COMPARISON OF ONE 3-LIFT LOCK WITH ONE 1-LIFT
PLUS ONE 2-LIFT LOCK AT THE PACIFIC SIDE

Canal Capacity Projects Division

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Figure 1. Miraflores locks (foreground) and Pedro Miguel Lock (background). Upper chamber excavation (left) performed in 1940-1942.
1 THE EXISTING PANAMA CANAL – PACIFIC LOCKS

The following is a description of the existing Pacific side lock arrangement and of other alternatives studied in the past to improve the Panama Canal by means of building larger locks to allow larger ships to transit the canal.

1.1 Original Construction - Pacific Locks

The existing canal has two sea-level segments of 12 Km at the Atlantic and 14 Km at the Pacific entrances and an elevated segment of about 51 Km with locks at both ends; this elevated segment has a normal water surface elevation of 25.9m (85 feet). There are 23 changes of courses for ships navigating through the Panama Canal (there are also sailing lines within the Gatun Lake, off-centerline of the channel and passing lanes along the 13 Km long Gaillard Cut). The total length of the Canal, including approaches, is 77 Km (48 miles), the 12 lock chambers have a nominal measurement of 305m (1000 feet) long, 33.5m (110 feet) wide, and have 12.2m (40 feet) limiting depth over the sills.

In 1906, plans were developed to build a lock and dam structure at the Pacific side of about 2400m length at the crest of dam between Sosa Hill and San Juan Hill at La Boca. Due to naval strategy and geotechnical reasons, the lock site was moved inland and excavation began at Miraflores and Pedro Miguel simultaneously, even before finishing the borings to search for suitable foundations. After these borings were completed, it was ascertained that good foundation rock was at Miraflores to build a three step twin lock at this site, but excavations at Pedro Miguel were advanced and the decision was made to continue the plans for two separate structures.

The advantage of having a commodious lake terminus at the southern extreme of Gaillard Cut if a three lift lock had been built at La Boca was lost. Building two separate structures at Miraflores and Pedro Miguel had an estimated extra construction cost of $4,000,000.00 in 1910.

Even though two separate locks were built, a comparison with the option of building one structure with three steps shows the following facts:

1. For one structure only one set of center wall and flare walls at each end would be required.
2. Only 20 lock gates and 33 valves were necessary for one lock, compared to 26 lock gates and 51 sets of valves for two locks. The extra six gates require additional length of concrete structure to fit them.
3. Less machinery to operate gates and valves for one structure.
4. Less operating and maintenance costs for one structure.
5. A three steps lock consumes less water.
6. A three step lock has more capacity than two separate locks.
7. A three step lock would require less infrastructure than two separate locks. For the existing locks some of the construction quantities are as follows:

- Total Excavation (up to 1910) \(130\text{ M yd}^3(100\text{ M m}^3)\)
- Total Dredged excavation \(83\text{ M yd}^3(63.5\text{ M m}^3)\)
- Total excavation (up to 1914) \(280\text{ M yd}^3(214\text{ M m}^3)\)
- Total concrete for three locks \(4.5\text{ M yd}^3(3.45\text{ M m}^3)\)
- Total concrete for two locks (M & P/M) \(2.4\text{ M yd}^3(1.9\text{ M m}^3)\)

1.2 Other Pacific Locks Options from 1939 through 1970

In 1939, the United States began plans to build a third lane of locks. Two separate structures at Miraflores and Pedro Miguel were designed, and construction excavation to build the locks at Miraflores began on July 1, 1940; in May 1942 these excavation efforts were halted because of World War II and were never resumed. Lock hydraulic system models to a prototype scale ratio of 1 to 25 were developed in Miraflores for the existing and the future Miraflores locks; filling and emptying through the bottom only was considered due to the existing locks experience and because the new locks would have the same boundary conditions at the lakes and oceans. Designed new locks were 352m (1,155 feet) long, 42.7m (140 feet) wide, and 12.5m (41 feet) deep.

The U.S. Congress authorized an expenditure of $277 million for construction on August 11, 1939. Construction began in July 1, 1940, most of the contracted excavation work at Gatun and Miraflores (about 62 million yd\(^3\) of dredging and dry excavation) was completed when in May 1942, after expending $75.25 million construction was halted because of higher priority war demands. Once the war was over, construction was never resumed.

After the war, a sea-level alternative was studied from 1947 through 1970 the required excavation for this canal would be a minimum of 1,147M m\(^3\) (1,500M yd\(^3\)).

1.3 1947 - Isthmian Canal Studies

In December 1945, Congress again directed the Governor of the Panama Canal to investigate the best means to increase the canal capacity and security. Thirty different routes and combinations of sea level and lock canals were investigated. These were located between Tehuantepec in Mexico and the Atrato River in Colombia. The most favorable route was within the existing Canal area in Panama, and five plans were developed there as follows:

1. *The Third Locks Project*: Same as the above outlined Project developed in 1939, except that the new locks chambers would have been 200’X1500’X50’, with a navigable channel of 55’deep by 500’ wide. Such locks would accommodate vessels up to 110,000 DWT and would increase the canal capacity to about 35,000 annual transits. The existing Canal and

2. **Lock Canal Plan I:** Modifications to the existing Panama Canal and Locks. Estimated cost: $130 million (1).

3. **Lock Canal Plan II:** The initial phase provided an additional set of twin chambers at the upper end of Miraflores Locks, eliminated Pedro Miguel Locks, and added an additional lock lane with chambers 200’ wide by 1500’ long parallel to both Miraflores and Gatun Locks. It also provided for widening of the channel to 500’ and deepening to 55’. Finally, the plan provided for abandonment of the original Miraflores and Gatun Locks, raising the level of Gatun Lake to 92’ above sea level, and construction of additional single-lane locks at Miraflores and Gatun, with the same dimensions of those originally built. Estimated cost: $1.63 billion (1).

4. **Lock Canal Plan III:** Same as Plan II with maximum protection against sabotage or attack. Estimated cost: $2.31 billion (1).

5. **Sea-Level Canal Plan:** Provided for excavation of a sea-level waterway along the alignment of the existing Canal in the regions of the deepest cut. The channel would have been 60’ deep by 600’ wide. Estimated cost: $2.48 billion. (1)

In 1947 one complex of three step locks was studied at Miraflores and one at Gatún designed locks would be 61m (200 feet) wide, 457m (1,500 feet) long, and a minimum of 15.2m (50 feet) of navigable depth. A study to investigate the relative advantages of three lifts as compared with two lifts revealed that the three lift arrangement would exceed by $13 million the two lifts alternative for both terminal locks but other factors not considered were:

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1 1947 dollars
Lockage Water Requirements:

- The two-lift design would require considerably more water for lockages

Size (Height) of Lock Gates at Miraflores:

- For two-lift design: 105 feet (32 m)
- For three-lift design: 85 feet (25.9m)

Water velocities in lock conduits:

- For two-lift design higher heads, even with larger conduits, will have larger velocities that would impact on concrete durability

Time of transit for ships:

- The two-lift design would require less time for ships passing through the locks

Hawser slopes (for locomotives):

- The deeper two-lift design is compensated by the increase in width

Length of Locks:

- The two-lift design would require about 1,560' (475.5m) less overall length. Most of the two-lift lock would be founded on basalt at Miraflores

It was concluded that, although adoption of the two-lift design would result in a prospective saving of about $13 million, saving was not important in a project in the billion-dollar cost bracket. The above outlined considerations deserved more detailed studies; therefore, no final recommendation was made at that time.

1.4 1957 - Panama Canal Improvements

In January 1957, the Board of Consultants of the Isthmian Canal Studies appointed a committee to study the capacity of the Canal and to recommend improvement to face the growth in traffic requirements. They recommended improvements pertaining to the illumination of chambers and channel, channel straightening, construction of a holding station North of Pedro Miguel and a dam at the Trinidad Arm of Gatun Lake, and widening of Gaillard Cut to 152m (500 feet) as well as deepening it to have a bottom at elevation +11.3m (+37 feet) Precise Level Datum (PLD).

1.5 1960 - Isthmian Canal Plans

After evaluating all past proposals and considering other possible new suggestions, it was again decided that a sea-level canal would provide the only permanent and adequate solution to all canal capacity problems. The use of nuclear explosives among other alternatives for excavation methods was considered (with today worldwide
environmental regulations, this method is a dead issue). They recommended a review of the entire situation by 1970.

1.6 1964 - Conventional Construction Plans

Methods of construction and cost estimate innovations were updated to reduce the above mentioned cost estimates. A two-stage conversion plan of the existing canal to a sea-level canal was investigated. Also, nuclear excavation was considered East of the existing Canal and the possibility of having larger, unlined locks without the use of locomotives were considered.

It was demonstrated that the use of unlined chambers, counterfort walls, and cellular construction for locks would represent significant savings. For the unlined lock alternative, lockage water consumption increases dramatically.

Alternatives of making a water diversion from the Rio Indio watershed to Gatun Lake or pumping seawater into the lake were studied. The conclusion was that pumping water would be the less expensive option to cover the water deficiency. These studies updated the cost estimates made in 1960.

1.7 1964 - Isthmian Canal Plans

Pacific Locks: (Miraflores 2 Lifts and Pedro Miguel 1 Lift) chambers were 42.7m X 365.8m X 12.3m (140’ X 1200’ X 40’).

The cost of a Third Locks Plan would have been $636 million in 1964 dollars.

Two- or 3-lifts were studied considering a Terminal Lake and Sea Level Canal.

1.8 1969 - Improvement Program for the Panama Canal

This program proposed a series of improvements to the existing Canal facilities.

1.9 1970 - Interoceanic Canal Studies

These studies also considered previous canal alternatives and concluded that the two most promising were The Third Locks Plan and The Terminal Lake Plan. The former has been described above, and the latter would consolidate Miraflores and Pedro Miguel locks on the Pacific side, raising Miraflores Lake to the same level as Gatun Lake. In the process, a third lane of locks would be added on both the Atlantic and Pacific sides.

The Deep Draft Locks Canal Plan with locks of 160 feet by 1450 feet by 65 feet, capable of accommodating 150,000 DWT ships, was studied. This plan also considered the excavations made in 1940-1942 for the Third Locks Plan.

Canal studies made in 1947, 1960, 1964, and 1970 concluded that a sea-level canal would be operationally the best solution; however, they counseled interim measures and postponement of construction. In addition to the environmental and economical issues,
mutual agreements between the United States and Panama Governments needed to be negotiated. The cost of a Third Set of Locks (one additional larger lane) would be $800 million in 1970 Dollars.

1.10 1993 - Canal Alternatives Study (CAS)

1.10.1 Phase I

Data Collection and Project Formulation of the Detailed Plan of Study made a prescreening of the following:

- Improvements to the present Canal
  - High Rise Lock alternatives with Gatun Lake mean water level at 85 to 90 feet.
  - Low Rise Lock with Gatun Lake mean water level at 30 to 55 feet, and,

- Sea-level canal alternatives
  - A sea-level canal to replace the existing canal (Route 14S).
  - A sea-level canal approximately 16 kilometers to the west of the existing canal (Route 10).

In 1992 this prescreening selected two enhancements for feasibility study as follows:

- A one- or two-lane high rise lock canal alternative capable of handling ships of a design of 150,000 or 200,000 DWT; and,
- A one-lane sea-level canal alternative capable of accommodating a design ship size of 250,000 DWT.

Both of these would operate simultaneously with the existing Canal and widened Gaillard Cut.

1.10.2 Phase II

Component Contractors Studies, concluded that High Rise Lock alternatives with a single lane in Gaillard Cut for 150,000 DWT and 200,000 DWT ships and a single lane approach channel for the sea-level alternative should be studied. Results were presented in Figure 2 (following).
**Figure – 2  Study Results and Evaluation**

<table>
<thead>
<tr>
<th>Option *1</th>
<th>Transit Capacity (1,000)</th>
<th>Cost Billions of Dollars</th>
<th>Economic Internal Rate of Return *2</th>
<th>Financial Internal Rate of Return *2</th>
<th>Result *2</th>
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<tr>
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<td>+</td>
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<td>× ×</td>
</tr>
<tr>
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<td>7.6%</td>
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<td>3-b</td>
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<td>12.7</td>
<td>5.0%</td>
<td>×</td>
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</tr>
<tr>
<td>S.Q.</td>
<td>17.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<th>Source of Data</th>
<th>OCCE Phase II</th>
<th>ECE Phase II</th>
<th>EAIU</th>
<th>FS/FA/MA</th>
</tr>
</thead>
</table>

Note:

*1  1-a; High Rise Lock Canal with Double lane Gaillard Cut and Design Ship size 150,000 DWT,

1-b; High Rise Lock Canal with Single lane Gaillard Cut and Design Ship size 150,000 DWT,

2-a; High Rise Lock Canal with Double lane Gaillard Cut and Design Ship Size 200,000 DWT,

2-b; High Rise Lock Canal with Single lane Gaillard Cut and Design Ship Size 200,000 DWT,

3-a; Sea-level Canal with single lane channel, 3 lane tidal locks and Design Ship size 250,000 DWT

3-b; Sea-level Canal with single lane Channel, a pair of tidal gates and design ship size 250,000 DWT.

S.Q.; Existing Panama Canal with widened Gaillard Cut

*2 □ Very feasible

• Feasible

‡ Marginally feasible

× Not feasible

N.A. Not Examined (obviously not feasible)

This Table is copied from Attachment II, page 11 of the CAS.
1.10.3 Phase III

Cost benefit analysis revised the remaining component studies:

- Financial Schemes, Financial Analysis and Management Arrangements;
- Biological Background and Biological Inventory;
- Economic Analysis and Analysis of Impact on Users;
- Environmental Analysis; and,
- Analysis of Impact upon Panama.

1.10.4 Phase IV

Final Report - Twenty volumes.

There are 36 cases studied, with variables as: size of ships, summit level of the lake, number of locks lanes, and route centerline location. Each historic alternative is classified into one of the following four groups:

- Group A High Rise lock canal (Water level 90 to 85 feet).
- Group B Low Rise lock canal (Water level 55 to 30 feet).
- Group C Sea level canal (Route 10).
- Group D Sea level canal (Route 14S).

These groups are further classified in nine study-cases.

Pacific twin locks: 2 steps, mitering gates, surge basin at the Rio Cocoli area, closure dam to keep that same river watershed within the surge basin, recycling pond at the Victoria-Velásquez area with a pump station, widened channel entrances to the twin lock. Locks located at the existing excavation West of Miraflores Lake or just at the existing excavation, with a cofferdam at the western edge of Miraflores Lake to divide a bypass channel to Gaillard Cut. (47 to 63) m wide X (319 to 428)m long X D, D=f(Chamber Size) 10m X 10m culverts, assuming 9 minutes for filling and emptying.

Final Report of the Canal Alternatives Study was presented in 1993 to the government of Panamá for considerations.

They considered 37 cases with variables as sizes of ships, summit of lake Gatún, number of locks lanes, and route centerline location. Sea-level and lock alternatives were considered. A two structures scheme at the Pacific side was not considered.
2 1998 –2002 CANAL CAPACITY PROJECTS DIVISION (IPC)

2.1 Other Pacific Locks Options from 1999 through 2002

A contracted study performed by Harza Engineering Company, Inc. for ACP, dated August 2000, concluded that for the Pacific end, two alignments resulted the best. "Specifically, these two alignments both utilize a single three-lift lock, bypassing Lake Miraflores and increasing operational efficiency when compared to separate locks at Miraflores and Pedro Miguel."

3 INTERNATIONAL BID FOR CONCEPTUAL LOCKS DESIGN AT THE PACIFIC EXTREME OF THE CANAL

International bid No. SAA 109422 for the Conceptual Design of only the Pacific-side lock was launched by ACP in June of 2001. Fifty-two international companies were interested and participated in a Pre-Proposal Conference and site visit on September 5, 2001. Eleven joint companies submitted proposals by October, and on January 11, 2002, contract No. SAA-79339 was awarded to Tractebel Development Engineering. Contract final report was presented to ACP on March 18, 2003.

4 COMPARATIVE ANALYSIS: COMPARISON OF ONE 3-LIFT LOCK VS ONE 1-LIFT PLUS ONE 2-LIFT LOCK

4.1 ADDED DIRECT CONSTRUCTION COSTS

1. Each lock requires an upper approach wall and a lower approach wall. The one-lock configuration would require one of each, while the two-lock arrangement would require two of each. The same would apply for the wing walls. The increase in cost would include the additional excavation and materials necessary to construct the walls.

2. Each lock requires an intake and an outlet for each main culvert. The one-lock configuration would require two inlets and two outlets (assuming two main culverts), while the two-lock arrangement would require four inlets and four outlets (assuming two main culverts). The added construction cost would be for the excavation, materials for the structures, as well as the operating systems for the equipment.

3. For a single lock with three lifts, gates would be required at four locations; at the lake, at the ocean, and between the steps. For two locks, gates would be required at five locations, at the upper lake, at the intermediate lake at each lock, at the ocean, and between lifts. The increase in the number of gates also requires an increase in the operating machinery for the gates.

4. Each lock requires a central control for the operation of the equipment. The one-lock configuration would require one control center with whatever
backup units are required. The two-lock setup would require two control centers.

5. Each lock requires the routing of utilities to the facilities. The two-lock configuration would require the construction of facilities for transporting potable water and electricity to each site. The incremental cost would probably be mainly in the main lines from the potable water plant and electrical substation to the additional site.

6. If the vessel positioning system is lock-based, then each lock will have to be supplied with the minimum number of components for the safe transit of vessels. This will result in at least twice the minimum number of components plus the additional infrastructure cost.

Equipment and Maintenance:
Assuming that 3 lifts are needed to negotiate the 26 m difference between Gatún Lake and the Pacific Ocean, with two lock structures the additional equipment required is:

- 2 sets of lock gates and operating equipment
- 4 culvert valves and operating equipment
- 12 locomotives
- 2 (580 m long) approach walls
- 1.5 km of tow track infrastructure (rails, racks, crossties, conductor slot)
- 1.5 km of return track infrastructure (rails, crossties, conductor slot)
- 4 locomotives switching devices (turntables or similar)
- Maintenance buildings
- Additional electrical control and feeders
- Additional electrical emergency generator
- Additional transformers and switchgears

The additional equipment will increase the maintenance costs.

Additional maintenance and operations personnel will be needed because of the separated structures.
A closure of any of the two locks would require closing the other lock also for PostPanamax ships, thus the only advantage when compared to a single structure is that ships up to Panamax size can still use the old and new locks.

4.2 NAVIGATION

To raise a ship from the Pacific Ocean to the elevation of Gatún Lake there are two main possibilities: navigate through Miraflor es Lake or just by-pass it. The first arrangement is similar to the existing Pacific end locks and the by-pass alternative does not need to go through this lake requiring a by-pass channel. We are comparing a three-lift lock that raises the ship from the ocean level to Gatún Lake with the alternative of
two separate structures near both ends of Miraflores Lake with one 2-lift lock plus one 1-lift lock structures that require a short navigation through Miraflores Lake.

Several alignments have been studied for placing these locks. Some of these alignments are briefly described below:

1. Alignment P1 is located to the west of and almost parallel to the existing Miraflores and Pedro Miguel locks. This alignment connects the Balboa reach at the Pacific end to Cucaracha reach at Gaillard cut and a single or multiple lifts lock can be built to raise ships.

2. Alignment P2 similar to P1 above but has a sharp turn within Miraflores Lake and a barrier dam to separate this lake from the access channel at Gatún elevation.

3. Alignment P3 is a dual lock arrangement located to the east of and parallel to the existing Miraflores and Pedro Miguel locks. It requires a sharp turn at the southern approach to Miraflores locks. There is also a sharp turn exiting near Pedro Miguel locks and requires a second turn into Gaillard Cut.

4. Alignment P4 is also a dual lock arrangement located to the west of and parallel to the existing Miraflores and Pedro Miguel locks. It requires that the ships make a sharp turn after exiting Pedro Miguel Locks heading north with another turn a short distance away. This represents a serious navigation hazard.

5. Alignment P5 is also a dual lock arrangement using the excavation of 1939 in the vicinity of Miraflores located to the west of the existing locks.

6. Alignment PM located between P1 and P2 is a single structure arrangement.

4.3 EXISTING FACILITIES

1. Alignment P3 affects: the existing water treatment plant, the electric generating plant, Miraflores Dam, the communities of Pedro Miguel and Paraiso with all of the utilities, the Panama Canal Railway and Gaillard Highway.

2. The other alternatives located to the West of the existing locks affect some roads and power lines that will need relocation.

4.4 CONSTRUCTION

1. The need to use Miraflores Lake in the two-lock option will adversely affect the traffic at the existing locks between Pedro Miguel and Miraflores locks. Additional channel excavation for larger ships west of the existing channel for Panamax ships will require drilling, blasting and dredging that may impact current operations.
4.5 OPERATIONS

1. The transit time for one three-step lock is shorter than for one one-step and one two-step lock. This is due to the fact that in the three-step lock there is only one approach and one exit maneuver to be accomplished, with the remaining movements from chamber to chamber. With two separate locks, there are one additional approach and one exit maneuver required when arriving and exiting at the second lock.

2. There is also an increase in the potential for accidents with two locks structures. The most likely time for accidents to occur is during approach operations when ships are moving from a wide channel into a very restricted chamber. The need for the additional approach increases the possibility of accidents.

3. The two-structure lock also requires additional personnel for operations. Since the control systems have to be duplicated at the second lock, personnel necessary to man the stations is also required. There is also a need for additional personnel when using a lock-based vessel positioning system for two structures.

4. For maintenance operations, two separate locks outages will be required, or alternately, two complete crews with corresponding equipment would be required.

5. Capacity of Miraflores lake has to be evaluated. The lake size will have to be increased and the channel deepened. The effects of the increased cumulative spilling from the Panamax and Post-Panamax locks into the small lake and the discharge capacity of the existing Miraflores Spillway would have to be considered.

6. The possibility of increased salinization of Miraflores Lake due to Post-Panamax ships lockages needs to be considered.

7. Additional locomotives required (see Figure 3 below)

In 1939 they considered navigation through Lake Miraflores because of redundancy in the event of a military attack to the existing locks. If the third lane is too close to the existing locks, there will be conflict to install water saving basins between the new and existing locks.

Lighting and control systems are more expensive for two separate locks. Transit times are increased with two structures in the Pacific side. The time difference when compared with a single lock structure is due to the required time to cross Miraflores Lake at low speed, make the approach into the second lock structure and secure the locomotive cables, if this would be the selected vessel positioning system.
An increase in transit time will diminish the projected new lock capacity. This could result in less revenues and a longer payback period.

Having longer and wider Post Panamax vessels sailing in Miraflores Lake will also adversely affect the capacity of the existing locks. If the 1939 alignments is used, Panamax ships would have to be held in the lock approaches and operations delayed to allow the use of the navigational channel by the Post Panamax vessel. In a parallel lock structures (west or east) alignment scenario two navigational channels would be need, and they should be clearly defined because of the different draft allowances and also Miraflores Lake would have to be expanded.

<table>
<thead>
<tr>
<th>Locomotive Requirement Table</th>
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<tr>
<td>Post-Panamax Locks Third Lane with Relay</td>
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<td>Distribution</td>
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<tr>
<td>Pacific Side 3-Lift lock</td>
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<td>Atlantic Side 3-Lift lock</td>
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<td><strong>Total</strong></td>
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<table>
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<tr>
<th>Post-Panamax Locks Third Lane with Relay</th>
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<tr>
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<tr>
<td>Atlantic Side Single 3-Lift lock</td>
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<tr>
<td><strong>Total</strong></td>
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Figure 3. Locomotive Requirement Table

4.6 **Alternatives Description, Advantages and Disadvantages of One 3-Lift Lock compared with Two 2 + 1 Lifts Locks**

4.6.1 **Alternative #1 of two separate structures**

Through the existing Third Locks excavation, one 2-Lift Lock Structure southwest of Miraflores and another 1-Lift Lock West but not parallel to the existing Pedro Miguel Lock.
ADVANTAGES:
✓ Excavation for the new Miraflores Lock is partially completed but partially refilled
✓ Excavated materials could be used to build levees and closures required
✓ Vulnerability or danger of Canal closing due to terrorism is decreased
✓ Excavated rock could be used to protect the slopes and for concrete aggregates

DISADVANTAGES:
♦ Removal and relocation of about 4 Km of Borinquen Highway and bridges
♦ Closure walls and levees would be required to form a channel south of the locks

4.6.2 Alternative #2 (One-lock Structure)

Three-lift lock with water saving basins and approach channel to Gaillard Cut (Alignment “PM”).

ADVANTAGES:
✓ Excavation through almost uninhabited lands (except Cocoli Northeast)

DISADVANTAGES:
♦ Removal and relocation of some electrical transmission lines
♦ Removal and relocation of about 7 Km of Borinquen Highway
♦ Closure walls and levees would be required to form a channel North of locks
♦ Long approach channel excavation (North of locks)
♦ Long haul distance for disposal. Disposal requirements would be large too
♦ Some excavation through area containing unexploded ordnance (UXO)

4.6.3 Alternative #3

Through the existing Third Locks excavation, one 2-Lift Lock Structure 400m offset Southwest of Existing Miraflores Lock and another 1-Lift Lock near Pedro Miguel.

ADVANTAGES:
✓ Panama Canal Authority property
✓ Consolidates locks operations and resources

DISADVANTAGES:
♦ Difficult access for materials and personnel during construction
- Removal and relocation of about 3 Km of Borinquen Highway
- All approach walls (4) need to be built in-the-wet
- Excavation through existing Pedro Miguel Dam toe

### 4.6.4 Alternative #4

Through the existing Third Locks excavation, one 3-Lift Lock Southwest of Miraflores and a Cofferdam to divide Lake Miraflores from the upper approach channel.

**ADVANTAGES:**
- Existing excavation through rock is partially completed for a two-lift lock
- Anchorage areas at West bank near to Río Cocolí

**DISADVANTAGES:**
- Different levels at Miraflores and Gatun Lake access channel
- New dam between lakes has a high risk. Construction of this dam is in-the-wet
- Difficult access for materials and personnel during construction at Miraflores Lake
- Northbound ships exiting the lock have a barrier dam in front before turning to port

### 4.6.5 Alternative #5

West of the existing Third Locks excavation, one 2-Lift Lock (CAS Alignment)

**ADVANTAGES:**
- Convenient straight alignment for Post-Panamax ships
- Long channel before Gaillard Cut to be excavated in dry terrain

**DISADVANTAGES:**
- Excavation through UXO areas
- Requires excavation of a 7.5-kilometers channel from locks upper end to Gaillard Cut
- Requires demolition of Rodman piers and tank farm

### 4.6.6 Alternative #6

Near the existing Third Locks excavation, one 3-Lift Lock Structure Southwest of Miraflores (As “P1” above, skewed towards NW).

**ADVANTAGES:**
- All excavation and dam through dry terrain
Good alignment for Post-Panamax ships
All lock founded on basalt

**DISADVANTAGES:**

- Only consider part of the existing excavation.
- Construction of New approach channel through hilly terrain.

### 4.6.7 Alternative #7

High Rise Lock (1 Lift).

**ADVANTAGES:**

- Required time to fill chambers could be longer but time within lock would decrease
- No closure construction works between locks required
- Only one lock entry and exit required

**DISADVANTAGES:**

- Water requirements would have to be carefully evaluated
- Gates would be exceptionally tall (about 46m (150 feet) high)
- Vessel positioning would be different, a new concept would be required
- New fenders within chambers would be required
- Larger (taller) lock structures
4.7 COSTS USING LOCOMOTIVES AS VESSEL POSITIONING SYSTEM (VPS)

**COST COMPARISON OF ONE 3-LIFT V/S ONE 2-LIFT AND ONE 1-LIFT LOCK**

<table>
<thead>
<tr>
<th></th>
<th>(RCC + RC)</th>
<th>(RC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 LIFT</td>
<td>$704,363,720</td>
<td>$723,480,150</td>
</tr>
<tr>
<td>1 LIFT-La Boca</td>
<td>$322,424,447</td>
<td>$332,577,993</td>
</tr>
<tr>
<td>2 LIFT-Basalt</td>
<td>$501,185,289</td>
<td>$521,670,791</td>
</tr>
<tr>
<td>1LIFT + 2 LIFT</td>
<td>$823,609,737</td>
<td>$854,248,785</td>
</tr>
<tr>
<td><strong>INCREASE</strong></td>
<td><strong>$119,247,017</strong></td>
<td><strong>$130,768,635</strong></td>
</tr>
</tbody>
</table>

(2 locks v/s 1 lock) Comparison is based on:
1-Consorcio Post-Panamax 3-lift design for the Pacific side
2-Modification to Consorcio Post-Panamax 3-lift design for 1 and 2 lifts
3-Cost used are based on Consorcio Post-Panamax Cost
4-Administrative, contingencies, excavation cost not included

Figure 4. Cost Comparison of One 3-Lift Lock vs. One 2-Lift and One 1-Lift Lock using locomotives as VPS

4.8 COSTS USING TUGBOATS AS VESSEL POSITIONING SYSTEM

**COST COMPARISON OF ONE 3-LIFT V/S ONE 2-LIFT AND ONE 1-LIFT LOCK**

<table>
<thead>
<tr>
<th></th>
<th>(RCC + RC)</th>
<th>(RC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 LIFT</td>
<td>$751,540,496</td>
<td>$767,660,921</td>
</tr>
<tr>
<td>1 LIFT-La Boca</td>
<td>$308,102,577</td>
<td>$315,634,580</td>
</tr>
<tr>
<td>2 LIFT-Basalt</td>
<td>$531,274,663</td>
<td>$552,460,725</td>
</tr>
<tr>
<td>1LIFT + 2 LIFT</td>
<td>$839,377,240</td>
<td>$868,095,305</td>
</tr>
<tr>
<td><strong>INCREASE</strong></td>
<td><strong>$87,836,743</strong></td>
<td><strong>$100,434,384</strong></td>
</tr>
</tbody>
</table>
(2 locks v/s 1 lock) Comparison is based on:
1-Consorcio Post-Panamax 3-lift design for the Pacific side
2-Modification to Consorcio Post-Panamax 3-lift design for 1 and 2 lifts
3-Cost used are based on Consorcio Post-Panamax Cost
4-Administrative, contingencies, excavation cost not included
5-Increase in width of 7m and length of 45m for all chambers
6-Reduction of 480m in length of upper and lower approach walls

Figure 5. Cost Comparison of One 3-Lift Lock vs. One 2-Lift and One 1-Lift Lock using tugboats as VPS.

<table>
<thead>
<tr>
<th>TRACK ESTIMATE FOR 1-LIFT, 2-LIFT AND 3-LIFT LOCKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track Assembly for 3 Lift Lock</td>
</tr>
<tr>
<td>Repair Facility</td>
</tr>
<tr>
<td>Total 3 Lift Lock</td>
</tr>
<tr>
<td>Track Assembly for 2 Lift Lock</td>
</tr>
<tr>
<td>Repair Facility</td>
</tr>
<tr>
<td>Total 2 Lift Lock</td>
</tr>
<tr>
<td>Track Assembly for 1 Lift Lock</td>
</tr>
<tr>
<td>Repair Facility</td>
</tr>
<tr>
<td>Total 1 Lift Lock</td>
</tr>
<tr>
<td>1 Lift + 2 Lift Lock</td>
</tr>
<tr>
<td>Increase cost for 2 locks</td>
</tr>
</tbody>
</table>

Figure 5. Track Cost Estimate for 1-Lift, 2-Lift and 3-Lift Locks
### 4.9 Comparison

The following table compares Alternatives 2 and 3. These Alternatives represent the most excavation requirement (Alternative 2) for One-lock Structure and the least excavation (Alternative 3) for Two Separate Lock Structures.

<table>
<thead>
<tr>
<th></th>
<th><strong>ONE LOCK STRUCTURE</strong></th>
<th><strong>TWO SEPARATE LOCK STRUCTURES</strong> *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>VOLUME (M m³)</strong></td>
<td><strong>COST</strong></td>
</tr>
<tr>
<td>Excavation **</td>
<td>48.9</td>
<td>$ 220,060,445</td>
</tr>
<tr>
<td>Dredging **</td>
<td>N/R</td>
<td>-</td>
</tr>
<tr>
<td>Subtotal For Excavation and Dredging</td>
<td>$ 220,060,445</td>
<td>$ 278,055,531</td>
</tr>
<tr>
<td>Lock Structure, Including Gates</td>
<td>$ 704,363,720</td>
<td>$ 823,609,737</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>Track</td>
<td>$ 28,960,223</td>
<td>$ 40,900,301</td>
</tr>
<tr>
<td>Locomotives</td>
<td>$ 44,000,000</td>
<td>$ 70,400,000</td>
</tr>
<tr>
<td>Total</td>
<td>$ 997,384,388</td>
<td>$ 1,212,965,568</td>
</tr>
</tbody>
</table>

* One 2-Lift Lock Near Miraflores, another 1-Lift Lock Near Pedro Miguel.

** Excavation and Dredging computed for a channel bottom width of 220m and lock site bottom width of 100m. Excavation (dry) at $4.50/m³. Dredging at Miraflores Lake Navigational Channel only. $23.00/m³ for drilling, blasting, and dredging.
Summary of alternatives including costs (Tugs as VPS)

<table>
<thead>
<tr>
<th></th>
<th>ONE LOCK STRUCTURE</th>
<th>TWO SEPARATE LOCK STRUCTURES *</th>
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<tr>
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<td>$ 220,060,445</td>
<td>$ 278,055,531</td>
</tr>
<tr>
<td>Lock Structure, Including Gates</td>
<td>$ 751,540,496</td>
<td>$ 839,377,240</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>$</td>
<td>*(4/3+n+)/n)</td>
</tr>
<tr>
<td>Tugboats</td>
<td>n</td>
<td>n+</td>
</tr>
<tr>
<td>Total</td>
<td>$ 971,600,041</td>
<td>$ 1,117,432,771</td>
</tr>
</tbody>
</table>

* One 2-Lift Lock Near Miraflores, another 1-Lift Lock Near Pedro Miguel.

** Excavation and Dredging computed for a channel bottom width of 220m and lock site bottom width of 100m. Excavation (dry) at $4.50/m³. Dredging at Miraflores Lake Navigational Channel only. $23.00/m³ for drilling, blasting, and dredging.

Figure 7. Summary of Alternatives Including Costs (Tugboats as VPS)

The cost of constructing two separate structures in the Pacific end of the Panama Canal exceeds by $215,581,180 the alternative of one three steps lock if locomotives are used as VPS. For the alternative of using tugboats as VPS the cost of constructing two separate structures still is
higher by $145,832,730 without considering that for two separate structures more tugboats would be necessary.

A break-even cost for both alternatives, keeping the dredging costs constant, would yield unit prices of $3 to $15 per cubic meter of dry excavation depending on the VPS chosen.

An item that is hard to account for is the potential for accidents if two separated structures would be the final arrangement. For the existing Pacific locks from 1956 to date 144 serious accidents have occurred within lock ends at Miraflores Lake. It is ACP responsibility to repair ships and structures if an accident occurs. A spillage of cargo from a damaged ship is also an environmental issue that has to be considered.

Costs of these accidents are most of the time confidential figures belonging to ACP and ship owners as they have up to three years to get to an agreement. Another item difficult to account for is the time lost for the ship and locks personnel when such an accident occurs. Fenders at the approaches, at the knuckles, tailbays and forebays are also very expensive and require permanent maintenance or replacements due to accidents.

Vessel Positioning System (VPS) within locks also have an initial investment and operational cost that is an ongoing study performed by ACP. The Panama Canal is the only Authority that uses locomotives as VPS in the world. The latest generation of locomotives have a fabrication price of $2,000,000.00, as they are custom fabricated for our operational requirements. For PostPanamax ships tugboats are used as VPS in Europe and Asia. ACP owns and operates four tugboats of 4,400 HP that are similar to the tugboats used by them as VPS. The cost of the latest generation of ACP tugs is around $5,600,000 each.

4.10 Water consumption

In 1999 the average water consumption from Pedro Miguel and Gatún locks was 204,985,633 m³ (7,239,000,000 ft³) just for lockages. The existing Miraflores Lock has an elevation of the lower chambers that requires spillage of some amount water to the sea for certain tidal conditions. It is a design-construction consideration that was foreseen in 1910, and shallower walls were built on account of costs.

If another larger pair of locks for larger ships would be connected to Miraflores Lake, the lake elevation would be more sensitive to the number of lockages and water consumption. The Miraflores Spillway is thus an important design criterion to consider as well as possible salt water intrusion and the fact that the water consumption of a two-structure, 2+1-lift lock is higher than that for one 3-lift lock.

4.11 Capacity

Existing Pedro Miguel and Miraflores Locks can handle a limited amount of ships per day. There is a ship holding facility for only one Panamax ship and a shorter 200m ship at the west prism line of the navigational channel in the Lake Miraflores. This facility has to be relocated (dredged) if a dual lock array is chosen but a good alternative
derived of this solution would be the possibility to divert ships though the new PostPanamax lock while performing maintenance works at one of the existing locks.

For two separate structures the bottleneck of the overall canal transit would be the Pedro Miguel lock (Existing and new), there will be a 100 min delay for a Panamax vessel if two separate structures are built, for a PostPanamax vessel the delay will be longer; hence, the capacity reduced.

4.12 Environment

Environmental issues are similar for both solutions; however, disposal of a percentage of the excavation and dredging material for the solution that involves larger quantities of excavation will be a part of another study. Water quality of both lakes is also a part of another study.
REFERENCES


3. The Panama Canal Third Locks Project, Department of Operation and Maintenance, Special Engineering Division. 1944.


10. Meetings with ACP Pacific Lock Operators.