Tropical Lake Ecology Assessment
With Emphasis on Changes in
Salinity of Lakes
Project No.SAA-140714
Technical Memorandum # 3
Recommended Salinity Standards
for Lake Gatun and Lake Miraflores

Prepared for:
Panama Canal Authority

Prepared by:
URS Holdings, Inc.

Panama – January, 2005

TABLE OF CONTENTS

1.0 INTRODUCTION 1-1
1.1 Objective 1-1
1.2 Background 1-1
1.3 Structure 1-2

2.0 RECOMMENDED SALINITY STANDARDS 2-1
2.1 Lake Gatun 2-1
2.1.1 Considerations Related to the Protection of Water Quality for Drinking Purposes 2-2
2.1.2 Considerations Related to the Protection of Biological Integrity 2-3

2.2 Considerations for a Different Standard at Corte Culebra 2-3

3.0 CONCLUSIONS 3-1

4.0 BIBLIOGRAPHY 4-1

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. Part of these studies includes the analysis of risks to increase the salinity of the freshwater 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. Lakes Gatun and Miraflores are adjacent to the locks on the Atlantic and Pacific extremes of the canal, respectively.

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 freshwater 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 third technical memorandum, which deals with the recommendation of salinity standards for Lake Gatun and Lake Miraflores. Emphasis has been given to the potable water and biological integrity criteria as required by the terms of reference for this contract.

1.1 OBJECTIVE

Based on the previous paragraphs, the objective of this third technical memorandum is to present the recommended standards for salinity tolerance in Lakes Gatun and Lake Miraflores. The standards are different for the two lakes and they take into account their use as potable water source in the case of Lake Gatun and the protection of aquatic communities.

1.2 BACKGROUND

The recommendation of salinity standards for Lake Gatun and Lake Miraflores takes into account the primary use of water from each water body. It is important to point out that from the salinity point of view both lakes are significantly different. Although the definition of freshwater is not precise, most sources put the limit between 500 and 1,500 milligrams per liter (mg/L)[1] of total dissolved solids (TDS), with normally less than 50% as Chloride ion (Tchobanoglous and Schroeder, 1987). These values were presented and discussed with ACP to select an upper limit for the salt content of freshwater in the Panama Canal System. After consideration of the current salinity levels in Lake Gatun and Corte Culebra, which are well below that range, a decision was reached to select the lower value. Consequently, for the purpose of this memorandum we will consider the upper limit for freshwater 500 mg/L.

[1] For physical-chemical water quality parameters such as dissolved solids concentration, the units of milligrams per liter (mg/L), which are equivalent to parts per million (ppm) are commonly used. Salinity, however, is commonly expressed in the units of parts per thousand (ppt). To convert from ppt to ppm, one must multiply by a factor of 1000.

Data collected by the University of Panama and the ACP during 2004 (April-August) indicates that TDS in Lake Gatun ranged between a maximum of 101.3 mg/L and a minimum of 52.9 mg/L, while the concentration of chloride ion for the same period ranged from a maximum of 18.6 mg/L to a minimum of 5.9 mg/L. Consequently, we can state that Lake Gatun is a truly freshwater lake, with excellent salinity levels from the point of view of potable water supply.

However, in the case of Lake Miraflores data collected from several points in the lake between January and September of 2004 indicate a higher salinity content, which leads us to regard Lake Miraflores more as a brackish water ecosystem, which is unsuitable for human consumption unless a desalination process is conducted. TDS values ranged from a maximum of 2,350.0 mg/L to a minimum of 357.0 mg/L. Although Chloride ion data where not collected during this period for Lake Miraflores, Sodium (Na^+) concentration can also be used for illustration, since they show most of the time values similar to those of Chloride. Concentration of Sodium ion ranged from a maximum of 484.0 mg/L to a minimum of 70.0 mg/L.

The average salinity levels measured in Lake Miraflores, in year 2004; show a significant influence of the rainy season on the salt content of the lake waters. Average values for TDS during the drier months – January to May – fluctuated from 1,027 to 1,642 mg/L. On the other hand, the average TDS concentrations during the more humid months of the sampling period – June to September – fluctuated between 535 and 697 mg/L

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 recommended standards. 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 Third Technical Memorandum. In addition, background information that explains the context of freshwater and brackish water ecosystem and how both lakes fit in that framework.

Recommended Salinity Standards. This section is the primary result of Task 3 of the project and presents the recommended standards for the consideration of ACP. The section has been organized into two sub-sections, one for each of the lakes.

Conclusions. This section presents basic conclusions applicable to Task 3 of the project (Recommendation of Appropriate Standards).

Bibliography. A list of relevant documents consulted during the preparation of the document is presented in this section.

2.0 RECOMMENDED SALINITY STANDARDS

This section of the Technical Memorandum presents the recommended salinity standards for Lake Gatun and Lake Miraflores. In the case of Lake Gatun considerations are made both for maintaining this water body as high-quality source for drinking water and to protect aquatic species of flora and fauna. In the case of Lake Miraflores the consideration for potable water quality is not appropriate since the lake is not currently used for that purpose, nor are there any plans to use it in the foreseeable future. In addition, in the section for Lake Gatun we make an effort to determine the feasibility of having different standards for Lake Gatun and the Gaillard Cut (Corte Culebra) section of the Canal.

2.1 Lake Gatun

The URS team considers it appropriate to establish a maximum and an action level value for salinity in Lake Gatun. The action level value is the value at which a review of the entire set of control measures shall be prompted in order to make sure that the salinity levels in the system will not exceed the maximum value of the standard and will not cause significant unanticipated impacts.

The maximum standard shall not be exceeded at any time and it should be similar to the upper limit for potable water sources around the region and shall not be harmful to freshwater biota. This value shall be established at 500 mg/L for TDS, 769 uS/cm for conductivity, and 230 mg/L for Chloride ion. It should be noted that the 769-uS/cm values for conductivity corresponds to the existing conductivity-dissolved solids relationship (0.65), which was calculated from actual water quality data from Lake Gatun.

The recommended value for the action level shall be set at a much lower level than the maximum salinity standard. At this time it is recommended that this value does not exceed 50% of the maximum standard value. It is to say that the mean value for TDS shall be set at 250 mg/L, the mean value for conductivity shall be set at 385 uS/cm and the mean value for Chloride ion shall be set at 115 mg/L. This will prevent major changes for the processes currently in use for potable treatment in the plants that take raw water from Lake Gatun. In addition it will prevent changes in taste of potable water, which may not be accepted by Panamanians, who are used to excellent drinking water quality. The concentrations suggested as action level values are more than double of the maximum concentrations reported for Lake Gatun in the most recent sampling campaign of 2004 and are considered to be indicative of excellent water quality from both potable water supply and protection of biological integrity points of view.

In addition, it should be pointed out that both values, the absolute standard and the action level value, shall be measured outside of the mixing zone or area where the salinity coming from the locks operation has been completely mixed in the water in Gatun Lake and Corte Culebra. The precise boundaries of that mixing zone are not available at this time and their definition require additional work, not included in the current URS's Scope of Work.

2.1.1 Considerations Related to the Protection of Water Quality for Drinking Purposes

Water from Lake Gatun is used for several purposes including lockage, potable water supply and hydropower. Water is also released to control Lake Gatun water level when necessary. From the point of view of potable water the lake is important because it contributes a significant portion of the total water supply to the Metropolitan Region of Panama. For the purpose of this memorandum we shall define potable source as one that is appropriate after required treatment for human consumption in several ways which may include direct drinking as well as culinary or food-processing purposes. Examples of the latter include waters that may be used in connection with the processing of milk, beverages, food, or other purpose, which requires water suitable for human consumption.

When potable water comes from multipurpose sources such is the case for Lake Gatun, it is customary that the priority of use is determined by human consumption in all matter related to both water quantity and quality. This is also the case for Lake Gatun and for the entire Panama Canal Watershed. When severe droughts have restricted the availability of water for all intended uses the ACP always assigned the highest priority to supplying the needs of potable water treatment plants.

Similarly, salinity levels as well as other water quality issues should be dealt in the same manner. It is to say, prioritizing the requirements for potable water use and human consumption. This conceptual framework will ensure that policy is enacted to allow for the best usage of existing water resources, which is as a source of water supply for drinking, culinary, or food-processing purposes.

The salinity related criteria that are included in the secondary drinking water regulations by the USEPA include Chloride and Total Dissolved Solids (TDS). The maximum value allowed for Chloride is 250 milligrams per liter (mg/L)[2] , 769 uS/cm for conductivity, and 500 mg/L for TDS. The chloride and TDS values were recently reviewed and confirmed by the USEPA during the winter of 2004 (USEPA, 2004). These values are suggested as maximum standard values. The Chloride value is similar to that suggested by the Pan American Health Organization (PAHO-WHO), however, the TDS values is significantly more stringent. Nonetheless, the more stringent value is recommended given the existing water treatment processes currently in use in the potable water plants using raw water from Lake Gatun, in an attempt to minimize potential effects and cost increases.

In addition to the upper limit value for the standard, the URS team recommends that a lower value be used as an annual average goal. The rationale behind an average goal lies on the seasonal behavior of rainfall, which will likely reduce the salinity levels in the lake during the wettest period of the year in spite of more or less constant vessels traffic through the canal. The average salinity goal shall be revised regularly using the information collected by the monitoring program. At this time it is recommended that the annual average goal is set at 50% of the upper limit. It is to say 250 mg/L for TDS, 385 uS/cm for conductivity and 125 mg/L for Chloride ion. This shall provide additional cushion for the operation of water treatment plants currently

[2] Milligram per liter (mg/L) is equivalent to parts per million (ppm)

taking raw water from Lake Gatun, to determine the needed adjustments in their treatment processes and estimate the potential financial implication for their operation.

2.1.2 Considerations Related to the Protection of Biological Integrity

As indicated before in Technical Memorandum 1, salinity and/or salinity-related parameters standards specifically drafted for conservation of biological integrity of fresh water ecosystems are uncommon. This is probably because the actual definitions of freshwater would normally take care of the limits. As indicated in the First Technical Memorandum species richness is normally high both in freshwater as well as marine water, but decreases considerably in brackish water, particularly around 5.0 - 7.0 ‰.

The only reference to salinity related criteria for freshwater ecosystems in the USEPA National Recommended Water Quality Criteria: 2002, is for Chloride. The recommended values are a maximum concentration of 860 mg/L[3] and a continuous concentration value of 230 mg/L[4]. These values were derived from literature describing bioassays conducted predominantly with Sodium Chloride (NaCl) (USEPA, 1988). Sodium Chloride is considered an appropriate source of Chloride for the case of Lake Gatun since the predominant source is ocean born Sodium Chloride entering the system with seawater.

Since the continuous concentration value for chloride mentioned above (230 mg/L) is lower than the maximum value from the potable water considerations criterion (250 mg/L), we believe that the maximum chloride level in Lake Gatun shall be set at 230 mg/L.

2.2 Considerations for a Different Standard at Corte Culebra

Consideration for different standards applicable to Lake Gatun and the section of the canal know as Corte Culebra (or Gaillard Cut) is discussed herein to acknowledge comments made by ACP during the review meeting for the First Technical Memorandum addressing the review of national and international salinity standards, as they relate to potable water and the protection of aquatic communities. URS understand that the primary concern for water quality in the Corte Culebra is associated with the intake for the Miraflores Potable Water Treatment Plant.

Since the analysis of applicable standards suggests that limits for both the upper limit for potable water supply and the protection of freshwater biota are very similar, the recommendation of a different maximum standard for Corte Culebra does not seem necessary or appropriate. However, since the Miraflores Potable Water Treatment Plant is the largest plant taking water from the Gatun water level a different action level value may be justified.

The rationale for this different value is that the increase of salinity will increase the treatment costs. However, the impacts on the operational costs are not available and the only way to

[3] The Criterion Maximum Concentration (CMC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect, normally one hour

4 The Criterion Continuous Concentration (CCC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

determine the magnitude of the cost increase is to conduct test to determine the impact in consumption of additional material and increase in the additional amount of time required for the process to complete.

These tests are out of the URS's current scope, and consequently at this time we recommend that the same value is used until this information becomes available. The tests shall include water with salinity levels up to the recommended standard to determine the potential economic impacts on the treatment plant in a variety of scenarios.

3.0 CONCLUSIONS

Considerations of existing information from the Panama Canal allow for the recommendation of salinity standards. Recommended standards are only applicable to Lake Gatun and the Corte Culebra Section of the Canal. No standards are considered necessary for Lake Miraflores. Lake Gatun is a truly freshwater reservoir and the water is used for a variety of purposes including supplying of raw water for potable water treatment plants. Potable water production is not an existing or foreseeable use for Lake Miraflores, which is considered to be a brackish water body. The details of recommended standards are indicated below:

- The URS team considers it appropriate to recommend a maximum and action level standard value for salinity in Lake Gatun.
- The key issue to determine the recommended standards is the use of lake waters for potable water production in the case of TDS and conductivity, while the need to protect the integrity of the biological community is the key issue in the case of the Chloride ion concentration.
- The maximum standards shall not be exceeded at any time and it shall be established at 500 mg/L for TDS, 769 uS/cm for conductivity and 230 mg/L for Chloride.
- The action level standards shall be revised periodically. URS suggests every five years.
- The initial recommended value for the action level standard is 50% of the maximum standard value; it is to say 250 mg/L for TDS, 385 uS/cm for conductivity and 115 mg/L for Chloride.

4.0 BIBLIOGRAPHY

Additional Cited Literature

Document Name	Author	Year	Source of Information
Ambient Water Quality Criteria for Chloride-1988. Office of Water Regulations and Standards.	USEPA.	1988.	Criteria and Standards Division. Washington, DC 2046.
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
Canal Zone Water Quality Study.	Gonzalez F., Alfredo	1975	Final Report. Vol 1-3. Water and Laboratory Branch, Panama Canal Company
Central American Sea-Level Canal: Possible Biological Effects.	Rubinoff, Ira	1968	Science, Vol. 161
Edition of the Drinking Water Standards and Health Advisories. EPA 822-R-04-005.	USEPA.	2004.	Office of Water U.S. Environmental Protection Agency. Washington, DC. Winter 2004
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.
El Inventario Biológico del Canal de Panamá. I. El Estudio Marino	D´Croz, L., Martínez V. & Arosemena, G.	1994	Scentia (edición especial), Enero de 1994.
Estudio de Impacto Ambiental, Proyecto Profundización del Cauce de Navegación	Universidad de Panamá	2003	Autoridad del Canal de Panamá
Exchange of Water Through the Proposed Sea-level Canal At Panama.	Harleman, Donald	1972	Bulletin of the Biological Society of Washington, No.2, 1972.
Implicaciones Ecológicas de las transformaciones Geográficas Ocasionadas por la Construcción del Canal de Panamá.	De Alba, Georgina		
Limnological Features of a Tropical Meromictic Lake.	Bosniak, E. G. et al	1969	Hidrobiology, 1969. V. 34, p. 524-532.
Manejo de Sistemas de Agua Potable y Saneamiento Ambiental.	Barajas, Oscar M.	1995	Oscar Barajas Webpage: www. Oscarbarajas.com/3cap.html
Municipal Engineering and Domestic Water Supply in the.	Wells, George M.	1916	Panama Canal Comission, Technical Resources Center
Physical Characteristics of the Proposed Sea Level Isthmian Canal	Sheffey, John	1972	Bulletin of the Biological Society of Washington, No.2, 1972.

Document Name	Author	Year	Source of Information
Possible Impact of Salinity Changes in the Panama Canal System on Marine Phytoplankton	Iverson, Richard L.	1974	Sea Water Pumping Environmental Study Phase I. Panama Canal
Report of Participating Scientist on Possible Effects of Sea Water Pumping on the Lake Gatun. Abstracts of papers	Engineering Division, Panama Canal Company	1975	Sea Water Pumping Environmental Study Phase I. Panama Canal
Sal Water Intrusion Analysis, Panama Canal Locks	Deltf Hydraulics	2004	Task Report For Evaluation of salt water intrusion mitigacion system for revised 3-lift lock configurations.
Salinity Intrusion in the Panama Canal.	Parchure, T.M. et al	2000	U.S. Army Corps of Engineers
Secondary Drinking Water Regulations: Guidance for nuisance Chemicals	U.S. Environmental Protection Agency.	1992	http://www.epa.gov/safewater/consumer/2ndstandards.html
Species Introduction in a Tropical Lake.	Zaret, Thomas M.& Paine, R.T.	1973	Science, Vol. 182
Use of Sea Water Augmentation in the Gatun Lake-Panama Canal System: Recommendations for Water Quality Research. Final Report	Harriss, Robert C.	1974	Sea Water Pumping Environmental Study Phase I. Panama Canal
Water Quality – Characteristics-Modeling-Modification.	Tchobanoglous G. and E.D. Schroeder.	1987	Addison-Wesley Publishing Company, Inc. Menlo Park, California. 768 pp.
What is the Ecological Condition of Fresh Waters.	U.S. Environmental Protection Agency.	2003	Technical Document, EPA´S Draft Report on the Environment 2003.