Extention Basin SYSTEMS™

Simple Orifice and Weir Outperforms Thirsty Duck Control Device

Abstract:

The “Thirsty Duck” (TD) company manufactures a buoyant flow control device and makes claims that the device reduces the volume of stormwater storage for stormwater detention systems. Claims of up to 50% savings are made on their web site and literature.

Our careful study belies such claims and we show here that a standard orifice and weir outlet control performs even better than the Thirsty Duck device.

Method:

The Thirsty Duck website provides a sample Rating Curve for their ER-100 Series device. The curve range is limited from 0 to 15.5 cubic feet per second. We reservoir-routed a random SCS Type 2 hydrograph within the lower and upper limits of the rating curve and determined the outflow peak discharge and the total storage volume. Next, in the same detention basin, we routed the same inflow hydrograph using a standard orifice and weir whose combination yielded the same outflow peak discharge as the Thirsty Duck (13.75 cfs).

The Army Corps HEC-1 computer software is used for the routing and the HEC-1 output file and all other data needed to reproduce our results are included in this paper.

Results:

Name	100 Year Storm (cfs)
INFLOW (Random Hydrograph)	15.439
DET-TD (Thirsty Duck)	13.748
DET-OW (Simple Orifice and Weir)	13.748

Storage and Flow Values from the HEC-1 Program

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PLAN  1 ..............                INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                        ELEVATION         100.50             105.50          105.50
                        STORAGE              .00                .26             .26
                        OUTFLOW              .00              15.13           15.13


              RATIO     MAXIMUM      MAXIMUM    MAXIMUM    MAXIMUM    DURATION     TIME OF     TIME OF
                OF     RESERVOIR      DEPTH     STORAGE    OUTFLOW    OVER TOP   MAX OUTFLOW   FAILURE
               PMF      W.S.ELEV    OVER DAM     AC-FT       CFS       HOURS        HOURS       HOURS

             12.00       104.57         .00        .164      13.75       .00         12.48         .00     Thirsty Duck
                       SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION   DET-OW


PLAN  1 ..............                INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                        ELEVATION         100.50             101.00          106.00
                        STORAGE              .00                .00             .31
                        OUTFLOW              .00               1.94           21.08


              RATIO     MAXIMUM      MAXIMUM    MAXIMUM    MAXIMUM    DURATION     TIME OF     TIME OF
                OF     RESERVOIR      DEPTH     STORAGE    OUTFLOW    OVER TOP   MAX OUTFLOW   FAILURE
               PMF      W.S.ELEV    OVER DAM     AC-FT       CFS       HOURS        HOURS       HOURS

             12.00       104.43         .00        .152      13.75       .00         12.48         .00     Orifice/Weir
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Table of Resulting Detention Storage (from HEC-1)

Device	Peak Discharge (cfs)	Storage Volume (ac-ft)	Storage Volume (cubic feet)
Thirsty Duck	13.75	0.164	7,144
Simple Orifice Weir	13.75	0.152	6,621

Discussion:

The standard orifice and weir outlet control structure provides about 8% less storage than the Thirsty Duck device for the same peak outflow for a randomly chosen inflow hydrograph.

We provide, herein, a graph of the routings taken from HEC-1 for both cases.

We also provide a Table of the volume of runoff and outlet hydrographs to show that inflow and outflow volumes are conserved in both cases, thereby, underscoring the reliability of the storage routings in this report.

Conclusion:

Based on this evidence, the Thirsty Duck device provides no benefit in reducing stormwater storage over a simple orifice and weir. In fact, a simple weir and orifice outperforms the Thirsty Duck since the weir and orifice result in about 8% less detention storage.

Submitted by:

Ralph G. Mastromonaco, PE
JULY 9, 2011

References:

Web Sites:
http://www.thirsty-duck.com/
Excel File ER100 SERIES RATING CURVE GENERATION V12.xls from thirsty Duck Web Site
Proprietary HEC-1 Software: http://www.hec-1.com/
HEC-1 input file used in this report http://www.hec-1.com/THIRSTY_DUCK_kp.zip
Free HEC-1 Software: http://www.hec.usace.army.mil/software/legacysoftware/hec1/hec1.htm

Our Website: http://www.extentionbasin.com

ExtentionBasin SYSTEMS

Input Data to HEC-1

Station INFLOW
Basin Area .00391 Sq. Miles
Basin Area 2.5024 Acres
Runoff Curve Number 98
Initial Abstraction computed internally.
Lag Time 0.6 Hrs.
Time of Concentration 1 Hrs.

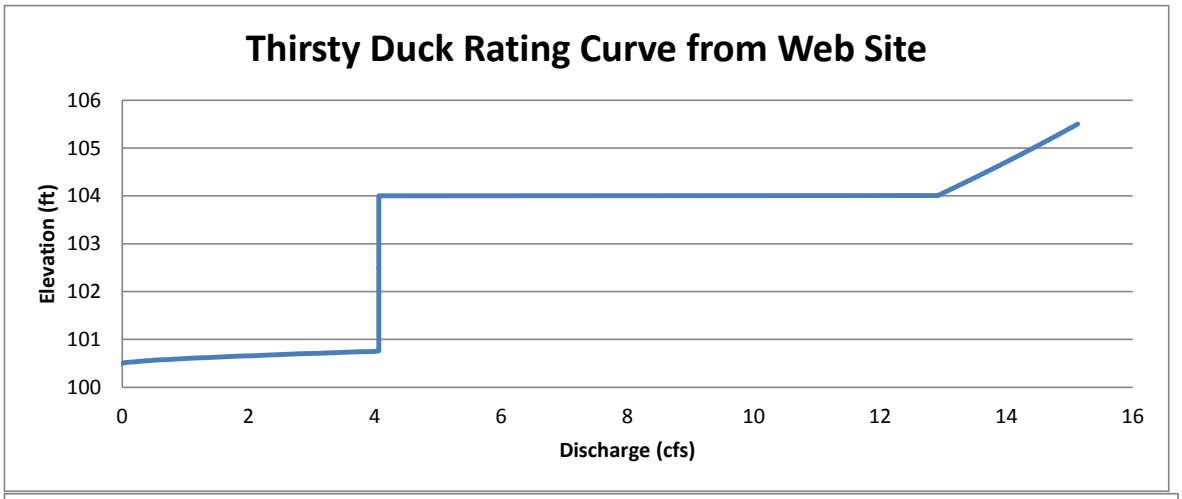
Station DET-TD
Starting Elevation of Flow 100.5
Surface Area Records of Reservoir / Retention Basin:
0 / 0.02 / 0.03 / 0.042 / 0.07 / 0.1 / 0.12 / 0.14 / 0.16 / 0.18
Elevation Records of Reservoir / Retention Basin:
100.5 / 101 / 102 / 103 / 104 / 105 / 106 / 112 / 113 / 114
Flow Records of Reservoir / Retention Basin:
0 / 4 / 4.06 / 4.06 / 4.06 / 5 / 8 / 10 / 12.92 / 15.13
Elevation Records of Reservoir / Retention Basin:
100.5 / 100.75 / 100.78 / 103.75 / 104 / 104.001 / 104.005 / 104.007 / 104.01 / 105.5
High Level Crest Spillway Length 5.00 Feet
High Level Crest Spillway Elevation 105.50 Feet
High Level Crest Spillway Coefficient 3.33
High Level Crest Spillway Exponent 1.50

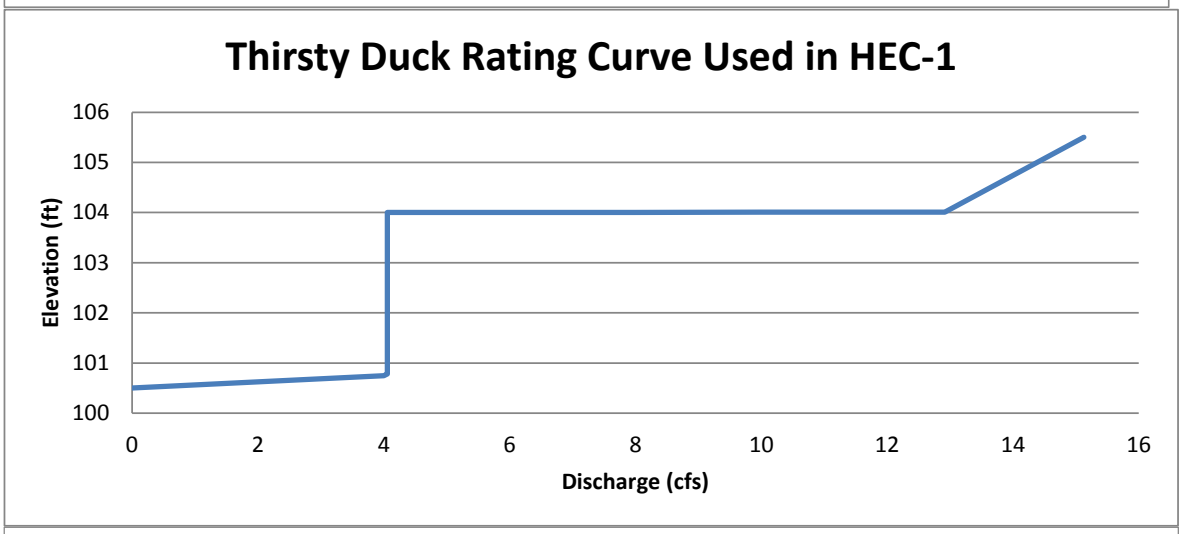
Station INFLOW
Basin Area .00391 Sq. Miles
Basin Area 2.5024 Acres
Runoff Curve Number 98.00
Initial Abstraction computed internally.
Lag Time .6 Hrs.
Time of Concentration 1 Hrs.

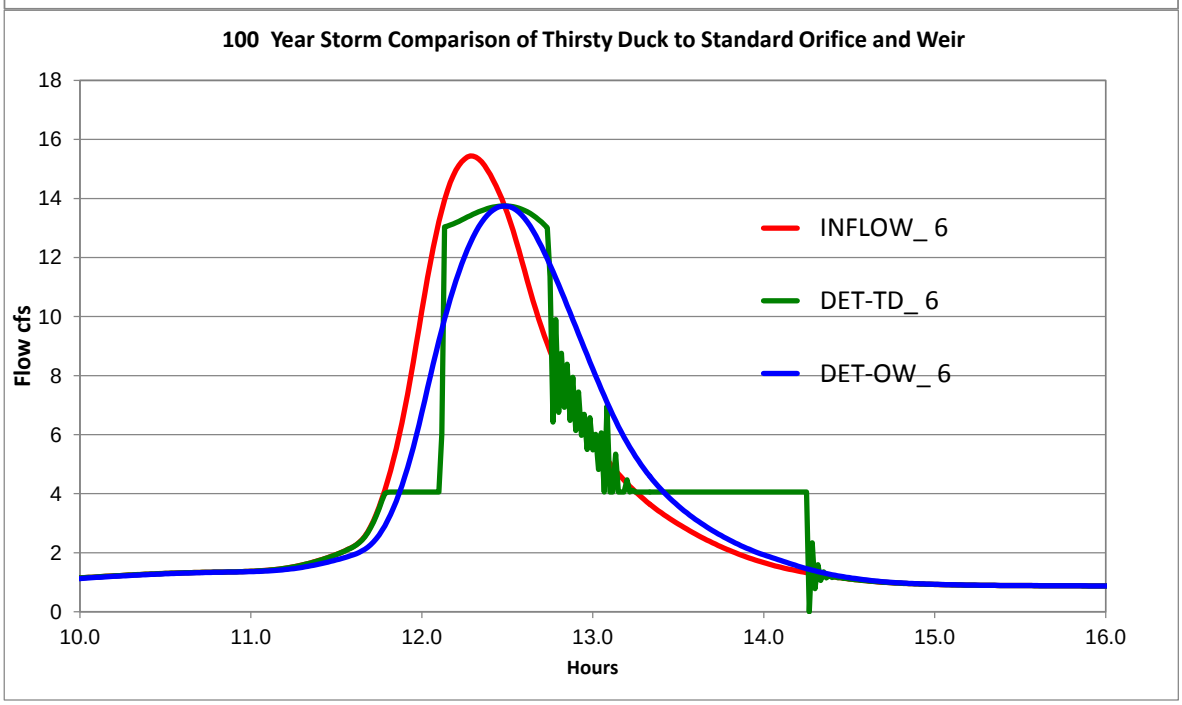
Station DET-OW
Starting Elevation of Flow 100.5
Surface Area Records of Reservoir / Retention Basin:
0 / 0.02 / 0.03 / 0.042 / 0.07 / 0.1 / 0.12 / 0.14 / 0.16 / 0.18
Elevation Records of Reservoir / Retention Basin:
100.5 / 101 / 102 / 103 / 104 / 105 / 106 / 112 / 113 / 114
Low Level Outlet Elevation 100.5 Feet
Low Level Outlet Area 0.56 Square Feet
Low Level Outlet Orifice Coefficient 0.61
Low Level Outlet Orifice Exponent 0.5
Spillway Length 0.3936 Feet
Spillway Elevation 101 Feet
Spillway Coefficient 3.33
Spillway Exponent 1.5
High Level Crest Spillway Length 0.2 Feet
High Level Crest Spillway Elevation 106 Feet
High Level Crest Spillway Coefficient 3.33
High Level Crest Spillway Exponent 1.5

Table of Hydrograph Volumes

ITEM	VOLUME (cubic feet)
NAME	INFLOW1
Volume (cf)	106,812.722 Inflow Hydrograph
NAME	DET-TD Thirsty Duck
Volume (cf)	107,380.301
NAME	DET-OW Orifice / Weir
Volume (cf)	107,798.893


Thirsty Duck Rating Curve from Web Site
Elevation (ft)
106
105
104
103
102
101
100
0
2
4
6
8
10
12
14
16
Discharge (cfs)


Thirsty Duck Rating Curve Used in HEC-1
Elevation (ft)
106
105
104
103
102
101
100
0
2
4
6
8
10
12
14
16
Discharge (cfs)


100 Year Storm Comparison of Thirsty Duck to Standard Orifice and Weir
Flow cfs
18
16
14
12
10
8
6
4
2
0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
Hours
INFLOW_ 6
DET-TD_ 6
DET-OW_ 6

ExtentionBasin SYSTEMS

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 ****************************************                                    ****************************************
 *                                      *                                    *                                      *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                                    *    U.S. ARMY CORPS OF ENGINEERS      *
 *        JUN 1998 AND FEB 2010         *                                    *    HYDROLOGIC ENGINEERING CENTER     *
 *           VERSION 4.1R               *                                    *         609 SECOND STREET            *
 *       RGMHEC2000 WWW.HEC-1.COM       *                                    *       DAVIS, CALIFORNIA 95616        *
 *  RUN DATE   09JUL11  TIME  09:45:26  *                                    *          (916) 756-1104              *
 *                                      *                                    *                                      *
 ****************************************                                    ****************************************

                                        X     X  XXXXXXX   XXXXX           X
                                        X     X  X        X     X         XX
                                        X     X  X        X               X
                                        XXXXXXX  XXXX     X        XXXXX  X
                                        X     X  X        X               X
                                        X     X  X        X     X         X
                                        X     X  XXXXXXX   XXXXX         XXX

          THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

          THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
          THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
          NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
          DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
          KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1                                                HEC-1 INPUT                                                PAGE  1

          LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

            1           ID  EXTENTION BASIN SYSTEMS, INC. RALPH G. MASTROMONACO, PE
            2           ID  THIRSTY DUCK - SAMPLE RUN TO COMPARE WITH WEIR AND ORIFICE
            3           ID     USE SCS TYPE 2 DISTRIBUTION FOR SELECTED STORM RAINFALLS
            4           ID  FILENAME  THIRSTY_DUCK_KP.DAT
            5           ID     USE SCS LAG 100 YEAR STORM RANDOMLY CHOSEN TO MEET RANGE OF RATING CURVE
                        *DIAGRAM
            6           IO       5       5
            7           IT       1               0    2000
            8           ID  100 YR STORM (SARASOTA, FL)
            9           JR    PREC      12
           10           IN       6               0
           11           KK  INFLOW
           12           KO                                    21
           13           KM  WATERSHED DATA
           14           PB       1
           15           PC  0.0013  0.0025  0.0038   0.005  0.0063  0.0075  0.0088    0.01  0.0113  0.0125
           16           PC  0.0138   0.015  0.0163  0.0175  0.0188    0.02  0.0213  0.0225  0.0238   0.025
           17           PC  0.0262  0.0274  0.0287  0.0299  0.0311  0.0323  0.0335  0.0347   0.036  0.0372
           18           PC  0.0384  0.0396  0.0408   0.042  0.0433  0.0445  0.0457   0.047  0.0485    0.05
           19           PC  0.0515  0.0529  0.0544  0.0559  0.0574  0.0588  0.0603  0.0618  0.0633  0.0648
           20           PC  0.0662  0.0677  0.0692  0.0709  0.0725  0.0741  0.0757  0.0774   0.079  0.0806
           21           PC  0.0823  0.0839  0.0855  0.0871  0.0888  0.0905  0.0924  0.0942   0.096  0.0978
           22           PC  0.0996  0.1014  0.1032   0.105  0.1069  0.1087  0.1105  0.1124  0.1149  0.1173
           23           PC  0.1197  0.1222  0.1246  0.1271  0.1295  0.1319  0.1345  0.1372  0.1398  0.1424
           24           PC   0.145  0.1486  0.1529  0.1571  0.1613  0.1655  0.1697   0.174  0.1784   0.183
           25           PC  0.1876  0.1922  0.1968  0.2014   0.206  0.2105  0.2151  0.2196  0.2242  0.2303
           26           PC  0.2384  0.2465  0.2563  0.2676  0.2796  0.2967  0.3214  0.5851  0.6355   0.665
           27           PC  0.6848  0.7029   0.718  0.7311  0.7394  0.7475  0.7553  0.7632  0.7698  0.7763
           28           PC  0.7828  0.7893  0.7946  0.7981  0.8017  0.8052  0.8088  0.8121  0.8151  0.8181
           29           PC  0.8211   0.824   0.827  0.8299  0.8328  0.8357  0.8385  0.8414  0.8443  0.8472
           30           PC  0.8501   0.853  0.8559  0.8588  0.8617  0.8645  0.8674  0.8703  0.8732  0.8761
           31           PC  0.8788  0.8816  0.8843   0.887  0.8897  0.8925  0.8952  0.8979  0.9006  0.9034
           32           PC  0.9061  0.9088  0.9111  0.9131  0.9152  0.9172  0.9192  0.9212  0.9232  0.9254
           33           PC  0.9276  0.9298   0.932  0.9342  0.9363  0.9385  0.9406  0.9423   0.944  0.9457
           34           PC  0.9474  0.9491  0.9508  0.9525  0.9542  0.9559  0.9576  0.9593   0.961  0.9627
           35           PC   0.964  0.9653  0.9665  0.9678  0.9691  0.9703  0.9716   0.973  0.9743  0.9757
           36           PC  0.9771  0.9785  0.9798  0.9812  0.9825  0.9837  0.9849  0.9862  0.9874  0.9886
           37           PC  0.9897  0.9905  0.9913   0.992  0.9928  0.9936  0.9944  0.9951  0.9957   0.996
           38           PC   .9964  0.9968  0.9972  0.9976   0.998  0.9984  0.9988  0.9992  0.9996       1
           39           BA  .00391
           40           LS              98
           41           UD     0.6
           42           KK  DET-TD
           43           KO                                    21
           44           KM  DETENTION BASIN USING THIRSTY DUCK OUTFLOW CURVE
           45           RS       1    ELEV   100.5
           46           SA       0    0.02    0.03   0.042    0.07     0.1    0.12    0.14    0.16    0.18
           47           SE   100.5     101     102     103     104     105     106     112     113     114
           48           SQ       0       4    4.06    4.06    4.06       5       8      10   12.92   15.13
           49           SE   100.5  100.75  100.78  103.75     104 104.001 104.005 104.007  104.01   105.5
           50           ST  105.50    5.00    3.33    1.50
           51           KK  INFLOW
           52           KM  WATERSHED DATA
           53           BA  .00391
           54           LS           98.00
           55           UD      .6
           56           KK  DET-OW
           57           KO                                    21
           58           RS       1    ELEV   100.5
           59           KM  DETENTION BASIN USING SIMPLE ORIFCE AND WEIR
           60           SA       0    0.02    0.03   0.042    0.07     0.1    0.12    0.14    0.16    0.18
           61           SE   100.5     101     102     103     104     105     106     112     113     114
           62           SL   100.5    0.56    0.61     0.5
           63           SS     101  0.3936    3.33     1.5
           64           ST     106     0.2    3.33     1.5
           65           ZZ
1
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```
                SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT

  LINE      (V) ROUTING          (--->) DIVERSION OR PUMP FLOW

   NO.      (.) CONNECTOR        (<---) RETURN OF DIVERTED OR PUMPED FLOW

    11      INFLOW
                 V
                 V
    42      DET-TD
                 .
                 .
    51           .      INFLOW
                 .           V
                 .           V
    56           .      DET-OW

 (***) RUNOFF ALSO COMPUTED AT THIS LOCATION
1****************************************                                    ****************************************
 *                                      *                                   *                                      *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                                   *    U.S. ARMY CORPS OF ENGINEERS      *
 *         JUN 1998 AND FEB 2010        *                                   *    HYDROLOGIC ENGINEERING CENTER     *
 *            VERSION 4.1R              *                                   *          609 SECOND STREET           *
 *       RGMHEC2000 WWW.HEC-1.COM       *                                   *       DAVIS, CALIFORNIA 95616        *
 *  RUN DATE   09JUL11  TIME  09:45:26  *                                   *           (916) 756-1104             *
 *                                      *                                   *                                      *
 ****************************************                                    ****************************************

                        EXTENTION BASIN SYSTEMS, INC. RALPH G. MASTROMONACO, PE
                        THIRSTY DUCK - SAMPLE RUN TO COMPARE WITH WEIR AND ORIFICE
                           USE SCS TYPE 2 DISTRIBUTION FOR SELECTED STORM RAINFALLS
                        FILENAME  THIRSTY_DUCK_KP.DAT
                           USE SCS LAG 100 YEAR STORM RANDOMLY CHOSEN TO MEET RANGE OF RATING CURVE

    6 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           5  PRINT CONTROL
                        IPLOT           5  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE
                           100 YR STORM (SARASOTA, FL)

      IT          HYDROGRAPH TIME DATA
                         NMIN           1  MINUTES IN COMPUTATION INTERVAL
                        IDATE      1    0  STARTING DATE
                        ITIME        0000  STARTING TIME
                           NQ        2000  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE      2    0  ENDING DATE
                       NDTIME        0919  ENDING TIME
                        ICENT          19  CENTURY MARK

                     COMPUTATION INTERVAL     .02 HOURS
                          TOTAL TIME BASE   33.32 HOURS

           ENGLISH UNITS
                DRAINAGE AREA         SQUARE MILES
                PRECIPITATION DEPTH   INCHES
                LENGTH, ELEVATION     FEET
                FLOW                  CUBIC FEET PER SECOND
                STORAGE VOLUME        ACRE-FEET
                SURFACE AREA          ACRES
                TEMPERATURE           DEGREES FAHRENHEIT

      JP          MULTI-PLAN OPTION
                        NPLAN           1  NUMBER OF PLANS

      JR          MULTI-RATIO OPTION
                      RATIOS OF PRECIPITATION
                    12.00
*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
              **************
              *            *
   11 KK      *    INFLOW  *
              *            *
              **************
   12 KO          OUTPUT CONTROL VARIABLES
                        IPRNT           5  PRINT CONTROL
                        IPLOT           5  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE
                        IPNCH           0  PUNCH COMPUTED HYDROGRAPH
                         IOUT          21  SAVE HYDROGRAPH ON THIS UNIT
                        ISAV1           1  FIRST ORDINATE PUNCHED OR SAVED
                        ISAV2        2000  LAST ORDINATE PUNCHED OR SAVED
                       TIMINT        .017  TIME INTERVAL IN HOURS
*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
              **************
              *            *
   42 KK      *    DET-TD  *
              *            *
              **************
   43 KO          OUTPUT CONTROL VARIABLES
                        IPRNT           5  PRINT CONTROL
                        IPLOT           5  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE
                        IPNCH           0  PUNCH COMPUTED HYDROGRAPH
                         IOUT          21  SAVE HYDROGRAPH ON THIS UNIT
                        ISAV1           1  FIRST ORDINATE PUNCHED OR SAVED
                        ISAV2        2000  LAST ORDINATE PUNCHED OR SAVED
                       TIMINT        .017  TIME INTERVAL IN HOURS

 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
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ExtentionBasin SYSTEMS

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            **************
            *            *
   56 KK    *    DET-OW  *
            *            *
            **************

   57 KO          OUTPUT CONTROL VARIABLES
                       IPRNT           5  PRINT CONTROL
                       IPLOT           5  PLOT CONTROL
                       QSCAL          0.  HYDROGRAPH PLOT SCALE
                       IPNCH           0  PUNCH COMPUTED HYDROGRAPH
                        IOUT          21  SAVE HYDROGRAPH ON THIS UNIT
                       ISAV1           1  FIRST ORDINATE PUNCHED OR SAVED
                       ISAV2        2000  LAST ORDINATE PUNCHED OR SAVED
                      TIMINT        .017  TIME INTERVAL IN HOURS

1

                PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
                            FLOWS IN CUBIC FEET PER SECOND,  AREA IN SQUARE MILES
                                        TIME TO PEAK IN HOURS

                                                                    RATIOS APPLIED TO PRECIPITATION
 OPERATION       STATION     AREA     PLAN                    RATIO 1
                                                                12.00

 HYDROGRAPH AT
+                 INFLOW      .004     1   FLOW                15.44
                                            TIME                12.28

 ROUTED TO
+                 DET-TD      .004     1   FLOW                13.75
                                            TIME                12.48

                                       ** PEAK STAGES IN FEET **
                                       1   STAGE              104.57
                                            TIME                12.48

 HYDROGRAPH AT
+                 INFLOW      .004     1   FLOW                15.44
                                            TIME                12.28

 ROUTED TO
+                 DET-OW      .004     1   FLOW                13.75
                                            TIME                12.48

                                       ** PEAK STAGES IN FEET **
                                       1   STAGE              104.43
                                            TIME                12.48

1     THIRSTY DUCK                  SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION    DET-TD


      PLAN  1 ..............                  INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                              ELEVATION            100.50             105.50          105.50
                              STORAGE                .00                .26             .26
                              OUTFLOW                .00              15.13           15.13

                      RATIO     MAXIMUM      MAXIMUM     MAXIMUM     MAXIMUM     DURATION     TIME OF     TIME OF
                        OF   RESERVOIR      DEPTH       STORAGE     OUTFLOW     OVER TOP     MAX OUTFLOW FAILURE
                       PMF   W.S.ELEV      OVER DAM      AC-FT       CFS         HOURS        HOURS       HOURS

                     12.00      104.57         .00         .164      13.75        .00          12.48         .00

1     ORIFICE AND WEIR              SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION    DET-OW


      PLAN  1 ..............                  INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                              ELEVATION            100.50             101.00          106.00
                              STORAGE                .00                .00             .31
                              OUTFLOW                .00               1.94           21.08

                      RATIO     MAXIMUM      MAXIMUM     MAXIMUM     MAXIMUM     DURATION     TIME OF     TIME OF
                        OF   RESERVOIR      DEPTH       STORAGE     OUTFLOW     OVER TOP     MAX OUTFLOW FAILURE
                       PMF   W.S.ELEV      OVER DAM      AC-FT       CFS         HOURS        HOURS       HOURS

                     12.00      104.43         .00         .152      13.75        .00          12.48         .00

 *** NORMAL END OF HEC-1 ***

(HIGHLIGHTING BY EDITOR)
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Website Showing Claim of “Reduce stormwater pond size up to 50%”

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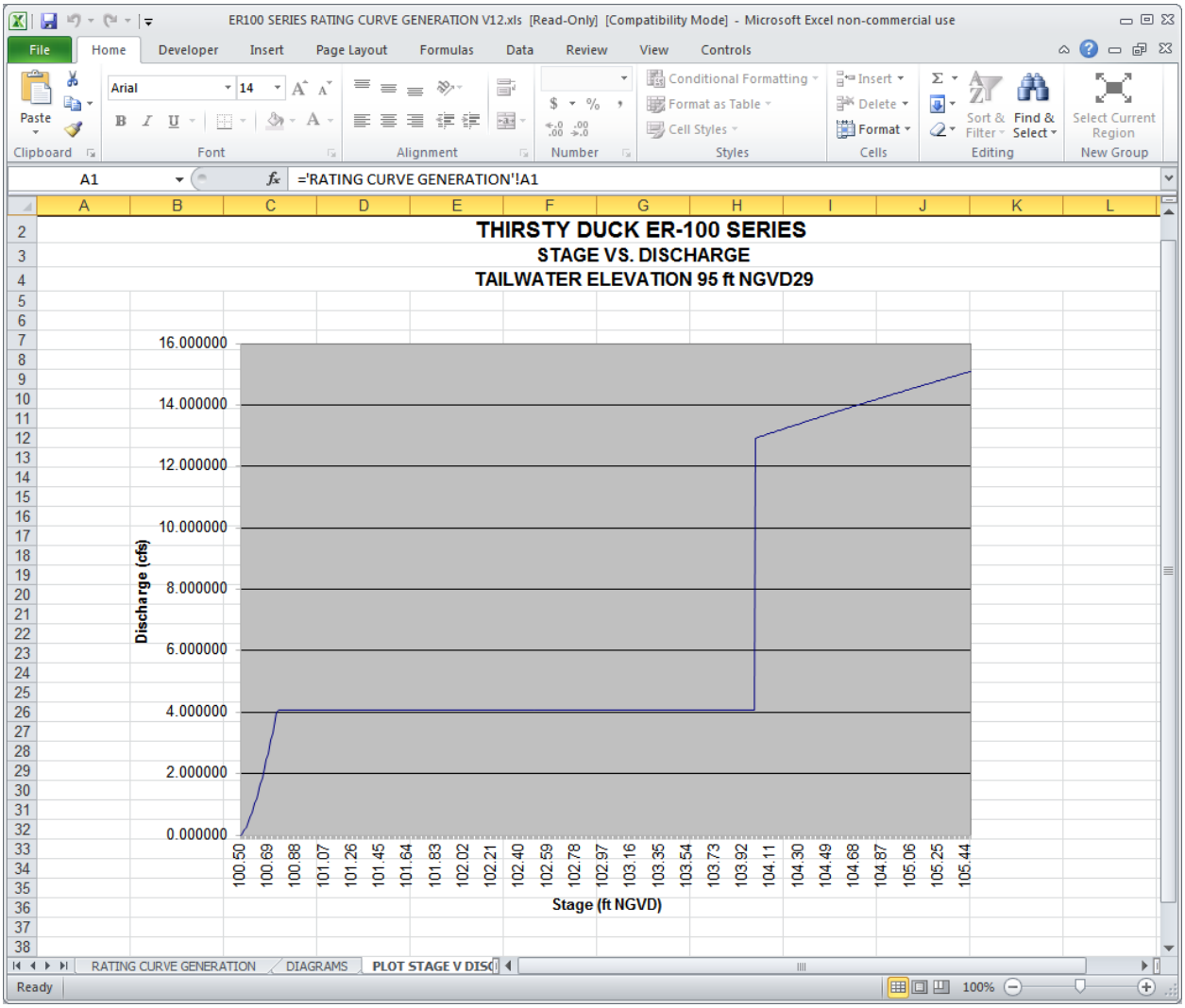
Website Downloaded Excel Spreadsheet showing ER-100 Rating Curve



Website Detail of Thirsty Duck Apparatus