

Alternatives for Expanding the Panama Canal

Agustin A. Arias*, Jorge de la Guardia**, Bruce L. Jihinke⁺, and Nicholas Pansic⁺⁺

*Director, Engineering Department, Panama Canal Authority, El Prado, Building 716, Balboa, Ancon, Panama, Republic of Panama; PH 507-272-5200; aaarias@pancanal.com

**Manager, Canal Capacity Projects Division, Panama Canal Authority, El Prado, Building 714, Balboa, Ancon, Panama, Republic of Panama; PH 507-272-6163; jdelaguardia@pancanal.com

⁺Senior Vice President, PB Consult, Balboa Heights, Building 632, Balboa, Ancon, Panama, Republic of Panama; PH 507-272-1234; jihinke.bruce@pbworld.com

⁺⁺Vice President, MWH Americas, Inc., 175 W. Jackson Boulevard, Suite 1900, Chicago, IL 60604, USA; PH 312-831-3192; nicholas.pansic@mwhglobal.com

Introduction

The Panama Canal Authority (Authority), assisted by PB Consult (PB) and MWH Americas, Inc. (MWH) in a program management advisory role, is currently developing a long-range master plan for the future of this vital 90-year-old waterway. The master planning process includes comprehensive marketing, operations, financial, engineering, and environmental investigations in order to establish a program of investment that will secure the Canal's future for all of its stakeholders. In connection with the master planning effort, the Authority has undertaken substantial studies of alternatives that will improve the operational efficiency and throughput capacity of the Canal to meet the changing needs of the marketplace.

With Canal transit-related revenues currently contributing over \$700 million to the Panama economy annually, maintaining the viability of the Canal is vital to the future of Panama and its maritime industry development. As a major gateway for world trade, the Canal permitted the transport of over 190 million metric tons of goods between the Pacific and Atlantic Oceans in fiscal year 2002. However, meeting traffic demands throughout the next century will require operational and physical improvements to continue to meet the needs of the Canal's customers.

There are two major factors affecting the ability of the Canal to maintain its vital role servicing world commerce. First, the number of large Panamax vessels, the largest ships capable of transiting the existing Canal, is approaching the capacity limit of the current system. As shown in Figure 1, the percentage of Panamax ship transits through the Canal has reached nearly 40% of total transits, doubling in the last 20 years and nearly quadrupling in the last 25 years. As the number of Panamax ship transits continues to increase, the capacity of the current system to operate at acceptable service levels will be reached soon, unless enhancements or improvements are undertaken.

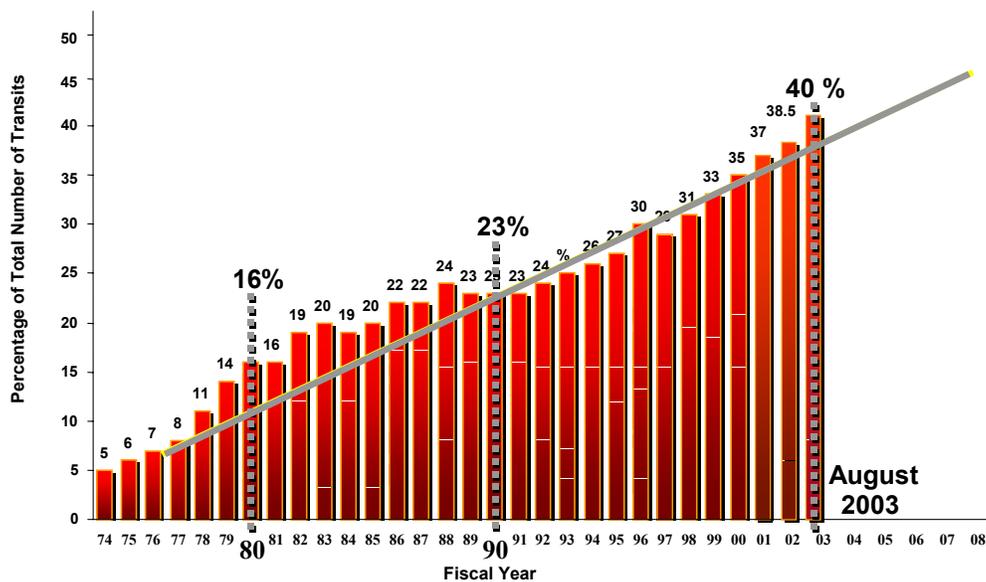


Figure 1. Historic trends for Panamax ship transits.

Second, economies of scale in world container shipping are driving the industry to larger vessels of Post-Panamax size that are too large to transit the existing Canal. The trend towards larger vessels is also reflected in traffic through the Canal. As shown in Figure 2, the number of transits through the Canal has remained relatively constant since the early 1970's; however, the average tonnage per transit has rapidly and steadily increased, indicating an industry trend towards larger ships. Should this trend continue, the existing Canal will be unable to continue to provide its services at the current levels of reliability to its customers, and will be unable to retain or expand its market share in the long term.

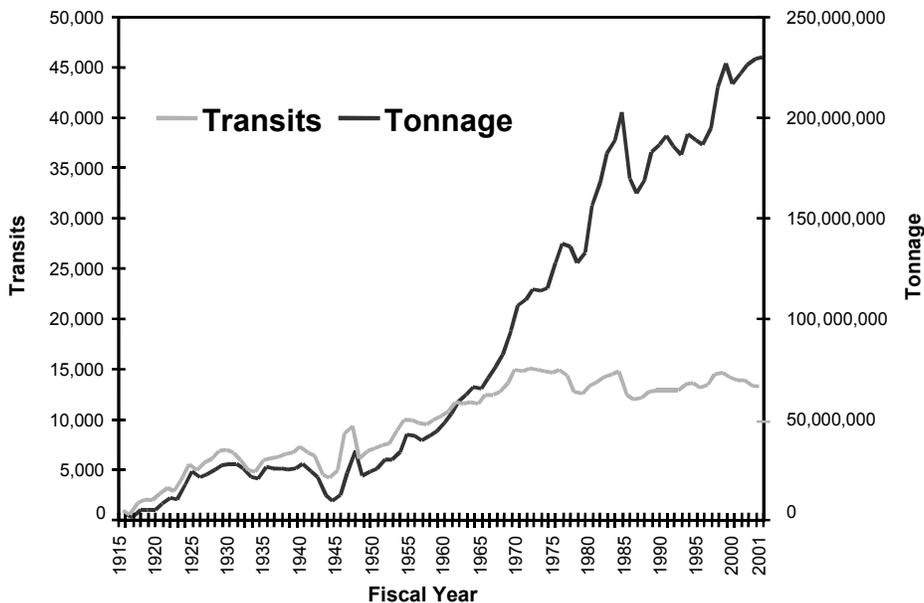


Figure 2. Ship transits versus ship tonnage.

To address the challenges facing the future of the Canal, the Authority's Master Plan will assist in determining the most beneficial and economical methods for improving Canal capacity and efficiency. In doing so, the Authority is presented with a variety of challenges. Not only must the Canal accommodate future capacity requirements safely and reliably, but it must also effectively supply and manage the water required for the operation of the Canal, optimize its operation and maintenance costs, and become more competitive in its most profitable markets in order to remain a cornerstone for global transportation and logistics networks.

The Existing Canal

The existing facility utilizes a system of locks on either side of the Isthmus of Panama to lift ships from sea level to Gatun Lake, located approximately 26 meters above sea level, and permit passage across the 80-kilometer isthmus between the Atlantic and Pacific Oceans. Locks on either the Atlantic or Pacific side include two parallel lanes for ship traffic and are named after the nearby towns: Gatun, on the Atlantic side, and Pedro Miguel and Miraflores on the Pacific side. Existing lock chambers are 33.53 meters wide by 304.8 meters long by 13 meters deep, and a flight of three locks is used to raise vessels to Gatun Lake level. The water used to raise and lower vessels in each set of locks comes from Gatun Lake by gravity, entering the locks through a system of main culverts that extend under the lock chambers from the sidewalls and the center wall.

The narrowest portion of the Canal is the Culebra Cut, which extends from the north end of the Pedro Miguel Locks to the south edge of Gatun Lake at Gamboa. This segment, approximately 13.7 kilometers long, is carved through the rock and shale of the Continental Divide.

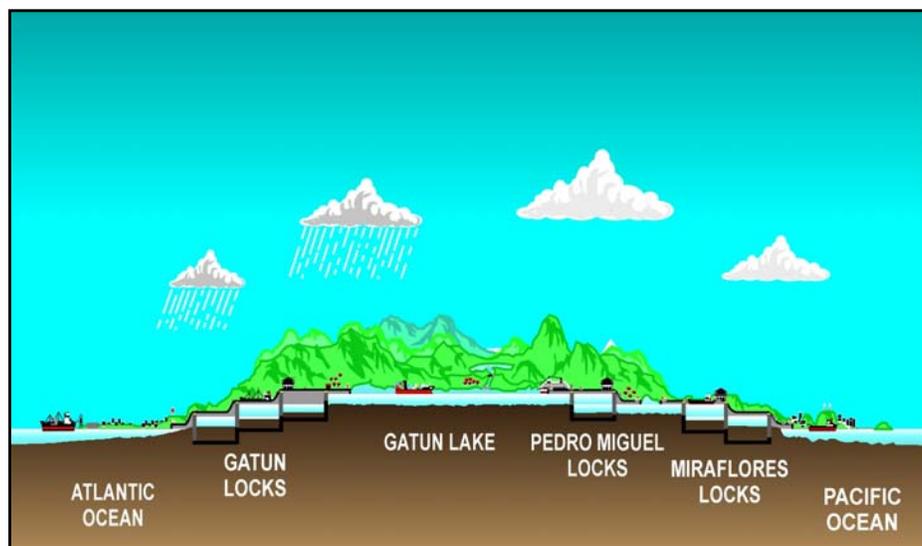


Figure 3. Schematic of existing Panama Canal operation.

Considering the size of the locks, the dimensions of the largest vessel which can transit the Canal (a Panamax ship) are defined as 32.3 meters in beam, 12 meters in draft, and 294.1 meters long.

The transit of ships across the Isthmus of Panama depends on the availability of fresh water stored within Madden and Gatun Lakes to maintain the system draft and to operate the locks. The existing system utilizes approximately 210 million liters (55 million gallons) of water per transit under normal operations. Insufficient water requires the Lakes to be lowered below normal operating levels and thus limits the maximum draft available for vessels passing through the Canal. Draft limitations have been imposed in the past during prolonged dry periods, as highlighted during the 1998 drought. The reliability of the maximum draft available to vessels transiting the Canal is a critical service metric for assessing Canal operating performance. In addition to water for Canal operations, the existing water resource system also plays a critical role in providing water for municipal and industrial usage in Panama.

The Master Plan

The framework of the Master Plan developed to address these challenges is shown in Figure 4. Through a program of studies, including marketing, operations, capital improvements, environmental, and financial studies, numerous alternatives are being proposed, developed, and analyzed. The Master Plan framework has been developed to provide the Authority with a robust and fully documented process for evaluating the many interdependent alternatives at a feasibility level of technical detail, addressing socioeconomic and environmental impacts, and generating a “bankable” plan for the international financing community.

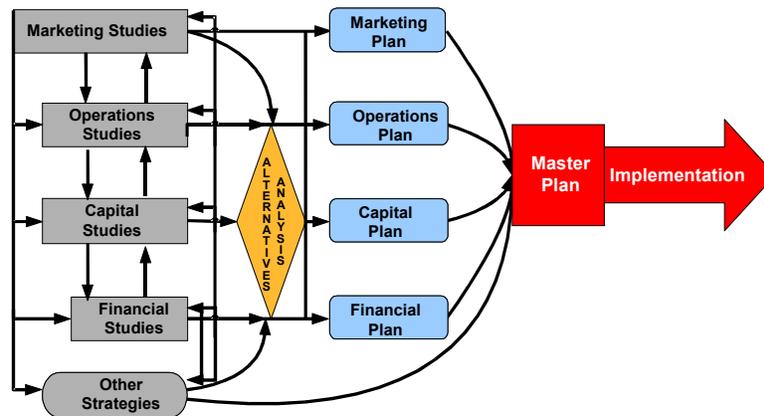


Figure 4. Framework for the Master Plan.

One of the key components of the Master Plan is the identification, development, and evaluation of alternative improvements to the Canal operation, performance, and facilities. This paper addresses primarily the review of the alternatives under consideration for physical works and facility improvements which may be required for the long term development of the Canal; it does not look at the broader social,

environmental, operational, legal, financial, and market implications which form a key part of the Master Planning process.

The Master Planning process has separated Canal improvements into two tracks, each of which represents a greater degree of modification to the existing Canal's functionality:

- Track 1 – Relieve the constraints on the existing Canal by improving the existing infrastructure and expanding the capacity of the Canal to accommodate the growing number of Panamax vessels;
- Track 2 – Expand the capacity and capabilities of the Canal to facilitate the navigation of Post-Panamax vessels.

Track 1. Track 1 includes improvements to maintain the aging existing lock system, as well as relieve some constraints. By improving the lighting system along the locks, ship transits can be accommodated for more non-daylight hours. Changes in operating rules and procedures, as well as modifications to the booking and scheduling system used to manage traffic through the Canal, will help to better manage the peak demands, with consequential improvements to capacity and operating efficiencies. Improvements to increase the reliability of the existing locks, dams, and spillways under seismic events, as well as increased spillway capacity at Gatun Lake, are also being evaluated. Operation and maintenance practices are reviewed on an ongoing basis, and potential improvements are also being incorporated into the Master Plan for assessment purposes and to provide a baseline for future improvements under Track 2.

Track 1 also considers a Capital Plan involving physical modifications to the existing Canal arrangement. Significant capital works will be required to expand certain critical Canal facilities. One of the proposed enhancements entails deepening the navigation channels through Gatun Lake and the Culebra Cut to allow vessels to transit the Canal at maximum allowable Canal draft at a lower lake level, thus increasing the reliability of the system during extended dry periods.

Deepening of the Gatun Lake navigation would create additional water storage within the system, and would also permit the transit of deep draft vessels between the locks and across the isthmus. Currently, Gatun Lake is maintained at a maximum level of El. 26.7 m Precise Level Datum (PLD). With a navigation channel bottom at El. 11.3, the Lake can safely pass a Panamax ship while still providing nearly two meters of live storage. In other words, lowering the Lake level to El. 24.8, or 1.9 meters below normal level, still provides the required 13.5-meter channel depth and 12-meter allowable draft for Panamax ships. The current project to deepen the navigation channel by 0.9 meters would place the channel bottom at El. 10.4. Panamax ships would now be able to navigate the channel even with the Lake lowered to El. 23.9. Therefore, the useful storage within Gatun Lake can be increased from 1.9 meters to 2.8 meters.

In order to facilitate the transit of large (Panamax) vessels through the more restrictive sections of the Canal and therefore increase Canal capacity, it is also proposed to undertake additional excavation to straighten the Gaillard Cut, located just north of the Pacific Entrance Locks.

Track 2. The second track of the Capital Plan calls for major modifications to the existing Canal, including the development of enhanced water resources, the deepening, widening, and realignment of the navigation channels, and the construction of a third lane of Post-Panamax locks. Extensive feasibility studies have been conducted or are currently underway to investigate the impacts of these proposed modifications.

Water Resources and Draft Reliability

The provision of sufficient water to provide reliable performance of the Canal system is a critical element of Canal development plans, and a wide range of approaches, and combinations of approaches, are being developed and investigated. The approaches include demand management techniques to reduce the water demand from the proposed new locks, the optimization of the water yield from the existing Canal watershed and water storage systems, water reuse or recycling, and supplies from possible new developments in the “Western Watershed” adjacent to the existing Canal watershed. No single project will effectively meet all the needs of the Canal – instead a staged program of complementary enhancements will be developed to meet the changing demands of the Canal and other water users.

In addition to water supply issues, social and environmental issues form a critical part of the assessments, particularly relating to the potential of increased salinity in Gatun Lake due to the intrusion of saltwater through the locks (saltwater does work its way upstream through the locks from the ocean due to the effects of ship operations and density effects), and the social and environmental impacts of any significant new water supply projects.

Due to the increased size of proposed new locks to cater for the transit of Post-Panamax vessels, the water demand for each transit through the new locks would be significantly greater than through the existing locks.

One water demand management technique under investigation is the construction of water saving basins in conjunction with the construction of new Post-Panamax locks. Water saving basins reduce the water required per lockage by storing and re-using a portion of the drained water for the following filling cycle of the locks. As shown in Figure 5, 60% of the water within the lock can be drained by gravity to the adjacent three-pool tiered water saving basins. To fill the lock during the next cycle, water from the basins is drained by gravity back into the lock, supplying 60% of the water required to fill the lock. The use of water saving basins has significant impacts on the risk of salinity intrusion into Gatun Lake, and environmental issues are a critical factor in the assessment of alternatives.

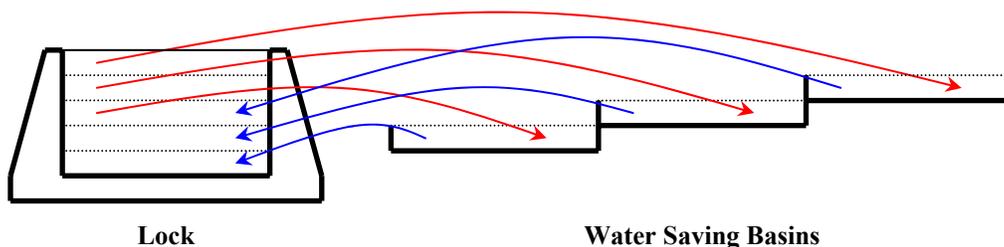


Figure 5. Lock draining and filling with water saving basins.

Other demand management techniques include operational techniques to allow the locking of multiple smaller vessels simultaneously, thus reducing the water demand per vessel.

Options for the optimization of the water yield from the existing watershed include the raising of the storage levels in existing reservoirs (with modifications to existing spillways or new spillways and structures if necessary), optimization of reservoir water management strategies to maximize navigation draft in times of water shortage, and navigation channel deepening.

Channel deepening is proposed under Track 1 to improve the draft reliability of the existing Canal. Further deepening of the channel is under consideration to allow additional live storage to improve draft reliability for the transit of Post-Panamax vessels.

Another potential method to satisfy the Canal's increasing water demand is the practice of water recycling, which utilizes a pumping station to pump spilled water from the lower locks up to the upper locks. The pumping system, added to a multiple-lift lock system with water saving basins, could allow nearly 100% of the water required for a lockage to be saved; however, pumping systems cause saltwater intrusion into freshwater sources.

A number of recycling/water management scenarios are under investigation, with the impact of the system on the salinity levels within Gatun Lake being a key criterion in assessing the performance of the alternatives.

Additionally, various scenarios for the development of potential new water storages in the Western Watershed have been identified and are under study. The social and environmental issues associated with potential new reservoirs form a critical part of the assessment of these options.

Navigation Channels

In the operating scenarios under consideration, it has been recognized that channel widening sufficient to allow unrestricted two-way traffic of Post-Panamax vessels would be prohibitively expensive, and an extension of the current “semi-convoy” operating mode would be used for Post-Panamax vessels, thus reducing the quantity of excavation and channel works required. Various refinements of current operating scenarios are under consideration to optimize the overall throughput and revenue earning capacity of the Canal.

Further channel deepening may be undertaken to meet the draft reliability requirements of Post-Panamax vessels.

New Locks

The critical element in the development of the Canal to allow the passage of Post-Panamax vessels would be the construction of a third lane of locks on both the Atlantic and Pacific sides. Figure 6 shows the dimensions of the existing locks in comparison to the proposed Post-Panamax locks. Conceptual designs have been developed by the US Army Corps of Engineers (USACE) and the Consorcio Post-Panamax (CPP), a Franco-Belgium consortium, for the Atlantic and Pacific locks, respectively, to provide the Authority with a comprehensive range of lock configuration, engineering, and operating alternatives for assessment.

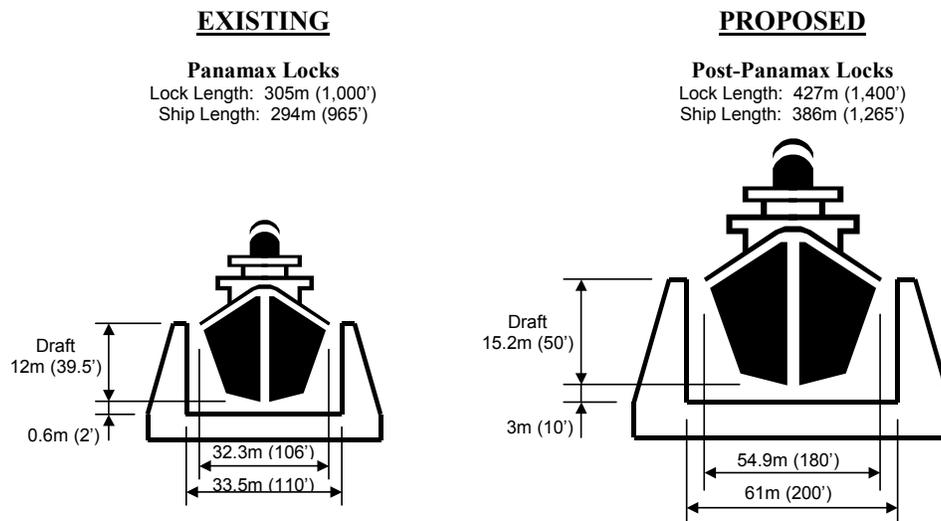


Figure 6. Lock dimensions.

The Authority contracted the USACE and the CPP to develop five alternatives for lock configurations, covering arrangements with differing number of lifts per lock (one, two, or three lift flights), alternative arrangements of water saving basins, and varying technology for key lock operating systems, including gates, and filling and emptying systems.

The assessment of options considers not only technical and capital cost issues, but also water demand; critical operations issues including throughput, vessel cycle times, safety, and operating equipment requirements; operations and maintenance costs; and key environmental issues such as salinity intrusion.

On the Atlantic side, the USACE evaluated two lock options: (1) a two-lift lock with two water saving basins per lift, and (2) a three-lift lock with two water saving basins. Both scenarios for the Atlantic side utilize miter gates and filling and emptying systems entering through the bottom of the lock chambers. The CPP evaluated three lock options for the Pacific side: (1) a three-lift lock with three water saving basins, (2) a one-lift lock with six water saving basins, and (3) a two-lift lock with two water saving basins. All three scenarios for the Pacific side utilize rolling gates and side port filling and emptying systems.

Generally, as more lifts are added to a lock system, less water is consumed, construction volumes increase, more equipment is required, salinity intrusion risks are lowered, and transit times are lengthened.

The USACE conceptual designs for the Atlantic locks are gravity chamber walls atop a stepped rock foundation, maximizing the use of roller compacted concrete (RCC) to reduce construction costs. The two-lift scenario investigated by the USACE would require roughly 2.4 million cubic meters of concrete to construct the 3 kilometers of walls, while the three-lift scenario would utilize 3.2 million cubic meters of concrete to construct the 4 kilometers of walls associated with this arrangement. The USACE proposed the use of miter gates over other gate options, although miter gates of the size proposed are not currently in use anywhere in the world.

The CPP performed similar studies for the Pacific locks to develop conceptual level designs. Studies initially evaluated proposed lock alignments and site layouts to minimize excavation, satisfy navigation requirements, and reduce impacts on the existing locks and the surrounding structures.

Similar to the USACE's design for the Atlantic locks, the CPP recommended the use of gravity-type lock walls to meet the expected loading conditions. The walls as proposed utilize both conventional reinforced concrete and RCC to minimize construction costs while still providing the structural stability required. Two different cross-sections of the lock walls would be required, however, to account for the varying deformation criteria associated with the two different subsoil conditions anticipated below the lock structures.

The CPP design recommended the use of rolling gates, similar to those already in use at the Behrendrecht Lock at the Port of Antwerp in Belgium. The gate rolls laterally into a gate recess chamber, and maintenance can be performed within the dewatered gate recess. As there are two lock gates and lock gate chambers on each lock head, traffic through the locks would not be interrupted while maintenance is performed on one of the rolling gates within its gate chamber. Moreover, the gate can be floated

and towed away as a vessel if necessary for either replacement or use as a bulkhead to dewater the lock chambers.

All of the proposed alternatives to increase capacity for Panamax vessels and/or permit the passage of Post-Panamax vessels will require massive amounts of excavation. Excavation quantities range for the elements of the proposed schemes from 5 million cubic meters (MCM) to deepen the Atlantic entrance to as much as 50 MCM to construct new Post-Panamax locks at the Pacific entrance. The required excavation to upgrade the existing facility is equivalent to nearly 75% of the original excavation to construct the Canal in the early 20th century.

The cost-effective disposal of such a large quantity of excavated earth and rock, while meeting strict environmental standards, presents a major challenge. Studies are currently underway to investigate various disposal options, including terrestrial, lake, and marine disposal sites, as well as options for beneficial use of the spoil in reclamation.

Conclusion

The issues facing the Authority regarding the long term development and operation of the Canal are complex and multi-dimensional. The Authority has a commitment to the Republic of Panama to continue to develop the Canal as an effective and profitable business, an obligation to world trade to provide an effective, safe and reliable service, and an obligation to meet the expectations of the local community and other stakeholders.

The Master Plan, currently scheduled for completion in mid-2004, blends countless marketing, operations, financial, engineering, and environmental studies with a common goal of improving the operational efficiency to meet the needs of the Authority's customers. At the same time, a program of such magnitude brings a host of technical, financial, and socioeconomic challenges that must be overcome through innovation and technological excellence.

The implementation of the Plan's recommendations in the coming years will ensure that the Panama Canal remains an integral and profitable component of the world shipping industry in the future.

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