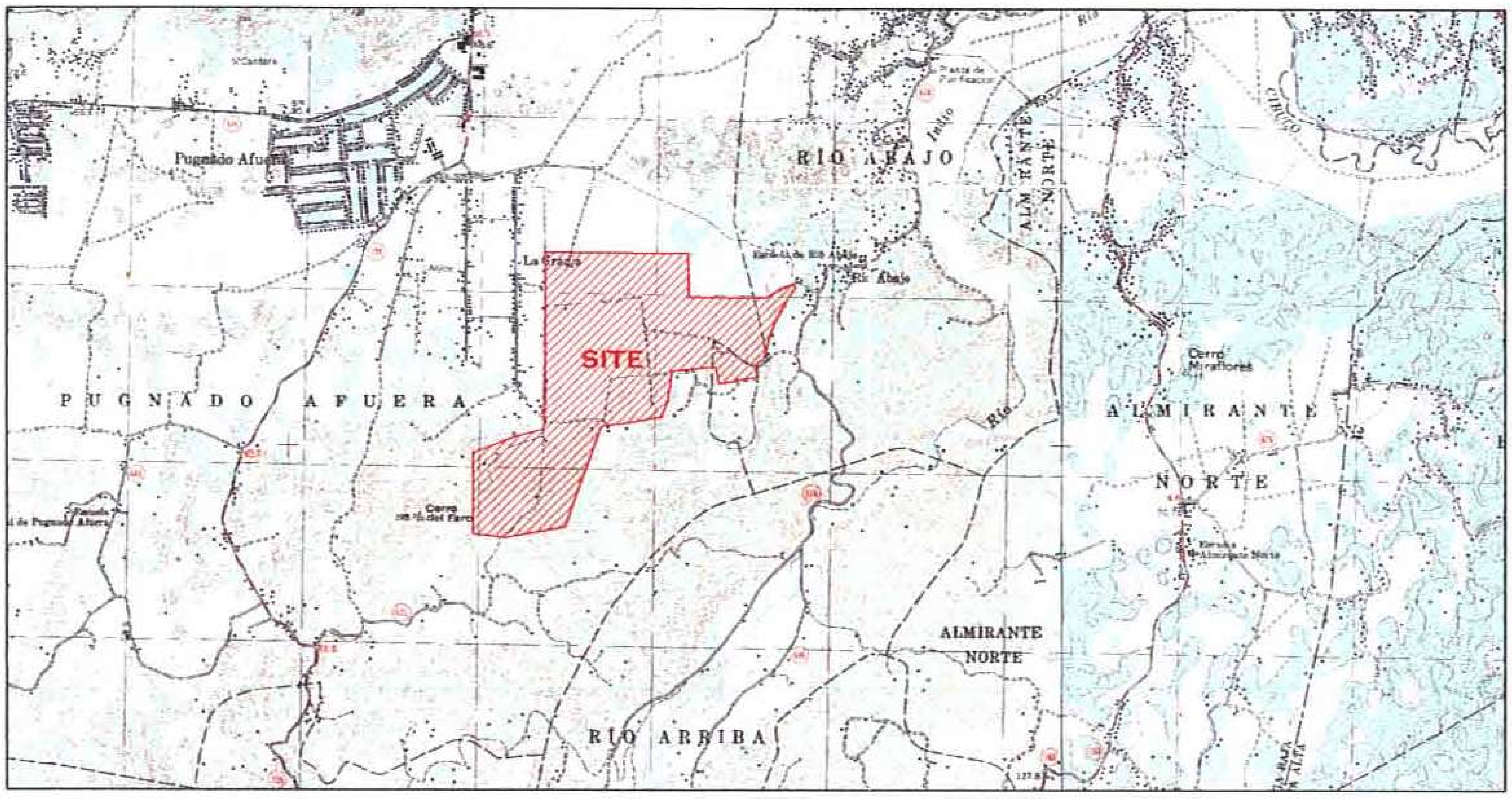
ANEJO 7: ESTUDIO HIDRALOGICO HIDRAULICO

MORA DEVELOPMENT CORP.
SAN JUAN, PUERTO RICO

HYDROLOGY-HYDRAULIC STUDY FOR LA SABANA VEGA BAJA, PUERTO RICO



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HYDROLOGIC-HYDRAULIC STUDY
LA SABANA
VEGA BAJA, PUERTO RICO

Casiano Ancalle, P.E.

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I. INTRODUCTION

Mora Development plans to construct a residential development project named La Sabana. The project site is located at Río Abajo, in the Municipality of Vega Baja. The project consists on several housing units provided with the pertaining facilities.

Runoff from an extensive offsite drainage area enters into the site. Runoff from the project site discharges to the north and runs from west to east at the northern limit of the site. According to the regulatory flood maps, the project site is not considered floodable for the 100-year rainfall event.

The southern portion of the project site is characterized by having karstic formations: hills and also sinkholes. The development will not affect these formations.

The development of the site will increase runoff. This increase has to be mitigated according to the stipulations of the Puerto Rico Planning Board Regulation No. 3.

Purpose of Study

The purpose of the study is to estimate the amount of runoff for existing and proposed condition. And since the project will increase runoff, the study will analyze mitigation for the increment in accordance to the Puerto Rico Planning Board Regulation No. 3. In addition, the study will determine the hydraulic performance of the proposed storm sewer system including the hydraulic impact resulting from the development.

Authorization

Mr. Alejandro Rubi on behalf of Mora Development Corp., authorized this study under a contract signed with Eng. Casiano Ancalle, principal of CA Engineering.

Approach

The following steps have been undertaken throughout the study:

Hydrologic Analysis: The following parameters were determined for the hydrologic analysis: drainage areas, average soil curve number and runoff lag time. Based on these parameters, discharge for 100-years frequency storm was determined for existing and proposed conditions. HEC-1 model was used. Hydrologic analysis more recurrent storm events were also estimated.

Mitigation Analysis: A mitigation analysis was made in order to counteract the impact of the proposed development. HEC-1 model was used for the mitigation analysis. Discharges for 2-, 10-, 25-, 50-, and 100-year frequencies were analyzed for mitigation

Hydraulic Analysis: A hydraulic analysis was made in order to size the storm sewer structures that will convey the offsite runoff through the site as well as the local runoff discharge. The hydraulic analysis was made for a 100-year discharge. The mathematical model HECRAS was used.

Conclusions and recommendations were elaborated.

II. PROJECT BACKGROUND

Location

The project site for development is located at Pugnado Afuera Ward, in the Municipality of Vega Baja. The site can be accessed from PR-155. The project site bounds north with Vega Serena II and part of Vega Serena I, east with the other part of Vega Serena I, south with the vast area of karstic formations, and west with Comunidad La Granja. The total area of the project site is about 326 acres. Figure 1 shows the approximate location of the site in the USGS quadrangle. Figure 2 shows a layout of the proposed project.

Site Description and Topography

Existing topography is mildly sloped from southwest to northeast with ground elevations varying from 130 to 48 m. (M.S.L.). Sinkholes are located to the northeast of the property. The project area it is covered by moderate to dense grass. Surface runoff with high water abstractions (storage and infiltration) are known to occur in the area. Figure 3 shows the existing topography of the site.

Storm Drainage

The total drainage area affecting the project site is about 851.83 acres: 525.57 acres corresponds to offsite areas located mainly to the south, and 326.26 acres to the project site. The whole runoff from the project site and offsite discharges into the sinkholes located west of the site. But there is no a prominent storm waterway channel, except for a mild valley converging to the sinkholes area. Alike other areas at the north coast of Puerto Rico, this watershed area lays on karstic formations. Thus, surface runoff is depressed as good amount of the rainfall infiltrates into the subsoil forming groundwater aquifers.

Water Bodies

There are no visible water bodies on the project site. Local runoff drains to the east towards the sinkholes. Most of the runoff water is disposed through sinkholes.

Flooding

From the regulatory point of view, the project site is not classified as floodable for a 100-year rainfall event. Figure 7 shows a portion of the Firm Insurance Rate Map, Sheet 295H issued on April 19, 2005.

Sinkholes

The totality of the project site storm water runoff discharge is disposed into the sinkholes and through percolation into the subsoil as runoff moves to the downstream. But there are unknowns about the runoff of major rainfall events. Some neighbors affirm that floods are common during a major rainfall, and that the sinkholes are overflowed; and others indicate that in spite of large amount of runoff floods are not a major problem. These sinkholes are located in the eastern end of the site.

Field Work

Field data used in this study was taken by drawings provided by Eng. Alejandro Rubi. This information was used for the hydraulic modeling. Results obtained in this study are strictly based on this information. Fieldwork is attached in a pocket at the end of this study as Appendix F.

Former Studies

No previous H/H studies for the area under study were found. So, all the information gathered for the study was through the survey work and visual site inspection.

Study Level

This study is intended as an aid to the design engineer in the preparation of the construction drawings for the recommended structures. Figures, schematics and drawings must not be used as construction drawings. The design engineer must elaborate the construction drawings in agreements with the recommendations of this study.

III. HYDROLOGIC ANALYSIS

Methodology

The computer program entitled Flood Hydrograph Package (HEC-1) developed by the U.S. Army Corps of Engineers [1990] was used for the hydrologic analysis. Using this program, the Unit Hydrograph method and the Runoff Curve Number (CN) method, both developed by the Soil Conservation Service (SCS), were applied to determine the design hydrograph. This was computed by a process of translating the rainfall excess into a runoff hydrograph known as convolution.

Peak discharges ranging in frequencies from 2-,10-, 25-, 50- and 100-year were estimated for the existing and proposed condition.

Drainage Areas and Runoff Pattern

The project's offsite drainage areas at existing condition are subdivided in eight (8): E (286.58 acres),E1 (5.30 acres), E2 (5.45 acres), E3 (17.77 acres), E4 (15.53 acres), E5 (21.03 acres) , E6 (39.77 acres) & E7 (94.47 acres) drains toward the project. And the project site is subdivided in three (3): P1 (69.18 acres), P2 (218.07 acres) and P3 (39.01 acres). At proposed condition, the drainage areas were rearranged. Area P1 now has 89.60 acres, Area P2A 16.82 acres, Area P2B 17.85 acres, Area P2C 14.90 acres, Area P2D 18.53 acres Area P2E 49.36 acres, Area P2F 28.25 acres, Area P2G 41.91 acres, Area P3A 13.46 acres and Area P3B 31.42 acres. Figure 4 shows these drainage areas at existing condition, and Figure 5 at proposed condition.

Curve Numbers

The Hydrologic Soil Group (HSG) for the site was obtained from the US Soil Conservation Service maps (See Figure 6). Curve Number for existing condition was estimated in virtue of the soil use as per the site inspection. A weighted Curve Number (CN) value was estimated for each drainage area. Values fluctuated between 80.45 and 87.89. A CN of 93 was adopted for proposed condition.

Time of Concentration

The Lag Time (T_{Lag}) was estimated using the SCS method defined as:

$$T_{Lag} = \frac{L^{0.8}(S+1)^{0.7}}{1900\ Y^{0.5}}$$

where :	L	=	channel length (ft)
	S	=	1000/CN - 10
	Y	=	average watershed slope

Detailed Lag Time calculation is shown in Appendix A.

Rainfall Data

The variation of rainfall volume with time was required as part of the storm input for the SCS Curve Number method. Therefore, the development of a design storm with a rainfall frequency and duration was necessary to compute the design hydrograph for the watershed. Rainfall data used in this study was obtained from the Technical Paper No. 42 (TP-42) [National Weather Service, 1961].

The rainfall event of 100-, 50-, 25, and 10-years frequency for many durations was used and are shown in Table 1. Rainfall for 5 and 15 minutes were estimated by regression analysis, details of these calculations are shown in Appendix A.

Table 1
Rainfall for 2, 10, 25, 50 y 100 years

Duration *Hrs.*	**Precipitation** *Inches*			
	10-yr	***25-yr***	***50-yr***	***100-yr***
0.083	0.27	0.32	0.34	0.39
0.25	0.75	0.90	0.97	1.10
1	3.35	3.62	4.00	4.50
2	3.95	4.65	5.30	5.65
3	4.40	5.25	5.90	6.80
6	5.40	6.50	7.50	8.00
12	6.60	7.70	8.70	9.80
24	7.80	9.20	10.50	11.60

Depth-Area Adjustment

Point rainfall estimates obtained from the TP-42 represent values for areas up to 10 mi^2; therefore, a depth-area adjustment should be applied to the rainfall data when the watershed area is greater. In this case, the project site watershed is approximately 0.448 mi^2. Hence, this adjustment was not applied.

Time Distribution of Rainfall

The triangular type methodology was used to distribute the rainfall depth in time. This method is considered acceptable for small areas.

Rainfall Extraction

Rainfall extraction such as the vegetative interception, the depressional storage, and the infiltration were estimated using the SCS's Runoff Curve Number method. Though this method is used to predict runoff volume directly, the rainfall extraction is incorporated in the model as function of the curve number of the watershed.

Hydrologic Results

Following HEC-1 methodology, peak discharges were determined from the hydrographs developed for existing and proposed condition.

Input and output data for the HEC-1 model are included in Appendix B and Appendix C for existing and proposed condition respectively. Table 2 shows the results of the hydrologic runs.

Table 2

Peak Discharges

AREA		Peak Discharge, cfs				
		2-yr	10-yr	25-yr	50-yr	100-yr
Existing	E3	45	71	77	87	98
	CHANN	46	71	78	88	99
	E4	30	50	58	66	76
	CHANN	28	50	57	67	77
	COMB1	71	121	135	154	176
	E2	15	23	25	28	31
	COMB2	83	141	158	180	205
	CHANN	82	135	154	173	197
	P1	134	213	244	273	311
	COMB3	211	337	387	436	494
	CHANN	208	338	388	436	495
	E1	10	17	19	22	25
	COMB4	214	354	407	457	519
	E	456	752	862	974	1103
	COMB5	668	1089	1238	1396	1583
	CHANN	666	1079	1232	1388	1577

	E5	51	82	90	101	114
	CHANN	51	82	91	102	115
	E6	93	150	167	189	214
	CHANN	92	149	164	187	211
	COMB6	132	219	247	279	318
	P2	338	582	672	763	872
	COMB7	451	763	873	989	1128
	CHANN	451	760	872	988	1126
	COMB8	1080	1800	2064	2334	2652
	CHANN	1078	1794	2060	2330	2648
	E7	175	278	315	353	400
	CHANN	174	276	314	353	399
	P3	81	132	151	170	193
	COMB9	242	386	436	490	556
	COMB10	1304	2172	2486	2808	3188
Proposed	E3	45	71	77	87	98
	CHANN	46	71	78	88	99
	E4	30	50	58	66	76
	CHANN	28	50	57	67	77
	COMB1	71	121	135	154	176
	E2	15	23	25	28	31
	COMB2	83	141	158	180	205
	CHANN	81	138	156	177	202
	P1	157	255	290	327	370
	COMB3	232	372	420	472	534
	CHANN	230	370	418	470	533
	E5	51	82	90	101	114
	COMB4	268	427	480	541	613
	CHANN	264	423	479	539	611
	P2E	113	167	188	209	235

PIPE	113	167	188	208	234
E6	93	150	167	189	214
COMB5	448	706	801	899	1017
CHANN	447	705	798	894	1013
E7	175	278	315	353	400
COMB6	619	975	1102	1237	1400
CHANN	616	974	1099	1233	1396
E	456	752	862	974	1103
E1	10	17	19	22	25
COMB8	460	762	873	987	1117
P2A	41	60	66	74	83
PIPE	40	60	66	73	83
P2B	46	68	75	84	94
COMB	86	128	141	157	177
P2D	44	66	73	81	92
PIPE	44	65	73	81	91
P2C	34	51	57	64	71
COMB	78	117	130	145	163
PIPE	78	116	130	144	162
COMB	161	240	268	296	334
PIPE	159	238	267	296	334
P2F	71	106	117	130	147
COMB	231	344	380	422	474
PIPE	228	340	379	421	474
P2G	100	149	165	183	206
P3B	95	137	145	163	183
P3A	41	60	64	71	80
COMB	136	197	208	234	263
COMB	1442	2271	2557	2871	3245

From the inspection of Table 2, the peak discharge at proposed condition is higher than that of the existing condition. The increment in discharge has to be mitigated as required by Puerto Rico Planning Board Regulation No. 3.

IV. RUNOFF MITIGATION ANALYSIS

The development of the site will increase the runoff discharge. The Puerto Rico Planning Board Regulation No. 3 requires a flow mitigation structure wherever an increase in discharge is produced. Therefore, flow detention structures will be included in the project.

Methodology

The computer program HEC-1 provides means for routing a hydrograph through detention structures. The purpose of detention is that the proposed condition peak discharge does not exceed the existing condition peak discharge. Runoff discharge mitigation at areas P3G, P3A and P3B will contribute in reducing the combined peak discharge of the overall project drainage areas below the discharge at existing condition.

Runoff Mitigation Ponds

Two detentions ponds were evaluated in the study. These ponds are addressed to mitigate the increment in discharge from the site. Pond P1 will be located at the northeast of the project site. Pond P2 at the very east. Figure 8 shows the location of both of them considering Alternative "A" and Figure 9 considering Alternative "B".

Depth-Volume Relations

Volume-depth relations developed for the mitigation system is based on rectangular ponds with a 5,354-square meter bottom area for Pond P1, 6,877-square meter bottom area for pond P2. Both ponds will have a bank slope of 2H:1V. Volume-Depth curve computations are included in Appendix D.

Flow Rating Curve

Flow–Depth relation for the detention pond P1 was estimated considering the discharge through one (1) 2.0'-diameter orifice located at the bottom of the pond, three (3) 2.0'-diameter orifices located at the 2.0 m above the pond bottom and a 7.31-meter long weir at 2.80 meter above the pond bottom. For pond P2, the control consists on one (1) 1.0'-diameter orifice at the bottom of the pond and a 2.43-meter long weir at 2.60 meter above the pond bottom. Flow through the orifices was computed using Torrecelli's formula. Appendix D shows the computations for the flow-depth relationship and the curves.

Results

The results of the detention analysis show that the proposed detention pond provides appropriate runoff mitigation for the 100-year frequency discharges. By routing the local discharges through the detention ponds, the 100-year discharge from the whole site was reduced from 3,245 cfs to 3,073 cfs, which is less than the discharge computed for existing condition, 3,188 cfs; thus complying with Regulation No.3. Mitigation for more recurrent discharges was also verified.

Input and output data for the HEC-1 mitigation model are included in Appendix E. Table 4 shows the comparison of the discharges for existing, and proposed condition.

Table 3
Mitigation Analysis Results Comparison

AREA		Peak Discharge, cfs				
		2-yr	10-yr	25-yr	50-yr	100-yr
Existing	E3	45	71	77	87	98
	CHANN	46	71	78	88	99
	E4	30	50	58	66	76
	CHANN	28	50	57	67	77
	COMB1	71	121	135	154	176
	E2	15	23	25	28	31
	COMB2	83	141	158	180	205
	CHANN	82	135	154	173	197
	P1	134	213	244	273	311

	COMB3	211	337	387	436	494
	CHANN	208	338	388	436	495
	E1	10	17	19	22	25
	COMB4	214	354	407	457	519
	E	456	752	862	974	1103
	COMB5	668	1089	1238	1396	1583
	CHANN	666	1079	1232	1388	1577
	E5	51	82	90	101	114
	CHANN	51	82	91	102	115
	E6	93	150	167	189	214
	CHANN	92	149	164	187	211
	COMB6	132	219	247	279	318
	P2	338	582	672	763	872
	COMB7	451	763	873	989	1128
	CHANN	451	760	872	988	1126
	COMB8	1080	1800	2064	2334	2652
	CHANN	1078	1794	2060	2330	2648
	E7	175	278	315	353	400
	CHANN	174	276	314	353	399
	P3	81	132	151	170	193
	COMB9	242	386	436	490	556
	COMB10	1304	2172	2486	2808	3188
Proposed	E3	45	71	77	87	98
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	CHANN	28	50	57	67	77
	COMB1	71	121	135	154	176
	E2	15	23	25	28	31
	COMB2	83	141	158	180	205

CHANN	81	138	156	177	202
P1	157	255	290	327	370
COMB3	232	372	420	472	534
CHANN	230	370	418	470	533
E5	51	82	90	101	114
COMB4	268	427	480	541	613
CHANN	264	423	479	539	611
P2E	113	167	188	209	235
PIPE	113	167	188	208	234
E6	93	150	167	189	214
COMB5	448	706	801	899	1017
CHANN	447	705	798	894	1013
E7	175	278	315	353	400
COMB6	619	975	1102	1237	1400
CHANN	616	974	1099	1233	1396
E	456	752	862	974	1103
E1	10	17	19	22	25
COMB8	460	762	873	987	1117
P2A	41	60	66	74	83
PIPE	40	60	66	73	83
P2B	46	68	75	84	94
COMB	86	128	141	157	177
P2D	44	66	73	81	92
PIPE	44	65	73	81	91
P2C	34	51	57	64	71
COMB	78	117	130	145	163
PIPE	78	116	130	144	162
COMB	161	240	268	296	334
PIPE	159	238	267	296	334

	P2F	71	106	117	130	147
	COMB	231	344	380	422	474
	PIPE	228	340	379	421	474
	P2G	100	149	165	183	206
	P3B	95	137	145	163	183
	P3A	41	60	64	71	80
	COMB	136	197	208	234	263
	COMB	1442	2271	2557	2871	3245
Proposed w/ Mitigation	E3	45	71	77	87	98
	CHANN	46	71	78	88	99
	E4	30	50	58	66	76
	CHANN	28	50	57	67	77
	COMB1	71	121	135	154	176
	E2	15	23	25	28	31
	COMB2	83	141	158	180	205
	CHANN	81	138	156	177	202
	P1	157	255	290	327	370
	COMB3	232	372	420	472	534
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	COMB6	619	975	1102	1237	1400
	CHANN	616	974	1099	1233	1396
	E	456	752	862	974	1103
	E1	10	17	19	22	25
	COMB8	460	762	873	987	1117
	P2A	41	60	66	74	83
	PIPE	40	60	66	73	83
	P2B	46	68	75	84	94
	COMB	86	128	141	157	177
	P2D	44	66	73	81	92
	PIPE	44	65	73	81	91
	P2C	34	51	57	64	71
	COMB	78	117	130	145	163
	PIPE	78	116	130	144	162
	COMB	161	240	268	296	334
	PIPE	159	238	267	296	334
	P2F	71	106	117	130	147
	COMB	231	344	380	422	474
	PIPE	228	340	379	421	474
	P2G	100	149	165	183	206
	POND	9	54	87	115	149
	P3B	95	137	145	163	183
	P3A	41	60	64	71	80
	COMB	136	197	208	234	263
	POND	28	37	41	50	64
	COMB	1299	2065	2370	2696	3073

For the mitigation analysis, the bottom geometry of the pond has been considered square but another shape can be used as well if the magnitude of the area is maintained. Figure 10 and Figure 11 shows the schematic design of the detention ponds.

Pond Discharge

Discharge pipe for pond P1 will be of 60" diameter and the discharge for Pond P2 will be through the 42" pipe.

Mitigation Structure Dimensions and Accessories

Final dimensions for the mitigation pond will have the characteristics shown in Table 4 and Table 5, for Pond P1 and Pond P2, respectively.

Table 4
Typical Detention Pond-1 Characteristics

Pond P1	Dimensions	Bottom Area	5,354 m^2
		Height	3.68 m
	Outlet Control	Orifice @ bottom	One-1.0'Diameter
		Orifice @ 2.0 m bottom	Three-2.0'Diameter
		Weir Length @ 2.80m	7.31 m

Table 5
Typical Detention Pond-2 Characteristics

Pond P1	Dimensions	Bottom Area	6877 m^2
		Height	3.55 m
	Outlet Control	Orifice @ bottom	One-1.0'Diameter
		Weir Length @ 2.60m	2.43 m

V. HYDRAULIC ANALYSIS

A hydraulic analysis of the main storm sewer system was made in order to secure its capacity to convey the 100-year discharge from the site and from the offsite.

The hydraulic analysis was made by using the mathematical model HEC-RAS developed by the US Corps of Engineers.

Roughness

The friction coefficient used in the modeling was obtained from visual inspection of the existing structures; and cross-checked with the typical values provided by Barnes (1967) and Chow (1959). Manning's coefficient used for modeling the drainage system was 0.013 concrete pipe and box culvert and 0.024 corrugated metal conduit.

Cross sections

The hydraulic analysis was made with the mathematical model HECRAS. Location of cross sections is shown in Figure 12.

Contraction and Expansion Coefficients

Coefficients of contraction and expansion used are those recommended by the HEC-RAS user's manual. Thus, coefficients of 0.1 and 0.3 respectively were used for gradual transitions.

Hydraulics Analysis

Hydraulic analysis has been made for sizing the main storm sewer collection. This main will take the offsite discharge, as well as the local runoff, and convey them to the east, to the sinkholes area. The system consists on three network of conduits: The larger at the north, a small one by the center and the last at the south. The two former are closed conduits and the last is a combination of trapezoidal peripheral open channel and closed conduits.

Two alternatives were tried for the northern network, both of the feasible. Alternative "A" is by using concrete box culverts and Alternative "B" by using corrugated aluminum Arch-Pipe.

The computer output for the hydraulics analysis is included in Appendix F. The following Tables 6 and 7 include the results for Alternative "A" and Alternative "B", respectively. Tables 8 include the summary of the results for the open channel, to serve Area P2E and the southern offsite area, and Table 9 for the 36" diameter pipe, telescoping to 60", to serve Area P2G.

Table 6

Hydraulics 100-yr for Area north with Box Culvert Alternative "A"

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
two	17	100 year	0.78	76.49	77.43	76.74	77.44	0.000075	0.41	1.89	2.00	0.14
two	16.8		Culvert									
two	16.51	100 year	0.78	73.34	74.59		74.59	0.000036	0.31	2.50	2.00	0.09
two	16.5	100 year	1.56	73.34	74.57	73.73	74.59	0.000149	0.63	2.47	2.00	0.18
two	16.2		Culvert									
two	16.1	100 year	1.56	70.69	72.43		72.44	0.000062	0.45	3.48	2.00	0.11
two	16	100 year	2.60	70.69	72.41	71.24	72.44	0.000178	0.76	3.44	2.00	0.18
two	15.5		Culvert									
two	15	100 year	2.60	65.19	66.37		66.43	0.000468	1.10	2.35	2.00	0.33
one	14	100 year	4.61	64.28	66.37	65.09	66.43	0.000348	1.10	4.17	2.00	0.24
one	13.5		Culvert									
one	13	100 year	4.61	55.82	59.02		59.04	0.000126	0.72	6.39	2.00	0.13
two	12	100 year	7.92	68.64	69.67	69.67	70.05	0.002456	2.72	2.92	3.95	1.01
two	11.1	100 year	7.92	61.64	62.05	62.67	68.27	0.124271	11.05	0.72	2.56	6.67
two	11	100 year	7.92	60.58	60.91	61.75	68.04	0.149494	11.83	0.67	2.00	6.53
two	10.5		Culvert									
two	10.1	100 year	7.92	57.37	61.03		61.09	0.000273	1.08	7.32	2.00	0.18
two	10	100 year	10.28	57.12	61.06	57.99	61.08	0.000049	0.65	15.74	4.00	0.11
two	9.5		Culvert									
two	9.1	100 year	10.28	56.91	60.54		60.56	0.000061	0.71	14.50	4.00	0.12
two	9	100 year	10.28	56.91	60.54	57.78	60.56	0.000061	0.71	14.50	4.00	0.12
two	8.5		Culvert									
two	8	100 year	10.28	56.17	59.84		59.87	0.000059	0.70	14.70	4.00	0.12
one	7	100 year	33.44	55.50	59.78	56.97	59.86	0.000135	1.30	25.66	6.00	0.20

one	6.5		Culvert									
one	6	100year	33.44	54.70	58.95		59.04	0.000137	1.31	25.49	6.00	0.20
two	5	100year	0.70	76.34	76.65	76.65	76.76	0.003043	1.48	0.47	2.15	1.01
two	4.5	100year	23.95	72.17	73.40	73.90	75.13	0.009556	5.83	4.11	5.17	2.09
two	4.1	100year	23.95	68.34	69.34	70.07	72.81	0.026228	8.25	2.90	4.92	3.43
two	4	100year	23.95	66.36	69.77	67.90	69.93	0.000383	1.76	13.64	4.00	0.30
two	3.8		Culvert									
two	3.51	100year	23.95	63.66	66.83		67.01	0.000461	1.89	12.66	4.00	0.34
two	3.5	100year	26.36	63.20	66.84	64.84	67.00	0.000395	1.81	14.54	4.00	0.30
two	3.3		Culvert									
two	3	100year	26.36	56.16	58.77		59.09	0.000913	2.53	10.44	4.00	0.50
one	2	100year	64.42	54.70	58.91	56.31	59.03	0.000131	1.53	42.13	10.00	0.24
one	1.8		Culvert									
one	1.51	100year	64.42	54.15	57.41		57.61	0.000266	1.97	32.62	10.00	0.35
one	1.5	100year	68.59	54.15	57.38	55.84	57.61	0.000311	2.13	32.27	10.00	0.38
one	1.2		Culvert									
one	1	100year	68.59	53.85	55.53	55.53	56.38	0.002057	4.07	16.85	10.00	1.00
one	0.8	100year	68.59	53.65	55.14	55.44	56.34	0.003296	4.86	14.10	10.97	1.37
one	0.5	100year	68.59	53.25	54.66	55.04	56.03	0.003977	5.18	13.23	10.81	1.50
one	0.1	100year	68.59	52.70	54.06	54.49	55.54	0.004439	5.38	12.75	10.72	1.58
one	22	100year	14.98	59.16	62.17	60.28	62.24	0.000206	1.25	12.02	4.00	0.23
one	21.5		Culvert									
one	21.1	100year	14.98	56.50	60.18		60.23	0.000124	1.02	14.72	4.00	0.17
one	21	100year	20.09	56.50	60.19	57.54	60.23	0.000071	0.91	22.13	6.00	0.15
one	20.5		Culvert									
one	20	100year	20.09	55.50	59.84		59.87	0.000047	0.77	26.03	6.00	0.12
one	19	100year	0.60	73.34	74.30	73.55	74.30	0.000043	0.31	1.91	2.00	0.10
one	18.8		Culvert									
one	18.51	100year	0.60	70.34	71.52		71.52	0.000025	0.26	2.35	2.00	0.08
one	18.5	100year	1.20	70.19	71.51	70.52	71.52	0.000074	0.46	2.64	2.00	0.13
one	18.3		Culvert									
one	18.1	100year	1.20	65.04	66.96		66.97	0.000029	0.31	3.85	2.00	0.07
one	18	100year	2.01	64.59	66.96	65.06	66.97	0.000049	0.42	4.74	2.00	0.09
one	17.8		Culvert									
one	17.5	100year	2.01	64.43	66.42		66.43	0.000074	0.50	3.98	2.00	0.11

Table 7

Hydraulics 100-yr for Area north with Arch-Pipe Alternative "B"

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
two	17	100year	0.78	76.49	77.43	76.74	77.44	0.000075	0.41	1.89	2.00	0.14
two	16.8		Culvert									
two	16.51	100year	0.78	73.34	74.59		74.59	0.000036	0.31	2.50	2.00	0.09
two	16.5	100year	1.56	73.34	74.57	73.73	74.59	0.000149	0.63	2.47	2.00	0.18
two	16.2		Culvert									
two	16.1	100year	1.56	70.69	72.43		72.44	0.000062	0.45	3.48	2.00	0.11
two	16	100year	2.60	70.69	72.41	71.24	72.44	0.000178	0.76	3.44	2.00	0.18
two	15.5		Culvert									
two	15	100year	2.60	65.19	66.37		66.43	0.000468	1.10	2.35	2.00	0.33
one	14	100year	4.61	64.28	66.37	65.09	66.43	0.000348	1.10	4.17	2.00	0.24

one	13.5		Culvert									
one	13	100year	4.61	55.82	59.26		59.28	0.000107	0.67	6.87	2.00	0.12
two	12	100year	7.92	68.64	69.67	69.67	70.05	0.002456	2.72	2.92	3.95	1.01
two	11.1	100year	7.92	61.64	62.05	62.67	68.27	0.124271	11.05	0.72	2.56	6.67
two	11	100year	7.92	60.58	60.91	61.75	68.04	0.149494	11.83	0.67	2.00	6.53
two	10.5		Culvert									
two	10.1	100year	7.92	57.37	60.81		60.88	0.000315	1.15	6.88	2.00	0.20
two	10	100year	10.28	57.12	60.84	57.99	60.87	0.000057	0.69	14.88	4.00	0.11
two	9.5		Culvert									
two	9.1	100year	10.28	56.91	60.32		60.35	0.000070	0.75	13.66	4.00	0.13
two	9	100year	10.28	56.91	60.32	57.78	60.35	0.000070	0.75	13.66	4.00	0.13
two	8.5		Culvert									
two	8	100year	10.28	56.17	59.64		59.66	0.000068	0.74	13.86	4.00	0.13
one	7	100year	33.44	56.00	59.63	56.98	59.66	0.000042	0.84	39.90	11.00	0.14
one	6.5		Culvert									
one	6	100year	33.44	54.70	59.26		59.28	0.000022	0.67	50.13	11.00	0.10
two	5	100year	0.70	76.34	76.65	76.65	76.76	0.003043	1.48	0.47	2.15	1.01
two	4.5	100year	23.95	72.17	73.40	73.90	75.13	0.009558	5.83	4.11	5.17	2.09
two	4.1	100year	23.95	68.34	69.34	70.07	72.81	0.026227	8.25	2.90	4.92	3.43
two	4	100year	23.95	66.36	69.75	67.90	69.91	0.000388	1.77	13.56	4.00	0.31
two	3.8		Culvert									
two	3.51	100year	23.95	62.50	65.63		65.81	0.000476	1.92	12.51	4.00	0.35
two	3.5	100year	26.36	62.50	65.57	64.14	65.81	0.000601	2.14	12.30	4.00	0.39
two	3.3		Culvert									
two	3	100year	26.36	54.70	59.18		59.29	0.000238	1.47	17.90	4.00	0.22
one	2	100year	64.42	54.70	59.20	56.13	59.27	0.000068	1.19	54.03	12.00	0.18
one	1.8		Culvert									
one	1.51	100year	64.42	54.15	57.67		57.79	0.000136	1.53	42.23	12.00	0.26
one	1.5	100year	68.59	54.15	57.65	55.64	57.79	0.000157	1.63	42.00	12.00	0.28
one	1.2		Culvert									
one	1	100year	68.59	53.85	55.85		56.27	0.000804	2.86	24.00	12.00	0.65
one	0.8	100year	68.59	53.65	55.44	55.44	56.23	0.001751	3.95	17.39	11.00	1.00
one	0.5	100year	68.59	53.25	54.70	55.04	55.98	0.003597	5.01	13.69	10.90	1.43
one	0.1	100year	68.59	52.70	54.08	54.49	55.52	0.004282	5.32	12.90	10.75	1.55
one	22	100year	14.98	59.16	61.91	59.87	61.93	0.000041	0.68	21.97	8.00	0.13
one	21.5		Culvert									
one	21.1	100year	14.98	56.50	60.07		60.08	0.000020	0.52	28.57	8.00	0.09
one	21	100year	20.09	56.50	60.06	57.29	60.08	0.000027	0.63	32.08	9.00	0.11
one	20.5		Culvert									
one	20	100year	20.09	56.05	59.64		59.66	0.000026	0.62	32.35	9.00	0.10
one	19	100year	0.60	73.34	74.30	73.55	74.30	0.000043	0.31	1.91	2.00	0.10
one	18.8		Culvert									
one	18.51	100year	0.60	70.34	71.52		71.52	0.000025	0.26	2.35	2.00	0.08
one	18.5	100year	1.20	70.19	71.51	70.52	71.52	0.000074	0.46	2.64	2.00	0.13
one	18.3		Culvert									
one	18.1	100year	1.20	65.04	66.96		66.97	0.000029	0.31	3.85	2.00	0.07
one	18	100year	2.01	64.59	66.96	65.06	66.97	0.000049	0.42	4.74	2.00	0.09
one	17.8		Culvert									
one	17.5	100year	2.01	64.43	66.42		66.43	0.000074	0.50	3.98	2.00	0.11

Table 8

Hydraulics 100-yr for Area P2E and Channel South

Reach	River Sta	Profile	Q Total	Min Ch El (m3/s)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m)	Vel Chnl (m/m)	Flow Area (m/s)	Top Width (m2)	Froude # Chl (m)
two	6	100y	0.87	84.00	84.25	84.25	84.35	0.002999	1.43	0.61	2.98	1.01
two	5.1	100y	0.87	82.00	83.66	82.25	83.66	0.000002	0.10	8.75	8.00	0.03
two	5	100y	15.12	82.00	83.22	83.22	83.62	0.002000	2.78	5.43	6.89	1.00
two	4.1	100y	15.12	79.00	79.62	80.22	82.52	0.030509	7.54	2.01	4.48	3.60
two	4	100y	17.36	79.00	79.70	80.31	82.44	0.025503	7.34	2.36	4.79	3.34
two	3.1	100y	17.36	65.00	67.15	66.31	67.24	0.000231	1.37	12.68	8.00	0.35
one	3	100y	28.80	65.00	66.68	66.68	67.20	0.001843	3.19	9.04	8.73	1.00
one	2.1	100y	28.80	58.00	58.85	59.68	63.09	0.031678	9.12	3.16	5.41	3.81
one	2	100y	39.53	58.00	59.09	59.96	62.95	0.022234	8.71	4.54	6.35	3.29
one	1	100y	39.53	51.00	52.04	52.96	56.43	0.026467	9.29	4.26	6.17	3.57
ONE	31	100y	1.99	79.03	80.68	79.49	80.70	0.000115	0.60	3.31	2.00	0.15
ONE	30.5		Culvert									
ONE	30	100y	1.99	76.03	77.44	76.49	77.46	0.000173	0.71	2.81	2.00	0.19
ONE	29.5		Culvert									
ONE	29	100y	3.99	73.73	75.88	74.47	75.92	0.000242	0.93	4.30	2.00	0.20
ONE	28.5		Culvert									
ONE	28	100y	3.99	73.63	75.48	74.37	75.54	0.000350	1.08	3.70	2.00	0.25
ONE	27.5		Culvert									
ONE	27	100y	3.99	72.73	74.88	73.47	74.93	0.000242	0.93	4.30	2.00	0.20
ONE	26.5		Culvert									
ONE	26	100y	6.65	72.25	74.51	73.29	74.62	0.000594	1.47	4.53	2.00	0.31
ONE	25.5		Culvert									
ONE	25	100y	6.65	65.43	67.84	66.47	67.94	0.000510	1.38	4.82	2.00	0.28
ONE	24.5		Culvert									
ONE	24	100y	6.65	65.00	67.11		67.24	0.000701	1.57	4.23	2.00	0.35

Table 9

Hydraulics 100-yr for Area P2G

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
ONE	35	100y	1.75	63.83	65.31	64.26	65.32	0.000119	0.59	2.95	2.00	0.16
ONE	34.5		Culvert									
ONE	34.1	100y	1.75	61.53	62.60		62.63	0.000275	0.82	2.13	2.00	0.25
ONE	34	100y	2.91	61.08	62.58	61.68	62.63	0.000314	0.97	3.00	2.00	0.25
ONE	33.5		Culvert									
ONE	33.1	100y	2.91	59.08	61.40		61.42	0.000107	0.63	4.65	2.00	0.13
ONE	33	100y	5.83	59.08	61.33	60.03	61.42	0.000463	1.29	4.50	2.00	0.28
ONE	32.5		Culvert									
ONE	32	100y	5.83	53.75	54.32	54.70	55.64	0.016800	5.09	1.15	2.00	0.28

The proposed piping system proves to be adequate for conveying the 100-year discharge across the project site. Local storm system must connect this main system.

V. CONCLUSIONS AND RECOMMENDATIONS

The following are the conclusions of this study:

1. According to the regulatory flood maps, the project site is not considered floodable for the 100-year rainfall event

2. Proposed condition discharge is higher than that of the existing condition. Mitigation is needed.

3. Mitigation reduces the 100-year discharge for proposed condition from 3,245 to 3,073 cfs, which is less than that of the existing condition, 3,188 cfs.

The following are the recommendations of this study:

1. Mitigation structure will have the dimensions and accessories indicated in Table 4 and Table 5 of this report.

2. Discharge from Pond P1 will be made through a 60" diameter pipe and from Pond P2 through a 42" diameter pipe, both provided with a headwall followed with rip-rap or concrete revetment.

3. The trapezoidal channel will be protected with concrete revetment. Rip-rap or gabions must be provided at the discharge from the ponds, to avoid erosion. Depending on the topography at the site of discharge, an energy dissipation structure may be necessary.

4. It is very important to prepare a long-term maintenance plan, which should include the proposed pond, inlets, the outlet structures and the receiving storm system inspection after each significant discharge events. Damages, if any, must be repaired promptly and properly.

Study Limits

All the recommendations specified in this study must be considered to assure the optimum performance of the proposed discharge mitigation ponds and receiving stream. The design engineer will be responsible for elaborating the drawings in conformance with the recommendations of this study.

The results of this study are based on free flow conditions through the hydraulic structures. Proper maintenance must be developed to assure this condition. On the event of the occurrence of any severe obstruction to the flow, the results and recommendations may be impaired. Finally, results and recommendations included in this report must be used only and exclusively by the design engineer for the intended purposes as indicated in this study.

VI. BIBLIOGRAPHY

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CERTIFICATION
HYDROLOGIC-HYDRAULIC STUDY

I hereby certify that the document "***Hydrologic and Hydraulic Study for La Sabana in Vega Baja, Puerto Rico***" has been prepared in accordance with the best hydrologic and hydraulic practices as described in this document and that, based on the studies and field measurements provided by other parties, results are true and correct.

Certified today, September 25, 2007

Casiano Ancalle, P.E.
Lic. 11294

Estado Libre Asociado de Puerto Rico
Departamento de Estado
Secretaria Auxiliar de Juntas Examinadoras

certificamos que,
Casiano Ancalle Choque
esta autorizado a ejercer como
Ingeniero Licenciado
en Puerto Rico

Licencia Num: **11294**
Expedición: **23 de abril de 2005**
Expiración: **22 de abril de 2010**

Secretario Auxiliar

Presidente de la Junta

Colegio de Ingenieros y Agrimensores de Puerto Rico

Ingeniero Licenciado
Miembro en Propiedad
11294 P.E.

Ing. Casiano Ancalle Choque

Colegiación expira 31/08/2007