YUMA DAM SITE ANALYSIS
DOMINICAN REPUBLIC

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COVER LETTER

April 15, 2015

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Dr. E. James Nelson:

The report following this letter is a comprehensive analysis of the proposed dam location on the Yuma River near the city of Higuey in the Dominican Republic. This report provides a hydrologic overview by way of engineering calculations and modeling on the Yuma watershed.

This report was a collaborative effort including students at INTEC and engineers at INDHRI in Santo Domingo, Dominican Republic. This report is not a professional design, rather an analysis and summary of the feasibility of the recommended dam location, with the given available data.

The resulting analysis from calculations will allow representatives at INDHRI to make concise and informed decisions for moving forward. Recommendations were given based on hydrologic analysis with no consideration given to local economics. Results provided will assist in the decision making process. Included within the report are the following resources: hydrologic models, mass curves, volume capacity curves, flood analysis for probable maximum storm, and flow duration curves.

Sincerely,

Tyler Remund — Matt Saguibo

Kevin Kofford — Nicklaus Stephens

Executive Summary

The Instituto Nacional de Recursos Hidráulicos (INDRHI) proposed a site for a dam seven kilometers northwest of the city of Salvaleón of Higuey in the province of La Altagracia. This dam would be used to provide water for the city of Higuey as well as water for irrigation in the areas of Los Jobos and Cuya. Higuey currently has a population of about 250,000 people and is growing. With a growing population and the additional need for agriculture, having a reliable water source is crucial.

In order to determine the feasibility of a dam at this site, several hydrologic analyses were performed. Runoff hydrographs, a storage capacity curve, a mass curve, and a dam break analysis were performed using the HEC-HMS (Hydrologic Engineering Center Hydrologic Modeling System) and GSSHA (Gridded Surface Subsurface Hydrologic Analysis) models for several return periods including the probable maximum precipitation (PMP). The analyses in this report were based off historical data from the Higuey weather station as well as information and computer data provided through INDRHI. The purpose of this report is to provide the hydrologic data INDRHI needs to determine the viability of this location as a future dam site.

Introduction

Northwest of the city of Higuey, a 32.5 meter dam is proposed on the Yuma River. The purpose of this dam is to provide irrigation and domestic use with sub benefits of generating hydroelectric power and flood control. The Instituto Nacional de Recursos Hidraulicos (INDRHI) provided our team with the anticipated dam usage. INDRHI also informed our team of the additional benefits a dam could provide. Using the data provided by INDRHI, a hydraulic analysis was performed to analyze feasibility of dam on the Yuma River. The results obtained will provide INDRHI with the information needed to make a proper decision.

Problem Description

Irrigation and domestic use are the main priorities of the Duey Dam; understanding the possible demand and storage in the future proposed reservoir is critical to its feasibility. Water is needed to irrigate approximately 1,748 hectares (17.5 square kilometers) of agricultural land and pasture. Also, meeting the domestic use demands of a city growing at a rate of 2.4 % per year is a challenge (The World Factbook).

Procedure

In order to have a complete perspective on the proposed dam, the following procedure was followed. All necessary information needed to complete the analysis was provided by students at INTEC and professionals at INDRHI. This information includes precipitation data, a preliminary dam report, soil type data, and land usage information. All hydrologic processes follow outlined procedures found in the book Hydrology (Wanielista, Kersten and Eaglin).

First, daily rainfall data from the Higuey gage station was organized and analyzed to determine rainfall return periods and the probable maximum precipitation (PMP). Using the calculated return periods, flow rates and runoff volume were predicted by hydrographs. These hydrographs were created by Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) and Gridded Surface Subsurface Hydrologic Analysis (GSSHA) simulations.

Second, storage capacity curves were generated by using the hydraulic toolbox found within the Watershed Modeling System (WMS) computer software. A flow duration curve was also created showing the reliability of flow in the Yuma River. This curve allowed a simple hydraulic analysis to estimate possible hydropower to be performed. A mass curve was created using precipitation data, and a demand was calculated from performing a consumptive use calculation and domestic consumption estimate. Lastly, a dam break analysis using GSSHA and WMS was created to show the possible implications of the proposed dam breaking.

Description of Site

Located in the eastern region of the Dominican Republic, the proposed dam site resides in an area mainly composed of foothills, which would be used to contain the proposed reservoir. The watershed area surrounding the site is named the Yuma watershed, named by the local river, and comprises an area of approximately 61 square kilometers. The surrounding area consists mainly of pasture for grazing livestock and agricultural land dedicated to several crop types. Because the proposed dam site is located only seven kilometers northwest of the city of Higuey, it would provide much needed flood control. With close proximity to the city, it may also pose a threat which is discussed further in this report.

Figure 1 shows the delineated watershed surrounding the Yuma River. **Figure 2** shows a photograph of the Yuma River and the surrounding site conditions. **Figure 3** shows the existing vegetation and soil conditions near the dam site.

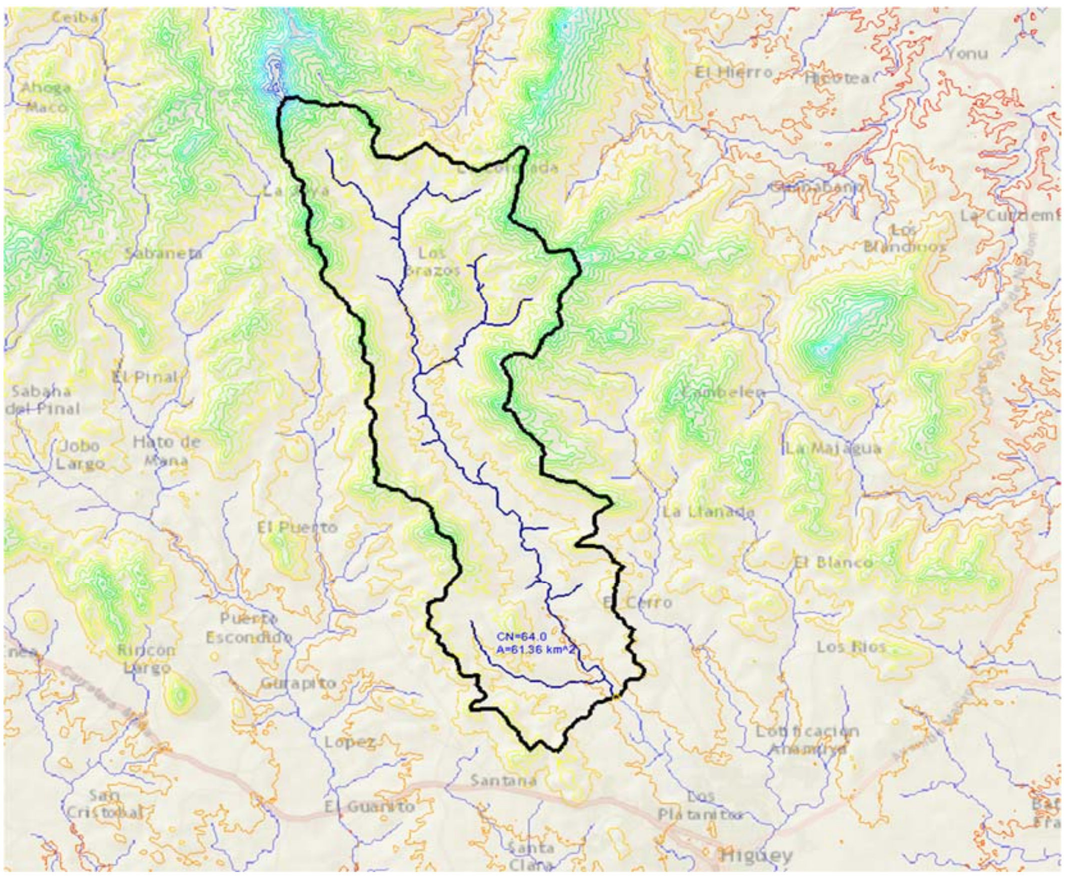

Figure 1: Yuma River and delineated watershed.

Figure 2: Photograph of the Yuma River near the dam site.

Figure 3: Photograph of surrounding vegetation and soil.

Hydrologic Analysis

Storm PMP and Return Periods

Precipitation data from the Higuey station was used for the return period and PMP calculations. Both of these calculations were for a 24 hour period. Data from stations at El Mamey and San Rafael was also considered but consequently rejected due to the short length of station records and the distance of these stations from the watershed. The lack of data at these stations resulted in PMP values that were two to three times greater than that of the Higuey station (see

Table 5 in the Appendix). The Higuey station is very close to the Yuma watershed (less than 10 kilometers) and provided nearly 50 years of precipitation data. We believe this station alone provided the most accurate results.

The PMP value was calculated using Hershfield's Method, with the Hershfield recommended value of *k* equal to 15. The average yearly maximum precipitation was added to the *k* value then multiplied by the standard deviation, 27.78 mm (

Table 5). The 50 years of precipitation data provided a relatively small standard deviation compared to the stations of El Mamey and San Rafael. As a result, we were able to obtain a PMP value that we believe to be fairly accurate.

Our team then calculated the return periods using the Weibull Method. Since the Weibull Method only allowed calculation of up to a 47-year return period, with the 50 and 100 year values being estimated. A logarithmic curve appeared to best fit the distribution of data while still returning slightly conservative values. The logarithmic curve function was used to estimate the 50 and 100 year storm values as shown in **Figure 4**.

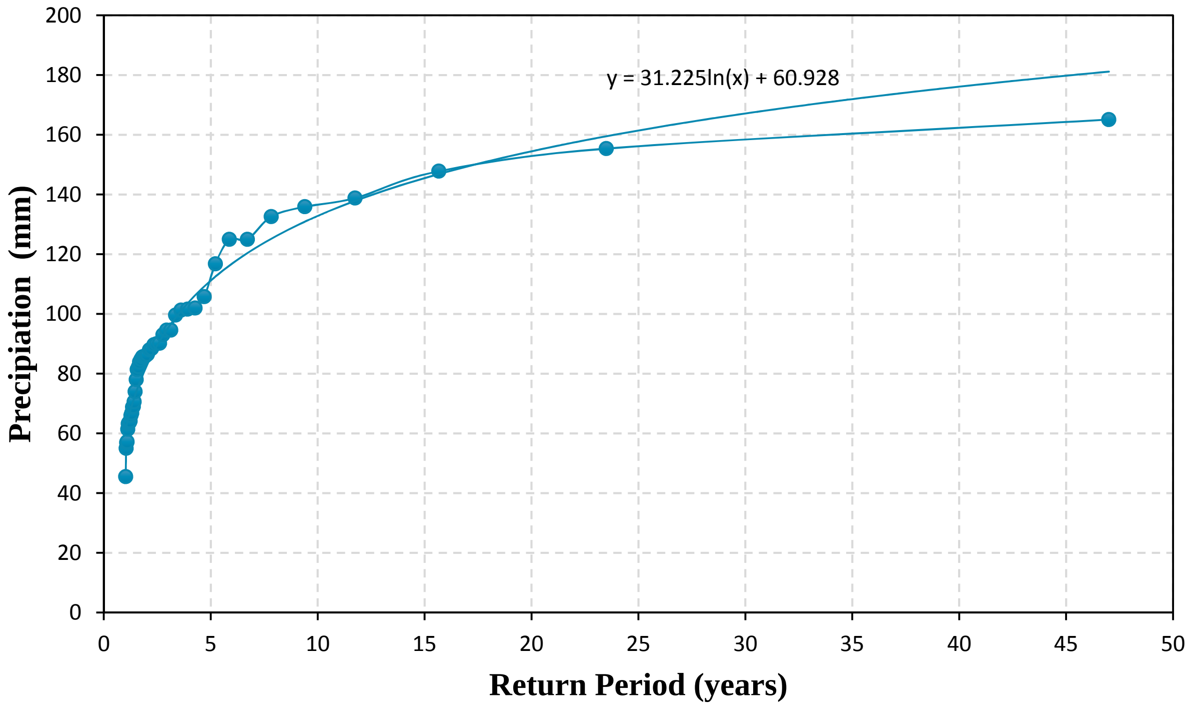

Figure 4: Calculated return periods and logarithmic trend line.

Storage Capacity Curves

In order to estimate the amount of storage a watershed can hold, a storage capacity curve can be created showing the relationship between volume and elevation of the water surface. The storage capacity curve was computed using WMS. The curve is created by estimating the desired elevation height at the outlet point of the watershed. As estimated by INDHRI, the height of the proposed Duey Dam is to be 32.5 meters. The current elevation of the outlet point is 97.3 meters above sea level, as determined from the coordinates of the WMS model. The program computes the storage discharge curves based on the area topography taken from a digital elevation model (DEM). Using the DEM, WMS found the volume of the reservoir as the elevation rose from elevation 97.3 to 129.8 meters (top of the dam). **Figure 5** shows the corresponding storage capacity curve for the dam on the Yuma River.

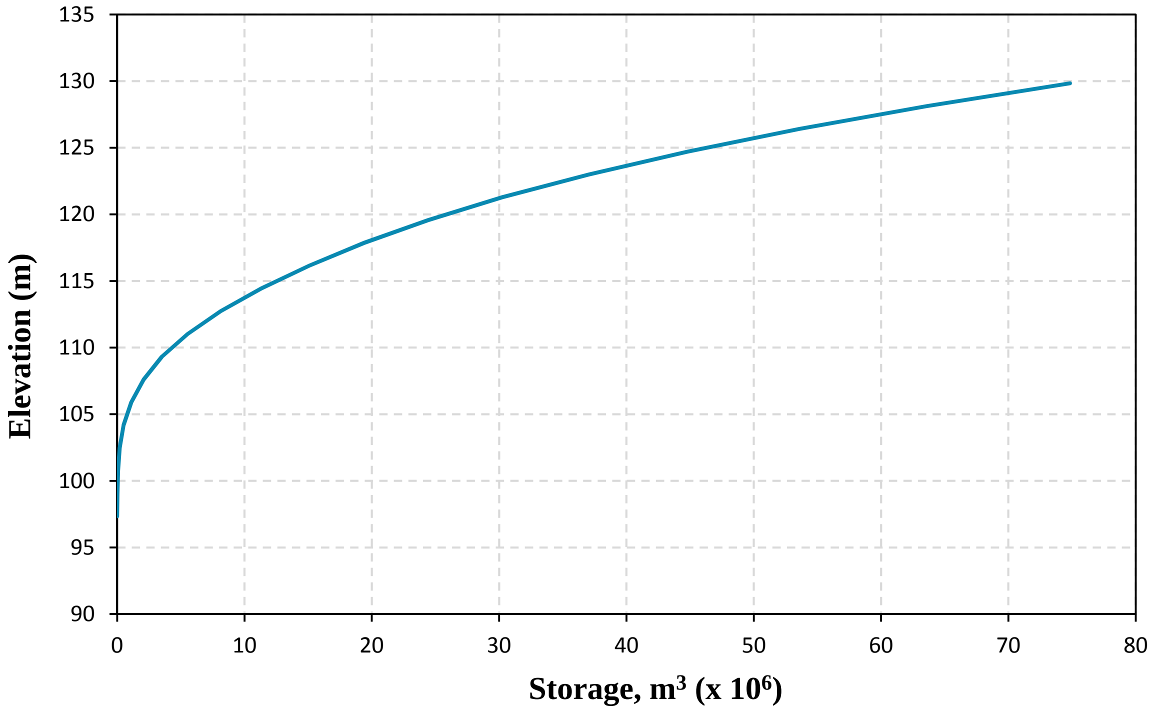

Figure 5: Storage Capacity Curve for the Duey Dam.

As seen from **Figure 5**, the curve rises quickly from the starting elevation and then slowly flattens out. This shape is typical of a normal watershed area due to the quick elevation gain close to the river bank and the expanding landscape once the water rises. INDRHI estimated a required storage of 35 million meters cubed in their preliminary analysis. That number is consistent with the results of the storage capacity curve. Thirty-five million meters cubed of storage would occur around 120 to 125 meters elevation, a little over half of the peak storage. Thus, according to the storage capacity curve, the proposed reservoir can hold the storage amount specified by INDRHI.

Consumptive Use

In order to estimate the correct demand needed for the area surrounding the dam, a very basic consumptive use calculation was performed. The consumptive use is an estimate of the volume of water that the existing crops will consume. Though many crop types are grown in the area surrounding Higuey, locals have suggested that livestock feeding is predominant**,** requiring large spaces of pasture.

From this information, our team concluded that sugar cane and pasture were the two crop types we would use in order to maintain simplicity. The Blaney and Criddle formula was used to find a monthly consumptive use in millimeters (Wanielista, Kersten and Eaglin). This depth was then multiplied by the corresponding area for each crop type. As specified by INDRHI, around 17.5 square kilometers of crops will be dependent on the proposed reservoir. It was assumed that 70% of the agriculture land was sugar cane which uses a consumptive use factor, k, of 0.85. Because sugar cane requires more water than pasture land, assuming 70% of the agricultural land as sugar cane is a conservative measure and will overestimate the actual volume of water needed. The other 30% of the land was assumed to be pasture with a k value of 0.70. **Table 6** in the Appendix shows how the analysis was performed.

We concluded that 0.0203 kilometers cubed (2.03×10^7 meters cubed) of water would be required to maintain the crops. This conservative estimate is used as part of the total demand on the dam and is further discussed in the section below.

MASS CURVE

The Mass Curve Model (Ripple's Method) was used to help determine the required reservoir capacity and yield. Cumulative streamflow volumes were summed and plotted against time. The demand was calculated by summing the consumptive use per year (**Table 6**) with the estimated water usage giving claim of 10% to the population of Higuey. Per capita water use was obtained and found to be 547.2 m^3/ year for the Dominican Republic (The World Factbook). The calculated demand was plotted against streamflow starting at the point of lowest flow over the time period of 1975 through 1980 (see **Figure 7**).

The Mass Curve shown in **Figure 6** is only a rough approximation of what the real streamflow values would be over time over a period of eight years. **Figure 7** shows the mass curve plotted with the demand line for 1978 to 1980.

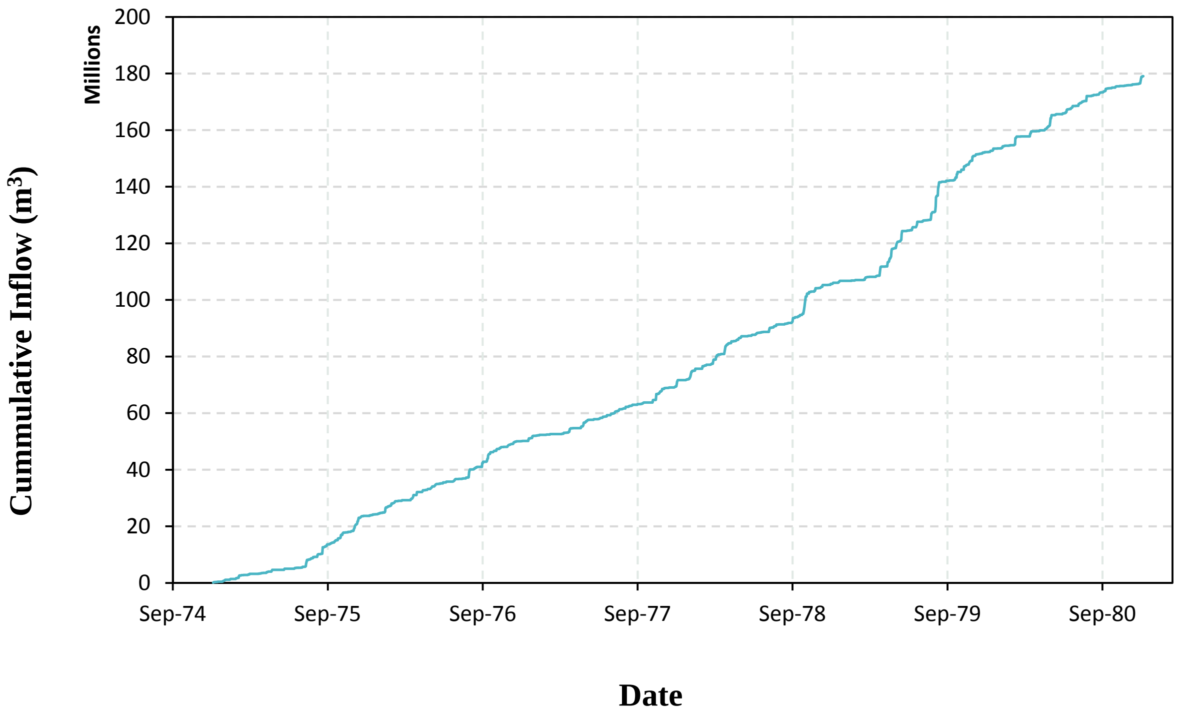

Figure 6: Mass Curve for the Duey Dam site.

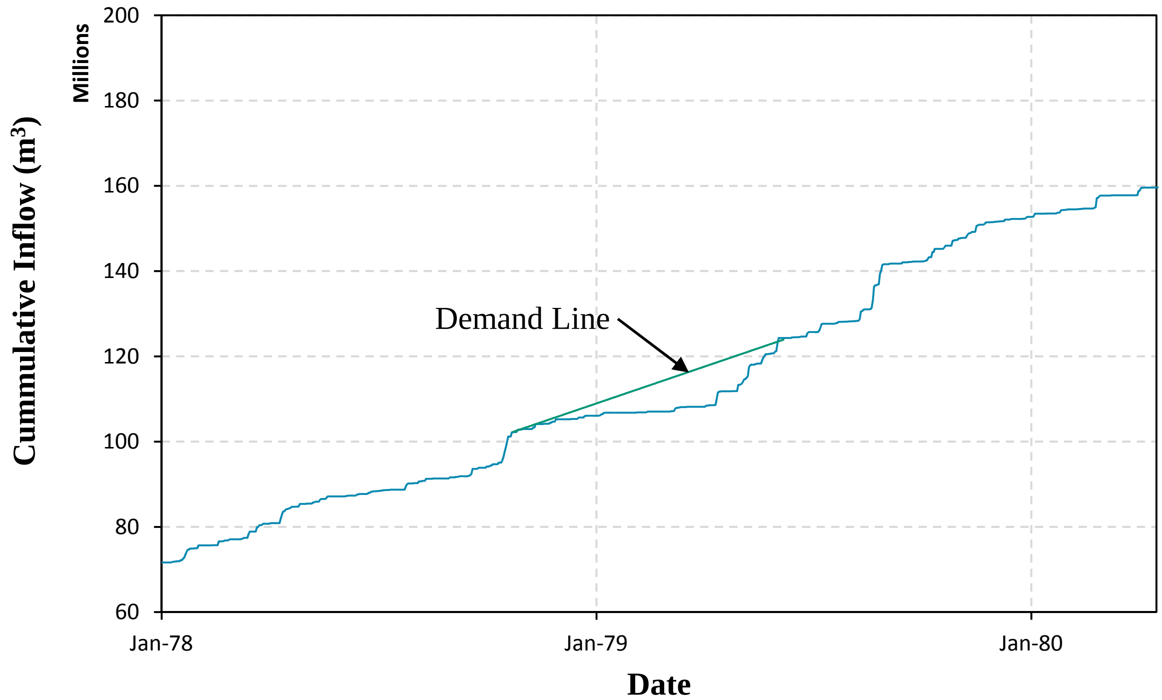

Figure 7: Mass curve with corresponding demand.

Figure 6 was created by converting historical precipitation data into precipitation volume over the watershed. The volume was then multiplied by a runoff coefficient to obtain streamflow. The runoff coefficient was obtained from the average HMS and GSSHA runoff values for a 2 year storm (**Error! Reference source not found.**). Due to the lack of streamflow data this analysis should only be used to give a general idea of how the reservoir will perform.

Table 1: HMS and GSSHA Runoff Coefficients

	HMS	GSSHA
Total Runoff (m^3)	1,016,377	2,775,415
Total Rainfall (m^3)	5,258,200	5,258,200
Runoff Coefficient	0.193	0.528
Average Coefficient	0.3606	

The difference between demand and streamflow was calculated to be 989,981,621 m^3. This analysis predicts that this will be the minimum storage required for the previously stated conditions.

Flow Duration Curve

The flow duration curve (FDC) is a cumulative frequency curve that shows the percent of time during which a specified discharge can be equaled or exceeded for a given period. The FDC is another means of representing streamflow data showing the range of discharges for a given time period. Understanding the FDC is crucial to know how much flow can be expected for generating hydroelectric power. It is also critical in designing the dam, spillways, and other hydraulic structures that will need to be constructed.

The flow duration curve used in this study was created by using formulas derived by Blake D. Buehler to estimate the flow duration curves at locations where data does not exist in the Dominican Republic. The equations involve four parameters: precipitation in millimeters, area in square kilometers, a curve number, and a slope as a percentage (Buehler, 2011). Using Buehler's equation, the following FDC was created and is shown in **Figure 8**.

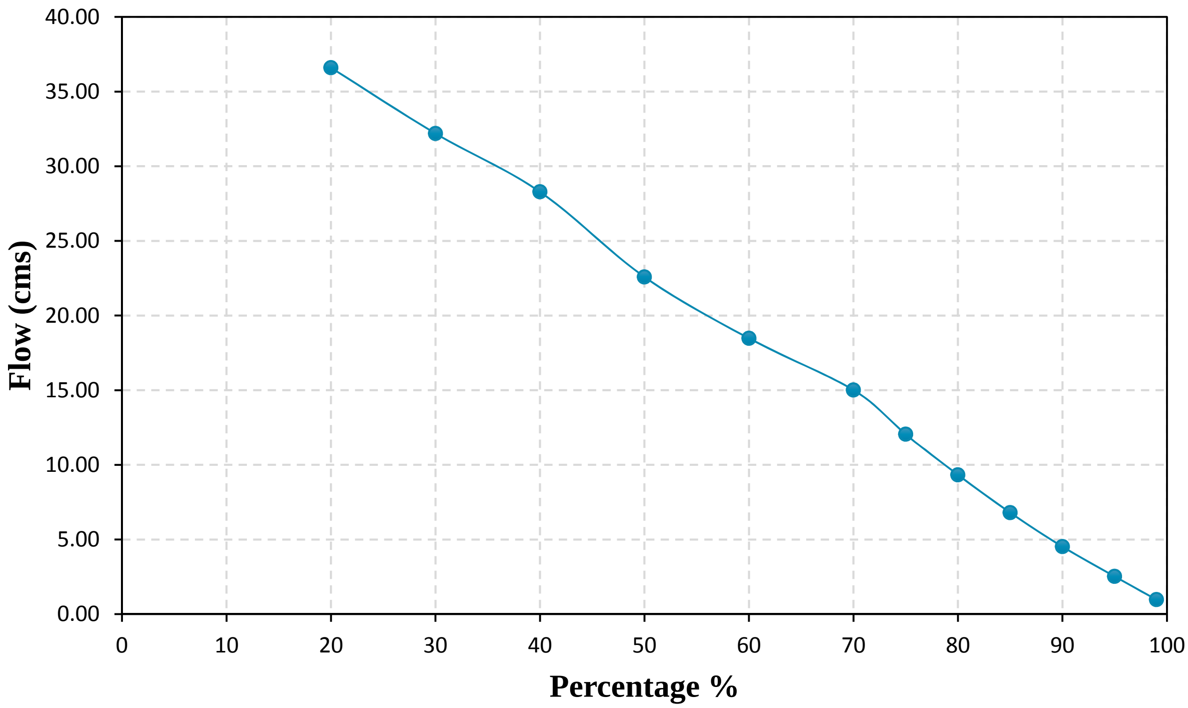

Figure 8: Flow Duration Curve (FDC) for the proposed Duey Dam.

The preliminary report done by INDRHI stated that an expected 0.9 cms of flow was required from the proposed dam. According to the FDC and the chosen parameters, a flow of 2.35 cms or greater can be produced 95% of the time. The values for precipitation, area, curve number, and slope are shown in

Table 2.

Table 2: FDC Values for Duey Dam.

Precipitation	1400 mm
Curve Number	63.98
Area	61 km^2
Slope	.35%

The greatest variable in determining the FDC was the percentage of slope. A slope of 0.35 percent was used because it represented the average whole value of the slope in the river bed. Higher slopes produce more flow and a more conservative estimate. Changing the value of the slope could give a broader range of results to determine more accurately the Q_{95} value. Because of the variability of the Buehler equations, the FDC shown in **Figure 8** may not show an accurate representation of the true flow. Additional analysis and data could verify the validity of the FDC curve.

Hydrologic Models

Introduction to the Models

After gathering the hydrologic parameters discussed previously, several hydrologic models were used to determine peak flows and hydrographs for each return period. Watershed Modeling Systems (WMS) was used as interface for running HEC-HMS, an Army Corps analysis program, Gridded Surface Subsurface Hydrologic analysis (GSSHA), and GSSHA Dam Break analyses. The main purpose for running the models was to create a hydrograph that will demonstrate how different volumes of flow will vary with time. Both models assume that the reservoir is empty and measure the outflows at a point on the river where the proposed dam is to be built. The Dam Break analysis was performed to provide a simulation for failure of the proposed dam, assuming a full reservoir. Each method has different assumptions and computes the hydrograph through different mathematical models. A hydrograph corresponding to each return period was generated and will be presented. All hydrographs assume a base flow of zero. The return period rainfall depths used were based on the collected 46 years of data from the Higuey weather station. A Weibull statistical distribution, as mentioned previously, was used to calculate the values, shown in

Table 3.

Table 3: Return Periods and Rainfall Depth

Return Period	Precipitation (mm)
2	86.2
5	112.1
10	136.6
25	156.9
50	183.1
100	204.7
PMP	550

HEC-HMS Parameters

The HEC-HMS model is a commonly used model in the industry because it's straightforward assumptions and parameters. HEC-HMS is highly dependent on a composite curve number (CN), which is assigned to the entire watershed, creating a general hydrograph and giving an estimate of peak flow. Because the curve number represents an overall value for loss, finding a curve number that accurately represented the site proved to be critical. WMS was used to find a composite curve number by using land use and soil type shapefiles. The soil type shapefile used was given by INDRHI, and land use shapefiles came from the "Global Land Cover" database linked to WMS. The default WMS land use shapefile was chosen because of the comprehensive list of land types. Adjustments to the default curve numbers were made to more accurately describe the terrain based on visual inspections of the site.

```
================================================================================
                        Runoff Curve Number Report
                           (Generated by WMS)
================================================================================

Mon Mar 16 15:39:20 2015


Runoff Curve Number Report for Basin 1B

HSG  Land Use Description                               CN   Area         Product
                                                             km^2         CN x A

A    Closed to open (>15) broadleaved evergreen or     60      29.130      1747.826
A    Mosaic vegetation (grassland/shrubland/forest)    58      11.562       670.595
A    Mosaic cropland (50-70) / vegetation (grassla     65       1.695       110.153
C    Mosaic vegetation (grassland/shrubland/forest)    73      15.539      1134.345
C    Closed to open (>15) broadleaved evergreen or     73       1.264        92.284
A    Rainfed croplands                                  65       0.116         7.551
C    Mosaic cropland (50-70) / vegetation (grassla     79       1.059        83.674
C    Rainfed croplands                                  79       0.991        78.276

CN (Weighted) = Total Product \ Total Area
==========================================
                                   63.9657
```

Table 4 shows the results for the composite curve number calculated using WMS.


```
================================================================================
                        Runoff Curve Number Report
                           (Generated by WMS)
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Mon Mar 16 15:39:20 2015


Runoff Curve Number Report for Basin 1B

HSG  Land Use Description                               CN   Area         Product
                                                             km^2         CN x A

A    Closed to open (>15) broadleaved evergreen or     60      29.130      1747.826
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CN (Weighted) = Total Product \ Total Area
==========================================
                                   63.9657
```


Table 4: Results for Composite Curve Number

As seen from

```
=================================================================================
                         Runoff Curve Number Report
                            (Generated by WMS)
=================================================================================

Mon Mar 16 15:39:20 2015


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HSG  Land Use Description                               CN  Area      Product
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CN (Weighted) = Total Product \ Total Area
==========================================
                                   63.9657
```

Table 4, the composite curve number used throughout each calculation was 63.9. The time of concentration calculated used the SCS method and this curve number, within WMS. Each storm modeled in HMS was patterned after a 24-hour SCS type 2 rainfall, which was chosen to most accurately represent the rainfall patterns for the Dominican Republic. This pattern consists of lower intensities of rainfall in the beginning and end of the storm with higher intensities of rainfall during the middle of the storm.

HMS Models

After running the HEC-HMS analysis, outflow hydrographs were produced. **Figure 9** shows the corresponding hydrographs for each storm. These models usually give conservative estimates due to overcompensation on loss by the curve number.

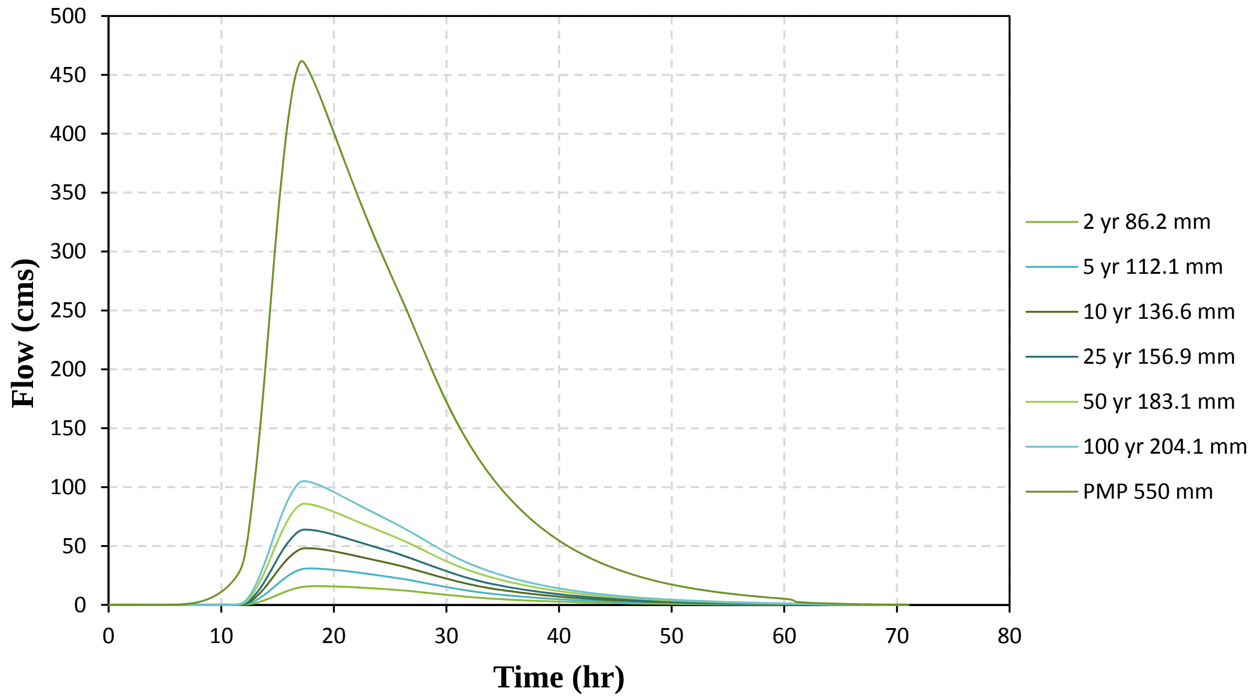

Figure 9: Outflow hydrographs for Yuma watershed using HEC-HMS.

Figure 9 shows that the peak flow for each return period occurs approximately around the 15 hour mark. It is important to note that the time of concentration, or the time from the peak flow to zero flow, is more than twice the time to peak. This indicates that soil infiltration and other forms of losses need to be accounted for when determining the time intervals that a storm may produce runoff. These hydrographs may be adjusted with different assumptions for the curve number. For a more in depth analysis, a slightly higher and lower value could be used to observe a more consistent peak flow.

GSSHA Model

GSSHA is a more in depth grid based model that uses land use and soil type mapped to a particular grid. A 100-meter grid cell size was used in the analysis of the Yuma watershed. Instead of assuming all of the watershed area to be one curve number, the GSSHA model individualizes each cell and controls how the water flows from one grid cell to another. Also, instead of using a curve number, GSSHA uses a roughness (n) value. The chosen n values were determined for each land using tables (Wanielista, Kersten and Eaglin). An image of the n values as entered into WMS are shown in **Figure 10**. **Figure 11** shows the GSSHA grid and how the model accounts for both soil type and land use.

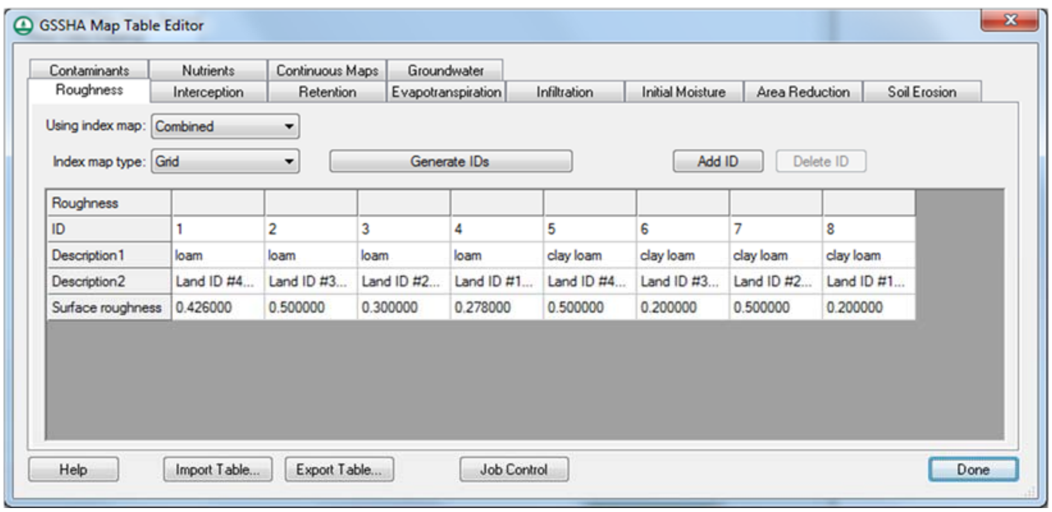

Figure 10: Roughness, n, values for each land use.

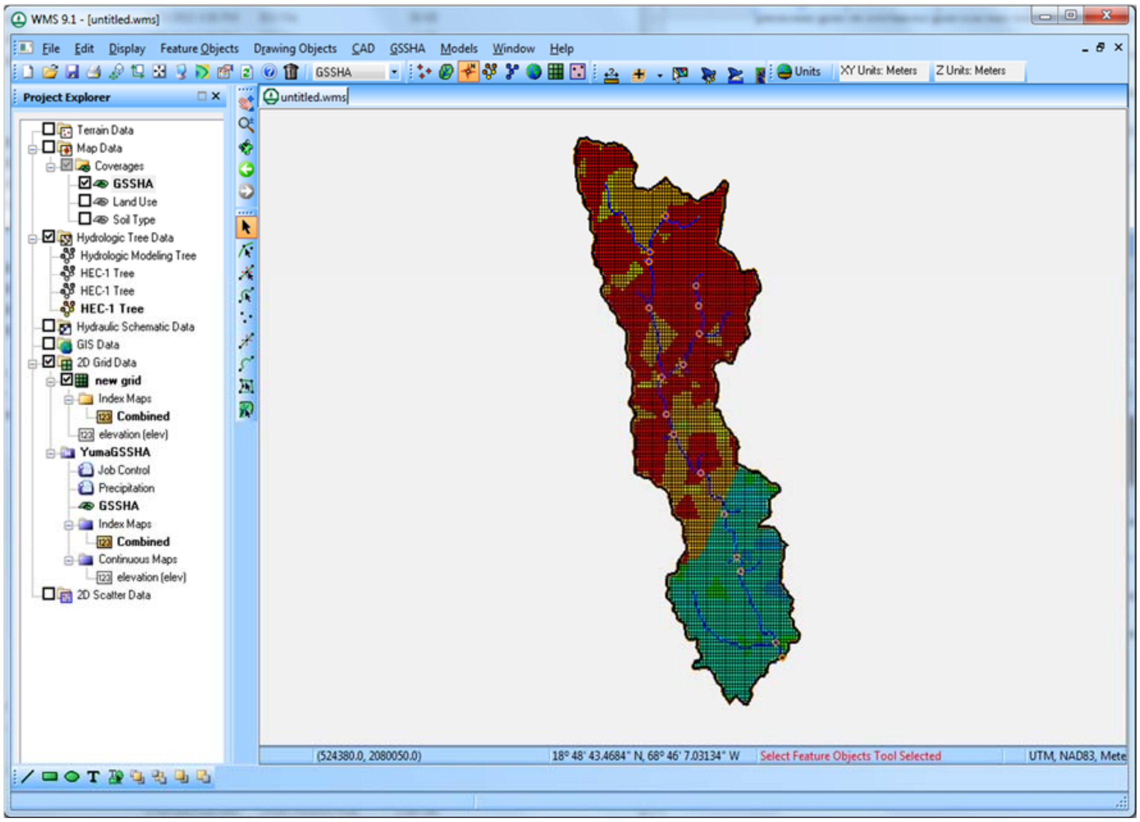

Figure 11: GHSSA model in WMS

The hydrographs produced from the GSSHA model assumed no infiltration or base flow in order to maintain consistency with the HMS model. Because HMS does not account for infiltration methods, it was determined to neutralize as many parameters as possible so that the two models could be compared with each other.

Figure 12 is the GSSHA model that ran for each return period on the Yuma watershed. Watershed characteristics are more evidently seen in the GSSHA model.

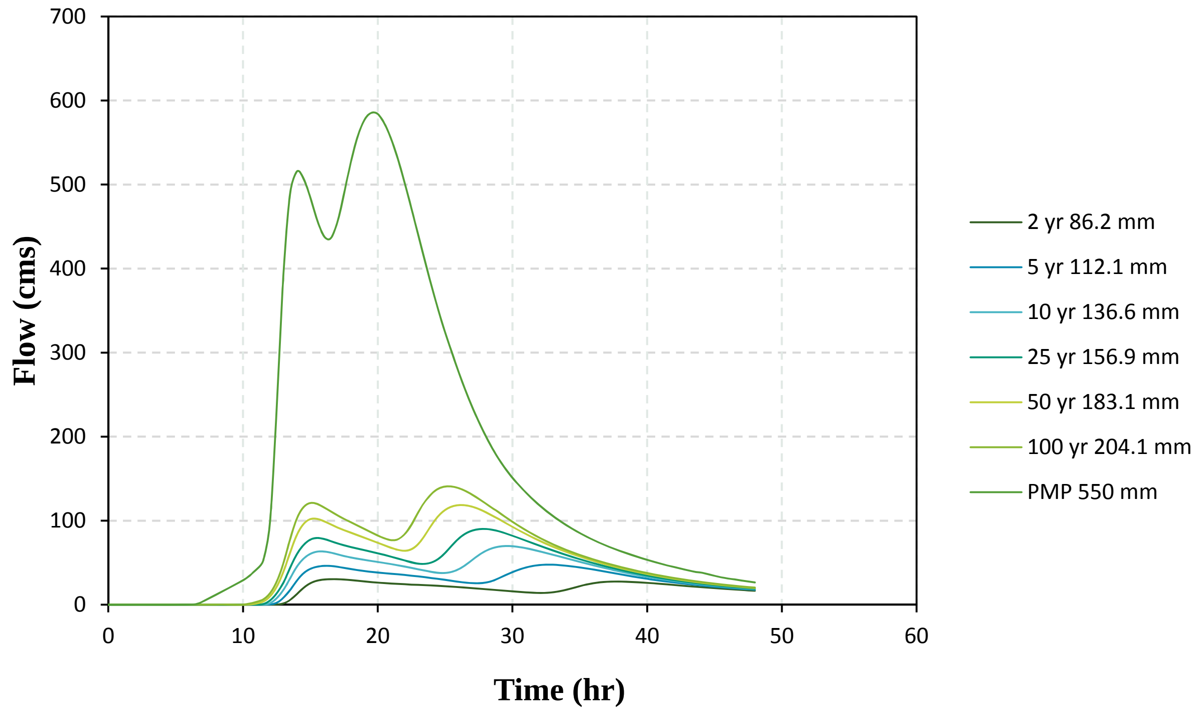

Figure 12: Outflow hydrographs for each return period using a GSSHA analysis.

GSSHA simulates that as the storm progresses there will be intermediate peaks in the runoff. Having alternate runoff peaks provides more information about the characteristics of the Yuma watershed. It is possible that this alternative peak is produced by a larger tributary that produces runoff at the outflow point before the main discharge from upstream arrives at the outflow point. It could also be due to the variation in roughness, which can constrict the amount of water and the time it takes to reach the channel. For more in depth analysis, the n values could be changed to show how the variation in flow and timing can be affected.

GSSHA AND HMS MODEL SUMMARY

Because the GSSHA model assumed no infiltration, the results were more comparable with the HMS models. When comparing **Figure 9** and **Figure 12**, it is interesting to observe that all hydrographs peak between 12 and 20 hours. Though, the GSSHA peak flows are slightly more delayed than the HMS models, the two models show very comparable timing for the peak flows. The GSSHA model has an additional peak flow which may more accurately account for surface roughness of the contributing tributaries. Furthermore, GSSHA predicted a peak flow close to 600 cubic meters per second (cms) for the PMP value, and around 150 cms for the 100 year storm. This was slightly higher than the HMS models which predicted a flow around 475 cms for the PMP value, and 100 cms for the 100 year storm. Thus, in this case, the GSSHA model proves to be slightly more conservative since it estimates slightly higher peak flows than the HMS model.

DAM BREAK ANALYSIS

An important aspect of any dam design is an analysis of the floodplain below the dam. This becomes important when analyzing the risks that are associated with the dam. The floodplain boundary extended from the face of the dam, down to the northern side of Higuey. This boundary extent was chosen in order to visualize what a flood wave would do if the Duey Dam were to break and empty the entire reservoir downstream towards the town of Higuey, Dominican Republic.

The flood model was created in GSSHA and utilizes a 30-meter by 30-meter DEM, with a 200-meter by 200-meter computation grid. The dam was specified to drain the reservoir in its full state, in only 1 hour. The simulation was also set up to run for just over eight hours to give the flood wave plenty of time to reach the city.

As displayed in **Figure 13**, the extents of the flood could potentially put parts of Higuey under 2-5 meters of water. This type of flood event could prove to be catastrophic to this city. Additionally, the agriculture of the area would be completely destroyed. This would place an immense economic strain on the surrounding areas, with a long lasting impact.

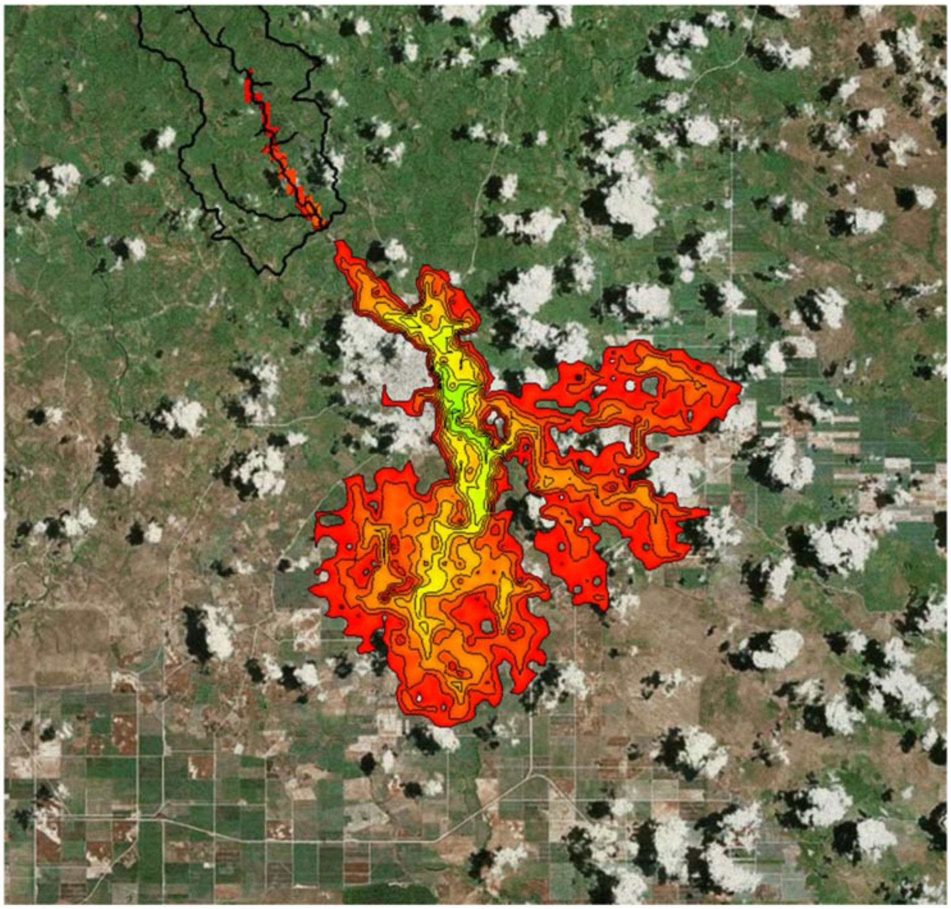

Figure 13: Flood extents for the Duey Dam.

However, it is important to point out that this simulation is conservative by nature. This simulates the event that the dam wall washes out in an instant and all of the contents of the reservoir are released downstream. In reality, most dam failures have a much slower release and failure rate than this. GSSHA floodplain modeling can produce very realistic and dramatic results. However, as this model is now, using a 30-meter DEM and a 200-meter grid can only give very simplistic idea of what will actually occur. For greater accuracy in this model simulation, a finer resolution DEM and grid would need to be obtained.

Hydroelectric Power

Hydroelectric power can be an enormous benefit to installing a dam. There are several factors that our team considered when analyzing the possibility of hydroelectric production. This mainly included the available water head, available flow, and required production. It is also important to note the assumption which we made concerning the site of the generator (turbine). It was assumed that the turbine would be placed at the dam, recognizing that it could be placed downstream to gain available head, but due to the existing slope of the ground in this area, the additional head would be negligible compared to head loss due to friction loss in the pipe. Thus, with this assumption, the head used on the turbine was the height of the dam, subtracting one meter of freeboard. Thirty meters of head was therefore used as the highest available water head for the generation process.

To discover the potential generated horsepower, we used the following horsepower equation, with all given values being converted to English units (Finnemore and Franzini).

$$Horsepower = \frac{\gamma \times Q \times H \times eff.}{550}$$

γ = 62.4 (lbs/ft^3)

Q = flow to turbine (cfs)

H = available water head on the turbine (ft)

eff. = efficiency of turbine, 85%

The flow used in this equation is the specified flow of 1 cms from INDRHI's preliminary report. If 95 percent of the time there is roughly a flow of 2.35 cms according to the flow duration curve, then an estimate of 1 cms would produce a conservative value of output horsepower. The efficiency of the turbine, 85 percent, was derived from the knowledge that the available head will not be maximized. For a turbine this represents a realistic efficiency.

After running the equation, we found that a conservative, yet maximized output for the turbine (generator) would be 335 horsepower. Using the conversion of 0.746 kilowatts per one horsepower, the potential amount of kilowatts produced by the turbine would be 250 KW (0.25 MW). This would not be a major contributor to the power grid, but it would be a great supplementary power to Higuey and other neighboring towns.

Environmental Assessment

Current Conditions

Higuey has a subtropical climate with dry and humid forest and large plains. Monthly rainfall varies on average from 50 to 200 mm, with rainfall values varying ranging within the region. The main river in the watershed is the Yuma River. Much of the region is lower-income rural area, where much of the region has been cleared for agriculture. Higuey represents the largest concentration of human population and is important to the local economy. The presence of insect, bird, fish, and small-mammal wildlife is small but present in much of the region.

Sedimentation

The typical design life of a dam is 50 years. However, in almost all cases the dam is expected to be used past it's design life. During this time the dam could possibly be accumulating sediment in two ways; it is either settling out naturally in the dam reservoir while water is being stored, or it could be filtered out while hydroelectric power is being produced. Overtime the sediment that collects in the reservoir decreases the storage capacity of the reservoir. At first this will not greatly impact the amount of water that is stored, but when considering a dam with a 50-year design life that will most definitely be used longer than that, the amount of sediment that accumulates greatly decreases the storage capacity of the reservoir.

Sediment management is an important aspect to consider when planning a future dam. Having a management plan intact at the beginning of the design life of the dam will prevent future problems and improve the output of the dam. For the current site, sedimentation is important to consider because of the occurrence of hurricanes. Hurricanes can cause sediment to travel downstream and get trapped by the dam in large quantities. We advise that before building the dam, consideration should be taken to determine an approximate rate at which sediment will accumulate in the reservoir. This will increase the overall cost of the dam, but the benefits of water storage overtime will pay for the extra cost incurred by sediment buildup. We recommend creating a management plan and installing sediment management facilities.

Conclusion

After completing the hydrologic analysis, it is the opinion of our team that the Duey Dam would be feasible, with the following recommendations. INDRHI's initial goals for desired storage and flow values would be achieved and maintained according to our hydrologic analysis. However, the analysis was performed with only one set of precipitation data and may be subject to error. Additional precipitation data from another station would be needed to verify accuracy of these results. More accurate peak flows could be obtained by running a model to produce an inflow hydrograph when the proposed reservoir is at full capacity. The current analysis only accounts for flow through the watershed without a full reservoir.

The dam could provide water for domestic use and irrigation, as intended, but only as supplemental to existing water networks. The estimated storage provides water for about 10% of the population Higuey after providing agricultural needs. After considering the proposed hydropower, the 0.25 MW would potentially be beneficial to the surrounding area. However, due to lack construction and maintenance costs, a recommendation cannot be given for or against the feasibility of developing hydropower. Lastly, after running the dam break analysis, the safety of the city of Higuey must be a concern. As mentioned in the report, the break in the dam will not be instantaneous, but a more thorough analysis is recommended to determine the extent of damage possible during a dam break.

Considering these few suggestions, we hope this hydrologic analysis will be beneficial to future decisions made by INDRHI and the Dominican Republic.

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APPENDIX

Table 5: Calculated PMP Value per Gage Station

	Station		
	Higuey Max	El Mamey	San Rafael
Mean (mm)	90.9	56.1	146.6
St Dev (mm)	27.8	73.1	52.2
k Value	15	15	15
PMP (mm)	**508**	**1153**	**929**

Table 6: Consumptive Use Calculations

Month	Temperature Average (F^o)	Average Temperature (C^o)	Precipitation Average (mm)	% of Daytime Hours	K Sugar	K Pasture	U Sugar (mm)	U Pasture (mm)	Area of Sugar Cane (km^2)	Area of Pasture (km^2)	Total Use (m^3)	Total Use (km^3)
January	73.58	23.10	68.64	7.796	0.85	0.70	123.83	101.98	12.24	5.24	1515142.15	0.00151514
February	74.52	23.62	98.92	7.2808	0.85	0.70	117.12	96.45	12.24	5.24	1433085.44	0.00143309
March	76.44	24.69	83.08	8.4156	0.85	0.70	138.86	114.36	12.24	5.24	1699114.70	0.00169911
April	77.58	25.32	74.53	8.50	0.85	0.70	142.31	117.20	12.24	5.24	1741250.15	0.00174125
May	79.00	26.11	105.70	9.1024	0.85	0.70	155.23	127.83	12.24	5.24	1899310.26	0.00189931
June	79.86	26.59	82.48	8.944	0.85	0.70	154.19	126.98	12.24	5.24	1886569.06	0.00188657
July	79.68	26.49	58.89	9.194	0.85	0.70	158.14	130.23	12.24	5.24	1934931.99	0.00193493
August	78.78	25.99	123.61	8.9236	0.85	0.70	151.75	124.97	12.24	5.24	1856758.99	0.00185676
September	77.49	25.27	106.64	8.2944	0.85	0.70	138.74	114.26	12.24	5.24	1697609.84	0.00169761
October	76.75	24.86	188.00	8.2024	0.85	0.70	135.89	111.91	12.24	5.24	1662740.39	0.00166274
November	74.84	23.80	192.33	7.6276	0.85	0.70	123.23	101.48	12.24	5.24	1507791.47	0.00150779
December	74.30	23.50	119.03	7.7216	0.85	0.70	123.85	101.99	12.24	5.24	1515362.82	0.00151536
Total:		24.95	1301.85								**20349667.29**	**0.0203**

Table 7: Precipitation Data for Higuey Gage Station

Year	Higuey Max (mm)
1935	101.6
1936	155.4
1937	132.6
1938	56.9
1939	68.8
1940	63.7
1941	70.6
1942	57.2
1943	89.7
1944	165.1
1945	135.9
1946	116.8
1947	90.2
1948	84.8
1949	45.5
1950	82.3
1951	78
1952	66
1953	102
1954	74
1955	90
1956	88
1957	55
1958	125
1959	86
1960	125
1961	66.8
1962	86.5
1963	83.9
1964	93
1965	99.6
1966	69
1967	64.2
1968	63.6
1969	81.4
1970	94.6
1971	61.4

1972	88.4
1973	138.8
1974	85.6
1975	105.8
1976	85.8
1977	94.6
1978	63.2
1979	147.8
1980	101.3