Chapter 4 - Major Pump Stations and Transmission

4.0 Introduction

Wastewater generated in Panama City is transported to the coastal areas and is discharged into the Pacific Ocean following the existing drainage basins. Existing sewer collection works follow the drainage streams or discharge directly into the open waterways.

Design services have been authorized to upgrade and expand the collection system to serve the entire city. All wastewater will be collected and transported to locations along the coastal area following natural grade and existing drainage basins. Transmission works consisting of major pump stations and force mains are needed to pick-up and intercept and deliver wastewater from the collection system to the new regional treatment plants. The Consolidated Master Plan (CMP) identified needed transmission works consisting of six major pump stations discharging into to a manifolded force main system that terminated at the Juan Diaz treatment plant. Preliminary sizing criteria and costs for the major pump station and force mains were presented in the CMP.

In this section, the proposed alternative is explored in more detail culminating in a conceptual design with cost estimates generated for the six major pump stations and related force mains. The six major pump stations considered in this report are identified as EB-3, EB-Boca La Caja, EB-3B, EB-5, EB-2F and EB-Tocumen. Figure 4-1 shows the location of the proposed facilities.

A description of the proposed pumping facilities is provided with selection of capacities, type, number of units and arrangement. Also the force main sizes were determined and a preliminary pipeline corridor established for further evaluation in subsequent phases. The conceptual design was aided by utilizing a hydraulic model that represented the proposed pump station and force main layout. A hydraulic model was developed to evaluate existing and future wastewater demand scenarios.

4.1 Hydraulic Model Development

Network analysis is the process of evaluating the performance of the wastewater transmission system through assessment of the existing system as well as through the use of mathematical computer models to predict the future system performance under a variety of conditions. To predict the future performance of a system, a mathematical computer model representing the piping network, pumping systems and operating parameters was developed. The completed model was then utilized to simulate the system behavior and properly size the major pumping facilities and force mains through the planning period of 2020.

The WaterCAD Version 4.5 computer modeling software system developed by Haestad Methods, was utilized to develop a steady state model of the proposed wastewater transmission system and analyze the City’s water distribution system. WaterCAD is a computer program for the design and analysis of pressurized piping systems. The pressure network is solved using a numerical modeling engine which employs the KYPIPE2 computational algorithms.

This computational algorithm permits the simulation of system network pressures, pipe flow rates, hydraulic grades, and pumping rates using Hazen-Williams or Darcy-Weisbach friction equations. The model provides a steady state analysis of the flow in each pipe and the hydraulic grade at each system node at a given point in time (peak hour, maximum day, average day, etc.). In this study, the hydraulic model was utilized to simulate series of multiple pump station discharging into a “manifolded” force main system.

The transmission system hydraulic model was used to evaluate potential scenarios to transmit the flow from the proposed six major pump station to the Juan Diaz Wastewater Treatment Plant. The model is a useful tool by providing the opportunity to perform in an efficient manner an array of computed solutions of scenarios of interest.

The pipe network data was set-up using a base map of roadways and water bodies within the study area. The base map was in AutoCAD format and imported into the WaterCAD program as a background file. The model pipe network was created by drawing directly over the top of the existing road base map. Prospective pipe corridors were used that followed the recommendations of local staff and the Coordinating Unit. The potential corridors used existing roadways and avoided sensitive areas such as those with known archeological value. All perspective corridors must be confirmed at a later stage when more detailed designs are developed.

During the layout of the transmission system, each pipe element was digitized and its associated descriptive information was input into the model. This information included pipe material, size and physical characteristics including pipe roughness. Nodes were placed at the interface of pipes with different diameters, junctions where force mains came together and point in the system with significant elevation changes.

Other data configured in the network set-up included pipe and the proposed pump station ground elevations and diameters. Ground elevations were approximated from topographical maps from the Tommy Guardia Institute.

Operations data inputted into the model included the proposed station minor losses and the proposed pump performance specification (pump curves). WaterCAD uses a standard three-point curve utilizing shutoff, design and maximum operating conditions. Pump curves were generated by the software and utilized during model simulations by comparing pump flow and system head.

4.1.1 Wastewater Model Design Criteria

In order to simulate the system performance through the use of hydraulic models, information on the proposed system elements were inputted and compared to the selected design criteria. The relevant criteria used to “test” the system are summarized in Table 4-1 below:

Table 4-1
Hydraulic Model Design Criteria

Parameter	Criteria
Force Mains:	
Maximum Velocity:	8 feet per second
Maximum Total Dynamic	80 psi
Pump Performance:	
Pump Capacity	2.4 Peaking Factor
Number of Duty Pumps (Peak 2020)	5 units

4.1.2 Wastewater Scenarios

Forecasts of wastewater flows to the major pump stations were based on the estimated population served in each basin times the total wastewater flow per capita presented in the Flow Monitoring and Sampling Report completed in April 2003. The total wastewater flow per capita used to develop the year 2005 estimate was 104 gallons per capita day based on the collected flow metered data from representative basins. For year 2020, a reduction in the flow per capita is expected as a result of the proposed rehabilitation programs to reduce infiltration and inflow. The estimated flow per capita adopted for year 2020 demand is 95 gallons per capita day. The following table presents the wastewater demand scenarios considered in this study.

Table 4-2
Wastewater Flow Demands

	Year 2005 Scenario		Year 2020 Scenario	
Major Pump Station	Average Daily Flow (MGD)	Peak Flow (MGD)	Average Daily Flow (MGD)	Peak Flow (MGD)
EB-3	16.1	38.6	18.1	43.4
EB-Boca La Caja	9.6	23.0	12.7	30.5
EB-5	18.3	43.9	19.6	47.0
EB-3B	15.5	37.2	17.9	43.0
Subtotal	**59.5**	**142.7**	**68.3**	**163.9**
EB-2F	10.0	24.0	11.3	27.1
EB-Tocumen	16.9	40.6	22.4	53.8
Subtotal	**26.9**	**64.6**	**33.7**	**80.9**
Total	**86.4**	**207.3**	**102.0**	**244.8**

Based on the above demands for each major pump station basin, pump curves were selected and inputted into the model. Output files were created representing the results of the specific scenario of interest.

In all scenarios, a peak factor of 2.4 was utilized to select the pump capacities. The major pump stations will be sized to handle extreme wet weather flows. As a result, overflows in the collection system are mitigated and all wastewater flows will be conveyed to the treatment plant.

4.1.3 Wastewater Model Results

The wastewater transmission scenario consists of six major pump stations and the manifolded force main system. Hydraulic modeling was used to analyze the Year 2005 and Year 2020 conditions based on the projected wastewater demands. The transmission system analysis included the modeling of four specific scenarios:

- Year 2005 Average Daily Flow
- Year 2005 Peak Flow
- Year 2020 Average Daily Flow
- Year 2020 Peak Flow

The following section tabulates the hydraulic model output for the facilities of interest.

4.1.3.1 Year 2005 Wastewater Transmission Scenario

Table 4-3
Year 2005 – Average Daily Flow
Hydraulic Model Output – Pump Stations

Major Pump Station	No. of Operating Pumps	Pump Discharge per unit (gpm)	TDH (ft)	Pump Station Total Flow (gpm)
EB-3	2 (VFD 60% Speed)	4,541	53.54	9,081
EB-Boca La Caja	2 (VFD 50% Speed)	3,295	42.07	6,590
EB-5	1	9,635	36.62	9,635
EB-3B	1	9,196	42.59	9,196
EB-2F	1	12,096	38.47	12,096
EB-Tocumen	1	9,008	52.12	9,008

Table 4-4
Year 2005 – Average Daily Flow
Hydraulic Model Output – Force Mains
C Factor 110

Force Main Label	Length (m)	Diameter (in)	Flow (gpm)	Velocity (ft/s)	Gradient (ft/1000 ft)
LI-3	3,011	42	9,081	2.10	0.46
LI-5	1,750	60	15,670	1.78	1.00
LI-11	4,890	72	25,305	1.99	0.22
LI-3B	2,669	84	34,501	2.00	0.19
LI-2H	4,312	42	9,008	2.09	0.45
LI-2F	231	54	12,096	1.69	0.17
LI-12	1,728	64	21,104	2.10	0.28

Table 4-5
Year 2005 – Peak Flow
Hydraulic Model Output – Pump Stations

Major Pump Station	No. of Operating Pumps	Pump Discharge per unit (gpm)	TDH (ft)	Pump Station Total Flow (gpm)
EB-3	3 (VFD 90% Speed)	7,682	104.80	23,046
EB-Boca La Caja	2 (VFD 75% Speed)	6,448	72.08	12,896
EB-5	3	8,119	57.12	24,357
EB-3B	3	8,684	49.52	26,052
EB-2F	2	11,556	43.28	23,112
EB-Tocumen	3	7,433	84.06	22,299

Table 4-6
Year 2005 – Peak Flow
Hydraulic Model Output – Force Mains
C Factor 110

Force Main Label	Length (m)	Diameter (in)	Flow (gpm)	Velocity (ft/s)	Gradient (ft/1000 ft)
LI-3	3,011	42	23,046	5.34	2.58
LI-5	1,750	60	35,943	4.08	1.03
LI-11	4,890	72	60,301	4.75	1.11
LI-3B	2,669	84	86,352	5.00	1.02
LI-2H	4,312	42	22,299	5.16	2.43
LI-2F	231	54	23,112	3.24	0.56
LI-12	1,728	64	45,410	4.53	1.16

4.1.3.2 Year 2020 Wastewater Transmission Scenario

Table 4-7
Year 2020 – Average Daily Flow
Hydraulic Model Output – Pump Stations

Major Pump Station	No. of Operating Pumps	Pump Discharge per unit (gpm)	TDH (ft)	Pump Station Total Flow (gpm)
EB-3	2 (VFD 80% Speed)	7,150	77.66	14,300
EB-Boca La Caja	2 (VFD 80% Speed)	8,179	61.16	16,358
EB-5	2	8,793	48.05	17,586
EB-3B	2	8,929	46.21	17,858
EB-2F	2	11,702	42.00	23,404
EB-Tocumen	2	8,218	68.29	16,436

Table 4-8
Year 2020 – Average Daily Flow
Hydraulic Model Output – Force Mains
C Factor 110

Force Main Label	Length (m)	Diameter (in)	Flow (gpm)	Velocity (ft/s)	Gradient (ft/1000 ft)
LI-3	3,011	42	14,300	3.31	1.07
LI-5	1,750	60	30,659	3.48	0.77
LI-11	4,890	72	48,245	3.80	0.73
LI-3B	2,669	84	66,103	3.83	0.62
LI-2H	4,312	42	16,436	3.81	1.38
LI-2F	231	54	23,404	3.28	0.57
LI-12	1,728	64	39,839	3.97	0.91

Table 4-9
Year 2020 – Peak Flow
Hydraulic Model Output – Pump Stations

Major Pump Station	No. of Operating Pumps	Pump Discharge per unit (gpm)	TDH (ft)	Pump Station Total Flow (gpm)
EB-3	5 (VFD 100% Speed)	5,954	180.92	29,770
EB-Boca La Caja	5 (VFD 100% Speed)	8,272	134.66	41,360
EB-5	5	5,346	93.56	26,730
EB-3B	5	7,827	61.02	39,135
EB-2F	5	10,102	55.44	50,510
EB-Tocumen	5	5,775	116.28	28,875

Table 4-10
Year 2020 – Peak Flow
Hydraulic Model Output – Force Mains
C Factor 110

Force Main Label	Length (m)	Diameter (in)	Flow (gpm)	Velocity (ft/s)	Gradient (ft/1000 ft)
LI-3	3,011	42	29,770	6.89	4.15
LI-5	1,750	60	71,127	8.07	3.66
LI-11	4,890	72	97,859	7.71	2.72
LI-3B	2,669	84	136,995	7.93	2.39
LI-2H	4,312	42	28,875	6.69	3.92
LI-2F	231	54	50,510	7.08	2.38
LI-12	1,728	64	79,386	7.92	3.28

4.2 Major Pump Station Facilities

All previous studies related to the Panama Bay Sanitation proposed the collection of wastewater flows at regional pump stations for transmission, via force main, to a regional plant located in the vicinity of Juan Diaz. In the latest two studies, six major pump stations were identified to provide the level of service required according to the layout of the existing wastewater collection basins and the areas they serve. Panama City is divided into service areas following natural drainage basins that flow on a north to south direction eventually discharging into Panama Bay. Similarly, the existing wastewater collectors have generally followed a parallel path to the riverbanks.

Pump stations are necessary to convey flows from a one point to another point through a close conduit. Pump stations impart the amount of energy necessary for the fluid to overcome the losses in the conduit system and elevation changes. Its primary components are inlet works such as bar screens, a wet well, to briefly store incoming wastewater, pump units, pump controls to activate the pumps when a desired wet well level is reached and valves necessary to isolate the pump station or part of it during maintenance or repair. In the following sections, a discussion is presented regarding the proposed conceptual design for these pump stations and its principal components.

4.2.1 Pumping Units and Capacity

Pump stations are typically designed with either conventional or submersible pumping units. Conventional pumping units require a dry well with only the pump suction piping entering the wet well. In contrast, submersible units are placed inside the wet well since they are designed to work submerged in wastewater. Submersible stations do not need a dry well structure. Submersible pumping technology has advanced and widely used in pumping applications. Submersible pumps are capable of handling the flows and pumping heads required for this project. Since no dry well is required, the structure has a smaller footprint and a cost savings realized. Submersible units are recommended for all major pump stations.

The capacity of the pumping units at each of the pump stations considered the wastewater demands previously presented in Section 4.1.2. The typical arrangement of pumping units will be as follows:

Number of Pumping Units:	8
Number of Pumping Units at Maximum Flow:	5
Number of Pumping Units at Minimum Flow:	1

The total pumping capacity with five duty pumps approximates the Year 2020 peak hourly flow condition.

Table 4-11
Design Criteria Major Pump Stations
Pump Station Requirements

Pump Station	No. of Pumps	Design Points per Unit Head (ft)	Design Points per Unit Flow (gpm)	Peak Flow[1] (MGD)	Pump Power (Hp/unit)
EB-3	8	160	7,000	44	375
EB-B La Caja	8	160	7,000	61	375
EB-5	8	98	5,000	41	168
EB-3B	8	98	5,000	56	168
EB-Tocumen	8	112	6,000	42	248
EB-2F	8	60	9,600	73	201

1 Five pump units online at all pump stations to handle projected peak flow rate.

4.2.2 Structures

The proposed structures for all major pump stations are standardized to simplify their construction and operation. Each wet well will have four submersible pumping units and manual coarse bar screens to protect the pumping equipment. The proposed plan and section layouts for the pump station structures are shown at the end of this chapter.

A separate structure will house the standby generators, electrical equipment and substation and all pump control equipment. An administrative office with storage room and bathroom facilities will be provided for the personnel assigned to maintain the pump station. The plan layout is shown in Appendix A

4.2.3 Odor Control

The control of odor emissions at the major pump stations is of importance since the land adjoining at least four of the six sites is already developed with residential and commercial activities. The remaining two sites will likely have adjacent future residential or commercial development. As such, the early implementation of odor control strategies will ensure a "good neighbor" policy by controlling the foul odors generated during the handling of raw wastewater. In warm weather climates, hydrogen sulfide (H_2S) is the most discernable foul odor. It is an easy compound to measure and used as the primary parameter to assess odor treatment equipment performance.

The anticipated levels of H_2S will range between 10 to 50 mg/L and cost effective technology is available to treat the source at each site. For this application, the recommended technology is the two stages packed tower odor control system. In the first stage of the scrubber system, caustic solution (sodium hydroxide), will be used as the scrubbing liquid where the majority of the H_2S removal occurs. The second stage is used as a polishing step and uses sodium hypochlorite to remove sulfur and other odorous compounds not readily absorbed in the first stage. The H_2S removal efficiency of a two stage packed tower odor control system is 99.9%.

4.2.4 Electrical Loads and Standby Power

The electrical loads of the major pump stations were calculated based on the proposed equipment list and their respective power requirements. The tabulation of electrical loads has a twofold objective: (1) provide a basis for discussion with the local utility and (2) sizing of the standby power generators. Table 4-12 presents the summary sheet for the electrical feed requirements.

Table 4-12
Major Pump Stations Preliminary Electrical Loads

	EB-3	EB-B La Caja	EB-5	EB-3B	EB-2F	EB-Tocumen
Pump Load (HP)	1,875	1,875	840	840	1,005	1,240
Aux. & Base Load (HP)	100	100	100	100	100	100
Total Operating Load (HP)	1,975	1,975	940	940	1,105	1,340
P.S. Operating Amps	2,568	2,568	1,222	1,222	1,437	1,743
P.S. Operating kW	1,637	1,637	779	779	916	1,111
P.S. Operating kVA	2,046	2,046	974	974	1,145	1,388

Note: Loads are calculated based on a 90% motor efficiency and an 80% power factor.

Two 480 volt, 3 phase standby diesel generators will be provided at each pump station sized to operate 3 pumps each. In the event of an electrical power outage, the generator will automatically be activated. An automatic transfer switch will deliver generated electrical power to the motor control center. The generator unit will have a two 10,000 gallon diesel fuel tanks. The entire generator unit will be enclosed in a steel sound attenuating enclosure. No off-site noise nuisance is expected when the generator is placed in operation.

Following is the proposed generator capacity for the major pump stations:

Table 4-13
Generator Capacity

Major Pump Station	Quantity	Generator Capacity (kW)
EB-3	2	1,250
EB-Boca La Caja	2	1,250
EB-5	2	600
EB-3B	2	600
EB-2F	2	700
EB-Tocumen	2	750

4.3 Major Transmission System

The recommended pumping and transmission scenario consists of six pump stations directly discharging into a manifolded force main system to the Juan Diaz WWTP. A force main is a pipe carrying wastewater under pressure from the discharge side of a pump station to a point of gravity flow downstream (i.e. treatment plant). Two separate force main systems are proposed with one system handling the flows west of the Juan Diaz WWTP and the other system handling the flows east of the Juan Diaz WWTP.

The transmission system was designed to carry the Year 2020 peak flows. Pipe diameters were sized to limit the maximum velocities to about 8 feet per second. The following table tabulates the proposed force main diameters and lengths for the transmission system:

Table 4-14
Transmission System

Force Main Label	From	To	Length (feet)	Diameter (in.)
LI-3	EB-3	EB-B La Caja	10,100	42
LI-5	EB-B La Caja	EB-5	9,100	60
LI-11	EB-5	EB-3B	16,200	72
LI-3B	EB-3B	J. Diaz WWTP	8,900	84
LI-2H	EB-Tocumen	EB-2F	14,200	54
LI-2F	EB-2F	LI-12	800	54
LI-12	EB-2F	J. Diaz WWTP	5,800	64

The initial selection of pipeline corridors for the transmission system primarily followed existing roadways, easements and right of ways. The proposed routes seek to use existing corridors which offer minimal disruption and impact to its surroundings. Confirmation of the selected corridors chosen in this conceptual design will be confirmed during the detailed design phases when geotechnical evaluations and interfering utilities are determined.

An adjustment to the LI-11 corridor was necessary after receiving the input from the local staff about the archaeological sensitive nature of the Plaza Mayor area within the "Panama Viejo" area. The LI-11 force main was re-routed and another corridor selected using and existing roadway that circumvented this sensitive area.

The recommended pipeline corridors for the major transmission mains are presented in Appendix A.

4.4 Cost Estimates

The recommended major pump stations and transmission scenario consists of six stations manifolded to a force main system that terminated at the Juan Diaz WWTP headworks. The cost estimate to construct a system capable of handling the Year 2020 flows is $42.15 million. The construction cost estimates for the major pump stations and transmission system is presented individually in the following sections.

4.4.1 Major Pump Stations Cost

The estimated construction cost to build six major pump stations is presented in Table 4-15. The proposed pump stations were standardized to the extent possible to ease construction, equipment purchase and eventual operation. The construction cost estimates represents facilities sized to meet the Year 2020 projected flows. Phasing will be implemented in the earlier stages of the project resulting in some equipment savings. Detailed cost estimates have been included in Appendix B.

Table 4-15
Construction Cost Estimate
Major Pump Stations

Pump Station EB-3	$3,780,000
Pump Station EB-Boca La Caja	$3,780,000
Pump Station EB-5	$2,900,000
Pump Station EB-3B	$2,900,000
West System Subtotal	**$13,360,000**
Pump Station EB-2F	$3,020,000
Pump Station EB-Tocumen	$2,990,000
East System Subtotal	**$6,010,000**
Total Construction Cost	**$19,370,000**

The annual operating and maintenance (O&M) costs for the major pump stations primarily consist of the power necessary to meet the pumping requirements. The cost per kilowatt-hour used is $0.09 per kWh. The estimated O&M costs are presented below:

Table 4-16
Operation and Maintenance Cost
Major Pump Stations

	Initial Operation Year 2005	Scenario Year 2020
Personnel		
Administrative	$12,000	$16,000
Operations	$62,000	$92,000
Maintenance	$11,000	$28,000
Power	$540,000	$1,300,000
Odor Control	$25,000	$42,000
Utilities	$10,000	$12,000
Annual Operating and Maintenance Cost	**$660,000**	**$1,490,000**

4.4.2 Transmission System Cost

The estimated construction cost to build the necessary pipeline transmission works to carry flows from the proposed pump stations to the Juan Diaz WWTP is presented in Table 4-16. The estimated cost represents force mains sized to meet the Year 2020 projected peak flows. Detailed cost estimates have been included in the Appendix C.

Table 4-17
Construction Cost Estimate
Transmission System

LI-3 (EB-3 to EB-Boca La Caja)	$2,140,000
LI-5 (EB-Boca La Caja to EB-5)	$3,160,000
LI-11 (EB-5 to EB-3B)	$7,670,000
LI-3B (EB-3 to J. Diaz WWTP)	$4,490,000
West System Subtotal	**$17,460,000**
LI-2H (EB-Tocumen to EB-2F)	$2,340,000
LI-2F (EB-2F to LI-12)	$440,000
LI-12 (to J. Diaz WWTP)	$2,540,000
East System Subtotal	**$5,320,000**
Total Construction Cost	**$22,780,000**