Tropical Lake Ecology Assessment
With Emphasis on Changes in
Salinity of Lakes
Project No.SAA-140714
Final Technical Memorandum # 5
Water Quality Sampling Plan

Prepared for:
Panama Canal Authority

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1.0 INTRODUCTION

The Panama Canal Authority (ACP) is currently performing a series of studies to assess the feasibility of a new set of locks, alternative systems to raise and lower vessels, and upgrading the navigation channel to prepare a Master Plan for the Modernization and Expansion of the Canal. Parts of these studies include the analysis of risks to increase the salinity of the lakes Gatun and Miraflores. This may occur as a consequence of increased traffic, lateral water saving basins, and anticipated structural modifications, which include an additional set of locks to accommodate larger Post-Panamax vessels. Lake Gatun is adjacent to the locks on the Atlantic and Pacific sides of the Canal and Miraflores Lake is adjacent to the locks on the Pacific side of the Canal.

Within this context, ACP retained URS Holdings, Inc. (URS) for the execution of the contract for the Tropical Lake Ecology Assessment with Emphasis on Changes in Salinity of Lakes. More specifically, under this agreement, URS shall recommend the maximum salinity levels, which may be tolerated in the lakes mentioned above. The salinity standards must consider the current procedures for treatment of potable water in Panama and must also maintain the biological integrity of freshwater ecosystems.

The terms of reference specify several intermediate products in the form of technical memoranda. In this context this is the fifth technical memorandum, which deals with the preparation of the sampling programs to identify asses and compare the viability of existing flora and fauna in Gatun Lake, its tributaries and Miraflores Lake in accordance to the terms of reference for this contract.

1.1 OBJECTIVE

Based on the previous paragraphs, the objective of this fifth technical memorandum is to present a water quality sampling plan for lakes Gatun and Miraflores that includes proposed monitoring sites, field and laboratory methodologies, as well as reporting and data management requirements.

1.2 BACKGROUND

During the preparation of this Technical Memorandum, published literatures as well as consulting studies were reviewed to develop the water quality sampling plan for Gatun and Miraflores Lakes. The most important sources of information consulted, due to their content, clarity and/or subject matter are listed below:

Table 1-1
List of Most Relevant Sources of Information

Document Name	Author	Year	Source of Information
Calidad de Agua en Sitios del Proyecto "Muestreos Biológicos en los Lagos Gatun y Miraflores"	Unidad de Calidad de Agua	2004	División de Administración Ambiental, Sección de Manejo de Cuenca
Documento Técnico de las Normas de Calidad de las Aguas Marinas y Costeras. Anteproyecto de Normas de Calidad de Aguas Marinas y Costeras.	URS	2004	Autoridad Nacional del Ambiente

Document Name	Author	Year	Source of Information
Salt Water intrusion Analysis, Panama Canal Locks.	Delft Hydraulics	2003	Panama Canal Authority
Estudio de Impacto Ambiental, Proyecto Profundización del Cauce de Navegación,	Universidad de Panamá	2003	Autoridad del Canal de Panamá
Water Quality Monitoring- A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programs	UNEP/WHPO	1996	World Health Organization. http://www.who.int/docstore
El Inventario Biológico del Canal de Panamá. IV. El Estudio de Aguas Continentales y Entomológico.	Gutiérrez, R. et al	1994	Scentia (edición especial), Diciembre de 1995.

A full list of documents is provided as section 4.0 of this Technical Memorandum.

1.3 STRUCTURE

This Technical Memorandum has been organized in a manner that is consistent with the objectives of the document and that will allow a clear and concise presentation of the sampling plan requirements. The structure of the document is briefly discussed in the next paragraphs.

Introduction. This introductory section contains a general description of the work to be carried out by URS as well as the objective, and structure for the Technical Memorandum. In addition, background information that explains the research activities performed during the preparation of the sampling plan is also presented.

Water Quality Sampling Plan. This section is the primary result of Task 5 of the project and presents the various requirements for the sampling plan. The section presents the recommended sites for sampling, as well as the sampling, analysis and reporting requirements for the selected water quality parameters. Sampling schedules are also provided.

Organization / Staffing. This section presents basic requirements for the organization of the plan and the human resources needed for implementation of the sampling plan.

Bibliography. Lists of relevant documents consulted during the preparation of the document are presented in this section.

Attachments. This section presents reference information and supporting documents and figures.

2.0 WATER QUALITY SAMPLING PLAN

This section presents the requirements for the implementation of the water quality sampling plan. It has been organized into four main components, site selection, sampling plan, monitoring schedule and costs.

2.1 SELECTION OF SAMPLING SITES

These sites were selected with the objective of establishing continuity and consolidating the information gathered by ACP's Water Quality Unit during various monitoring efforts such as the Biological Monitoring performed by the University of Panama in the lakes Gatun and Miraflores and other studies (Delft, 2003, Gonzales, 1975, US Corp of Engineers, 2000). These sites represent a wide range of habitats that can be found in both lakes and that would allow the identification of any source of salinity of marine, geologic or anthropogenic origin. The sites proposed for monitoring achieve a balance between ecological objectives and economic constraints.

2.1.1 Selection of Sampling Sites

The selection of water quality sampling sites was based on the following criteria:

- Sites must be adequate for monitoring salinity and salinity related parameters from geologic and / or anthropogenic origin, in the main tributaries; and
- Sites must be adequate for monitoring salinity and salinity related parameters from a marine source as it intrudes through the existing Gatun and Pedro Miguel locks, as well as for the future post – Panamax locks.

2.1.1.1 Gatun and Miraflores Lakes Sites

Fourteen (14) sampling sites are proposed for Gatun Lake and two (2) for Miraflores Lake. As indicated previously, the rationale behind the selection of these sites is to provide continuity with the data gathered in previous studies, as well as to provide sites that are representative of various geographic regions of the lakes. Existing water quality and salinity data was reviewed as part of this effort, which indicates that the salinity in Gatun Lake is between 0.05 and 0.08 ppt and from 0.1 to 0.5 ppt in Miraflores Lake (Table 2-2). The proposed sites will allow the long-term monitoring of salinity levels in representative areas of the lakes during pre-construction and construction activities, as well as during the operation of the proposed new set of locks. In addition, the proposed monitoring sites will allow the long-term monitoring of saltwater intrusion in the existing locks system as well as the natural contribution from the main tributaries.

Table 2-1
Proposed Water Quality Sampling Sites
Gatun Lake and Tributaries

Site Name	Coordinates	
Lake Gatun		
LG. 1. Guarapo Island	617526 E	1023132 N
LG. 2. Monte Lirio Bay	625253 E	1023134 N
LG. 3. Zorra Island	627503 E	1026302 N
LG. 4 Gatun River Marsh	632249 E	1023431 N

Site Name	Coordinates	
LG. 5. Brujas Islands	619485 E	1018483 N
LG. 6. Frijoles Bay	629967 E	1013931 N
LG. 7. Raíces – Canal Arenosa	611660 E	1004237 N
LG. 8. Cirí Grande Marsh	605244 E	996555 N
LG. 9. Ciricito Marsh	601099 E	998383 N
LG. 10 Peñas Blancas Bay	624293 E	1008758 N
LG. 11. La Laguna Marsh	628115 E	1000704 N
LG. 12. Chagres River Marsh	645729 E	1011533 N
LG. 13. Gamboa	643977 E	1008022 N
LG. 14. Paraíso - Pedro Miguel	652103 E	997051 N
Lake Miraflores		
M1. Mirafloes Tripartita	653526 E	996004 N
M2. Humedal Cocolí	654074 E	994585 N
Permanent Measurement Stations		
Buoy 11[1]	618089 E	1020640 N
Buoy 47[1]	628594 E	1013928 N
Buoy 82[1]	641627 E	1007276 N
TAP.S[1]	651156 E	997997 N
Tributaries		
TG-1 Honda Creek	647395 E	1014945 N
TG-2 Agua Salud River	633581 E	1017179 N
TG-3 Trinidad River at the El Chorro Station	613138 E	993931 N
TG-4 Mandinga River	643700 E	1003641 N
TG-5 Ciri River at the Los Cañones Station	603064 E	989270 N

LG: Gatun Lake; LM: Miraflores Lake; TG: Gatun Lake Tributary; TM: Miraflores Lake Tributary.
TAP.S: Miraflores aqueduct, water intake area.
Source: University of Panama and Panama Canal Authority, 2004 and Additional sites selected by URS.
Note: [1]Permanent salinity monitoring stations

Table 2-2
Practical Salinity, Sodium Chloride Salinity and Conductivity Measured In Top and Bottom Samples from Gatún and Miraflores Lakes

Site Sampling	Locality	Practical Salinity (ppt)		Salinity NaCl (ppt)		Conductivity (µS/cm)	
		Surface	Bottom	Surface	Bottom	Surface	Bottom
Isla Guarapo	L. Gatún NW	0,080	0,082	0,054	0,055	99,0	101.7
Humedal R. Gatún	L. Gatún NE	0,084	0,087	0,058	0.061	106,3	111,6
Islas Brujas	L. Gatún NW	0,078	0,080	0,050	0,051	92,6	94,2
Bahía Frijoles	L. Gatún NW	0,083	103,5	0,056	0,084	102,4	103,5
Humedal Ciricito	L. Gatún NW	0,060	0,061	0,029	0,029	54,0	54,0
Humedal La Laguna	L. Gatún SE	0,055	0,055	0,024	0,024	45,1	44,6
Boya 67	L. Gatún SE	0,084	0,086	0,056	0,059	103,0	108,3
Boya 82	L. Gatún SE	0,089	0,089	0,062	0,063	114,5	115,3
Humedal R.Chagres	L. Gatún SE	0,055	0,055	0,024	0,024	45,1	44,6
Paraíso	L. Gatún SE	0,104	0,104	0,079	0,079	144,3	144,2
Miraflores Tripartita	L. Miraflores	0,573	(*)	0,554	(*)	1000	(*)
Humedal Cocolí	L. Miraflores	0,530	0,385	0,511	0,368	926	670

Ppt – Parts per Thousand
(*) Sample not collected.
Source: Unidad de Calidad de Agua, División de Administración Ambiental, ACP (2004).

2.1.1.2 Gatun and Pedro Miguel Lock Sites

To monitor water quality near the existing locks as well as near the proposed new locks, a grid system of sampling sites has been established. Sampling sites for the existing Gatun and Pedro Miguel Locks are shown in Figures 2-3 and 2-4. The information to be gathered at these sites will allow for comparison with the data developed by Delft Hydraulics (2003) and ACP's Water Quality Unity.

A 9-point grid, spaced every 200 meters, was established just to the South of the existing Gatun Locks. Sampling locations are presented in Figure 2-2 and their coordinates listed in Table 2-3. At the location for the new locks in Gatun, a 7-point grid, adequately spaced, was established just south of the entrance to the proposed new Post Panamax locks system. Sampling locations are presented in Figure 2-3 and their coordinates listed in Table 2-3.

Table 2-3
Existing Locks Water Quality Sampling Sites

Pedro Miguel Locks		
Site Name	**Coordinates (UTM)**	
PM-1	652337E	996901N
PM-2	652372E	996938N
PM-3	652210 E	997127 N
PM-4	652130 E	997036 N
PM-5	652098 E	997227 N
PM-6	652012 E	997139 N
PM-7	651989 E	997348 N
Existing Gatun Locks		
Site Name	**Coordinates (UTM)**	
GL-1	618195 E	1024586 N
GL-2	618247 E	1024579 N
GL-3	618072 E	1024403 N
GL-4	618356 E	1024362 N
GL-5	618046 E	1024207 N
GL-6	618298 E	1024153 N
GL-7	617867 E	1024114 N
GL-8	618434 E	1024004 N
GL-9	618124 E	1023893 N

PM: Pedro Miguel Locks sampling points; GL: Gatun Locks sampling points
Source: URS GIS

A 7-point grid, adequately spaced, was established just to the North of the existing Pedro Miguel Locks. Sampling locations are presented in Figure 2-3 and their coordinates listed in Table 2-3. Finally, a 9-point grid system, spaced every 250 m, was established for the new Pacific-side locks near Gaillard Cut. Sampling locations are presented in Figure 2-3 and their coordinates listed in Table 2-4.

Table 2-4
Sampling Points Proposed to the New Locks Areas in Gatun and Corte Culebra

New Locks Area Near to Actual Gatun Locks		
Site Name	**Coordinates**	
NGL-1	619377E	1023786N
NGL-2	619626E	1023852N
NGL-3	619878E	1023845N
NGL-4	619425E	1023437N
NGL-5	619685E	1023479N
NGL-6	619917E	1023496N
NGL-7	619755E	1022991N
Entrance to New Lock in Corte Culebra Area		
NLCC-1	651270 E	997620 N
NLCC-2	651188 E	997748 N
NLCC-3	651121 E	997859 N
NLCC-4	651046 E	997727 N
NLCC-5	650700 E	997902 N
NLCC-6	650621 E	998089 N
NLCC-7	650622 E	997965 N
NLCC-8	650438 E	998128 E
NLCC-9	650274 E	998315 N

NGL: Sampling points in the proposed area to the new area en Gatun.
NLCC: Sampling points in proposed entrance to the new locks at the Pacific side in Culebra
Source: SIG of URS based in the ACP information.

2.2 WATER QUALITY SAMPLING

This Section describes the field and laboratory methodologies, as well as the equipment to be used during field measurements. Sampling frequencies as well as reporting and data management requirements are also presented.

2.2.1 Sample Collection

Sample collection for Gatun Lake, its tributaries and new locks areas will be done using a Van Dorn or Niskin type bottle with a 2.5-liter capacity. These bottles are capable of collecting samples at a given depth using a trap door system. These sample bottles are well suited for general-purpose sampling at any depth. This bottle is EPA approved for ultra-clean analysis of water (See attached information about sample bottles). Horizontal bottles may be used for sampling at the tributaries. At each site, one sample will be collected at 1 meter from the bottom of the water column. In case of shallow waters and tributaries the samples must be taken at 50 cm from the bottom.

The flow of water in the tributaries reduces significantly during the dry season which may make it difficult to use the sampling bottles indicated above. Under these circumstances, the sample may be directly collected using a semi-closed labeled plastic bottle. The bottle may be introduced to the desired depth and the lid opened to allow entry of the sample. Once the sample is collected, the bottle is closed and placed in a cooler with ice and preserved at 4 °C. Appropriate precautions such as the use of gloves should be taken to avoid the contamination of the sample when using this alternate method.

Field parameters shall be recorded from samples at each depth and the samples shall be introduced into 1000 ml polyethylene bottles and preserved at 4°C until they reach the laboratory. The following bottle washing procedures shall be carried out in preparation of the sample collection, this procedure is recommended to avoid interferences by contamination (Bartram, 1996):

1- Rinse the bottle three times using tap water,
2- Rinse once with chromic acid (35 ml solution saturated with $Na_2Cr_2O_7$ in 1 liter concentrated, reactive grade H2SO4)
3- Rinse three times with tap water,
4- Rinse once with nitric acid prepared on a 1:1 acid-water ratio, and
5- Rinse three times with distilled water, seal and label.

The laboratory that will perform the analysis should do the preparation of the sample containers that must be labeled with the information of location, site number, depth and sampling date.

Once the samples are collected, a chain of custody form must be filled out to specify the analysis to be carried out, general information about the samples, and the responsible parties involved during sample collection, handling and transportation (Table 2-5).

2.2.2 Field Measurements

Field measurements will be taken at each location using either a handheld instrument or through the use of a permanent monitoring station as explained in the following sections.

2.2.2.1 Handheld Instruments

The following parameters must be measured at each of the sampling locations, at two depths (bottom and surface): depth, temperature, pH, turbidity, electric conductivity, salinity, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), and % Dissolved Oxygen (% DO). These measurements may be carried out using a Hydrolab 4a or similar type of instrumentation. It should be noted that samples to be analyzed at the laboratory will be collected from the bottom of the water column, however field parameters will be measured both at the surface and at the bottom of the water column.

Field data will be recorded in a form that will also include relevant information such as climate conditions, date, time, site coordinates, sample ID, laboratory analyses requirements, etc. (Table 2-5).

2.2.2.2 Permanent Measurement Stations

As briefly indicated in section 2.1, several permanent salinity measurement stations are being proposed as part of the monitoring plan. The purpose of these stations is to have long-term measurements on a continual basis of salinity along the navigational channel. This data will be valuable in identifying seasonal trends (if any) and any other water quality variations that may exist in the lake.

The permanent stations are in the form of water quality buoys capable of analyzing and transmitting information via cell phone telemetry. The buoys must be made of durable

material such as plastic, and must have all necessary equipment and accessories such as solar panels, on board processor, measuring instrumentation and data transmission system.

The buoys can be towed into measuring position and easily deployed and operated. Typically, the sensors are mounted in a cage just below the buoy. The cage can be released from its position and brought to the surface for easy access to the sensors when doing service and calibration.

The recommended parameters to be analyzed by the permanent stations are: temperature, pH, conductivity, dissolved oxygen and salinity. Other parameters such as chlorophyll (algae biomass), nitrate, and surface current (velocity and direction) may be added if deemed necessary by ACP. The collected data can be downloaded daily and processed using software provided by the buoy manufacturer. This software usually allows for the presentation of time series plots, statistical analysis, development of plots and graphs, etc.

Various suppliers of this type of equipment were consulted during the preparation of this Technical memorandum. These include: Oceanor; Applied Microsystems; and Axys Technologies.

Table 2-5
Field Data Collection and Laboratory Analyses Request Form

Site Name:	**Site ID:**
Date:	**Coordinates (UTM):**
Weather Conditions:	
Problems encountered/Adaptations made during sampling:	

FIELD MEASUREMENTS

Sampling Method:

Sample ID	Equipment	PH	Temp. ºC	Salin. mg/L	D.O. mg/L	D.O.% %	TDS mg/L	Cond. mS/cm	Depth m	Comments

Sampling Preservation and storage:

REQUESTED LABORATORY ANALYSES

Parameters	Method	Sample ID			Comments
Alkalinity					
Practical Salinity					
NaCl Salinity					
Conductivity					
TSS					
TDS					
Nitrates					
Nitrites					
SO_4-2					
Cl-					
Metals (Na,K,Ca,Mg)					
Total Hardness					

Sample Transport:

Laboratory Name:

General Remarks:

Collector Name:	**Signature:**	**Date**
Samples Received by:	**Signature:**	**Date**
Data received by:	**Signature:**	**Date**

Temp.: Temperature in ºC; Salin. Salinity; D.O: Dissolved oxygen; D.O %: Percentage of Dissolved oxygen
TDS: Total dissolved solids; TSS: Total Suspended Solids; Cond.: Conductivity

2.2.3 Laboratory Analysis

Samples will be analyzed in a laboratory for the following parameters: total alkalinity, total suspended solids (TSS), Total Dissolved Solids$^-$, SO_4^{2-}, Cl^-, Na^+, Ca^{+2} , Mg^{+2}, K^+, total hardness ($CaCO_3$), electric conductivity, practical salinity, and sodium chloride salinity.

The methods to be used in the laboratory to determine the parameters mentioned above are listed in Table 2-6. These methods are recommended by the United States Environmental Protection Agency (USEPA) and the World Health Organization (WHO) and are presently used by ACP's Water Quality Unit.

Table 2-6
Methods used For the Analysis in Laboratory for Water Samples

Parameter	Method	Comments
Alkalinity	(SM 2320-H B)	Titration
Conductivity, Practical Salinity and NaCl Salinity	SM 2510Electrometric	Denver 250 Multi-parameter analyzer
Total Suspended Solids (TSS)	SM 2540 D	
Total Dissolved Solids (TDS)	SM 2540 C	
SO_4^{2-}	SM 4500-SO4	Colorimetric
Cl^-	Ion Selective Electrode (ISE)	Denver 250 Multi-parameter analyzer
Metals (Na, K, Ca, Mg)	SM 3110	Atomic Absorption Spectrometry
Total Hardness	SM 2340 B	Calculated

Source: URS, ACP Water Quality Unit
SM – Standard Methods for the Evaluation of Water and Wastewater

2.2.4 Frequency

To determine the baseline, the monitoring must be performed at the beginning and at the end of the dry and rainy seasons during 1 or 2 years; thereafter, the monitoring must be performed twice a year until construction is completed. If there are any significant variations in the measured parameters, the need to increase the sampling frequency should be assessed. During the first year of operation, the sampling frequency will be the same as during the baseline. Monitoring after the first year of operation will be performed twice a year (see tables 2-7 and 2-8).

2.2.5 Report Preparation

Progress reports must be presented every six months. They shall include: (1) Executive Summary, (2) Introduction or Background Information, (3) Sampling Objectives, (4) Collection Methods, (5) Results Obtained, (6) Analysis of the Results, (7) Recommendations, and (8) Bibliography.

2.3 MONITORING SCHEDULE

To understand the monitoring/frequency proposed it is necessary to visualize the various stages or phases associated to the potential Panama Canal Expansion. For the purposes of this document, the following phases have been identified:

- **Baseline**. Corresponds to the start of the monitoring plan for a period of up to 2 years.
- **Pre-Construction.** Corresponds to the period after the baseline and before the start of construction activities.
- **Construction.** Corresponds to the period when construction activities would take place.
- **Operation**. Corresponds to the period following construction, when the lakes system could be influenced by an influx of saltwater.

Given that each phase of the project is unique, the required monitoring frequency may be different as the project moves forward. Tables 2-7 and 2-8 provide the monitoring schedule/frequencies for the phases/stages identified above.

It will be necessary to separate the sampling in the lakes and tributaries from the sampling to be done near the existing and proposed locks, due to the large number of sites in the latter. Therefore, it is recommended that monitoring start with the locks (Actual and proposed sites to the new locks) and continues with the lake and tributaries to avoid overwhelming the laboratory and the data analysis efforts.

Table 2-7
Water Quality Monitoring Schedule
Gatun Lake, Tributaries and Locks (existing and proposed)
Baseline and First Year of Operation

Sites Proposed	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Lakes		X		X					X		X	
Tributaries		X		X					X		X	
Gatun and Pedro Miguel Locks	X		X					x		X		
New Locks Area	X		X					X		X		

Table 2-8
Water Quality Monitoring Schedule
Gatun Lake, Tributaries and Locks (existing and proposed)
Pre-Construction, Construction and after First Year of Operation

Sites Proposed	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Lakes				X							X	
Tributaries				X							X	
Gatun and Pedro Miguel Locks		X							X			
New Locks Area		X							X			

2.4 COST

The unit cost for the analysis of samples in a private laboratory is $304.50/sample, which includes the determination of the parameters described in the table 2-6. The total number of points during a campaign is 37 (21 for the lakes and tributaries and 16 for the existing and proposed locks), which translates into $11,266 per campaign. During the first two years, two campaigns per season were recommended which would total $22,532 per season and $45,064 per year. Therefore, the laboratory analysis cost for the first two years of the sampling program would be $90,128. The costs of the sampling plan for the various phases of the project are summarized below in a general manner:

Table 2-9
Cost of Monitoring Plan per Phase per Year[5]

Description	**Phase (Cost/year)[4]**				
	Baseline	**Pre-construction**	**Construction**	**Operation First Year**	**Operation (After first year)**
Sample Collection and Field Measurements[1]	$15,000	$7,500	$7,500	$15,000	$7,500
Laboratory Analyses[2]	$45,064	$22,532	$22,532	$45,064	$22,532
Permanent Stations[3]	$10,000	$5,000	$5,000	$5,000	$5,000
Total	**$70,064 / year**	**$35,032 / year**	**$35,032 / year**	**$70,064 / year**	**$35,032 / year**

Note:

1. A cost of $100/site is assumed for sample collection and field parameter measurement
2. A cost of $304.50 / sample is assumed based on private laboratory quotation. This cost may be significantly reduced if analyses are performed in-house.
3. An initial investment of $20,000 during the baseline phase (which lasts two years) would be necessary to acquire and install equipment (buoys, sensors, data loggers, software, etc.) as well as perform the necessary training for the four proposed permanent station. The cost provided after the baseline phase is for maintenance and calibration activities.
4. Costs are based on previous experience, consulted literature, and local laboratories. ACP did not provide internal costs for the sampling and analysis of water samples. This cost estimate may be refined once the data becomes available.
5. The costs presented in this table are for budgetary purposes and are not intended to be an exhaustive estimate of all costs associated with the monitoring plan.

3.0 ORGANIZATION / STAFFING

Due to the large number of stations and size of the work to be performed, in order to attain the objectives sought, URS considers necessary to establish a strategy or guidelines. Most of the recommendations deal primarily with the organizational aspects of the program, and are summarized below:

- This project must have an office or a building where the specialized personnel, laboratories and the working team are to be gathered. It must also have a secretary and furniture, such as computers, printers, etc. to ensure the efficiency and speed of the tasks to be carried out under the monitoring program. A suggested organization scheme, taking into account the existing organizational structure of ACP is presented as an Attachment.

- Highly specialized human resources, dedicated to the program on a full-time basis, will be required for the successful implementation of the program. This includes a coordinator, as well as field technicians and office staff (see organizational chart provided as an attachment). In addition, the internal coordination with other units that may provide services to the program must be procured efficiently and planned for ahead of time.

- As mentioned above, the project must have a general coordinator (chemist or environmental engineer/scientist, with experience related to water quality analysis) who shall be in charge of the project and the one directly responsible for the program. This person must have the ability to report and present data efficiently and clearly as well as to coordinate with other departments and personnel to be able to execute the field, laboratory and office work.

- The general coordinator shall be in charge, among other tasks, of coordinating the monitoring, follow up and maintenance of the necessary equipment before and after the sampling, and of supervising the scientific and technical personnel of the project. Similarly, he/she shall be responsible for the correct and timely analysis and report of the results obtained, and may timely recommend amendments to the designs and methods used in the execution of the project and should be ready to report and aid in the correction of the limitations, which may eventually arise in this process.

- For the execution of the field tasks (sample collection and field measurements), as well analysis to be done in the lab, it will be necessary to have a work team made up of environmental scientists / chemists and lab technicians qualified or with proven experience in the areas of limnology, water quality or aquatic sciences, and who should have preferably worked in monitoring projects or similar scientific studies, in any of the above-mentioned fields.

4.0 BIBLIOGRAPHY

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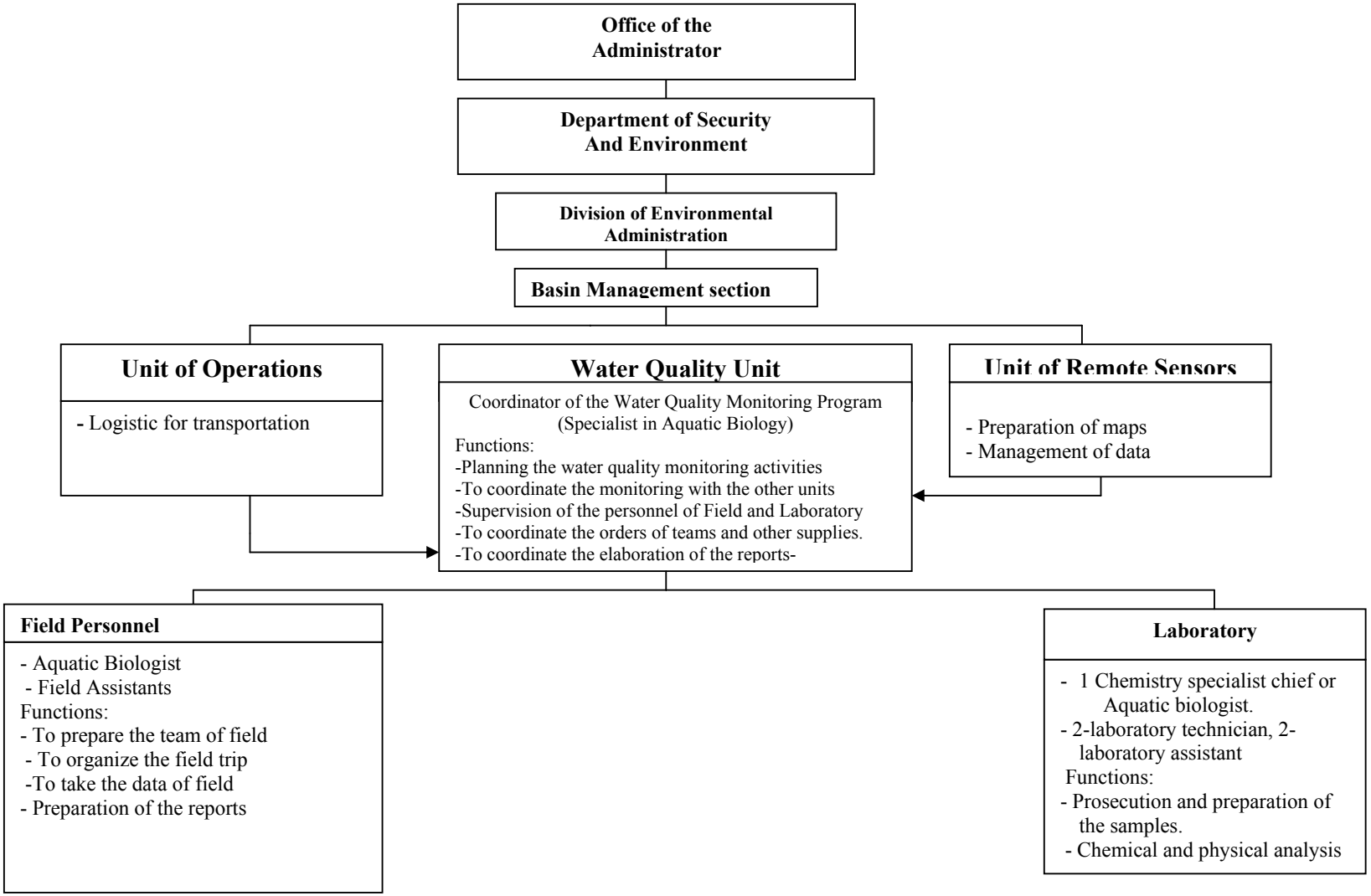
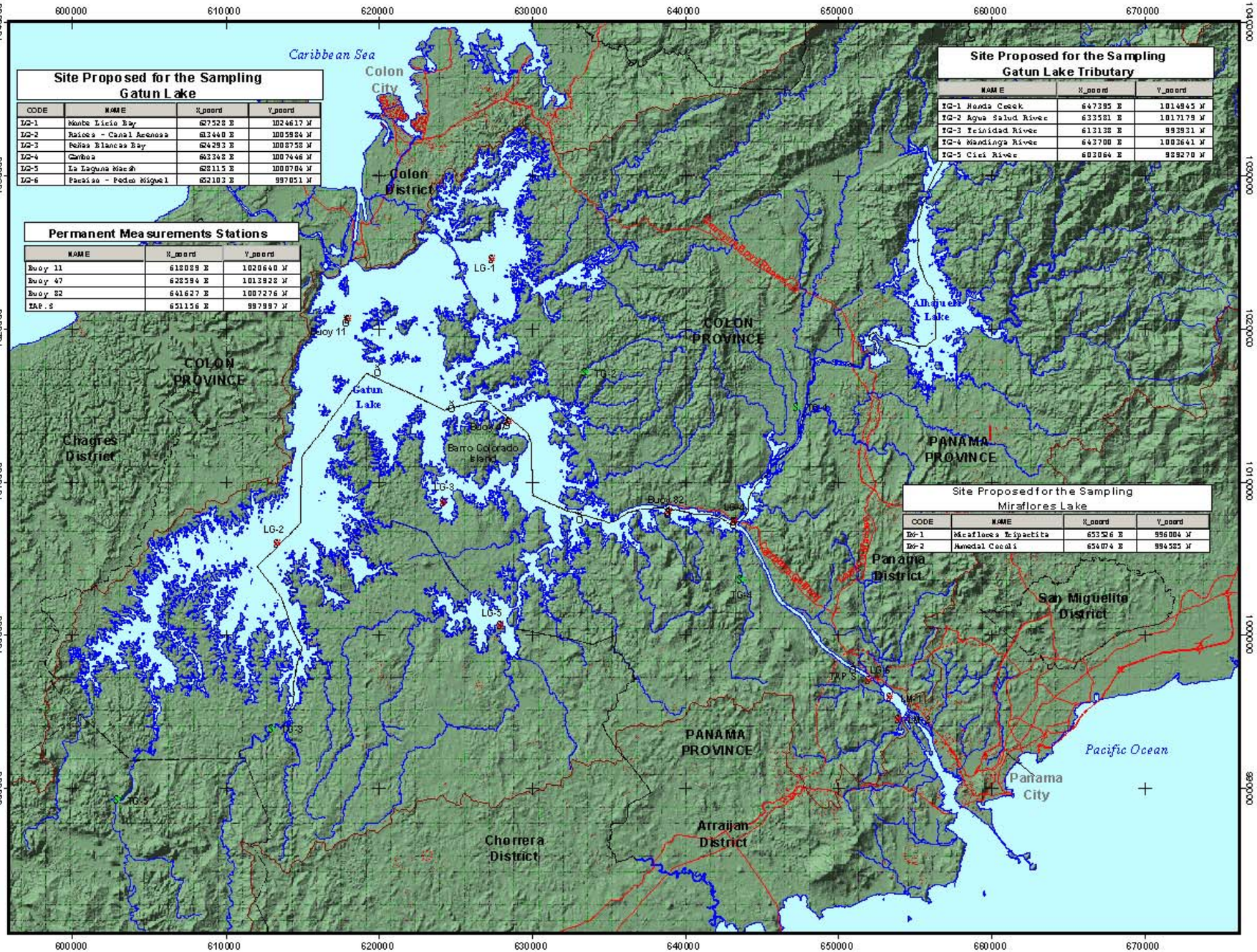
Water Quality Monitoring- A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programs	UNEP/WHPO	1996	World Health Organization. http://www.who.int/docstore
El Inventario Biológico del Canal de Panamá. IV. El Estudio de Aguas Continentales y Entomológico.	Gutiérrez, R. Et al	1994	Scentia (edición especial), Diciembre de 1995.



ORGANIZATIONAL CHART FOR THE WATER QUALITY MONITORING PROGRAMS



Site Proposed for the Sampling Gatun Lake

CODE	NAME	X_coord	Y_coord
LG-1	Monte Lirio Bay	627528 E	1024617 N
LG-2	Raices - Canal Arenosa	613440 E	1005884 N
LG-3	Peñas Blancas Bay	624293 E	1008758 N
LG-4	Gamboa	643348 E	1007446 N
LG-5	La Laguna Marsh	628115 E	1000704 N
LG-6	Pacaiso - Pedro Miguel	652103 E	997051 N

Permanent Measurements Stations

NAME	X_coord	Y_coord
Buoy 11	618089 E	1020640 N
Buoy 47	628594 E	1013928 N
Buoy 82	641627 E	1007276 N
TAP.S	651156 E	987997 N

Site Proposed for the Sampling Gatun Lake Tributary

NAME	X_coord	Y_coord
TG-1 Monte Creek	647395 E	1014945 N
TG-2 Agua Salud River	633581 E	1017179 N
TG-3 Trinidad River	613138 E	993931 N
TG-4 Mandinga River	643700 E	1003641 N
TG-5 Cirí River	603064 E	989270 N

Site Proposed for the Sampling Miraflores Lake

CODE	NAME	X_coord	Y_coord
MF-1	Miraflores Tripartita	653526 E	996004 N
MF-2	Humedal Cocoli	654074 E	994585 N

Tropical Lake Ecology Assessment with Emphasis on Changes in Salinity of Lakes

Sites Proposed for the Water Quality Sampling Program in Gatun Lake, Tributaries and Sites Proposed for the New Locks in the Pacific and Atlantic Side

Panama Canal Authority

LEGEND

- Main Road
- Secondary Road
- Coast
- Main River
- Panama Canal Boundaries
- District Boundaries
- Buoy
- Sites Proposed for the Sampling - Lake Area
- Sites Proposed for the Sampling - Tributary Rivers

Clark 1866
1927 North American Datum
UTM Zone 17

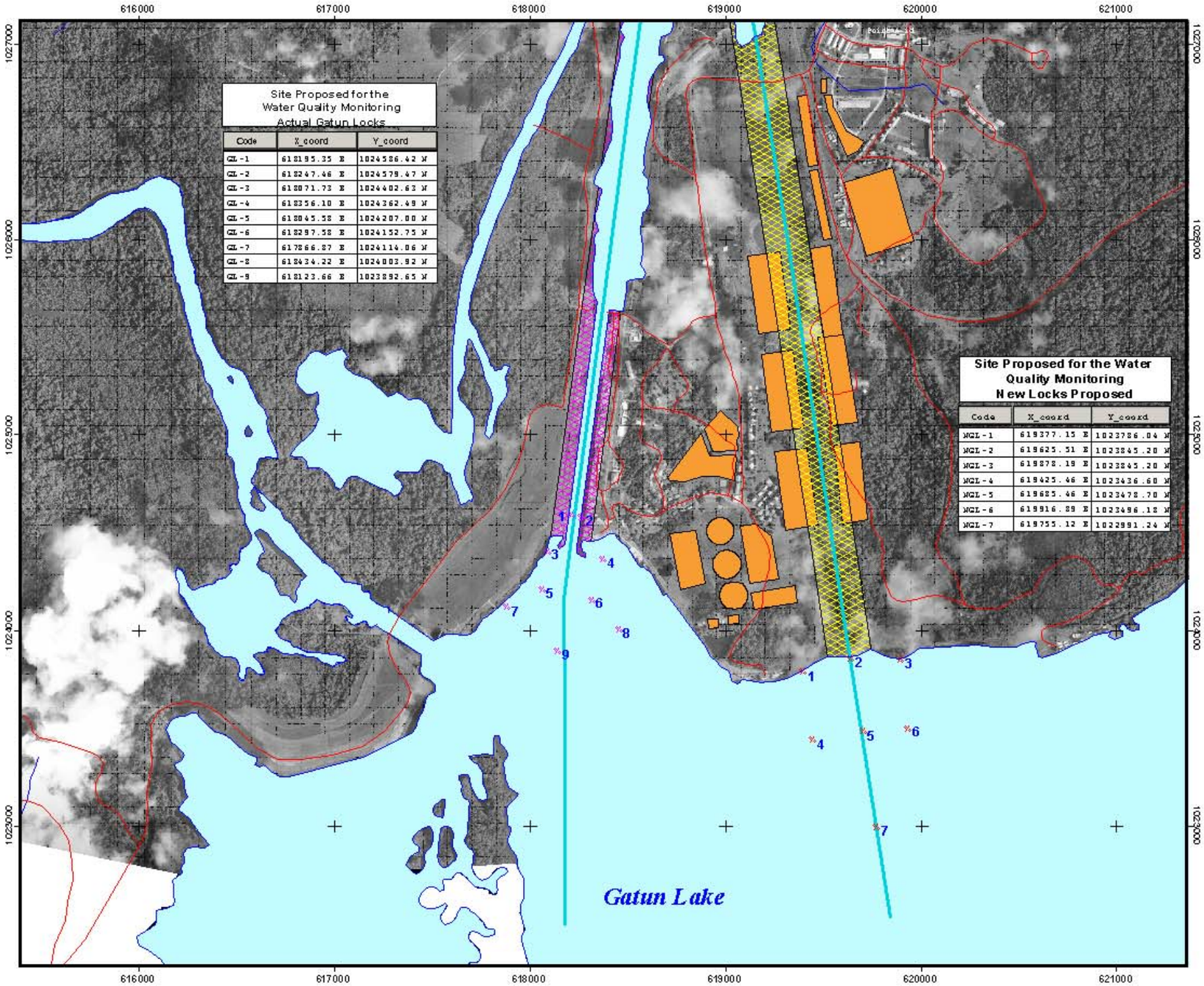
Graphic Scale
2 0 2 4 Kilometers

Scale 1:250,000

Regional Location

Figure 2-1

URS



Site Proposed for the Water Quality Monitoring Actual Gatun Locks

Code	X_coord	Y_coord
GL-1	618195.35 E	1024586.42 N
GL-2	618247.46 E	1024579.47 N
GL-3	618071.73 E	1024402.63 N
GL-4	618356.10 E	1024362.49 N
GL-5	618045.58 E	1024207.00 N
GL-6	618297.58 E	1024152.75 N
GL-7	617866.87 E	1024114.06 N
GL-8	618434.22 E	1024003.92 N
GL-9	618123.66 E	1023892.65 N

Site Proposed for the Water Quality Monitoring New Locks Proposed

Code	X_coord	Y_coord
NGL-1	619377.15 E	1023786.04 N
NGL-2	619625.51 E	1023845.20 N
NGL-3	619878.19 E	1023845.20 N
NGL-4	619425.46 E	1023436.60 N
NGL-5	619625.46 E	1023478.70 N
NGL-6	619916.89 E	1023496.18 N
NGL-7	619755.12 E	1022991.24 N

Tropical Lake Ecology Assessment with Emphasis on Changes in Salinity of Lakes

Sites Proposed for the Water Quality Monitoring in Gatun Lock and Proposed Area for the New Locks

Panama Canal Authority

LEGEND

- Main Road
- Secondary Road
- Coast
- Main River
- Navegation Line
- Actual Route of the Panama Canal
- Route Proposed in the the New Locks
- Infrastructure to Develop with the New Locks
- Sites Proposed for Monitoring - New Locks
- Sites Proposed for Monitoring - Actual Gatun Locks

Clark 1866
1927 North American Datum
UTM Zone 17

Graphic Scale

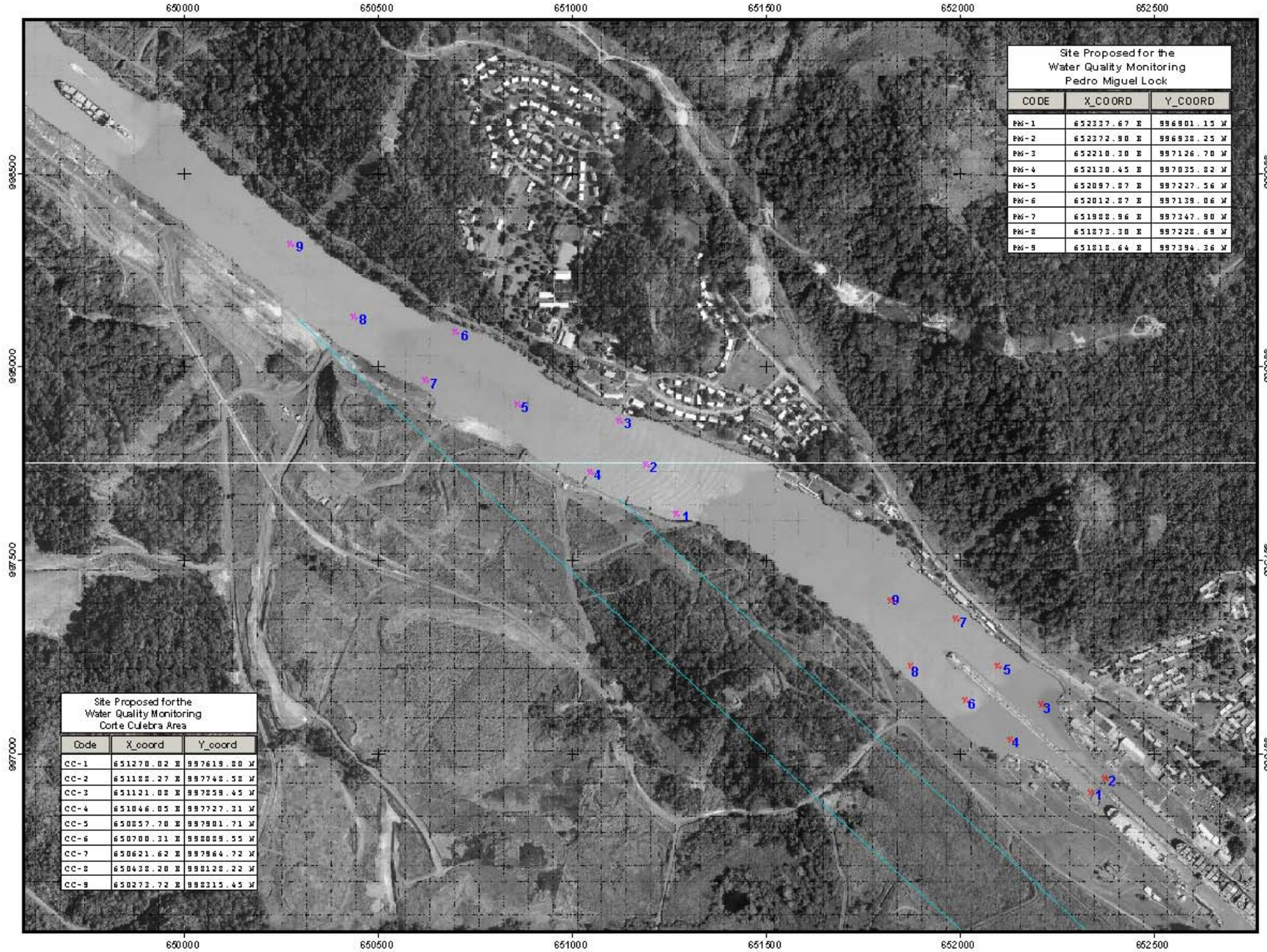
0.5 0 0.5 Kilometers

Scale 1:20,000

Regional Location

Figure 2-2

URS



Site Proposed for the Water Quality Monitoring Pedro Miguel Lock

CODE	X_COORD	Y_COORD
PM-1	652337.67 E	996901.15 W
PM-2	652372.90 E	996938.25 W
PM-3	652210.30 E	997126.70 W
PM-4	652130.45 E	997035.82 W
PM-5	652097.87 E	997227.56 W
PM-6	652012.87 E	997139.06 W
PM-7	651988.96 E	997347.90 W
PM-8	651873.30 E	997228.69 W
PM-9	651818.64 E	997394.36 W

Site Proposed for the Water Quality Monitoring Corte Culebra Area

Code	X_coord	Y_coord
CC-1	651270.02 E	997619.80 W
CC-2	651188.27 E	997748.58 W
CC-3	651121.08 E	997859.45 W
CC-4	651046.05 E	997727.31 W
CC-5	650857.70 E	997901.71 W
CC-6	650700.31 E	998089.55 W
CC-7	650621.62 E	997964.72 W
CC-8	650438.20 E	998128.22 W
CC-9	650273.72 E	998315.45 W

Tropical Lake Ecology Assessment with Emphasis on Changes in Salinity of Lakes

Sites Proposed for the Water Quality Monitoring in Pedro Miguel Lock and the Corte Culebra Area

Panama Canal Authority

LEGEND

- Main Road
- Secondary Road
- Coast
- Main River
- Route Proposed in the New Locks
- Site Proposed for Monitoring - Pedro Miguel Lock
- Site Proposed for Monitoring - Corte Culebra

Clark 1866
1927 North American Datum
UTM Zone 17

Graphic Scale

100 0 100 200 Meters

Scale 1:10,000

Regional Location

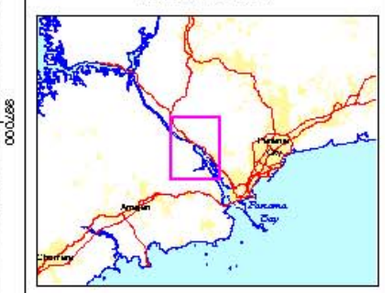


Figure 2-3

URS