APENDICE N

Estudio de Alternativas para Abasto de Aguas de Procesos

Noviembre 2010

Declaración de Impacto Ambiental – Preliminar

Planta de Generación de Energía Renovable y Recuperación de Recursos

BARRIO CAMBALACHE DE ARECIBO

EnergyAnswers Arecibo

Alternatives for Water Sources

Preliminary Environmental Impact Statement

Renewable Power Generation and Resources Recovery Facility

CAMBALACHE - ARECIBO

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LIST OF ACRONYMS

Ave.	Average
BOD	Biochemical Oxygen Demand
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
gpm	Gallons per minute
HP	Horsepower
M	Meters
MGD	Million gallons per day
NPDES	National Pollutant Discharge Elimination System
O&M	Operation & Maintenance
PRASA	Puerto Rico Aqueduct and Sewer Authority
TSS	Total Suspended Solids
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

1 EXECUTIVE SUMMARY

Energy Answers International has the intention of constructing a Renewable Power Generation and Resources Recovery Facility at Cambalache Ward in the Municipality of Arecibo, Puerto Rico. The proposed Renewable Power Generation and Resources Recovery Facility has specific water needs for its different processes. This study intends to analyze the feasibility of available water sources necessary for the cooling process of the Renewable Power Generation and Resources Recovery Facility. Considering the proposed project location and the cooling process water quality requirements, the following water sources were identified and analyzed:

- Alternative 1 – Puerto Rico Aqueduct and Sewer Authority (PRASA) water main;
- Alternative 2 – Groundwater;
- Alternative 3 – Surface water;
- Alternative 4 – Brackish water from Caño Tiburones; and
- Alternative 5 – Reclaimed water from Arecibo Waste Water Treatment Plant (WWTP).

Once-through seawater, another possible alternative, will require the construction of off-shore intake, pump station, discharge structures and lines. This is a high capital cost, extensive operation and maintenance, and difficult permitting alternative; therefore this alternative was not included in this study.

This Study also analyzes each of the sources in terms of reliability, infrastructure needs, environmental issues, and capital, operation, and maintenance costs.

In order to evaluate and select the preferred alternative, the following information was considered:

- Cooling Process demand for the Renewable Power Generation and Resources Recovery Facility is 1.8 Million Gallons per Day (MGD). Boilers (deionized water) and other operations demand accounts for an additional 0.30 MGD.
- The use of brackish cooling towers at the proposed Renewable Power Generation and Resources Recovery Facility is considered under the Caño Tiburones brackish water alternative.

- In order to use the Arecibo WWTP primary effluent, additional treatment must be provided to achieve secondary level water quality.
- Use of brackish water for boilers operation shall be explored. A specific characterization is recommended to verify the salinity of the raw water source.
- The production of deionized water, from high salinity brackish or reclaimed water will require expensive treatment costs. In such case, potable water from PRASA shall be used as the source for this purpose.

This study recommends to further develop the use of brackish water from Caño Tiburones (Alternative 4) since it is the most feasible and reliable alternative to fulfill the Renewable Power Generation and Resources Recovery Facility needs. It is recommended to perform detailed characterization of the source to properly address any seasonal variations in its composition. Also, it will be necessary to negotiate with DNER in order to obtain the water franchise and the permission for construction of the necessary infrastructure at El Vigía Pump Station facilities.

2 WATER REQUIREMENTS

2.1 WATER NEEDS

As informed by Energy Answers International, the proposed Renewable Power Generation and Resources Recovery Facility will need 2.1 MGD for all of its processes. This demand includes need for potable and deoinized water, which accounts for 0.3 MGD, and 1.8 MGD for cooling process. This report will only study different sources for the cooling process water.

3 ALTERNATIVES CONSIDERED

This feasibility study evaluates five alternatives to supply 1.8 MGD for the cooling towers process at the Renewable Power Generation and Resources Recovery Facility proposed by Energy Answers. These alternatives consist in five different types of water sources evaluated in terms of reliability, infrastructure needs, environmental issues, and capital, operation, and maintenance costs. The evaluated alternatives are:

- Alternative 1 – PRASA's water main
- Alternative 2 – Groundwater
- Alternative 3 – Surface water
- Alternative 4 – Brackish water from Caño Tiburones
- Alternative 5 – Reclaimed water from Arecibo WWTP

Figure 3-1 presents the location of each alternative water source.

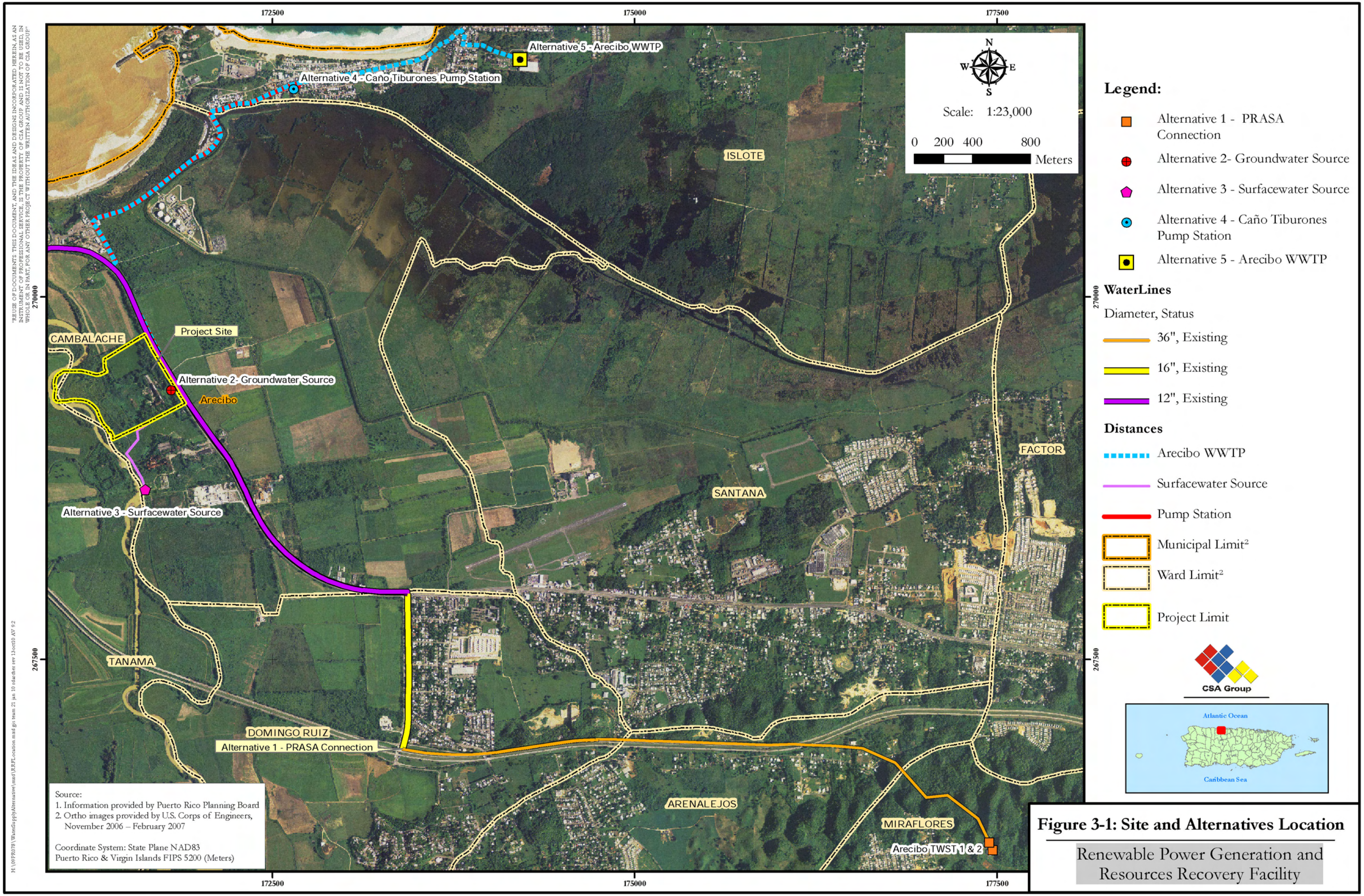

Figure 3-1: Site and Alternatives Location

Renewable Power Generation and Resources Recovery Facility

3.1 ALTERNATIVE 1 – PRASA’S WATER MAIN

This alternative proposes to obtain potable water from PRASA’s distribution system connecting a new transmission line from the project site to the existing 36” pipeline at the intersection of Domingo Ruiz Avenue with Highway PR-22.

The projected site for the Renewable Power Generation and Resources Recovery Facility is located within PRASA’s Miraflores and Superaqueduct Service Area. This service area is supplied by Dr. Santiago Vázquez WTP (Superaqueduct) and three wells. The water is distributed from the plant to the service area by Arecibo Treated Water Storage Tanks (TWST) which are part of the seven TWST that distribute most of the annual average of 98 MGD produced at the plant. Arecibo TWST distributes an estimated annual average of 4.74 MGD and consists of two main tanks, and a distribution system with a 1,200 gpm pump station and a gravity distribution system. The service area also received about 1 MGD from three wells: Santana II, Santana III and Pérez Mayol for a total estimated average of 5.74 MGD of potable water within the service area.

Puerto Rico Department of Natural and Environmental Resources (DNER) “Plan de Aguas de Puerto Rico” estimate an average daily demand of 5.76 MGD currently served by PRASA within the Miraflores and Superaqueduct Service Area. Superaqueduct performance targets expect to increase Arecibo TWST production to produce a surplus of about 0.40 mgd after 2010, which could supply the potable water requirement for the WTE plant. However, this increase will not be enough to satisfy an additional 1.8 MGD of process water demand. For these reasons this study will not be further evaluated.

3.2 ALTERNATIVE 2 – GROUNDWATER

Alternative 2 consists of extracting water from aquifers at the project area. Previous studies have reported three (3) main hydrogeologic units of groundwater at the project vicinity: (1) a shallow water system comprised of alluvial deposits: (2) a limestone unconfined system contained within the Aymamón and Aguada Limestone; and (3) a confined aquifer contained within the Montebello and Lares Limestone.

On February 2000, Gregory L. Morris and Associates (GLMA) prepared a pump test report for a 240-feet well drilled at the proposed site. Groundwater quality was also monitored on the study. The report concluded that the well can produce a yield of 1.0 MGD without significant drawdown in the aquifer. Quality analysis showed Total Dissolved Solids (TDS) values over 15,000 mg/L, which indicates the presence of brackish water in the aquifer.

Based on the pumping test results of the GMLA report, it is concluded that this source will not produce the required 1.8 MGD cooling process water needs on a daily basis.. **Appendix 1** presents water quality data for a monitoring well drilled at the aquifer. These results were part of the study, *Informe final, Programa de Monitoreo del Estuario de Río Grande de Arecibo*, performed by PRASA at Río Grande de Arecibo estuary in 1998.

3.3 ALTERNATIVE 3 – SURFACE WATER

This alternative consists of obtaining surface water from Río Grande de Arecibo, which is located west of the proposed site. Global Fibers, a former paper mill at the site, conveyed surface water from the river for their process water needs. Global Fibers ceased operations in 1996 and their DNER water franchise expired. The river intake structure was abandoned.

In 2000, the Santiago Vazquez WTP, which is located upstream the proposed site, started operation. This WTP has its intake located at a Regulation Lake, which is fed from the Dos Bocas – Caonillas Reservoir System at the Río Grande de Arecibo. DNER “Plan de Aguas de Puerto Rico” (Appendix A, Table 4) sets the safe yield of the Dos Bocas – Caonillas System in

102 MGD, from which 100 MGD are actually compromised for the Santiago Vazquez WTP intake extraction.

PRASA, as part of the effort to obtain the increase of the water franchise to 100 MGD, was required to perform a 4-year study of the Río Grande de Arecibo estuary. The study, mentioned in Section 3.2, required the installation of surface water monitoring stations and monitoring wells.

It is concluded that Río Grande de Arecibo safe yield is practically compromised, and government and federal agencies permits will be difficult to obtain. For this reason, this alternative will be no longer evaluated.

3.4 ALTERNATIVE 4 – WATER FROM CAÑO TIBURONES

This alternative consists on obtaining water from Caño Tiburones estuary. Caño Tiburones extends eastward from the Rio Grande de Arecibo to the Río Grande de Manatí as a western boundary and covers approximately 7,000 acres. In 1998, the Government of Puerto Rico designated 3,428 acres of the Caño Tiburones as a natural reserve to protect the island's largest wetland and its animal and flora species.

El Vigía Pump Station was constructed in 1949 to provide drainage for water and control water levels at the Caño Tiburones. Daily brackish water pumping of 100 MGD has been informed by DNER personnel. The Pump Station consists in an intake structure, screening, and two (2) 80,000 gpm pumps. The use of brackish cooling towers at the proposed Renewable Power Generation and Resources Recovery Facility is considered under this alternative.

3.4.1 **Reliability**

Water balances for the Caño Tiburones for normal rainfall periods (Zack and Class-Cacho, USGS, Water Resources Investigation Report 83-4071, 1984) estimates an average brackish water discharge of 106 MGD from El Vigía Pump Station into the ocean. A summary of this water balance is presented on

Table 3-1. It is important to notice that PRASA has envisioned the construction of a Reverse Osmosis Treatment Plant (10 to 25 MGD capacity) to treat brackish water from the Caño

Tiburones. Even if this project is developed, brackish water will be available to meet Renewable Power Generation and Resources Recovery Facility water needs.

Table 3-1 Caño Tiburones Water Balance (Zack and Class-Cacho, 1984)

Caño Tiburones Water Sources In	Total Inflow (MGD)	Caño Tiburones Water Sources Out	Total Outflow (MGD)
Ocean	36	Evapotranspiration	18
Aymamon Limestone Aquifer	44	El Vigía Pump Station	106
Río Grande de Arecibo	10	Unaccounted	2
Direct Rainfall	24		
Direct Runoff	12		
Total Water In	126	Total Water Out	126

3.4.2 Infrastructure

Under this alternative, a 1250 gpm pump station and transmission line is required. The pump station shall include a new intake structure with screening, and a wet pit. Pumping should be provided by three (3) pumps. All three pumps shall be rated at 1250 gpm (2 pumps alternating, one stand by) and a total dynamic head (TDH) of 55 ft. Raw water shall be transferred by means of a 3.4 kilometers, 14-inch ductile iron line. The pump station shall include an emergency generator to provide reliability during possible power shortages. **Figure 3-2** shows the proposed pump station location and the transmission line alignment from El Vigía Pump Station to the proposed Renewable Power Generation and Resources Recovery Facility site.

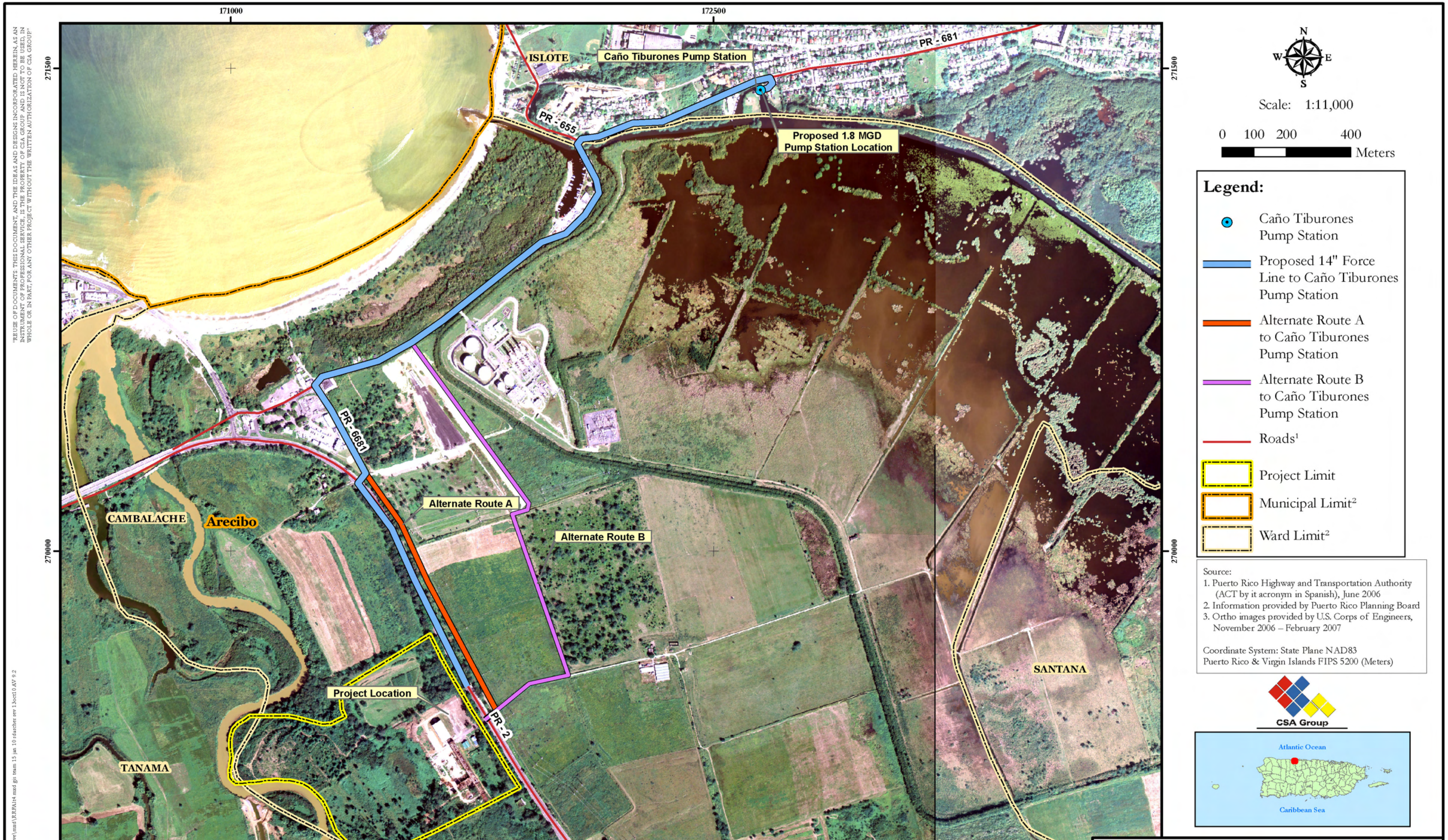

Figure 3-2: Alternative 4 Brackish Water from Caño Tiburones

Renewable Power Generation and Resources Recovery Facility

3.4.3 **Space Requirements**

Potential locations for the pump station are limited. The best scenario is to locate the proposed new intake and pump station upstream and next to El Vigía Pump Station. The site has easy access and the necessary electrical infrastructure for the project needs. Another option is to expand the existing pump station to include new dedicated pumps for Renewable Power Generation and Resources Recovery Facility demand. An agreement must be reached with DNER, in order obtain permission to design and construct the pump station improvements. Transmission line can be installed along state roads PR-681 and PR-2. It is foreseen that the level of existing infrastructure along the proposed state road PR-2 segment will be an issue. Also this is a high traffic road. Two alternate routes are suggested: a) an eastment to the north of state road PR-2; and b) a cross country alignment through dirt roads present in the agricultural lots at the north of the project site. Alternate routes are presented on Figure 3-2. The preliminary construction cost estimate for this alternative was based on the PR-681 and PR-2 alignment.

3.4.4 **Water Quality**

Water quality characterization is limited for the brackish water at Caño Tiburones. A sampling effort was performed by PRASA as part of the planning stage report for a reverse osmosis treatment plant. **Table 3-2** presents the average results of two samples of the brackish water quality that were obtained on the summer of 2006. As informed by El Vigía Pump Station personnel, water may vary on a seasonal basis. They informed that higher TDS values, ranging from 6,000 to 14,000 mg/L, have been observed on other sampling efforts. Brackish water composition at Caño Tiburones is estimated in a fresh water content of 70% and 30% for seawater.

Table 3-2 Caño Tiburones Brackish Water Quality Data

PARAMETER	Units	May 2006 Sampling	Typical Seawater
Barium	mg/L	0.03	0.02
Calcium	mg/L	108	412
Magnesium	mg/L	74.8	1290
Potassium	mg/L	36	380
Sodium	mg/L	832	10770

PARAMETER	Units	May 2006 Sampling	Typical Seawater
Heterotrophic Plate Count	CFU/mL	785	
Sulfate	mg/L	203.5	2700
Chloride	mg/L	1414.5	19500
Fluoride	mg/L	0.129	1.3
Total Organic Carbon	mg/L	6.7	
pH	Units	7.61	
Specific Conductance	umhos/cm	6300	
Total Dissolved Solids	mg/L	2990	34500
Turbidity	NTU	4.4	
Alkalinity	mg/L as $CaCO_3$	197	
Bicarbonate Alkalinity	mg/L as $CaCO_3$	197	117
Fecal Coliform	CFU/100 mL	TNTC[1]	
Total Coliform	CFU/100 mL	2400	
Escherichia Coli	CFU/100 mL	730	
Lead	mg/L	0.0032	
Nitrate	mg/L as N	0.17	
Nitrite	mg/L as N	0.02	
OtherInorganic Compounds	mg/L	BDL[2]	
Volatile Organic Compound	mg/L	BDL[2]	
Pesticides and PCBs	mg/L	BDL[2]	

1. TNTC: Too numerous to count.
2. BDL: Below Detection Limit.

3.4.5 **Treatment**

As mentioned, this alternative considers the use of brackish cooling towers. Total dissolved solids on the reported sampling are typical for brackish water. However, a high bacterial content is evident in the results. This will require disinfection that can be achieved with chlorination. In addition, brackish water must be treated with acid and corrosion inhibitors.

3.4.6 **Environmental Issues**

Water balance for the Caño Tiburones showed the reliability of brackish water as raw water source for the proposed project. Process controls must be implemented in other to minimize the effect of brackish water mist on nearby areas. Construction materials shall be corrosion resistant, due to the corrosive tendency of brackish water. No mayor opposition is foreseen.

3.4.7 **Capital and O&M Costs**

3.4.7.1 *Capital Costs*

The preliminary capital costs for this alternative is **$2,317,844**. This includes the construction of the intake, pump station and transmission line. Additional treatments, such as acid and corrosion inhibitors are not included. Design fees for this alternative are estimated in $250,000. This estimate is based on Puerto Rico College of Professional Engineers (CIAPR) suggested fees for engineering design services based on project construction cost. **Appendix B** presents the preliminary construction cost estimate.

3.4.7.2 *O&M Costs*

Table 3-3 summarizes annual operation and maintenance (O&M) costs for this alternative. The components included in the estimation of the total O&M cost are: pump station, forceline, power costs, and water extraction fees. Water extraction fee was approximated to one fifth of a cent per gallon. The total annual O&M cost is approximately **$1,378,864**.

Table 3-3 O&M Cost Estimate for Alternative 4

System Component	**Total Estimated Construction Cost**	**Percent O&M**	**Estimated Annual O&M**
Forceline	$ 962,200	1.0%	$ 9,622
Pump station	$ 655,000	2.5%	$ 16,375
Power Cost			
Pump Station Horsepower	**Energy Cost ($/kWh)**	**Operating Time (hours)**	**Estimated Annual Power Cost**
35	$ 0.20	24	$ 45,726
Water Franchise Extraction Fee			
Extraction (MGD)	**Fee ($/gallon)**		**Estimated Annual Fee**
1.8	$ 0.002		$ 1,314,000
		Total:	**$ 1,385,723**

3.5 ALTERNATIVE 5 - RECLAIMED WATER FROM ARECIBO'S WWTP

This alternative consists of reusing water from the Arecibo's WWTP National Pollutant Discharge Elimination System (NPDES) discharge for cooling process in the Renewable Power

Generation and Resources Recovery Facility. The cooling process, as informed by Energy Answers International, requires 1.8 MGD of water with a water quality similar to a typical effluent of a secondary WWTP. Therefore, discharge data for Arecibo WWTP was reviewed and analyzed to verify that this facility consistently discharges the amount of water required by the cooling process.

3.5.1 **Reliability**

Discharge Monitoring Reports (DMR) from January 2007 to June 2009 were collected and revised to find the minimum and average flow discharged from Arecibo WWTP. The average flow discharged for this period was 5.6 MGD. **Appendix C** includes a summary of the DMR data obtained.

The reclaim and reuse of the effluent from Arecibo WWTP as cooling water has the advantage of a stable quantity; however some problems can occur that could result in the interruption of the Arecibo WWTP treatment process. A big concern of this alternative is the possibility of a temporary by-pass of a wastewater at the WWTP. Power failures of lift pumps and treatment unit’s problems can lead to a process by-pass. If a by-pass event arises, then the Power Generation and Resources Recovery Facility cannot use the Arecibo WWTP effluent.

Arecibo WWTP Plant Supervisor informed that the plant has never been by-passed, and that if it does occur, it would constitute a permit violation. Therefore, it can be assumed that the WWTP will be able to supply the Renewable Power Generation and Resources Recovery Facility with the water required for the cooling process in a continuous basis. The Renewable Power Generation and Resources Recovery Facility should be provided with a backup tank or lagoon within the site in case a by-pass event occurs at the Arecibo WWTP.

3.5.2 **Water quality**

3.5.2.1 *Feed water quality and common problems in cooling towers*

The most frequent water quality problems in fresh water cooling water systems are scaling, corrosion, biological growth, and fouling. These problems arise from substances that are typically found in reclaimed water. A list of recommended quality limits for water to be used in a cooling process is presented in **Table 3-4**. Reclaimed water should be at least treated to secondary wastewater effluent levels in order to be used as raw water in the cooling process. However, processes like softening, filtration, and chlorination are usually required prior to feeding water to cooling towers.

Table 3-4 Cooling towers feed water typical characteristics

Parameter	Limit	
TDS	500	mg/l
Hardness	650	mg/l
Alkalinity	350	mg/l
pH	6.9 a 9.0	
COD	75	mg/l
TSS	100	mg/l
Turbidity	50	NTU
BOD	25	mg/l
Organics	1	mg/l
NH_4 - N	1	mg/l
PO_4	4	mg/l
SiO_2	50	mg/l
Al	0.1	mg/l
Fe	0.5	mg/l
Mn	0.5	mg/l
Ca	50	mg/l
Mg	0.5	mg/l
HCO_3	24	mg/l
SO_4	200	mg/l

The cooling water must not lead to the formation of scale (hard deposits) since such deposits reduce the efficiency of the heat exchange. The principal causes of scaling are calcium (as carbonate, sulfate and phosphate) and magnesium (as carbonate and phosphate) deposits. Scale control in reclaimed water is achieved through chemical means and sedimentation.

The water must not be corrosive to metal in the cooling system. High concentrations of TDS promote corrosion by increasing the electrical conductivity in water. Corrosion can also occur when acidic conditions develop in the cooling tower. Therefore, nutrients concentrations such ammonia, should be low in the feed water.

Biological growth in cooling systems is common due to the moist environment. Therefore, organics and nutrient concentrations has to be low in order to avoid the growth of microorganisms that can significantly reduce the heat exchange, water flow and in some cases generates corrosive by-products.

Fouling is generally defined as the accumulation of unwanted materials on the surfaces of processing equipment. The fouling layer has a low thermal conductivity. This increases the resistance to heat transfer and reduces the effectiveness of heat exchangers. Fouling is controlled by preventing the settling of particulate matter.

3.5.2.2 *Source water quality*

Arecibo WWTP is a primary treatment facility that discharges into the Atlantic Ocean under the 301H waiver. **Appendix C** includes an analysis of the DMR data from January 2007 to June 2009 for different parameters and monthly values for the parameters included in the NPDES permit. Despite the fact that this facility only offers a primary treatment, the effluent BOD and TSS are low when compared to typical values for a primary treatment facility. However, discharge water quality is expected to be poor when compared to a secondary WWTP. Therefore, additional treatment must be provided to remove nutrients, such as phosphorous to avoid problems in the cooling towers, like biological growth and corrosion. Addition of secondary treatment with at least biological process, chlorine addition, acid and corrosion inhibitors will result in a water quality comparable to a fresh water quality. .

3.5.3 **Infrastructure Needs**

3.5.3.1 *Reclaimed Water Conveyance*

To convey water from the Arecibo WWTP discharge structure to the proposed Renewable Power Generation and Resources Recovery Facility location, a new pump station and a transmission line will be required. The proposed pump station requires pumps rated to convey 1,250 gpm, at a TDH of 65 ft. The transmission line will be a 14" diameter pipeline with an approximate length of 5,400 meters from the proposed pump station to the Power Generation and Resources Renewable Facility. **Figure 3-1** shows the location for the proposed alternative.

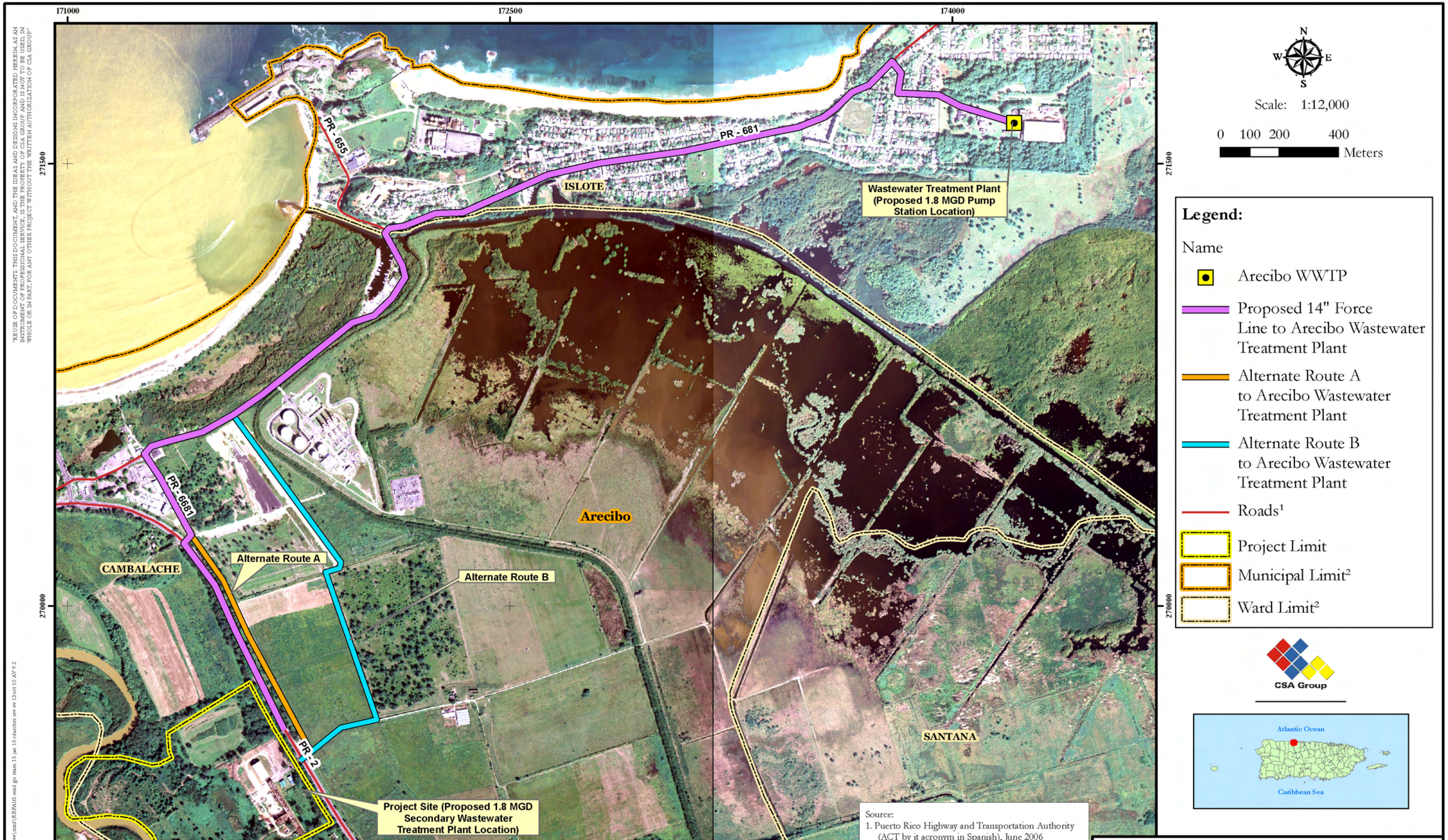

Figure 3-3: Alternative 5: Reclaimed Water from Arecibo Regional WWTP

Renewable Power Generation and Resources Recovery Facility

3.5.4 **Treatment Requirements**

Treatment to the Arecibo WWTP discharge is required to achieve the desirable quality of water for the cooling towers. Different technologies are available to provide the required treatment. Available technologies include activated sludge reactors (from complete mix to sequence batch reactors), and package treatment plants. Mostly all of the secondary treatment process available can reach the desired effluent quality. Therefore, the selection of an appropriate treatment will depend on available space, cost and operation and maintenance reliability. A Preliminary Engineering Report evaluating different process treatment alternatives must be performed in order to select the appropriate secondary treatment process.

3.5.5 **Space Requirements**

Space requirements under this alternative will depend on the selected secondary treatment for the reclaimed water. From the available technologies, one which appears to require the smallest footprint is the Sequence Batch Reactor (SBR). SBR units to treat approximately 2.0 mgd of wastewater usually have a footprint ranging from 1,700 sq. meters to 2,200 sq. meters. Other types of secondary treatment may require higher space.

For the pump station, a footprint of approximately 150 sq. meters is needed. The pump station shall be located as close as possible to the Arecibo WWTP. Land acquisition will be required for the pump station location. Also the possibility of installing the pump station within the WWTP perimeter shall be evaluated and negotiated with PRASA. The transmission line will can be installed along state roads PR-681 and PR-2. Two alternate routes are being presented (see Section 3.4.3), in case the PR-2 segment is not feasible due to the high volume of existing infrastructure on this state road.

3.5.6 **Environmental Issues**

From all the five alternatives mentioned in this study, this alternative will have a positive impact on the environment since it proposes the reuse of Arecibo WWTP discharge, therefore it will reduce the amount of effluent discharged into the Atlantic Ocean. This alternative will not add additional demand to PRASA Aqueduct System. Also, since this alternative does not consider the use of a surface water intake it will not limit the available water resources in the study area.

This alternative requires a more streamlined permitting process, that most of it will be performed during the project EIS approval.

However, measures have to be taken to avoid environmental impacts derived from the construction of the pump station, transmission line and secondary treatment unit. These impacts are temporary and proper mitigation measures can be taken.

3.5.7 **Capital and O&M Costs**

3.5.7.1 *Capital Costs*

The capital costs for this alternative includes the construction of the pump station, transmission line and the estimated cost typical for secondary treatment units. The treatment cost only contemplates treating the Arecibo WWTP effluent to a secondary level effluent. Additional treatments, such as acid and corrosion inhibitors are not included in this estimate. The construction cost for this alternative is estimated to be **$9,425,879**. The final cost will depend on the selected secondary treatment. Design fees for this alternative are estimated in $800,000. This estimate is based on Puerto Rico College of Professional Engineers (CIAPR) suggested fees for engineering design services based on project construction cost. **Appendix B** presents the preliminary construction cost estimate.

3.5.7.2 *O&M Costs*

Table 3-1 summarizes annual operation and maintenance (O&M) costs for Alternative 5. The components included in the estimation of the total O&M cost are: pump station, forceline, secondary treatment plant, and power costs. This alternative assumes that one tenth of a cent per gallon fee will be set for the use of the reclaimed water. The total annual O&M cost is approximately **$1,287,811**.

Table 3-5 O&M Cost Estimate for Alternative 5

System Component	Total Estimated Construction Cost	Percent O&M	Estimated Annual O&M
Forceline	$ 1,471,600.00	1.0%	$ 14,716
Pump station	$ 605,000.00	2.5%	$ 15,125
Treatment Plant	$ 4,500,000.00	9.0%	$ 405,000
Power Cost			
Estimated Pump Station and WWTP Horsepower	**Energy Cost ($/kWh)**	**Operating Time (hours)**	**Estimated Annual Power Cost**
150	$ 0.20	24	$ 195,970
Water Franchise Extraction Fee			
Extraction (MGD)	**Fee ($/gallon)**		**Estimated Annual Fee**
1.8	$ 0.001		$ 657,000
		Total:	**$ 1,287,811**

4 SELECTION OF PREFERRED ALTERNATIVE

The alternatives described in the previous sections were evaluated in a series of categories in order to determine the preferred alternative. A detailed analysis that leads to the selection of the preferred alternative is included next.

4.1 PRESENT WORTH COST ANALYSIS

A present-worth analysis was developed to compare the alternatives from a monetary standpoint. Present-worth of annual O&M cost was estimated using an interest rate of 3.0% for 20 years. **Table 4-1** shows a comparative analysis of each alternative evaluated.

Table 4-1 Present Worth Analysis

Item	Alternatives	
	Alternative 4	Alternative 5
Estimated Construction Cost	$ 2,317,844	$ 9,425,879
Engineering Design	$ 200,000	$ 800,000
Estimated O&M Cost	$ 1,385,723	$ 1,287,811
Interest rate	3.00%	3.00%
Years	25	25
Present Worth O&M	$24,129,805	$22,424,842
Total Present Worth	**$ 26,647,649**	**$ 32,650,721**

4.2 ALTERNATIVE SELECTION

The preferred alternative will be selected by evaluating and comparing the alternatives in a series of categories using an evaluation matrix with a point scale range representing lowest to highest score (**Table 4-2**). These categories include present worth, reliability, environmental impact, water quality, present worth analysis, land requirements. A valuation hierarchy was established using a weighted numeric scale range of 1 to 5, which represents from the less to most favorable. The categories are defines as follow:

Reliability: defined here as the ability of the source to consistently provide the required 1.8 MGD of water for the cooling process. A weight factor of 4 was assigned to this category.

Water Quality: defined as the ability of the source to use with the least treatment needed. A weight factor of 3 was assigned to this category.

Land Requirement: defined as the alternative requirement of land acquisition. A weight factor of 2 was assigned to this category.

Present Worth Analysis: The present worth of each alternative was determined in Section 4.1. The alternative with the lowest cost was assigned a value of 5. A weight factor of 4 was assigned to this category.

Public Perception: defined as the level of public opposition to the alternative. The less expected opposition, the higher the score. A weight factor of 4 was assigned to this category. A weight factor of 3 was assigned to this category.

Schedule: defined as the overall construction and permitting period of the alternative. Less permit and construction period receives higher score. A weight factor of 3 was assigned to this category.

After reviewing all alternatives, Alternative 4, use of brackish water from Caño Tiburones, is the preferred alternative to meet Renewable Power Generation and Resources Facility needs.

Table 4-2 Alternative Comparison Matrix

Category	Weight Factor	Alternative 1 PRASA Water Main	Alternative 2 Groundwater	Alternative 3 Surface Water	Alternative 4 Brackish Water from Caño Tiburones		Alternative 5 Reclaimed Water from Arecibo WWTP	
					Score	Weighted Score	Score	Weighted Score
Reliability	4	**N/A**	**N/A**	**N/A**	5	20	3	12
Water Quality	3				4	12	2	6
Land requirement	2				2	4	2	4
Present Worth Analysis	4				5	20	4	16
Public Perception	4				3	12	5	20
Permits	3				4	12	4	12
Schedule	3				4	12	3	9
Total Score						**92**		**79**

N/A: Eliminated from further study.

5 CONCLUSIONS AND RECOMMENDATIONS

This study intends to analyze the feasibility of available water sources necessary for the cooling process of the Renewable Power Generation and Resources Recovery Facility proposed by Energy Answers International at Cambalache Ward in the Municipality of Arecibo Puerto Rico. Considering the proposed project location, necessary project schedule and the cooling process water quality requirements, the following alternatives for water sources were analyzed:

- Alternative 1 – Puerto Rico Aqueduct and Sewer Authority (PRASA) water main;
- Alternative 2 – Groundwater;
- Alternative 3 – Surface water;
- Alternative 4 – Brackish water from Caño Tiburones
- Alternative 5 – Reclaimed water from Arecibo Waste Water Treatment Plant (WWTP).

After analyzing all the alternatives, the preferred alternative is to further develop the use of brackish water from Caño Tiburones (Alternative 4), since it is the most feasible and reliable alternative to fulfill the Renewable Power Generation and Resources Recovery Facility needs. It is recommended to perform detailed characterization of the source to properly address any seasonal variations in its composition. Also, it will be necessary to negotiate with DNER in order to obtain the water franchise and the permission for construction of the necessary infrastructure at El Vigía Pump Station facilities.

6 REFERENCES

- Department of Natural and Environmental Resources, “Plan de Aguas de Puerto Rico

- Zack and Class-Cacho, “USGS Water Resources Investigation Report 83-4071, 1984

- PRASA. “Costos Unitarios para Estimados Preliminares de Sistemas de Acueductos y Alcantarillados”. Electronic file in Excel format.

- Gregg L. Morris and Associates, Well drilling and Testing Program, in the Cambalache Area, Arecibo, P.R.” 2000.

- PRASA. “Informe Final Programa de Monitoreo del Estuario de Río Grande de Arecibo”, 1998.

7 APPENDICES

Appendix A Water Quality Data for Monitoring Well at Río Grande de Arecibo Estuary

Water Quality Data for Monitoring Well at Rio Grande de Arecibo Estuary

Parameter	Units	Average	Minimum	Maximum
Alkalinity - $CaCO_3$	mg/L- $CaCO_3$	432.5	5.000	630.000
Alkalinity - CO_3	mg/L- $CaCO_3$	4	5.000	5.000
Total Alkalinity	mg/L- $CaCO_3$	447.650	414.6	632.0
Bromuro	mg/L	1.000	0.05	6.49
Calcium	mg/L	85.300	0.005	108.0
Cloruro	mg/L	92.500	42.7	243.9
Fluor	mg/L	0.159	.005	0.285
Magnesium	mg/L	28.140	.005	38.6
Nitrate	mg/L	0.010	.005	0.04
Nitrite	mg/L	0.005	.005	0.04
Phosphate	mg/L	0.110	.005	1.344
Phosphorus	mg/L	1.20	0.02	1.700
Potassium	mg/L	5.180	0.08	13.50
Silicon Dioxide	mg/L- $CaCO_3$	30.000	14.3	48.96
Sodium	mg/L	97.80	0.160	162.0
Sulfate	mg/L	21.00	0.50	46.0
Temperature	(°C)	25.730	0.000	26.63
Ph	unit	6.71	0.000	6.94
Dissolved Oxygen	mg/L	0.135	0.000	3.1
Salinity	ppm%	0.630	0.000	1.01
Conductivity	mS/cm	01.197	0.000	1.906
Total Dissolved Solids	mg/L	756	420	1,215

Appendix B Preliminary Construction Cost for Alternatives 4 and 5

CSA Architects And Engineers, LLP

CSA Group
CSA Plaza, 1064 Ponce De León Ave. Suite 500 San Juan PR
Ph. (787) 641-6801 Fax (787) 641-6850

Project Name: *WTE Water Alternatives*	Date: *22-Jan-10*	Plot Date: ***-NA-***	
	Revision Date:	***Preliminary***	
Client Name & Proj No. Alternative #4 Caño Tiburones Brackish Extraction	CSA Work Order:		
	Department:	**Water**	
Project Location: ***Arecibo, PR***	Prepared By:	**C. Aymerich**	
	CSA Proj. Manager:	**W. Ortiz**	

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
A	**Brackish Treatment**	NA	NA	NA	$ -
	Sub-Total				
B	**New Caño Transfer Pump Station 1.8 MGD**				
1	Site Preparation	1	LS	$ 40,000	$ 40,000
2	Trolley Hoist Equipment and Structure	1	LS	$ 20,000	$ 20,000
3	Pumps 1,250 gpm	3	EA	$ 20,000	$ 60,000
4	Pump Sta. Structure Construction	1	LS	$ 400,000	$ 400,000
5	Electrical Emergency Generator (House & Tank)	1	LS	$ 135,000	$ 135,000
	Sub-Total Pump Station				**$ 655,000**
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	***TOTAL***
C	**Placement of 14" Diameter Pipeline**				
1	14" Diameter DI Pipeline (installed)	3,400	LM	$ 283	$ 962,200
	Sub-Total Pipeline				**$ 962,200**
	Bare Cost				$ 1,617,200
	Mobilization and Demobilization			3%	$ 48,516
	GC & OH			10%	$ 166,572
	Contingency			15%	$ 274,843
	Contractor's Profit			10%	$ 210,713
	Total Construction Cost				**$ 2,317,844**
	Construction Cost Estimate				**$ 2,317,844**

CSA Architects And Engineers, LLP

CSA Group
CSA Plaza, 1064 Ponce De León Ave. Suite 500 San Juan PR
Ph. (787) 641-6801 Fax (787) 641-6850

Project Name: ***WTE Water Alternatives***	Date: ***22-Jan-10***	Plot Date:	***-NA-***
	Revision Date:		***Preliminary***
Client Name & Proj No. Alternative #5 Wastewater Reuse	CSA Work Order:		
	Department:	**Water**	
Project Location: ***Arecibo, PR***	Prepared By:	**C. Aymerich**	
	CSA Proj. Manager:	**W. Ortiz**	

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
A	**1.8 MGD Secondary Wastewater Treatment Plant**	**1**	**LS**	**$ 4,500,000**	$ 4,500,000
	Sub-Total				**$ 4,500,000**
B	**New Arecibo WWTP Pump Station 1.8 MGD**				
1	Site Preparation	1	LS	$ 40,000	$ 40,000
2	Trolley Hoist Equipment and Structure	1	LS	$ 15,000	$ 15,000
3	Pumps 1,250 gpm TDH 24'	3	EA	$ 20,000	$ 60,000
4	Pump Sta. Structure Construction	1	LS	$ 350,000	$ 350,000
5	Electrical Emergency Generator (House & Tank)	1	LS	$ 140,000	$ 140,000
	Sub-Total Pump Stations				**$ 605,000**
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	***TOTAL***
C	**Placement of 14" Diameter Pipeline**				
1	14" Diameter DI Pipeline (installed)	5,200	LM	$ 283	$ 1,471,600
	Sub-Total Pipeline				**$ 1,471,600**
	Bare Cost				$ 6,576,600
	Mobilization and Demobilization			3%	$ 197,298
	GC & OH			10%	$ 677,390
	Contingency			15%	$ 1,117,693
	Contractor's Profit			10%	$ 856,898
	Total Construction Cost				**$ 9,425,879**
	Construction Cost Estimate				**$ 9,425,879**

Appendix C Arecibo Regional WWTP DMR Data

Arecibo WWTP Discharge Monitoring Report Data

Period	Flow MGD (Monthly Ave.)	Flow MGD (Daily Max.)	Temp. (Max.) °C	TSS mg/L	Turbidity NTU	pH Max	pH Min	DO mg/L	Oil & Grease mg/L	BOD mg/L	Residual Cl mg/L	Color Pt-Co	Zn µg/l	As µg/l	CN µg/l	Hg µg/l	NO2+NO3+NH3 mg/L	Ag µg/l	Cd µg/l	Cu µg/l	Fecal Coliforms colonies per 100ml	Total Coliforms colonies per 100ml	MBAS µg/l	Ni µg/l	Pb µg/l	Se µg/l	TKN µg/l	Tl µg/l
Jan-07	6.4	8.5	29.0	21	38	7.3	6.2	3.4	10	58	0.40	20	24	0.18	1	0.021	19.2	2.0	0.1	80	197		2480	24	3.5	5.0	13700	10.0
Feb-07	5.8	9.5	28.0	22	29	7.0	5.8	1.8	4	54	0.50	15	5	0.18	1	0.014	20.7	2.0	1.3	80	2		4520	5	2.9	5.0	18700	10.0
Mar-07	5.7	11.4	29.0	37	24	7.5	6.7	1.7	3	65	0.50	5	5	0.18	1		17.4	2.0	0.1	20	8	18	4160	13	1.1	5.0	20700	10.0
Apr-07	6.8	10.0	28.0	48	23	7.1	6.1	2.0	19	49	0.50	20	5	0.18	5	0.010	17.5	2.0	0.1	96	215	913	5800	5	1.5	5.0	17500	10.0
May-07	7.1	9.6	30.0	35	50	7.5	6.9	1.8	6	49	0.50	20	7	0.18	2	0.007	16.8	2.0	0.1	54	8	12	6160	5	3.7	5.0	17	10.0
Jun-07	6.7	8.8	28.0	36	27	7.5	6.9	1.7	3	56	0.40	15	24	0.18	1	0.019	14.7	2.0	0.1	104	67	187	2800	5	3.9	5.0	16200	10.0
Jul-07	6.2	8.4	28.0	39	15	7.5	6.8	3.0	6	56	0.40	15	23	0.18	7	0.025	13.5	2.0	0.2	106	4	6	2770	12	10.8		13	10.0
Aug-07	5.7	9.1	29.6	22	24	7.4	6.2	2.1	6	54	0.50	25	5	0.18	2	0.012	22.2	2.0	0.1	88	2	3	3110	16	0.8	5.0	22	10.0
Sep-07	4.7	8.0	28.4	43	22	7.8	6.3	1.0	28	76	0.50	15	5	0.18	4	0.037	17.8	2.0	0.1	75	47	214	3520	5	0.8	5.0	18	10.0
Oct-07	4.7	7.4	28.1	31	27	7.6	6.4		1	65	0.54	15	13	0.18	2	0.050	12.2	2.0	0.1	106	1350	1911	1370	5	1.4	5.0	12	10.0
Nov-07	5.3	13.1	29.2	19	39	7.4	6.7	2.2	3	45	0.53	15	19	0.19	1	0.009	16.6	2.0	0.1	15	2	2	2490	5	0.8	5.0	17	10.0
Dec-07	6.1	11.5	28.9	21	10	7.3	6.5	2.8	4	44	0.50	10	32	0.44	13	0.021		2.0	0.1	52	20	20	2470	5	8.0	5.0	11	10.0
Jan-08	4.9	10.8	27.7	22	8	7.6	6.3		10	62	0.50	15	10	0.18	9	0.010		2.0	0.1	53	3	4	1840	5	0.8	5.0	15	10.0
Feb-08	5.2	8.0	27.7	28	16	7.4	6.7	2.9	11	51	0.50	20	19	3.30	1	0.007	18.5	0.6	0.3	94	24	78	3770	8	0.8	10.9	19	0.120
Mar-08	5.7	8.0	28.1	43	17	7.3	6.7		4	52	0.50	15	8	2.60		0.013	18.9	0.8	0.3	15	8	57	5352	24	0.8	7.6	21	0.120
Apr-08	5.6	13.6	28.5	28	10	7.8	6.6	2.7	4	46	0.50	15	7	4.30	1	0.009	16.3	0.2	0.3	18	589	1091	4640	7	0.8	12.9	16	0.120
Jul-08	5.1	6.4	29.1	38	35	7.3	6.3	1.5	6	38	0.47	15	5	0.18	1	0.016	18.7	2.0	0.1	20	23	58	5033	5	0.9	10.0	23060	0.001
Aug-08	5.5	7.0	30.2	34	8	7.5	6.8	2.5	4	52	0.52	10	9	4.70	1	0.012	21.7	0.5	0.3	5	2	2	3900	5	0.8	15.1	17290	0.120
Sep-08	6.3	11.8	28.9	28	30	7.3	6.8	1.7	7	52	0.50	20	13	1.50	1	0.010	18.5	0.5	0.3	87	39	129	4204	3	0.8	5.0	19020	0.120
Oct-08	4.9	8.8	28.5	27	9	7.4	6.8	4.0	4	51	0.40	15	5	4.10	4	0.001	18.3	0.0	0.0	8	15	23	458	5	0.8	13.4	18460	0.120
Nov-08	5.4	14.6	29.4	15	10	7.2	6.8	2.3	36	46	0.04	10	5	3.30	4	0.005	27.9	0.2	0.4	5	31	43	1768	2	0.8	9.6	19750	0.230
Dec-08	5.3	9.5	27.0	35	21	7.3	6.8	1.9	3	43	0.05	20	5	0.18	2	0.005		2.0	0.1	5	3	5	1663	5	0.8	1.0	14450	1.000
Jan-09	4.4	8.5	27.3	48	10	7.6	6.9	4.2	5	44	0.50	15	5	0.18	1	0.004	19.2	2.0	0.1	5	5	10	178	5	5.0	1.0	21110	1.000
Feb-09	6.1	10.4	27.0	33	22	7.2	6.9	1.0	3	48	0.50	10	5	3.70	4	0.004		0.2	0.4	5	3	6	3026	7	6.7	11.7	17030	1.000
Mar-09	5.2	7.5	27.8	23	40	7.5	6.8	4.8	3	65	0.42	15	5	3.30	4	0.007		0.3	0.4	8	6	35	2464	7	6.5	10.0	24250	0.230
Apr-09	5.1	6.2	28.5	26	400	7.2	6.6	5.2	2	56	0.50	15	5	3.08	2	0.011		0.2	0.4	13	2	3	2692	4	3.5	10.3	17260	0.280
May-09	5.4	8.2	28.3	27	17	7.3	6.7	5.9	4	56	0.50	15	5	2.00	2	0.006		0.2	0.4	5	3	4	3896	3	2.7	6.2	18100	0.230
Jun-09	5.4	9.4	28.6	46	32	7.3	6.8	3.0	4	56	0.49	15	16	0.18	1	0.012		2.0	0.1	135	5	13	5046	9	9.0	1.0	21240	1.000
Average	5.6	9.4	28.5	31	36	7.4	6.6	2.7	7	53	0.45	15	11	1.40	3	0.013	18.3	1.4	0.2	48	96	186	3271	7	2.9	6.9	11357	4.8
Maximum	7.1	14.6	30.2	48	400	7.8	6.9	5.9	36	76	0.54	25	32	4.70	13	0.050	27.9	2.0	1.3	135	1350	1911	6160	24	10.8	15.1	24250	10.0
Minimum	4.4	6.2	27.0	15	8	7.0	5.8	1.0	1	38	0.04	5	5	0.18	1	0.001	12.2	0.0	0.0	5	2	2	178	2	0.8	1.0	11	0.001
90th Value	6.4	12.2	29.5	44	39	7.6	6.9	4.6	14	65	0.51	20	23	3.82	6	0.022	21.7	2.0	0.4	105	202	564	5138	14	7.1	12.2	21149	10.0
NPDES Limit	10.0		32.2	110	250	9.0	6.0	0.5	10 (Avg) 15 (Max)	120	0.50	65	316	7.20	1	2.000	63.0	50.0	9.0	2.9	2000	10000	1198	95	92.0	14.0	Monitoring Only	10.0