1   61    0
   12      PARKING MOD            1    1    1   61    0
   14      POND                   1    1    1   61    0
    1      ROADS FLAT             1    1    1   61    0
    5      DRIVEWAYS FLAT         1    1    1   61    0
  END GEN-INFO
  *** Section IWATER***

  ACTIVITY
    <PLS > ************* Active Sections *****************************
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL    ***
    2         0    0    1    0    0    0
    4         0    0    1    0    0    0
    6         0    0    1    0    0    0
    8         0    0    1    0    0    0
    9         0    0    1    0    0    0
   11         0    0    1    0    0    0
   12         0    0    1    0    0    0
   14         0    0    1    0    0    0
    1         0    0    1    0    0    0
    5         0    0    1    0    0    0
```

```
END ACTIVITY

PRINT-INFO
  <ILS > ******** Print-flags ******** PIVL  PYR
  # -  # ATMP SNOW IWAT  SLD  IWG IQAL    *********
  2         0    0    4    0    0    0    1    9
  4         0    0    4    0    0    0    1    9
  6         0    0    4    0    0    0    1    9
  8         0    0    4    0    0    0    1    9
  9         0    0    4    0    0    0    1    9
 11         0    0    4    0    0    0    1    9
 12         0    0    4    0    0    0    1    9
 14         0    0    4    0    0    0    1    9
  1         0    0    4    0    0    0    1    9
  5         0    0    4    0    0    0    1    9
END PRINT-INFO

IWAT-PARM1
  <PLS >  IWATER variable monthly parameter value flags  ***
  # -  # CSNO RTOP  VRS  VNN RTLI     ***
  2         0    0    0    0    0
  4         0    0    0    0    0
  6         0    0    0    0    0
  8         0    0    0    0    0
  9         0    0    0    0    0
 11         0    0    0    0    0
 12         0    0    0    0    0
 14         0    0    0    0    0
  1         0    0    0    0    0
  5         0    0    0    0    0
END IWAT-PARM1

IWAT-PARM2
  <PLS >      IWATER input info: Part 2         ***
  # -  # ***  LSUR     SLSUR      NSUR     RETSC
  2            400      0.05       0.1      0.08
  4            400      0.01       0.1       0.1
  6            400      0.05       0.1      0.08
  8            400      0.01       0.1       0.1
  9            400      0.05       0.1      0.08
 11            400      0.01       0.1       0.1
 12            400      0.05       0.1      0.08
 14            400      0.01       0.1       0.1
  1            400      0.01       0.1       0.1
  5            400      0.01       0.1       0.1
END IWAT-PARM2

IWAT-PARM3
  <PLS >      IWATER input info: Part 3         ***
  # -  # ***PETMAX    PETMIN
  2              0         0
  4              0         0
  6              0         0
  8              0         0
  9              0         0
 11              0         0
 12              0         0
 14              0         0
  1              0         0
  5              0         0
END IWAT-PARM3

IWAT-STATE1
```

```
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  RETS      SURS
    2            0         0
    4            0         0
    6            0         0
    8            0         0
    9            0         0
   11            0         0
   12            0         0
   14            0         0
    1            0         0
    5            0         0
  END IWAT-STATE1

END IMPLND

*** SURO:  surface outflow
*** IFWO:  interflow outflow
*** AGWO:  active groundwater outflow
*** AGWI:  active groundwater inflow
*** IGWI:  inflow to inactive (deep) groundwater
*** PERO:  total outflow of pervious area
*** TAET:  total simulated ET of pervious area
*** CEPS:  interception storage of pervious area
*** PERS:  total water stored of pervious area
*** IMPEV: total simulated ET of impervious area
*** IMPS:  total water stored of impervious area

SCHEMATIC
*** SCHEMATIC BLOCK - PERLND (SURO, IFWO, AGEO) PERO AND IMPLND ***
<-Source->                  <--Mult-->     <-Target >   MSLK      ***
<Name>   #                  <-factor->     <Name>   #   Tbl#      ***
*** ENTIRE WATERSHED -- SAMPLE
*** SUB-BASIN Mouth
PERLND   2                       21.86     RCHRES  33      5
PERLND   5                       35.47     RCHRES  33      5
PERLND  11                        0.02     RCHRES  33      5
PERLND  14                        0.55     RCHRES  33      5
IMPLND   2                          53     RCHRES  33      6

*** SUB-BASIN HWY 510
PERLND   2                        4.93     RCHRES  33      5
PERLND   5                       13.72     RCHRES  33      5
PERLND  11                        0.47     RCHRES  33      5
PERLND  14                           0     RCHRES  33      5
IMPLND   2                           8     RCHRES  33      6

*** SUB-BASIN Anderson Lane
PERLND   2                         310     RCHRES  33      5
PERLND   5                         523     RCHRES  33      5
PERLND  11                         373     RCHRES  33      5
PERLND  14                         301     RCHRES  33      5
IMPLND   2                          53     RCHRES  33      6

*** SUB-BASIN Thurston County Gage
PERLND   2                          20     RCHRES  32      5
PERLND   5                         296     RCHRES  32      5
PERLND  11                          13     RCHRES  32      5
PERLND  14                          40     RCHRES  32      5
IMPLND   2                         148     RCHRES  32      6

*** SUB-BASIN EnviroVision Gage
PERLND   2                           0     RCHRES  31      5
```

```
PERLND   5                          0     RCHRES  31       5
PERLND  11                          0     RCHRES  31       5
PERLND  14                          0     RCHRES  31       5
IMPLND   2                          0     RCHRES  31       6

*** SUB-BASIN Wetland
PERLND   2                        117     RCHRES  34       5
PERLND   5                        201     RCHRES  34       5
PERLND  11                        343     RCHRES  34       5
PERLND  14                        525     RCHRES  34       5
IMPLND   2                         82     RCHRES  34       6

***   CHANNEL LINKAGES
RCHRES  34                                RCHRES  31      30
RCHRES  31                                RCHRES  32      30
RCHRES  32                                RCHRES  33      30
END SCHEMATIC

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
***   CHANNEL EXPORT TO PLOT FILE
  12.1 converts acre-ft per hour to cfs, or 43560/3600   ***
RCHRES  34 HYDR   ROVOL  1      12.1       PLTGEN   1     INPUT  MEAN   1
RCHRES  31 HYDR   ROVOL  1      12.1       PLTGEN   1     INPUT  MEAN   2
RCHRES  32 HYDR   ROVOL  1      12.1       PLTGEN   1     INPUT  MEAN   3
RCHRES  33 HYDR   ROVOL  1      12.1       PLTGEN   1     INPUT  MEAN   4
RCHRES  34 HYDR   STAGE                    PLTGEN   2     INPUT  MEAN   1
RCHRES  34 HYDR   ROVOL         12.1       PLTGEN   2     INPUT  MEAN   2

END NETWORK


EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
WDM      3 HPRCP    ENGL                   PERLND   1 999 EXTNL  PREC
WDM      3 HPRCP    ENGL                   IMPLND   1 999 EXTNL  PREC
WDM      4 EVAP     ENGL    0.76           PERLND   1 999 EXTNL  PETINP
WDM      4 EVAP     ENGL    0.76           IMPLND   1 999 EXTNL  PETINP
WDM      4 EVAP     ENGL    0.76           RCHRES  34     EXTNL  POTEV

END EXT SOURCES

RCHRES
  GEN-INFO
    RCHRES       Name        Nexits   Unit Systems   Printer                 ***
    # -  #<------------------><---> User T-series  Engl Metr LKFG            ***
                                           in  out                           ***
   34     WETLAND                 1    1    1    1    6    0    0
   31     ENVIROVISION            1    1    1    1    6    0    0
   32     TC GAGE                 1    1    1    1    6    0    0
   33     MOUTH                   1    1    1    1    6    0    0

  END GEN-INFO
  ACTIVITY
    RCHRES *************** Active Sections *****************
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG                  ***
   31   34   1    0    0    0    0    0    0    0    0    0

  END ACTIVITY
  PRINT-INFO
    RCHRES *************** Printout Flags ****************** PIVL  PYR
```

```
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB *********
   31   34    6    0    0    0    0    0    0    0    0    0    1    9

  END PRINT-INFO
  HYDR-PARM1
    RCHRES  Flags for each HYDR Section                                ***
    # -  #  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
            FG FG FG FG  possible   exit *** possible   exit     possible   exit
             *  *  *  *    *  *  *  *  *        *  *  *  *  *         ***
   31   33   0  0  0  0    4  0  0  0  0        0  0  0  0  0       2  2  2  2  2
   34        0  1  0  0    4  0  0  0  0        0  0  0  0  0       2  2  2  2  2
  END HYDR-PARM1
  HYDR-PARM2
    RCHRES                                                             ***
    # -  #    FTABNO       LEN     DELTH     STCOR        KS      DB50       ***
  <------><--------><--------><--------><--------><--------><-------->       ***
   34             34   1.000                               0.5
   31             31   1.000                               0.5
   32             32   1.000                               0.5
   33             33   1.000                               0.5
  END HYDR-PARM2
  HYDR-INIT
    RCHRES  Initial conditions for each HYDR section                   ***
    # -  # ***   VOL     Initial  value  of COLIND     Initial  value  of OUTDGT
           *** ac-ft     for each possible exit        for each possible exit
  <------><-------->     <---><---><---><---><---> *** <---><---><---><---><--->
   31   34  0.0            4.0
  END HYDR-INIT
END RCHRES

FTABLES

  FTABLE     34
 ROWS COLS                                                             ***
   31    4
*** Wetland Ftable
***
<--Depth-><---Area-><-Volume-><Outflow1><Outflow2>***
   (ft)    (acres)  (acre-ft)   (cfs)     (cfs)    ***
         0    573.92         0         0
       0.1    574.02      57.4         0
       0.2    574.11     114.8         0
       0.3    574.21     172.2      0.09
       0.4     574.3     229.7      0.46
       0.5    574.39     287.2         1
       0.6    574.49     344.7      1.66
       0.7    574.58     402.2      2.41
       0.8    574.68     459.7      3.26
       0.9    574.77     517.3      4.19
         1    574.87     574.8       5.2
       1.1    574.96     632.4      6.27
       1.2    575.06       690      7.41
       1.3    575.15     747.6      8.61
       1.4    575.25     805.3      9.87
       1.5    575.34     862.9     11.18
       1.6    575.44     920.6     12.55
       1.7    575.53     978.3     13.97
       1.8    575.63      1036     15.44
       1.9    575.72    1093.8     16.96
         2    575.82    1151.5     18.52
       2.1    575.91    1209.3     20.13
       2.2    576.01    1267.1     21.78
       2.3     576.1    1324.9     23.48
```

```
       2.4    576.19    1382.7     25.22
       2.5    576.29    1440.6        27
       2.6    576.38    1498.5     28.82
       2.7    576.48    1556.4     30.68
       2.8    576.57    1614.3     32.58
       2.9    576.67    1672.2     34.51
         3    576.76    1730.1     36.48

  END FTABLE 34


  FTABLE     31
 ROWS COLS                                                                     ***
   22    4
*** Subbasin EnviroVision Gage Ftable
***
<--Depth-><---Area-><-Volume-><Outflow1><Outflow2>***
   (ft)    (acres)  (acre-ft)   (cfs)     (cfs)   ***
      0.00      0.00      0.00      0.00
      0.94      0.84      0.40      0.50
      1.22      1.56      0.78      1.00
      1.37      1.65      1.01      1.50
      1.50      1.73      1.23      2.00
      1.61      1.76      1.42      2.50
      1.71      1.80      1.60      3.00
      1.80      1.83      1.77      3.50
      1.89      1.86      1.93      4.00
      1.97      1.89      2.09      4.50
      2.05      1.92      2.24      5.00
      2.13      1.95      2.39      5.50
      2.20      1.98      2.54      6.00
      2.28      2.01      2.68      6.50
      2.34      2.04      2.82      7.00
      2.41      2.07      2.95      7.50
      2.48      2.10      3.09      8.00
      2.54      2.12      3.22      8.50
      2.60      2.15      3.35      9.00
      2.72      2.20      3.60      10.00
      2.83      2.25      3.85      11.00
      2.93      2.29      4.09      12.00

  END FTABLE 31

  FTABLE     32
 ROWS COLS                                                                     ***
   25    4
*** Subbasin TG Gage Ftable
***
<--Depth-><---Area-><-Volume-><Outflow1><Outflow2>***
   (ft)    (acres)  (acre-ft)   (cfs)     (cfs)   ***
      0.00      0.00      0.00      0.00
      0.69      1.04      0.43      1.00
      0.93      1.24      0.69      2.00
      1.10      1.38      0.92      3.00
      1.25      1.47      1.13      4.00
      1.37      1.55      1.31      5.00
      1.49      1.62      1.49      6.00
      1.59      1.67      1.66      7.00
      1.68      1.70      1.82      8.00
      1.77      1.74      1.97      9.00
      1.85      1.77      2.11      10.00
      1.93      1.80      2.25      11.00
      2.00      1.83      2.39      12.00
```

```
      2.08      1.86      2.53      13.00
      2.15      1.88      2.66      14.00
      2.22      1.91      2.79      15.00
      2.28      1.94      2.91      16.00
      2.76      6.08      4.73      17.00
      2.80      6.29      4.97      18.00
      2.83      6.38      5.16      19.00
      2.86      6.47      5.35      20.00
      2.89      6.56      5.54      21.00
      2.92      6.65      5.72      22.00
      2.95      6.73      5.91      23.00
      3.24      7.61      7.98      35.00

  END FTABLE 32

  FTABLE     33
 ROWS COLS                                                                ***
   30    4
*** Subbasin Mouth Ftable
***
<--Depth-><---Area-><-Volume-><Outflow1><Outflow2>***
   (ft)    (acres)  (acre-ft)   (cfs)     (cfs)   ***
      0.00      0.00      0.00      0.00
      0.42      0.80      0.17      1.00
      0.54      1.04      0.28      2.00
      0.63      1.22      0.38      3.00
      0.70      1.36      0.48      4.00
      0.76      1.47      0.56      5.00
      0.82      1.57      0.65      6.00
      0.86      1.65      0.72      7.00
      0.91      1.72      0.80      8.00
      0.94      1.76      0.86      9.00
      0.98      1.81      0.93      10.00
      1.02      1.84      0.99      11.00
      1.05      1.87      1.05      12.00
      1.08      1.89      1.11      13.00
      1.11      1.92      1.17      14.00
      1.14      1.93      1.22      15.00
      1.17      1.95      1.27      16.00
      1.19      1.97      1.33      17.00
      1.22      1.99      1.38      18.00
      1.25      2.01      1.43      19.00
      1.27      2.02      1.48      20.00
      1.30      2.04      1.53      21.00
      1.32      2.06      1.58      22.00
      1.34      2.07      1.63      23.00
      1.37      2.09      1.68      24.00
      1.39      2.10      1.73      25.00
      1.50      2.18      1.96      30.00
      1.60      2.25      2.18      35.00
      1.69      2.31      2.39      40.00
      1.86      2.42      2.79     175.00

  END FTABLE 33

END FTABLES

MASS-LINK
<Volume>   <-Grp> <-Member-><--Mult-->     <Target>       <-Grp> <-Member->***
<Name>            <Name> # #<-factor->     <Name>                <Name> # #***
  MASS-LINK        1
  0.083333 is to convert inches to acre-ft/acre/invld, or 1/12              ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
```

```
  END MASS-LINK    1

  MASS-LINK        5
  0.083333 is to convert inches to acre-ft/acre/invld, or 1/12             ***
PERLND     PWATER SURO       0.0833333     RCHRES          INFLOW IVOL
PERLND     PWATER IFWO       0.0833333     RCHRES          INFLOW IVOL
PERLND     PWATER AGWO       0.0833333     RCHRES          INFLOW IVOL
  END MASS-LINK    5

  MASS-LINK        6
IMPLND     IWATER SURO       0.0833333     RCHRES          INFLOW IVOL
  END MASS-LINK    6

  MASS-LINK       11
  1.0083333 is to convert acre-inch per hour to cfs, or 1/12*43560//3600   ***
PERLND     PWATER PERO       1.0083333     COPY            INPUT  MEAN   1 1
  END MASS-LINK   11

  MASS-LINK       12
PERLND     PWATER SURO       1.0083333     COPY            INPUT  MEAN   1 1
  END MASS-LINK   12

  MASS-LINK       13
PERLND     PWATER IFWO       1.0083333     COPY            INPUT  MEAN   1 1
  END MASS-LINK   13

  MASS-LINK       14
PERLND     PWATER AGWO       1.0083333     COPY            INPUT  MEAN   1 1
  END MASS-LINK   14

  MASS-LINK       21
PERLND     PWATER SURO       1.0083333     COPY            INPUT  MEAN   1
PERLND     PWATER IFWO       1.0083333     COPY            INPUT  MEAN   1
PERLND     PWATER AGWO       1.0083333     COPY            INPUT  MEAN   1
  END MASS-LINK   21

  MASS-LINK       22
IMPLND     IWATER SURO       1.0083333     COPY            INPUT  MEAN   1
  END MASS-LINK   22

  MASS-LINK       30
RCHRES     HYDR   ROVOL                    RCHRES          INFLOW IVOL
  END MASS-LINK   30

  MASS-LINK       40
*** 12.1 converts acre-ft per hour to cfs, or 43560/3600
RCHRES     HYDR   ROVOL      12.1          COPY            INPUT  MEAN   1
  END MASS-LINK   40

END MASS-LINK


PLTGEN
  PLOTINFO
    #  - # FILE  NPT  NMN LABL  PYR PIVL   ***
    1        31          4    0    9   24
    2        32          2    0    9   24

  END PLOTINFO

  GEN-LABELS
    # -  #<--------------TITLE----------------->  ***      <-------YLABL----->
    1    2 THURSTON HIGHLANDS
```

```
  END GEN-LABELS

  SCALING
  <-RANGE><--YMIN--><--YAVER--><--IVLIN-><-THRESH->  ***
    #    #                                          ***
    1    2      0.         3.        20.
  END SCALING

*** Column 1
  CURV-DATA
  <-RANGE>    <-----LABEL----><LIN><INT><COL> <TR>  ***
    #    #                                          ***
    1          WETLAND OUTFLOW                AVER
    2          WETLAND DEPTH                  MAX
  END CURV-DATA
***Column 2
  CURV-DATA
  <-RANGE>    <-----LABEL----><LIN><INT><COL> <TR>  ***
    #    #                                          ***
    1         ENVIRO RCH OUTFL                AVER
    2          WETLAND FLOW                   MAX
  END CURV-DATA
***Column 3
  CURV-DATA
  <-RANGE>    <-----LABEL----><LIN><INT><COL> <TR>  ***
    #    #                                          ***
    1         TC GAGE OUTFLOW                 AVER
  END CURV-DATA

***Column 4
  CURV-DATA
  <-RANGE>    <-----LABEL----><LIN><INT><COL> <TR>  ***
    #    #                                          ***
    1         MOUTH RCH OUTFLO                AVER
  END CURV-DATA

END PLTGEN
```

END RUN