Mid-Valley Drainage Management Plan

VOLUME 5 – Appendix 3

Prepared for:

The City of Albuquerque, NM

and

AMAFCA

Albuquerque Metropolitan Arroyo
Flood Control Authority

Prepared by:

Smith Engineering Company
2201 San Pedro NE, Bldg 4 Suite 200
Albuquerque, NM 87110
(505)884-0700

<u>SEC Project No.</u> 110112

April, 2012

VOLUME 5 APPENDICES

(included on a DVD in Map Pocket)

APPENDIX 3 AHYMO_97 AND SWMM PROGRAMS SENSITIVITY ANALYSES REPORT

Mid-Valley Drainage Management Plan,

May 2011,

Smith Engineering Company

Solutions for Today...

Vision for Tomorrow

May 31, 2011

Mr. John Curtin, PE Senior Engineer
Storm Drainage Design Section, Engineering Division
Department of Municipal Development,
P.O. Box 1293
City of Albuquerque, 87103

RE: Mid Valley Drainage Management Plan

COA Project No. P7963.06
SEC Proj. No. 110112

Submittal of Report titled -

AHYMO_97 and SWMM Programs Sensitivity Analyses Report, May 2011
Prepare by Smith Engineering Company

AMAFCA requested that this analysis be documented as a report as part of this project, so I am pleased to submit the referenced report.

As you recall, Smith Engineering Company (SEC) conducted a meeting in February with the COA and AMAFCA, where I presented a summary of the many AHYMO_97 and SWMM Program test model assumptions and results conducted to understand program differences and sensitivity of input data values on the model results, particularly with respect to the SWMM Program.

Note that to compute a runoff hydrograph in AHYMO_97 the data input required is 6 variables as compared to SWMM that allows 22 variables (excluding water quality items).

I have updated this report from the Draft Report that I submitted previously, and have included an <u>Executive Summary</u> (beginning of binder) in an effort to simplify the extensive analyses and data tables that are presented in the <u>Report and Appendices</u> (model input data and output).

Sincerely,

Smith Engineering Company
Patrick Stovall, PE, CFM
Principal

CC: Lynn Mazur, Pat Conley (letter only), Chuck Easterling

May 31, 2011

Ms. Lynn Mazur, PE

Albuquerque Metropolitan Arroyo Flood Control Authority
2600 Prospect Ave. NE
Albuquerque, NM 87107

RE: Mid Valley Drainage Management Plan

COA Project No. P7963.06
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Sincerely,

Smith Engineering Company
Patrick Stovall, PE, CFM
Principal

CC: John Curtin, Pat Conley (letter only), Chuck Easterling

Smith Engineering Company

Solutions for Today.....Vision for Tomorrow

December 20, 2010

emailed on this date

Mr. John Curtain, PE

RE: **RESPONSE TO YOUR EMAIL 12-20-2010 included below:**

REGARDING Report I provided you on 12-16-2010 titled:

SWMM (EPA V. 5.0.021) & AHYMO 97 (V.97)
Basin Hydrograph Results Comparison SEC Proj. No. 110112

Dear Mr. Curtain,

Attached are your comments as listed with a bullet, my response follows in italics:

Pat,
Here are my comments:

- The City Design Criteria is the 100 year - 6 hour Storm. What is your reasoning behind using the 100 year - 24 hour Storm?

DPM section 22 states that if detention ponds are evaluated a 24-hour duration storm or longer is the design storm. We have detention ponds in the study area.

- I could not find the Depth-Area curves and Figure B-2 in Appendix 1 as indicated on page 1.

I apologize for this omission, I will provide this to you. Our total area is probably about 5 square miles and if major subgroups are considered independently, each would be say 2 square miles, therefore areal reduction factors, as you will see really do not apply.

- Why did you take the worst of the six rainfall data instead of the average? If you insist on making the most conservative assumptions on everything, then you are going to drown the Mid-Valley and cover it with floodplain. Your goal should not be to invalidate 30 years of Capital Improvement & development.

Please review the data in Table 1 for each of the 6 locations that I will summarize here with the ranges as follows:
1-hour ranges from 1.73 – 1.79 inches
6-hour ranges from 2.23 – 2.29 inches
24-hour ranges from 2.51 – 2.60 inches

Note – depth for <u>18-hours after the 6 hour depth is only 0.31 inches</u> (2.6-2.29). This depth is very small spread over 18-hours and for pervious area basically generates no runoff as this is less than the infiltration rate. Only minor runoff volume will be generated on impervious areas and the peak discharge will not increase - again due to the minor rain depth spread over 18-hours.

If you recommend we select an average rainfall based on the data I computed for six areas, we will apply that average data for the full Mid Valley SWMM Model.

)1 San Pedro Drive, NE
Building 4, Suite 200
Albuquerque, NM 87110
pats@smithengineering.pro
Telephone 505/884-0700 Fax 505/884-2376

- The basins that you have chosen for your comparison are not compatible with SWMM and are not applicable to the model. You seem to be trying to make SWMM mirror AHYMO. The feedback that I have received indicates that AHYMO produces excess runoff in flat areas.

The basins were intended to be generic and may well be similar to many basins we will later delineate and model, although we are not at that point yet. The intent of this sensitivity analysis as per the scope, was to present and understand the differences in results between the two models because the community for years has used AHYMO as the accepted model. We considered four generic basins that were GENERIC for purpose of testing model input and result differences.

- It was not clear to me what you were trying to prove with your complicated spreadsheets.

The spreadsheet were intended to show the multitude of input data that can be input and manipulated with SWMM and the corresponding actual data we did manipulate with various iterations in comparison to the limited data input allowed by AHYMO. At the bottom of the table the results of each model run is presented under each column and this results illustrate the changes in peak discharge and runoff volume attained by changing input data in SWMM. The final SWMM adjustment is that which produced results most similar to the AHYMO_97 results.

- Your conclusions are hidden behind the spreadsheets and I missed them at first. The only thing that you proved to me is that you should have chosen rectangular basins instead of square.

The purpose of the analysis is to understand what input data can be manipulated in order produce results similar to AHYMO. I am not proposing these changes, only illustrating how input data COULD BE changed to attain results similar to AHYMO. Basins of many different shapes will probably be developed and therefore presuming that basins should be rectangular is not prudent.. Therefore again, that is why generic basins were assumed for this sensitivity analysis.

Pat Stovall other AMAFCA Comment - Since AMAFCA is spending money on our fee for this project and since Lynn Mazur attended our last meeting at your office - and to keep the project moving, I provided her a review copy when I handed you a copy. I have not had a response from her yet.. After you and I discuss these comments again. I will then provide Brad a copy also, at your request.. I had planned that after the COA and AMAFCA reviewed the analysis, we could have a meeting to discuss the results and discuss related issues regarding our full SWMM model.

John Curtain - Instead of killing trees & sticking it in an expensive binder, e-mail a pdf of the report to AMAFCA, Brad and I so that we can all review it.

Thank You, John P. Curtin, P.E. Senior Engineer
Storm Drainage Design Section, Engineering Division
Department of Municipal Development, City of Albuquerque
Tel: 768-2727 FAX: 768-2765

PS Jerry: Who have you assigned to represent AMAFCA for this plan?

You may reach me at 314-5567 if you would like to discuss this fee proposal.

____________________________Sincerely,

Smith Engineering Company
Patrick Stovall, PE, CFM
Vice President

Q:\SEC---PROJECTS\2010 Projects\110112 COA MID VALLEY DMP\Correspondence\john c 12-20-10.docx

Pat Stovall

From: Curtin, John P. [JCurtin@cabq.gov]
Sent: Monday, December 20, 2010 2:58 PM
To: Pat Stovall
Cc: Lovato, Jerry; Bingham, Brad L.; Penttila, Roland V.; Pat Conley
Subject: 796395 Mid Valley DMP Hydrology Comparison

Pat,

Here are my comments:

- The City Design Criteria is the 100 year - 6 hour Storm. What is your reasoning behind using the 100 year - 24 hour Storm?
- I could not find the Depth-Area curves and Figure B-2 in Appendix 1 as indicated on page 1.
- Why did you take the worst of the six rainfall data instead of the average? If you insist on making the most conservative assumptions on everything, then you are going to drown the Mid-Valley and cover it with floodplain. Your goal should not be to invalidate 30 years of Capital Improvement & development.
- The basins that you have chosen for your comparison are not compatible with SWMM and are not applicable to the model. You seem to be trying to make SWMM mirror AHYMO. The feedback that I have received indicates that AHYMO produces excess runoff in flat areas.
- It was not clear to me what you were trying to prove with your complicated spreadsheets.
- Your conclusions are hidden behind the spreadsheets and I missed them at first. The only thing that you proved to me is that you should have chosen rectangular basins instead of square.

Instead of killing trees & sticking it in an expensive binder, e-mail a pdf of the report to AMAFCA, Brad and I so that we can all review it.

Thank You, John P. Curtin, P.E. Senior Engineer
Storm Drainage Design Section, Engineering Division
Department of Municipal Development, City of Albuquerque
Tel: 768-2727 FAX: 768-2765

PS Jerry: Who have you assigned to represent AMAFCA for this plan?

EXECUTIVE SUMMARY

FOR:

AHYMO_97 and SWMM PROGRAMS

SENSITIVITY ANALYSES REPORT

Mid Valley Drainage Management Plan

SWMM (EPA V. 5.0.021)
&
AHYMO_97 (V. 97)

MID VALLEY DMP

SEC Proj. No. 110112 COA Proj. No. P7963.06

Prepared for:

City of Albuquerque
&
AMAFCA

Prepared by:

Smith Engineering Company

May, 2011

EXECUTIVE SUMMARY

SECTION 1
INTRODUCTION

1.1 Background

The City of Albuquerque (COA), the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) and the local engineering community have applied the Arid Lands Hydrology Model (AHYMO_97) (V.97) Hydrologic computer program for most Drainage Management Plans (DMP's) and smaller drainage plans in the Albuquerque Area for about the last 20 years.

The Albuquerque Mid Valley area has an intricate system of storm drains, ponds and pumps and the AHYMO_97 Program does not have the capability to simulate the dynamic infrastructure features that should be modeled as part of the Mid Valley DMP.

However, the EPA Storm Water Management (SWMM) (V.5.0.021) Hydrologic / Hydraulic Program has the following capabilities:

1. Can dynamically route hydrographs in storm drain pipes and allows flow to change directions within pipes as a function of hydrograph timing and hydraulic grade line (HGL) differences at pipe ends.

2. Can allow manhole surcharge water volume (when the HGL exceeds manhole rim elevation) to be temporarily stored. This feature allows simulation of street flooding when the HGL exceeds the rim elevation and then allows the stored volume to re-enter the same manhole as the HGL decreases below the rim elevation.

3. Can model pumps, orifices, weirs, detention ponds.

Therefore, the EPA SWMM Program has been adopted for the Mid Valley Drainage Management Plan (DMP) as it has the required capabilities.

1.2 Purpose

The purpose of this report is to present the results of a several computer modeling sensitivity analyses between the AHYMO_97 Program and the SWMM Program.

1.3 Goals

There are several goals of these sensitivity analyses as listed here:

1. Develop general conclusions regarding basin hydrograph results in the AHYMO_97 Program between the Runoff Curve Number Method and the Land Treatment Type Method for simulating rainfall initial abstraction and uniform loss rates.

2. Develop general conclusions regarding basin hydrograph input data differences, and peak discharge and runoff volume differences between the AHYMO_97 Program and the SWMM Program.

3. Develop general conclusions regarding the three subcatchment (basin) "subarea routing options" available in SWMM as follows:
   "Outlet Routing Option" – runoff from pervious and impervious areas both flow directly to outlet .
   "Impervious Routing Option" – runoff from pervious area flows directly to impervious area, then routed to outlet.
   "Pervious Routing Option" - runoff from impervious area flows directly to pervious area, then routed to outlet.

4. Develop general conclusions regarding the significance of not modeling storm drains smaller that 36-inch diameter (COA initial decision that only 36-inch storm drains and larger be modeled).

5. The most important goal for Smith Engineering Company (SEC) is to develop decisions regarding assumptions for model data preparation and modeling methods and to attain agreement on modeling / data assumptions with the COA and AMAFCA. This is important before preparation of the large SWMM model for the Mid Valley drainage area.

SECTION 2
HYDROLOGIC DATA AND MODEL INPUT DIFFERENCES

2.1 Hydrologic Assumptions And Model Development

Design Criteria

The 100-yr. - 24-hr. storm was selected for the design return period. However, the 2-yr. 10-yr. and 50-yr. 24-hr. duration storms were also evaluated for some analyses.

General Test Basin Descriptions

Four "generic basins" were used for testing various input parameters and results between the SWMM and AHYMO_97 hydrologic programs. Note that this is a sensitivity analysis and actual basins will vary in land use type, soil type, shape and longest flow paths.

The table here presents the generic basins names and general characteristics.

Generic Basin Name	Description / Land Use Assumptions	Shape	Area (acres)	% Impervious	Hyd. Soil Group(s) & Runoff Curve Number
FR	Flat residential 100%	Approx. square 6 blocks by 6 blocks	102.7	56	B, 85
FIC	Flat com. 50% / Indust. 50%	Approx. square approx. 6 blocks by 6 blocks	105.5	80	B, 90
SR	Steep residential 100%	Approx. square 6 blocks by 6 blocks	95.7	56	65% A - 35% B, 80
SIC	Steep com. 50% / Indust. 50%	Approx. square 6 blocks by 6 blocks	95.7	80	65% A – 35% B, 87

Valley Area Rainfall Initial Abstraction Adjustments

A rainfall initial abstraction study was completed on an actual rainfall event with rainfall records in the Albuquerque south valley and presented in the following report :

Bohannan-Huston, Inc. (BHI) February 1995. "Analysis of the AHYMO Program for Flat Valley Areas"

The recommendations of the study are that for design of flood control structures in flat valley areas of Albuquerque, that the AHYMO Program default initial abstraction values should be increased, however, the default uniform loss rates should remain unchanged. The following table presents the AHYMO Program default values and recommended values for flat valley areas in Albuquerque.

Land Treatment Type	Default Initial Abstraction	Recommend Initial Abstraction	Recommended and Default and Uniform Infiltration Rate
	(inches)	(inches)	(inches / hour)
A	0.65	1.20	1.67
B	0.50	1.05	1.25
C	0.35	0.90	0.83
D	0.10	0.85	0.04

The Average Initial Abstraction for Land Treatment Types A, B, C, D in the Table above computed by Smith Engineering Company = 1.0 inches NA (inches/hour)

Discussion of the Runoff Curve Number "CN" Method

The CN is an "initial abstraction and uniform infiltration rate" rainfall loss method.

Note that selection of a CN from NRCS tables begins with selection of a "cover description" and hydrologic soil group (HSG), and for urban areas (residential, commercial, industrial) would therefore include imperviousness. The SWMM subcatchment data input allows for inclusion of the percent impervious area.

Therefore, if percent impervious area is included in the SWMM input data, then a CN must be selected for undeveloped / pervious conditions based on assumed native cover description and HSG, to avoid over estimation of percent imperviousness.

EPA SWMM "Subcatchment"

SWMM uses the term "subcatchment" to define a basin and does not allow direct input of "tc", "tp" or longest flow length. Therefore, SWMM computes longest flow length to assist in hydrograph computation as:

length (ft) = basin area (input) / basin width (input)

width is defined as - the average overland flow path (length until overland flow becomes concentrated)

The SWMM Users Manual *suggests adjustment of basin width to calibrate SWMM model results if a known hydrograph is available.*

Unit Hydrograph Method

AHYMO_97 Model "Compute Hyd" Command

The SCS Unit Hydrograph Method is the only choice available with the Compute Hyd command.

EPA SWMM

SWMM does not allow selection of any Unit Hydrograph Method for computation of a "subcatchment" runoff hydrograph.

Model Input Differences

The basin input data options for AHYMO_97 are very limited at 6 input variables – relative to 22 input variables (excluding water quality options) that may be selected in SWMM.

SECTION 3
HYDROLOGIC AND HYDRAULIC ANALYSES RESULTS

3.1 AHYMO_97 Model Results For Initial Comparison Of CN's VS Land Treatments

Purpose

Prior to comparison of AHYMO_97 to EPA SWMM results, **SEC** wanted to understand the results from AHYMO_97 (not compared to SWMM) for differences in hydrologic results between two rainfall loss methods that are:

1. The Runoff Curve Number "CN" Method and
2. The Land Treatment Method

In addition to testing results based on basic basin input data, tests were also completed for both rainfall loss methods including *adjustments to account for backyard ponding* as described in the COA DPM. The DPM states to account for backyard ponding - if justified, that 35% of Land Treatment Type D may be assumed to be Land Treatment Type A.

For this comparison, Basin FR (flat 100% residential basin approximately 6 blocks by 6 blocks or 103 acres) was adopted as previously described.

RESULTS - AHYMO_97 FOR CN Method and Land Treatment Method (rainfall loss methods):

A summary of the results for the 100% flat residential generic basin is presented here:
CN = Curve Number Rainfall Loss Method and LTM = Land Treatment Rainfall Loss Method

ITEM	Unit	AHYMO_97		AHYMO_97	
		CN no backyard ponding	LTM No backyard ponding	CN with backyard ponding	LTM with backyard ponding
Peak Discharge	cfs	60	98	42	74
Runoff Volume	ac-ft	10.77	14.32	8.2	10.96
Time to Peak	hours	2.5	2.35	2.55	2.35

CONCLUSIONS:

The SCS CN rainfall loss method produces significantly smaller peak discharges and runoff volumes than the Land Treatment Type rainfall loss method.

3.2 Initial Analysis – Initial Run

Basin Hydrograph Comparison Between AHYMO_97 And SWMM (4 Basins) Assumed Same Data Input for both programs

For the Initial Analysis, the goal is to use the same data for those data values that are common to both programs, and evaluate the results between AHYMO_97 and SWMM.

RESULTS INITIAL RUN:
A summary of the results for all 4 generic basins as defined previously is presented here:

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	7	92	15	80	17	145	36
Runoff Volume	ac-ft	10.77	11.71	14.25	15.21	7.56	10.15	10.99	13
Time to Peak	hours	2.5	3.4	2.4	2.2	1.7	2.1	1.65	2.1

CONCLUSIONS:

The AHYMO_97 model produces much greater peak discharges and less runoff volumes that the SWMM model for the same basic input data. Note that the peak discharges are much to low for SWMM relative to AHYMO_97 because the "basin width factor" was initially computed as area divided by the basin width, not "overland flow" length, for the purpose of understanding the sensitivity of very large "widths". SWMM computes time of concentration internally.

3.3 Sensitivity Analysis #1 – Run 1

Basin Hydrograph Comparison Between AHYMO_97 And SWMM (4 Basins)

For Sensitivity Analysis #1 Run 1, the goal is to modify SWMM subcatchment data ONLY for Pervious Area - additional initial abstraction to account for BHI recommendations listed previously. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated in this and all successive runs except Run #12, by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

RESULTS RUN 1:
A summary of the results for all 4 generic basins as defined previously is presented here:

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	2	92	5	80	5	145	9
Runoff Volume	ac-ft	10.77	6.19	14.25	8.31	7.56	5.92	10.99	7.21
Time to Peak	hours	2.5	6.17	2.4	6.0	1.7	3.67	1.65	2.67

CONCLUSIONS:

The SWMM model results are much less than the AHYMO_97 model results as a result of the increased initial abstraction included in the SWMM model as prescribed by the BHI report.

3.4 Sensitivity Analysis #1 - Run 2

Basin Hydrograph Comparison Between AHYMO_97 And SWMM (4 Basins)

For Sensitivity Analysis #1 Run 2, the goal is to modify SWMM subcatchment data as follows: Assume a reduced CN for undeveloped / pervious conditions and add % imperviousness, for pervious areas do not add additional initial abstraction to account for recommendations of the BHI report. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated in this and all successive runs except Run #12, by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

RESULTS RUN 2 :
A summary of the results for all 4 generic basins as defined above is presented here:

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	109	92	136	80	213	145	267
Runoff Volume	ac-ft	10.77	14.1	14.25	19.23	7.56	13.58	10.99	17.51
Time to Peak	hours	2.5	1.58	2.4	1.58	1.7	1.5	1.65	1.5

CONCLUSIONS:

The SWMM model results are much greater than the AHYMO_97 model results as a result of the increased the % imperviousness included in SWMM even with lower CN's. (Additional initial abstraction was not included in the SWMM model as prescribed by the BHI report).

3.5 Sensitivity Analysis #1 - Run 3

Basin Hydrograph Comparison Between AHYMO_97 And SWMM (4 Basins)

For Sensitivity Analysis #1 Run 3, the goal is to modify SWMM subcatchment data as follows: Assume a reduced CN for undeveloped / pervious conditions and add % imperviousness, for pervious areas, do not add additional initial abstraction for pervious areas to account for recommendations of the BHI report. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated in this and all successive runs except Run #12, by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

RESULTS RUN 3 :
A summary of the results for all 4 generic basins as defined above is presented here:

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	109	92	136	80	213	145	267
Runoff Volume	ac-ft	10.77	14.1	14.25	19.19	7.56	13.58	10.99	17.51
Time to Peak	hours	2.5	1.58	2.4	1.67	1.7	1.5	1.65	1.5

CONCLUSIONS:

The SWMM model results are much greater than the AHYMO_97 model results as a result of the increased the % imperviousness included in SWMM even with lower CN's. (Additional initial abstraction was not included for pervious areas in the SWMM model as prescribed by the BHI report.

3.6 Sensitivity Analysis #1 - Run 4

Basin Hydrograph Comparison Between AHYMO_97 And SWMM (4 Basins)

For Sensitivity Analysis #1 Run 4, the goal is to modify SWMM subcatchment data as follows: Assume a reduced CN for undeveloped / pervious conditions and add % imperviousness, for pervious areas do not add additional initial abstraction to account for recommendations of the BHI report. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated in this and all successive runs except Run #12, by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

Increase the Manning's Roughness Coefficients ("n" 's) for pervious and impervious portions of subcatchment to determine effect of "n" 's.

RESULTS RUN 4 :
A summary of the results for all 4 generic basins as defined above is presented here:

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	83	92	103	80	177	145	211
Runoff Volume	ac-ft	10.77	13.86	14.25	19.07	7.56	13.49	10.99	17.48
Time to Peak	hours	2.5	1.67	2.4	1.75	1.7	1.5	1.65	1.5

CONCLUSIONS:

Increasing Manning's roughness coefficients has some effect on reducing peak discharge and runoff volume as compared to the previous SWMM Run results with lower "n" values.

3.7 Sensitivity Analysis #1 - Run's 5, 6, 7, 8, 9, 10

Basin Hydrograph Comparison Between
SWMM (4 Basins) Testing Internal Subcatchment Routing as follows :

1. **Choice of Three Internal Routing Options – To Route Runoff between Pervious and Impervious areas within a Subcatchment**

2. **Choice of 0% or 100% of Runoff Routed between areas within a Subcatchment**

For Sensitivity Analysis #1 Runs 5 – 10, the goal is to modify SWMM subcatchment data as follows: Assume a reduced CN for undeveloped / pervious conditions and add % imperviousness, for pervious areas, do not add additional initial abstraction for pervious areas to account for recommendations of the BHI report. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated in this and all successive runs except Run #12, by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

Also reduced basin width in an effort to increase peak discharges to be similar or match AHYMO_97 peak discharges.

1. Choice of Three Internal Routing Options – To Route Runoff between Pervious and Impervious areas within a Subcatchment

The subcatchment hydrograph input data allows the user to specify one of the following 3 routing options:

Outlet Routing –	The impervious and pervious areas both drain directly to subcatchment outlet
Impervious Routing –	The Pervious portion of subcatchment is routed over the Impervious portion of subcatchment to subcatchment outlet
Pervious Routing –	The Impervious portion of subcatchment is routed over the Pervious portion of subcatchment to subcatchment outlet.

CONCLUSIONS:

*Please Refer to **Table R** (next page) that illustrates graphically the difference in internal subcatchment routing options and the results for each assuming either 0% or 100% of runoff is routed from one area to another.*

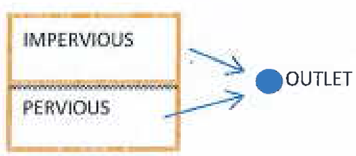
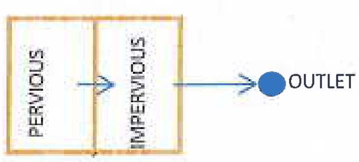
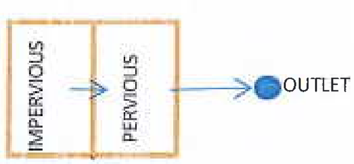
Table R (next page) illustrates that there are no differences in results of any routings except for the Pervious Routing Option for 100% of the runoff routed. For that option, the runoff volumes decrease significantly and the peak discharges have an enormous decrease.

This option may be valuable to simulate a landscaped / depressed area that may be used as a water quality improvement feature and peak discharge / volume reduction feature prior to the hydrograph leaving the subcatchment.

TABLE R
SWMM RESULTS FOR SUBCATCHMENT ROUTING OPTIONS

Sensitivity Analysis #1 - Runs, 5, 6, 7, 8, 9, 10

Yellow represents results for only routing option that changed -
reduced results if 100% of runoff is routed between subareas

SUBCATCHMENT ROUTING SCHEMATIC	SUB-AREA ROUTING METHOD	TYPE OF BASIN	PERCENT ROUTED	RUNOFF VOLUME	PEAK DISCHARGE	TIME TO PEAK	SWMM Run No.
			(%)	(ac-ft)	(cfs)	(hr)	
	(a)	(b)	(c)	(d)	(d)	(d)	(d)
	OUTLET	FR	0%	13.61	60	1.83	6
			100%	13.61	60	1.83	5
		FIC	0%	19.13	92	1.83	6
			100%	19.13	92	1.83	5
		SR	0%	13.03	80	1.67	6
			100%	13.03	80	1.67	5
		SIC	0%	17.48	145	1.58	6
			100%	17.48	145	1.58	5
	IMPERVIOUS	FR	0%	13.61	60	1.83	8
			100%	13.61	60	1.83	7
		FIC	0%	19.13	92	1.83	8
			100%	19.13	91	1.83	7
		SR	0%	13.03	80	1.67	8
			100%	13.03	80	1.67	7
		SIC	0%	17.48	145	1.58	8
			100%	17.48	144	1.58	7
	PERVIOUS	FR	0%	13.61	60	1.83	10
			100%	8	4	6.6	9
		FIC	0%	19.13	92	1.83	10
			100%	13.06	23	3.33	9
		SR	0%	13.03	80	1.67	10
			100%	7.88	6	4.5	9
		SIC	0%	17.48	145	1.58	10
			100%	12.11	47	2.25	9

(a) Choice of internal routing of runoff between pervious and impervious areas.
(b) FR - Flat Residential, FIC - Flat Industrial/Commercial, SR - Steep Residential, SIC - Steep Industrial/Commercial.
(c) Percent of runoff routed between sub-areas.
(d) From SWMM summary tables FR, FIC, SR, SIC included in Appendix B

3.8 Sensitivity Analysis #1

SWMM Width Adjustments to Match AHYMO Peak Discharges

Sensitivity Analysis #1 - Run's 5, 6, 7, 8, 9, 10

After many tests and variations of EPA model subcatchment input data assumptions, the following conclusions were developed as general guidelines assuming the goal of this analysis is to determine how to adjust the EPA input to attain similar model results as compared to the AHYMO_97 model results:

Peak Discharge Comparison – EPA Model Adjustments

As prescribed in the EPA Users Manual, the "basin width" parameter may be adjusted in order to attain results similar to a known hydrograph. Therefore the width was adjusted in Runs 5 through 10 to attain similar peak discharge as AHYMO_97. Note that Run 9 does not match the AHYMO_97 Peak Discharge due to the 100% Pervious Routing Option applied (see Section 3.7).

Summary of Basin EPA "Subcatchment Width" Adjustment Factors Required to Match AHYMO_97 Peak Discharges

Basin Name	Description / Land Use Assumptions	Shape	Initial Basin Widths Assumed Very Large for Initial Testing	Width Determined by Trial and Error to Match AHYMO_97 Peak Discharges	% of Initial Basin Width Required to Match AHYMO_97 Peak Discharge
FR	Flat residential 100%	Approx. square 6 blocks by 6 blocks	2060	750	36
FIC	Flat com. 50% / Indust. 50%	Approx. square approx. 6 blocks by 6 blocks	2150	1050	49
SR	Steep residential 100%	Approx. square 6 blocks by 6 blocks	2020	315	16
SIC	Steep com. 50% / Indust. 50%	Approx. square 6 blocks by 6 blocks	2020	670	33

CONCLUSIONS:

As this table shows, significant reduction factors would be required to reduce "basin widths" in order to increase SWMM peak discharges to match AHYMO_97 peak discharges. Based on the table above Runs #'s 11 and 12 were developed as described in the Section 3.9.

3.9 Sensitivity Analysis #1

SWMM Width Assumptions for All Basins

Sensitivity Analysis #1 - Run's 11 and 12

The "width" factor is really the average overland flow length before overland flow becomes concentrated. A distance of 400 feet is a generally accepted length for overland flow and this value has been adopted as the "width" for Runs 11 and 12.

The only difference between Runs 11 and 12 follows:

Run 11 does not allow the impervious area to have depression storage of 0.1 inches (99% of the area is not available) for storage – or initial abstraction.

Run 12 does allow the impervious area to have depression storage of 0.1 inches (100 % of the area is available) for storage – or initial abstraction.

For Sensitivity Analysis #1- Runs 11 and 12, the goal is to modify SWMM subcatchment data as follows: Assume a reduced CN for undeveloped / pervious conditions and add % imperviousness, for pervious areas and do not add additional initial abstraction to account for recommendations of the BHI report. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated for Run 11 by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%). Run #12, the 0.1 inches for impervious areas is applied by setting the "% of impervious area with no depression storage to 0%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

RESULTS RUN 11

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	41	92	50	80	92	145	107
Runoff Volume	ac-ft	10.77	13.28	14.25	18.89	7.56	13.15	10.99	17.41
Time to Peak	hours	2.5	2.0	2.4	2.0	1.7	1.58	1.65	1.67

RESULTS RUN 12

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	39	92	47	80	87	145	101
Runoff Volume	ac-ft	10.77	10.29	14.25	14.63	7.56	10.19	10.99	13.49
Time to Peak	hours	2.5	2.0	2.4	2.08	1.7	1.58	1.65	1.75

CONCLUSIONS:

As highlighted in the tables above, the runoff volume is significantly reduced by utilizing the 0.1 inches of depression storage (initial abstraction for the impervious). A value of 0.1 inches for impervious areas appears to be a generally accepted value and will be adopted for the Mid Valley Drainage Management Plan.

3.10 RECOMMENDATIONS FOR SUBCATCMENT ASSUMPTIONS for the MID VALLEY DRAINAGE MANAGEMENT PLAN SWMM MODEL

Based on the Sensitivity Analyses results, literature review and experience, for the more subjective data values, the following assumptions will be applied during subcatchment data preparation.

Width – Assume 400 feet for all subcatchments

Impervious Area Depression Storage – (initial abstraction) – Assume 0.1 inches

Percent of the Impervious Area with No Depression Storage – Assume a value of 0%, this allows the entire impervious area to store 0.1 inch.

Pervious Area Depression Storage – (initial abstraction) – For *pervious areas in valley basins (mild slopes - less than 1% average basin slope)*, assume no additional value if the Runoff Curve Number (CN) initial abstraction value is greater than 1.0 inch. If the CN value is less than 1.0 inch, then compute the difference to attain 1.0 inch, as the value. For steep slope basins (>1%), do not add any additional value.

Sub-Area Routing – Set this Option to the "Pervious Option" and this will be in effect *only if* the "Percent Routed" Parameter is set greater than 0%.

Percent Routed – This parameter will be visually estimated based on review of the most recent orthophotography, by estimating how much of the impervious area of the subcatchment may be routed or may travel across the pervious area of the subcatchment.

SCS Runoff Curve Number (CN) – Select CN values *only for Pervious Areas* from Technical Publication TR55 "Urban Hydrology for Small Watersheds", June 1986. USDA Soil Conservation Service. Obtain the "Initial Abstraction values for each CN from "Chapter 10 – Estimation of Direct Runoff From Storm Rainfall. Part 630 National Engineering Handbook. U.S. Dept. of Agriculture , Natural Resources Conservation Service Last updated July 2004.

4.0 Sensitivity Analysis #2

SWMM Only –
For 2 Basin Hydrographs –
What Storm Will Exceed Capacities of 24-inch and 36-inch Storm Drains

- Added 2 Basin hydrographs per storm drain,
- Tested what return period storm would choke pipes (2-yr., 10-yr., 50-yr. and 100-yr.)
- Tested change to street ponding HGL if 2 manholes are modeled vs. 4 manholes for 24-inch and 36-inch total storm drain length (400 ft) is the same for both models

Conclusion – The 2-yr. 24-hr. storm will choke a 24-inch storm drain, and the 10-yr. storm will choke a 36-inch storm drain. The street ponding HGL elevation is nearly the same for both manhole tests (2 vs 4 manholes). Therefore, the decision to model only 36-inch storm drains and larger is valid because smaller storm drains will not effect the SWMM 100-yr. model overall results and the small storm drains are insignificant to reduce 100-yr. storm street flooding depths.

AHYMO_97 and SWMM PROGRAMS

SENSITIVITY ANALYSES REPORT

Mid Valley Drainage Management Plan

SWMM (EPA V. 5.0.021)
&
AHYMO_97 (V. 97)

MID VALLEY DMP

SEC Proj. No. 110112   COA Proj. No. P7963.06

Prepared for:

City of Albuquerque
&
AMAFCA

Prepared by:

Smith Engineering Company

May, 2011

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TABLE OF CONTENTS

SECTION

FIGURES AND TABLES

NOTE ALL FIGURES ARE WITHIN APPENDIX A

TABLES

APPENDICIES -

APPENDIX A -

Figure R – Rainfall Depth – Intensity 100-yr. 24-hour Storm
Table 1 – Rainfall Data for 6 Locations
NOAA Atlas 14 Internet Printouts for 6 Locations
Figure B-2 – Approximate Geographic Boundaries for SCS Rainfall Distributions
Figure 14 – Depth- Area Curves (NOAA Atlas 2)
AHYMO_97 Output File – Purpose – to Generate the SCS Type II
100-yr. Hyetograph for Input in the SWMM Model
Figure 1 – FR (generic flat residential basin)
Figure 2 – FIC (generic flat 50% commercial / 50% industrial basin)
Figure 3 – SR / SIC (generic basin used for steep residential basin & steep 50% commercial / 50% industrial basin)
Table 2 – Basin Hydrologic Data
Table 3-1 - Runoff Curve Numbers for Arid and SemiArid Rangelands
Table 3-4 - Runoff Curve Numbers for Urban Areas
NRCS Soils Data for the 3 Generic Basins as Obtained from the NRCS Website
AHYMO_97 SUMMARY TABLE for: (100-yr. 24-hour storm)
For Rainfall Loss Method Comparison between -
Runoff Curve Number Method
and
Land Treatment Method
Chapter 10 – Estimation of Direct Runoff From Storm Rainfall. Part 630 National Engineering Handbook. U.S. Dept. of Agriculture, Natural Resources Conservation Service. Last updated July 2004.

APPENDIX B - SENSITIVITY ANALYSIS # 1

Basin Hydrograph Comparison Between AHYMO_97 & SWMM (4 Basins)

Table FR – Sensitivity Analysis # 1
Table FIC – Sensitivity Analysis # 1
Table SR – Sensitivity Analysis # 1
Table SIC – Sensitivity Analysis # 1

AHYMO_97 SUMMARY TABLE (a) (100-yr. 24-hour storm)
for:
Runoff Curve Number Method

(a) For 4 Generic Basins as follows:

1. Flat 100% Residential
2. Flat 50% commercial / 50% industrial
3. Steep 100% Residential
4. Steep 50% commercial / 50% industrial

SWMM SUMMARY TABLES (a) (100-yr. 24-hour storm)
for:
(100-yr. 24-hour storm) for "Initial Run" and "Final Run"

(a) For 4 Generic Basins as follows:

1. Flat 100% Residential
2. Flat 50% commercial / 50% industrial
3. Steep 100% Residential
4. Steep 50% commercial / 50% industrial

APPENDIX C - SENSITIVITY ANALYSIS # 2

SWMM Only –

For 2 Basin Hydrographs – What Storm Will Exceed Capacities of 24-in. and 36-in. Storm Drains

Table - Sensitivity Analysis # 2
SWMM SUMMARY TABLES -

SECTION 1
INTRODUCTION

1.1 Background

The City of Albuquerque (COA), the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) and the local engineering community have applied the Arid Lands Hydrology Model (AHYMO_97) (V.97) Hydrologic computer program for most Drainage Management Plans (DMP's) and smaller drainage plans in the Albuquerque Area for about the last 20 years.

The Albuquerque Mid Valley area has an intricate system of storm drains, ponds and pumps and the AHYMO_97 Program does not have the capability to simulate the dynamic infrastructure features that should be modeled as part of the Mid Valley DMP.

However, the EPA Storm Water Management (SWMM) (V.5.0.021) Hydrologic / Hydraulic Program has the following capabilities:

1. Can dynamically route hydrographs in storm drain pipes and allows flow to change directions within pipes as a function of hydrograph timing and hydraulic grade line (HGL) differences at pipe ends.

2. Can allow manhole surcharge water volume (when the HGL exceeds manhole rim elevation) to be temporarily stored. This feature allows simulation of street flooding when the HGL exceeds the rim elevation and then allows the stored volume to re-enter the same manhole as the HGL decreases below the rim elevation.

3. Can model pumps, orifices, weirs, detention ponds.

Therefore, the EPA SWMM Program has been adopted for the Mid Valley Drainage Management Plan (DMP) as it has the required capabilities.

1.2 Purpose

The purpose of this report is to present the results of a several computer modeling sensitivity analyses between the AHYMO_97 Program and the SWMM Program.

1.3 Goals

There are several goals of these sensitivity analyses as listed here:

1. Develop general conclusions regarding basin hydrograph results in the AHYMO_97 Program between the Runoff Curve Number Method and the Land Treatment Type Method for simulating rainfall initial abstraction and uniform loss rates.

2. Develop general conclusions regarding basin hydrograph input data differences, and peak discharge and runoff volume differences between the AHYMO_97 Program and the SWMM Program.

3. Develop general conclusions regarding the three subcatchment (basin) "subarea routing options" available in SWMM as follows:

"Outlet Routing Option"	– runoff from pervious and impervious areas both flow directly to outlet .
"Impervious Routing Option"	– runoff from pervious area flows directly to impervious area, then routed to outlet.
"Pervious Routing Option"	- runoff from impervious area flows directly to pervious area, then routed to outlet.

4. Develop general conclusions regarding the significance of not modeling storm drains smaller that 36-inch diameter (COA initial decision that only 36-inch storm drains and larger be modeled).

5. The most important goal for Smith Engineering Company (SEC) is to develop decisions regarding assumptions for model data preparation and modeling methods and to attain agreement on modeling / data assumptions with the COA and AMAFCA. This is important before preparation of the large SWMM model for the Mid Valley drainage area.

SECTION 2
HYDROLOGIC DATA AND MODEL INPUT DIFFERENCES

2.1 Hydrologic Assumptions And Model Development

Design Criteria

The 100-yr. - 24-hr. storm was selected for the design return period. However, the 2-yr. 10-yr. and 50-yr. 24-hr. duration storms were also evaluated for some analyses.

Rainfall Data and Distribution

Rainfall data depth data were obtained for 6 locations within the Mid Valley study area to first determine what variation may occur, and to select one location for the final Mid Valley SWMM modeling. The actual point rainfall data was obtained from NOAA Atlas 14 on the internet and that data is included in **Appendix A**. Note that due to the small size of the basins that rainfall areal reduction factors were not applied to reduce the point rainfall depth. Refer to "Figure 14 – Depth-Area Curves form NOAA Atlas 2, Vol. IV, New Mexico"(1973) (included in **Appendix A**) as recommended by the NOAA Atlas 14 staff.

Table 1 (Appendix A) contains a summary of the rainfall data for 6 locations, and the Table illustrates that depths are nearly the same throughout the study area. However, the rain depths are slightly larger at the I-25 and I-40 location, so that data was selected for the Mid Valley Study rainfall depths.

The SCS Type II Rainfall Distribution was adopted as recommended by the Soil Conservation Service. **Appendix A** contains a copy of Figure B-2 that illustrates New Mexico is within the Type II boundary. The Type II distribution assigns the storm peak rainfall intensity at 1.4 hours. Figure B-2 was obtained from a report titled "Urban Hydrology for Small Watersheds", TR-55 Soil Conservation Service, June 1986.

The rainfall depths were included in the AHYMO_97 model and the model output provides the tabular rainfall hyetograph (included in **Appendix A**). That hyetograph was input in the SWMM model to ensure that the same rainfall distribution was utilized in both programs. **Figure R**

(Appendix A) presents a graphical representation of the rainfall hyetograph as a cumulative depth curve and also as the rainfall intensity curve.

General Test Basin Descriptions

Four "generic basins" were used for testing various input parameters and results between the SWMM and AHYMO_97 hydrologic programs. Note that this is a sensitivity analysis and actual basins will vary in land use type, soil type, shape and longest flow paths.

The table here presents the generic basins names and general characteristics.

Generic Basin Name	Description / Land Use Assumptions	Shape	Area (acres)	% Impervious	Hyd. Soil Group(s) & Runoff Curve Number
FR	Flat residential 100%	Approx. square 6 blocks by 6 blocks	102.7	56	B, 85
FIC	Flat com. 50% / Indust. 50%	Approx. square approx. 6 blocks by 6 blocks	105.5	80	B, 90
SR	Steep residential 100%	Approx. square 6 blocks by 6 blocks	95.7	56	65% A - 35% B, 80
SIC	Steep com. 50% / Indust. 50%	Approx. square 6 blocks by 6 blocks	95.7	80	65% A – 35% B, 87

Figures 1, 2, and 3 (Included in Appendix A) present the generic drainage basins that were modeled. Note that only Figure 3 was used to simulate both Basins SR and SIC and only the land use type assumption and CN's were changed between model test runs for that basin.

Rainfall Loss Rate Methods

Note that the SWMM Program provides three rainfall loss methods that are:

Curve Number (CN) - (SCS Runoff Curve Number Method)
Horton
Green-Ampt

The AHYMO_97 Program provides for two rainfall loss methods that are:

Curve Number (SCS Runoff Curve Number Method)
Land Treatments

For comparison of the two programs, the Curve Number Method was selected since this is the only common rainfall loss method between the two programs.

Soils Data, Hydrologic Soil Group (HSG) and Runoff Curve Number (CN) Assumptions

The NRCS online digital soils map viewer was utilized to obtain Hydrologic Soil Groups for the given basins. Subsequently, the TR-55 SCS 1986, "Runoff Curve Number Table for Urban Areas" and also Runoff Curve Number for Arid and Semiarid Rangelands" were used to select the Runoff Curve Numbers (CN's) for the basins and assumed land treatment types. The results are presented in the previous table.

Valley Area Rainfall Initial Abstraction Adjustments

A rainfall initial abstraction study was completed on an actual rainfall event with rainfall records in the Albuquerque south valley and presented in the following report :

Bohannan-Huston, Inc. (BHI) February 1995. "Analysis of the AHYMO Program for Flat Valley Areas"

The study evaluated the AHYMO model results based on modeling two actual drainage basins using actual rainfall data, with the AHYMO Program default initial abstraction values assigned to the Land Treatment Types "A", "B", "C" and "D". Actual storm runoff volume was computed for several small ponds that retained water after the storm event. The AHYMO model runoff volume results were compared to the actual computed pond volumes. The results of the comparison indicated the model produced far greater runoff volume than actual volume.

Subsequently, the AHYMO program initial abstraction default values were adjusted (increased) in an effort to simulate the actual runoff volume as measured / computed in the ponds.

The recommendations of the study are that for design of flood control structures in flat valley areas of Albuquerque, that the AHYMO Program default initial abstraction values should be increased, however, the default uniform loss rates should remain unchanged. The following table presents the AHYMO Program default values and recommended values for flat valley areas in Albuquerque.

Land Treatment Type	Default Initial Abstraction	Recommend Initial Abstraction	Recommended and Default and Uniform Infiltration Rate
	(inches)	(inches)	(inches / hour)
A	0.65	1.20	1.67
B	0.50	1.05	1.25
C	0.35	0.90	0.83
D	0.10	0.85	0.04

The Average Initial Abstraction for Land Treatment Types A, B, C, D in the Table above computed by Smith Engineering Company = 1.0 inches NA (inches/hour)

Discussion of the Runoff Curve Number "CN" Method

The CN is an "initial abstraction and uniform infiltration rate" rainfall loss method.

Note that selection of a CN from NRCS tables begins with selection of a "cover description" and hydrologic soil group (HSG), and for urban areas (residential, commercial, industrial) the CN selection from Table 3-4 in Appendix A, would therefore include imperviousness. The SWMM subcatchment data input allows for inclusion of the percent impervious area.

Therefore, if percent impervious area is included in the SWMM input data, then a CN must be selected for undeveloped / pervious conditions based on assumed native cover description and HSG, to avoid over estimation of percent imperviousness.

Table CN (next page) presents the Runoff Curve Numbers along with various other data including computation of the NRCS initial abstraction values and adjustment of those values to account for additional initial abstraction (based on the BHI 1995 report previously described).

Longest Flow Path Assumptions

AHYMO_97 Model "Compute Hyd" Command

The AHYMO_97 model requires the unit hydrograph time to peak. The City of Albuquerque DPM Time of Concentration (tc) equations were applied to each drainage basin to compute tc and subsequently the unit hydrograph Time to Peak (tp). **Table 2** in **Appendix A** contains the tc data and results and other basin data. The longest flow path in each basin are delineated and shown on **Figures 1, 2, and 3.**

Three tc equations were applied (depending on longest flow path length) as described presented in the COA DPM. The tc, "conveyance factors" and "lag equation basin factors" were selected based on recommendations in the COA DPM.

Table 2 (Appendix A) presents a summary of all "tc" and "tp" and lag time (Lg) data, formulas and unit hydrograph lag time (lg) results required.

EPA SWMM "Subcatchment"

SWMM uses the term "subcatchment" to define a basin and does not allow direct input of "tc", "tp" or longest flow length. Therefore, SWMM computes longest flow length to assist in hydrograph computation as:

length (ft) = basin area (input) / basin width (input)

width is defined as - the average overland flow path (length until overland flow becomes concentrated

The SWMM Users Manual *suggests adjustment of basin width to calibrate SWMM model results if a known hydrograph is available.*

Unit Hydrograph Method

AHYMO_97 Model "Compute Hyd" Command

The SCS Unit Hydrograph Method is the only choice available with the Compute Hyd command.

EPA SWMM

SWMM does not allow selection of any Unit Hydrograph Method for computation of a "subcatchment" runoff hydrograph.

TABLE CN

RUNOFF CURVE NUMBER "CN" INITIAL ABSTRACTION VALUES (a)

(implicit within CN's)

Runoff Curve Number (Antecedent Moisture Condition II)	Cover Type Assumption	Percent Imper - viousness to add to SWMM Subcatchment data	Hydrologic Soil Groups (A, B, C or D)	NRCS - Maximum Potential Retention	NRCS - Initial Abstraction	Assumed Average Initial Abstraction in Valley Areas (per BHI report)	Additional Initial Abstraction to add to SWMM Subcatchment data for Pervious Valley Areas	Comment
CN				S	Ia = 0.2(S)	Ia		
				(inches)	(inches)	(inches)	(inches)	
(a)	(d)	(d)	(d)	(a)	(a)	(b)	(c)	
FR - Flat Residential Basin								
85	100% residential	0	B	1.76	0.35	1.00	0.65	
51	Native undeveloped Sagebrush with Grass Understory	56	B	9.61	1.92	1.00	0.00	NRCS value greater than 1.0 inch, so don't included additional abstraction in subcatchment data
FIC - Flat Industrial Commercial Basin								
90	50% com. 50% ind.	0	B	1.11	0.22	1.00	0.78	
51	Native undeveloped Sagebrush with Grass Understory	80	B	9.61	1.92	1.00	0.00	NRCS value greater than 1.0 inch, so don't included additional abstraction in subcatchment data

TABLE CN

RUNOFF CURVE NUMBER "CN" INITIAL ABSTRACTION VALUES (a)

(implicit within CN's)

Runoff Curve Number (Antecedent Moisture Condition II)	Cover Type Assumption	Percent Imper - viousness to add to SWMM Subcatchment data	Hydrologic Soil Groups (A, B, C or D)	NRCS - Maximum Potential Retention	NRCS - Initial Abstraction	Assumed Average Initial Abstraction in Valley Areas (per BHI report)	Additional Initial Abstraction to add to SWMM Subcatchment data for Pervious Valley Areas	Comment
CN				S	Ia = 0.2(S)	Ia		
				(inches)	(inches)	(inches)	(inches)	
(a)	(d)	(d)	(d)	(a)	(a)	(b)	(c)	
SR - Steep Residential Basin								
80	100% residential	0	65% A, 35%B	2.50	0.50	1.00	0.50	
52	Native undeveloped Sagebrush with Grass Understory	56	65% A, 35%B	9.23	1.85	1.00	0.00	NRCS value greater than 1.0 inch, so don't included additional abstraction in subcatchment data
SIC - Steep Industrial Commercial Basin								
87	50% com. 50% ind.	0	65% A, 35%B	1.49	0.30	1.00	0.70	
52	Native undeveloped Sagebrush with Grass Understory	80	65% A, 35%B	9.23	1.85	1.00	0.00	NRCS value greater than 1.0 inch, so don't included additional abstraction in subcatchment data

(a) US Dept. of Agriculture, Natural Resouces Conservation Service, Part 630 National Engineering HandbookChapter 10 Estimation of Direct Runoff from Storm Rainfall, Table 10-1 (last updated July 2004)

(b) See Table BH in SEC Sensivity Analysis Report - 1.0 inches is an average (computed by SEC) of the Recommended Initial abstraction values for Land Treatment Types A, B, C, D as recommended by Bohannan-Huston, Inc. in "Analysis fo the AHYMO Program for Flat Valley Areas, February 1995". For this analyses, we are using the CN method, not the Land Treatment Type Method

(c) Add this value for the SWMM subcatchment "Depth of depression storage on the pervious portion of the subcatchment

(d) - See NRCS Runoff Curve Number Tables 3-1 and 3-4 in Appendix A

SECTION 3
HYDROLOGIC AND HYDRAULIC ANALYSES RESULTS

3.1 AHYMO_97 Model Results For Initial Comparison Of CN's VS Land Treatments

Purpose

Prior to comparison of AHYMO_97 to EPA SWMM results, **SEC** wanted to understand the results from AHYMO_97 (not compared to SWMM) for differences in hydrologic results between two rainfall loss methods that are:

1. The Runoff Curve Number "CN" Method and
2. The Land Treatment Method

In addition to testing results based on basic basin input data, tests were also completed for both rainfall loss methods including *adjustments to account for backyard ponding* as described in the COA DPM. The DPM states to account for backyard ponding - if justified, that 35% of Land Treatment Type D may be assumed to be Land Treatment Type A.

For this comparison, Basin FR (flat 100% residential basin approximately 6 blocks by 6 blocks or 103 acres) was adopted as previously described. **Table 3** (next page) summarizes the basic data, assumptions and results for this rainfall loss method comparative analysis.

RESULTS - AHYMO_97 FOR CN Method and Land Treatment Method (rainfall loss methods):

A summary of the results for the 100% flat residential generic basin is presented here:
CN = Curve Number Rainfall Loss Method and LTM = Land Treatment Rainfall Loss Method

ITEM	Unit	AHYMO_97		AHYMO_97	
		CN no backyard ponding	LTM No backyard ponding	CN with backyard ponding	LTM with backyard ponding
Peak Discharge	cfs	60	98	42	74
Runoff Volume	ac-ft	10.77	14.32	8.2	10.96
Time to Peak	hours	2.5	2.35	2.55	2.35

CONCLUSIONS:

The SCS CN rainfall loss method produces significantly smaller peak discharges and runoff volumes than the Land Treatment Type rainfall loss method.

TABLE 3

AHYMO_97 Model Results Summary of Runoff Curve Number (CN) VS Land Treatment Type Comparison

(rainfall loss method comparison)

= no back yard ponding

= yes back yard ponding

ASSUMPTION	CN	Land Treatment Types				AHYMO_97 Results *			
100% Residential Basin, flat valley area, approx. 6 blocks x 6 blocks, drainage area = 0.1605 sq mi. = 102.72 acres Hyd. Soil Group B		A	B	C	D	Qp	Runoff Volume	Time to Peak	Total Hydrograph Time
		%	%	%	%	cfs	ac-ft	hours	hours
	(c)	(b)	(b)	(b)	(a) (b)				
1/8 acre lot Hyd. Soil Group B (initial CN assumption)	85	----	----	----	----	60	10.77	2.50	26.4
1/8 acre lot Hyd. Soil Group B (assume CN reduction due to back yard ponding)	80	----	----	----	----	42	8.20	2.55	26.3
Assume max. of 6 units / acre per DPM **(a)**, as equivalent to 1/8 acre lots = 56% impervious area (a)	----	0	22	22	56	98	14.32	2.35	27.2
Assume max. of 6 units / acre per DPM (a) as equivalent to 1/8 acre lots = 56% impervious area **(a)** AND assume 35% of Type D is backyard ponding and assume that fraction is moved into Type A	----	20	22	22	36	74	10.96	2.35	26.6

CONCLUSIONS -

Peak Discharge - An initial CN assumption produced a peak discharge less than the Land Treatment approach even after applying 35% adjustment of Land Treatment Type D into Land treatment Type A to account for back yard ponding.

Runoff Volume - An initiial CN assumption produced a runoff volume that is similar to the Land Treatment approach after applying 35% adjustment of Land Treatment Type D into Land treatment Type A to acccount for back yard ponding.

(a) Computed from COA DPM Equation a-4, pg. 22-11.
Equation a-4: % Land Treatment D = 7* (((N*N) + (5*N))) ^ 0.5
Single Family Residential where N = units/acre, N<=6

(b) See COA DPM Table A-4 for Land Treatment Type Definitions

(c) Included in Appendix A - Table 3-4 Runoff Curve Numbers for Urban Areas, TR-55 SCS, 1986
Note - The Compute Hyd Command for the CN method requires the SCS Unit Hydrograph

* AHYMO_97 test file name = ahymo97test2ot.txt summary table name = ahymo97test2ot.sm

3.2 Initial Analysis – Initial Run (Appendix B) –

Basin Hydrograph Comparison Between
AHYMO_97 And SWMM (4 Basins)
Assumed Same Data Input for both programs

For the Initial Analysis, the goal is to use the same data for those data values that are common to both programs, and evaluate the results between AHYMO_97 and SWMM.

The basin input data options for AHYMO_97 are *very limited at 6 input variables - relative to 22 input variables (excluding water quality options) that may be selected in SWMM*.

The definitions of the input values and the input values applied in various test models for both AHYMO_97 and EPA SWMM are presented side by side in tables **(included in Appendix B)** as listed here:

INITIAL Analysis - Table FR – Flat 100% Residential Basin
INITIAL Analysis - Table FIC – Flat 50% Commercial 50% Industrial Basin
INITIAL Analysis - Table SR – Steep 100% Residential Basin
INITIAL Analysis - Table SIC – Steep 50% Commercial 50% Industrial Basin

Please refer to these tables **(Appendix B)** for listing of all data, data descriptions, assumed values and **results (at bottom of table)** for each of the test basins and models.

RESULTS INITIAL RUN:

A summary of the results for all 4 generic basins as defined previously is presented here:

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	7	92	15	80	17	145	36
Runoff Volume	ac-ft	10.77	11.71	14.25	15.21	7.56	10.15	10.99	13
Time to Peak	hours	2.5	3.4	2.4	2.2	1.7	2.1	1.65	2.1

CONCLUSIONS:

The AHYMO_97 model produces much greater peak discharges and less runoff volumes that the SWMM model for the same basic input data. Note that the peak discharges are much to low for SWMM relative to AHYMO_97 because the "basin width factor" was initially computed as area divided by the basin width, not "overland flow" length, for the purpose of understanding the sensitivity of very large "widths". SWMM computes time of concentration internally.

3.3 Sensitivity Analysis #1 – Run 1 (Appendix B) –

Basin Hydrograph Comparison Between
AHYMO_97 And SWMM (4 Basins)

For Sensitivity Analysis #1 Run 1, the goal is to modify SWMM subcatchment data ONLY for Pervious Area - additional initial abstraction to account for BHI recommendations listed previously.

Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated in this and all successive runs except Run #12, by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

RESULTS RUN 1:

A summary of the results for all 4 generic basins as defined previously is presented here:

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	2	92	5	80	5	145	9
Runoff Volume	ac-ft	10.77	6.19	14.25	8.31	7.56	5.92	10.99	7.21
Time to Peak	hours	2.5	6.17	2.4	6.0	1.7	3.67	1.65	2.67

CONCLUSIONS:

The SWMM model results are much less than the AHYMO_97 model results as a result of the increased initial abstraction included in the SWMM model as prescribed by the BHI report.

3.4 Sensitivity Analysis #1 - Run 2 (Appendix B) –

Basin Hydrograph Comparison Between AHYMO_97 And SWMM (4 Basins)

For Sensitivity Analysis #1 Run 2, the goal is to modify SWMM subcatchment data as follows: Assume a reduced CN for undeveloped / pervious conditions and add % imperviousness, for pervious areas do not add additional initial abstraction to account for recommendations of the BHI report. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated in this and all successive runs except Run #12, by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

RESULTS RUN 2 :

A summary of the results for all 4 generic basins as defined above is presented here:

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	109	92	136	80	213	145	267
Runoff Volume	ac-ft	10.77	14.1	14.25	19.23	7.56	13.58	10.99	17.51
Time to Peak	hours	2.5	1.58	2.4	1.58	1.7	1.5	1.65	1.5

CONCLUSIONS:

The SWMM model results are much greater than the AHYMO_97 model results as a result of the increased the % imperviousness included in SWMM even with lower CN's. (Additional initial abstraction was not included in the SWMM model as prescribed by the BHI report).

3.5 **Sensitivity Analysis #1 - Run 3** (Appendix B) –

Basin Hydrograph Comparison Between AHYMO_97 And SWMM (4 Basins)

For Sensitivity Analysis #1 Run 3, the goal is to modify SWMM subcatchment data as follows: Assume a reduced CN for undeveloped / pervious conditions and add % imperviousness, for pervious areas, do not add additional initial abstraction for pervious areas to account for recommendations of the BHI report. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated in this and all successive runs except Run #12, by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

RESULTS RUN 3 :

A summary of the results for all 4 generic basins as defined above is presented here:

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	109	92	136	80	213	145	267
Runoff Volume	ac-ft	10.77	14.1	14.25	19.19	7.56	13.58	10.99	17.51
Time to Peak	hours	2.5	1.58	2.4	1.67	1.7	1.5	1.65	1.5

CONCLUSIONS:

The SWMM model results are much greater than the AHYMO_97 model results as a result of the increased the % imperviousness included in SWMM even with lower CN's. (Additional initial abstraction was not included for pervious areas in the SWMM model as prescribed by the BHI report.

3.6 **Sensitivity Analysis #1 - Run 4** (Appendix B) –

Basin Hydrograph Comparison Between AHYMO_97 And SWMM (4 Basins)

For Sensitivity Analysis #1 Run 4, the goal is to modify SWMM subcatchment data as follows: Assume a reduced CN for undeveloped / pervious conditions and add % imperviousness, for pervious areas do not add additional initial abstraction to account for recommendations of the BHI report. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated in this and all successive runs except Run #12, by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

Increase the Manning's Roughness Coefficients ("n" 's) for pervious and impervious portions of subcatchment to determine effect of "n" 's.

RESULTS RUN 4 :

A summary of the results for all 4 generic basins as defined above is presented here:

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	83	92	103	80	177	145	211
Runoff Volume	ac-ft	10.77	13.86	14.25	19.07	7.56	13.49	10.99	17.48
Time to Peak	hours	2.5	1.67	2.4	1.75	1.7	1.5	1.65	1.5

CONCLUSIONS:
Increasing Manning's roughness coefficients has some effect on reducing peak discharge and runoff volume as compared to the previous SWMM Run results with lower "n" values.

3.7 Sensitivity Analysis #1 - Run's 5, 6, 7, 8, 9, 10 (Appendix B) –

Basin Hydrograph Comparison Between
SWMM (4 Basins) Testing Internal Subcatchment Routing as follows :

1. **Choice of Three Internal Routing Options – To Route Runoff between Pervious and Impervious areas within a Subcatchment**

2. **Choice of 0% or 100% of Runoff Routed between areas within a Subcatchment**

For Sensitivity Analysis #1 Runs 5 – 10, the goal is to modify SWMM subcatchment data as follows: Assume a reduced CN for undeveloped / pervious conditions and add % imperviousness, for pervious areas, do not add additional initial abstraction for pervious areas to account for recommendations of the BHI report. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated in this and all successive runs except Run #12, by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

Also reduced basin width in an effort to increase peak discharges to be similar or match AHYMO_97 peak discharges.

1. Choice of Three Internal Routing Options – To Route Runoff between Pervious and Impervious areas within a Subcatchment

The subcatchment hydrograph input data allows the user to specify one of the following 3 routing options:

Outlet Routing –	The impervious and pervious areas both drain directly to subcatchment outlet
Impervious Routing –	The Pervious portion of subcatchment is routed over the Impervious portion of subcatchment to subcatchment outlet
Pervious Routing –	The Impervious portion of subcatchment is routed over the Pervious portion of subcatchment to subcatchment outlet.

CONCLUSIONS:

Please Refer to ***Table R*** *(next page) that illustrates graphically the difference in internal subcatchment routing options and the results for each assuming either 0% or 100% of runoff is routed from one area to another.*

Table R illustrates that there are no differences in results of any routings except for the Pervious Routing Option for 100% of the runoff routed. For that option, the runoff volumes decrease significantly and the peak discharges have an enormous decrease.

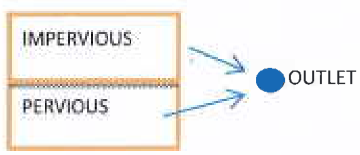
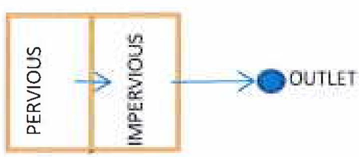
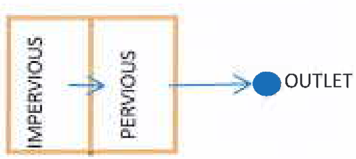
This option may be valuable to simulate a landscaped / depressed area that may be used as a water quality improvement feature and peak discharge / volume reduction feature prior to the hydrograph leaving the subcatchment.

TABLE R

SWMM RESULTS FOR SUBCATCHMENT ROUTING OPTIONS

Sensitivity Analysis #1 - Runs, 5, 6, 7, 8, 9, 10

Yellow represents results for only routing option that changed - reduced results if 100% of runoff is routed between subareas

SUBCATCHMENT ROUTING SCHEMATIC	SUB-AREA ROUTING METHOD	TYPE OF BASIN	PERCENT ROUTED	RUNOFF VOLUME	PEAK DISCHARGE	TIME TO PEAK	SWMM Run No.
			(%)	(ac-ft)	(cfs)	(hr)	
	(a)	(b)	(c)	(d)	(d)	(d)	(d)
	OUTLET	FR	0%	13.61	60	1.83	6
			100%	13.61	60	1.83	5
		FIC	0%	19.13	92	1.83	6
			100%	19.13	92	1.83	5
		SR	0%	13.03	80	1.67	6
			100%	13.03	80	1.67	5
		SIC	0%	17.48	145	1.58	6
			100%	17.48	145	1.58	5
	IMPERVIOUS	FR	0%	13.61	60	1.83	8
			100%	13.61	60	1.83	7
		FIC	0%	19.13	92	1.83	8
			100%	19.13	91	1.83	7
		SR	0%	13.03	80	1.67	8
			100%	13.03	80	1.67	7
		SIC	0%	17.48	145	1.58	8
			100%	17.48	144	1.58	7
	PERVIOUS	FR	0%	13.61	60	1.83	10
			100%	8	4	6.6	9
		FIC	0%	19.13	92	1.83	10
			100%	13.06	23	3.33	9
		SR	0%	13.03	80	1.67	10
			100%	7.88	6	4.5	9
		SIC	0%	17.48	145	1.58	10
			100%	12.11	47	2.25	9

(a) Choice of internal routing of runoff between pervious and impervious areas.
(b) FR - Flat Residential, FIC - Flat Industrial/Commercial, SR - Steep Residential, SIC - Steep Industrial/Commercial.
(c) Percent of runoff routed between sub-areas.
(d) From SWMM summary tables FR, FIC, SR, SIC included in Appendix B

3.8 **Sensitivity Analysis #1** (Appendix B) –

SWMM Width Adjustments to Match AHYMO Peak Discharges

Sensitivity Analysis #1 - Run's 5, 6, 7, 8, 9, 10 (Appendix B) –

After many tests and variations of EPA model subcatchment input data assumptions, the following conclusions were developed as general guidelines assuming the goal of this analysis is to determine how to adjust the EPA input to attain similar model results as compared to the AHYMO_97 model results:

<u>Peak Discharge Comparison – EPA Model Adjustments</u>

As prescribed in the EPA Users Manual, the "basin width" parameter may be adjusted in order to attain results similar to a known hydrograph. Therefore, the **Tables (FR, FIC, SR and SIC in Appendix B,** Width required for Runs 5 to 10 to attain similar peak discharge as AHYMO_97. Note that Run 9 does not match the AHYMO_97 Peak Discharge due to the 100% Pervious Routing Option applied (see Section 3.7).

Summary of Basin EPA "Subcatchment Width" Adjustment Factors Required to Match AHYMO_97 Peak Discharges

Basin Name	Description / Land Use Assumptions	Shape	Initial Basin Widths Assumed Very Large for Initial Testing	Width Determined by Trial and Error to Match AHYMO_97 Peak Discharges	% of Initial Basin Width Required to Match AHYMO_97 Peak Discharge
FR	Flat residential 100%	Approx. square 6 blocks by 6 blocks	2060	750	36
FIC	Flat com. 50% / Indust. 50%	Approx. square approx. 6 blocks by 6 blocks	2150	1050	49
SR	Steep residential 100%	Approx. square 6 blocks by 6 blocks	2020	315	16
SIC	Steep com. 50% / Indust. 50%	Approx. square 6 blocks by 6 blocks	2020	670	33

<u>CONCLUSIONS:</u>

As this table shows, significant reduction factors would be required to reduce "basin widths" in order to increase SWMM peak discharges to match AHYMO_97 peak discharges. Based on the table above Runs #'s 11 and 12 were developed as described in the Section 3.9.

3.9 **Sensitivity Analysis #1** (Appendix B) –

SWMM Width Assumptions for All Basins

Sensitivity Analysis #1 - Run's 11 and 12 (Appendix B) –

The "width" factor is really the average overland flow length before overland flow becomes concentrated. A distance of 400 feet is a generally accepted length for overland flow and this value has been adopted as the "width" for Runs 11 and 12.

The only difference between Runs 11 and 12 follows:

Run 11 does not allow the impervious area to have depression storage of 0.1 inches (99% of the area is not available) for storage – or initial abstraction.

Run 12 does allow the impervious area to have depression storage of 0.1 inches (100 % of the area is available) for storage – or initial abstraction.

For Sensitivity Analysis #1- Runs 11 and 12, the goal is to modify SWMM subcatchment data as follows: Assume a reduced CN for undeveloped / pervious conditions and add % imperviousness, for pervious areas and do not add additional initial abstraction to account for recommendations of the BHI report. Note that initial abstraction for impervious areas is set to 0.1 inches, however, this is negated for Run 11 by setting the "% of impervious area with no depression storage to 99% (program has an error at 100%). Run #12, the 0.1 inches for impervious areas is applied by setting the "% of impervious area with no depression storage to 0%. Run #12 will illustrate the effect of assuming the entire impervious area will abstract 0.1 inches.

RESULTS RUN 11

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	41	92	50	80	92	145	107
Runoff Volume	ac-ft	10.77	13.28	14.25	18.89	7.56	13.15	10.99	17.41
Time to Peak	hours	2.5	2.0	2.4	2.0	1.7	1.58	1.65	1.67

RESULTS RUN 12

ITEM	Unit	FR Basin		FIC Basin		SR Basin		SIC Basin	
		AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM	AHYMO_97	SWMM
Peak Discharge	cfs	60	39	92	47	80	87	145	101
Runoff Volume	ac-ft	10.77	10.29	14.25	14.63	7.56	10.19	10.99	13.49
Time to Peak	hours	2.5	2.0	2.4	2.08	1.7	1.58	1.65	1.75

CONCLUSIONS:

As highlighted in the tables above, the runoff volume is significantly reduced by utilizing the 0.1 inches of depression storage (initial abstraction for the impervious). A value of 0.1 inches for impervious areas appears to be a generally accepted value and will be adopted for the Mid Valley Drainage Management Plan.

3.10 RECOMMENDATIONS FOR SUBCATCMENT ASSUMPTIONS for the MID VALLEY DRAINAGE MANAGEMENT PLAN SWMM MODEL

Based on the Sensitivity Analyses results, literature review and experience, for the more subjective data values, the following assumptions will be applied during subcatchment data preparation.

Width – Assume 400 feet for all subcatchments

Impervious Area Depression Storage – (initial abstraction) – Assume 0.1 inches

Percent of the Impervious Area with No Depression Storage – Assume a value of 0%, this allows the entire impervious area to store 0.1 inch.

Pervious Area Depression Storage – (initial abstraction) – For *pervious areas in valley basins (mild slopes - less than 1% average basin slope)*, assume no additional value if the Runoff Curve Number (CN) initial abstraction value is greater than 1.0 inch. If the CN value is less than 1.0 inch, then compute the difference to attain 1.0 inch, as the value. For steep slope basins (>1%), do not add any additional value.

Sub-Area Routing – Set this Option to the "Pervious Option" and this will be in effect *only if* the "Percent Routed" Parameter is set greater than 0%.

Percent Routed – This parameter will be visually estimated based on review of the most recent orthophotography, by estimating how much of the impervious area of the subcatchment may be routed or may travel across the pervious area of the subcatchment.

SCS Runoff Curve Number (CN) – Select CN values *only for Pervious Areas* from Technical Publication TR55 "Urban Hydrology for Small Watersheds", June 1986. USDA Soil Conservation Service. Obtain the "Initial Abstraction values for each CN from "Chapter 10 – Estimation of Direct Runoff From Storm Rainfall. Part 630 National Engineering Handbook. U.S. Dept. of Agriculture , Natural Resources Conservation Service Last updated July 2004.

4.0 **Sensitivity Analysis #2** (Appendix C) –

SWMM Only –
For 2 Basin Hydrographs –
What Storm Will Exceed Capacities of 24-inch and 36-inch Storm Drains

- Added 2 Basin hydrographs per storm drain,
- Tested what return period storm would choke pipes (2-yr., 10-yr., 50-yr. and 100-yr.)
- Tested change to street ponding HGL if 2 manholes are modeled vs. 4 manholes for 24-inch and 36-inch total storm drain length (400 ft) is the same for both models

Conclusion – The 2-yr. 24-hr. storm will choke a 24-inch storm drain, and the 10-yr. storm will choke a 36-inch storm drain. The street ponding HGL elevation is nearly the same for both manhole tests (2 vs 4 manholes). Therefore, the decision to model only 36-inch storm drains and larger is valid because smaller storm drains will not effect the SWMM 100-yr. model overall results and the small storm drains are insignificant to reduce 100-yr. storm street flooding depths.