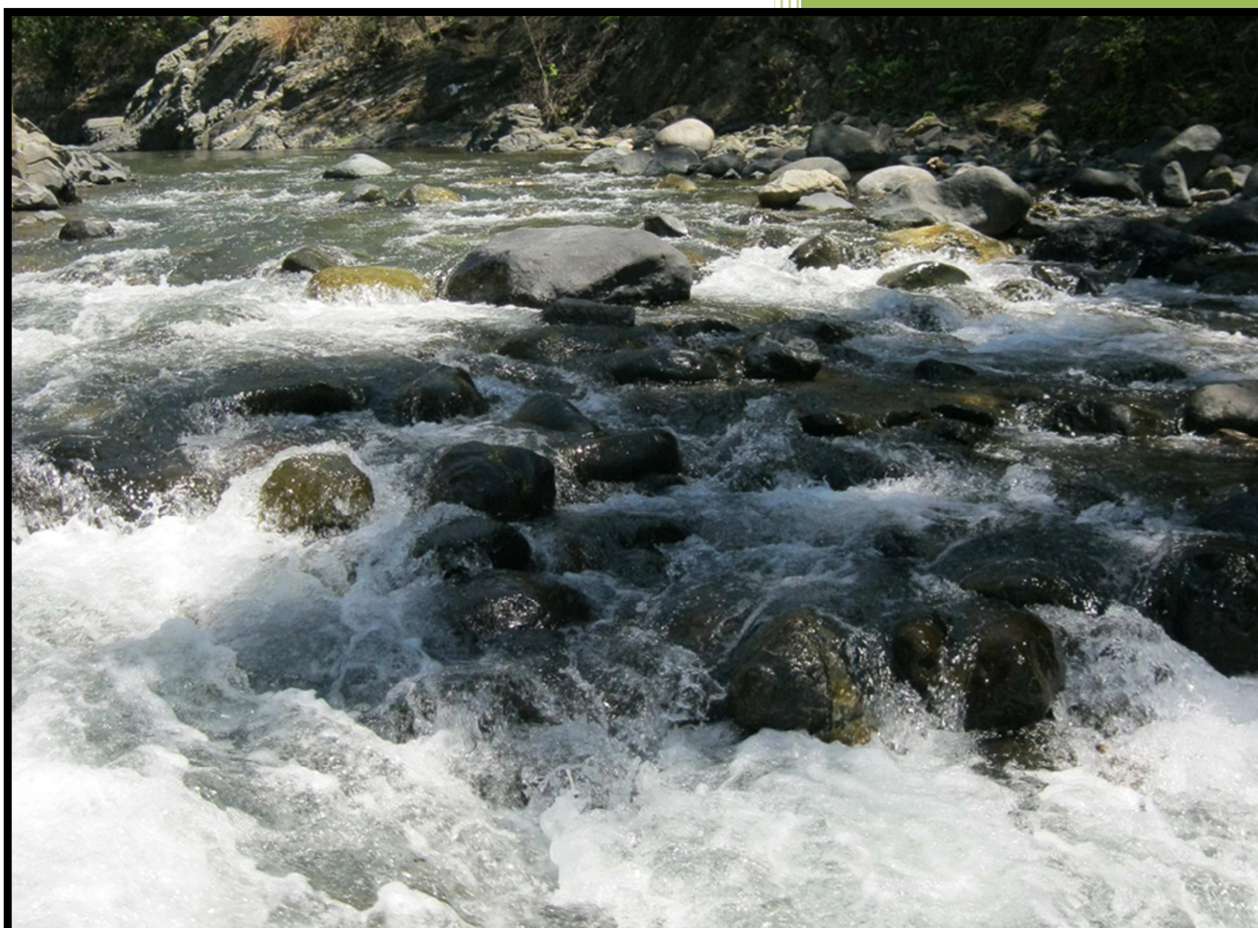
2012

Mijo River Project



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Executive Summary

The Mijo river project consisted of building a series of dams on the river Mijo in the Dominican Republic. One dam would be located at Los Rulos near the confluence of the river Mijo and its tributary stream Arroyo Grande. Los Rulos is 5 kilometers upstream from the stream gage site El Cacheo, which is 28 kilometers east of the city of San Juan. The proposed construction site of El Yayales, a second dam, is 7.5 kilometers upstream of the confluence of the river Mijo and Arroyo Grande forming a chain of dams of the river Mijo. The purpose of the project is to improve the availability of irrigation water (3.598 hectares) and electric power generation (7.78 MW).

The Instituto Nacional de Recursos Hidraulicos (INDRHI) provided the proposed layout for the dam system on the Mijo river. In summary, the first dam located near Yayales would generate 5.91 MW of power, where the lower dam at the confluence of the Mijo and the Arroyo Grande would generate 1.9 MW of power. The proposed height for the dam at Yayales is 18 meters providing 84 meters of head for the turbine located 5.5 kilometers downstream from dam. The lower dam located at the confluence would have a height of 16 meters, providing 45 meters of head for the lower turbine located 1.5 kilometers downstream from the dam. The water used to produce hydropower would continue to go downstream to supply the water needed for irrigation.

In the Dominican Republic, the design efficiency for turbines is 60%. Using this efficiency (η) in the power equation, ($P = \eta\gamma Qh$), he needed flow rate was determined for both turbines. Those flow rates were determined to be 12 cms for Yayales and 7 cms for Los Rulos. To determine if these flows were even plausible, ArcGIS and historical data from a stream gage at El Cacheo were used to generate flow duration curves. The flow duration curves were used to find the flow at 85%, or in other words, the flow that could be guaranteed at least 85% of the time. It was found by both

methods, that 85% of the time there will be a flow of approximately 4 cms. By verifying the historical data with the analytical method, we feel confident that the historical data is accurate.

Using the same historical data mentioned above, a cumulative storage curve was generated. Using the cumulative storage curve, the amount of storage capacity needed for specific flows was able to be determined. It was found that to produce 12 cms for Yayales, a storage capacity of 147 million cubic meters would be needed. The storage capacity of Yayales was determined using Watershed Modeling System (WMS), and was found to be 1.5 million cubic meters, a much smaller capacity than what is needed. Therefore, the cumulative storage curve was used to find what flow would be plausible given 1.5 million m3 of storage and that flow was found to be 1.5 cms. The analysis shows that the dams do not provide sufficient storage to produce the desired hydroelectric power during the entire year.

Introduction

The Dominican Republic is a land rich in natural resources, and is currently experiencing growing pains as its population and economy expand. In order to satiate increasing demand for electric power, INDRH intends to use the Domincan Republic's renewable water resources and has proposed that several dams and reservoirs be constructed in conjunction with hydroelectric power stations throughout the country. The Mijo river project is one of these proposed dams.

Project Constraints

The project specified that one dam would be located at Los Rulos near the confluence of the river Mijo and its tributary stream Arroyo Grande. A second dam constructed at the site of El Yayales, 7.5 km upstream of the first dam; the goal being to improve availability of irrigation water (3.598 hectares) and electric power generation (7.78 MW).

Approximately 5.9 MW of power would be generated at El Yayales, while the remaining 1.9 MW would be generated at Los Rulos. El Yayales would have approximately 84 m of head available while Los Rulos would have approximately 45 m of head. In the Dominican Republic, a design efficiency of 60% is used because of the lack of availability of super-efficient turbines. To calculate how much flow would be needed to produce the desired power, the power equation was used. We used these values for head, efficiency, and power to find out what flow rate we would need to generate the desired power.

Materials and Methods

Data

INDRHI provided historical data from a water station called El Cacheo. This water station is located on the Mijo river, downstream from Yayales and Los Rulos. El Cacheo provided 12 years of flow data which was imperative to our analysis. We also took our own flow data at the confluence of the Mijo and Arroyo Grande at the site of Los Rulos. Measurements were taken on the width and depth of the river for six cross sections at this point in the river. Then using small sticks, a measuring tape, and a timer, the speed that the stick moved a distance of 9.1 meter was recorded. Using these measurements we calculated the flow rate to be about 2 cms, which is a reasonable value given our flow duration curves. These measurements and calculations are summarized below in Table 1.

Table 1: Flow Calculation Results for Mijo River at Los Rulos		
Total Cross Sectional Area [m^2]	**Avg. Velocity [m/s]**	**Estimated Flow [cms]**
2.95	0.70	2.08

WMS

An Elevation-Storage curve was an essential tool that we had to generate to determine if there would be enough storage in our proposed reservoir to support the desired demand of 12 cms. To generate the curve, the Digital Elevation Model in WMS was utilized with the detention basin calculator, a built in tool of WMS. The proposed reservoir would have a volume of 1.5 million cubic meters as opposed to the nearly 150 million cubic meters that is necessary to fulfill the 12 cms demand.

ArcGIS/Excel

Using the program ArcGIS and the DEMs provided by INDRHI, a flow duration curve was generated (Figure 1). This flow duration curve is a result of mathematical equations and predictive methods, therefore the flows from this curve are estimates. However, the accuracy of the estimated curve was verified by the use of historical data from the water station El Cacheo. The data from the El Cacheo station was also used to generate a flow duration curve in Excel (Figure 2). By comparing the two curves, we found that the flows were quite similar; yielding an average 85% flow of approximately 4 cms.

The historical data provided by El Cacheo was also utilized to produce an Accumulative Storage Curve (Figure 3). The needed storage capacity to maintain these flows was found by graphing certain flow rates on this curve. The difference between the flow line and the curve line represents the storage capacity needed. A summary of the conclusions from this analysis can be found under the results section of this report.

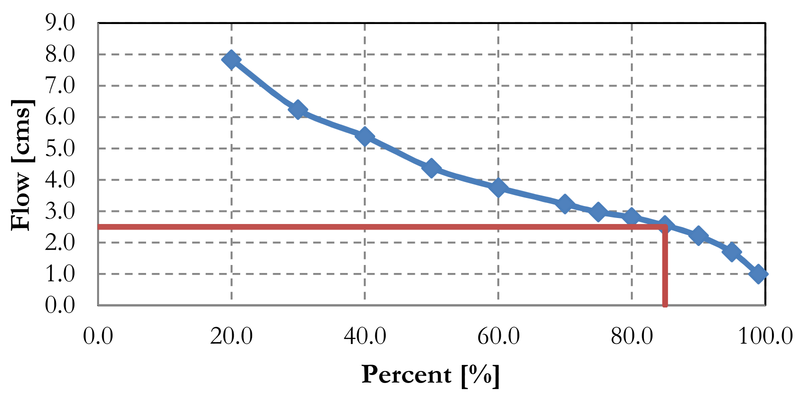

Figure 1: Flow Duration Curve-Yayales

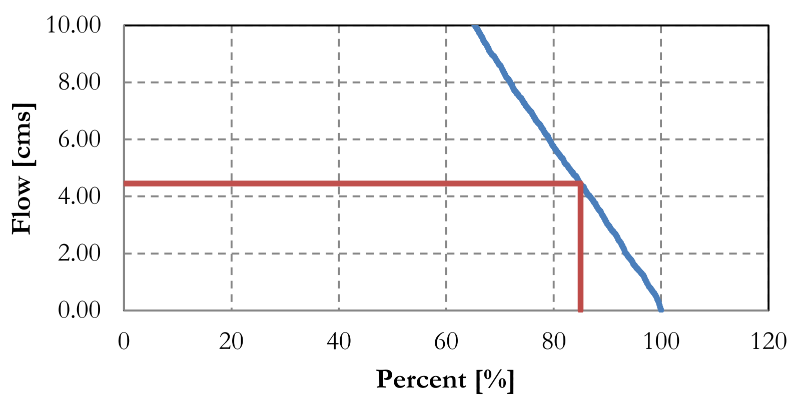

Figure 2: Flow Duration Curve- El Cacheo

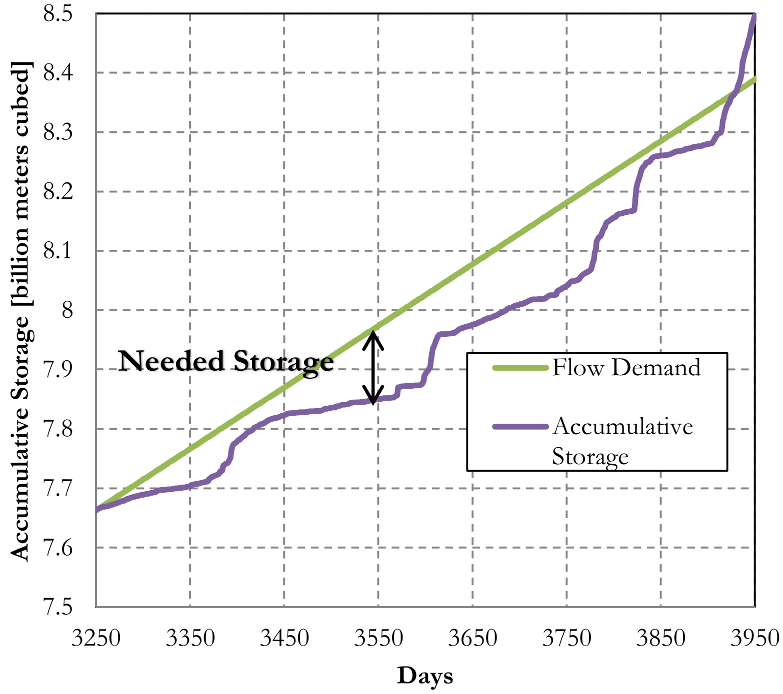

Figure 3: Accumulative Storage Curve

Results

WMS

Basin Delineation

Using WMS we were able to generate basin data such as the watershed area, this was useful because it made it possible to generate flow values in the river based on a specified precipitation event, as well as determine the flow duration curve based on the Cacheo flow data (Figure 4).

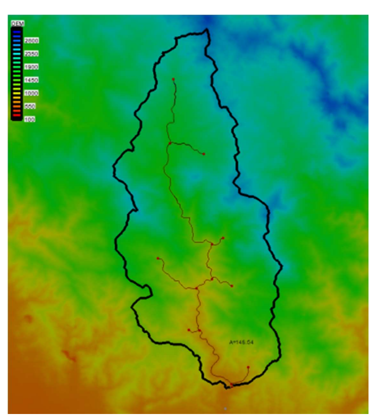

Figure 4: Watershed delineation for Yayales

We were also able to determine the volume that a reservoir on the Mijo River would hold given certain dam heights. To maintain a demand of 12 cms on the Mijo River during dry periods, the dam would have to produce a reservoir of 150 million cubic meters and a peak water surface height of 120 meters. A reservoir of this size on the Mijo River could take between 4 and 8 years to fill.

A reservoir of the size proposed with a dam height of 18 meter would not contain enough storage to affect a Probable Maximum Flood event on the Mijo River. Also, as residents of the valleys adjacent to the Mijo River explained to us, the flood waters never rise to a dangerous enough height to necessitate at dam for common flood control.

Dam Break

When we had successfully made a model that we were comfortable with then we took that model and simulated the flood that would occur if all the water behind the proposed dam of 18 meters in height was suddenly sent downstream. This would allow us to understand the outcome of the worst case flood during a catastrophic event in which there was complete dam failure. As stated above, we found that no populations would be in danger in a dam break event. If the dam height were increased to produce more storage more investigation would have to be made as to its effects on flooding and the impact of a dam failure.

ArcGIS/Excel

The storage requirements found for several demand flow rates are shown below in Table 2. As the table indicates, the storage capacity needed to generate the 12 cms to produce the desired power at El Yayales (5.9 MW), is far beyond what the site can produce. As explained above, the location under the current dam proposal only has 1.5 million cubic meters of volume. This means that only a flow rate of 1.5 cms can be used or the reservoir will not have enough flow to refill (Table 2).

Table 2: Potential Power and Needed Storage		
Flow [cms]	**Power [MW]**	**Storage [million m^3]**
1.5	0.7	1.03
2.0	1.0	2.0
2.5	1.2	2.9
3.0	1.5	4.4
3.5	1.7	7.2
4.0	2.0	12.4
4.5	2.2	17.6
5.0	2.5	23.0
6.0	3.0	33.6
12.0	5.9	146.5

Alternatives and Recommendations

Due to the lack of storage, generating a total of 7.78 MW on the Mijo river is not plausible with the proposed design. Therefore, we recommend to either simply lower expectations and produce less power, or increase the storage capacity by increasing the height of the upper dam at Yayales.

To produce 2.2 MW of power at Yayales, the storage capacity would have to increase by 16.1 million cubic meters (Table 3). This is possible, as shown by the Elevation Storage Curve, if a dam height of 50 meters is used. However, the cost associated with such a large increase in dam height must be considered. Most likely, the added power generated will not compensate for the extra building cost.

Therefore, we conclude that the best possible option is to lower power expectations, and simply use the run of the river (flow of approximately 4 cms) to produce 2.0 MW of power. However, this amount of power can only be generated if the 84 meters of head is supplied. We suggest constructing the pipeline on the existing potable water and irrigation pipeline to produce the 84 meters of head. The largest disadvantages of this method are that this power can only be guaranteed 85% of the time, and the river flow cannot be regulated.