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Rio Cumayasa

HYDROLOGIC STUDY

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Executive Summary

Project Background

The Dominican Republic is in need of more power and flood control. A sensible simultaneous solution to these problems is the construction of dams in advantageous watersheds. However, the question becomes which watershed would be advantageous. This project brought together INDRHI engineers, a group of students from INTEC and a group of students from BYU to answer that question. The proposed sites for these dams were split between multiple groups of BYU students; this report discusses the potential dam site in the Rio Cumayasa watershed.

Project Scope

This project mainly consisted of three parts, two of which are covered in this paper. The first part was to pick out the possible sites for the new dam and limit it to one site for hydrologic study. This group focused on a possible site for the Rio Cumayasa out of many other watersheds. INDRHI had already picked out a site for this watershed, knowing there was really only one optimum site for a dam in this area. So the first part of this project was to study the watershed and to see how feasible it was by analyzing the preliminary data we received and by using intuition. This involved travel to the Dominican Republic and included a site visit. The second major part of the project is to conduct a hydrologic study with the information gathered to determine the actual feasibility of the dam site. The third part of the whole project is to hydraulically design the dam at the site, this part of the project will be completed by the INTEC students.

Procedures

The first part of the project followed some general steps:

1. Gather online data of the water shed, including topography and the river path.
2. Visit the area which the dam site is located to gather physical conditions about the surrounding area
3. Collect data from INDHRI about rainfall, flows, and soil types.

The second part of the Project followed these general steps:

1. Order data and calculate necessary inputs from data for Hydrologic Models

2. Run Hydrologic Models using assumed parameters and data gathered.
3. Analyze results and draw conclusions.

Introduction

This project is a study of the hydrologic and environmental effects of constructing a dam in the Rio Cumayasa watershed. The project site is located at the point where River Cumayasa and River Limon meet (Figure 1 is a better visual of the site). This project is a preliminary study; more data would be needed for an in-depth analysis of the effects of constructing a dam in this location. The conclusions made in this report are based on results from observable data and certain hydrologic models run from the limited data given.

The following report covers the information about the site found in the course of this project's study. It will include descriptions of how each model was run as well, the reasonable assumptions made and where data was not available. An Environmental Impact Statement was also prepared and included in this report. It covers a wide variety of environmental concerns that follow the construction of a dam.

At the end of the report, some demands expected from the construction of a dam in this area are discussed. These demands were assumed from general dam uses worldwide, and knowledge about the Dominican Republic and surrounding areas.

Description of the Site

The project area is located in the eastern part of the Dominican Republic, along the Rio Cumayasa watershed. Components of the project lie in the La Romana, San Pedro de Macoris and El Seibo provinces. Some portions of the project fall within the Rio Cumayasa Cuevas De Las Maravillas National Park. The Rio Cumayasa originates from the northern part of Batey Florida and has River Limon at Mata Hombre joining it before it flows into the ocean down south. The project site is 20 km from the La Romana which is the capital of the La Romana province. The location of the Cumayasa project is shown below in Figure 1.

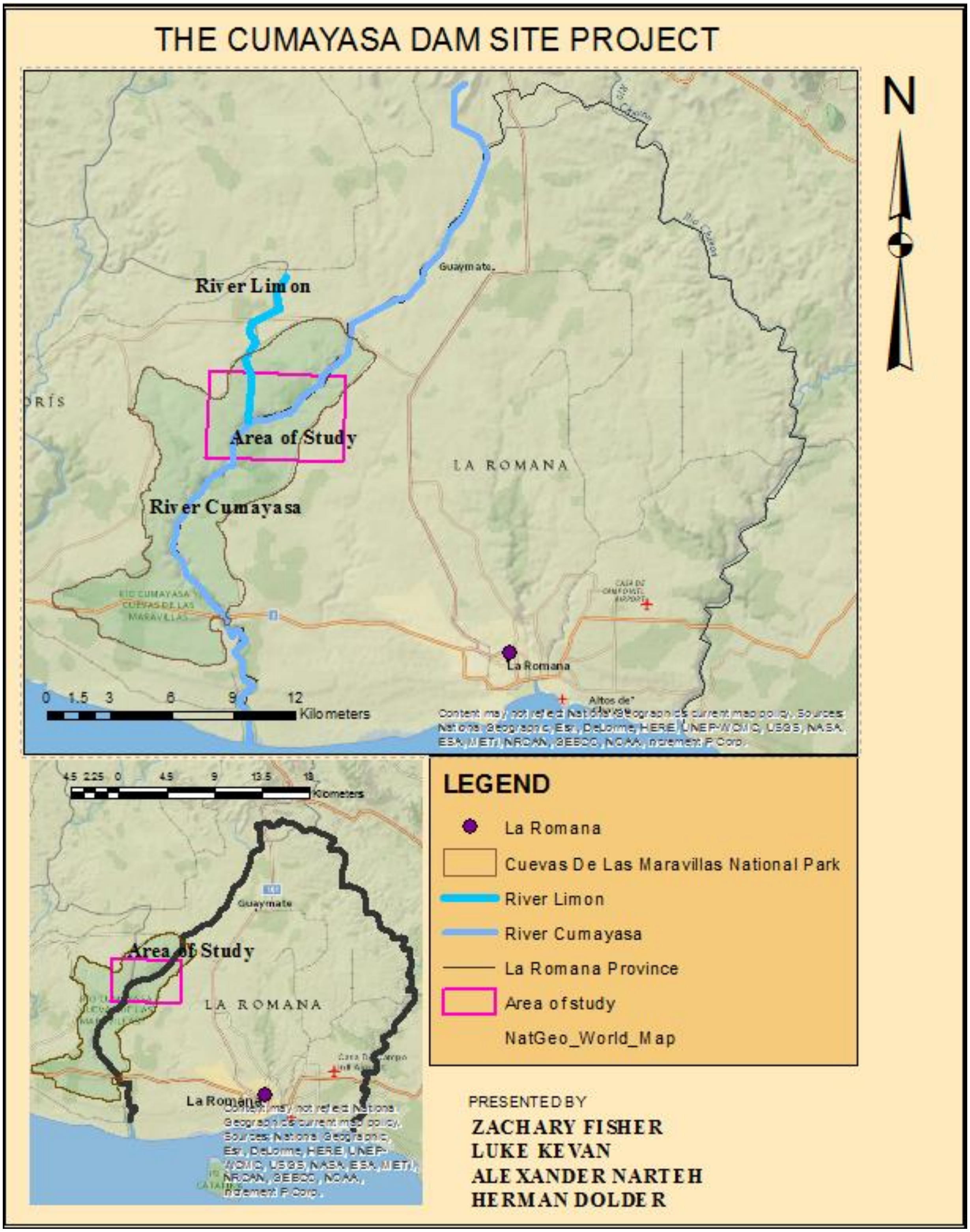

Figure 1 -Cumayasa Dam Site Project

The project is specifically located at the point where River Cumayasa and River Limon meet. The Dominican Republic, like most of the Caribbean, is located in a tropical humid area where hurricanes occur. There are three distinct vegetation zones in the Cumayasa watershed catchment area above the Cumayasa dam site, resulting in a relatively rare juxtaposition of riverine gallery forest along the Cumayasa River and its tributaries and savannah woodland away from the river. Some of the proposed inundation area to be created by the project lies within the Rio Cumayasa Cuevas De Las Maravillas National Park which is an archeological site and a fun tourist location. Aside from the Cuevas de Las Maravillas National Park, land in the project area is mainly used for farming and animal husbandry with majority of the people being farmers.

During the dry season (December –May), the Cumayasa river runs dry and has little or no water. During our visit in February we noticed that the river was totally dry. Fig 2 is an outlook of what we saw on our trip. During the wet season (June - November) the river is full and sometimes over flows its banks.

Figure 2 -The Cumayasa River on the 11th of February 2015

There is very limited aquatic and semi-aquatic vegetation in the study area, which is likely to be due to the lack of year-round surface flow in the river. The vegetation in the area consists of more than a 100 plant species, belonging to 45 plant families. All the plant species found in the study area are common and can be found within similar vegetation types within Dominican Republic. Some examples are shown in Figure 3 such as cassava and corn.

The system of farming is predominantly shifting cultivation or land rotation cultivation on a mostly subsistence basis. Most parts of the area are susceptible to accelerated soil erosion as show in Fig 9, and features of erosion are evident throughout the area, due to the light textured nature of the top soils.

Several insect surveys, conducted in the area over the past decade, indicate that the Cumayasa area is rich in terrestrial insect fauna with a high level of species diversity. Bird surveys indicate that the vast majority of bird species in Cumayasa are savannah woodland or riparian forest species. Present also are large mammal species which belong to a variety of families.

Figure 3 - Plants Found Near Site

Figure 4 - Nature of vegetation found near the site

Pre-Feasibility

The visited site was in a karstic soil zone, so it was not suitable for a dam. We've been told that the proposed site that we couldn't reach was on a different type of soil, so it wouldn't be a problem there, nevertheless, the geologic maps we found describe the proposed site also in the karstic zone. The visited site provided useful information about the topography, the land use, etc.

On the 11th of February 2015, a site near the proposed one was visited, and many factors were discovered that raised concerns about the feasibility of a dam in the area. It was obvious from the observation of the river bed that the soil was karstic which could strongly limit the storage capability of a dam on this site. In Figure 5 we can see an example of one of the rocks at the bottom of the river bed.

Figure 5 -Presence of porous rocks

Reading the geologic map (Figure 7) it can be observed that the proposed site and the surrounding region consist of this karstic soil type. The nearby Cueva De Las Maravillas National park which is a famous historical site in the Dominican Republic is displayed in the geologic map below (Fig 6).

Figure 6-Cueva De Las Maravillas displayed on Geologic Map as a **white Historic Site overlay**

Figure 7 - Yellow region represents Karstic Soil type and the Red box represents Area of Study

It was observed that even though there was no water in the river bed, there were evident signs of erosive processes consistent with high flow events. As an example, in Figure 9 we can see the erosion pattern of a bend of the river. Nevertheless, the presence of sprouts in the river bed (Figure 8) is an indication that the flow of water is sporadic.

Figure 8 - Sprouts in River Bed

Figure 9 - Erosion in Bank

Hydrologic Models

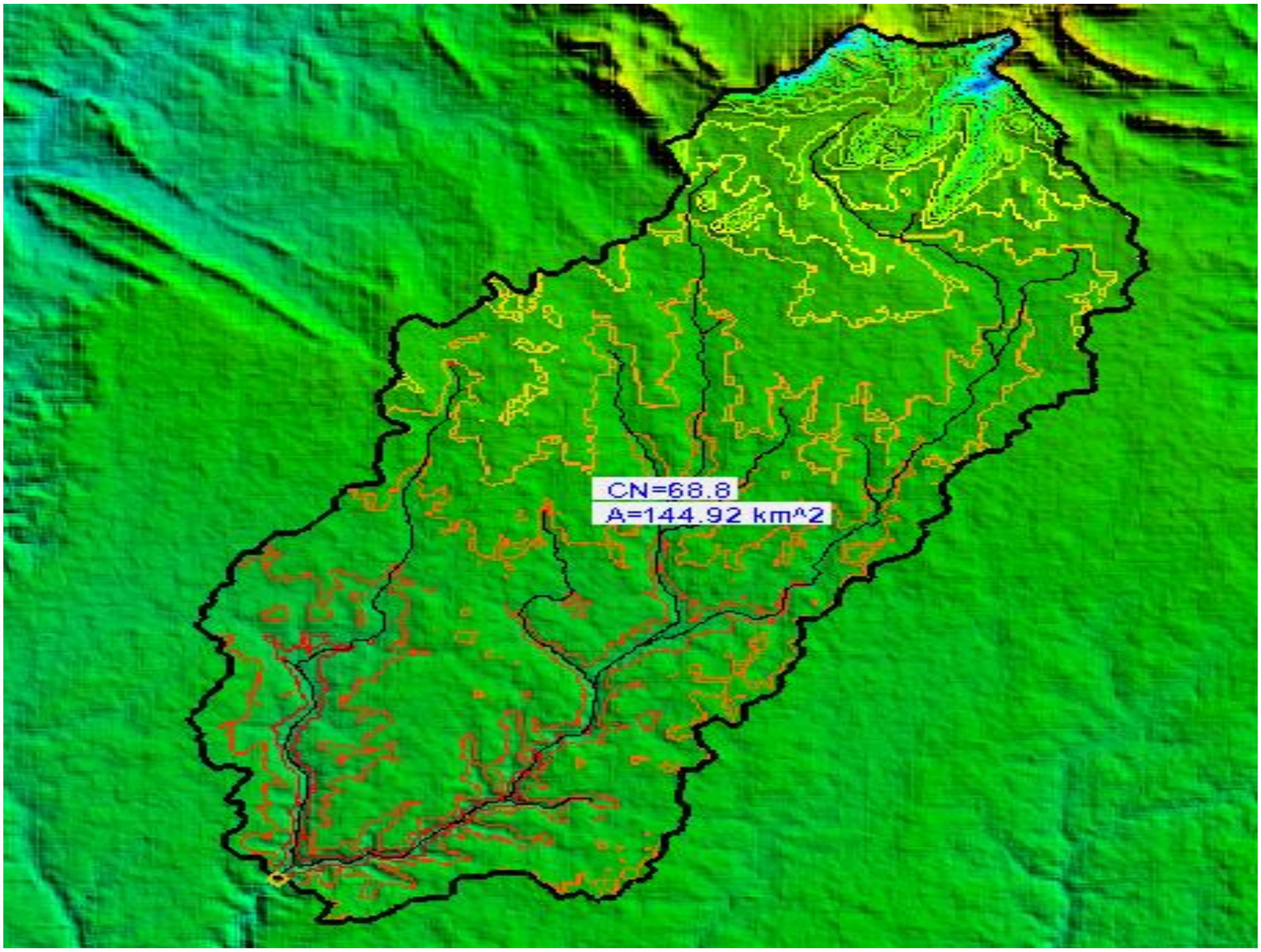

Figure 10 – Delineated watershed of the Cumayasa river.

Model Engines

All hydrologic models were prepared using WMS. Two model engines were used to address the particularities of the analysis performed. For the determination of the stream flows for different return periods and for the calculation of the flow duration curve and HEC-HMS was used while for the dam break flooding analysis GSSHA was utilized.

HEC-HMS

This model engine performs the convolution of a unit hydrograph to transform the precipitation into runoff. In its basic application the whole watershed is considered a unit with uniform characteristics. These kinds of model engines are usually labeled “lumped parameters” models because they use a limited set of parameters to represent complex hydrologic processes. Nevertheless, HEC-HMS provides an ample range of options to model routing, infiltration, base flow, evaporation, and so on.

GSSHA

GSSHA stands for "Gridded Surface Subsurface Hydrologic Analysis". Unlike HMS, this model engine is spatially distributed and physically based. Spatially distributed means the parameters and the characteristics vary throughout the watershed. Being physically based implies that the model produce the interaction of several physical models. For example, in each cell of the grid, several hydrologic processes are analyzed concurrently, precipitation, infiltration, evapotranspiration, snow accumulation, snow melt, groundwater exfiltration, etc., and any excess water is routed downslope based on the topography of the watershed. Also, GSSHA allows the implementation of 1D routing coupled with the grid to better represent the propagation of the flow in the rivers and streams. This characteristic makes this model engine a good option for determining flood areas.

Data Used and Calibration

No model is better than the data used to build it. For this work we used data from different sources. Some of the data was ready to use while some other required significant cleaning and processing before it could be incorporated in the model. INDRHI provided precipitation data such as return period maps and rain gage records; they also provided land use and soil type GIS data. DEM data was obtained from the SRTM data sets published by NASA. Satellite imagery, used to estimate the width and path of the streams was obtained from google earth.

To perform a calibration it is necessary to have boundary conditions and control points. In the models developed for this work the boundary conditions were mainly precipitation data, and unfortunately not many control points such as stream flows or water depths were available so some indirect methods were required. Also, since the precipitation data consisted of daily averages it was necessary for some of the analysis to artificially increase the resolution of the data by replacing the average with a corresponding 15-min SCS Type II Storm each day. The calibration therefore was performed by matching the flow duration curve obtained with a regression analysis to the one obtained by the resulting flows of the model. It goes without saying that they only matched in the order of magnitude as it will be shown later in the paper.

Hydrologic Analysis

Several analyses were performed to provide data to better assess the feasibility and the characteristics of the dam and its reservoir.

Stream Flows for Different Return Periods

The HMS hydrologic model was used to transform the maximum precipitations for different return periods into maximum flows for the corresponding return period. To obtain the precipitation for the 2.33, 5, 10, 25, 50, and 100 year return periods, the Dominican Republic Hydrologic Atlas was used by overlapping the watershed boundary and averaging the values read. The PMP was then calculated using the Herschfield method with a K of 15. It must be noted however, that the obtained value seems to be too high to be even physically feasible, therefore some caution should be used in its application.

Return Period	**Precipitation (mm)**
2.33	**85**
5	**120**
10	**150**
25	**175**
50	**180**
100	**237**
PMP	**919**

Table 1- Return Period vs. Precipitation Table Flow Duration Curves

Next, two flow-duration curve were determined using two different methods. For the first one, a set of regression formulas was used. These formulas used, as an input, some characteristics of the watershed such as; the area, the average annual precipitation, the curve number, and the average slope. Each of the formulas would produce the flow for a different duration. For the second method, a long-term model was run using as an input the precipitation data provided by INDRHI for that region and the resulting flows were sorted from maximum to minimum to generate the curve. Since the SCS curve number method for infiltration is not reliable for long-term simulations, an initial and constant method was used instead. Also, in order to better model the base flow, a linear reservoir method was used. The flow-duration curves obtained by these two methods resulted in quite different graphs, even though the values are in the same order of magnitude (refer to Figure 16).

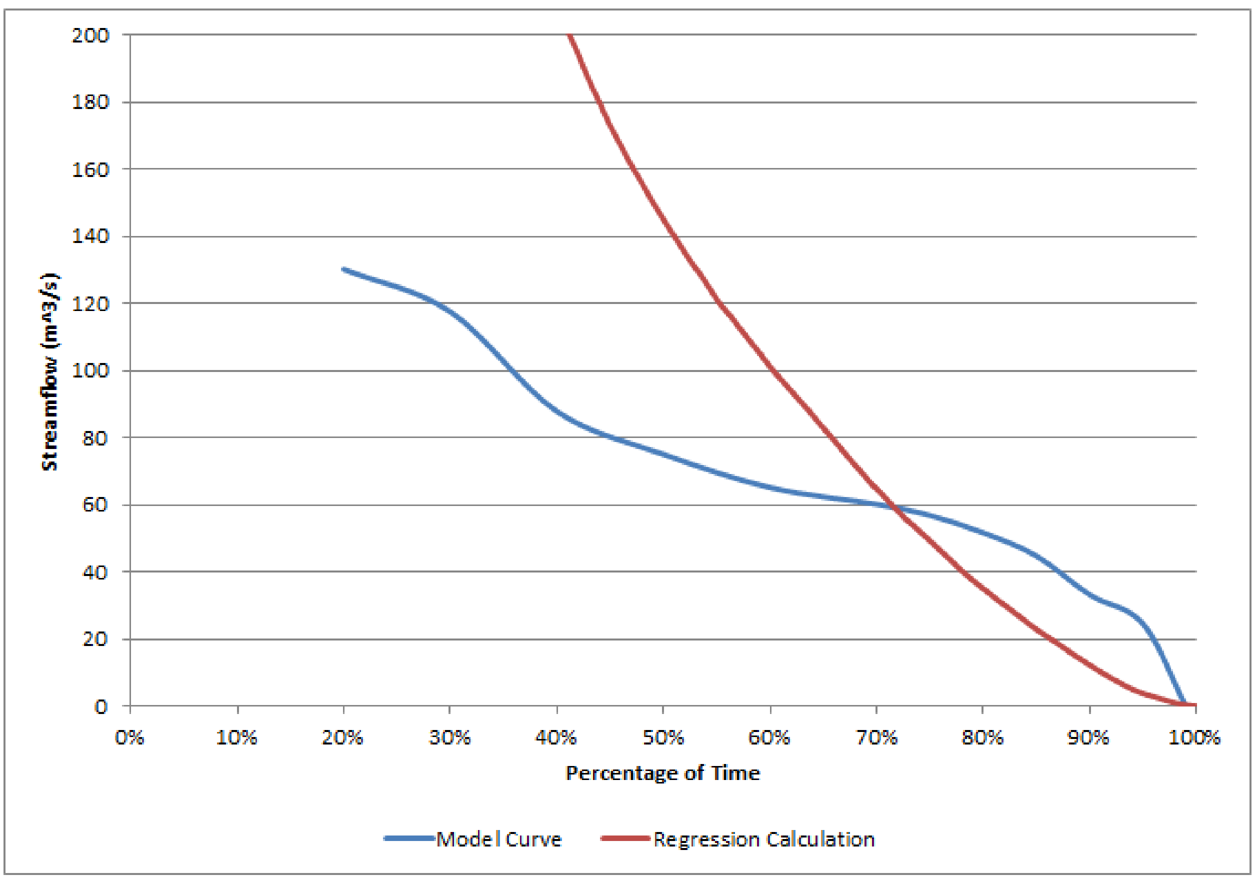

Figure 11 -Flow Duration Curve

Storage Capacity

The storage capacity curve was then calculated using a digital elevation model based on SRTM data (with a 90 meter cell size) under the following assumptions; the toe of the dam would be at an elevation of 46 meters above sea level, and the crest of the spillway at an elevation of 61 meter above sea level. It was found that at a level of 65 meters the water would overflow to the adjacent Soco river watershed. At a spillway crest height of 64 meters the total area of the reservoir created would be 4,477,553 square meters. See Figure xx for the results of this analysis.

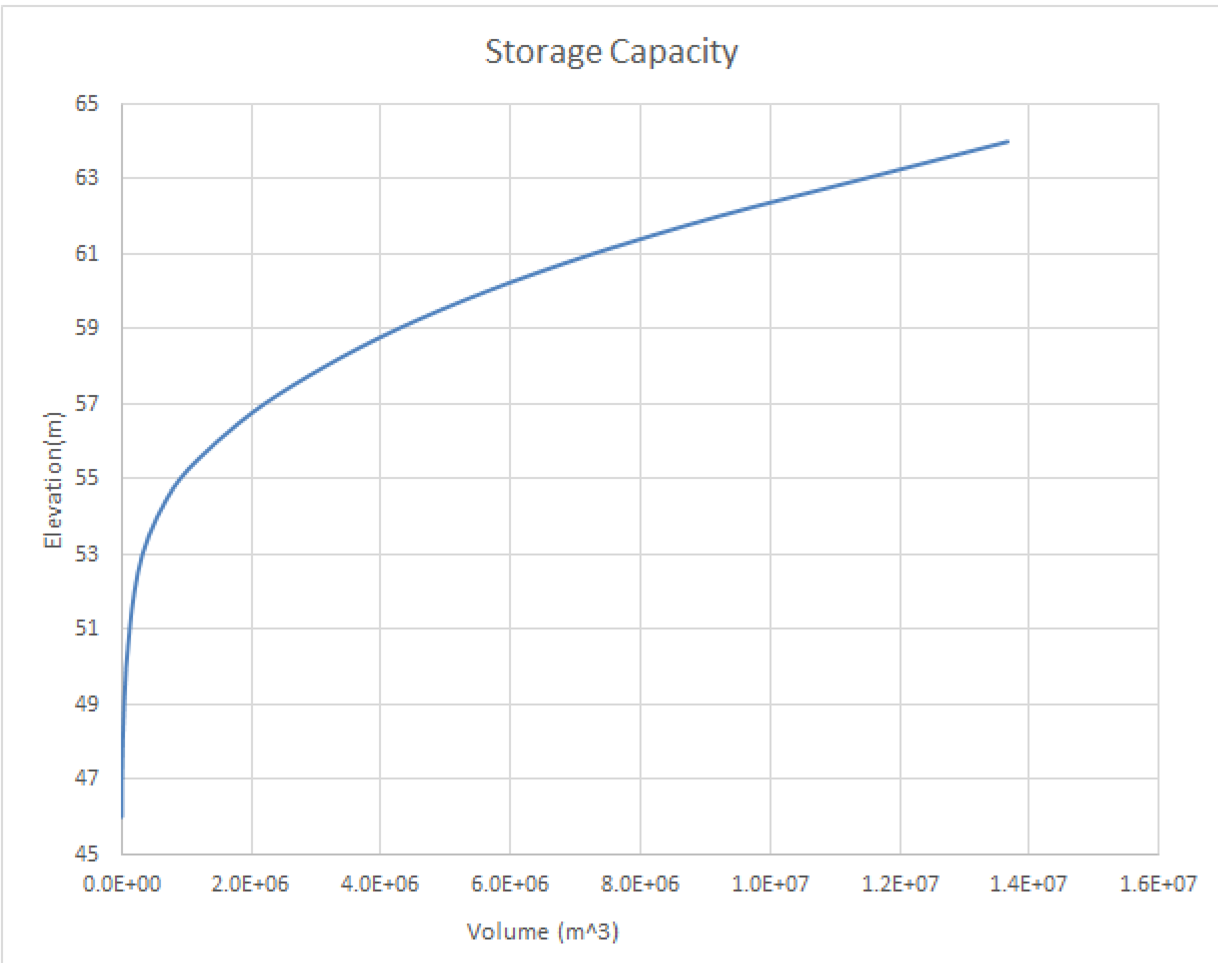

Figure 12 - Storage Capacity Curve

Flood Prevention

For a flood prevention analysis the same long-term simulation ran from the flow-duration curve analysis was used routing the incoming flows through a model of the reservoir consisting in a coupled orifice and weir. Given the sporadic nature and large magnitude of the floods, the dam provides significant attenuation of the events. See Figure xx for the results of this analysis.

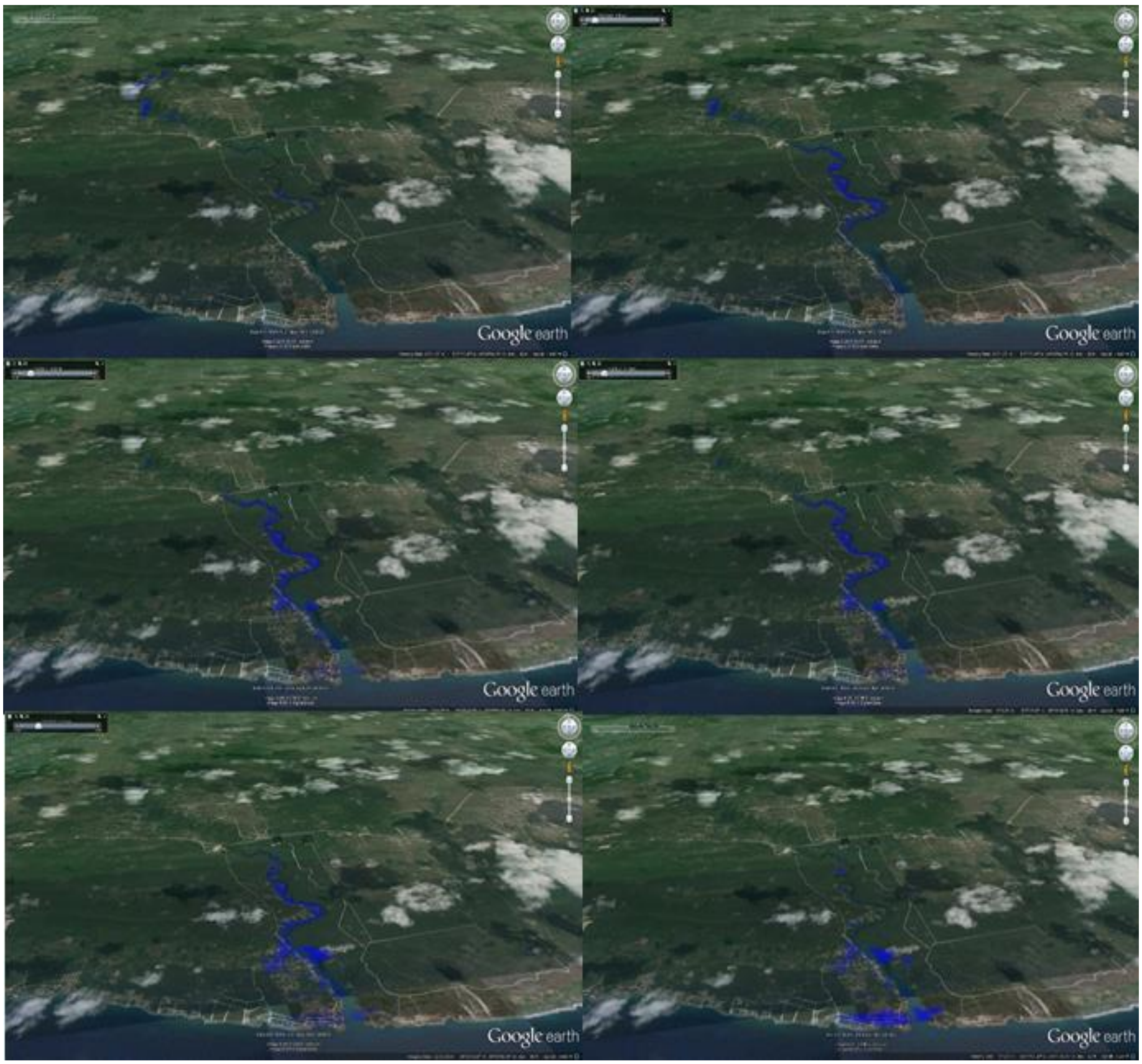

Figure 13 – Dam-Break Photo Series

Demand

No clear objectives were defined for this dam. Therefore, an analysis was performed assuming that the dam would serve one of two main purposes: power generation or irrigation.

Power Generation

The sporadic nature of the flow makes it unfeasible to be used for power generation without the interposition of a storage structure in the river. A dam with the characteristics of the one proposed at this site could accomplish that purpose. Assuming an elevation of 61 meters for the crest of the spillway and an elevation of 46 meters for the invert of the turbines, and using as the inflow the values obtained in the long-term simulation, a power-duration curve could be created. As we can see in Figure 18, an average power of 980 kW could be produced with a power of 700 kW guaranteed 80% of the time.

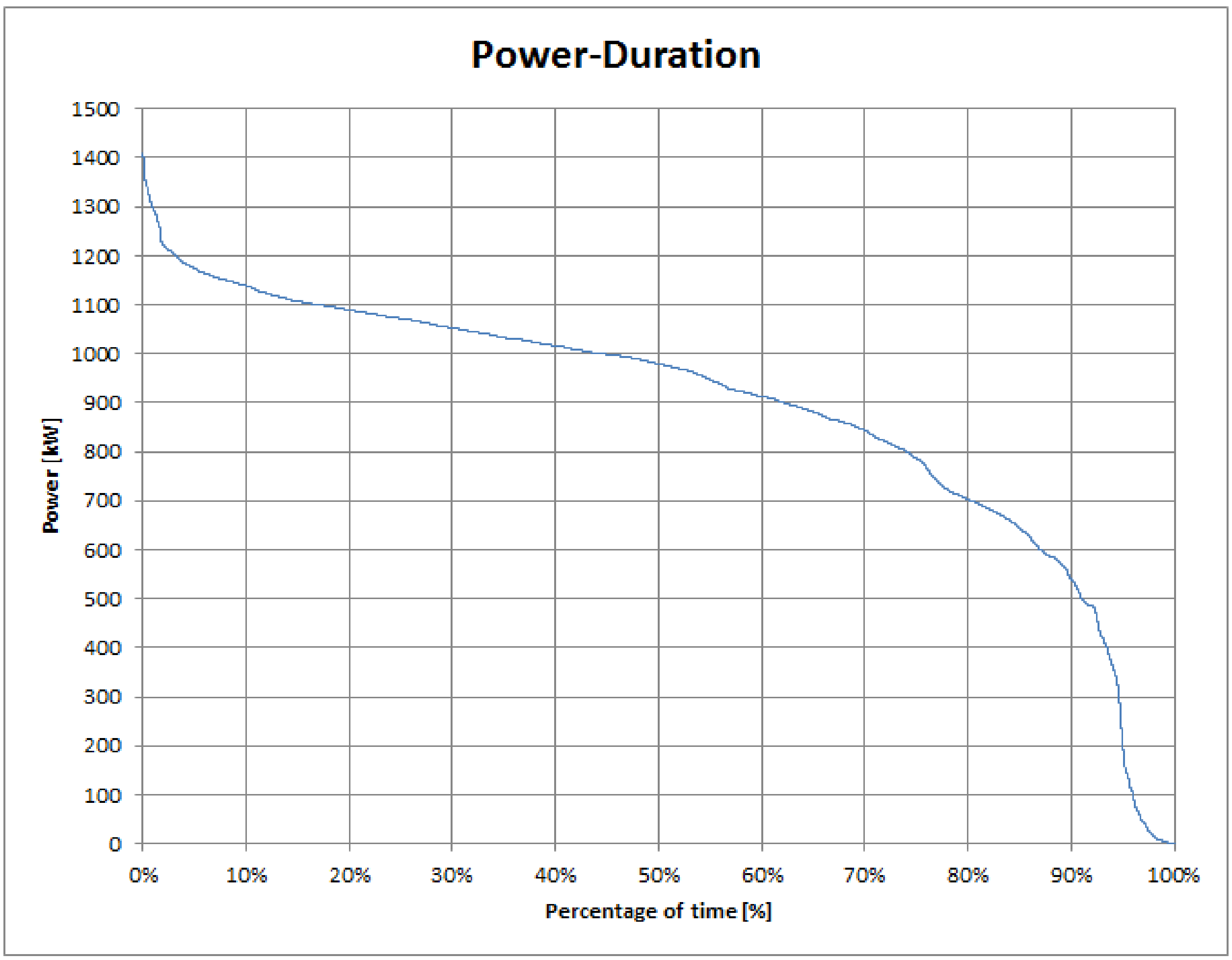

Figure 14 - Power-Duration Curve

Crop Water Demand

The crop water demand was calculated using the evapotranspiration equations found in Hydrology: Water Quantity and Quality Control. The crops analyzed were sugar cane, pasture, cotton, and small vegetables. These crops were chosen based on observations of the farmland while visiting the site and by further research on the web. The K values were chosen to be on the higher end of their range in order to produce more conservative results. The latitude used was 20 degrees north because the Cumayasa watershed lies above and below 20 degrees north. The length of the growing season was determined to be year-round because the Dominican Republic does not have a frost period. The precipitation data used was given by INDRHI. This information was used to calculate the precipitation deficit needed to support the crops and the volume of the reservoir to support that deficit (see Table 2 & 3 for results).

Month	Precipitation (mm)	Precipitation (in)	Average Temperature (C^o)	Average Temperature (F^o)	Percent of Daytime Hours	Consumptive Use Factor	u			
							Sugar Cane	Pasture	Cotton	Vegetables
January	15.2	0.6	24.0	75.2	7.74	5.82	5.238432	4.36536	4.3654	3.492288
February	10.4	0.4	24.0	75.2	7.25	5.45	4.9068	4.089	4.089	3.2712
March	33.6	1.3	25.0	77.0	8.41	6.48	5.82813	4.85678	4.8568	3.88542
April	20.7	0.8	25.0	77.0	8.52	6.56	5.90436	4.9203	4.9203	3.93624
May	78.2	3.1	26.0	78.8	9.15	7.21	6.48918	5.40765	5.4077	4.32612
June	90.7	3.6	27.0	80.6	9.00	7.25	6.5286	5.4405	5.4405	4.3524
July	65.7	2.6	27.0	80.6	9.25	7.46	6.70995	5.59163	5.5916	4.4733
August	62.4	2.5	27.0	80.6	8.96	7.22	6.499584	5.41632	5.4163	4.333056
September	75.5	3.0	27.0	80.6	8.30	6.69	6.02082	5.01735	5.0174	4.01388
October	115.1	4.5	26.0	78.8	8.18	6.45	5.801256	4.83438	4.8344	3.867504
November	86.1	3.4	25.0	77.0	7.58	5.84	5.25294	4.37745	4.3775	3.50196
December	40.6	1.6	24.0	75.2	7.66	5.76	5.184288	4.32024	4.3202	3.456192

Table 2 - Consumptive Use Analysis

Crop	k = K	F	U	Total Precipitation (in)	Deficiency (in)	Deficiency (mm)	Yearly Volume (m^3)	Area (km^2)
Sugar Cane	0.9	70.36	63.33	27	36.00	914.30	3786912000	4141.890764
Pasture	0.75	58.64	43.98	27	16.65	422.80	3786912000	8956.733555
Cotton	0.75	58.64	43.98	27	16.65	422.80	3786912000	8956.733555
Vegitables	0.6	46.91	28.15	27	0	0	0	0

Table 3 - Consumptive Use Analysis

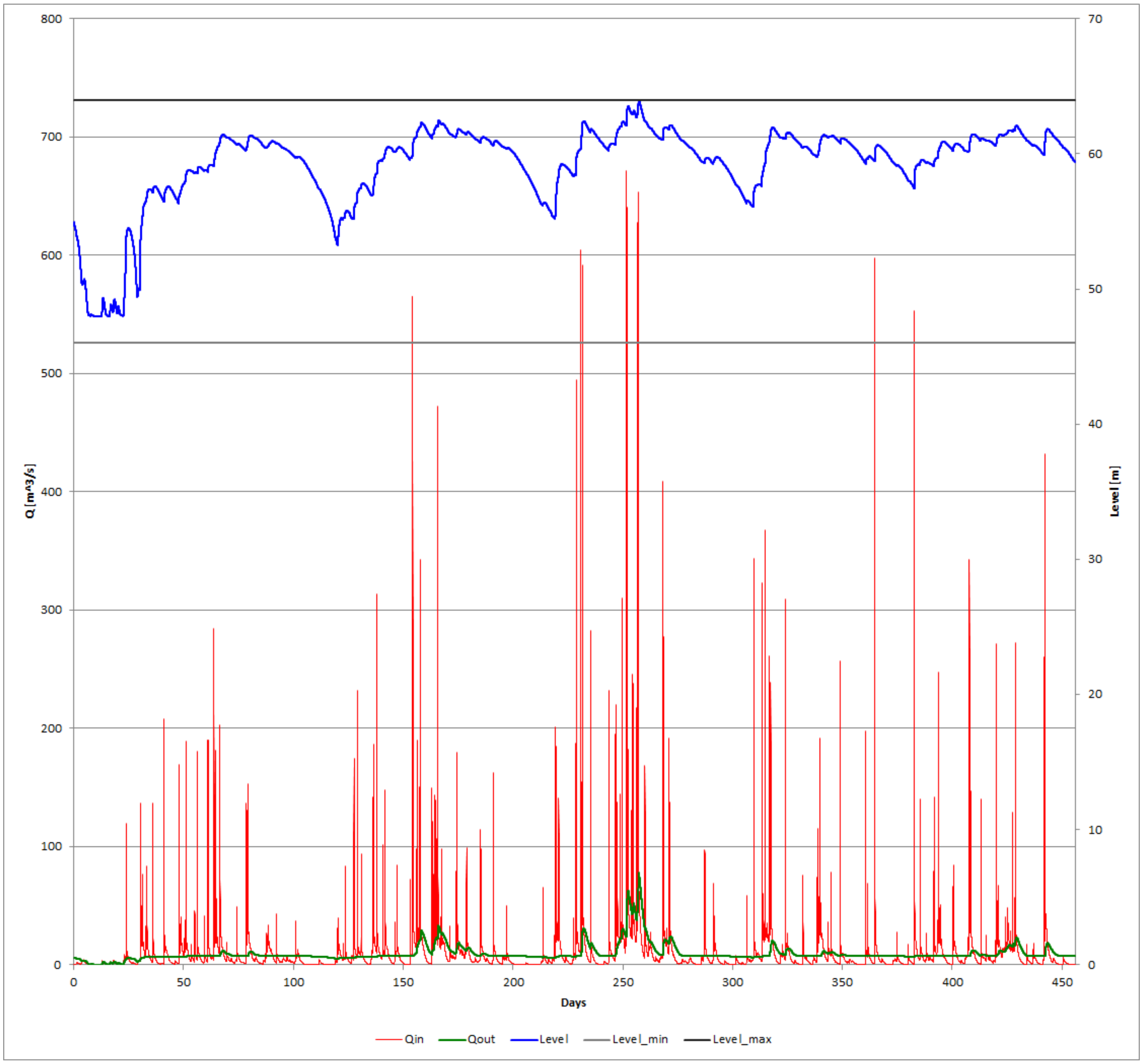

Figure 15 - Attenuation Curve

Environmental Impact Statement

Environmental Baseline

The Dominican Republic, like most of the Caribbean, is located in an area where hurricanes can occur. Officially, the Caribbean hurricane season runs from the beginning of June to the end of November. The climate in the project area is characterized mainly by a single rainy season (maxima in August-September).

There are three distinct vegetation zones in the Cumayasa watershed catchment area above the Cumayasa dam site, resulting in a relatively rare juxtaposition of riverine gallery forest along the Cumayasa River and its tributaries and savannah woodland away from the river. The proposed inundation area to be created by the project lies close to the Rio Cumayasa Cuevas De Las Maravillas National Park. Aside from the Cuevas de Las Maravillas National Park, land in the project area is mainly used for farming and animal husbandry with majority of the people being farmers. The system of farming is predominantly shifting cultivation or land rotation cultivation on a mostly subsistence basis. Most parts of the area are susceptible to accelerated soil erosion, and features of erosion are evident throughout the area, due to the light textured nature of the top soils.

90% of the total river discharges occur between June and November each year, peaking in September. Flooding occurs annually along the Cumayasa River between September and November. During the dry season, when the volume of the Cumayasa River reduces drastically, disconnected pools are formed which are separated by dry stretches of sandy deposits and rock boulders along the river course.

Groundwater levels increase away from the river, and although no groundwater quality data are currently available for this project area, anecdotal evidence suggests that it is of brackish quality. There is very limited aquatic and semi-aquatic vegetation in the study area, which is likely to be due to the lack of year-round surface flow in the river. The vegetation in the area consists of more than a 100 plant species, belonging to 45 plant families. All the plant species found in the study area are common and can be found within similar vegetation types within Dominican Republic. Several insect surveys, conducted in the area over the past decade, indicate that the Cumayasa area is rich in terrestrial insect fauna with a high level of species diversity. There appears to be relatively low diversity of small mammal species in Cumayasa project area, although the total species number differs widely in the available studies. Bird surveys indicate that the vast majority of bird species in Cumayasa are savannah woodland or riparian forest species. Present also are large mammal species which belong to a variety of families.

Social Baseline

The population density in the region of the Cumayasa project is very low as compared to the La Romana province of the Dominican Republic. La Romana province which has its capital also called La Romana is the third-largest town in the country. The province was split from La Altagracia in 1968. La Romana is also home to Casa de Campo, one of the world's largest resorts and top golfing destinations. Batey Lima, Batey Ragajo, Batey Lechega, Batey Diego, Gatey Pinones, Batey Almeyda, Mata Hombre,Batey are areas around the project site characterized with dispersed settlements surrounded by agricultural lands that are actively cultivated or lying fallow and savannah type open lands. Most of these areas are very small consisting of only housing compound and perhaps a primary school. Educational levels and literacy in the area are low. Principal illnesses in the area include Dengue fever, Malaria, Yellow fever, African trypanosomiasis and Schistosomiasis. Other common health problems include enteric fever, diarrheal diseases, cholera, jaundice and respiratory illnesses. The region has limited regional and local infrastructure, with a limited road network. In most villages; boreholes, shallow wells, or often streams are the primary sources of water for household use, and the dominant source of household energy is fuelwood collected by household members, with kerosene the primary source of lighting.

Sediment Transport

Sediment transport is a function of both river discharge and sediment concentration. There is no definitive measure of sediment transport for the Cumayasa project, however a number of studies have been carried out over the years that give a rough indication of the level of sediment transport in the river at this location. The reservoir will result in the loss of about 55 km of river bank, and the creation of about 450 km of reservoir shoreline during the avalanche season. It will have a maximum depth of about 60 m and an average depth of 29 m. As a result of the considerable variation of inflow into the reservoir from the Rio Limon, the fluctuation in water levels in the reservoir over the year, and the mean annual drawdown within the reservoir is predicted to be approximately 8 m, at which level the reservoir surface area will reduce by 9,825 ha (18% of the maximum reservoir surface area). Monthly variations in water level will be relatively small, with an average change in reservoir level of 1.4 m per month and a maximum average monthly change of approximately 4.5 m.

Impacts on The Water Environment

The new lake environment will differ markedly from the current riverine conditions. Vegetation decomposition, algal and weed growth in the period immediately following inundation, reduced gas exchange resulting from reduced turbulence in the river, and increased temperatures in the reservoir may result in reduced dissolved oxygen levels in the water, impairing reservoir water quality in the short term and leading to long term dissolved oxygen levels lower than those in the existing river over the long term. The extent of these impacts will be determined by the detailed characteristics of the reservoir, including its circulatory patterns, temperature profile, and water chemistry.

Flow in the existing river will be captured in the reservoir and released at a controlled rate for a relatively steady generation of hydropower. Downstream river flows will therefore be evened out, with reduced flood peaks (August to October) and increased the low (base) flows (December to June). The results of hydrological modelling indicate that there will be a significant reduction in the overall range of water levels experienced under average flow conditions in the river, with dry season levels as much as 3m higher than present, and flood levels as much as 3.5m lower than current levels. This will have consequences for water uses downstream, including aquatic and riverine habitats and existing water users, including any fisheries and floodplain agriculture that depends on the regular replenishment of nutrients from silt-laden floodwaters.

During filling of the new reservoir a greater proportion of the existing flow will be intercepted with consequent short term impacts downstream. Without compensation flows during this period, there could be severe impacts on ecosystems and livelihoods in the river downstream of the dam. The presence of a large body of water in the new reservoir will also impact on groundwater conditions in the surrounding area, by raising the water table. The extent of this effect is difficult to predict, since it will depend on detailed hydrogeological conditions in the reservoir zone. However, making some broad assumptions about the homogeneity and permeability of aquifers in the area allows a very approximate area of influence to be determined. In addition, changes to the downstream river flow regime may also influence water table conditions adjacent to the river channel. Rising water tables could result in waterlogging of soils, soil salinization and possible iron-pan formation in low-lying areas, and alter the quantity and quality of water supplied by community boreholes. Further to this, the use of water for construction is likely to affect the quantity of groundwater available for local communities.

Various risks to water quality could arise from sources of pollution during construction including spillage of fuels, lubricants and other toxic materials at the construction site, discharge of silt laden run off from sites, and the inadequate treatment and disposal of waste and wastewater from worker facilities. In addition, long-term operation of the project will require a low level of ongoing use of vehicles, fuels and chemicals at project facilities and in the vicinity of the reservoir. With effective operational controls including spill response arrangements the risk of pollution of the reservoir is small and the impact will be negligible.

Impacts on Land and Land Use

The project will create a reservoir occupying about 450 Km^2 of the Cumayasa Gorge at full supply level. This will reduce to less than 200 Km^2 at minimum operating level. The height of the dam is estimated to 50 m due to the fact is a mid- size dam and the height of the spill way being 61 m. Permanent land take will also result from the construction of the saddle dams, powerhouse, switchyard, upgrading of roads, the new transmission lines extending from the site to Guaymate.

The land to be occupied is predominantly vegetation comprising about 55% grassland, 35% savannah woodland and 15% water and riverine gallery forest. It also includes more than 7 major communities located around the project area. Land inundated by the reservoir will include domestic, business and community facilities (shops, schools, local healthcare centers, recreation areas, cattle sheds, water pumps, latrines, etc) together with farming, fishing, forest and hunting grounds around them. Cultural sites including ancestral villages which are no longer occupied and sites associated with the occupied villages (graves, churches, etc) will also be lost. The project will also result in the temporary loss of about 40 hectares owing to worker camps, contractor lay-down areas, cofferdams, and the river diversion channel. The sites for most these will be determined by the contractor but the main worker camp will be near Guaymate. Further land may be occupied by the informal migration of people into the area stimulated by the construction activity and the long term availability of water. The extent and duration of impact will be determined primarily by policies implemented to manage these population movements. Finally, resettlement of communities displaced by the project will result in land take in areas away from the project.

Aquatic Ecology

Construction of the dam will permanently alter the fundamental hydrology and aquatic ecology of the impounded reach, with a highly significant impact. During inundation, biological communities in the reservoir will begin to acquire lacustrine characteristics, resulting in the decline of mayflies and certain fish species that prefer moving water and coarse substrate. Species that prefer shallow habitat are likely to colonize the periphery of the reservoir, and others that require moving water will disappear or persist as relict populations in the headwaters of the reservoir.

Over the longer term, a more characteristically lacustrine aquatic biological community will become established, and will remain for the operational life of the project. The most significant habitat change will be the creation of a new shallow water littoral zone around the reservoir and the many islands created within the reservoir. The surface area of the new littoral zone at FSL will be approximately 2,315 ha, providing vastly increased habitat availability for aquatic and semi-aquatic vegetation. In the littoral zone, proliferation of certain plant species could provide a favored habitat of the snail host of disease vectors carrying urinary schistosomiasis.

Water fluctuations in the reservoir will undoubtedly affect the composition and diversity of aquatic vegetation. This will encourage the growth of terrestrial and semiaquatic vegetation tolerant of temporary inundation and possibly nuisance aquatic plants (given their presence in upper reaches of the Cumayasa River), and reduce the abundance of rooted large aquatic plant species

Terrestrial Habitats

The loss of a large portion of riverine forest and adjacent savannah woodland (about a quarter of the total forest and woodland area close to the national park) will fragment riparian gallery forest and savannah woodland habitats in the national park, where most wildlife currently resides.

Vegetation loss and disturbance will alter the area, shape, and continuity of remaining vegetation patches within the landscape, altering the floral and faunal species composition and possibly rendering the fragmented ecosystems unable to support the species assemblages found in undisturbed ecosystems.

Wildlife

Inundation of the reservoir will result in drowning of some terrestrial fauna unable to escape from flooded forest, grassland, and savannah woodland habitats. The reservoir will fill slowly which should avoid large scale direct loss, as most animals will be able to move to higher ground as the water level rises. Mortality due to drowning is likely to be most prevalent in ground-dwelling and feeding mammals, and certain primates, which mainly reside in the upper canopies of trees.

The presence of the reservoir will cause a shift in the terrestrial wildlife species assemblage from riparian to lacustrine with some adverse and some beneficial effects. Specifically, the reservoir will reduce habitats for wildlife species that require flowing water (some insectivorous birds and bats) but increase foraging habitat for wildlife that prefer still or slow-moving waters such as water birds. Beneficial effects will arise from the new habitats provided by presence of the reservoir, and an increase in the year-round availability of water for wildlife

Social, Health and Economic Impacts

The project will result in the total loss of livelihoods and immovable assets for several communities, and the loss of land standing crops and trees for some farmers in several further communities. A number of other settlements, which will not be displaced, will permanently or temporarily lose productive wooded forest land and farmland due to land take. The loss of or pressure on water resources will result in a decline in farming and fishing incomes, owing to the cessation of the yearly deposition of silt on farms downstream of the dam and impacts on fisheries. Drinking water of acceptable standard is scarce in the area, so the project may result in a decline in local standard of living due to reduced availability of water around and downstream of the dam.

Impacts on Archaeological and Cultural Heritage

The Cuevas de Las Maravillas is one of the famous National archaeological sites in the Dominican Republic and it is located downstream. In the case of excessive flooding downstream this National monumental cave could be highly damaged. The destruction of ancestral sites, indigenous paintings on rocks, features and material remains, due to land take or flooding is an irreplaceable loss. Mitigation measures should center on 'salvage archaeology' to obtain an adequate documentation of and samples from a selected number of areas. Cultural heritage of significance in the project area includes: old and contemporary cemeteries and old settlement sites. However, the level to which particular sites are valued varies between the settlements.

Other Issues

Other issues include the increased emission of greenhouse gases from the reservoir due to rotting vegetation and carbon inflows from the catchment, and upper watershed management. Provided that vegetation is at least partially cleared prior to inundation, greenhouse gas emissions would be relatively low, given that the surface area of the reservoir is not large in comparison to other man-made reservoirs, and so the significance of this impact is considered to be minor

There is considerable discussion over whether reservoirs cause significant changes in the micro-climate in the immediate environs of the large body of water that forms the reservoir. Meteorological stations will be set up at Cumayasa itself and three other locations around the reservoir in the first year of construction, to that a baseline of data will be available before any micro-climatic changes would take effect after the reservoir fills. Continuing collection of climate data will facilitate analysis of the nature and significance of any changes in meteorological parameters that are detected by the meteorological stations.

Feasibility Analysis

The feasibility of placing a dam in the site selected will be based on the criteria discussed in the demands section of this report. The power generated from this dam would be at least 700 kW 80% of the time. This amount is very low. In fact, if the electricity was sold for US 1¢ a kW (which is fairly high), it would take 20 years (not including operation and maintenance costs) to make a US $1000000 back. So, for power alone the dam would need to be created at an extremely low cost in order to ever make back the cost of construction.

The crops potentially produced by the reservoir that this dam would create look promising. The end amount of area that could be irrigated by this land to produce crops would be around 9000 square kilometers. If this dam was needed for farming in the region to improve, there could be further studies done to calculate a cost-benefit analysis of the farming benefits vs. the construction and maintenance costs. Observations made on visiting the Rio Cumayasa watershed suggested irrigation was not required, further investigation than could be done within the bounds of this project would need to be done.

The environmental cost of placing a dam in this area cannot be given an estimated cost. However, the impact study done in the course of this project suggests that the construction of the dam would be damaging to the surrounding ecology in the ways most dams are, however not excessively damaging. The loss of some communities upstream could be a very costly endeavor, and may not outweigh the possible population growth the reservoir would create in that area.

Most importantly, the geologic data available during the course of this study suggests a karstic soil type in the entire region that would cause strongly limit the storage capability of a dam on this site. Not only this, but if a dam were to be constructed there would be extra costs involved in stopping groundwater from seeping beneath the dam and upturning the dam. Further research would need to be conducted on the site especially in this area. The recommendation of this project is that a dam is not feasible at this site, based on the limited amount of energy that could be generated and the karstic soil that dominates the region.

Conclusion

The conclusions drawn about this site as a potential area for a dam to be built and reservoir created are mostly discussed in the Feasibility Analysis section. The main conclusion drawn is that the data suggests this would not be a feasible dam site. More research would be necessary before a final decision could be made. A simple survey of the soil type found in the area discussed in this project would be the next step to take. If the karstic soil type does not dominate the region, or if even it is only the top geologic layer and a better soil type is found not very far beneath the surface, more research could be done involving the hydrologic properties of the region. The models run above assume a karstic soil type unless specified in the report, so some of the elements of this project would need to be redone, however it would not be an arduous process.

The next step in the process, if the soil proved suitable for water retention, would be to study the hydraulics involved in creating a dam in the Rio Cumayasa. Most importantly, research into what kind of hydraulic structure would be most cost-effective and efficient at stopping the water up to the specified elevation would need to be done. Some more study of varying processes of hydroelectric power generation would be useful to decide an optimum point between power generation and cost of construction.

Overall, the result this group decided on answering the original question "Would the Rio Cumayasa be a probable site for a dam?" was no. Unless more research was done that found better soil on the riverbed at a different site or less of it than the data found suggests, the Rio Cumayasa does not prove to be a feasible region for a dam.

References

http://ucanr.org/sites/Test1/files/92127.pdf **(Used this to find a consumptive use coeficient for sugar cane)**

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Appendix

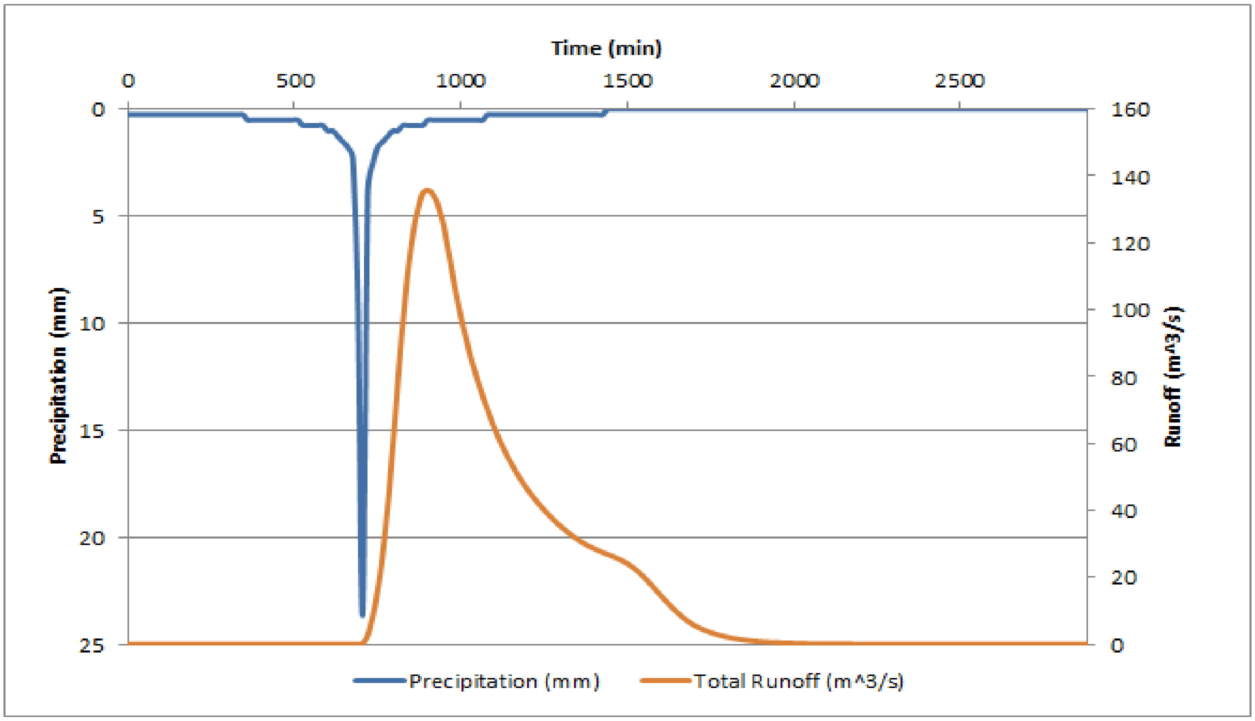

Figure 16 - Hydrograph of 2.33 Year Return Period

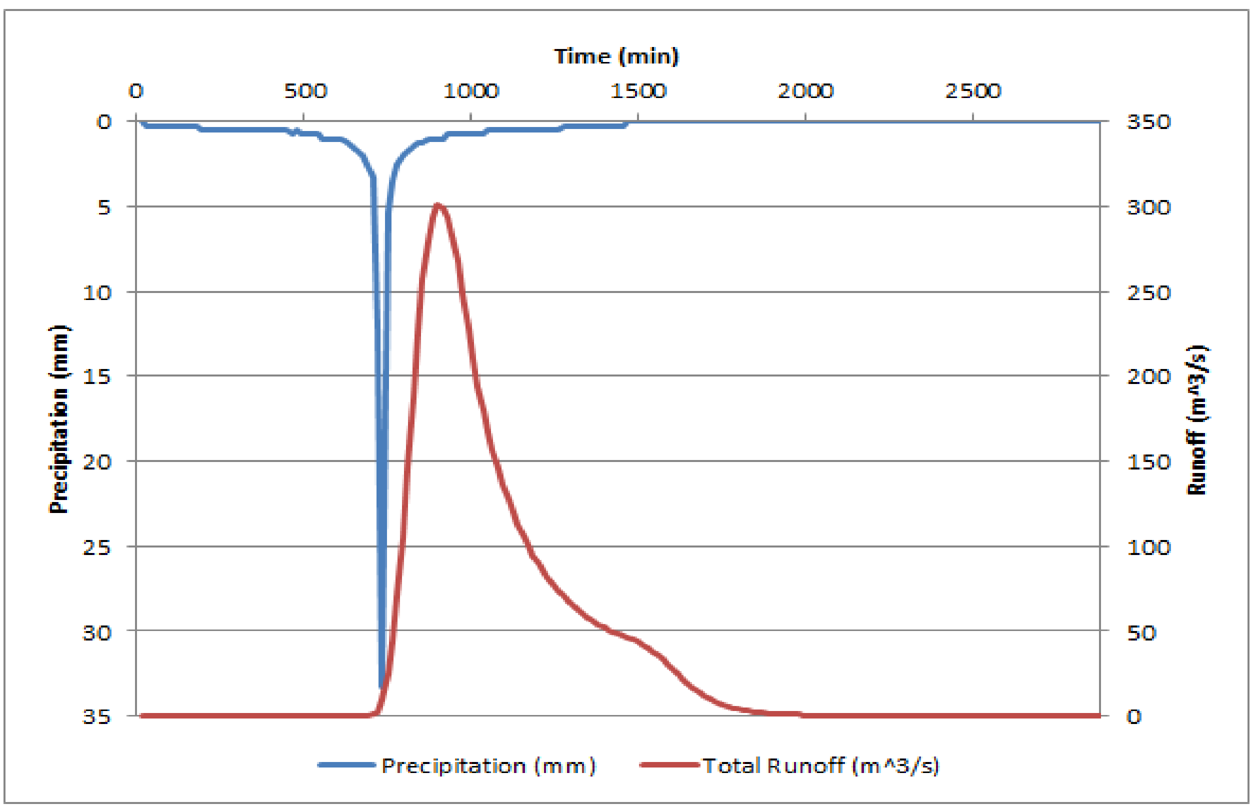

Figure 17 - Hydrograph of 5 Year Return Period

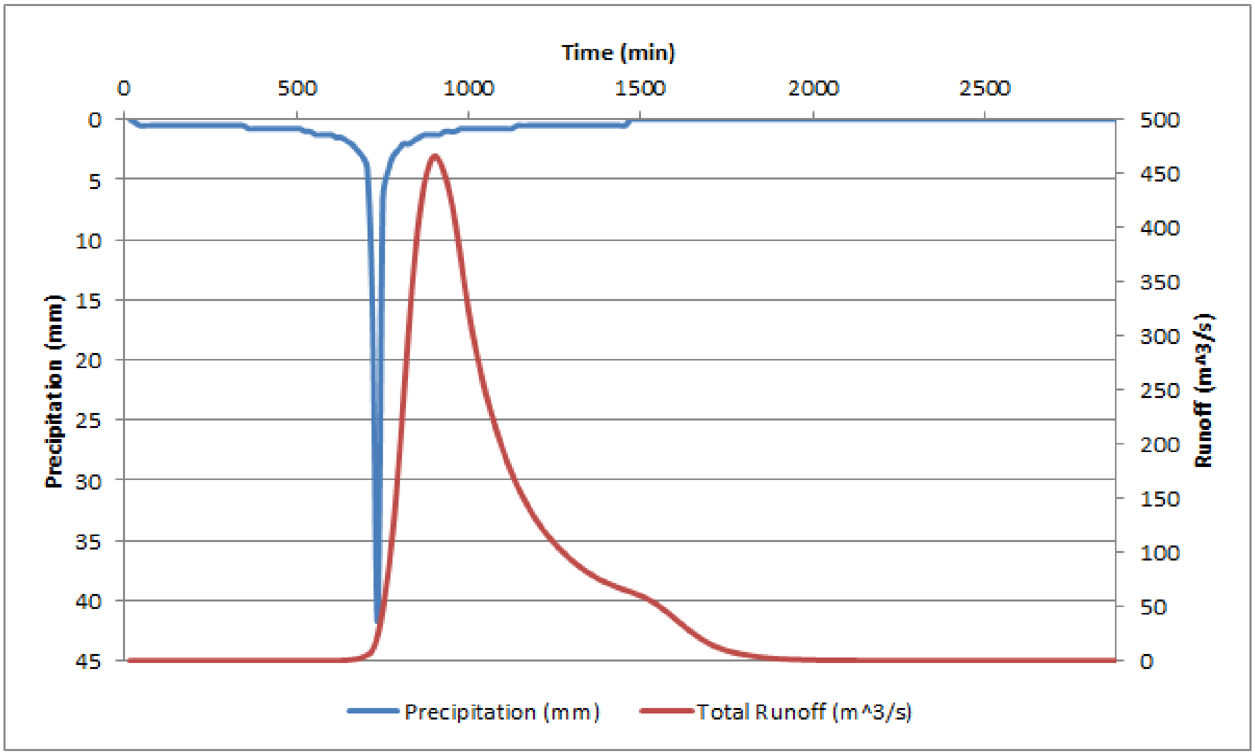

Figure 18 - Hydrograph of 10 Year Return Period

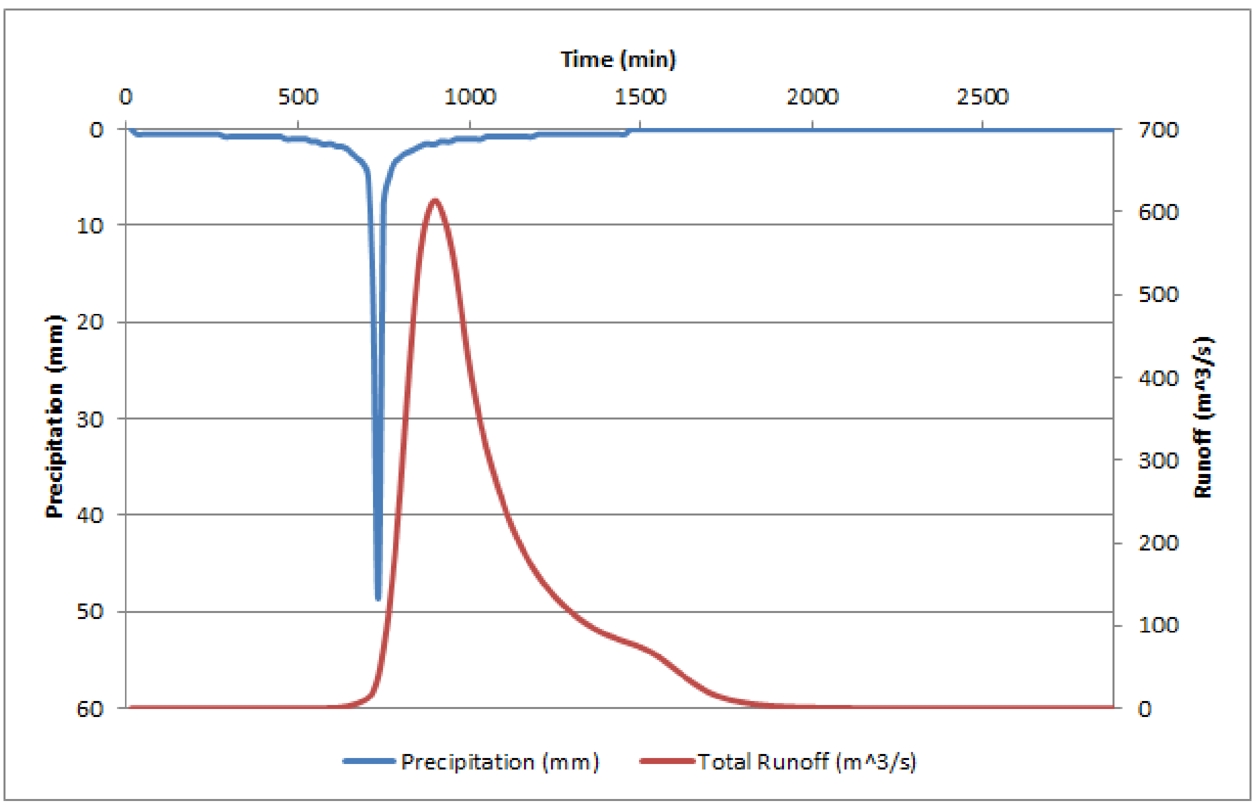

Figure 19 - Hydrograph of 25 Year Return Period

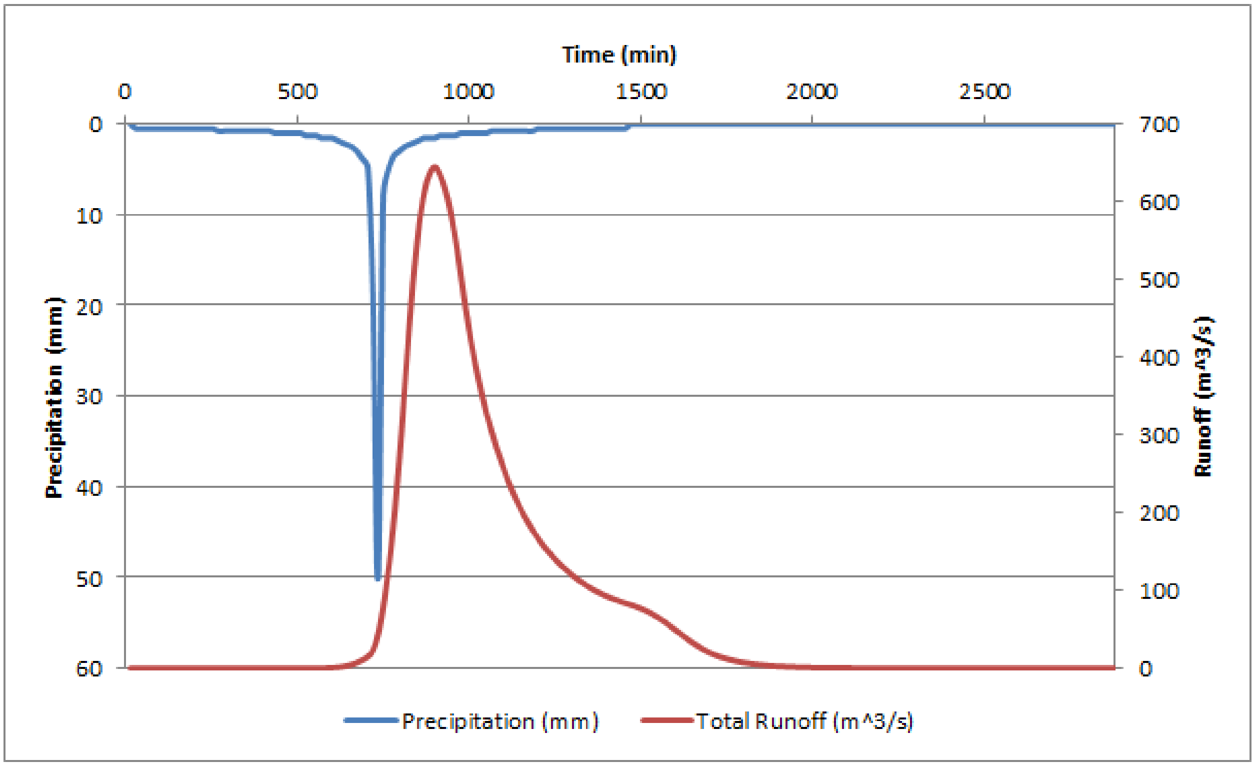

Figure 20 - Hydrograph of 50 Year Return Period

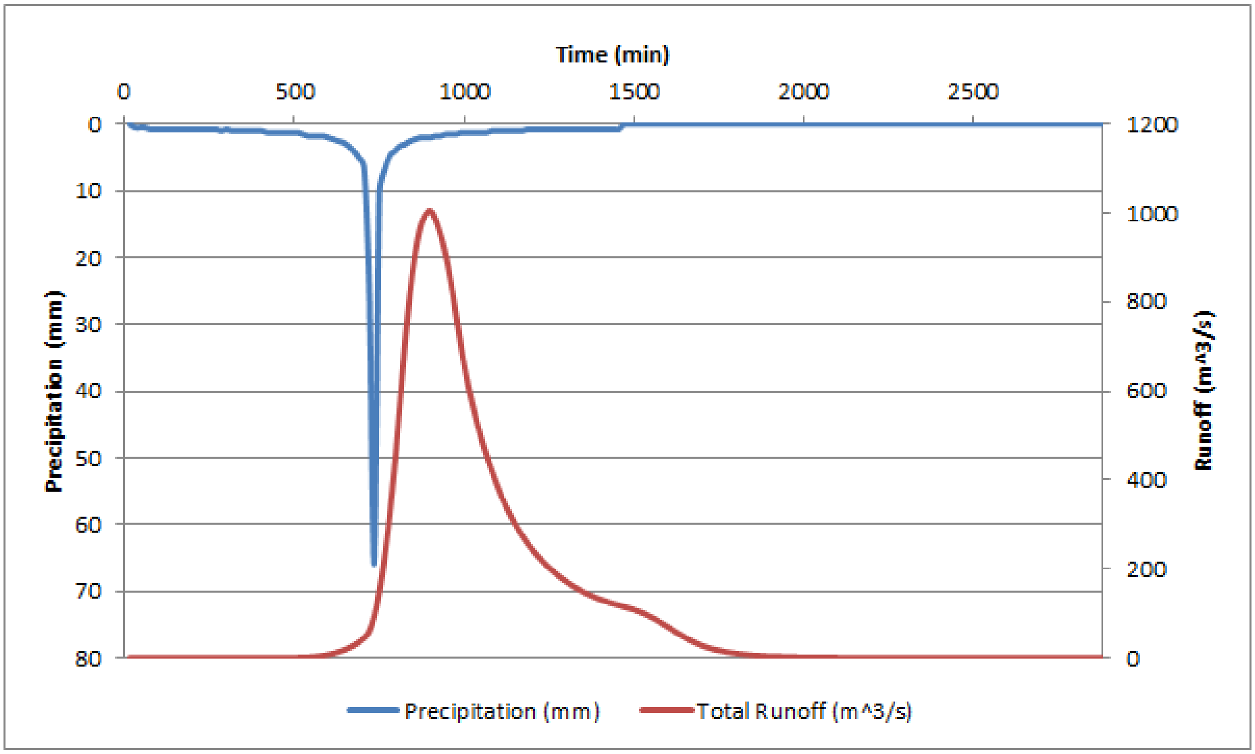

Figure 21 - Hydrograph of 100 Year Return Period

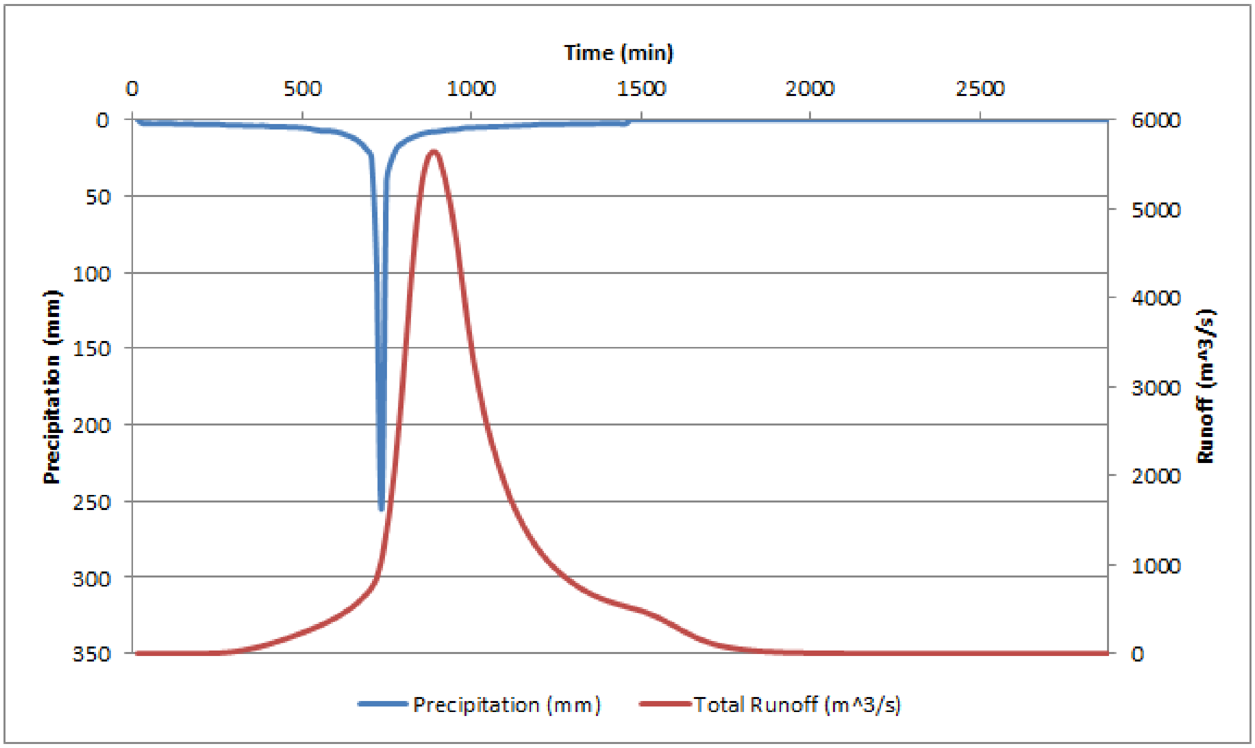

Figure 22 - Hydrograph of Probable Maximum Precipitation

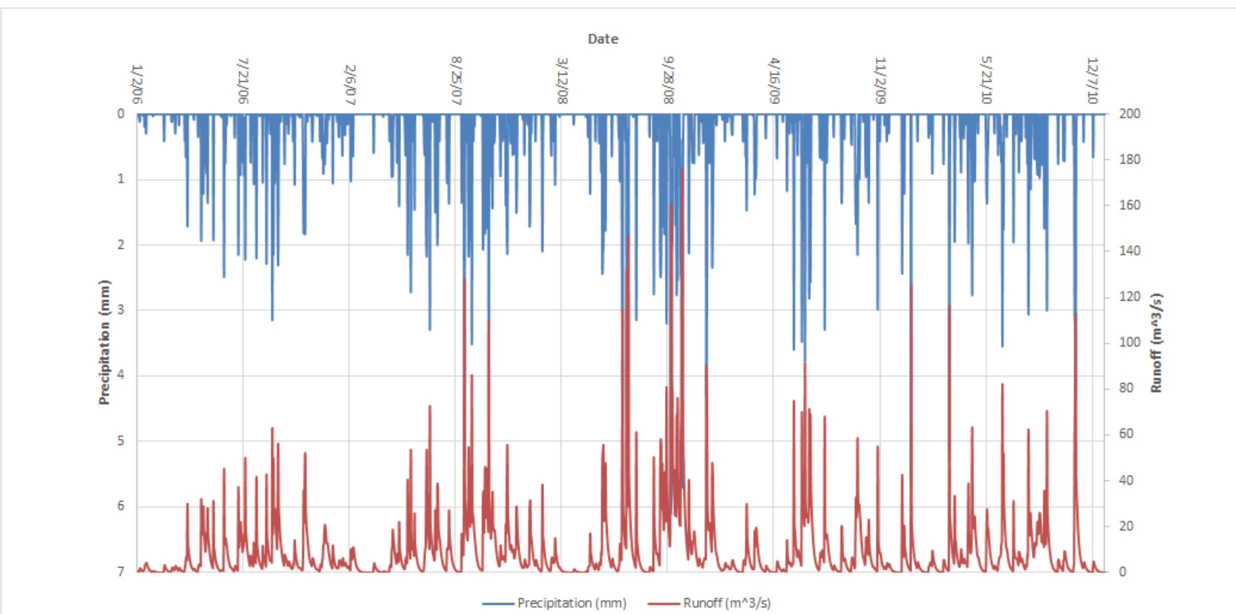

Figure 23 - Long Term Hydrograph for a Period of 4 Years

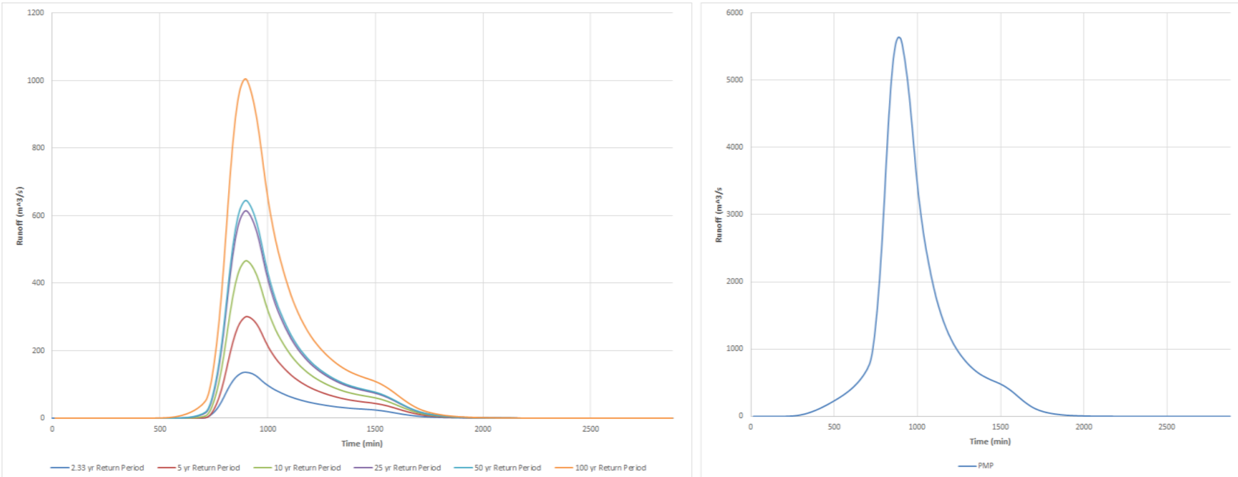

Figure 24 - Hydrograph of Various Return Periods Compared to PMP