HIGUAMO RIVER: DAM FEASIBILITY STUDY

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CE EN 439

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Executive Summary

This report was prepared to evaluate the feasibility of building a dam in the eastern region of the Dominican Republic on the Higuamo River. The results of this assessment were reached via collaboration and cooperation between the students from Brigham Young University and Instituto Tecnológico de Santo Domingo and the engineering staff from the Instituto Nacional de Recursos Hidráulicos (INDRHI) of the Dominican Republic.

The scope of this feasibility report includes a hydrologic analysis, hydrologic models, and an environmental assessment of the dam site. The hydrologic analysis included determining the probable maximum precipitation and return period storm events, the flow duration curve, mass curve, and elevation-storage-discharge curve, and evaluating the potential for hydropower at the site. Necessary hydrologic data was collected in order to conduct this analysis, including streamflow, precipitation, and agricultural profiles. This data was gathered from multiple sources, including INDHRI staff, internet resources, and an on-site visit. Hydrologic models were prepared within the Watershed Modeling System application, and include an HMS model for studying runoff hydrographs and a GSSHA model for evaluating the results of a dam failure.

The resulting recommendation from this analysis was that building a dam at this location would likely not be desirable, due primarily to the low flow rate of the river and the geomorphology of the valley, requiring a huge volume of earth fill in order to build the dam. The low flow rate contributes to other negative effects as well, including minimal hydropower generation, increased eutrophication levels, and an extended time to refill the reservoir.

Introduction

The eastern region of the Dominican Republic is covered by a rural zone of sugar cane, plantain, and other crop fields. To meet or even accelerate agricultural production within the region, a reliable source of water would be ideal. A dam along the Higuamo River would theoretically be able to provide the necessary control of water to allow accelerated agricultural production. A proposed site for this dam was given by the Instituto Nacional de Recursos Hidráulicos (INDRHI) of the Dominican Republic. A full assessment of the feasibility of this potential dam site was conducted by students of Brigham Young University (BYU) and Instituto Tecnológico de Santo Domingo (INTEC), in full collaboration with the engineering staff at INDRHI. The assessment was conducted through a detailed hydrologic analysis and models to determine if the location of the dam site would be economically and physically feasible.

Problem Description

Located on the southeast coast of the Dominican Republic, the city of San Pedro de Marcoris is a popular tourist location and a fairly large city with 185,255 inhabitants. It is located near the delta of the Higuamo River, and because of an increasing population, the demand for water and energy in the area is increasing. These demands come from agriculture, industry, the municipality, and tourism. There are large cement plants, sugar cane plantations, resorts, hotels, and a city of people who need the resources. Figure 1 shows some of these areas.

Figure 1. Influenced water users.

In order to meet the increasing demands, a dam site on the Higuamo River about 20 kilometers inland from the delta is proposed to create a reservoir to store water and create hydropower to fulfill these needs. Figure 2 shows the proposed dam site in relation to San Pedro de Macoris.

Figure 2. The dam site upstream of San Pedro de Macoris.

Site Description

The proposed dam site is in a very flat region of the Dominican Republic, and because of the location, the topography of the dam site is somewhat challenging. The dam would have to be relatively shallow and very long to generate a reasonable amount of storage. At the river bottom, the elevation is 15 meters and the hillside of the surrounding terrain has a maximum elevation of 42 meters. The available dam height is approximately 25 meters. The crest length of the dam needs to be 800 meters in order to span the two hillsides.

This site is very close to a cement plant, but it is also located in a rural area where native materials from the area could be obtained for construction. The cost analysis and the ecological impact of a gravity concrete dam versus an earth fill dam would determine which construction method to use.

With the very shallow slope in the area, the flow in the river is almost stagnant as can be seen in Figure 3. Eutrophication and contamination become much more challenging to eliminate when the velocities are low. When a water body is eutrophic, it can be assumed that there are high levels of nitrogen and phosphorus in the water. The Higuamo River at the proposed dam site has a large amount of eutrophication already, and the reservoir could experience similar results if left untreated. After reviewing the site, the hydrologic properties of the Higuamo River watershed were analyzed to analyze the benefits of the dam’s construction.

Figure 3. Photo of the proposed dam site.

Hydrologic Analysis

PMP and Return Period Storms

The Probable Maximum Precipitation (PMP) event was determined for simulation in a hydrologic model. To determine the PMP, precipitation data from the Higuey watershed was used, due to the lack data for the Higuamo watershed. The Higuey watershed is fairly close to the Higuamo watershed and has roughly the same terrain. Therefore, the precipitation data from the Higuey watershed most likely resembles the actual precipitation data over the Higuamo watershed as well. The Probabilistic Frequency Analysis, or the Hershfield Method, was used to determine the PMP from the precipitation data; a K value of 15 was conservatively used. An average rainfall amount was found from the maximum precipitation value for each month from 1934-1980. The standard deviation was computed from the same data. With these variables, the PMP was found to be 565 mm.

Storm data was interpolated from various hydrologic maps and can be seen compiled in Table 1. This storm data includes 24-hour return periods for the 2.33-year, 5-year, 10-year, 25-year, 50-year and 100-year storms. The calculated PMP value seems reasonable based on the other return period storm values. These values were eventually used in a hydrologic model.

Table 1. Storm Summary

Storm	Precip. (mm)
PMP	565
100 Yr	360
50 Yr	268
25 Yr	190
10 Yr	165
5 Yr	135
2.33 Yr	93

Flow Duration Curve

The Flow Duration curve was used to determine how much water can be assumed to be entering the reservoir. This value will determine the amount of water that can be allowed to pass through the outlet works. To calculate this, the flow data from INDRHI in the document "Caudal Cuencas del Este" was used. This document gives mean monthly flow rates for the Higuamo River from the early 1960s to 1995. Any month's data that was missing was corrected with the 30 year average for that month. With this data, the flow duration curve, seen in Figure 4, shows what flows are available for what percent of the time over the 30 years.

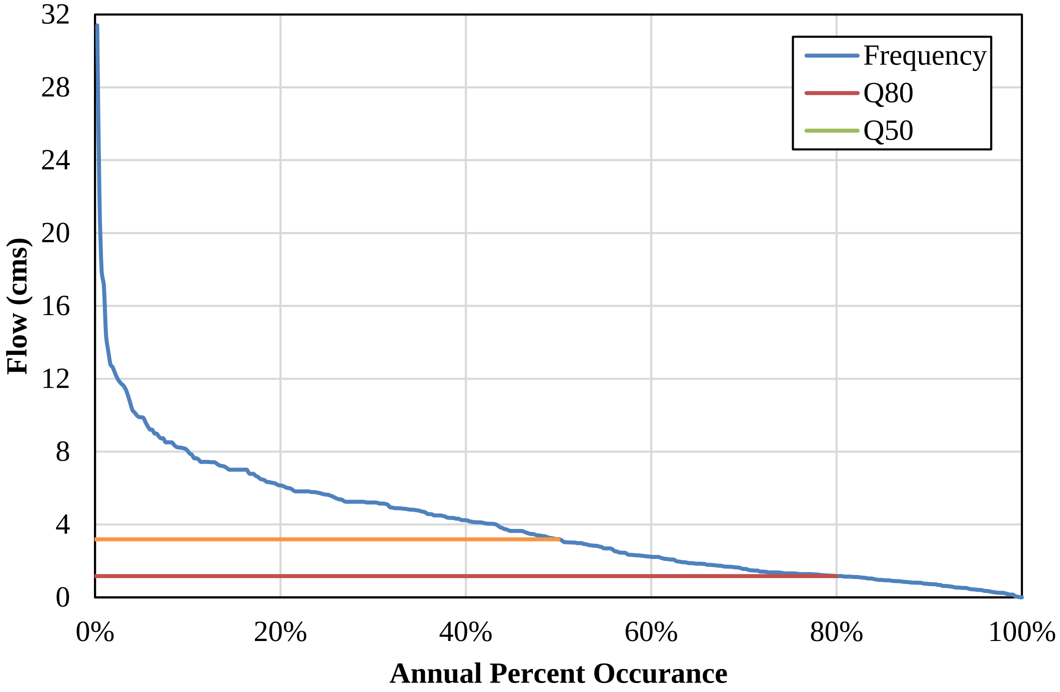


Figure 4. Flow duration curve.

From this curve, the Q_{80} and Q_{50}, or the amount of flow in the Higuamo River 80 and 50 percent of the time, were obtained. The values for Q_{80} and Q_{50} are 1.17 cms and 3.2 cms, respectively. The time required to fill the reservoir was calculated by using the value for Q_{50}. To fill the 114.5 million m^3 reservoir at the flow rate of 3.2 cms would take 4.8 months. A more conservative estimate would be to assume that the first 6 months of the dam's existence will be simply used to fill the reservoir without passing any of the inflow. Likewise, it would always take this long to fill if ever emptied entirely due to water demands.

Demands

The demands on the water stored behind the Higuamo Dam determine the amount of water passed through the outlet works. These demands come from irrigation, potable water, and industrial water. The demands for each were estimated.

The Blainey-Criddle method was used to estimate the amount of water used by different types of crops. Blainey and Criddle estimated water consumption factors for many different crops and then created an equation to estimate the amount of water lost in evapotranspiration per month due to the irrigation of these different crops. Their equation is given as:

$$u = kp(45.7t + 813)/100$$

U is the monthly amount of water lost to evapotranspiration in millimeters. The p value is the percent of daytime hours per year in the month of study, and it is dependent on the latitude of the location of interest. The p value table is included in the appendix. The k value is the water consumption factor that changes from one crop to another. This table is also included in the appendix. Finally, t is the average monthly temperature in degree Celsius. The temperature and precipitation data for San Pedro was obtained from http://www.myweather2.com/City-Town/Dominican-Republic/San-Pedro-De-Macoris/climate-profile.aspx?month=12. As determined from the site visit, the crops in the area were sugar cane and plantains.

Table 2 shows the results of the Blainey-Criddle equation. The amount of irrigation water required per month was simply obtained as the difference between the amount of water consumed by the crops and the precipitation during that month in millimeters. The serviceable irrigation area was determined by multiplying these required irrigation flow rates by an area until the required flow didn't exceed 1/2 of the value of Q_{80}. This was based on our assumption that the water passed through the dam would be used with one half for agriculture and one half for the city of San Pedro's industry and potable water.

The serviceable area of the dam is approximately 2000 hectares with the driest months sending nearly 0.8 cms for agriculture. The other half would be sent downstream to be used by industry and the municipality of San Pedro.

The municipal demands were calculated using the design document provided by INDRHI, "R-008 Instalaciones Sanitarias." The assumption made was that the reservoir would supply one fourth of the industrial and municipal demands because there is currently water supplied without the reservoir. The demand results can be seen in Table 2.

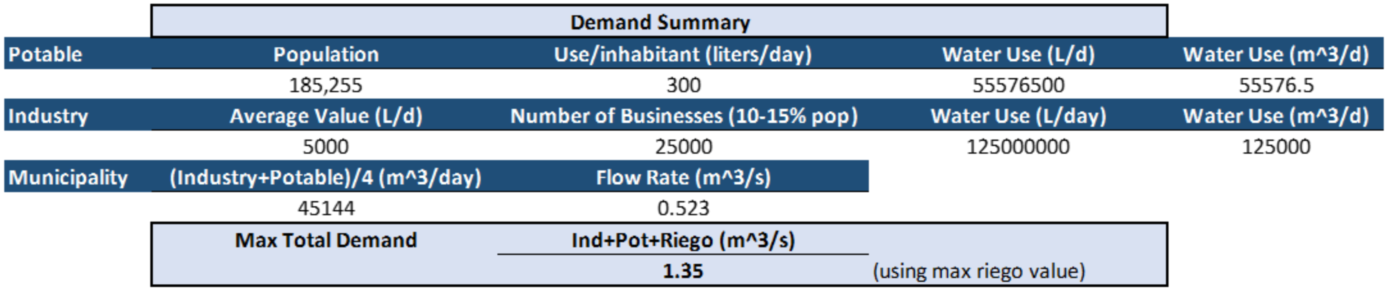
In summary, the reservoir created by the proposed dam would be used to supplement the agricultural, industrial, and potable demands. The agricultural area that could be reliably serviced during the driest months with the available flow rate is approximately 2,000 hectares. One fourth of the assumed municipal demands could also be met with the flow rate available.

Table 2. Blainey Criddle Method Results

	Blainey-Criddle Method San Pedro de Marcoris, Dominican Republic. Latitude 18.5 °N, major crops: sugar cane and bananas								
Month	**P (18.5°N)**	**Mean Monthly Temperature (°C)**	**Mean Monthly Precip (mm)**	**$K_{\text{sugar cane}}$**	**K_{banana}**	**ET (mm)$_{\text{sugar cane}}$**	**ET (mm)$_{\text{banana}}$**	**Deficit (mm)$_{\text{sugar cane}}$**	**Deficit (mm)$_{\text{banana}}$**
Jan	7.80	24.5	36	0.85	1	128.1	150.7	92.1	114.7
Feb	7.28	24	35	0.85	1	118.2	139.1	83.2	104.1
Mar	8.42	25	32	0.85	1	139.9	164.6	107.9	132.6
Apr	8.50	26	64	0.85	1	144.5	170.0	80.5	106.0
May	9.10	26	126	0.85	1	154.8	182.1	28.8	56.1
Jun	8.94	27.5	64	0.85	1	157.3	185.0	93.3	121.0
Jul	9.19	27.5	77	0.85	1	161.7	190.2	84.7	113.2
Aug	8.92	28	104	0.85	1	158.7	186.7	54.7	82.7
Sept	8.29	27	129	0.85	1	144.3	169.8	15.3	40.8
Oct	8.20	26.5	130	0.85	1	141.1	166.1	11.1	36.1
Nov	7.63	26.5	104	0.85	1	131.3	154.5	27.3	50.5
Dec	7.73	25	71	0.85	1	128.4	151.1	57.4	80.1

	Req'd Water (m^3/Hectare/mo)		Land Use		Total Land Area Seviced	Vol. Water Used	Req'd Flow Rate
Month	**Sugar Cane**	**Bananas**	**Sugar Cane**	**Bananas**	**Hectares**	**m^3/mo**	**cms**
Jan	921	1147	90%	10%	2000	1887918	0.7
Feb	832	1041				1706270	0.7
Mar	1079	1326				2207145	0.8
Apr	805	1060				1661380	0.6
May	288	561				630143	0.2
Jun	933	1210				1921117	0.7
Jul	847	1132				1750633	0.7
Aug	547	827				1149579	0.4
Sept	153	408				357019	0.1
Oct	111	361				272718	0.1
Nov	273	505				592076	0.2
Dec	574	801				1193717	0.4

Table 3. Summary of Demands



	Demand Summary			
Potable	**Population**	**Use/inhabitant (liters/day)**	**Water Use (L/d)**	**Water Use (m^3/d)**
	185,255	300	55576500	55576.5
Industry	**Average Value (L/d)**	**Number of Businesses (10-15% pop)**	**Water Use (L/day)**	**Water Use (m^3/d)**
	5000	25000	125000000	125000
Municipality	**(Industry+Potable)/4 (m^3/day)**	**Flow Rate (m^3/s)**		
	45144	0.523		
	Max Total Demand	**Ind+Pot+Riego (m^3/s)**		
		1.35	(using max riego value)	

Mass Curve

The mass curve was plotted as the cumulative volume of water entering the reservoir each month. The demand line was plotted against the mass curve in order to see the amount of storage that is needed within the reservoir. A time period in the mass curve where there is a dip in the data, representing a dry period, is used to calculate the storage need. In this case it was from 1982 to 1985. The demand was set at a high value of 3.2 cms to give a conservative needed storage volume. From the plot, the max difference between the demand line and the mass curve is approximately 23 million cubic meters. This is the needed storage capacity of the reservoir. The plot is shown in Figure 5 below.

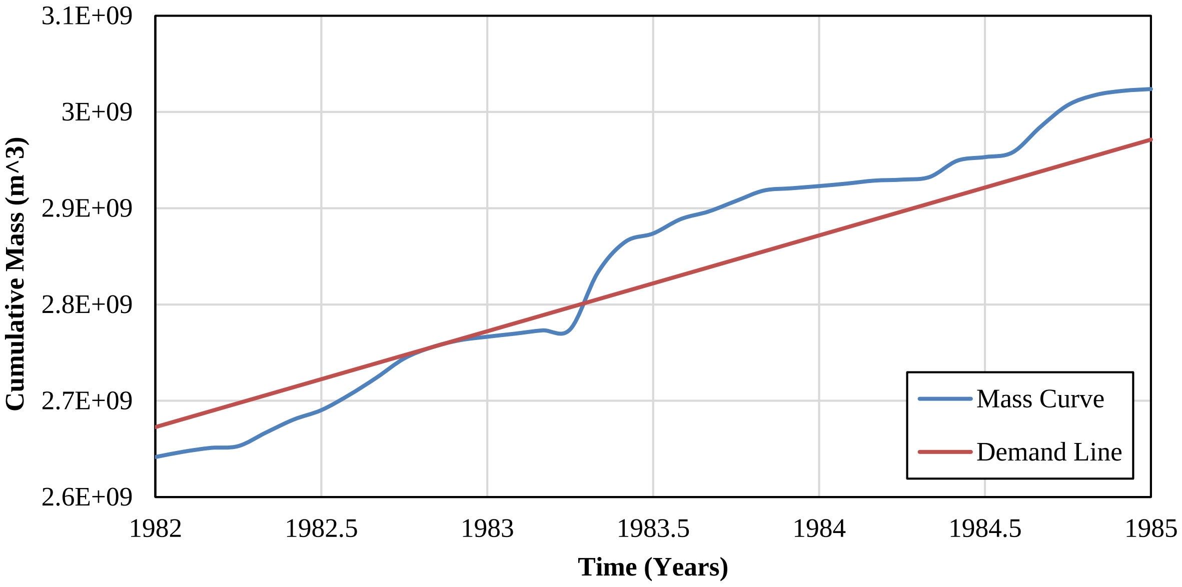


Figure 5. Mass curve and demand line.

Elevation-Storage-Discharge Curve

The Elevation-Storage-Discharge curve was generated within the Watershed Modeling System application (WMS) and a 30 m DEM of the region. For this analysis, the dam was set to be 25 m high with a 7 m spillway weir placed 18 m above the base of the dam and a 2 m outlet orifice placed 3 m above the base of the dam. Figure 6 shows the resulting curves.

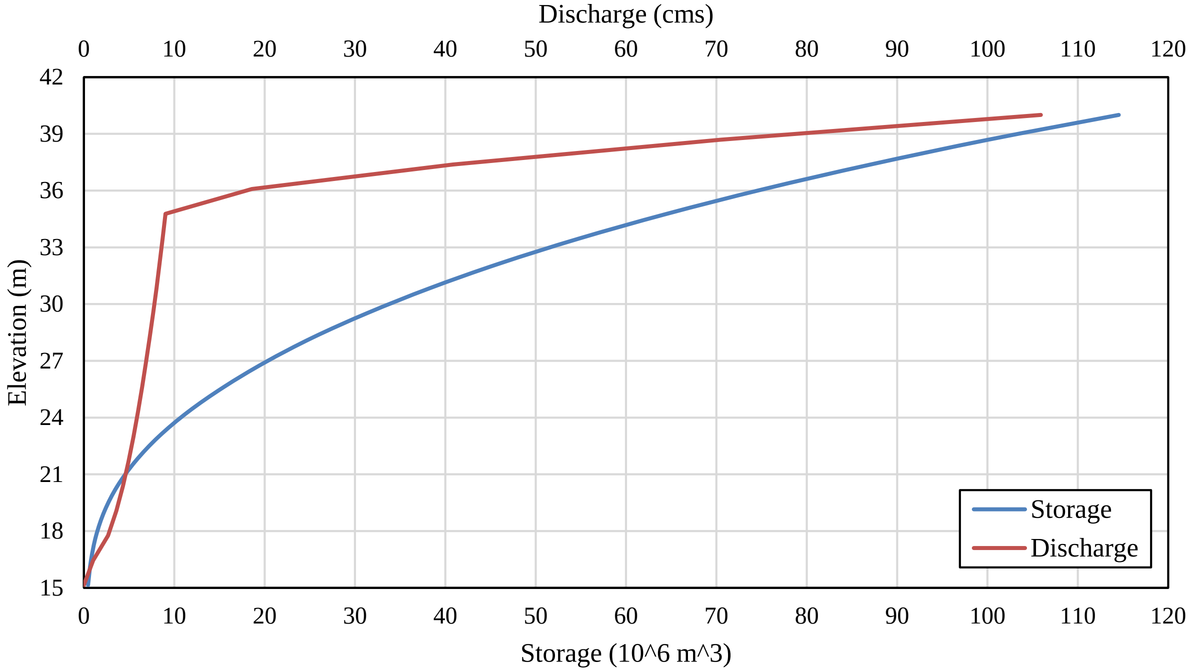


Figure 6. Elevation-Storage-Discharge curve for Higuamo Reservoir.

As indicated by the legend, the blue line shows the relationship of the elevation with storage and the red line represents discharge's relationship. This plot could be used to calculate those two parameters at varying elevations. The values that define these curves are eventually used as part of the hydrologic model.

Hydropower Potential

The hydropower potential at this site was evaluated by using an Excel tool. The assumption was made that hydropower would be generated at the base of the dam. As the hydropower generated here is expected to be a reliable source, the flow value used in the power generation equation was the 90th percentile flow from the flow duration curve, or Q_{90}. This value is 0.7 cms, and coupling that with an anticipated change in head through the dam of 20 m and 85% turbine efficiency, the resulting hydropower capacity is 116 kW. This amount of power is almost considered a micro hydropower project and would only be sufficient for a small community or business. It is not practical to expect a dam built at this site to produce enough power to be transmitted to San Pedro for use. The benefits would not outweigh the costs.

An alternative design could include drawing the water through a pipe further downstream in order to increase the head driving flow, effectively resulting in higher power generation. The problem with this alternative at this site is that the slope of the terrain is very gentle and the base of the dam is already only at 15 m above sea level. Trying to create more head by producing power downstream would not be very effective as the head loss introduced would counteract the head gained.

Hydrologic Models

Watershed Delineation

The Higuamo watershed was delineated using WMS. The projection used was UTM NAD 83 Zone 19N, with the NAVD 88 (US) datum. The minimum flow accumulation threshold used was 5.0 km^2. The watershed's area was calculated as approximately 204 km^2 and its delineation can be seen in Figure 7. The Land Use and Soil Type coverages used throughout the project were created from land use and soil type shapefiles provided by INDRHI.

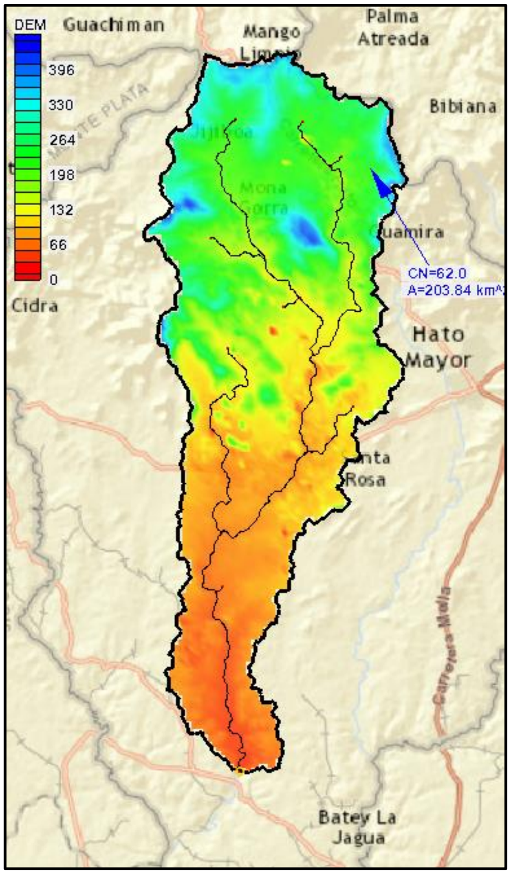


Figure 7. The Higuamo Watershed in the Dominican Republic.

Dam Design

Within WMS, a polyline was placed at the outlet of the delineated watershed to represent the dam. By viewing the DEM elevations along that polyline, an elevation view of the front side of the dam can be seen. Figure 8 shows this. The red line on the figure represents the crest of the dam. The estimated height of the dam is 25 m. Unfortunately, this requires a length of approximately 800 m. The resulting volume of earth fill for this dam would be very large, and may not be feasible.

The dam and its related features were also digitized and saved as shapefiles for use in ArcMap. Figure 9 shows these shapefiles.

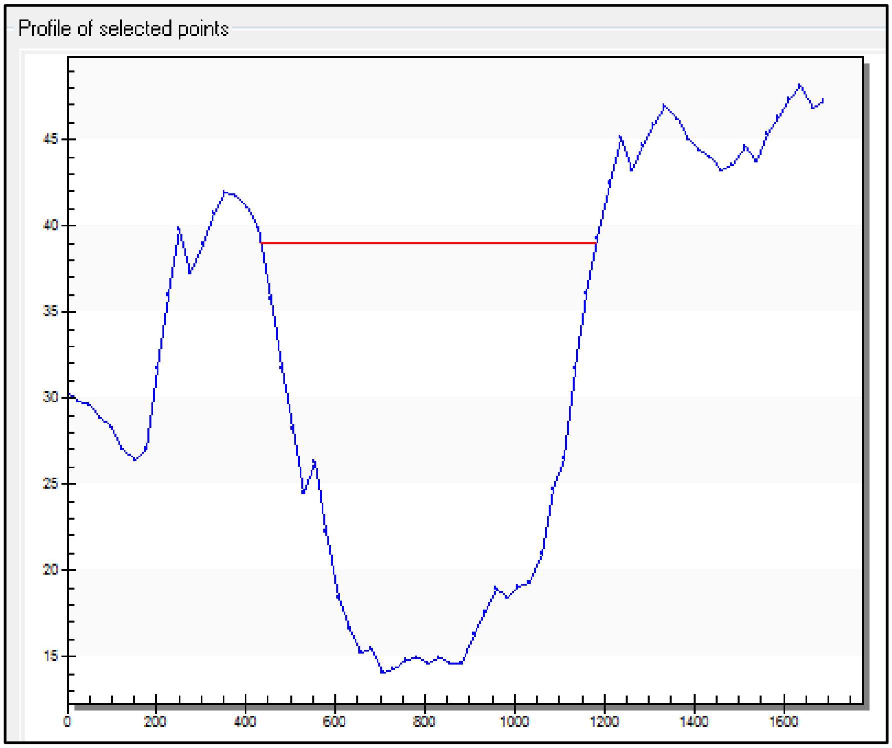


Figure 8. Elevation view of the front of Higuamo Dam.

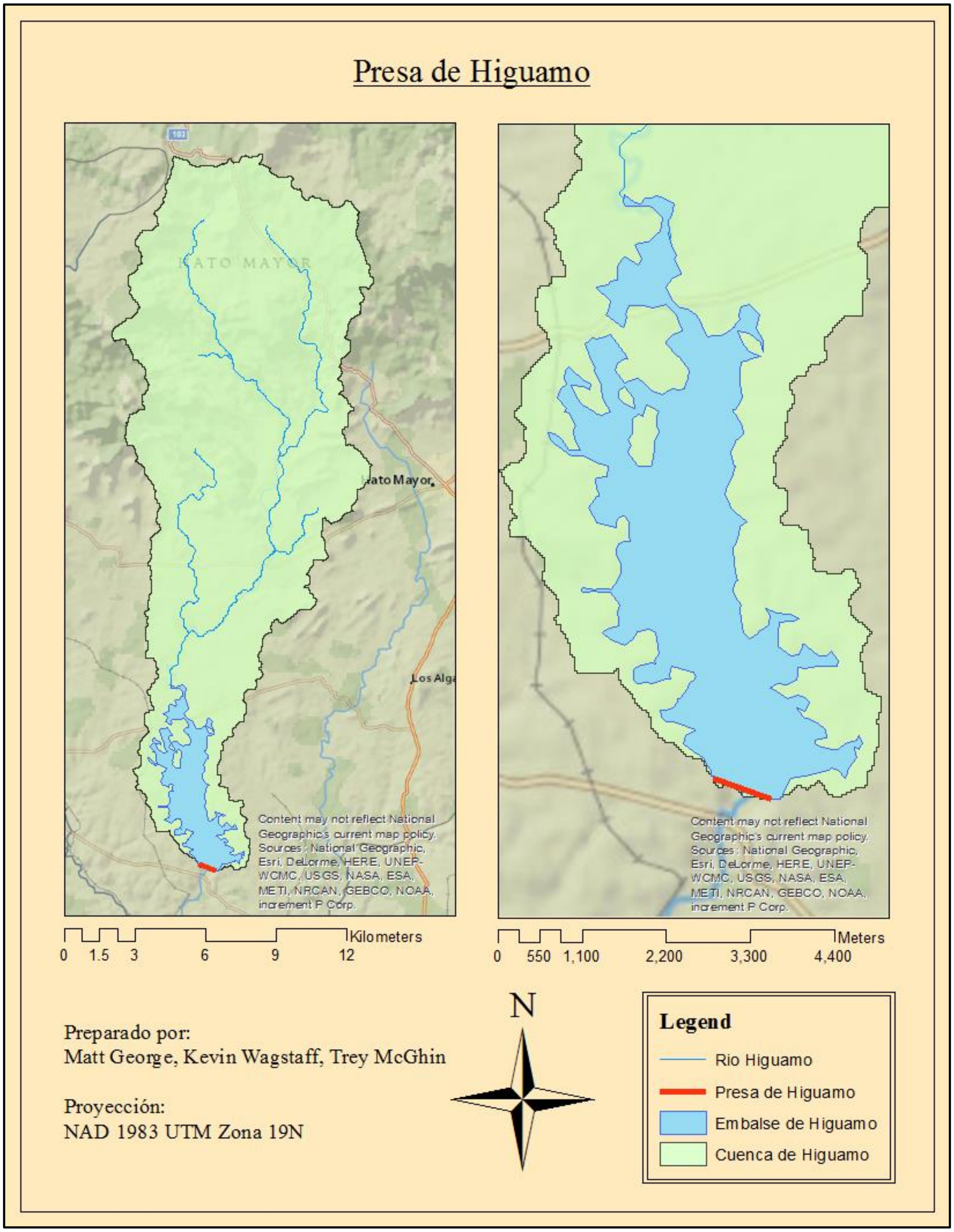


Figure 9. ArcMap shapefiles for the Higuamo Dam.

HEC-HMS Model Development

The HEC-HMS model was built originally in WMS. A schematic of the base HMS model can be seen in Figure 10. Preliminary runs were performed on this model, while a more advanced model also included a detention basin at outlet 3C.

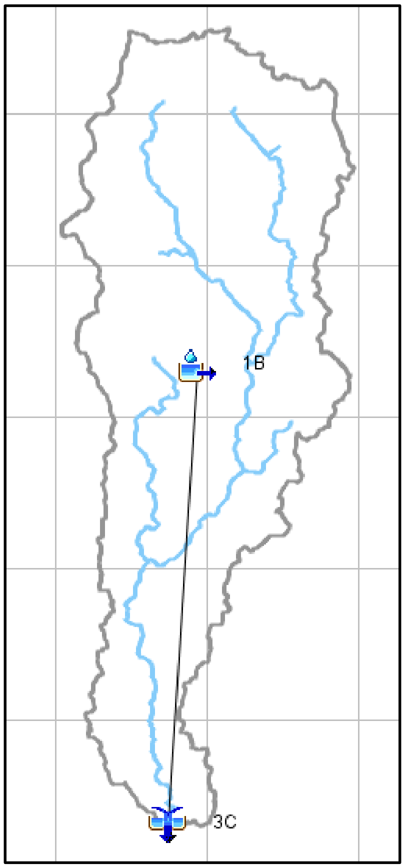


Figure 10. HEC-HMS Higuamo Watershed Schematic.

Model parameters were determined within the WMS application. The loss method used was SCS Curve Number. The curve number was calculated using INDRHI's land use and soil type shapefiles, and the curve number table that can be referenced in the appendix. The resulting curve number was 62. The transform method used was Clark, using the Kirpich Method for overland flow on grassy earth with 0% impervious area. This equation was used due to the terrain characteristics of the Higuamo Watershed.

The model was used to determine the hydrographs at the outlet of the reservoir for the previously tabulated return period and PMP storm data. The analysis was run with the reservoir being approximately 40% full. A more detailed study would be necessary to evaluate how full the reservoir could actually be and still pass the PMP event without failure. If such a study were to be undertaken, it should also include varying the spillway weir length and low-level orifice diameter to find the ideal sizes. Figure 11 shows how the reservoir responds to varying storm events, including the PMP.

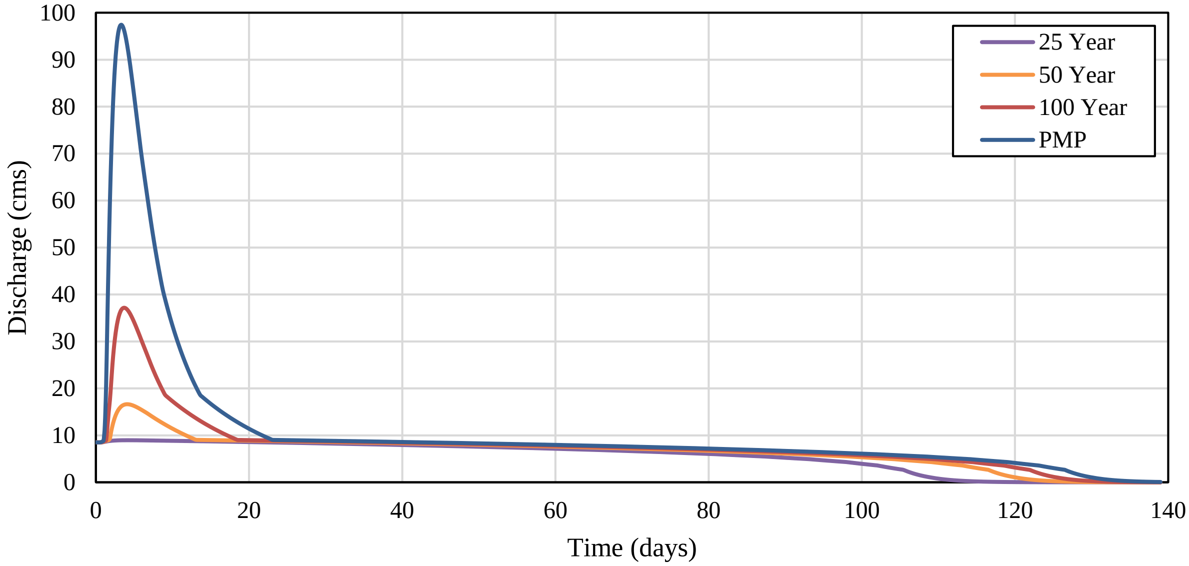


Figure 11. Higuamo Dam large storm hydrographs.

The spikes on each hydrograph show the flow over the weir, while the flow values less than 10 cms represent the orifice flow. The events plotted terminated at the 25-year event because there was no visible peak on the hydrograph. The hydrographs begin at just under 10 cms because the reservoir was modelled as already being 40% full (as previously stated).

The construction of this dam attenuates the hydrograph greatly. Figure 12 shows what the PMP's hydrograph would look like without the dam in place.

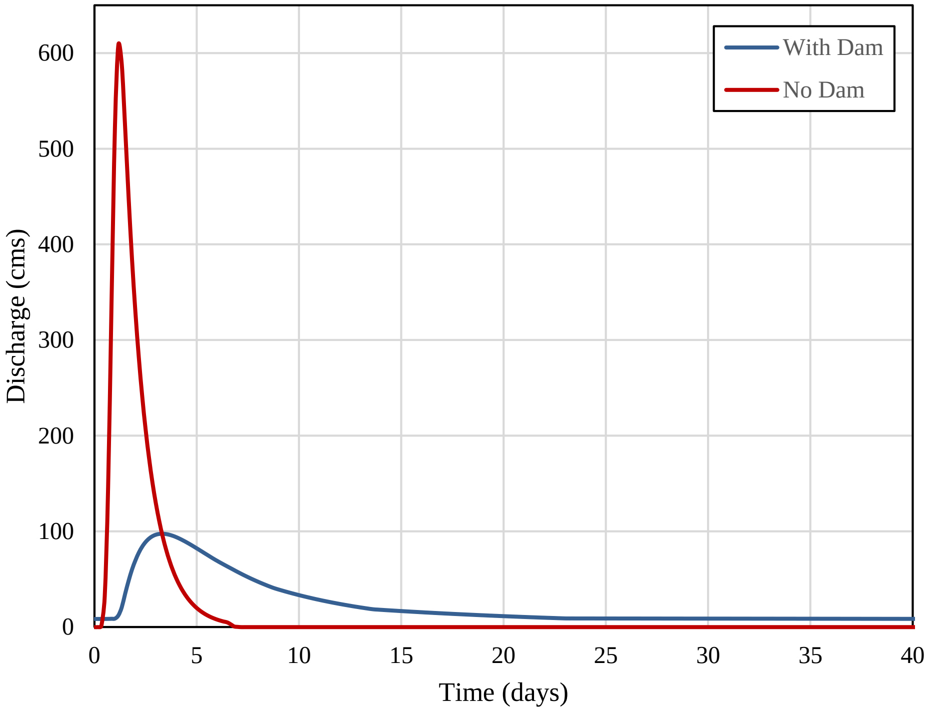


Figure 12. Higuamo Dam PMP attenuation.

With no dam, the peak discharge would be just over 600 cms, whereas the peak discharge with the dam in place would be just under 100 cms. The dam and its outlet works greatly attenuate the discharge.

Dam Break Analysis

An analysis was also performed to show what would happen if the dam were to fail. This was done in WMS using a GSSHA model. The grid layout for the model can be seen in Figure 13. It is important to note that the only stream used in this model was the one going from the dam down to the ocean. The other stream networks were less important because the dam flood waters would almost primarily flow along the main channel.

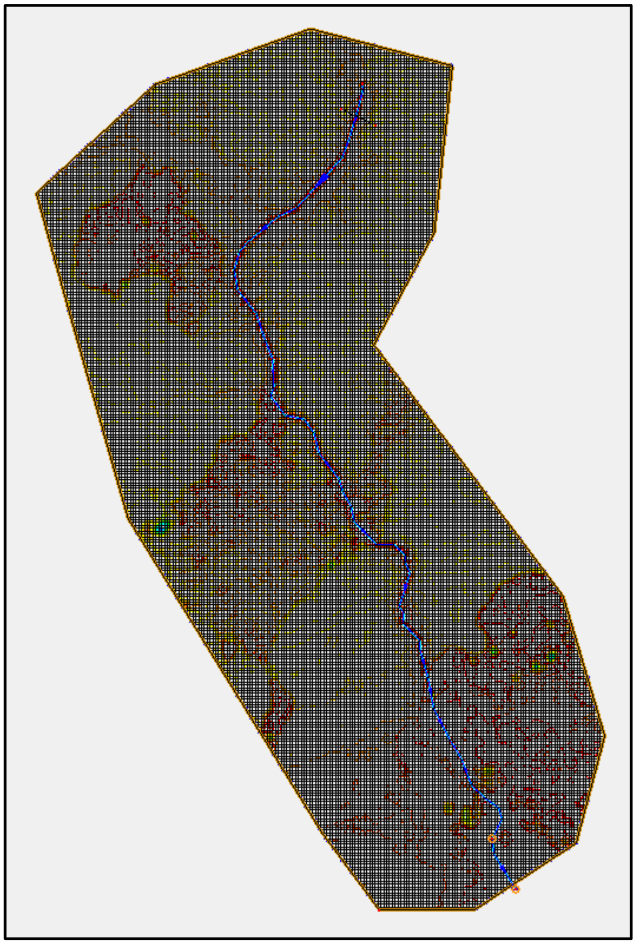


Figure 13. Higuamo Dam Break GSSHA Model Grid.

The grid cells are 75 m in both height and width, in an attempt to capture a more accurate flood path with the higher resolution grid. The main stream was set as a trapezoidal channel with a depth of 2 m and a bottom width of 4 m. An n value of 0.017 was used for the channels. A uniform map table was used for the overland flow roughness with a value of 0.08. The model was set up to allow overbank flow with diffusive wave river routing. The model was only executed for a 250 minute simulation to see the bulk of the flood impact downstream, with a 2 second time step.

Thirty minutes after the dam break was simulated the flood wave propagates as seen in Figure 14. There is significant flooding along all areas near the bank of the Higuamo River. San Pedro, at the coastline, begins to flood after about 1 hour. The northwest portion of the city may experience flooding as deep as 15 m.

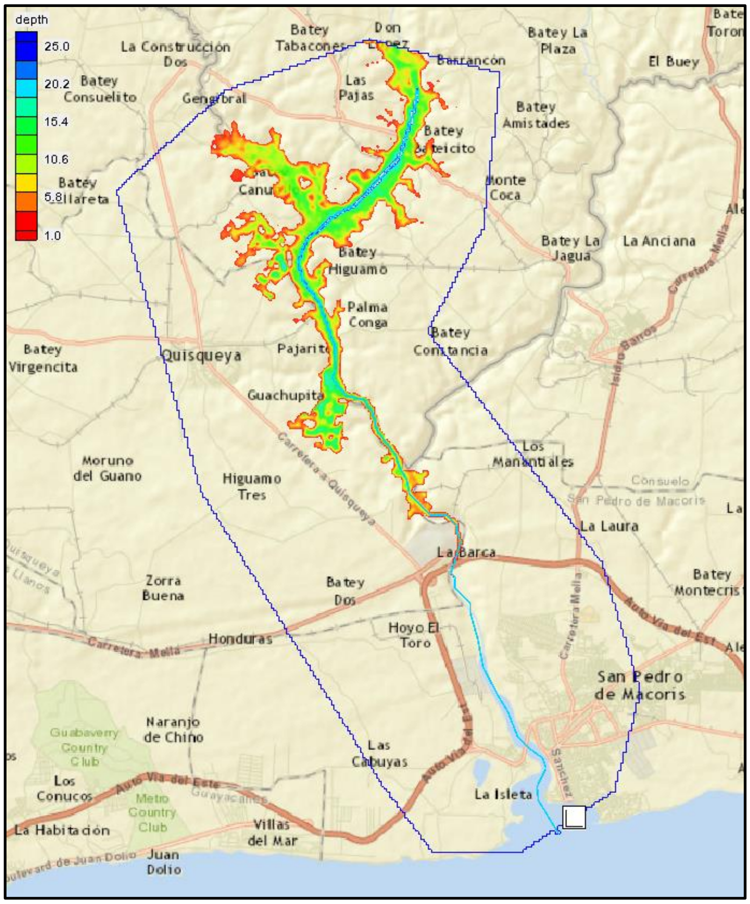


Figure 14. Dam break initial flood wave.

Three hours after the break, the water depths can be seen in Figure 15. The northwestern region of San Pedro would still have ponding inside the city. This will eventually dissipate after several more hours. These risks and the associated costs should be evaluated prior to dam construction. Further analysis could help make this model even more accurate.

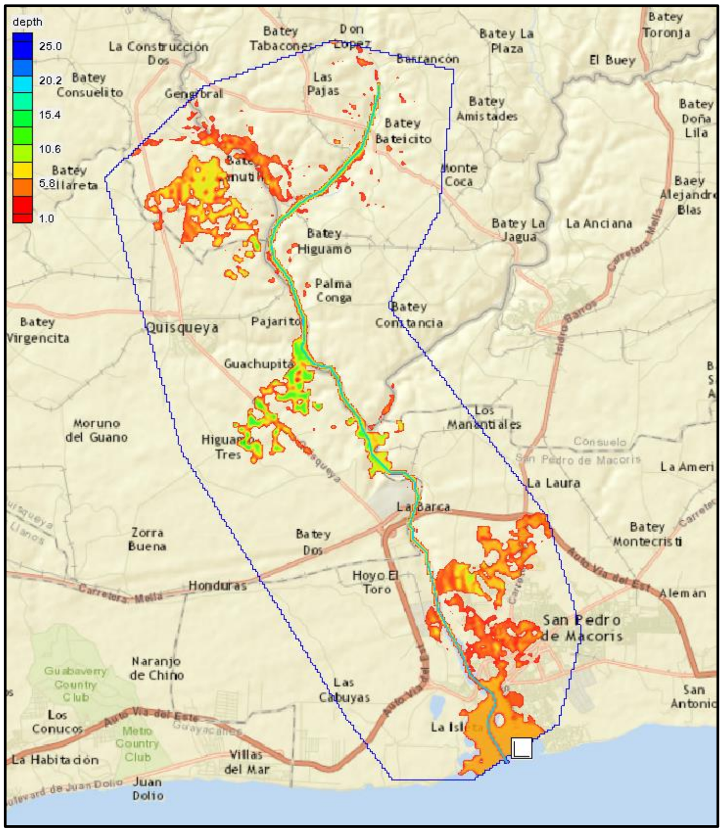


Figure 15. Three hours after dam failure.

Environmental Impact Assessment

Nearly all large-scale infrastructure projects impact their surroundings significantly. Dams, in particular, can cause a plethora of problems for humans, the environment, and potentially, the economy.

People

The impact on people is of principal importance when designing a dam. The proposed Higuamo Dam's reservoir will inundate an 11 km^2 region. This region includes several smaller communities which will need to relocate their homes and businesses. Evacuating and relocating communities is an unpopular requirement which will not be appreciated by the affected communities. Besides this, the approximately 800 m long embankment might be considered out of place in the densely forested region and seen as an "eye sore" for the small communities nearby.

The other major effect the dam will have on people is with regards to transportation. The dam will disrupt some roads in the area which would need to be completely rerouted to avoid the inundation zone. This could potentially be a major inconvenience depending on how frequently the rerouted roads are used.

Planet

Sedimentation

Reservoir sedimentation is apparent in the Dominican Republic and should be taken into heavy consideration when designing hydraulic structures. With the heavy tropical storms and hurricanes prevalent in the region, it is no surprise that sedimentation is a problem. A few years ago, the Aguacate Dam, one of the largest hydroelectric dams in the Dominican Republic, suffered having its penstocks plugged entirely with sediment. This excessive sediment was due to massive soil erosion from Hurricane George. While the dam was designed to pass sediment, the gates were mismanaged, resulting in the penstocks being completely plugged with sediment. The Aguacate Dam then proved to be great loss in money.

By preparing for sedimentation, and then managing it accordingly, the Dominican Republic will be creating sustainable infrastructure for future generations. Ignoring the problem and simply allowing reservoirs to silt in is a very present-oriented paradigm which neglects the well-being of those who will use the facilities in the future.

Deforestation and Eutrophication

As previously mentioned, the proposed site is heavily forested in a jungle region. Significant deforestation would be required to construct the dam. This will disrupt the ecosystem for several local species. A side effect of deforestation is increased sediment yield from the watershed, effectively exacerbating the issue of sedimentation. As long as the deforestation is monitored and limited to the smallest area possible, it might not leave too large of an environmental footprint.

Because of the shallow slope in the Higuamo Watershed, the water is very stagnant. It was concluded from the site visit that the stagnant water is rich with algae and other growths. This eutrophication will likely only worsen with the construction of a reservoir. INDRHI informed us that other contaminants are present as well along the Higuamo River. Contaminants can often travel with sediment; high rates of sedimentation in the area mean that contaminants will be able to enter the reservoir on the sediment particles unless monitored.

Profit

The primary effect of the proposed Higuamo Dam on the economy will be the large principal costs associated with building a dam. Because the dam would be required to be so long, massive amounts of earth fill or cement and aggregate would be required to build it over numerous lifts. Transporting the required material to this isolated area would be extremely costly and would require building a much better transportation network out to the site. The principal cost for building this facility will be very high, and as discussed in the hydrologic analysis sections, may not yield as high of a return as expected. Further economic analyses are recommended in order to determine whether this dam could be cost-effective.

Conclusion

After a thorough hydrologic analysis of the potential dam site, it does not seem feasible to construct a dam at this location. Due to the valley's geomorphology, the dam length would be approximately 800 meters, requiring an excessive and expensive amount of material for construction. The other main drawback is the low flow rate of the Higuamo River, which would limit the reservoir being able to reliably meet both the water and energy demands of the region. The low flow rate of the river has also resulted in high eutrophication levels, which would likely only worsen with the construction of a dam. While the hydrologic models showed some potential benefit from the dam at this location, the low hydropower potential, excessive length and volume necessary for construction, and the low flow rate of the river all contribute to the resulting recommendation that building a dam at this location would likely not be desirable.

Appendix

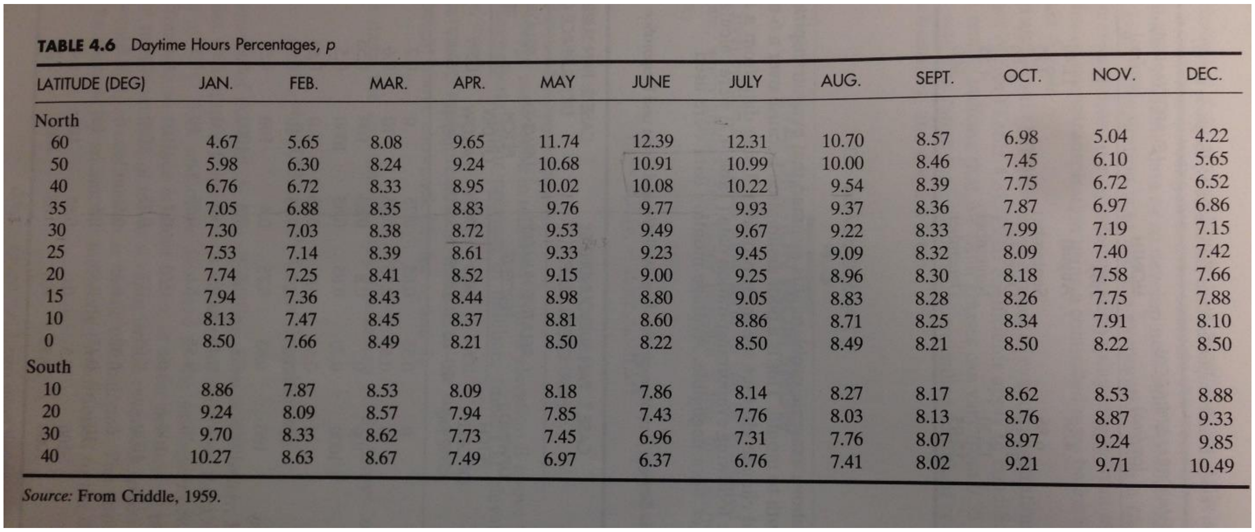


TABLE 4.6 Daytime Hours Percentages, *p*

LATITUDE (DEG)	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
North												
60	4.67	5.65	8.08	9.65	11.74	12.39	12.31	10.70	8.57	6.98	5.04	4.22
50	5.98	6.30	8.24	9.24	10.68	10.91	10.99	10.00	8.46	7.45	6.10	5.65
40	6.76	6.72	8.33	8.95	10.02	10.08	10.22	9.54	8.39	7.75	6.72	6.52
35	7.05	6.88	8.35	8.83	9.76	9.77	9.93	9.37	8.36	7.87	6.97	6.86
30	7.30	7.03	8.38	8.72	9.53	9.49	9.67	9.22	8.33	7.99	7.19	7.15
25	7.53	7.14	8.39	8.61	9.33	9.23	9.45	9.09	8.32	8.09	7.40	7.42
20	7.74	7.25	8.41	8.52	9.15	9.00	9.25	8.96	8.30	8.18	7.58	7.66
15	7.94	7.36	8.43	8.44	8.98	8.80	9.05	8.83	8.28	8.26	7.75	7.88
10	8.13	7.47	8.45	8.37	8.81	8.60	8.86	8.71	8.25	8.34	7.91	8.10
0	8.50	7.66	8.49	8.21	8.50	8.22	8.50	8.49	8.21	8.50	8.22	8.50
South												
10	8.86	7.87	8.53	8.09	8.18	7.86	8.14	8.27	8.17	8.62	8.53	8.88
20	9.24	8.09	8.57	7.94	7.85	7.43	7.76	8.03	8.13	8.76	8.87	9.33
30	9.70	8.33	8.62	7.73	7.45	6.96	7.31	7.76	8.07	8.97	9.24	9.85
40	10.27	8.63	8.67	7.49	6.97	6.37	6.76	7.41	8.02	9.21	9.71	10.49

Source: From Criddle, 1959.

Figure 16. P values for the Blainey Criddle equation.

Table 4: K Values in the Blainey-Criddle Equation.

Crop	**Length of normal growing season or period** [1]	**Consumptive-use coefficient (*K*)** [2]
Alfalfa	Between Frosts	0.80 to 0.90
Bananas	Full year	0.80 to 1.00
Beans	3 months	0.60 to 0.70
Cocoa	Full year	0.70 to 0.80
Coffee	Full year	0.70 to 0.80
Corn (Maize)	4 months	0.75 to 0.85
Cotton	7 months	0.60 to 0.70
Dates	Full year	0.65 to 0.80

Flax	7 to 8 months	0.70 to 0.80
Grains, small	3 months	0.75 to 0.85
Grain, sorghums	4 to 5 months	0.70 to 0.80
Oilseeds	3 to 5 months	0.65 to 0.75
Orchard crops:		
Avocado	Full year	0.50 to 0.55
Grapefruit	Full year	0.55 to 0.65
Orange and lemon	Full year	0.45 to 0.55
Walnuts	Between Frosts	0.60 to 0.70
Deciduous	Between Frosts	0.60 to 0.70
Pasture crops:		
Grass	Between Frosts	0.75 to 0.85
Ladino Whiteclover	Between Frosts	0.80 to 0.85
Potatoes	3 to 5 months	0.65 to 0.75
Rice	3 to 5 months	1.00 to 1.10
Sisal	Full year	0.65 to 0.70
Sugar Beers	6 months	0.65 to 0.75
Sugar cane	Full year	0.80 to 0.90
tobacco	4 months	0.70 to 0.80
Tomatoes	4 months	0.65 to 0.70
Truck crops, small	2 to 4 months	0.60 to 0.70
Vineyard	5 to 7 months	0.50 to 0.60

[1] Length of season depends largely on variety and time of year when the crop is grown. Annual crops grown during the winter period may take much longer than if grown in the summertime.

[2] The lower values of K for use in the Blainey-Criddle formula, $U = KF$, are for the more humid areas, and the higher values are for the more arid climates.

Curve Number Table

01, "Dense Conifer Forest", 46,68,78,84

04, "Cloudy Broadleaf Forest", 36,60,70,77

06, "Humid Broadleaf Forest", 15,44,54,61

07, "Open Conifer Forest", 56,75,86,91

08, "Semi-Humid Broadleaf Forest", 26,52,62,69

09, "Dry Forest", 45,66,77,83

11, "Dry Thicket", 51,67,76,80

18, "Broadleaf Thicket", 50,66,75,78

22, "Marsh", 59,65,72,78

23, "Rice", 67,78,85,89

35, "Scarce Vegetation", 55,69,78,83

36, "Intensivly Cultivated", 61,72,79,82

38, "Sugar Cane", 70,81,87,90

40, "Pasture", 39,61,74,80

41, "Cacao", 72,81,88,91

45, "Coco", 63,75,83,87

53, "Coffee", 65,76,84,88

54, "Zona no clasificada (use residential)", 61,75,83,87

59, "Mixed Agriculture", 77,86,91,94