COMPARISON OF ESTIMATED AND OBSERVED STORMWATER RUNOFF FOR FIFTEEN WATERSHEDS IN WEST-CENTRAL FLORIDA, USING FIVE COMMON DESIGN TECHNIQUES

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hydrographs in either size or shape. Peak discharges are overestimated for the South Creek watershed and underestimated for the Forked Creek and Rock Creek watersheds. Surface detention, subsurface storage and flow, and discharge from the surficial aquifer system influence the shape of the observed hydrographs in these watersheds.

STATISTICAL ANALYSIS OF DATA

The mean estimation error indicates the tendency of a method to under- or overestimate observed data. The mean estimation error, in percent, was calculated for each watershed, all urban watersheds, all natural watersheds, all mixed watersheds, and for all watersheds for each method using the following equation:

$$\xi = 100\left[\frac{\sum_{i=1}^{n}\left(\frac{est_i - obs_i}{obs_i}\right)}{n}\right] \qquad (8)$$

where:

ξ = mean estimation error, in percent;

est_i = estimated peak discharge for event i, in cubic feet per second or runoff volume, in inches;

obs_i = observed peak discharge for event i, in cubic feet per second or runoff volume, in inches;

n = number of storm events.

Mean estimation errors for peak discharge for all storms in each watershed for the rational method ranged from an underestimation of 31 percent to an overestimation of 767 percent. The smallest mean estimation error was calculated for storms in the urban watershed of Allen Creek. The largest was for storms in the natural watershed of South Creek (table 10). The mean estimation error for all storms occurring in the urban watersheds was an overestimation of about 67 percent. The error was an

Table 10. The mean estimation error for each watershed, all urban watersheds, all natural watersheds, all mixed watersheds and for all the watersheds, in percent, for peak discharges calculated using five common design techniques

[-, negative values represent underestimations; --, error could not be computed, U, urban; N, natural; M, mixed]

		Peak Discharge					
						Environmental Protection Agency StormWater Management Model Infiltration Method	
Watershed Name	Watershed Classification	Rational Method	USGS Regression Equations	TR-20 Model	HEC-1 Model	Green-Ampt	Horton
Arctic Street storm drain	U	4.57	-87.3	3.73	75.2	33.5	34.7
Kirby Street drainage ditch	U	525	24.7	-28.4	42.5	37.3	38.0
St. Louis Street drainage ditch	U	-31.0	--	-60.9	-28.3	-63.0	-59.3
Gandy Boulevard drainage ditch	U	29.7	-74.4	1.21	80.9	-6.15	-4.42
Allen Creek	U	13.3	--	73.6	164	-13.1	-11.6
Clower Creek	U	21.3	-44.7	22.0	104	86.0	83.1
All Urban Watersheds		67.1	-25.3	12.5	88.0	19.6	20.2
IMC Creek	N	511	1140	153	331	111	135
Grace Creek	N	163	--	56.4	114	82.8	105
CFI-3 Creek	N	88.7	283	245	452	237	258
South Creek	N	767	-2.26	126	108	45.5	39.9
Forked Creek	N	446	-42.9	2.70	200	-10.8	-14.0
Rock Creek	N	351	8.26	-8.73	46.2	22.9	21.9
All Natural Watersheds		416	277	104	201	83.7	93.9
Walker Creek	M	249	-42.2	20.3	57.5	132	135
Catfish Creek	M	360	--	65.3	169	-4.21	-4.88
Gottfried Creek	M	319	72.3	110	140	36.3	30.0
All Mixed Watersheds		287	-13.6	46.7	98.4	83.1	83.9
All Watersheds		235	72.2	50.4	127	56.4	60.0

overestimation of 416 percent for all storms occurring in the natural watersheds and an overestimation of 287 percent for all storms occurring in the watersheds with mixed land use. The mean estimation error for all the storms modeled was an overestimation of 235 percent. This method overestimates peak discharges for all watershed types included in this study.

Mean estimation errors calculated for peak discharge for the USGS regression equations ranged from an underestimation of 87.3 percent to an overestimation of 1,140 percent (table 10). The smallest and largest errors were calculated for the South Creek and IMC Creek watersheds, respectively. The South Creek watershed is a large, natural watershed with low topographic relief. The IMC Creek watershed is a very small, natural watershed with fairly steep topographic relief. The mean estimation error for all storms occurring in the urban watersheds was an underestimation of about 25 percent. The error was an overestimation of 277 percent for all storms occurring in the natural watersheds and an overestimation of about 14 percent for all storms occurring in the watersheds with mixed land use. The mean estimation error for all the storms modeled was an overestimation of about 72 percent. The mean estimation errors calculated for runoff volume for the USGS regression equations ranged from an underestimation of 93.9 percent to an overestimation of 324 percent (table 11). The mean estimation error for all storms occurring in the urban watersheds was an underestimation of about 32 percent. The error was an overestimation of about 68 percent for all storms occurring in the natural watersheds and an underestimation of about 68 percent for all storms occurring in the watersheds with mixed land use. The mean runoff estimation error for all the storms modeled was an underestimate of 12.5 percent. The mean estimation errors indicate the regression equations have a tendency to overestimate peak discharges in all the watersheds included in this study. Runoff volumes for storms in the urban and mixed watersheds were underestimated and storms in the natural watersheds were overestimated. The regression equations have a general tendency to underestimate runoff volume.

Mean estimation errors calculated for peak discharge for the TR-20 model ranged from an underestimation of 60.9 percent to an overestimation of 245 percent (table 10). The mean estimation error for all storms occurring in the urban watersheds was an overestimation of 12.5 percent. The error was an overestimation of 104 percent for all storms occurring in the natural watersheds and an overestimation of about 47 percent for all storms occurring in the mixed watersheds. The mean estimation error for all the storms modeled was an overestimation of about 50 percent. The mean estimation errors calculated for runoff volume for the TR-20 model ranged from an underestimation of 41.5 percent to an overestimation of 395 percent (table 11). The mean estimation error for all storms

Table 11. The mean estimation error for each watershed, all urban watersheds, all natural watersheds, all mixed watersheds and for all the watersheds, in percent, for runoff volumes calculated using four common design techniques

[-, negative values represent underestimations; --, error could not be computed, U, urban; N, natural; M, mixed]

		Runoff Volume				
					Environmental Protection Agency Storm Water Management Model infiltration method	
Watershed name	Watershed classification	USGS regression equations	TR-20 model	HEC-1 model	Green-Ampt	Horton
Arctic Street storm drain	U	-87.7	32.4	33.0	15.0	20.1
Kirby Street drainage ditch	U	35.0	6.70	7.77	-63.3	-56.8
St. Louis Street drainage ditch	U	--	145	145	0.62	86.1
Gandy Boulevard drainage ditch	U	-52.0	-2.64	-2.64	-54.0	-43.6
Allen Creek	U	--	-13.2	-13.1	-47.6	-42.1
Clower Creek	U	-93.9	27.9	29.4	-12.8	-13.9
All Urban Watersheds		-31.8	24.6	25.2	-27.6	-14.3
IMC Creek	N	324	59.4	58.5	-30.5	6.55
Grace Creek	N	--	19.3	19.3	-46.0	-19.5
CFI-3 Creek	N	290	395	395	201	296
South Creek	N	-90.2	55.2	17.5	15.9	12.7
Forked Creek	N	-93.9	-29.5	-6.95	30.4	38.0
Rock Creek	N	-91.1	-41.5	-3.70	3.70	4.03
All Natural Watersheds		67.8	75.8	74.2	21.4	47.1
Walker Creek	M	-75.1	43.9	43.6	11.1	13.8
Catfish Creek	M	--	103	94.1	-30.0	-16.9
Gottfried Creek	M	-90.9	-1.97	-2.47	-6.83	-6.73
All Mixed Watersheds		-79.1	49.7	47.4	-1.72	2.97
All Watersheds		-12.5	47.3	46.5	-5.35	9.69

occurring in the urban watersheds was an overestimation of about 25 percent. The error was an overestimation of about 76 percent for all storms occurring in the natural watersheds and an overestimation of about 50 percent for all storms occurring in the mixed land use watersheds. The mean estimation error for all the storms modeled was an overestimation of about 47 percent. The model has a tendency to overestimate peak discharges and runoff volumes for storms occurring in the all the watershed types.

Mean estimation errors calculated for peak discharge for the HEC-1 model ranged from an underestimation of 28.3 percent to an overestimation of 452 percent (table 10). The mean estimation error for all storms occurring in the urban watersheds was an overestimation of 88 percent. The error was an overestimation of 201 percent for all storms occurring in the natural watersheds and an overestimation of about 98 percent for all storms occurring in the mixed watersheds. The mean estimation error for all the storms modeled was an overestimation of 127 percent. The mean estimation errors calculated for runoff volume for the HEC-1 model ranged from an underestimation of 13.1 percent to an overestimation of 395 percent (table 11). The mean estimation error for all storms occurring in the urban watersheds was an overestimation of about 25 percent. The error was an overestimation of about 74 percent for all storms occurring in the natural watersheds and an overestimation of about 47 percent for all storms occurring in the mixed watersheds. The mean estimation error for all the storms modeled was an overestimation of 46.5 percent. The model has a tendency to overestimate peak discharges and runoff volumes for storms occurring in all the watershed types.

Mean estimation errors calculated for peak discharge for the EPA SWMM model with the Green-Ampt infiltration method, ranged from an underestimation of 63.0 percent to an overestimation of 237 percent (table 10). The mean estimation error for all storms occurring in the urban watersheds was an overestimation of about 20 percent. The error was an overestimation of about 84 percent for all storms occurring in the natural watersheds and an overestimation of about 83 percent for all storms occurring in the mixed land use watersheds. The mean estimation error for all the storms modeled was an overestimation of about 56 percent. The mean estimation errors calculated for runoff volume for the EPA SWMM model with the Green-Ampt infiltration method, ranged from an underestimation of 63.3 percent to an overestimation of 201 percent (table 11). The mean estimation error for all storms occurring in the urban watersheds was an underestimation of about 28 percent. The error was an overestimation of about 21 percent for all storms occurring in the natural watersheds and an underestimation of under 2 percent for all storms occurring in the mixed land use watersheds. The mean estimation error for runoff volume for all the storms modeled was an underestimation of about 5 percent. The model with the Green-Ampt infiltration method has a tendency to overestimate peak discharges and slightly underestimate runoff volume for storms occurring in the watersheds included in the study.

Mean estimation errors calculated for peak discharge for the EPA SWMM model with the Horton infiltration method, ranged from an underestimation of 59.3 percent to an overestimation of 258 percent (table 10). The mean estimation error for all storms occurring in the urban watersheds was an overestimation of about 20 percent. The error was an overestimation of about 94 percent for all storms occurring in the natural watersheds and an overestimation of about 84 percent for all storms occurring in the mixed land use watersheds. The mean estimation error for all the storms modeled was an overestimation of 60 percent. The mean estimation errors calculated for runoff volume for the EPA SWMM model with the Horton infiltration method, ranged from an underestimation of 56.8 percent to an overestimation of 296 percent (table 11). The mean estimation error for all storms in the urban watersheds was an underestimation of about 14 percent, an overestimation of about 47 percent in the natural watersheds, and an underestimation of about 3 percent in the mixed land use watersheds. The mean estimation error for all the storms modeled was an overestimation of about 10 percent.

The model with the Horton infiltration method overestimates peak discharges for all watersheds included in the study. It underestimates runoff volumes in the urban watersheds, and overestimates runoff volumes in the natural and mixed watersheds.

The standard estimation error quantifies the absolute magnitude of the error, in percent. It could not be calculated for individual watersheds with less than 2 equivalent storms; however, all equivalent storms were used to calculate the standard error for each of the watershed types and for all the watersheds, all natural watersheds, all mixed watersheds. The standard estimation error was calculated using the following equation:

$$\varepsilon = 100\left[\frac{\sum_{i=1}^{n}\left(\frac{est_i - obs_i}{obs_i}\right)^2}{n-1}\right]^{0.5} \qquad (9)$$

where:

ε = standard estimation error, in percent;

est_i = estimated peak discharge for event i, in cubic feet per second or runoff volume, in inches;

obs_i = observed peak discharge for event i, in cubic feet per second or runoff volume, in inches;

n = number of storm events.

The standard estimation errors calculated for peak discharges for the five common design techniques are shown in table 12. For the urban watersheds, the USGS regression equations, the TR-20 model and the EPA SWMM model using both the Green-Ampt and the Horton infiltration methods had standard estimation errors less than 65 percent. The rational method and the HEC-1 model had standard estimation errors of 193 and 121 percent, respectively. The TR-20, HEC-1 models, and the EPA SWMM model with the Green-Ampt infiltration method, had standard estimation errors that ranged between 207 and 358 percent for the natural watersheds. The rational method and the USGS regression equations had standard errors of 695 and 588 percent, respectively. The USGS regression equations for peak discharge and the TR-20 model had standard errors of less than 100 percent for the mixed watersheds. The SWMM model with both infiltration methods and the HEC-1 model had standard errors that ranged between 116 and 133 percent. A standard error of 404 percent was calculated for the mixed watersheds using the rational method. When the standard estimation error was calculated for all the watersheds, the TR-20 model, and the SWMM model with both infiltration methods had errors that ranged between 128 and 152 percent. The HEC-1 model had an error of 223 percent, and the USGS regression equations and the rational method had a standard errors greater than 300 percent.

The standard estimation errors for runoff volumes for the methods other than the rational method, are shown in table 13. The SWMM model with both the Green-Ampt and Horton infiltration methods had standard estimation errors of about 26 and 44 percent, respectively, for the urban watersheds. The TR-20 and HEC-1 models had standard errors of about 60 percent, and the USGS regression equation had a standard error of about 81 percent for the urban watersheds. All the methods except the SWMM model with the Green-Ampt infiltration method had standard error greater than 200 percent, for the natural watersheds. Standard errors of about 42 percent were calculated for the mixed watersheds using

Table 12. Summary of the standard estimation error for each watershed, all urban watersheds, all natural waterseds, all mixed watersheds and for all watersheds, in percent, for peak discharges calculated using five common design techniques

[--, standard estimation error could not be computed, U, urban; N, natural; M, mixed]

Watershed name	Watershed classification	Peak Discharge: Rational method	USGS regression equations	TR-20 model	HEC-1 model	Environmental Protection Agency StormWater Management Model infiltration method: Green-Ampt	Horton
Arctic Street storm drain	U	35.7	--	36.3	110	47.9	49.0
Kirby Street drainage ditch	U	667	52.3	57.8	98.0	54.5	55.8
St. Louis Street drainage ditch	U	46.2	--	75.1	37.5	78.5	74.1
Gandy Boulevard drainage ditch	U	119	--	23.8	99.2	14.8	14.5
Allen Creek	U	54.9	--	109	206	44.1	43.5
Clower Creek	U	79.5	79.0	31.8	120	104	101
All Urban Watersheds		193	64.4	57.8	121	60.9	59.6
IMC Creek	N	879	--	308	580	282	329
Grace Creek	N	313	--	99.0	162	137	179
CFI-3 Creek	N	264	--	441	770	548	602
South Creek	N	1127	--	192	168	67.7	62.5
Forked Creek	N	972	--	9.55	377	15.7	21.5
Rock Creek	N	661	--	63.7	125	114	112
All Natural Watersheds		695	588	207	358	217	244
Walker Creek	M	351	57.8	50.4	81.2	150	154
Catfish Creek	M	481	--	76.5	196	17.6	16.4
Gottfried Creek	M	635	--	191	234	74.7	74.7
All Mixed Watersheds		404	63.0	84.2	133	116	118
All Watersheds		452	308	128	223	139	152

Table 13. Summary of the standard estimation error for each watershed, all urban watersheds, all natural watersheds, all mixed watersheds, and for all watersheds, in percent, for runoff volumes calculated using four common design techniques

[--, standard estimation error could not be computed, U, urban; N, natural; M, mixed]

		Runoff Volume				
					Environmental Protection Agecy Storm Water Management Model infiltration method	
Watershed name	Watershed classification	USGS regression equations	TR-20 model	HEC-1 model	Green-Ampt	Horton
Arctic Street storm drain	U	--	41.6	42.5	26.7	31.6
Kirby Street drainage ditch	U	73.8	63.4	64.2	79.5	72.8
St. Louis Street drainage ditch	U	--	179	179	3.55	106
Gandy Boulevard drainage ditch	U	--	29.1	29.1	61.8	51.5
Allen Creek	U	--	31.4	31.3	62.2	56.5
Clower Creek	U	133	44.4	46.6	23.7	24.5
All Urban Watersheds		80.6	60.0	60.5	44.2	26.5
IMC Creek	N	--	194	193	112	165
Grace Creek	N	--	61.6	61.6	58.0	26.5
CFI-3 Creek	N	--	735	735	544	755
South Creek	N	--	121	109	64.8	64.2
Forked Creek	N	--	54.8	87.3	57.4	72.1
Rock Creek	N	--	92.5	80.2	103	103
All Natural Watersheds		231	254	252	184	252
Walker Creek	M	102	82.2	81.9	40.0	42.1
Catfish Creek	M	--	123	112	37.3	25.7
Gottfried Creek	M	--	81.0	80.2	71.2	72.7
All Mixed Watersheds		92.1	86.4	83.3	42.3	42.2
All Watersheds		136	152	151	108	145

the SWMM model with both infiltration methods. The TR-20 model and the HEC-1 model had standard errors of 86.4 and 83.3 percent, respectively, for the mixed watersheds. The USGS regression equations for runoff volume produced a standard estimation error of about 92 percent. When the standard estimation error was calculated for all the watersheds, the four techniques produced errors that ranged between 108 percent and 152 percent.

SUMMARY AND CONCLUSION

Measured peak discharges and runoff volumes were compared to estimated values using the rational method, the USGS regional regression equations, the NRCS TR-20 model, the U.S. Army Corp of Engineers HEC-1 model and the EPA SWMM model. Sixty-six storms in 15 watersheds located in west-central Florida were estimated. Observed rainfall was used with all these techniques except the USGS regression equations, which calculates runoff from rainfall for specified recurrence intervals. Estimated peak discharge and runoff data were then compared to observed data. Six of the watersheds are urban, 6 are natural, and 3 watersheds have varying degrees of natural, agricultural or urban characteristics. They range in size from 0.14 to 15.22 mi^2, with slopes that range from 1.4 ft/mi to 47 ft/mi.

Peak discharges and runoff volumes were calculated with each of these techniques except for the rational method which only provides a peak discharge. Techniques were applied using recommended or customary procedures. The choice of input parameters was not influenced by observed data.

The rational method is usually applied in sewered or natural watersheds with drainage areas less than 5 mi^2, where infiltration, surface detention, and time of concentration are not large influences. The rational method overestimated peak discharge rates for most of the storms modeled. Estimation errors were generally smaller for storms occurring in the six urban watersheds. The largest error was for a storm occurring in the South Creek watershed which is a large natural watershed, and contains over 30 percent wetland areas. Examination of estimation errors and watershed characteristics indicate that errors decrease as the amount of urban development in the watershed increases. The mean estimation error for all the storms modeled indicates the method has a tendency to overestimate peak discharge for the watersheds included in the study. The largest errors were for storms occurring in the natural watersheds. The smallest errors were for storms occurring in the urban watersheds.

The USGS regional regression equations are used to determine flood flow for specific recurrence intervals; therefore, direct comparison of estimated and observed discharges from actual storms could not be made. However, observed peak discharges and runoff volumes from 16 storms with rainfall comparable to specific recurrence intervals could be used to compare estimated runoff to measured runoff. This method underestimated peak discharge and runoff volumes for most individual storms. Mean estimation errors for peak discharge indicate the method was more accurate for the urban watersheds than for the natural and mixed watersheds. When the runoff volume regression equations were used, mean estimation errors indicate the method was more accurate for the urban watersheds than for the natural and mixed watersheds. The mean estimation error for all the storms modeled indicates the regression equations have a tendency to overestimate peak discharge and underestimate runoff volume for the watersheds included in the study. The watershed characteristics in this study are closer to the watershed characteristics used to develop the peak discharge regression equations, but differ from those used to develop the runoff volume regression equations. The runoff regression equation may not be applicable to the type of watersheds located in west-central Florida.

Peak discharges and runoff volumes for most storms were overestimated using the TR-20 model. The average errors between observed and estimated discharges and runoff volumes are smaller for the six urban watersheds than for the six natural watersheds using this method. Mean estimation errors for peak discharge indicate the method is more accurate for the urban watersheds than for the mixed or natural watersheds. Mean estimation errors for runoff volume data indicate the method is more accurate for the urban and mixed watersheds than for the natural watersheds. The mean estimation errors for all the storms modeled indicate the model has a tendency to overestimate peak discharges and runoff volumes for the watersheds. Examination of estimation errors and curve numbers indicate errors decrease as the average curve number for the watershed increases.

Peak discharges and runoff volumes for most storms were overestimated using the U.S. Army Corp of Engineers HEC-1 model. The average errors between observed and estimated discharges and runoff volumes are smaller for the six urban watersheds than for the six natural watersheds using this method. Mean estimation errors for peak discharge and runoff data indicate the method is more accurate for the urban watersheds than for the mixed or natural watersheds. The mean estimation error for all the storms modeled indicates the model has a tendency to overestimate peak discharge rates and runoff volumes for the watersheds included in the study. Examination of estimation errors and curve numbers indicates that errors decrease as the average curve number for the watershed increases.

The EPA SWMM model was run using both the Green-Ampt and the Horton infiltration methods, in separate simulations. Estimates calculated with the Horton method were slightly higher than those calculated with the Green-Ampt method. The average errors between observed and estimated peak discharges and runoff volumes are smaller for the six urban watersheds than for the six natural watersheds using the Green-Ampt infiltration method. Mean estimation errors for peak discharge indicate the Green-Ampt infiltration method is more accurate for the urban watersheds than for the mixed or natural watersheds. Mean estimation errors for runoff volume data indicate the Green-Ampt method is more accurate for the mixed watersheds than for the urban and natural watersheds. The mean estimation errors for all the storms modeled indicates the model, with the Green-Ampt infiltration method has a tendency to overestimate peak discharges and slightly underestimate runoff volumes. The mean estimation errors for peak discharges calculated using model with the Horton infiltration method, indicate the method is more accurate for the urban watersheds than for the mixed or natural watersheds. Mean estimation errors for runoff volume indicate that the Horton infiltration method is more accurate for the urban and mixed watersheds than for the natural watersheds. Comparison of estimation errors for peak discharge rates with watershed characteristics indicates very little correlation. Comparison of estimation errors for runoff volumes; however, indicates that errors generally decrease as the impervious area of the watershed increases. No correlation between runoff volume errors and other watershed characteristics is evident.

Evaluation of the standard estimation errors indicate the TR-20 model was more accurate than the other models for estimating peak discharges. The SWMM model with the Green-Ampt infiltration method was more accurate than the other models for estimating runoff volumes.

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Appendix I

Estimated Peak Discharges and Runoff Volumes for Synthetic Storms of 2, 5, 10, 25, 50, and 100 Year Recurrence Intervals Using the U.S. Geological Survey Regional Regression Equations

Apendix 1. Estimated peak discharges and runoff volumes for synthetic storms for the 2, 5, 10, 25, 50, and 100 year recurrence intervals using the U.S. Geological Survey regional regression equations

[cfs, cubic feet per second; in, inches]

Watershed name	Recurrence interval	Estimated: Peak discharge (cfs)	Estimated: Runoff volume (in)
Arctic Street storm drain	2	18	0.16
	5	40	.29
	10	60	.38
	25	89	.50
	50	113	.60
	100	140	.70
Kirby Street drainage ditch	2	75	.59
	5	157	1.00
	10	226	1.30
	25	327	1.70
	50	411	2.00
	100	502	2.30
St. Louis Street drainage ditch	2	43	.19
	5	93	.33
	10	135	.43
	25	196	.56
	50	247	.66
	100	303	.77
Gandy Boulevard drainage ditch	2	57	.24
	5	121	.40
	10	175	.53
	25	256	.69
	50	324	.82
	100	398	.95
Allen Creek	2	113	.24
	5	232	.40
	10	331	.51
	25	476	.66
	50	594	.78
	100	721	.90
IMC Creek	2	28	.41
	5	62	.72
	10	90	.94
	25	132	1.24
	50	166	1.46
	100	202	1.68

Apendix 1. Estimated peak discharges and runoff volumes for synthetic storms for the 2, 5, 10, 25, 50, and 100 year recurrence intervals using the U.S. Geological Survey regional regression equations (Continued)

[cfs, cubic feet per second; in, inches]

Watershed name	Recurrence interval	Estimated: Peak discharge (cfs)	Estimated: Runoff volume (in)
CFI-3 Creek	2	23	.39
	5	50	.69
	10	74	.91
	25	108	1.19
	50	136	1.41
	100	166	1.63
Grace Creek	2	68	.38
	5	141	.64
	10	204	.83
	25	294	1.07
	50	368	1.27
	100	447	1.46
Walker Creek	2	164	.26
	5	332	.43
	10	471	.55
	25	676	.71
	50	845	.84
	100	1030	.97
Clower Creek	2	24	.18
	5	53	.32
	10	78	.42
	25	115	.55
	50	147	.66
	100	182	.76
Catfish Creek	2	156	.40
	5	315	.67
	10	448	.86
	25	645	1.12
	50	808	1.32
	100	988	1.52
South Creek	2	57	.10
	5	124	.17
	10	187	.23
	25	271	.30
	50	347	.35
	100	432	.42

Apendix 1. Estimated peak discharges and runoff volumes for synthetic storms for the 2, 5, 10, 25, 50, and 100 year recurrence intervals using the U.S. Geological Survey regional regression equations (Continued)

[cfs, cubic feet per second; in, inches]

Watershed name	Recurrence interval	Estimated	
		Peak discharge (cfs)	Runoff volume (in)
Forked Creek	2	26	.14
	5	57	.24
	10	85	.32
	25	128	.44
	50	164	.52
	100	205	.61
Gottfried Creek	2	34	.17
	5	74	.29
	10	109	.39
	25	161	.51
	50	205	.61
	100	253	.71
Rock Creek	2	18	.13
	5	40	.23
	10	61	.31
	25	92	.42
	50	118	.50
	100	148	.59

Appendix II

Selected Input parameters to the U.S. Environmental Protection Agency Storm Water Management Model

Appendix 2. Selected input paramaeters to the U.S. Environmental Protection Agency Storm Water Management model. Ranges of values are given where varying initial soil moisture conditions were modeled

[DCIA, directly connected impervious area (percentage of the basin); IMPN, impervious area Manning's number; PERVN, pervious area Manning's number; IDS, impervious area depression storage (inches/impervious area); PDS, pervious area depression storage (inches/pervious area); F_0, maximum infiltration rate (in/hr); F_c, minimum infiltration rate (in/hr); SUCT, average capillary suction (in.); --, not applicable]

Watershed name	Area (acres)	Width (ft)	DCIA	Watershed slope (%)	IMP N	PERVN	IDS	PDS	F_o	F_c	SUCT
Arctic Street storm drain	218	11000	40	0.00233	0.012	0.25	0.0	0.0	3.0	0.30	4.0
Kirby street drainage ditch	736	25344	5.5	0.00153	0.010	0.35	0.1	0.1	3.0	0.30	4.0
St. Louis Street drainage ditch	326	11827	9.0	0.00193	0.010	0.16	0.0	0.0	1.0	0.10	8.0
Gandy Boulevard drainage ditch	826	17200	20	0.00087	0.010	0.29	0.0	0.0	1.0	0.10	8.0
Allen Creek	1203	14800	20	0.00443	0.012	0.28	0.0	0.0	0.5-1.0	0.10	8.0
IMC Creek	109	2000	0	0.00890	--	0.37	--	0.0	2.0-3.0	0.20	4.0
CFI-3 Creek	90	3960	0	0.00682	--	0.37	--	0.0	2.0-3.0	0.30	4.0
Grace Creek	422	10800	0	0.00492	--	0.32	--	0.0	3.0	0.30	4.0
Walker Creek	13	760	25	0.00300	0.015	0.45	0.1	0.1	1.0-3.0	0.30	4.0
	423	9200	30	0.00050	0.015	0.45	0.1	0.1	1.0-3.0	0.30	4.0
	326	7000	40	0.00100	0.015	0.45	0.5	0.5	1.0-3.0	0.30	4.0
	109	1580	20	0.00400	0.015	0.45	0.1	0.1	1.0-3.0	0.30	4.0
	755	7000	15	0.00100	0.015	0.45	0.2	0.2	1.0-3.0	0.30	4.0
	486	7200	40	0.00300	0.015	0.45	0.3	0.3	1.0-3.0	0.30	4.0
	346	5400	25	0.00100	0.015	0.45	0.1	0.1	1.0-3.0	0.30	4.0
	346	9000	40	0.00080	0.015	0.45	0.2	0.2	1.0-3.0	0.30	4.0
	256	4500	40	0.00200	0.015	0.45	0.1	0.1	1.0-3.0	0.30	4.0
Clower Creek	223	5300	85	0.00070	0.012	0.35	2.0	0.5	4.0	0.10	4.0

Appendix 2. Selected input paramaeters to the U.S. Environmental Protection Agency Storm Water Management model. Ranges of values are given where varying initial soil moisture conditions were modeled (Continued)

[DCIA, directly connected impervious area (percentage of the basin); IMPN, impervious area Manning's number; PERVN, pervious area Manning's number; IDS, impervious area depression storage (inches/impervious area); PDS, pervious area depression storage (inches/pervious area); F_0, maximum infiltration rate (in/hr); F_c, minimum infiltration rate (in/hr); SUCT, average capillary suction (in.); --, not applicable]

Watershed name	Area (acres)	Width (ft)	DCIA	Watershed slope (%)	IMP N	PERVN	IDS	PDS	F_0	F_c	SUCT
Catfish Creek	128	11000	5	0.00090	0.015	0.50	0.0	0.0	1.0-3.0	0.20	4.0
	160	6400	0	0.00030	--	0.30	--	0.1	1.0-3.0	0.20	4.0
	96	3400	5	0.00030	0.015	0.30	0.0	0.1	1.0-3.0	0.20	4.0
	262	5500	0	0.00050	--	0.35	--	0.1	1.0-3.0	0.20	4.0
	134	6000	0	0.00030	--	0.45	--	0.1	0.5-1.0	0.10	4.0
	13	600	30	0.00050	0.015	0.30	0.0	0.0	0.5-1.0	0.10	4.0
	26	2200	10	0.00050	0.015	0.30	0.0	0.0	0.5-1.0	0.10	4.0
	70	3400	5	0.00060	0.015	0.35	0.0	0.1	1.0-3.0	0.20	4.0
	77	4000	0	0.00030	--	0.40	--	0.1	1.0-3.0	0.20	4.0
	70	4400	10	0.00050	0.015	0.40	0.0	0.0	1.0-3.0	0.20	4.0
	333	6400	10	0.00080	0.015	0.40	0.0	0.1	1.0-3.0	0.20	4.0
	243	10340	0	0.00030	--	0.30	--	0.1	0.5-1.0	0.10	4.0
	102	3200	0	0.00030	--	0.35	--	0.0	0.5-1.0	0.10	4.0
	154	5610	0	0.00030	--	0.35	--	0.0	1.0-3.0	0.20	4.0
	250	5000	15	0.00060	0.015	0.20	0.0	0.1	1.0-3.0	0.20	4.0
	96	2660	0	0.00050	--	0.45	--	0.0	1.0-3.0	0.20	4.0
	442	2800	0	0.00020	--	0.45	--	0.1	1.0-3.0	0.20	4.0
	173	7200	20	0.00060	0.015	0.45	0.0	0.0	1.0-3.0	0.20	4.0
	128	5100	20	0.00070	0.015	0.45	0.0	0.0	1.0-3.0	0.20	4.0
	96	2600	0	0.00050	--	0.45	--	0.0	1.0-3.0	0.20	4.0

Appendix 2. Selected input paramaeters to the U.S. Environmental Protection Agency Storm Water Management model. Ranges of values are given where varying initial soil moisture conditions were modeled (Continued)

[DCIA, directly connected impervious area (percentage of the basin); IMPN, impervious area Manning's number; PERVN, pervious area Manning's number; IDS, impervious area depression storage (inches/impervious area); PDS, pervious area depression storage (inches/pervious area); F_0, maximum infiltration rate (in/hr); F_c, minimum infiltration rate (in/hr); SUCT, average capillary suction (in.); --, not applicable]

Watershed name	Area (acres)	Width (ft)	DCIA	Watershed slope (%)	IMP N	PERVN	IDS	PDS	F_o	F_c	SUCT
South Creek	269	6720	0	0.00030	--	0.40	--	0.0	3.0	0.05	4.0
	595	5720	5	0.00030	0.015	0.40	0.0	0.2	3.0	0.05	4.0
	832	7920	5	0.00050	0.015	0.40	0.0	0.0	3.0	0.10	4.0
	883	29100	0	0.00050	--	0.30	--	0.0	5.0	0.25	4.0
	256	12800	0	0.00040	--	0.30	--	0.0	5.0	0.25	4.0
	429	14000	0	0.00030	--	0.40	--	0.0	3.0	0.05	4.0
	262	10000	3	0.00040	0.015	0.40	0.0	0.1	3.0	0.05	4.0
	378	15600	0	0.00030	--	0.35	--	0.1	5.0	0.25	4.0
	512	12600	0	0.00030	--	0.35	--	0.1	3.0	0.10	4.0
	755	36000	1	0.00040	0.015	0.40	0.0	0.2	3.0	0.05	4.0
	640	18000	0	0.00030	--	0.35	--	0.1	5.0	0.25	4.0
	698	15200	0	0.00040	--	0.30	--	0.1	5.0	0.25	4.0
	416	6000	1	0.00040	0.015	0.35	0.0	0.1	3.0	0.05	4.0
	33	3200	0	0.00030	--	0.40	--	0.2	3.0	0.05	4.0
	1300	27000	0	0.00040	--	0.35	--	0.1	3.0	0.10	4.0
	704	9800	1	0.00060	0.015	0.35	0.0	0.1	3.0	0.05	4.0
	474	9200	0	0.00060	--	0.40	--	0.1	3.0	0.10	4.0
Forked Creek	58	2000	0	0.00060	--	0.25	--	0.1	3.0	0.05	4.0
	173	4800	0	0.00050	--	0.40	--	0.1	5.0	0.25	4.0
	877	5000	0	0.00060	--	0.25	--	0.2	5.0	0.25	4.0
	224	4200	0	0.00020	--	0.35	--	0.0	3.0	0.05	4.0
	102	2000	0	0.00040	--	0.35	--	0.2	3.0	0.05	4.0
	205	7650	0	0.00040	--	0.30	--	0.1	5.0	0.25	4.0
	166	8200	0	0.00060	--	0.40	--	0.1	5.0	0.25	4.0

Appendix 2. Selected input paramaeters to the U.S. Environmental Protection Agency Storm Water Management model. Ranges of values are given where varying initial soil moisture conditions were modeled (Continued)

[DCIA, directly connected impervious area (percentage of the basin); IMPN, impervious area Manning's number; PERVN, pervious area Manning's number; IDS, impervious area depression storage (inches/impervious area); PDS, pervious area depression storage (inches/pervious area); F_0, maximum infiltration rate (in/hr); F_c, minimum infiltration rate (in/hr); SUCT, average capillary suction (in.); --, not applicable]

Watershed name	Area (acres)	Width (ft)	DCIA	Watershed slope (%)	IMP N	PERVN	IDS	PDS	F_0	F_c	SUCT
Gottfried Creek	326	4700	0	0.00030	--	0.40	--	0.1	3.0	0.05	4.0
	64	2900	0	0.00050	--	0.40	--	0.1	3.0	0.05	4.0
	58	1200	10	0.00030	0.015	0.40	0.2	0.2	5.0	0.25	4.0
	192	2700	5	0.00050	0.015	0.40	0.2	0.2	3.0	0.05	4.0
	58	3000	2	0.00050	0.015	0.35	0.2	0.2	5.0	0.25	4.0
	19	600	0	0.00050	--	0.35	--	0.1	4.0	0.10	4.0
	38	1400	0	0.00050	--	0.40	--	0.1	5.0	0.25	4.0
	115	1500	10	0.00040	0.015	0.30	0.1	0.1	4.0	0.10	4.0
	64	1500	5	0.00050	0.015	0.40	0.1	0.1	3.0	0.05	4.0
	83	1200	10	0.00050	0.015	0.30	0.1	0.1	4.0	0.10	4.0
	77	900	0	0.00050	--	0.40	0.1	3.0	3.0	0.05	4.0
	77	2000	10	0.00040	0.015	0.30	0.1	0.1	5.0	0.25	4.0
	109	3000	10	0.00040	0.015	0.30	6.0	6.0	5.0	0.25	4.0
Rock Creek	589	12000	0	0.00070	--	0.35	--	0.5	3.0	0.05	4.0
	832	6000	0	0.00050	--	0.35	--	0.8	3.0	0.05	4.0
	262	9000	0	0.00050	--	0.35	--	0.1	3.0	0.05	4.0

Appendix III

Selected Ground Water Input Parameters to the U.S. Environmental Protection Agency Storm Water Management Model

Appendix 3. Selected ground water input paramaeters to the U.S. Environmental Protection Agency Storm Water Management model. Ranges of values are given where varying initial soil moisture conditions were modeled

[IMD, initial moisture deficit of soil (in/in); A_1, ground water flow coefficient (in/hrft); HKSAT, saturated subsurface hydraulic conductivity (in/hr); TH_1, initial upper zone moisture content (in/in); --, not applicable]

Watershed name	IMD	Depth to water table (ft)	A_1	B_1	Soil porosity (in/in)	Wilting point (in/in)	Field capacity (in/in)	HKSAT	TH_1
Arctic Street storm drain	0.30	--	--	--	--	--	--	--	--
Kirby street drainage ditch	0.30	--	--	--	--	--	--	--	--
St. Louis Street drainage ditch	0.25	--	--	--	--	--	--	--	--
Gandy Boulevard drainage ditch	0.25	--	--	--	--	--	--	--	--
Allen Creek	0.15-0.25	--	--	--	--	--	--	--	--
IMC Creek	0.25-0.30	2.6-4.4	4.06E-06	2	0.40	0.12	0.26	5.35	0.24-0.28
Grace Creek	0.25-0.30	1.8-2.0	1.58E-06	2	0.40	0.12	0.26	0.57	0.25-0.28
CFI-3 Creek	0.30	0.9-2.9	5.49E-05	2	0.40	0.12	0.26	0.65	0.25-0.28
Walker Creek	0.20-0.30	1.5-2.0	5.00E-05	2	0.40	0.13	0.26	2.00	0.25-0.28
	0.20-0.30	1.5-2.0	5.00E-05	2	0.40	0.13	0.26	2.00	0.25-0.28
	0.20-0.30	1.5-2.0	5.00E-05	2	0.40	0.13	0.26	2.00	0.25-0.28
	0.20-0.30	1.5-2.0	5.00E-05	2	0.40	0.13	0.26	2.00	0.25-0.28
	0.20-0.30	2.5-3.0	5.00E-05	2	0.40	0.13	0.26	2.00	0.25-0.28
	0.20-0.30	1.5-2.0	5.00E-05	2	0.40	0.13	0.26	2.00	0.25-0.28
	0.20-0.30	1.5-2.0	5.00E-05	2	0.40	0.13	0.26	2.00	0.25-0.28
	0.20-0.30	1.5-2.0	5.00E-05	2	0.40	0.13	0.26	2.00	0.25-0.28
	0.20-0.30	1.5-2.0	5.00E-05	2	0.40	0.13	0.26	2.00	0.25-0.28
Clower Creek	0.20	--	--	--	--	--	--	--	--

Appendix 3. Selected ground water input paramaeters to the U.S. Environmental Protection Agency Storm Water Management model. Ranges of values are given where varying initial soil moisture conditions were modeled (Continued)

[IMD, initial moisture deficit of soil (in/in); A_1, ground water flow coefficient (in/hrft); HKSAT, saturated subsurface hydraulic conductivity (in/hr); TH_1, initial upper zone moisture content (in/in); --, not applicable]

Watershed name	IMD	Depth to water table (ft)	A_1	B_1	Soil porosity (in/in)	Wilting point (in/in)	Field capacity (in/in)	HKSAT	TH_1
Catfish Creek	0.10-0.20	1.4-2.2	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.4-2.2	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.2-2.0	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.4-2.2	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.2-2.0	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.2-2.0	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.2-2.0	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.7-2.5	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	0.9-1.7	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.0-1.8	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.7-2.5	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.4-2.2	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.2-2.0	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.2-2.0	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.2-2.0	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	0.7-1.5	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.2-2.0	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	0.7-1.5	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	0.7-1.5	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30
	0.10-0.20	1.2-1.5	5.00E-05	2	0.40	0.17	0.26	6.00	0.25-0.30

Appendix 3. Selected ground water input paramaeters to the U.S. Environmental Protection Agency Storm Water Management model. Ranges of values are given where varying initial soil moisture conditions were modeled (Continued)

[IMD, initial moisture deficit of soil (in/in); A_1, ground water flow coefficient (in/hrft); HKSAT, saturated subsurface hydraulic conductivity (in/hr); TH_1, initial upper zone moisture content (in/in); --, not applicable]

Watershed name	IMD	Depth to water table (ft)	A_1	B_1	Soil porosity (in/in)	Wilting point (in/in)	Field capacity (in/in)	HKSAT	TH_1
South Creek	0.20	1.5-3.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5-3.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.5-3.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.0-2.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.0-3.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5-2.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5-2.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5-2.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.0-2.5	5.00E-03	2	0.40	0.17	0.26	20.00	0.25
	0.20	1.5-2.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.0-2.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.0-3.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.0-2.5	5.00E-03	2	0.40	0.17	0.26	20.00	0.25
	0.20	1.0-1.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5-2.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.0-2.0	5.00E-03	2	0.40	0.17	0.26	20.00	0.25
	0.20	1.5-2.5	5.00E-03	2	0.40	0.17	0.26	20.00	0.25
Forked Creek	0.20	1.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.0	5.00E-03	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.0	5.00E-03	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.0	5.00E-03	2	0.40	0.17	0.26	10.00	0.25

Appendix 3. Selected ground water input paramaeters to the U.S. Environmental Protection Agency Storm Water Management model. Ranges of values are given where varying initial soil moisture conditions were modeled (Continued)

[IMD, initial moisture deficit of soil (in/in); A_1, ground water flow coefficient (in/hrft); HKSAT, saturated subsurface hydraulic conductivity (in/hr); TH_1, initial upper zone moisture content (in/in); --, not applicable]

Watershed name	IMD	Depth to water table (ft)	A_1	B_1	Soil porosity (in/in)	Wilting point (in/in)	Field capacity (in/in)	HKSAT	TH_1
Gottfried Creek	0.20	1.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5	5.00E-03	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	3.0	5.00E-03	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.5	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.0	5.00E-03	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.0	5.00E-03	2	0.40	0.17	0.26	10.00	0.25
	0.20	2.5	5.00E-03	2	0.40	0.17	0.26	10.00	0.25
Rock Creek	0.20	1.0	1.00E-04	2	0.40	0.17	0.26	10.00	0.25
	0.20	0.7	1.00E-03	2	0.40	0.17	0.26	10.00	0.25
	0.20	1.0	1.00E-02	2	0.40	0.17	0.26	10.00	0.25