Panama Canal Concept Design of Atlantic Locks Structure Third Lane Lock Double-Lift Configuration

Diseño Conceptual del Canal de Panamá Estructura de Esclusas del Atlántico Tercera Vía Configuración de Dos Niveles

USACE

4 de abril de 2003

Contrato No. 80640

Resumen Ejecutivo

1. EXECUTIVE SUMMARY

1.1. Background

This Report presents the Concept Level Design for a double-lift single-lock structure at the Atlantic Ocean side of the Canal with water saving basins. When the basins are used in operations, they would save 50% of the water required for normal lock operations. The locks and water saving system were designed to be operated with or without using the water saving basins.

The Notice To Proceed for this work was received on 25 February 2002 with an eight-month delivery date for this first configuration. Work initiated with meetings in Panama and Pittsburgh, PA, USA, that were attended by ACP staff as well as a large number of experienced Corps staff in multiple disciplines from numerous Corps District and Division Offices and research facilities.

1.2. Overview

This Report presents the concept level design for a double-lift single structure lock configuration through narratives, drawings, design calculations and cost computations. While it is complete and suits present site conditions and criteria as stated in the Scope of Work, changes in criteria can have significant effects on the presented design. The Report also presents the estimated construction cost as well as costs for continuing engineering and design and construction management. This design shows that the locks are constructible at the adjusted A-2 Gatun site, adjacent to the existing locks at an angle of 9.75 degrees, generally using conventional construction techniques. Special construction techniques would be needed to construct the entrance walls in the most efficient manner. The siting of the locks has been adjusted to provide safe and efficient traffic management. The estimated first-cost for the construction of the lock is approximately $840,000,000. Additionally, recommended items of work needed to proceed into the final design have also been identified and costed. A time schedule for accomplishing the design and construction is also presented. The estimated construction time for the completion of all features is six years. This can be reduced as discussed below.

A design criteria report was prepared in accordance with the requirements of the Scope of Work and was expanded as design development proceeded. The criteria is in accordance with Corps of Engineers criteria and would result in a structure that is expected to be as reliable and time durable as the existing Panama Canal Locks, while minimizing risk of operation and maintenance. In preparing the final criteria for preparation of plans and specifications for construction, the criteria should be standardized for the locks construction at both ends of the Canal.

1.3. Project Features

This is a brief overview of the evaluation, conclusions reached, and the recommendations for the major project features. The Main Report and Appendices present the detailed work along with supporting calculations and written description of methodology and procedures used. A summary of the main features is as follows:

1.3.1. Lock Gates

Using a pre-screening process to establish evaluation criteria, the possible gate types and configurations were evaluated with a minimum of design effort but using experience and engineering judgment. The initial screening was performed at the Panama Project Initial Team Meeting held in Pittsburgh Pennsylvania on April 2002. The initial screening effort identified gates to carry forward as alternatives in the gate selection study. This initial screening process showed that the rolling and miter gates were the most favorable gate types for use in the Canal double-lift structure. Because of recent design information available from a current Corps project, it was decided to also advance the evaluation of the sector type gate along with the other two gate types.

A separate detailed gate selection study has been performed and is included with the main report as Appendix B – Gate Selection Study. The significance of the lock gate selection required that these three gate types be developed to a nearly equal level of design to provide a true comparison of the types and to make a justifiable recommendation of the gate type. In order to identify costs associated with each structure type the following analysis were perform:

1. Structural design of each gate type was performed using STAADPro, a general purpose structural analysis and design software package. CMITER, a computer program developed by USACE to design and analyze miter gates was used to design the mitering lock gates. Separate finite element analysis was performed to investigate the performance of the rolling gate and the miter gates. The gate designs resulted in an estimated cost for each gate type including appurtenant features.
2. Installation plans were developed by the Corps Marine Design Center. Where appropriate, the costs for additional features (ballast, cranes, etc) required to install and remove gates was identified and included in the gate alternative cost summary.
3. The rock excavation required to construct each of the proposed gate type was computed and priced.
4. The lock masonry features were proportioned for each gate type. The quantity of concrete and reinforcing steel was estimated and priced for each option.
5. Mechanical equipment was sized and priced for each gate type.

The following table gives the summary of the gate weights and total construction costs for the respective gate type features.

Sector Gate Alternative		
Sector Gates	**Comment**	**TOTAL**
Sector Gates with Operating Equipment	Gate Weight = 4,400 MT	$155,227,600
Construction of Gate Bays and Recesses (Includes Reinforcement and Excavation)	Complex Geometry, Large, Result in Excess Water Use	$184,065,500
Associated Features	Long Span Bridge Structures, Maintenance Facility	$9,792,514
	Total	$349,085,613

Rolling Gate Alternative		
Rolling Gates	**Comment**	**TOTAL**
Rolling Gates with Operating Equipment	Gate Weight = 5,100 MT	$187,378,304
Construction of Gate Bays and Recesses (Includes Reinforcement and Excavation)	Easily Constructed but Large	$167,880,171
Associated Features	Moderate Span Bridges, Does not include separate maintenance facility	$3,852,975
	Total	$359,111,450

Miter Gate Alternative		
Miter Gates	**Comment**	**TOTAL**
Miter Gates with Operating Equipment	Gate Weight = 3,550 MT	$131,914,854
Construction of Gate Bays and Recesses (Includes Reinforcement and Excavation)	Minimal Size Recess	$63,267,751
Associated Features	12 Bridges, Maintenance Facility Infrastructure, Titan used to set gates	$6,732,514
	Total	$201,915,118

Figure 1-1 Comparative Gate Costs

The comparative cost table shows that the miter gates are significantly lower in gate weight, having a total weight of 3550 t compared to 4400 t for the sector gates and 5100 t for the rolling gates. The miter gates are also significantly lower in total feature construction cost for the gates and associated costs (gate bays, recesses and bridges) with a total cost of $202,000,000, compared to $349,000,000 for the sector gates and $360,000,000 for the rolling gates. The lower weight of the miter gate would also provide a gate that would also be easier to handle. As expected, the cost of the gates and the recesses for the rolling gate and sector gate are significantly higher because of the recess size in comparison to the extra wall length requirements for the miter gate. The water use for the miter gate is almost equal to that required for the rolling gate being only 0.5% greater. The sector gate would require 13% more water than for a rolling gate. All three gate types were evaluated against the evaluation criteria stated in Appendix B - Gate Selection Study, and, as shown in the following table, the miter gate has the most favorable rating.

Evaluation Criteria and Rating								
Feature Alternative	First Cost	Ease and Frequency of Maintenance	Risk to Extented Navigation Closure Resulting from Significant Accidents	Access for Crossing Over Lock	History of Reliable Service or Precedent	Compatibility with Water Saving Basin and Filling and Emptying System	Water Conservation	WEIGHTED EVALUATION
Miter Gates	3	3	3	2	3	3	3	2.86
Rolling Gate	1	2	2	3	3	3	3	2.43
Sector Gates	2	1	2	1	1	2	1	1.43
Procedure included ranking the individual alternative by individual criteria to consider relative comparison. 3 is the highest, 1 is the lowest								

Figure 1-2 Evaluation Criteria and Rating

In summary, the miter gate has a significantly lower cost, is about equal in water usage, has a proven reliability, provides the filling and emptying system layout and conduit configuration most compatible with the project, has the lowest risk for operation and maintenance and can be the most easily maintained especially with the ACP experience from the existing Canal locks. The miter gate is the recommended gate type for use in the Atlantic Locks. Operation of the gates would be accomplished using direct-connect hydraulic cylinders similar to those being installed on the existing locks. Two methods for handling the gates for maintenance were developed and presented in the Main Report. A complete discussion on the evaluation of gate alternatives is presented in Appendix B – Gate Section Study.

An emergency closure system capable of closing open channel flow from Gatun Lake through the new Third Lane Locks is recommended as a project feature. This structure would be located upstream of the Gatun Lock Gates. The use of single gate at the Gatun entrance as opposed to double lock gates may be justified as an additional cost saving measure in consideration of the protection offered by an emergency closure system. Cost reduction could be realized in gate fabrication, masonry construction, operating equipment, and reduced length of in-the-wet entrance wall construction.

1.3.2. Locks Structure Alignment

The double-lift lock structure alignment was optimized both longitudinally and transversely through a progressive process of studying various alignments and angled possibilities. It is at the best-fit location to use the geologic stratigraphy of the Gatun site. The location avoids problems with the existence of the Atlantic "muck" while placing the structures on rock foundations to minimize construction costs. The recommended alignment is at an angle of 9.75 degrees from the north navigation channel line into the existing Gatun Locks. As such, it places the locks structure at a near continuous straight line from the Atlantic entrance channel and provides only a minor deviation from the navigation channel entrance in Gatun Lake. It has only a minor impact on the Gatun Lake mooring facility while maintaining three ship lengths as a straight line for lock entry. The offset of the alignment with the addition of water saving basins provides sufficient distance to the side of the channel entry from the Atlantic Ocean and Gatun Lake to safely manage ships entering and exiting the existing and new locks.

1.3.3. Filling and Emptying System

A number of possible filling and emptying system types were screened to select the most favorable type of system for use in these large locks. Evaluations centered around filling/emptying times with water saving basins, rates of water transfer, ship handling characteristics and hawser loads, compatibility with other project features, cost/constructibility, and integration of water saving basins. Two designs are provided as required by the Scope of Work: an interlaced bottom lateral fill/empty system similar to the existing locks system, and an in chamber longitudinal culvert system (ILCS). The interlaced bottom lateral system utilizes side wall culverts while the ILCS system has the culverts located longitudinally along the lock floor. The systems were designed to provide the required fill/empty time of about 12-15 minutes when equalizing with water saving basins and to minimize impacts for operations without water saving basins and under maintenance conditions. Filling and emptying through the sills of the gates was investigated for this lock and lift configuration but discarded due to maintenance considerations. The interlaced bottom lateral filling and emptying system is similar to the existing locks and its performance is proven. The system provides average equalization times between 10.8 and 12.9 minutes for operations without water saving basins. When using water saving basins, average equalization times are expected to range between 13.4 and 15.1 minutes. Hawser forces would be within reasonable levels throughout the equalization cycle. The ILCS design provides similar equalization times ranging between 9.2 and 11.8 minutes for operations without water saving basins. Equalization times for the bottom longitudinal system with use of water saving basins are expected to range between 13.3 and 14.9 minutes. Hawser forces would be higher with the ILCS compared to the interlaced bottom lateral but would be within acceptable limits. Both systems are expected to perform well for the double-lift configuration and are compatible with other recommended design features. The systems have been designed to operate safely and efficiently with water saving basins during normal operation. The interlaced bottom lateral system will perform well when equalizing without water saving basins and under maintenance conditions. Hydraulic performance could be slightly degraded for the ILCS when operating without water saving basins or under maintenance conditions.

1.3.4. Water Saving Basins

Water saving basins were integrated into the use of the filling/emptying system to provide 50% water savings as required. These consist of two lateral basins located to the West side of the locks for each lock level. The Moffatt & Nichol reports, previously prepared to investigate the potential use of the water saving basins systems, were used as a starting point for the design. For reasons of economy, the basins were integrated into the back of the lock walls. This minimizes lateral space requirements as well as basin conduit excavation. The basins were designed to provide a reasonable and reliable system performance time based on technology in use today. This produced a total fill/empty time with water saving basins of approximately 13-15 minutes, as requested by the ACP. Hydraulic modeling is recommended in future studies to further refine design parameters and operating conditions.

1.3.5. Lock Walls

The lock walls have been designed considering the related features, with space provided for locomotives as the ship-positioning system, and provide the most economical solution for the integration of the project features. The water saving basins are located on the West side of the lock and are integrated spatially (non-structural) into the back of the walls. The valve operation monoliths are incorporated into the walls and basins. The lock walls include the lock filling/emptying culverts and are gravity monoliths founded on a rock foundation. Specifically, the monoliths utilize a stub toe at the base to increase stability, to reduce bearing pressures and to eliminate the need for a concrete bearing base slab. Roller compacted concrete is used extensively for economy of construction of the lock walls; conventional concrete is used in the areas of culverts, galleries and the lock chamber face. The lock walls contain 810 100 m^3 of cast-in-place concrete and 993 000 m^3 of roller compacted concrete. Applicable loads were applied with the controlling loads being for the dewatered condition and the earthquake event. Space has been allowed at the top of walls to include a ship positioning system similar to the existing locks. The lock gate monoliths would be constructed as conventional gravity structures founded on a rock foundation. Approximately 40% of this construction would be of cast-in-place construction.

1.3.6. Entrance Walls

These walls present a special condition because of the size of the impact loads that would be transmitted by the large Post-Panamax ships. Loads developed based on discussion with the Canal pilots were considered and found to be excessively high. Criteria for ship impact was developed based on consultation with fender manufactures and PIANC design recommendations. However, a detailed investigation should be performed before final design to define the necessity and size of these loads. The wall length represents one and one-half ship length as requested by the Canal Capacity Projects Office. The Atlantic entrance walls would be constructed on roller compacted concrete and the Gatun entrance walls would be cast-in-place concrete cap walls founded on a drilled shaft foundations and would be constructed for the most part in the wet using specialized construction techniques. If tugs are used to manage the ships in lock entry, these walls could be reduced in length and size and have a significant savings in project cost.

1.3.7. Seismic Design

In selecting the design level for the earthquake event, existing reports, seismicity of the region, and studies for the existing lock system were examined and analyzed. It was determined that a mean value of 0.31g as the maximum credible earthquake (MCE) would be used for this concept level design. It has a return period of between 300 and 1,000 years. Additional studies are currently being conducted by the USGS and this value should be reevaluated upon completion of their studies, which are due at the end of 2002. More sophisticated analyses need to be conducted to verify performance under seismic events following Corps standard practices for seismically active regions.

1.4. Recommendations

In proceeding with this design process, it is recommended that Feature Design Memorandum Reports be prepared concurrently with physical modeling for the major features of work before proceeding into the design-for-construction and preparation of the construction plans and specifications. This report would provide a final evaluation of the options available for the specific site conditions, select the most appropriate features, optimize the design, and establish the design parameters. Using this document, final construction plans and specifications would be prepared. While the concept level design report presents the design for various features for the specific site, it does not optimize the design nor consider possible ongoing changes. Changes could include the method of handling the ships that would change the dimensions of the locks and reduce wall loads by eliminating the loads transmitted to the walls with the use of locomotives. Selection of emergency closure systems should be considered with development of any project specific security considerations. Also, decisions need to be made on methods of maintaining the locks and gates, and these could change certain presented designs of the features. Life cycle economic cost analysis should be performed to assess viability of purchasing a high capacity gate lifter crane to serve in emergency response scenarios and support other canal system maintenance activities. The use of a single lock gate at the Gatun Entrance should be re-evaluated in conjunction with an emergency closure system as a potential cost saving measure.

1.5. Opportunities

Other decisions that need to be made relate to funding flows and opportunities for economies of construction. If tug boats are used to handle the ships into and through the locks, the entrance walls could be reduced in length or eliminated to using short stub walls similar to those commonly used in large locks in Europe. Advance work that could be taken out of the main construction contract could include separate purchase of the lock gates (cost of $100,000 and/or performing the lock excavation (cost of $80,000,000) first as self-funded items of work. This would delay the date that borrowed money is started and reduce the period of accruing interest, thus lowering the investment cost. Another item for consideration involves the timing for providing the water saving basins. This is a costly item at $66,000,000 and may not be needed until some point in the future, after the locks are opened. Provisions could be made for including them into the lock construction but they would not be constructed until after the lock is operationally producing income and they are needed. All of these items relate to lowering the investment. Also, seismic design parameters need to be standardized and sized in accordance to the risk level acceptable to the ACP considering the associated costs for each level of design earthquake. These designs need to be prepared in order to evaluate risk and ACP needs to participate in these discussions to balance level of risk with the associated cost.