Chapter 3 – Effluent Requirements and Process Selection

3.1 Effluent Requirements

The Rio Juan Diaz Wastewater Treatment Plant will be capable of treating raw wastewater flows to produce an effluent in conformance with effluent standards established by the Panamanian Government. The Panamanian national standards for wastewater discharges to water bodies and groundwater are contained in Reglamento Técnico DGNTI-COPANIT 35-2000. The maximum permissible values are presented in Table 3-1 below.

Table 3-1
Maximum Effluent Discharge Limits to Receiving Water Bodies

Parameter	Unit	Symbol	Limit
Grease and Oils	mg/l	A y G	20
Aluminum	mg/l	Al	5
Arsenic	mg/l	As	0,50
Boron	mg/l	B	0,75
Cadmium	mg/l	Cd	0,01
Calcium	mg/l	Ca	1 000
Cyanide	mg/l	CN	0,2
Residual Chlorine	mg/l	Cl	1,5
Chlorides	mg/l	Cl_2	400
Copper	mg/l	Cu	1
Total Coliforms	NMP/100 ml	Coli/100ml	1 000
Phenolic Compounds	mg/l	Fenoles	0,5
Hexavalent Chromium	mg/l	Cr^{6+}	0,05
Total Chromium	mg/l	Crt	5
Biochemical Oxygen Demand	Mg O_2/l	BOD_5	35
Chemical Oxygen Demand	mg/l	COD	100
Detergents	mg/l		1
Detergent foam	Mm	PE	7
Fluoride	Mg/l	F-	1,5
Total Phosphorous	mg/l	P	5
Total Hydrocarbons	mg/l		5
Total Iron	mg/l	Fe	5
Manganese	mg/l	Mn	0,3
Mercapatans	mg/l		0,02
Mercury	mg/l	Hg	0,001
Molybdenum	mg/l	Mo	2,5

Table 3-1 (continued)
Maximum Effluent Discharge Limits to Receiving Water Bodies

Parameter	Unit	Symbol	Limit
Nickel	mg/l	Ni	0,2
Nitrates	mg/l	NO_3	6
Total Organic Nitrogen	mg/l	N	10
Ammonium Nitrogen	mg/l	NH_3-N	3
Odor			No perceptible
Organochlorides	mg/l		1,5
Pentaclorophenol	mg/l	C_6OHCl_5	0,009
pH	Unidad	pH	5,5 - 9,0
Lead	mg/l	Pb	0,050
Selenium	mg/l	Se	0,01
Sodium	%	% Na	35
Settleable Solids	mg/l	S.SED.	15
Suspended Solids	mg/l	SS	35
Total Dissolved Solids	mg/l	TDS	500
Sulfates	mg/l	SO_4^{-2}	1 000
Sulfur	mg/l	S^{-2}	1
Temperature	ºC		± 3°C de la T. N
Toluene	mg/l	$C_6H_5CH_3$	0,7
Tricloroethane	mg/l	HC_2Cl_3	0,04
Triclorомethane	mg/l	$CHCl_3$	0,02
Turbidity	NTU	NTU	30
Xylene	mg/l	$C_6H_4C_2H_6$	0,05
Zinc	mg/l	Zn	3

NOTE:
Color: The discharged effluent should not add color to the receiving water body
All concentrations refer to total values.
T.N: Normal site temperature.

Critical parameters for the design of a wastewater treatment plant are BOD, TSS, total phosphorus (TP) and nitrogen. Three nitrogen based parameters are listed: nitrate, ammonia, nitrogen, and total organic nitrogen. Total organic nitrogen consists of natural materials such as proteins and peptides, nucleic acids, urea, and numerous synthetic organic materials. For the purposes of this report, the total organic nitrogen limit of 10 mg/l will be applied as total nitrogen (TN). Therefore, a summary of the design biological treatment effluent limits is presented in Table 3-2.

Table 3-2
Design Biological Treatment Effluent Limits

Parameter	Effluent Limit	
BOD_5	35	mg/l
Total Nitrogen, TN	10	mg/l
Total Phosphorus, TP	5	mg/l
Total Suspended Solids, TSS	35	mg/l
Total Residual Chlorine, TRC	1.5	mg/l
Total Coliforms	1,000	NMP/100ml

It is anticipated that these effluent standards represent the minimum level of effluent quality and it is assumed will be applied as follows based upon daily composite samples in accordance with U.S. Environmental Protection Agency (EPA) regulatory guidelines as follows:

BOD_5

a. The 30-day average shall not exceed 35 mg/l
b. The 7-day average shall not exceed 50 mg/l

TSS

a. The 30-day average shall not exceed 35 mg/l
b. The 7-day average shall not exceed 50 mg/l

TN

a. The 30-day average shall not exceed 10 mg/l
b. The 7-day average shall not exceed 15 mg/l

TP

a. The 30-day average shall not exceed 5 mg/l
b. The 7-day average shall not exceed 8 mg/l

While Table 3-1 includes parameters that are pertinent to the design of a domestic wastewater treatment plant, several of the parameters are not expected in domestic sewage; but may be present as a result of discharges from local industry. The biological processes being considered are not designed to remove these constituents. However, if these constituents are found to be in the wastewater in quantities of concern, this can be addressed through the implementation of a collection system pretreatment program.

3.2. Juan Diaz WWTP Process

3.2.1. Secondary Treatment Process

The secondary wastewater treatment process recommended for the regional treatment works in Panamá is conventional activated sludge. To meet the Total Nitrogen (TN) effluent criteria of 10 mg/liter, the conventional activated sludge process can be modified by adopting one of several Biological Nutrient Removal (BNR) options.

In the 2002 Consolidated Master Plan, an anoxic compartment was located in the first pass of the aeration tank to stabilize the raw wastewater influent and provide a mechanism to reduce TN. This same BNR configuration was adopted in the process layout in this report to provide the ability to meet the 10 mg/l TN effluent criteria.

3.2.2. Evaluation of Primary Treatment Process

The liquid treatment process train proposed in the 2002 Consolidated Master Plan consisted of the following sequential steps:

- Primary treatment in sedimentation tanks
- BNR activated sludge process with anoxic and oxic zones followed by secondary clarification
- Chlorination of final effluent prior to discharge into the receiving waters of the Pacific Ocean

Primary treatment via gravity settling has been utilized for almost 100 years in major cities throughout the world. In most locations, primary sedimentation tanks were initially installed as the only means of waste treatment to minimize the nuisance discharge of pollutants to receiving waters, to protect public health and to improve water quality. As regulatory requirements became more stringent the original gravity settling primary treatment units were upgraded either by chemical addition to improve sedimentation performance or by installing secondary treatment works. In the United States, secondary treatment was mandated on a federal level in 1968. Over the next decades treatment works were upgraded or expanded in all communities across the USA. These construction programs were subsidized by federal grants up to 75 to 85 percent of the capital cost depending upon the technologies installed. Coastal cities such as Boston and San Diego postponed installation of costly secondary treatment works for almost 30 years due to a variety of fiscal, institutional and water quality reasons. The traditional wastewater treatment process sequence is primary sedimentation tanks followed by the activated sludge process.

In cold or temperate climates, gravity settling is an effective unit process. In large systems located in tropical and semi-tropical climates, primary treatment has not always been installed due to the following reasons:

a. At warmer liquid temperatures, the sedimentation process is not as effective.

b. In large collection systems, wastewater will become septic and some solids components will begin to breakdown into soluble BOD. This reduces the BOD level in the settled solids and the overall BOD removal by the sedimentation process.

c. In large collection systems with long detention times, hydrogen sulfide will be generated causing odor problems in treatment plant headworks and primary tanks. As a result of odor problems, primary sedimentation tanks are usually covered and all gases are collected and processed in chemical scrubbers. This is an additional capital and O&M expense.

In South Florida, regional wastewater treatment plants were constructed or expanded in the 1970's in response to the federal requirements mandating secondary treatment. The status of these secondary plants with respect to primary treatment works is as follows:

Table 3-3
South Florida Regional Secondary Treatment Works

	Design Capacity		Primary Treatment Facilities	
Location	**MGD**	**M^3/Sec.**	**Yes**	**No**
Miami-Dade County				
-Homestead	8	0.35	--	√
-South District	100	4.39	--	√
-Virginia Key	143	6.27	--	√
-North District	120	5.26	√	--
Broward County				
-Hollywood	58	2.54	--	√
-Fort Lauderdale	52	2.28	--	√
-Broward County OES	80	3.50	--	√
-Miramar	8	0.35	--	√
Palm Beach County				
-Boca Raton	20	0.88	√	--
-Boynton/Delray	26	1.14	--	√
-South Central	30	1.32	--	√
-ENCON	8	0.35	--	√
TOTAL	653	28.64		

These plants serve a population over 4 million South Florida residents. Two treatment plants with primary sedimentation tanks are the North District Plant located in Miami-Dade County and the Boca Raton facility. The primary treatment tanks have aluminum covers. All gases are captured and treated in chemical scrubbers. Hazen and Sawyer designed the original 60 MGD

North District plant in 1974 and subsequent expansions in 1980, 1992, and 2000 to 120 MGD capacity. The original plant capital cost was funded by a 75 percent federal grant. The Miami-Dade Water and Sewer Department funding only 25 percent of the capital cost from local sources wanted to maximize their capital assets. Primary tanks were added. It should be noted that the original Miami-Dade County Virginia Key secondary plant constructed in 1954 did not have primary tanks. Hazen and Sawyer has provided professional services either in the planning or design of all the treatment works listed in Table 3-3.

The primary sedimentation tanks in the North District plant remove between 18 and 23 percent of the BOD_5 in the influent stream. At the same loading rate we would expect 25 to 30 percent BOD_5 removal in a colder northern climate.

In general primary sedimentation tanks are not utilized in semi-tropical south Florida for the following reasons:

a. Fair to poor BOD_5 removal anticipated. Performance has been confirmed in smaller primary treatment plants phased out of operation in the 1980's.

b. Elimination of odor problems associated with primary tanks and avoidance of odor scrubbing capital and O&M cost. Most regional plants are located in the close proximity of residential communities and odor emissions are not tolerated.

c. Cost effectiveness not demonstrated. Once the federal grant program was eliminated, communities could not fiscally justify the additional cost of primary sedimentation works.

d. Less land is required.

In the 2002 Consolidated Master Plan, the construction cost of primary sedimentation tanks were estimated at $6,908,000. Due to poor soils found in the general vicinity of the Juan Diaz plant site, it is anticipated that foundation piles will be needed to support the tanks. Additional cost associated with the foundation requirements will increase the installation cost of the primary sedimentation tanks.

In the event that no primary tanks are installed, then the raw influent wastewater will first be treated in an enclosed headworks facility. Large solids and grit (sand) will be removed from the liquid stream. All gaseous emissions in the headworks facility will be collected and treated in chemical scrubbers. The liquid stream will be discharged directly into the anoxic zone of the aeration basin. The BOD_5 associated with the settled solids captured in the primary sedimentation tanks must be aerobically treated in the aeration basins. Treatment of the higher loadings in the aeration basin will increase the annual power cost. The Present Worth Cost of the increased power cost associated with treating the additional BOD in the secondary aeration system versus the construction cost of installing the primary clarifiers is summarized in the following Table 3-4:

Table 3-4
Primary Clarification Process Present Worth Cost Analysis

Option	Present Worth Cost (1)
(A) Construction of primary sedimentation tanks	\$6,908,000
(B) No primary tanks. Power cost associated with additional BOD_5 removal in aeration basin	\$4,595,000

Note (1) – Present worth cost calculated on a Capital Recovery Factor of 0.1241 based upon a 12 percent interest rate over a 30 year period.

The "No Primary Tank" option is 50 percent more cost effective. This analysis does not take into account the additional construction cost of tank covers and odor control works and O&M needed for the primary clarifiers or the incremental cost of increasing the solids digestion facilities associated with the higher BOD loading in the aeration basins. These are offsetting costs and therefore do not impact the above conclusion.

Process material analysis indicates that there is no significant impact on the quantity of stabilized solids generated and to be disposed of in an environmentally sound manner with or without primary sedimentation works. Secondary treatment facilities are required in Panamá to meet the "Normas Para Aguas Residuales". Primary treatment works are not cost effective in tropical climates. This is documented in 10 regional secondary wastewater treatment plants operating in South Florida handling 22 m^3/s of wastewater generated by over 3 million residents.

3.3 Veracruz Wastewater Treatment Plant

3.3.1 Treatment Requirements

The Veracruz wastewater treatment plant at buildout will be treating flow generated from a projected population of 19,200 capita. Annual average flows will be about 78.2 L/S (1.78 MGD). Secondary treatment is required to meet effluent standards. The principal unit process steps are as follows.

- Secondary Treatment Process with capability to reduce TN levels to less than 10 mg/liter.
- Aerobic digestion to stabilize waste activate sludge.
- Liquid stabilized sludge would be hauled to the Rio Juan Diaz treatment plant or other environmentally acceptable land application site.
- Chlorination of final effluent prior to discharge into receiving waters.

3.3.2 Biological Plant Process Evaluation

The plant size is larger than nominal prefabricated "package plants" offered for small communities and too small for traditional unit processes utilized for regional treatment plants. The following three viable biological activated sludge processes were evaluated for the new 1.8 MGD wastewater plant.

1. Oxidation Ditch.
2. Extended Air Activated Sludge plant.
3. Sequencing Batch Reactor (SBR).

The biological processes to be considered should be able as a minimum to meet the following conditions.

- Process should be reliable in secondary treatment and nitrogen removal modes and meet required effluent limits on a consistent basis.
- Process should be simple to operate.
- Process should be relatively free of odor.
- Process should provide for future expansion capability (modular design) to meet the projected and possible accelerated growth needs of the City.
- Process should have economical capital and O&M costs.

3.3.2.1 Option A – Oxidation Ditch

The Oxidation Ditch (OD) process is an extended aeration type of activated sludge that has an aeration basin shaped like a racetrack in which wastewater and mixed liquor are continuously recirculating. The oxidation ditch aeration basin is a single channel or multiple interconnected channels. A single channel OD with oval configuration is the most common. Mechanical aerators are commonly used for mixing, oxygen supply, and for circulating of mixed liquor. The most common aeration equipment used with oxidation ditches is horizontal brush, cage, or disc-type aerators. The aerators normally span the width of the channel and may be installed in one or more locations around the channel. Minimums of two aerators are recommended so that at least partial aeration can be provided when problems occur. If the first aerator isn't efficient enough, the second airbrush aerator runs also. Secondary clarification is required with the oxidation ditch processes to separate the bacteria (sludge) from the MLSS. The design of the final clarifier is consistent with other activated sludge processes. Depending on the relative location of the wastewater input and removal, sludge return, and the aeration equipment, oxidation ditches can achieve nitrification and denitrification. Nitrogen removal is achieved by producing both aerobic and anoxic zones within the same channel, controlling the aerator oxygen transfer rate so that mixed liquor dissolved oxygen is depleted within a portion of the aeration channel creates these zones.

The aeration of the ditch is controlled with a DO Sensor (DO = dissolved oxygen). The sensors will pick up as soon as there is sufficient oxygen in the basin liquid, and the aerator will then be turned off. It is also possible to run the whole process over a PLC/SCADA monitoring system to assist the operator in the process operation control.

After treatment, the sewage is then pumped to conventional final tanks (2) where the sludge and the water are allowed to separate. These are separate circular clarifiers with a slowly revolving scraper arm at the bottom that scrapes the sludge to a center well from where it is pumped back to the treatment basin and to the sludge digester.

Treated effluent is piped to the disinfection treatment process. The sludge that has accumulated on the bottom of the settling tank is then removed and a portion of it is returned to the ditch to facilitate microbial activity in the next batch of sewage to be treated. With proper design and careful operation, 80 percent nitrogen removal can be achieved in a single channel oxidation ditch process.

The system's energy demands are moderate; however, they tend to exceed SBR systems energy demands. They require a moderate amount of skill to operate and maintain, and they work well under all weather conditions.

Advantages of the Oxidation Ditch process include:

- Capable of consistently achieving high levels of BOD and TSS removals with minimum operation.
- Nitrogen removal can be achieved with proper operation, proper channel configuration design, tailoring position and intensity of aeration devices, and selecting sludge return points.
- The plants are easy to keep in service and can function for long periods of time with little operation attention and maintenance.
- Flexibility of operation.
- Simple to operate.
- Constant flow.
- Low sludge production.
- Excellent performance.
- High reliability.
- Relatively low initial cost.

- Has long sludge retention time, which minimizes frequency of sludge wasting.
- Can be designed for biological phosphorous removal.

Disadvantages of the Oxidation Ditch process include:

- Separate aerobic digesters must be provided.
- Limited in operation units' redundancy.
- Aeration and mixing costs are 20 to 30 percent higher than for fine bubble activated sludge.
- Requires separate secondary clarifier units.
- The system can be noisy and can also produce odors if not operated properly.
- Requires large area of land when compared to SBR and extended aeration systems.
- Potential for rising sludge due to denitrification in final clarifier.

3.3.2.2 Option B – Extended Air Activated Sludge Package Plant

Extended aeration is a variation of the activated sludge process, with the aeration time increased to about 24 hours from the usual 6 to 8 hours aeration time of an activated sludge process. In addition to its long aeration time, the extended aeration basin has a high MLSS concentration, a high RAS pumping rate, and low sludge wastage. Suppliers of the package plant will provide sludge stabilization aerobic digestion tankage and equipment as part of the total package. The plant configuration is either rectangular common wall tankage or circular units with internal baffle walls separating different compartments. Typical unit processes included within the respective package plants are as follows.

- Hydraulic Surge Tank
- Nitrification Basin
- Anoxic or Denitrification Zones
- Clarification
- Aerobic Digesters

Advantages of the Extended Aeration Package Plant include:

- Entire package designed by manufacturer to owner's specifications.
- Exterior wall construction can be reinforced concrete or less expensive steel.

- Circular or rectangular compact unit configuration, which includes aeration basins, anoxic zones, clarification, return sludge system, and aerobic digestion.
- Minimizes wave actions and sewage haze and spreading of aerosol in the atmosphere.
- Low noise level.
- Adjustable process control. Oxygen input can be adjusted to the varying organic loads.
- Consistently produces effluent with low BOD and SS and can achieve reliable nitrogen removal by proper control of the aeration and mixing functions.

Disadvantages of the Extended Aeration process include:

- Difficult to provide incremental expansion.
- Limited in operation units' redundancy.
- Has moving mechanical parts submerged in water.

3.3.2.3 Option C – Sequencing Batch Reactor (SBR)

The SBR is a fill and draw activated sludge treatment process. Sequencing batch reactors can achieve combined carbon and nitrogen oxidation, nitrogen removal, and phosphorous removal. The SBR process involves a single, complete-mix reactor in which all steps of treatment occur, eliminating the need for both secondary clarifiers and a sludge recycle system. The SBR reactor is filled during a discrete period of time and then operated in a batch treatment mode. MLSS remains in the reactor during the treatment cycle, thereby eliminating the need for a separate clarifier.

Each SBR tank carries out the functions of equalization, aeration, denitrification, and sedimentation in a time sequence, rather than in the conventional space sequence of continuous flow systems where these functions are carried out in separate tanks.

Advantages of SBR operation include:

- Production of an effluent very low in organic compounds, and thus can meet strict effluent standards.
- Avoidance of MLSS "washout" during peak flow events.
- In a cost and energy comparison, studies found that the energy use cost of SBR is 13.5 percent more efficient than the conventional oxidation ditch.

- Process redundancy. The process tanks can operate independently; and therefore, if one tank is taken out of service, the remaining tank continues to provide treatment and can meet the effluent requirements for a short period of time.
- Eliminates the need for a secondary clarifier and return activated sludge (RAS) pumping.
- High tolerance for peak flows and shock loading.
- The process has the flexibility to either aerate or mix independently, without additional equipment. Air to the system can be varied, or completely shut off, and the pumps will provide the required mixing action.
- The process operates in a batch treatment mode, resulting in a more controllable system.
- Process flexibility to control filamentous bulking.
- The system can be located on a small area of land.
- It is relatively easy to expand this system incrementally by adding additional reactors.
- It tends to have fewer maintenance problems over the lifetime of the system, compared to systems which use more moving mechanical equipment.
- Clarification of the MLSS is accomplished under ideal quiescent conditions.
- The reactor of SBR is ideal for situations with excessive diurnal variations in flow and BOD.
- Operator can routinely change cycle duration, aeration/mixing strategies allowing more operation flexibility.
- SBR units are under construction in the City of Panamá and provide the opportunity of local operator cross training.

Disadvantages of SBR operation include:

- Need for frequent and regular disposal of the sludge.
- Periodic rather than continuous discharge of effluent which may necessitate provision to the disinfection system to accommodate peak flows at intermittent periods.

3.3.3 Cost Comparison

The aerobic digestion units are an integral component of both the extended air package plants and the SBR works. Common wall construction results in cost savings. Mechanical aeration equipment (blowers) have common operating conditions and can be used as redundant units in an emergency. The oxidation ditch alternatives have stand alone sludge stabilization works, as well as separate secondary clarifier and sludge pumping systems.

In order to better appreciate the cost differential between the biological plant options, the combined present worth costs of the biological plant and aerobic digestion units were calculated. The primary O&M cost is electrical power. In Table 3-5, only construction cost and annual power operating cost were used to calculate the Total Present Worth cost.

Table 3-5
Present Worth Analysis
Biological Plant and Aerobic Digestion Works

Option	Construction Cost	Present Worth of Power Cost(1)	Total Present Worth Cost
Oxidation Ditch			
A-1 Carousel System	$1,850,000	$1,420,000	$3,270,000
A-2 AE Denitro System	$2,300,000	$966,000	$3,266,000
Extended Air			
B-1 SEQUOX	$2,130,000	$1,125,000	$3,255,000
B-2 Anoxic Package	$1,775,000	$1,225,000	$3,000,000
Sequencing Batch Reactor			
C-1 SBR Vendor No. 1	$1,645,000	$965,000	$2,610,000
C-2 SBR Vendor No. 2	$1,725,000	$965,000	$2,690,000

(1) Present Worth cost of electrical power calculated at 12 percent discount rate over 30-year period. Power consumption based upon plant operating requirements and projected flows over the 30-year planning period.

Based upon this Total Present Worth Cost analysis, biological plant options are ranked as follows.

Table 3-6
Veracruz Biological Process Ranking

Rank	Biological Plant & Aerobic Digestion Option		Present Worth Cost	Incremental Present Worth Cost Increase
1	C-1	SBR Vendor No. 1	$2,610,000	--
2	C-2	SBR Vendor No. 2	$2,690,000	3.1%
3	B-2	Anoxic Package Plant	$3,000,000	11.5%
4	B-1	SEQUOX Package Plant	$3,255,000	24.7%
5	A-2	AE Denitro Oxidation Pond	$3,266,000	25.1%
6	A-1	Carousel Oxidation System	$3,270,000	25.3%

The Sequencing Batch Reactors (SBR) options are the least costly to construct and have the lowest 20-year power cost. The typical cost accuracy for these analyses is about 5 to 10 percent. Three options (A-1, A-2, B-1) are 20 percent or higher in Present Worth Cost. This is a significant differential.

The cost comparison of the three activated sludge technologies arrived at the following observations.

1. Sequencing Batch Reactors (SBR) technology is the most cost effective option over the 20-year planning period.

2. Sequencing Batch Reactors (SBR) units have the lowest initial capital cost.

3. Option B-2, two prefabricated extended air package plants, are about 11 to 12 percent more costly over the life of the project.

4. The other three options (A-1, B-1, A-2) Present Worth costs are 20 percent or more higher than the SBR options.

3.3.4 Technology Selection

From strictly a cost perspective (capital cost, O&M cost, and Total Present Worth cost), the Sequencing Batch Reactor (SBR) technology is the most cost effective biological process under consideration.

In Table 3-7, the three generic activated sludge technologies are evaluated. The following assessment criteria were used to evaluate each technology.

Process Reliability
Secondary Removals
TN Removals
Operational Simplicity
Maintenance Requirements
Modular Expansion Capability
Odor Potential
Power Consumption
Capital Cost
Present Worth Cost

A simple point system was used to assign values to each criterion to arrive at a total score (1 = excellent, 2 = fair, 3 = poor). It is acknowledged that this matrix evaluation system is subjective. However, this approach does provide guidance in evaluating the biological processes under consideration. The ranking of the biological processes under consideration are as follows.

Biological Process	Total Score
Sequencing Batch Reactor	11
Oxidation Ditch	15-17
Extended Air Activated Sludge Package Plant	17-18

In the evaluation matrix, cost considerations constituted about one-third of the overall criteria. The majority of the evaluation addressed issues as process reliability, operational simplicity, maintenance requirements, and odor potential.

Sequencing Batch Reactor (SBR) technology is the recommended biological treatment process for the Veracruz WWTP.

Table 3-7
Biological Process Evaluation Matrix
New Treatment Plant
Veracruz WWTP, Panamá

	Oxidation Ditch		Extended Air Activated Sludge Plant		Sequencing Batch Reactor (SBR)	
Evaluation Criteria	**Option A-1 Carousel System**	**Option A-2 AE Denitro Ditch**	**Option B-1 SEQUOX Process**	**Option B-2 Anoxic Process**	**Option C-1 Vendor No. 1 SBR**	**Option C-2 Vendor No. 2 SBR**
Process Reliability						
Secondary Removals	1	1	1	1	1	1
TN Removals	2	1	1	2	2	2
Operational Simplicity	1	1	2	2	1	1
Maintenance Requirements	1	1	3	3	2	2
Modular Expansion Capability	3	3	3	3	1	1
Odor Potential	2	1	1	1	1	1
Power Consumption	3	1	2	2	1	1
Capital Cost	1	3	2	2	1	1
Present Worth Cost	3	3	3	1	1	1
Total Score	**17**	**15**	**18**	**17**	**11**	**11**

Scoring Criteria: 1 = Excellent
2 = Fair
3 = Poor