2.4 Water Circulation Plan (Indirect System)

2.4.1 Basic Concept

Though the storage volume can be increased by adding new dams above Gatun and Maden lakes, total catchment yield is generally not sufficient to provide the required lockage water for the lock systems proposed at this time. Therefore the use of pump stations to recycle lockage water has been proposed.

The number of pump stations necessary depends on the study case, in particular the size of locks and number of ship transits. Considering the L-1 case, pump stations are not necessary when lockage water is available from existing lakes and from the two new dams, but if lockage water is available only from existing lakes then two pump stations are required. For the L-2' case with a single lift, twelve pump stations are needed with the two new dams and thirteen pump stations are needed without the two new dams.

2.4.2 Pump Stations

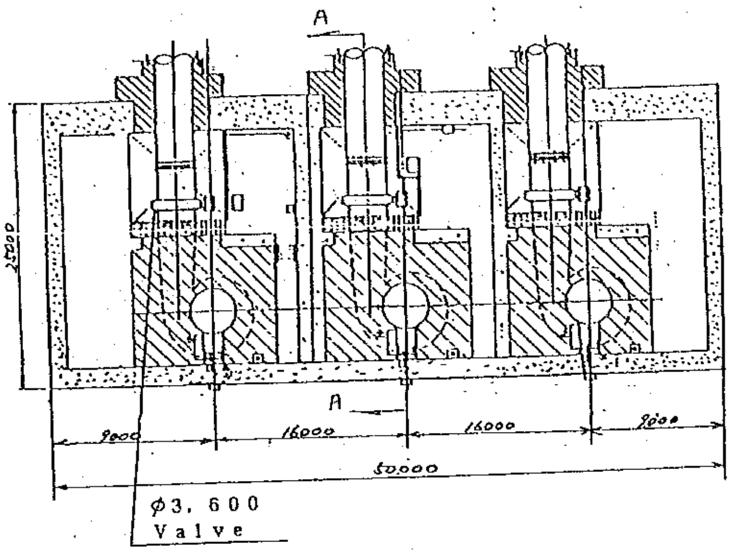
A pump station consists of three pumps (including one spare pump) and the characteristics of each pump are shown in Table 2.4.1.

A schematic drawing is shown in Fig. 2.4.1.

Table 2.4.1 Pump Characteristics

Type	Vertical mixed flow centrifugal volume pump
Diameter	3,600 mm
Pressure head	27.3 meters
Volume	30 m3/sec
Rotation ratio	190 r.p.m.
Motor	9,200 kw
Number/pump station	Three (including spare pump)

PLAN



A-A SECTION

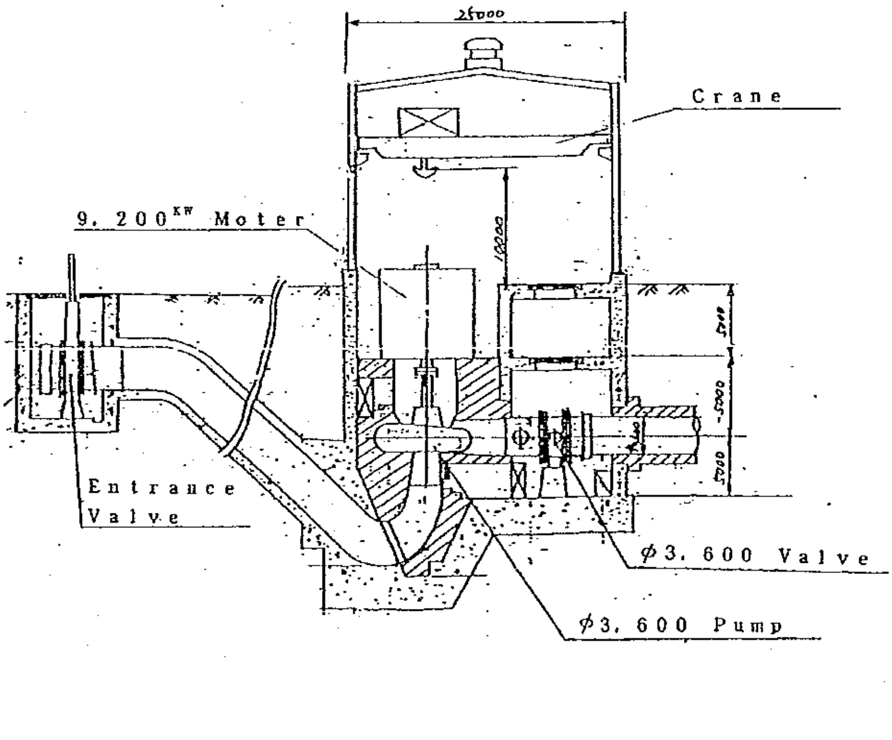


Fig. 2.4.1 Schematic Drawing of Pumps

2.5 Water Circulation Plan (Direct System)

2.5.1 General

In section 2.4, the indirect pumping method was discussed. Here the forced discharge method with pumps from one lock chamber to the neighboring lock chamber will be considered. However, according to the entering and outgoing ship schedule a special chamber for water storage purposes between the lock chambers may be necessary.

This is the preferred method among the 3 methods for conserving lake water which have previously been proposed. (Reference "Consideration for Lockage System and Water of L. Canal" by T. Mochizuki.)

1 Counter balanced lock system (proposed by Mr. Lopez)
2 Air-lift lock system (proposed by Mr. Omachi)
3 Parallel lock system (proposed by Mr. J.A. Morales)

In 1, there is a vertically movable steel floor on the bottom of the lock chamber. By moving this floor vertically using compressed air, the water level of a lock chamber is raised or lowered and the lock may be operated in the same way as a conventional lock. In this case there is almost no consumption of lockage water.

In 2, instead of mechanically moving a steel floor up and down, in simple terms, rubber balloons (or rubber chambers) are inflated with air and the water in the lock chamber is moved up and down, performing the lock operation.

In 3, water drainage and infill is performed using a pump system from one lock chamber to the neighboring chamber.

Of these 3 proposals, 1 and 2 use air methods and with sufficient study are considered feasible. However, a study of such an advanced system including cost analysis would be very difficult and such a study of methods 1 and 2 is not proposed at this stage.

However, with regard to method 3 , there are considered to be no particular technical problems using existing technology and this method is proposed for the purposes of this study.

The pump capacity requirements and electrical power requirements are studied in more detail below.

2.5.2 System

The system proposed is shown in Fig. 2.5.1. As a ship enters the lock from the lake the gate is closed and the valve is opened whereby the water in chamber A drains firstly by gravity to chamber B and then a pump system would expel further water from chamber A to chamber B to raise chamber B to the required level.

Consideration must be given to the increase in salinity of the Gatun Lake.

2.5.3 Pump Specifications

The following specifications are for pumps that can expel and flood water into and out of 250,000 ton lock chambers in 10 minutes. The movement of water from right to left or left to right is controlled by valve operation.

1)	Type	MESV.
2)	Head	15 m
3)	Discharge rate	33.3 m3 / sec
4)	Number of pumps / lock chamber	20 units
5)	Motor output	6,000 kw

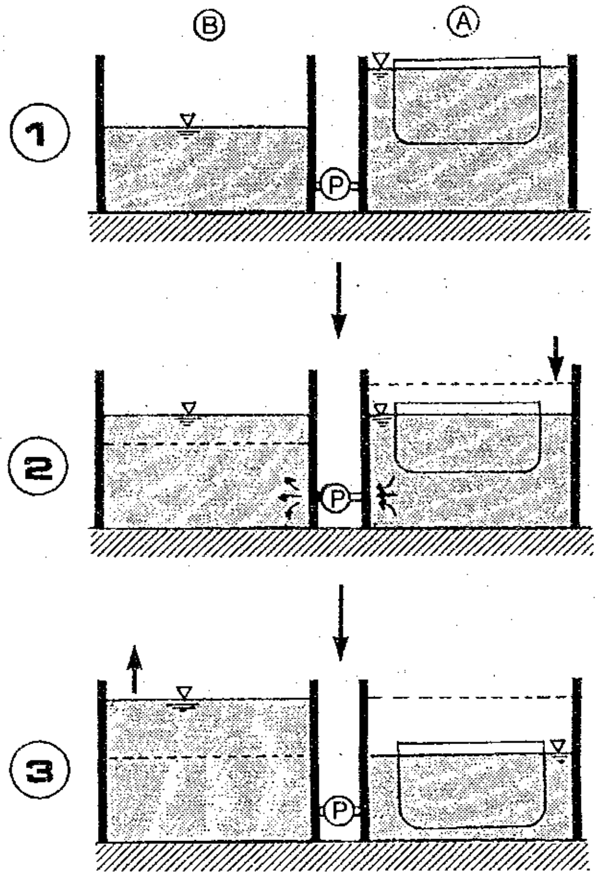


Fig. 2.5.1 Direct Pumping System

2.6 Flood Control and Potential Use of Excess Runoff

2.6.1 Flood Control and Inlet Facilities

(1) Flood Control Facilities

Flood control measures have to be taken when the following alternatives are considered:

a) Low rise lock (WL.55'-30')

When this alternative is considered construction of Barrier dams will separate the Gatun Lake watershed into 5 independent reservoirs (Fig. 2.6.1). Modification of Pedro Miguel Lake and Gatun Lake spillways will be required due to the reduction in water level from 85' to 55'/30'. Flood control measures incorporating new spillways at 4 dam sites will be needed and also a diversion culvert between dam C and D has to be provided in order to maintain the same water level. The flood control plan for the Low Rise Lock case is shown in Fig. 2.6.1. Details of Barrier dams are presented in Chapter 5.

b) Sea Level Canal (Route 10)

A sea level canal along the Route-10 alignment would intercept the drainage of several major streams from the west side, but would leave the drainage pattern of streams on its east side relatively intact. Uninterrupted operation of the existing lock canal could continue both during and after construction of sea level canal. The Gatun Dam will continue to control the runoff from the Chagres and Gatun Rivers. Dams will be required on the east side of the canal to retain Gatun Lake at its operating level, and on the west side a culvert is required to divert the Trinidad and Ciri Rivers in order to control any possible flood. The proposals are shown in Fig. 2.6.2.

c) Sea Level Canal (Route 14S)

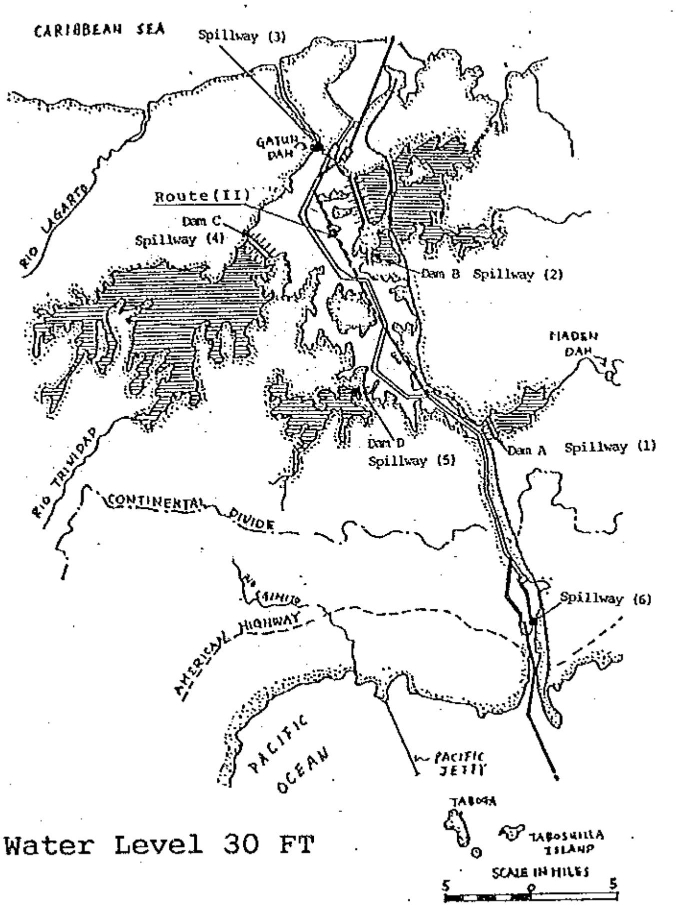
In this plan the existing canal will be used as it is but 3 new dams must be constructed. Flood control measures would not be required during the construction stage because flood water could be released through the existing Gatun Spillways. As a flood control structure after construction, Chagres diversion plug at Gamboa will be required in order to divert the flood of Chagres River to the Pacific Ocean. The plan is shown in Fig. 2.6.2.

(2) Inlet Facilities

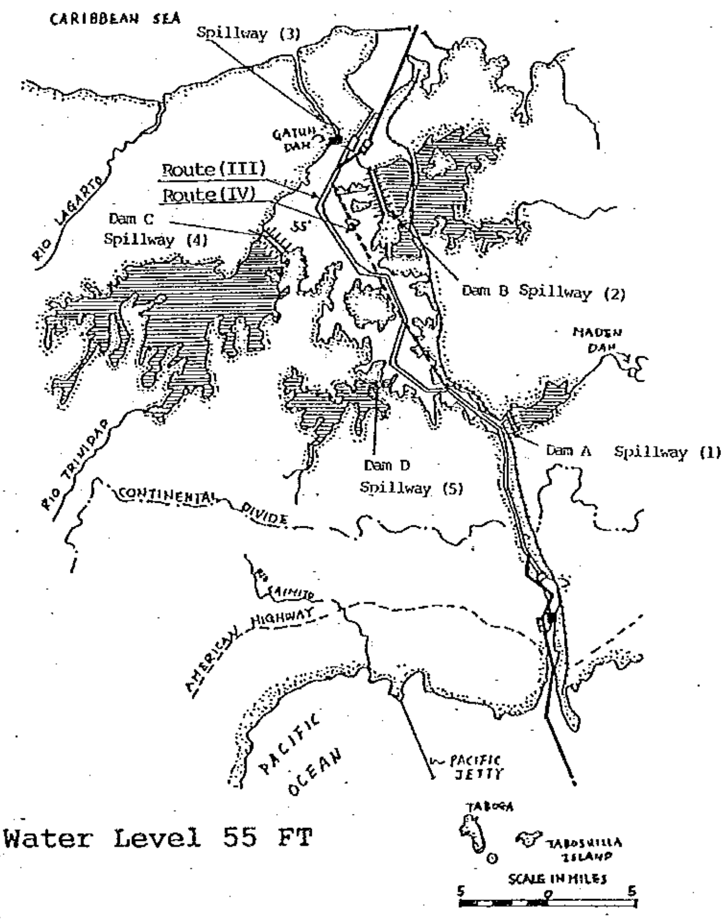
In Low Rise Lock Case, inlet facilities will be required to intake water from barrier dams to facilitate lockages. Considering the fluctuations of water levels, orifice gate type inlet structures are suggested (See Fig. 2.6.3).

2.6.2 Potential Use of Excess Runoff

In the previous chapters various flood control measures according to alternatives have been described. Due to the geo-physical configuration of the project area each alternative has dams as main components. From the primary judgment these dams can also be served as hydroelctric power generation units using the excess runoff, reservoirs as fish culture/recreational purposes etc. Therefore, during the planning/design stage an indepth study should be carried out considering the above mentioned potentials and their impacts on surrounding environment.

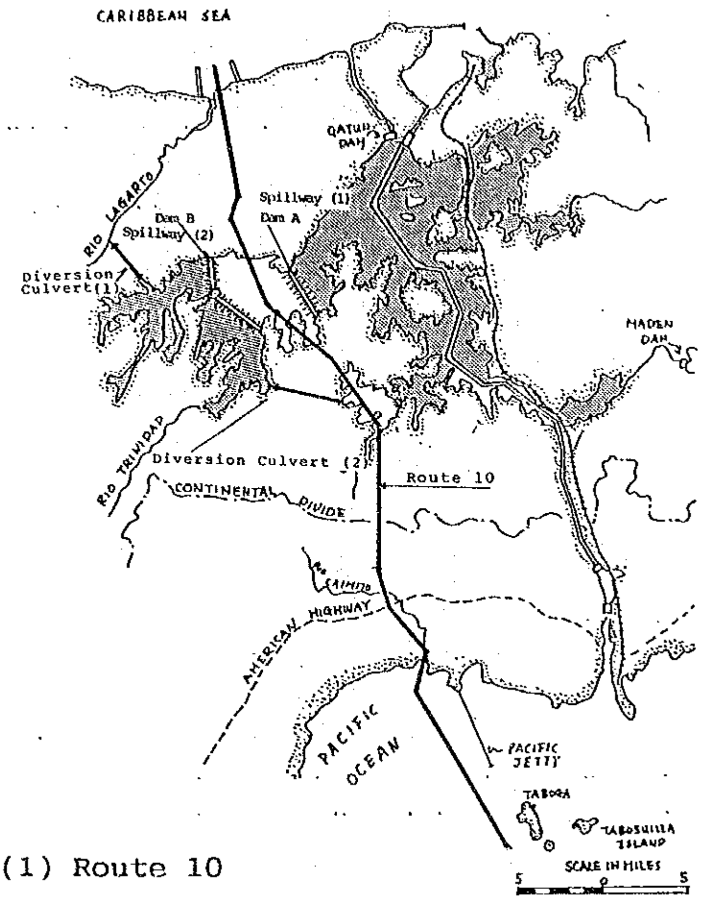


(1) Design Water Level 30 FT

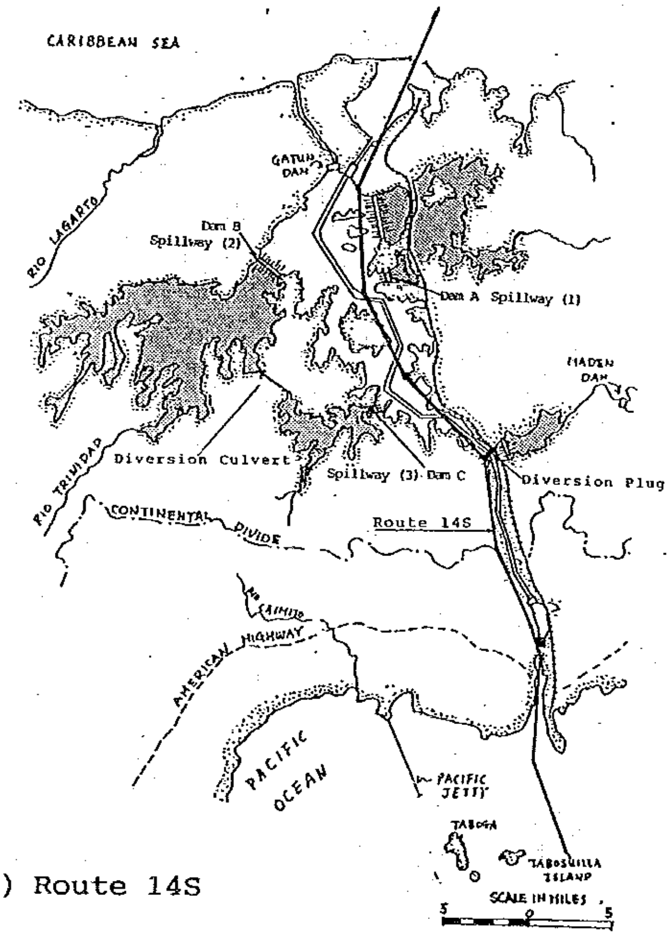


(2) Design Water Level 55 FT

Fig. 2.6.1 Flood Control Plan for Low Rise Case



(1) Route 10



(2) Route 14S

Fig. 2.6.2 Flood Control Plan for Sea Level Canal Case

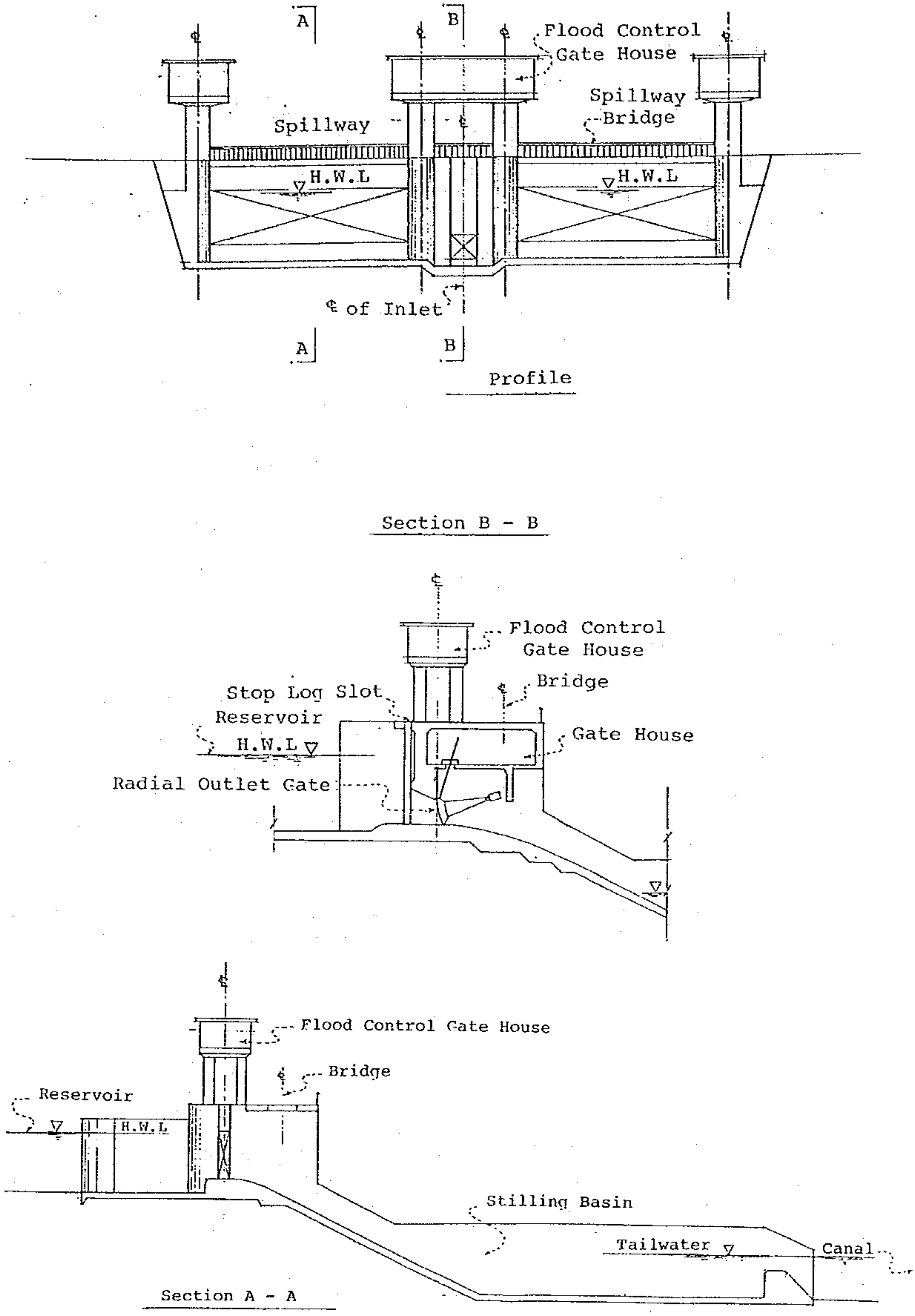


Fig. 2.6.3 Typical Spillway and Inlet Structure

2.7 Technical Feasibility

2.7.1 New Dams

Judging from the technical points of view considered in the preliminary analysis it seems there would be no major engineering difficulties in the construction of new dams at the sites mentioned above. However, considering the hydrological points of view mentioned in water management plan, total available capacity of new dams within Gatun watershed would be limited. A detailed study should be performed which would include geological, hydrological and aerial surveys to confirm the technical feasibility and visual reconnaissance should also be carried out in order to determine the number of inhabitants who would have to be resettled to a safer place outside the dam area. A study should also be done on the environmental aspects. Moreover, an economic comparison with the other alternatives should to be taken into consideration.

2.7.2 Pump Station

Technically, construction of pump stations and availability of pumps with appropriate capacity and quality required for the purpose would not be a problem. Nevertheless, a detailed study of the embilomental impacts including salinity effects on the Gatun watershed and other environmental impacts upon on surrounding areas resulting from recycling water, particularly for the indirect system, should be carried out. An economic analysis should also be performed. Likewise embilomental impacts should be assessed

2.7.3 Barrier Dams

Technically, construction of barrier dams would not be a problem. However, flood control measures during and after construction should be taken into consideration. Likewise environmental impacts should also be assessed.

CHAPTER 3 - CANAL EXCAVATION PLAN

3.1 Routes

There are 4 routes under consideration for the Lock Systems. The 4 routes are made up of variations in the vicinity of Miraflores Lake and alternative alignments through a part of Gatun Lake. In addition, there are 2 proposals for sea level canals, a route (Route 10) well away from the existing canal and a route (Route 14S) which mainly follows the existing canal.

3.1.1 Route I (Route 15 + Third Lock) (Ref. Fig. 3.1.1)

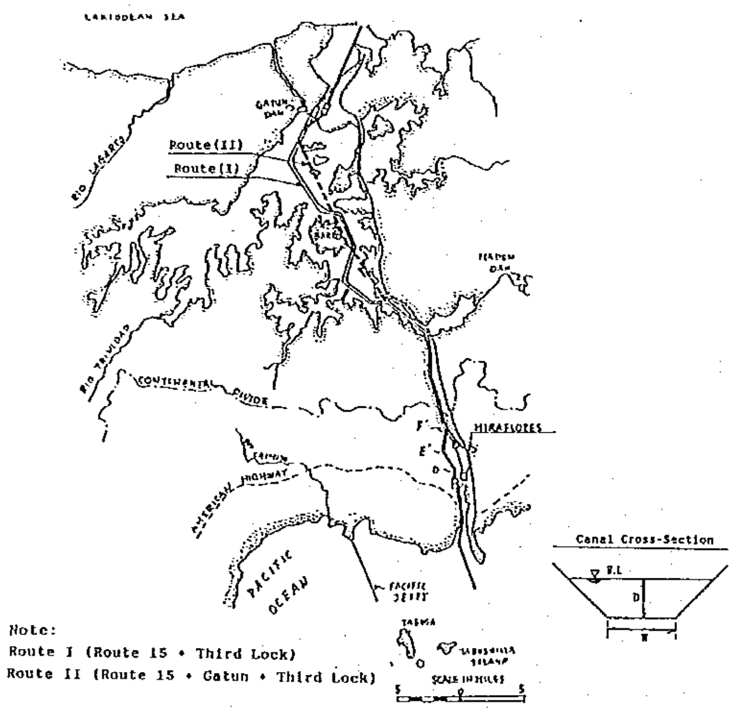
This lock system route makes as much use of the existing canal as possible. Therefore the proposed route detours around the existing Pedro Miguel Lock and Miraflores Lock including Miraflores Lake. New Miraflores locks would be constructed on the west side of the existing canal. The route also detours around the existing Gatun Locks. New Gatun Locks and the approach channel would be constructed on the east side of the existing locks.

From the Caribbean approach Route I drives to the east of the existing route 3 km north of the existing Gatun Locks. It passes through the new locks and joins Gatun Lake merging with the existing route. The route of the channel in Gatun Lake would be almost the same as the existing channel route, with the new canal being widened on the western side of the existing canal to accommodate new requirements. At Pedro Miguel Locks and Miraflores Lake the route detours and takes a new route on the western side of the existing canal. The new route is on the opposite side of Cerro Nitro and may impact its residential area. A new bypass canal connects to the new Miraflores Locks. The proposed new Miraflores Lock site is approximately 1 km away to the western side of the existing locks. The Pacific approach on Route I joins the existing canal approximately 3 km to the Pacific side of the new Miraflores Locks via an area proposed and cancelled in the 1940's for the Third Lock new route. It is proposed that from this point to the Pacific, the western side of the existing route be widened. The distance between the new Gatun Lock and the new Miraflores Lock will be about 55 km.

3.1.2 Route II (Route 15 + Gatun + Third Lock) (Ref. Fig. 3.1.1)

The approach sections are basically the same as Route I, but the route is shorter than Route I by about 6 km over the Gatun Lake section.
From Gatun Locks to the Gamboa entrance Route II follows almost a straight line course and then follows the existing route for about 4 km on the east side of Barro Colorado.

The distance between the new Gatun Lock and the new Miraflores Lock is about 49 km.



Study Case	Route	W. Level	No. of Lifts	No. of Lanes	Ship Size (1000 DWT)	Canal Size W (m) D
L-1	I	90'	2	2	100	301 x 18.7
2	I	85'	2	2	100	301 x 18.7
4	I	90'	2	2	150	343 x 20.9
5	I	85'	2	2	150	343 x 20.9
7	I	90'	2	2	250	399 x 24.2
8	I	85'	2	2	250	399 x 24.2
2'	I	85'	1	2	100	301 x 18.7
10	II	85'	2	2	100	301 x 18.7
13	II	85'	2	2	150	343 x 20.9
16	II	85'	2	2	250	399 x 24.2

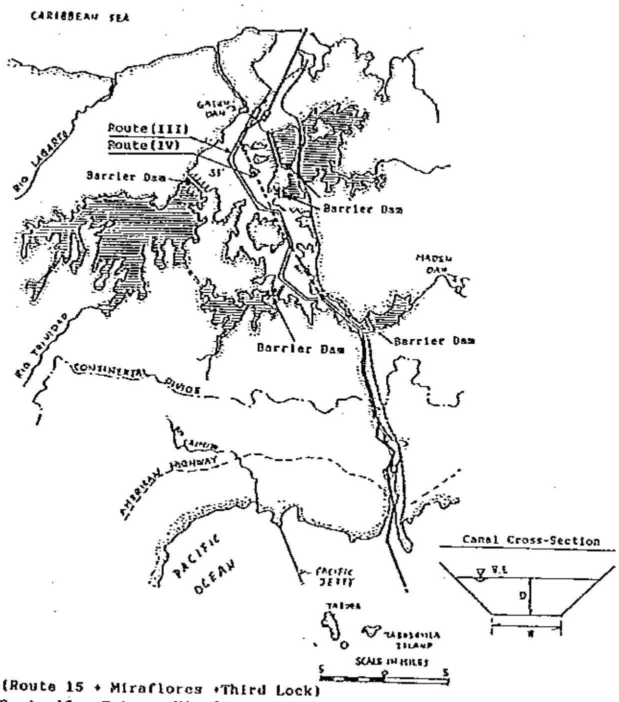
Fig. 3.1.1 Layout of High Rise Lock System for Route I and II

3.1.3 Route III (Route 15 + Miraflores + Third Lock) (Ref. Fig. 3.1.2)

Route III is basically the same as Route I. The lock rise is 55 feet so that Miraflores Lake can be used and the existing route can be followed. The new locks on this route are in different locations from those of the existing canal.

3.1.4 Route IV (Route 15 + Gatun + Miraflores + Third Lock) (Ref. Fig. 3.1.2)

Basically the same as Route II, however, there is a 55 foot lock rise and Route IV therefore passes along Miraflores Lake the same way as Route III and new locks will be constructed.

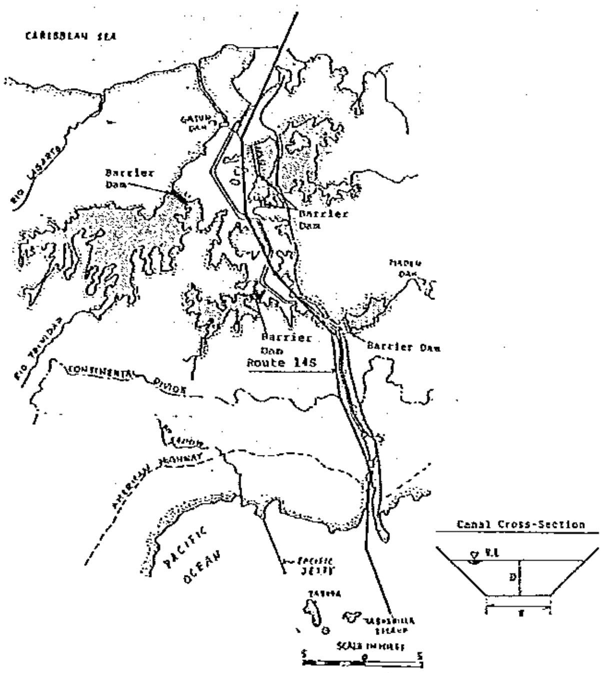


Study Case	Route	W. Level	No. of Lifts	No. of Lanes	Ship Size (1000 DWT)	Canal Size W (m) D
L-3	III	55'	1	2	100	301 x 18.7
6	III	55'	1	2	150	301 x 20.9
9	III	55'	1	2	250	399 x 24.2
11	IV	55'	1	2	100	301 x 18.7
14	IV	55'	1	2	150	343 x 20.9
17	IV	55'	1	2	250	399 x 24.2
L-12	II	30'	1	2	100	301 x 18.7
15	II	30'	1	2	150	343 x 20.9
18	II	30'	1	2	250	399 x 24.2

Fig. 3.1.2 Layout of Low Rise Lock System for Route III and IV

3.1.5 Route 14S (Ref. Fig. 3.1.3)

This is a sea level route which basically follows the existing route. The approach section is the same route as the lock canal proposals but crosses the existing route at 2 places on Gatun Lake, the Gamboa section and the Barro Colorado section.



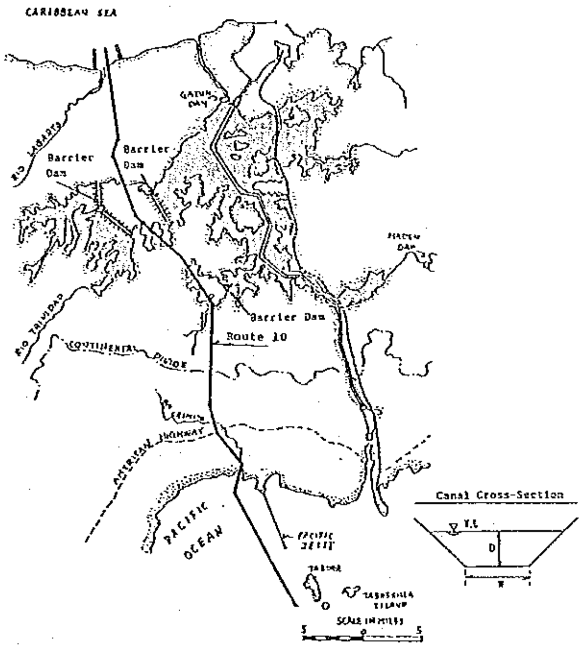
Study Case	Route	W. Level	No. of Lifts	No. of Lanes	Ship Size (1000 DWT)	Canal Size W (m) D
S-7	14S	0	-	1	150	147 x 20.9
8	14S	0	-	2	150	343 x 20.9
9	14S	0	-	1	250	171 x 24.2
10	14S	0	-	2	250	399 x 24.2
11	14S	0	-	1	300	183 x 25.3
12	14S	0	-	2	300	424 x 25.3
16	14S	0	-	50%-1	150	147 x 20.9
				50%-2		343 x 20.9
17	14S	0	-	50%-1	250	171 x 24.2
				50%-2		399 x 24.2
18	14S	0	-	50%-1	300	183 x 25.3
				50%-2		424 x 25.3

Fig. 3.1.3 Layout of Sea Level Canal for Route 14S

3.1.6 Route 10 (Ref. Fig. 3.1.4)

Located approximately 16 km to the south-west of the existing route, using the plains section of Cano river, Gatun Lake and Caimito river.

It is a sea level proposal passing along the Nuebo Chargres on the Caribbean Sea side and along the Puerto Caimito on the Pacific Ocean side.



Study Case	Route	W. Level	No. of Lifts	No. of Lanes	Ship Size (1000 DWT)	Canal Size W (m) D
S-1	10	0	-	1	150	147 x 20.9
2	10	0	-	2	150	343 x 20.9
3	10	0	-	1	250	171 x 24.2
4	10	0	-	2	250	399 x 24.2
5	10	0	-	1	300	183 x 25.3
6	10	0	-	2	300	424 x 25.3
13	10	0	-	50%-1	150	147 x 20.9
				50%-2		343 x 20.9
14	10	0	-	50%-1	250	171 x 24.2
				50%-2		399 x 24.2
15	10	0	-	50%-1	300	183 x 25.3
				50%-2		424 x 25.3

Fig. 3.1.4 Layout of Sea Level Canal for Route 10

3.2 Geology

3.2.1 General Geology

As is shown in Fig. 3.2.1, using the plate tectonics principle, the Panama Canal zone is located at the southern tip of the Caribbean plate.

In the south western part of the Panama isthmus the Cocos Plate slides in under the Caribbean plate making up the border of the Middle American Arc. In addition, in the western part of the Canal zone a transformation feature, the Panama fracture zone, runs north to south. Looking at the Canal zone geologically over a wide area, it is in a complex geological area with the 3 plates (Cocos plate, Nazca plate and Caribbean plate) all converging.

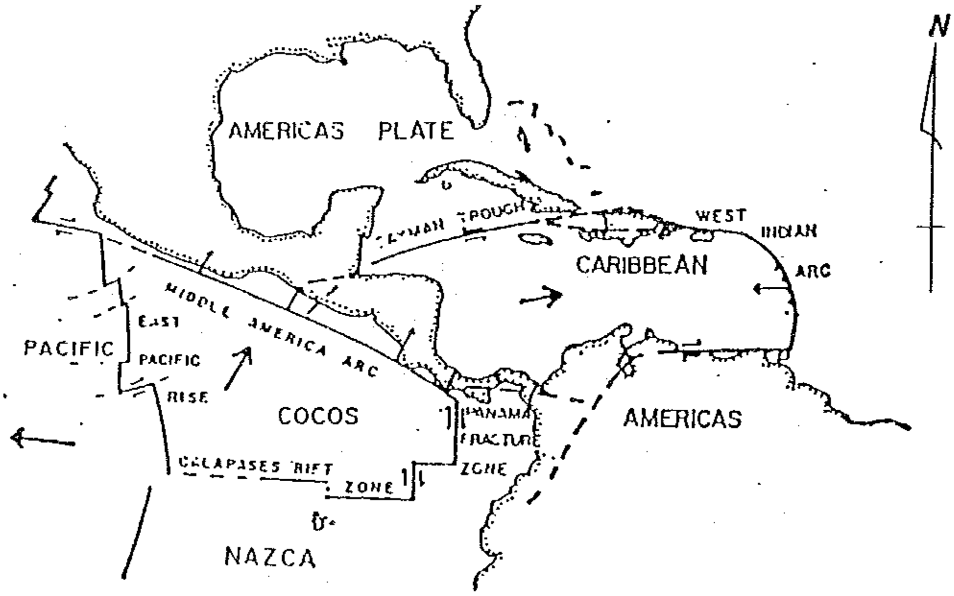


Fig. 3.2.1 Lithospheric Plates of the Middle America Region

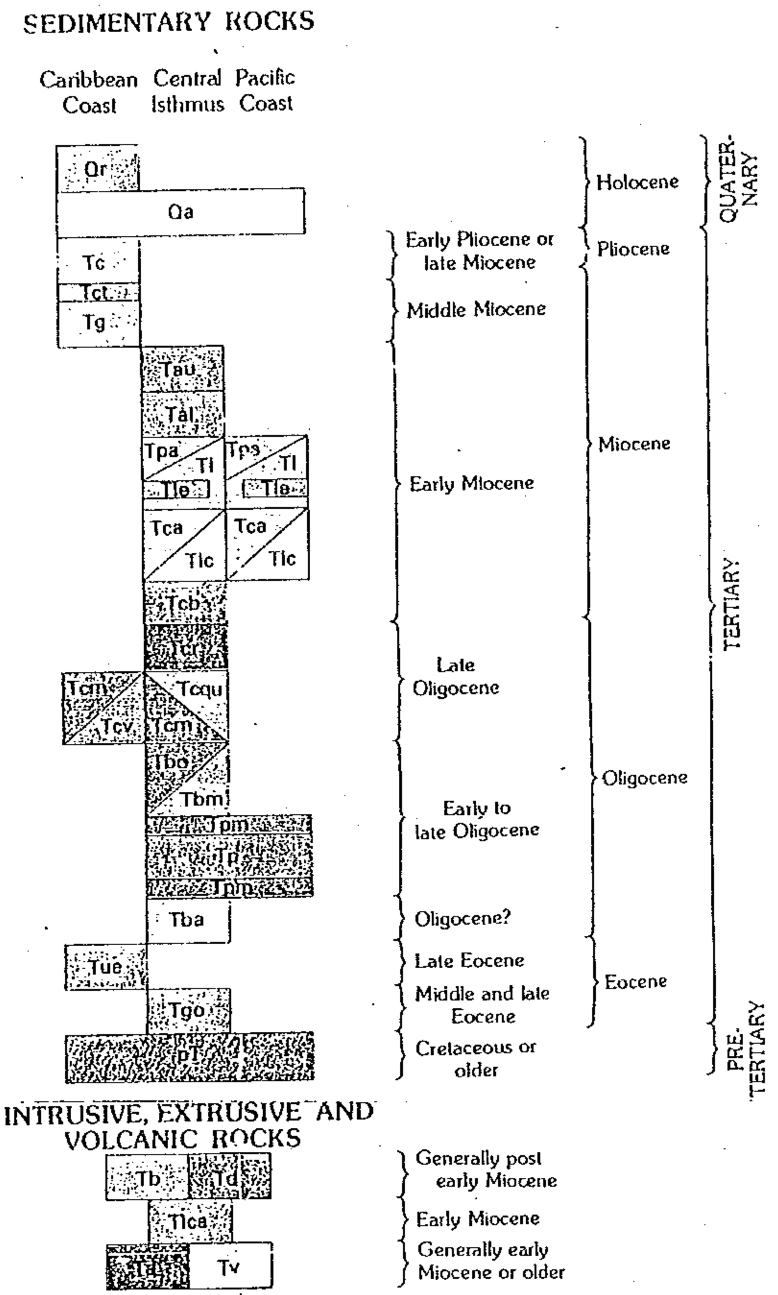
Source: JAX-93 Summary of Geology of Route 10 Panama (1969)
by John C. Bowman Jr.

3.2.2 Topography and Geology of The Canal Area

The Central Panama isthmus, located between the Panama bay in the Pacific and the Caribbean sea in the Atlantic ocean, generally runs in an east west direction with the north south width of the country being approximately 80 kms. The characteristics of the geology forming the topography of the Canal Area are well reflected in the central part where the continental divide runs east to west. The topography of this area is made up of tertiary formations presenting a gentle hill-like mountain range. Other characteristics include a plateau made up of basalt lava and cone-like topography made up of intrusive basalt. On both the Caribbean ocean side and Panamanian bay side the areas with these characteristics are small and plains made up of alluvial sediment predominate.

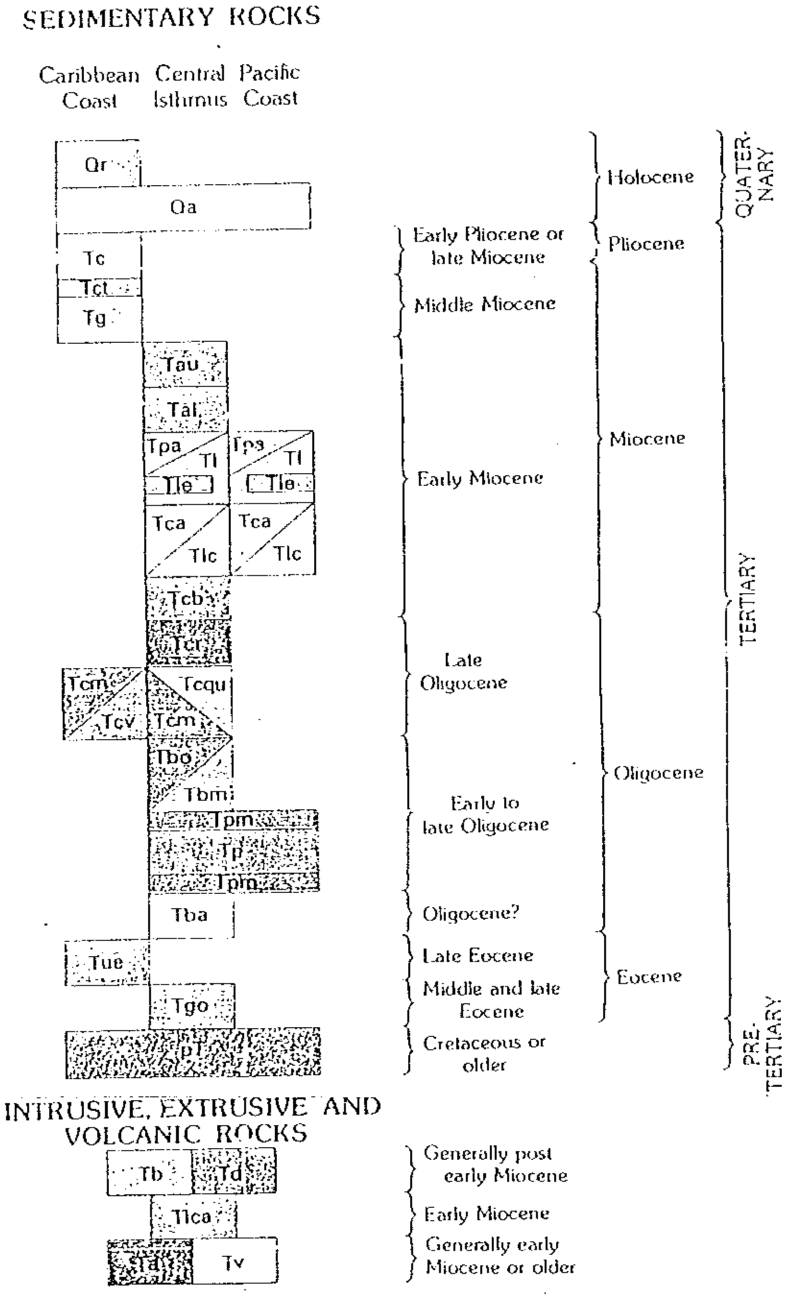
As shown in Fig. 3.2.2, the Canal Area bed rock is made up of tertiary sedimentary rocks and extrusive or intrusive volcanic rocks. In addition, on the Caribbean side plains there is a distribution of quaternary sediments and along the Caribbean ocean channel there are distributions of coral reefs. Moreover there are no active quaternary time volcanoes in the Canal Area.

CORRELATION DIAGRAM



Source: Geological Map of the Panama Canal and Vicinity, Republic of Panama (1980) R.H and J.L. Stewart et al

CORRELATION DIAGRAM



Source: Geological Map of the Panama Canal and Vicinity, Republic of Panama (1980) R.H and J.L. Stewart et al

LEGEND FOR GEOLOGIC MAP OF PANAMA AND CANAL ZONE

Undivided Holocene sediments, principally alluvium or fill	Qa	Sedimentos Holocenos, no diferinciados, principalmente aluvión o relleno
Holocene fringing coral reefs	Qr	Arrecifes coralíferos Holocenos
Chagres Sandstone, late Miocene or early Pliocene. Massive, generally fine-grained sandstone	Tc	Arenisca Chagres, Mioceno superior o Plioceno inferior. Arenisca maciza, generalmente de grano-fino
Toro Limestone, basal member of Chagres Sandstone. Coquina	Tct	Caliza Toro, miembro basal de formación arenisca de Chagres, coquina
Gatun Formation, middle Miocene. Sandstone, siltstone, tuff and conglomerate	Tg	Formación Gatún, Mioceno medio. Arenisca, lutita, toba y conglomerado
Alhajuela Formation, upper member, late early Miocene. Tuffaceous sandstone, calcareous sandstone and limestone	Tau	Formación Alhajuela, miembro superior, Mioceno inferior superior. Arenisca tobacea, arenisca calcarea y caliza
Alhajuela Formation, lower member, late early Miocene. Calcareous sandstone.	Tal	Formación Alhajuela, miembro inferior, Mioceno inferior superior. Arenisca calcarea
La Boca Formation, early Miocene. Mudstone, siltstone, sandstone, tuff and limestone	Tl	Formación La Boca, Mioceno inferior. Esquito arcilloso, lutita, arenisca, toba y caliza
Emperador Limestone, member in lower La Boca. Coraliferous limestone	Tle	Caliza Emperador, miembro en La Boca inferior. Caliza coralifera
Pedro Miguel Formation, early Miocene. Fine-to coarse-grained agglomerate	Tpa	Formación Pedro Miguel, Mioceno inferior. Aglomerado, grano-fino-a grueso
Cucaracha Formation, early Miocene. Bentonic clay shale, carbonaceous clay shale and in lower part, a thin ash flow tuff	Tca	Formación Cucaracha, Mioceno inferior. Arcilla laminada bentonítica, arcilla laminada carbonífera y en la parte inferiór, una capa delgada de ignimbrita
Las Cascadas Formation, early Miocene. Agglomerate and soft, fine-grained tuff	Tlc	Formación Las Cascadas, Mioceno inferior. Aglomerado y toba suave de grano-fino
Culebra Formation, early Miocene. Calcareous sandstone and siltstone	Tcb	Formacion Culebra, Mioceno inferiór. Arenisca calcarea y lutita calcárea
Caraba Formation, late Oligocene. Principally a dacite porphyry agglomerate. In type area, conglomerate, fossiliferous calcareous sandstone and limestone	Tcr	Formación Caraba, Oligoceno superior. Principalmente aglomerado de dacítico pórfido. En area typo, conglomerado, arenisca calcarea y caliza, ambas fosilíferas
Caimito Formation, late Oligocene, marine. Tuffaceous sandstone, tuffaceous siltstone, tuff and foraminiferal limestone	Tcm	Formación Caimito, Oligoceno superior, marino. Arenisca tobácea, lutita tobácea, toba y caliza foraminífera
Caimito Formation, volcanic facies, late Oligocene. Agglomerate and tuffaceous graywacke	Tcv	Formación Caimito, facies volcanicas, Oligoceno superior. Aglomerado y grauvaca tobácea
Quebrancha Limestone, member of Caimito Formation, late Oligocene. Foraminiferal limestone and calcareous siltstone	Tcqu	Caliza Quebrancha, miembro de la formacion Caimito, Oligoceno superior. Caliza foraminífera y lutita calcárea
Bohio Formation, early to late Oligocene. Conglomerate, principally basaltic and graywacke sandstone	Tbo	Formación Bohío, Oligoceno inferior a superior. Conglomerado principalmente basáltico y arenisca (grauvaca)
Bohio Formation, marine facies, early to late Oligocene. Calcareous sandstone and small-pebble conglomerate	Tbm	Formación Bohío, facies marino, Oligoceno inferior a superior. Arenisca calcárea y conglomerado con guijarros pequeños
Panama Formation, early to late Oligocene. Principally agglomerate, generally andesitic in fine-grained tuff. Includes stream-deposited conglomerate	Tp	Formación Panamá, Oligoceno inferior a superior. Principalmente aglomerado generalmente andesítico en tobas de grano-fino. Incluye conglomerado depositado por corrientes
Panama Formation, marine facies, early to late Oligocene. Tuffaceous sandstone, tuffaceous siltstone, algal and foraminiferal limestone. Sandy siltstone in basal part of formation in Quebrancha syncline	Tpm	Formación Panamá, facies marino, Oligoceno inferior a superior. Arenisca tobácea, lutita tobácea, caliza algácea y foraminífera. Lutita arenosa en la parte basal en el sinclinal Quebrancha
Bas Obispo Formation, Oligocene(?). Agglomerate and hard tuff	Tba	Formación Bas Obispo, Oligoceno(?). Aglomerado y toba dura
Marine rocks, late Eocene. Sandstone and siltstone	Tue	Rocas marinas. Eoceno superior. Arenisca y lutita
Gatuncillo Formation, middle and late Eocene. Mudstone, siltstone, quartz sandstone, algal and foraminiferal limestone	Tgo	Formación Gatuncillo, Eoceno medio a superior. Esquisto arcilloso, lutita, arenisca de cuarzo, caliza algácea y foraminífera
Pre-Tertiary. Altered basaltic and andesitic lavas and tuff. Includes dioritic and dacitic intrusive rocks	pT	Anti-Terciario. Lavas y tobas basálticas y andesíticas alteradas. Incluye rocas intrusivas dioríticas y dacíticas
INTRUSIVE, EXTRUSIVE AND VOLCANIC ROCKS		**ROCAS INTRUSIVAS, EXTRUSIVAS Y VOLCANICAS**
Intrusive and extrusive basalt, middle and late Miocene	Tb	Basalto, intrusivo y extrusivo, Mioceno medio y superior
Intrusive dacite and dacite porphyry, Miocene	Td	Dacita, intrusiva y dacita pórfido, Mioceno
Andesite, equal in age to Las Cascadas Formation, early Miocene	Tlca	Andesita, la misma edad de formación Las Cascadas, Mioceno inferior
Intrusive and extrusive andesite, Oligocene and early Miocene	Ta	Andesita, intrusiva y extrusiva, Oligoceno y Mioceno inferior
Volcanic rocks, undifferentiated, generally early Miocene or older	Tv	Rocas volcanicas no diferenciadas, generalmente Mioceno inferior o mas viejo
Contact		Contacto
Fault—Dashed where approximately located; dotted where concealed. Ball and bar on downthrown side; arrows show relative horizontal movement		Falla—Linea interrumpida donde su localid es approximada; punteada donde su localidad es cubierta. Bala y barra indica el desplazamiento descendente; flechas indican el movimiento horizontal relativo
Strike and dip of beds		Direccion y buzamiento de los estratos

Fig. 3.2.2 Schematic Stratigraphy in the Canal Zone

LEGEND FOR GEOLOGIC MAP OF PANAMA AND CANAL ZONE

Undivided Holocene sediments, principally alluvium or fill	Qa	Sedimentos Holocenos, no diferenciados, principalmente aluvion o relleno
Holocene fringing coral reefs	Qr	Arrecifes coraliferos Holocenos
Chagres Sandstone, late Miocene or early Pliocene. Massive, generally fine-grained sandstone	Tc	Arenisca Chagres, Mioceno superior o Plioceno inferior. Arenisca maciza, generalmente de grano-fino
Toro Limestone, basal member of Chagres Sandstone. Coquina	Tct	Caliza Toro, miembro basal de formación arenisca de Chagres, coquina
Gatun Formation, middle Miocene. Sandstone, siltstone, tuff and conglomerate	Tg	Formación Gatún, Mioceno medio. Arenisca, lutita, toba y conglomerado
Alhajuela Formation, upper member, late early Miocene. Tuffaceous sandstone, calcareous sandstone and limestone	Tau	Formación Alhajuela, miembro superior, Mioceno inferior superior. Arenisca tobacea, arenisca calcarea y caliza
Alhajuela Formation, lower member, late early Miocene. Calcareous sandstone.	Tal	Formacion Alhajuela, miembro inferior, Mioceno inferior superior. Arenisca calcarea
La Boca Formation, early Miocene Mudstone, siltstone, sandstone, tuff and limestone	Tl	Formación La Boca, Mioceno inferior. Esquisto arcilloso, lutita, arenisca, toba y caliza
Emperador Limestone, member in lower La Boca. Coralliferous limestone	Tle	Caliza Emperador, miembro en La Boca inferior. Caliza coralifera
Pedro Miguel Formation, early Miocene. Fine-to coarse-grained agglomerate	Tpa	Formación Pedro Miguel, Mioceno inferior. Aglomerado, grano fino a grueso
Cucaracha Formation, early Miocene. Bentonic clay shale, carbonaceous clay shale and in lower part, a thin ash flow tuff	Tca	Formación Cucaracha, Mioceno inferior. Arcilla laminada bentonitica, arcilla laminada carbonifera y en la parte inferior, una capa delgada de ignimbrita
Las Cascadas Formation, early Miocene. Agglomerate and soft, fine-grained tuff	Tlc	Formación Las Cascadas, Mioceno inferior. Aglomerado y toba suave de grano fino
Culebra Formation, early Miocene. Calcareous sandstone and siltstone	Tcb	Formacion Culebra, Mioceno inferior. Arenisca calcarea y lutita calcarea
Caraba Formation, late Oligocene. Principally a dacite porphyry agglomerate. In type area, conglomerate, fossiliferous calcareous sandstone and limestone	Tcr	Formación Caraba, Oligoceno superior. Principalmente aglomerado de dacinco pórfido. En area typo, conglomerado, arenisca calcarea y caliza ambas fosiliferas
Caimito Formation, late Oligocene, marine. Tuffaceous sandstone, tuffaceous siltstone, tuff and foraminiferal limestone	Tcm	Formacion Caimito, Oligoceno superior, marino. Arenisca tobacea, lutita tobacea, toba y caliza foraminifera
Caimito Formation, volcanic facies, late Oligocene. Agglomerate and tuffaceous graywacke	Tcv	Formación Caimito, facies volcanicas, Oligoceno superior. Aglomerado y grauvaca tobácea
Quebrancha Limestone, member of Caimito Formation, late Oligocene. Foraminiferal limestone and calcareous siltstone	Tcqu	Caliza Quebrancha, miembro de la formacion Caimito, Oligoceno superior. Caliza foraminifera y lutita calcárea
Bohio Formation, early to late Oligocene. Conglomerate, principally basaltic and graywacke sandstone	Tbo	Formación Bohío, Oligoceno inferior a superior. Conglomerado principalmente basáltico y arenisca (grauvaca)
Bohio Formation, marine facies, early to late Oligocene. Calcareous sandstone and small-pebble conglomerate	Tbm	Formacion Bohío, facies marino, Oligoceno inferior a superior. Arenisca calcárea y conglomerado con guijarros pequeños
Panama Formation, early to late Oligocene. Principally agglomerate, generally andesitic in fine-grained tuff. Includes stream-deposited conglomerate	Tp	Formación Panamá, Oligoceno inferior a superior. Principalmente aglomerado generalmente andesítico en tobas de grano fino. Incluye conglomerado depositado por corrientes
Panama Formation, marine facies, early to late Oligocene. Tuffaceous sandstone, tuffaceous siltstone, algal and foraminiferal limestone. Sandy siltstone in basal part of formation in Quebrancha syncline	Tpm	Formación Panama, facies marino, Oligoceno inferior a superior. Arenisca tobacea, lutita tobacea, caliza algácea y foraminifera. Lutita arenosa en la parte basal en el sinclinal Quebrancha
Bas Obispo Formation, Oligocene(?). Agglomerate and hard tuff	Tba	Formación Bas Obispo, Oligoceno(?). Aglomerado y toba dura
Marine rocks, late Eocene. Sandstone and siltstone	Tue	Rocas marinas. Eoceno superior. Arenisca y lutita
Gatuncillo Formation, middle and late Eocene. Mudstone, siltstone, quartz sandstone, algal and foraminiferal limestone	Tgo	Formación Gatuncillo, Eoceno medio a superior. Esquisto arcilloso, lutita, arenisca de cuarzo, caliza algacea y foraminifera
Pre-Tertiary. Altered basaltic and andesitic lavas and tuff. Includes dioritic and dacitic intrusive rocks	pT	Anti-Terciario. Lavas y tobas basalticas y andesiticas alteradas. Incluye rocas intrusivas dioríticas y dacíticas
INTRUSIVE, EXTRUSIVE AND VOLCANIC ROCKS		**ROCAS INTRUSIVAS, EXTRUSIVAS Y VOLCANICAS**
Intrusive and extrusive basalt, middle and late Miocene	Tb	Basalto, intrusivo y extrusivo, Mioceno medio y superior
Intrusive dacite and dacite porphyry, Miocene	Td	Dacita, intrusiva y dacita pórfido, Mioceno
Andesite, equal in age to Las Cascadas Formation, early Miocene	Tlca	Andesita, la misma edad de formacion Las Cascadas, Mioceno inferior
Intrusive and extrusive andesite, Oligocene and early Miocene	Ta	Andesita, intrusiva y extrusiva, Oligoceno y Mioceno inferior
Volcanic rocks, undifferentiated, generally early Miocene or older	Tv	Rocas volcanicas no diferenciadas, generalmente Mioceno inferior o mas viejo
Contact	----------	Contacto
Fault--Dashed where approximately located; dotted where concealed. Ball and bar on downthrown side. arrows show relative horizontal movement		Falla --Linea interrumpida donde su localid es approxunada; punteada donde su localidad es cubierta. Bala y barra indica el desplazamiento descendente. flechas indican el movimiento horizontal relativo
Strike and dip of beds		Direccion y buzamiento de los estratos

Fig. 3.2.2 Schematic Stratigraphy in the Canal Zone

3.2.3 Seismology in Panama

For the seismic intensity scale, "The modified metrical scale of 1931" is now used by the Balboa Heights Seismological Observatory in Panama. It is believed that the earthquake of September 1882 is the most severe since 1502 and is rated VI to VII on the Modified Mercalli Scale of 1931. It will be noted that this scale is based on human observation and not instrumental recordings. All the number of times for seismic disturbances felt by Canal Area residents from 1909~1965 are shown below. Scales more than V are not felt in this period.

Scale	Times
I	77
II	107
III	79
IV	36
V	9
Total	308

Modified Mercalli Intensity Scale of 1931 is shown in the following page.

(Source: IOCS Memorandum PCC-3, Seismological History of the Canal Zone and Panama)

Table 3.2.1 Modified Mercalli Intensity Scale of 1931

I	Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel scale)
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel scale)
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing truck. Duration estimated. (III Rossi-Forel scale)

IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls made creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. (IV to V Rossi-Forel scale)
V	Felt by nearly everyone; many awakened. Some dishes, windows, etc. broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VII Rossi-Forel scale)
VI	Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale)
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars. (VIII Rossi-Forel scale)
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars. (VIII+ to IX Rossi-Forel scale)
IX	Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel scale)
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel scale)

XI	Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII	Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

3.2.4 Geology along The Routes

(1) Geology along Route I and III (R 15 + Third lock)

On the Pacific and Caribbean sides, with the exception of a part of the third lock alignment, Route-I is on the same alignment as the existing canal. Through the continental divide Route I is parallel to the existing canal but almost 1 km to the south.

The geology of the bed rock along Route-I is divided into 4 divisions consisting of the Pacific Coast, the Continental Divide, Gatun Lake and the Caribbean Coast. The characteristics of each zone are outlined below. Refer to Fig. 3.2.2 and Fig. 3.2.3 for a more detailed description of each formation type.

a) Pacific Coast Zone: Ranging from the Pacific Coast to the Pedro Miguel lock.

This zone is made up of the 4 main formations listed below.

Panama Formation	(Tpm)
La Boca Formation	(Tl)
Pedro Miguel Formation	(Tpa)
Intrusive and extrusive Basalt	(Tb)

Panama Formation and La Boca Formation are found along the coast and the third lock excavation is made up of Basalt. There are no large land slides and the geology is stable.

b) Continental Divide

This zone extends from the Pedro Miguel locks to the Rio Limon Fault, and is made up of the 6 main formations listed below.

Pedro Miguel Formation	(Tpa)
Cucaracha Formation	(Tca)
Culebra Formation	(Tcb)
La Boca Formation	(Tl)
Las Cascadas Formation	(Tlc)
Intrusive and extrusive Basalt	(Tb)

With the exception of the basalt, all are formations of the Miocene period and will result in land slides on the excavation slopes. In particular Route I passes through 3 km of the Cucaracha Formation which is interbedded with clay shale, likely to lead to major land slides.

c) Gatun Lake Zone: This zone extends from the Rio Limon Fault to the Gatun Lake coast and wholly contained within Gatun Lake. This zone is made up of the 3 main formations listed below.

Bas Obispo Formation	(Tba)
Bohio Formation	(Tbo)
Caimito Formation	(Tcm, Tcv)

These 3 formations are made up of an Oligocene formation and major land slides will not occur inside these formations.

d) Caribbean Coast: This zone extends from the Gatun Lake coast to the Caribbean ocean and includes the third lock excavation site. This zone is made up of the 2 main formations listed below.

Gatun Formation	(Tg)
Undivided Holocene Sediments	(Qa)

In this area the topography is gently sloping and there are no likely problems concerning land slides. It should also be noted that there are coral reefs.

(2) Geology along Route II and IV (R 15 + Third lock + Gatun Lake)

There are no great differences in alignment between Route I and Route II. On the Pacific and Caribbean coasts and through the continental divide, Route I and Route II are the same.

In the Gatun Lake zone most of the route runs to the north of the existing canal but is made up of the same kind of geology as Route I.

(3) Geology Along Route V (Route 10)

The basic geology along Route 10 is divided into the following 5 main categories.

a) Atlantic coast plain

b) The Atlantic coast to the north shore of Gatun Lake

c) The north shore of Gatun Lake to the mouth of Rio Pescado

d) The mouth of Rio Pescado to the Rio Caimito plain

e) The Rio Caimito plain to the Pacific coast

The geological characteristics of each zone are outlined below.

a) Atlantic coast plain

Quaternary sediments are dispersed over Chagres sandstone which is the base rock in the coastal vicinity. The sediments (non-solid sand, silt and clay) are dispersed along the coast and in a narrow area around the river month and the thickness of sediments is less than 10 m.

b) Atlantic ocean to the north shore of Gatun Lake

The geography in this area is hilly with gentle mountain slopes and the basic geology is made up of tertiary miocene Chagres sandstone formations and Gatun formations (sandstone, silt, tuff and conglomerate).

The base is a semi-hard mass and there is no possibility of major landslides.

c) The north shore of Gatun Lake to the mouth of Rio Pescado

This sector applies to the Gatun Lake region. The geology is tertiary oligocene Caimito formation tuffaceous sandstone, tuffaceous siltstone, tuff and limestone). The rock base is stable with no possibility of major landslides.

d) The mouth of Rio Pescado to the Rio Caimito plain

This sector geographically applies to the continental divide. The geology is tertiary miocene volcanic rocks which is made up of volcanic pyroclastic rock (tuff, aglomerate etc.) and intrusive and extrusive basalt with the distribution being very complex. The condition of rocks is generally softened because of alteration. In particular altered tuff could become a cause for landslides.

e) The Rio Caimito plain to the Pacific coast

The sector geographically applies to the Rio Caimito mouth vicinity and the rock base is made up of quaternary unconsolidated sediments (sand, silt and clay).

3.2.5 Rock Base Categories for Excavation

Excavation is divided into land based open excavation (dry) and water based dredging (underwater).

Excavation on land is divided into rock and earth excavation. The former is divided into the following four categories with consideration of the rock base hardness and bedding.

a) High quality rock
b) Intermediate quality rock
c) Low quality rock
d) Soft rock

Earth excavation is generally unconsolidated sediments.

In summarizing existing information, all formations appearing on the respective routes and depths of the weathered zones are categorized as shown in Fig. 3.2.3.

	Rock Classification		Formation	Depth of Weathered Zone (Weathered ← → Sound)
Open Excavation	Rock	High Quality Rock	. Basalt (Tb) . Intrusive Dacite, Porphyry and Andesite (Td.Tlca,Ta.Tv) . Pedro Miguel F.(Tpa) . Bas Obispo F. (Tba) . Emperador L.S. (Tlc)	2m Sound Rock Zone 2m
		Intermediate Quality Rock	. Toro L.S. (Tct) . Gatun F. (Tg) . Bahio F. (Tbo.Tbm) . Caimito F. (Tcm) . Marine rocks (Tue) . Gatuncillo F. (Tgo)	5m 10m
		Low Quality Rock	. Las Cascadas F. (TlC) . Culebra F. (Tcb) . La Boca F. (Tl) . Panama F. (Tp.Tpm)	Weathered Rock Zone all
		Soft Rock	. Cucaracha F. (Tca)	10m all
	Earth	Unconsolidated Sediments		
Dredging	Sediments	Loose Material (Sand & Pebble)		
		Clayey Material (A. Muck) (P. Muck)		all
	Soft Rock	Weathered Rock (Altered Rock)		Weathered Rock Zone all

Fig. 3.2.3 Classification of Rocks and Sediments for Excavation

Note: Rock classification and soil strata characteristics are based on IOCS Jax. 96.

3.3 Excavation Volume

3.3.1 Excavation Zoning

With consideration to the canal structure, construction method and excavation volume, each route is divided up into 5 zones. These zones consist of the Atlantic approach, Gatun Lake, Continental divide, Miraflores and the Pacific approach.

(1) Zones of Route I, II, III, IV

a) Atlantic approach zone (Zone I)

The section between the Atlantic Ocean and Gatun Lock, depending on the size of the ships targeted 11.8 km - 12.5 km in length. Excavation in this zone will be carried out totally by dredging.

b) Gatun Lake zone (Zone II)

Extending from the Gatun Lock to the Rio Charges, Routes I and III will use the existing route with the west side of the canal to be expanded and its length is 42 km. Excavation for these routes will be almost all by dredging in the Gatun Lake. Routes II and IV will be shortcuts of the existing route with a length of 36 km. There are a large number of islands on Gatun Lake that intersect this route but excavation for the most part is calculated as dredging work. However, in the area around Island Barbacoa there are a number of areas where dry excavation can be performed therefore dry excavation will be carried out in this area.

c) Culebra zone (Zone III)

A 10 km sector extending from Gamboa to Paraiso using the existing route with the west side of the canal to be expanded. Excavation will be carried out in 2 steps, step 1, dry excavation works leaving the section where the canal and dry excavation areas meets is executed. Then the section left will be dredged in step 2.

d) Miraflores zone (Zone IV)

The sector between Paraiso and the Miraflores Lock with routes I and II is 9 km and routes III and IV is 9.2 km. The dredging and dry excavation method in this sector will be the same as in the Culebura zone.

e) Pacific approach zone (Zone V)

The sector between the Miraflores Lock and the Pacific Ocean, depending on the size of the vessels targeted, it will be 14.3 km - 21.9 km in length. Because this zone is almost all maritime, excavation will be carried out using the dredging method.

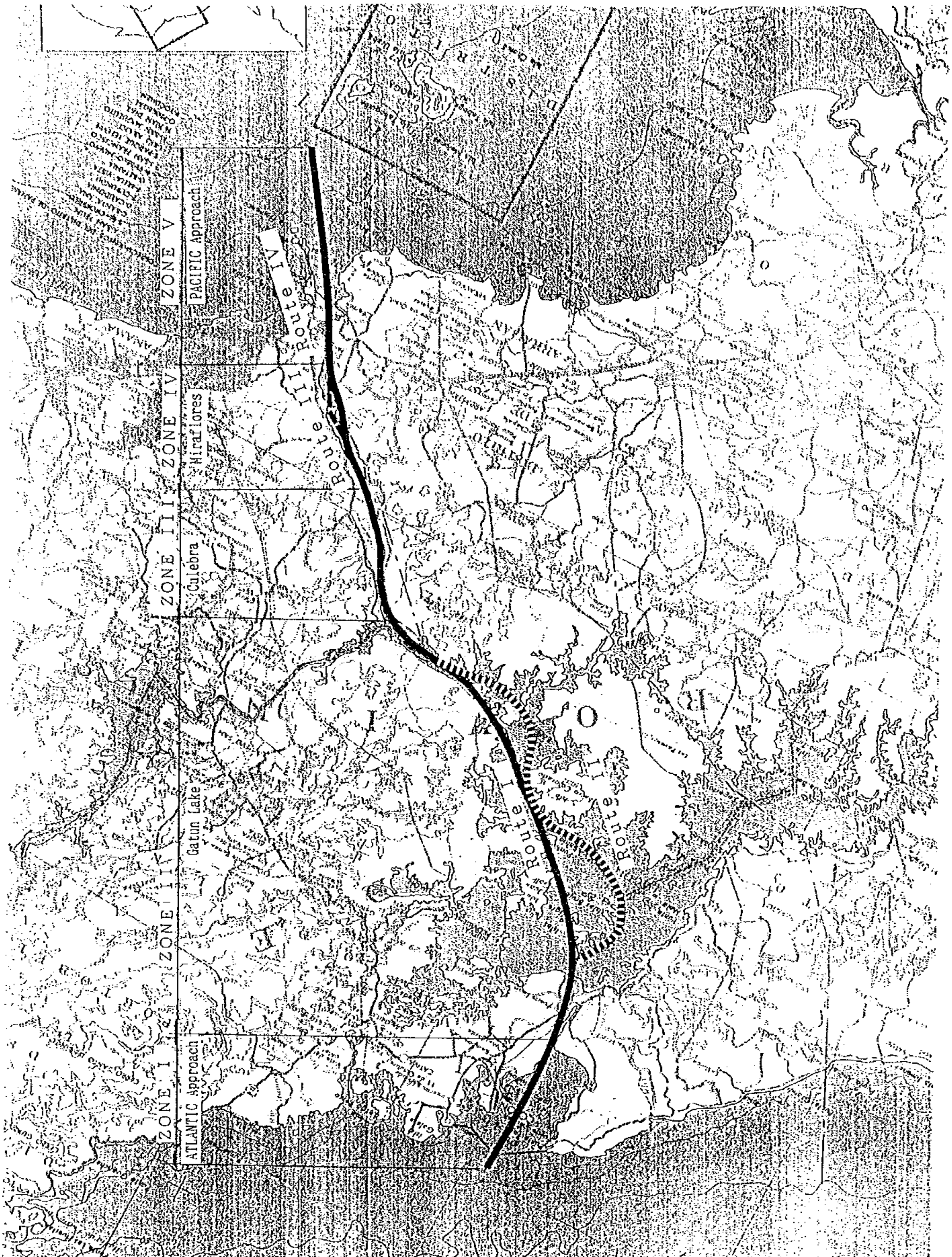


Fig. 3.3.1 Zone Map in Route I. II. III. IV.

(2) Route V (Route 14S)

a) Atlantic approach zone

The section between the Atlantic Ocean and Gatun Lock, depending on the size of the vessels targeted 12.1 km - 12.6 km in length. Excavation in this zone will be carried out totally by dredging.

b) Gatun Lake zone

Extending from Gatun Lock to Juan Grande where the width of Gatun Lake narrows, the zone is 22 km in length. This route sector is the same as that in routes II and IV. This sector intersects the existing canal route in 4 places, considering to keep safe ship operation in the existing canal, all excavation works will be done by dredging method.

c) Culebra zone

This zone extends 27 km from Juan Grande to Paraiso with the route alignment running 1 - 2 km to the west side of, and parallel to the existing canal. It is calculated that the sectors in the existing Gatun Lake will be excavated by dredging while the rest will all be done by dry excavation.

d) Miraflores zone

The sector extending 4 km from Paraiso to Miraflores Lake, it is basically the same as routes I and III. Dry excavation and dredging in this zone will be carried out in the same way as for routes I and III.

e) Pacific approach zone

The sector between the Miraflores Lock and the Pacific Ocean, depending on the size of the vessels targeted, it will be 17.5 km - 23.2 km in length. Because this zone is almost all maritime, excavation will be carried out using the dredging method.

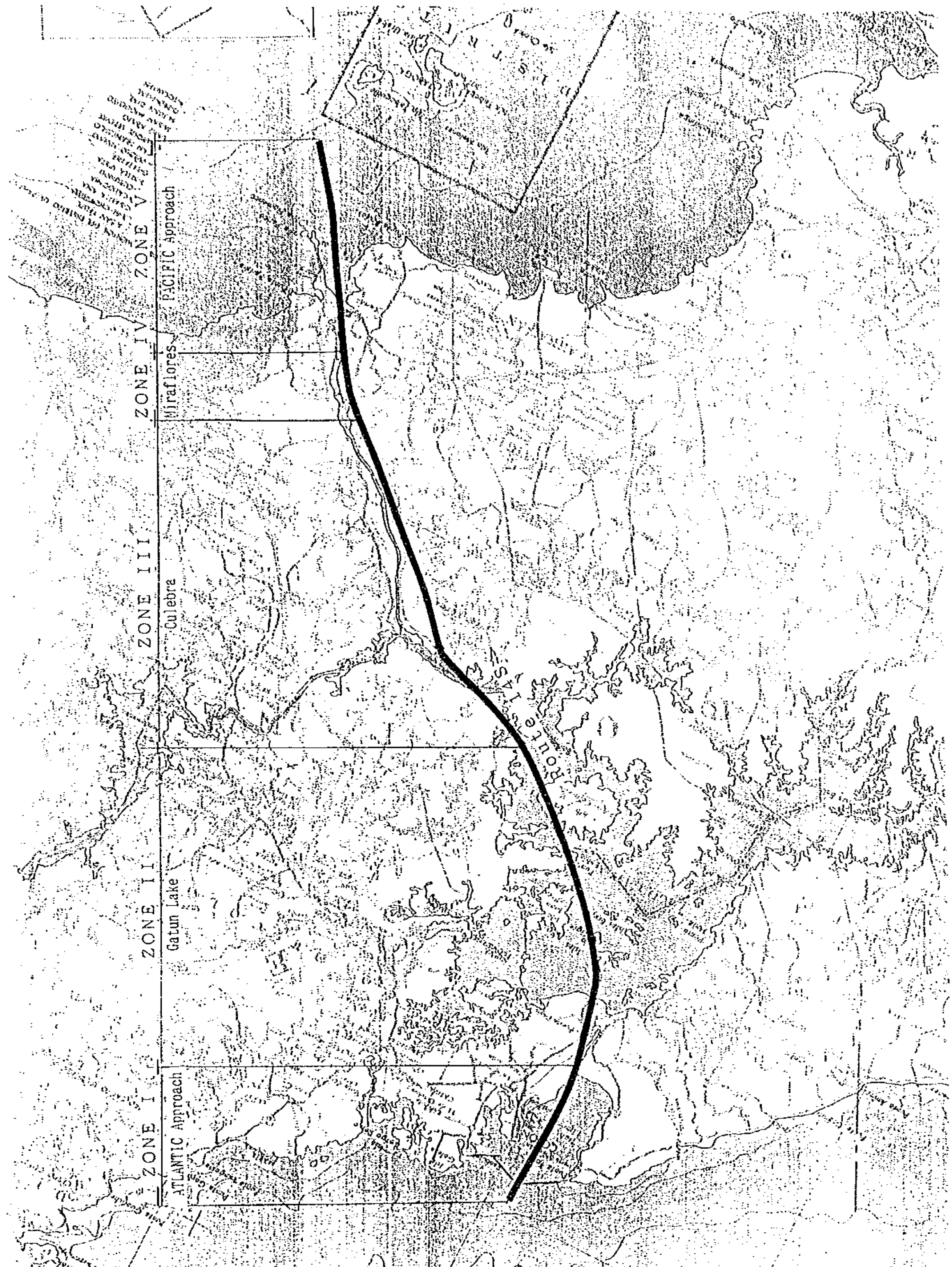


Fig. 3.3.2 Zone Map in Route 14S

(3) Route VI (Route 10)

a) Atlantic approach zone

This zone extends from the Atlantic Ocean to the coast line 3 km to the north east of Nuevo Chagres on the river mouth of the Rio Lagarto and depending on the size of the vessels targeted, it will be 3.5 km - 3.9 km in length. All excavation in this zone will be by dredging.

b) Gatun Lake zone

This zone extends 26 km from the Caribbean coast to the Tidal Gate located in northern port of Gatun Lake. A part of the Gatun Lake will be drained by a barrier dam and dry excavation will be carried out.

c) Continental divide

This zone extends 26 km from the Gatun Lake Tidal Gate to the Pacific side Tidal Gate. This sector will be excavated totally by dry excavation.

d) Caimito zone

This zone extends 5 km from the Pacific side Tidal Gate to Puerto Caimito. This zone contains a lot of swamp area but it is calculated that excavation will be dry.

e) Pacific approach zone

The sector between Puerto Caimito and the Pacific Ocean, depending on the size of the vessels targeted, it will be 25.7 km - 28.7 km in length. All excavation will be carried out using the dredging method in this zone.

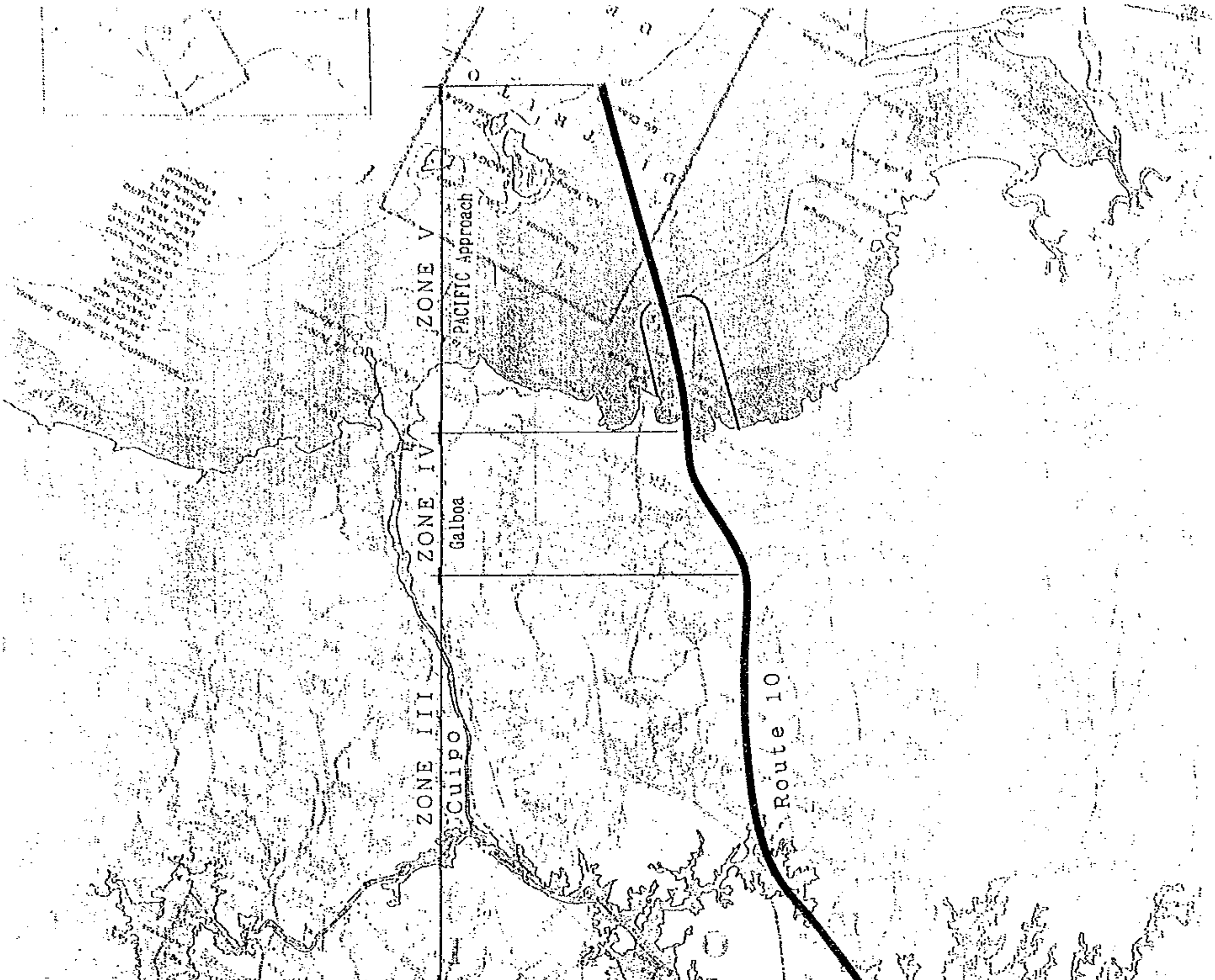


Fig. 3.3.3 Zone Map in Route 10

3.3.2 Excavation Slope

(1) Slope Criteria

Slope criteria for 5 types of geological conditions have been developed based on the criteria provided by the Secretariat and are described below.

Type 1. Strong unaltered or slightly altered volcanic rocks, e.g. basalt and hard agglomerate limestone. Slopes not exceeding 50 meters in height of moderately consolidated intact sedimentary rocks and tuffs. (Fig. 3.3.4)

Type 2. High slopes of moderately consolidated intact sedimentary rocks and tuffs, altered but still solid volcanic rocks. (Fig. 3.3.5)

Type 3. Soft volcano-sedimentary rocks, including soft agglomerate, with partial clay shales, but relatively stable as to form high massive hills. (Fig. 3.3.6)

Type 4. Soft volcano-sedimentary rocks, including soft agglomerate, with frequent development of clay shales and technically highly distorted and sheared, located in a landslide-inflicted zone. (Fig. 3.3.7)

Type 5. Unconsolidated deposits (Fig. 3.3.8)

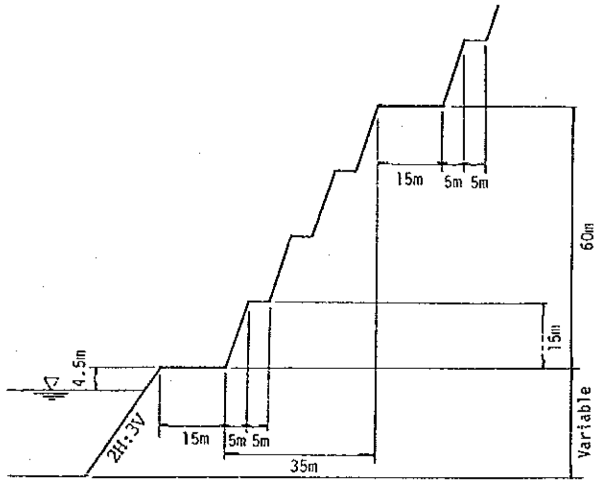


Fig. 3.3.4 Slope Criteria for Type 1

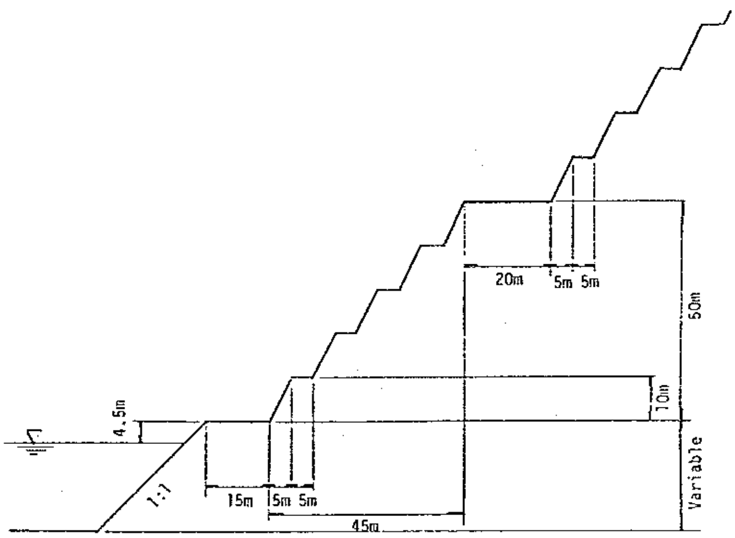


Fig. 3.3.5 Slope Criteria for Type 2

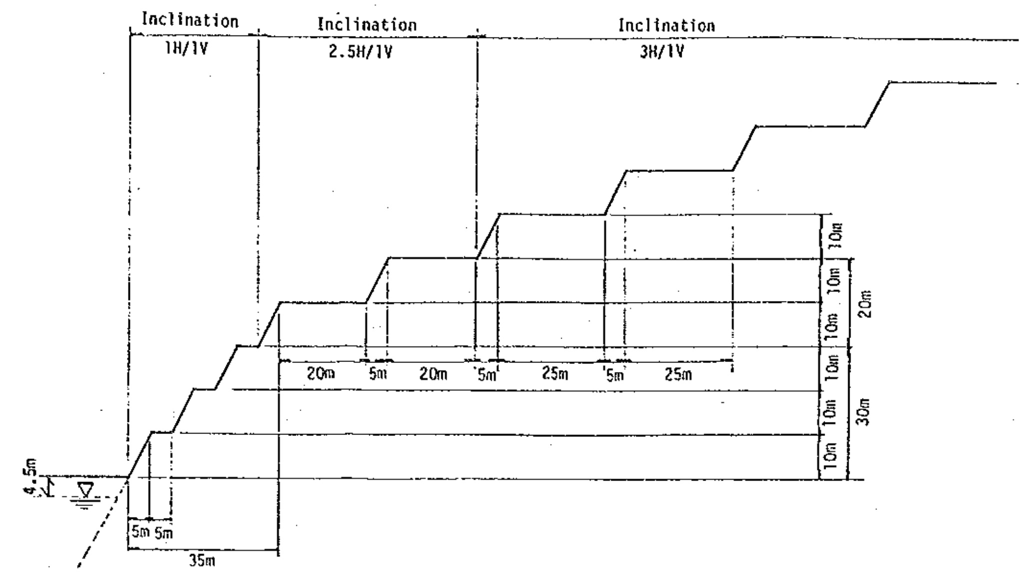


Fig. 3.3.6 Slope Criteria for Type 3

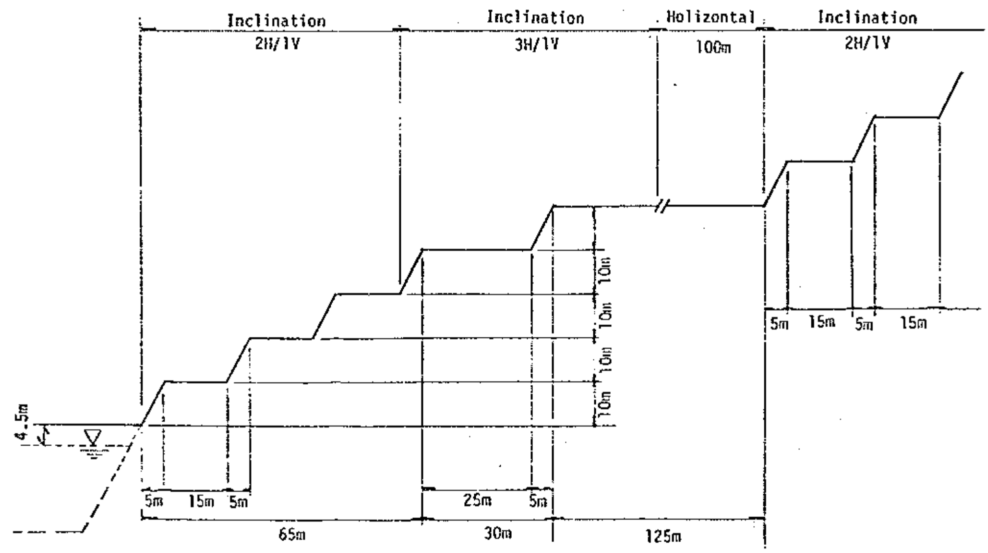


Fig. 3.3.7 Slope Criteria for Type 4

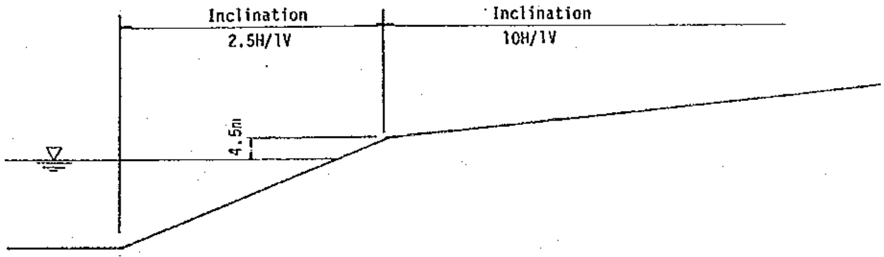


Fig. 3.3.8 Slope Criteria for Type 5

(2) Slope Type Suitability for each Route

a) Routes I, II, III, IV

1) Caribbean Ocean - Gatun Lock

This sector runs along the Rio Chagres plain hilly regions and the existing canal with Gatun formation in Miocene. The depth of excavation is shallow and not overly affected by the excavation volume, the slope type of this sector is applied Type 5.

2) Gatun Lock - Darien Island - Rio Mandinga

The existing canal will be widened in this sector with excavation being almost all existing bed sedimentation. The geology is Caimito Formation and Bohio Formation in tertiary Oligocene and is extremely stable as can be seen at the Isla-Bruja Grande quarry on Gatun Lake. For this reason, Type 1 is appropriate for the slope resulting from widening.

3) Rio Mandinga - Paraiso

This sector is known as the Culebra Cut Zone and has a lot of faults giving a complex geology makeup. There are a lot of landslide formations such as the Cucaracha formation in intrusive basalt and with the exceptions of Gold Hill and Contractor Hill, a Type 4 slope is appropriate.

4) Paraiso - Miraflores Lock

This sector consists of the Panama Formation, La Boca Formation, Pedro Miguel Formation in sedimentary rock and basalt which relatively stable geological formations therefore it is suitable for slope Type 3.

5) Gold Hill, Contractor Hill Cerro Nitro

These hills are made up of hard basalt are suitable for slope Type 1.

6) Miraflores Lock - Pacific Ocean

This sector consists of La Boca Formation in tertiary Miocene, Panama Formation and Basalt. The swamp area consists of Quarternary aluminum sediments along the Rio Chagres plain and the river mouth. The depth of excavation is shallow and not overly affected by the excavation volume making a Type 5 slope appropriate.

b) Route V (Route 14S)

This route is almost the same as those of routes II and IV and the slopes will be basically the same. However, as it is a sea level canal with deep excavation it will be slightly different to the route II and IV cases.

1) Caribbean Ocean - Gatun Lock

This sector runs along the Rio Chagres plain and the existing canal with the surface formation an even covering of sedimentation. The depth of excavation is shallow and not overly affected by the excavation volume making a Type 5 slope appropriate.

2) Gatun Lock - Darien Island

The existing canal will be widened in this sector with excavation being almost all existing bed sedimentation. The geology is Caimito Formation and Bohio Formation and is extremely stable as can be seen at the Isla-Bruja Grande quarry on Gatun Lake. For this reason, Type 1 is appropriate for the slope resulting from widening.

3) Darien Island - Rio Mandinga

The geology along this sector is the relatively stable Caimito formation and Bohio formation. However, the slope resulting from excavation will be a maximum 220 m and as such Type 2 which is extraordinarily stable is appropriate.

4) Rio Mandinga - Larhen Dam

This sector is located in the north east part of the continental divide and the geology is complex, made up of La Boca F. and Las Cascada F. These formations are relatively stable but there are faults and fault sections that have undergone metamorphic effects are seen in places as being prone to landslides. Therefore Type 3 is appropriate for this slope.

5) Larthen Dam - Rio Grande North

This sector is in the continental divide and the geology consists mainly of Culebra F. and Cucaracha F. with a lot of fault areas and seen as having a lot of landslide areas. Slope Type 4 is therefore appropriate in this sector.

6) Rio Grande North - Cerro Escobal

This sector is relatively stable intrusive basalt and Type 1 is appropriate for this slope.

7) Cerro Escobal - Cerro Paraiso

The formations in this sector consist mainly of Cucaracha F. Pedro Miguel F. and intrusive basalt. the formations have faults and the geology is unstable making a Type 4 slope appropriate.

8) Paraiso - Miraflores Lock

This sector consists of the Panama formation, La Boca Formation, Pedro Miguel Formation and extrusive Basalt which relatively stable geological formations and therefore suitable for slope type 3.

9) Miraflores Lock - Pacific Ocean

This sector passes lowlands, and consists of La Boca F. and Panama F. A part of swampland will be quarternary Alluvial Sediment, and the depth of excavation is shallow and not overly affected by the excavation volume making Type 5 slope appropriate.

b) Route VI (Route 10)

This route is located about 10 km west of the existing canal and the slope planning is basically the same as for route I-IV. This route is a sea level canal with deep excavation and it results a slight difference compared with the route I-IV.

1) Caribbean Ocean - North Shore

This sector has a surface formation with an even covering of sedimentation from the Rio Lagarto. Furthermore the depth of excavation is shallow and not overly affected by the excavation volume making a Type 5 slope appropriate.

2) North Shore - Mouth of Rio Pescado

The geology of this sector is Chagres sand and which is relatively stable making a Type 1 slope appropriate.

3) Mouth of Rio Pescado - South of Loma De Jacob

This sector is in the swamp lands of the Rio Pescado plain, the geology is loose and weathered. Type 4 slope is appropriate.

4) South of Loma De Jacob - Continental Divide

This sector is located in the west region of the continental divide with a geology of intrusive basalt and judged to be stable. type 1 slope is appropriate.

5) Continental Divide - Chorrera, Nuevo Emperador Road

This sector is located along the Rio Congo and the geology consists of intrusive basalt in places. However, there are a lot of faults and because of metamorphic effects due these faults, the geological formations are not considered stable. Type 4 slope is appropriate.

6) Chorrera, Nuevo Emperador Road - South of Loma Alta

This sector intersects Quebrada Naranjal and the geology is relatively steep, the geological formation is assumed as being intrusive basalt or extrusive basalt. These basalt are relatively hard and stable making slope Type 1 appropriate.

7) South of Loma Alta - Hill of North Puerto Caimito Vicinity

This sector along the Rio Caimito with weathered extrusive basalt formations is unstable and slope Type 4 is appropriate.

8) Hill of North Puerto Caimito Vicinity - Pacific Ocean

This sector passes along the Rio Caimito plain and the river mouth with the surface formation and even covering of sedimentation from the river. Furthermore the depth of excavation is shallow and not overly affected by the excavation volume making Type 5 slope appropriate.

3.3.3 Rock Classification for Excavation

(1) General

In order to translate a geological characteristics into an engineering ones, each geological zone is divided up into 3 sub zones according to the hardness of the excavated materials; earth, weathered rock and rock referring to existing boring information, land surveys and existing canal reports. Furthermore, these are divided up into 7 categories according to the operating conditions (in order words dry or underwater excavation).

a) Earth (common)
   Diluvial Formation, Alluvial Formation, weathered earth gravel and sand that can be excavated in dry conditions.

b) Rock (weathered)

   Altered rock and weathered rock that can be excavated in dry conditions.

c) Rock

   Rock that is excavated using a bulldozer with a dipper or explosives if carried out under dry conditions.

d) Rock (underwater)

   Rock that is excavated underwater requiring the use of large bucket, large cutter suction pump or explosives and bucket.

e) Dredging (loose material)

   Loose material on the lake bed or marine bed that can be excavated using a suction pump.

f) Dredging (clay)

   Clay on the lake bed or marine bed that can be excavated using a cutter suction pump.

g) Dredging (weathered softrock)

   Altered or weathered rock on the lake bed or marine bed that can be excavated using cutter suction pump.

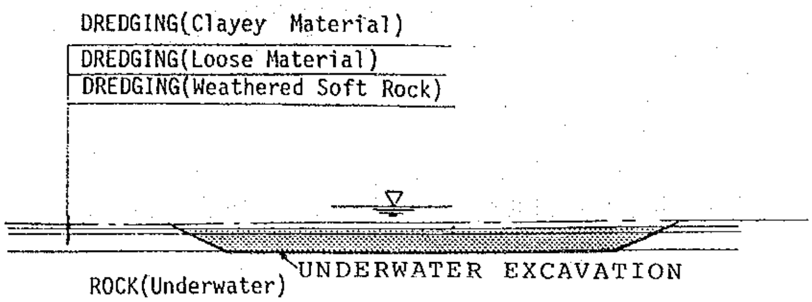


Fig. 3.3.9 Criteria for Marine Section

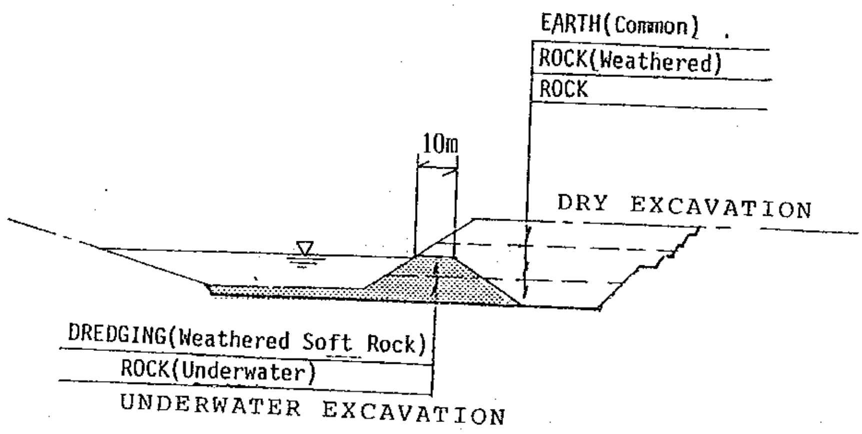


Fig. 3.3.10 Criteria for Existing Canal Section

(2) Route I-IV, VI Excavation Zones

These routes consist of widening of the existing route or an located in the vicinity of it and are made up of the following formations; Panama F., La Boca F., Pedro Miguel F., Las Cascada F., Bas Obispo F., Bohio F. and Caimito F. With the exception of the area around the Culebra Cut on the continental divide, they are relatively stable. In addition, on the vicinity limits of earth construction and with the exception of intrusive basalt, about 10 m from the surface formation is overburden or covered in weathered formation. For this reason, cut volume calculations for over 10 m from the surface layer use the weathered formation. Moreover the continental divide Culebra Cut are has many faults and is a complex geology with metamorphose caused by the faults making it very unstable. For this reason, for a high rise lock, the zone is zoned according to the surveyed faults chart ("Technical Report S-70-9" by P.C.C.) which records existing geological boring information and geology. The depth for a low rise lock would be too great to allow the use of the surveyed faults chart used for a high rise lock and therefore this zone will be aligned with the neighboring zones and a weathered formation 10 m from the surface formation will be assumed.

There are large areas of plains and relative few mountain areas with the overburden for all zones at 4 m. It is calculated that the surface formation of the Gatun Lake and Ocean approach beds consist of 2 m of Alluvial clay materials and under the surface formation at 2 - 4 m there is 2 m is Alluvial loose materials.

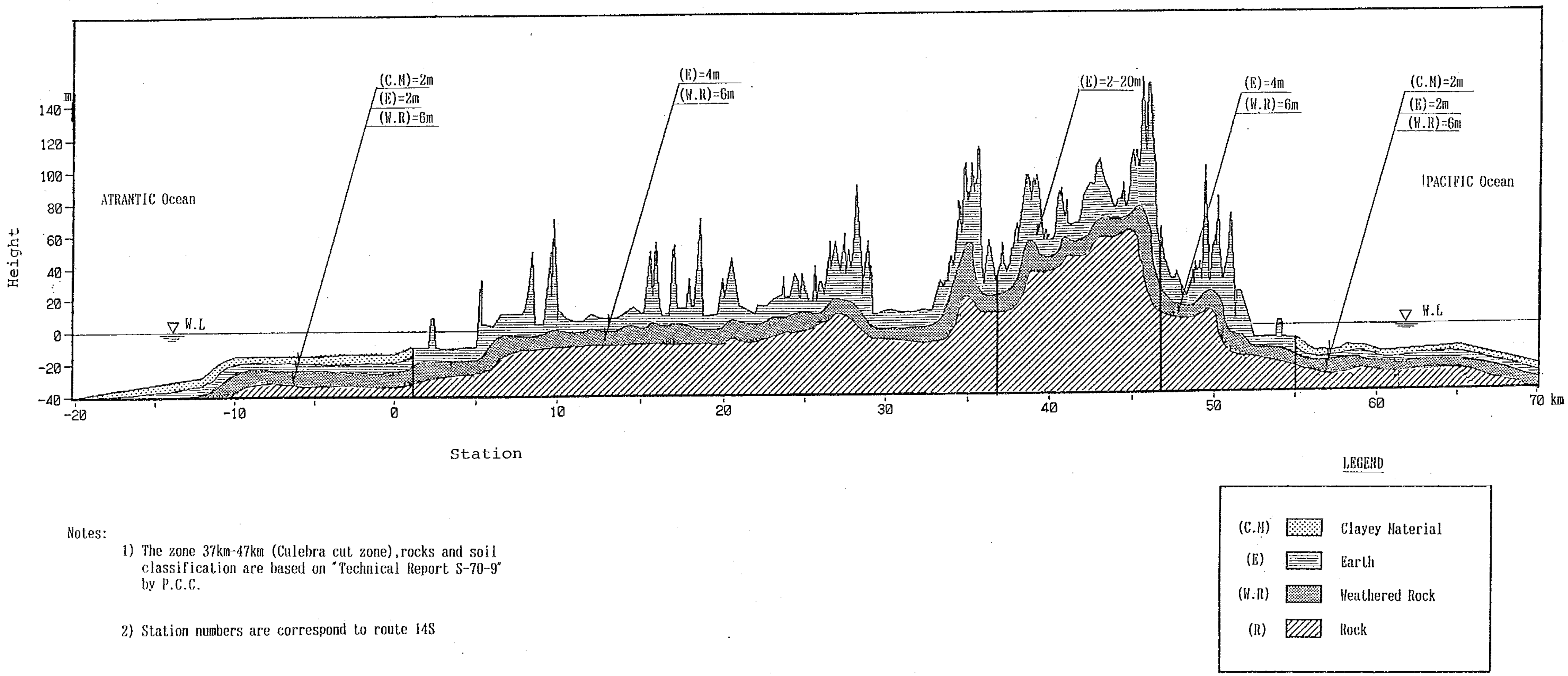
(3) Route V (Route 10)

According to the Anderson Report the geology of the route is made up of Gatun sandstone (Gatun F.), Chagres sandstone (Chagres F.), extrusive basalt, intrusive basalt and Caimito F., etc. and soft altered volcanics. Of these, the Caimito formation is thought to be hard and dense as can be seen at the Gatun Rock Quarry. In addition, sandstone, intrusive basalt and sections of extrusive basalt are dense and hard while the rest of the rest of the extrusive basalt and various formations are in relatively altered states. Furthermore, the soft altered volcanics in the vicinity of the north west slope of the continental divide consist of many faults, the rocks are in an advanced altered state and is all considered to be soft rock or soil. The basic formation from the Caribbean Ocean to Gatun Lake, for which there is almost no boring data, is assumed to be sandstone. In the Caimito F. from Gatun Lake to Rio Pescado, and the continental divide extrusive basalt region overburden is present in considerable quantity. This is considered to be 4 m and the formation underneath is considered to be 6 m of weathered. The layer under this is calculated as being hard rock. Other area will be treated as earth, sand and soft rock zones with reference to IOCS Memorandum JAX Boring Log Report (IOCS Jax-93 Report).

3.3.4 Typical Cross Sections of Canals

Fig. 3.3.11 (1) and (2) show geologic profiles of Route 14S and Route 10. Considering rock and soil characteristics above, typical cross sections of the Canals are shown Fig. 3.3.12 - Fig. 3.3.14.

Geologic Profile (Route I, II, III, IV, 14-S)



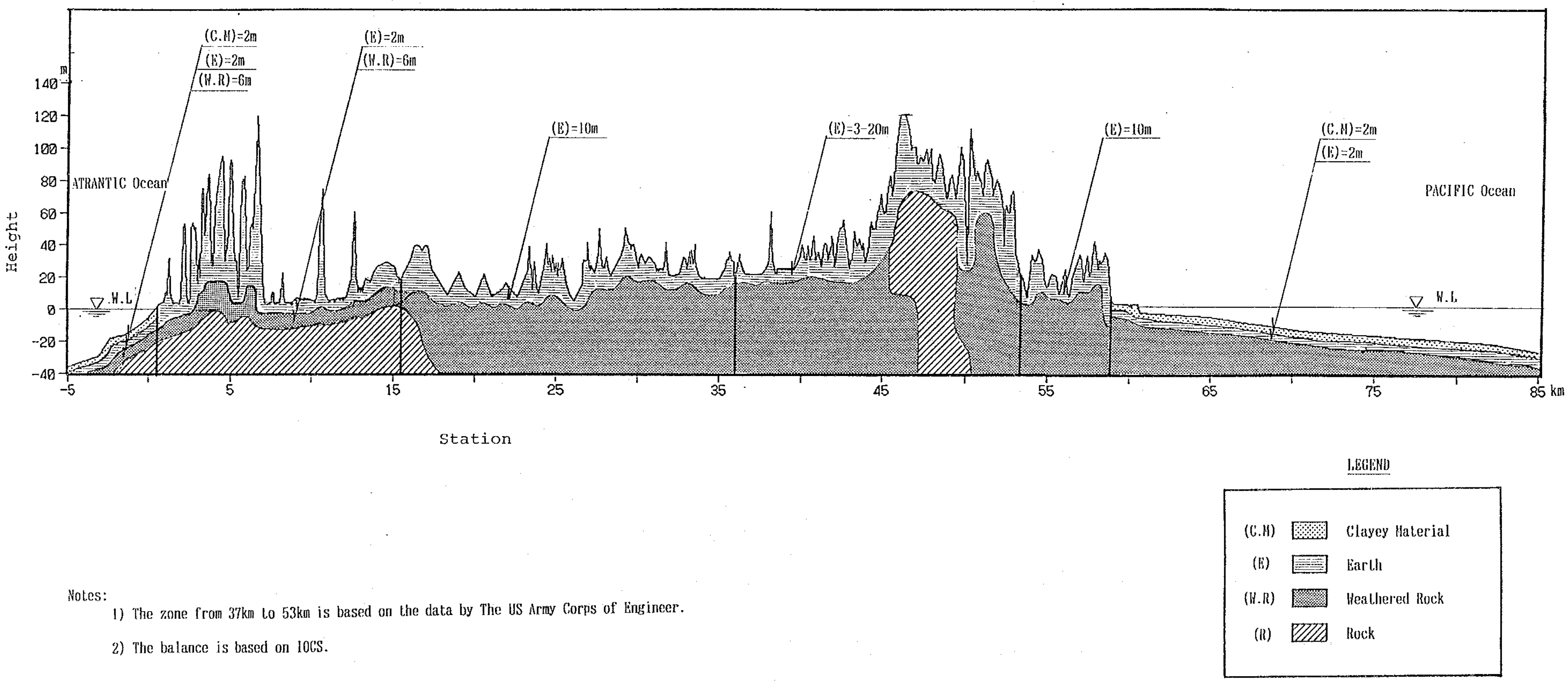
Notes:

1) The zone 37km-47km (Culebra cut zone), rocks and soil classification are based on "Technical Report S-70-9" by P.C.C.

2) Station numbers are correspond to route 14S

Fig. 3.3.11(1) Geologic Profile (Route I, II, III, IV, 14S)

Geologic Profile (Route 10)



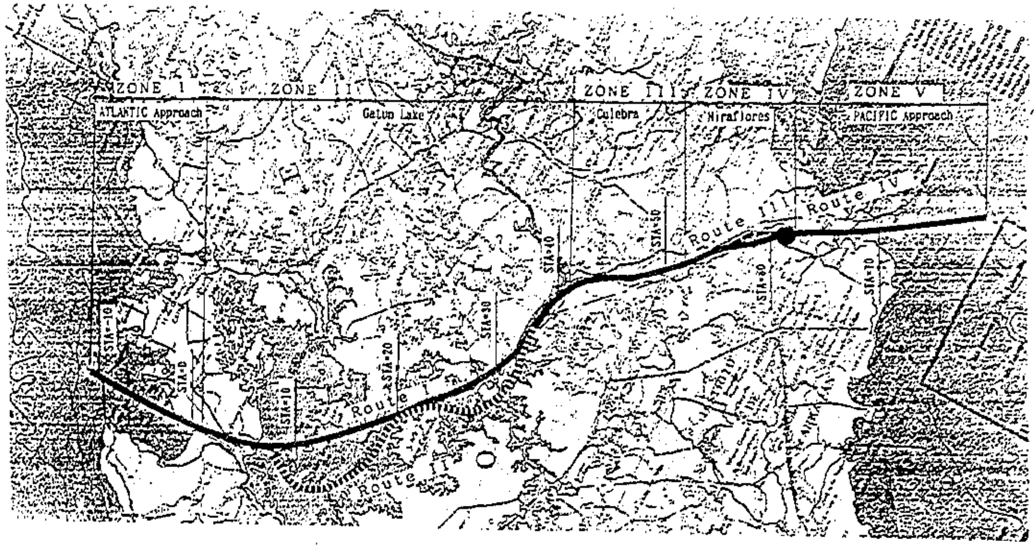
Notes:

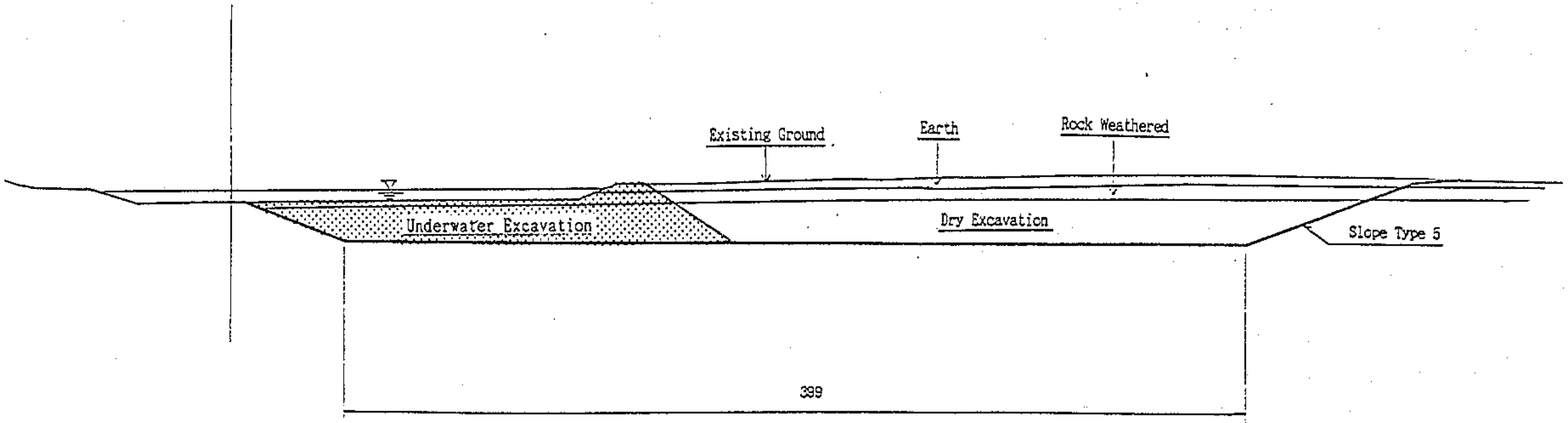
1) The zone from 37km to 53km is based on the data by The US Army Corps of Engineer.

2) The balance is based on IOCS.

Fig. 3.3.11(2) Geologic Profile (Route 10)

L-7
STA.62+00
GH=-7.0





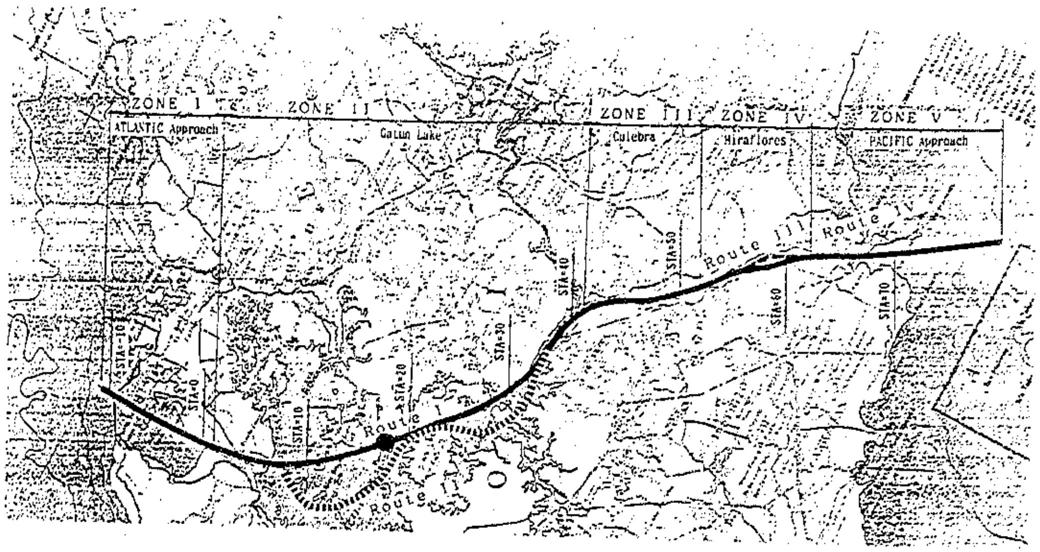
Note : GH = Ground Height

Fig. 3.3.12 Cross Section for L-7 Case

L-18

STA.17+00

GH=53.0



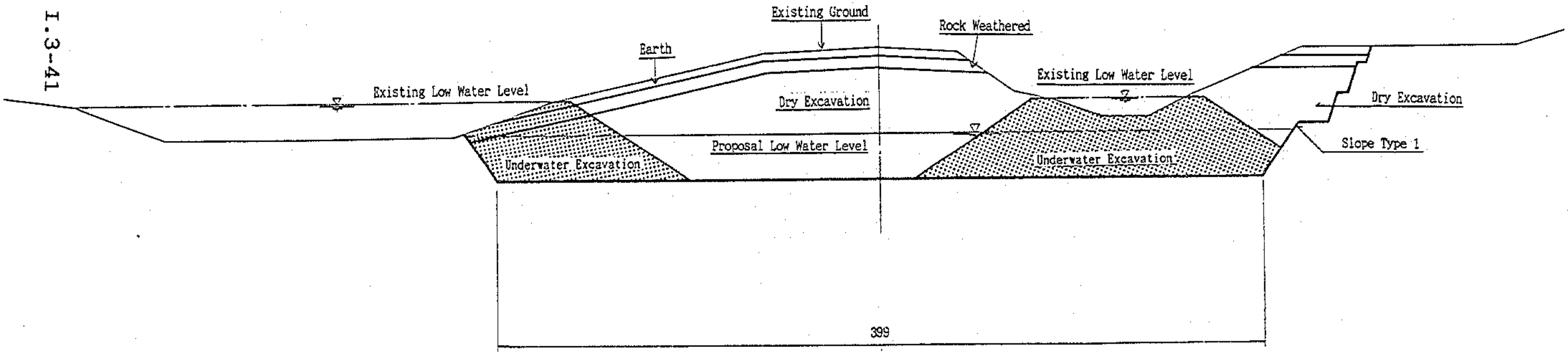


Fig. 3.3.13(1) Cross Section for L-18 Case

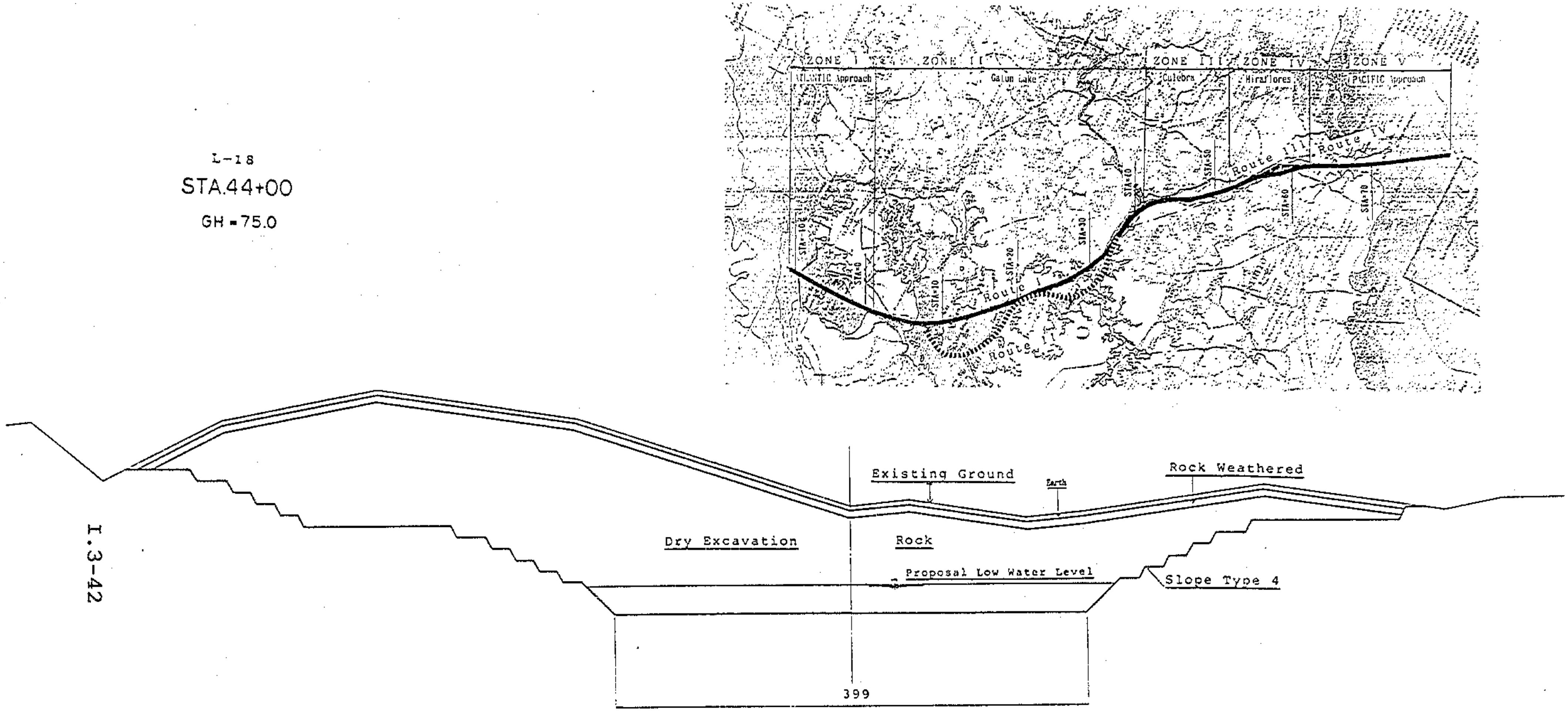
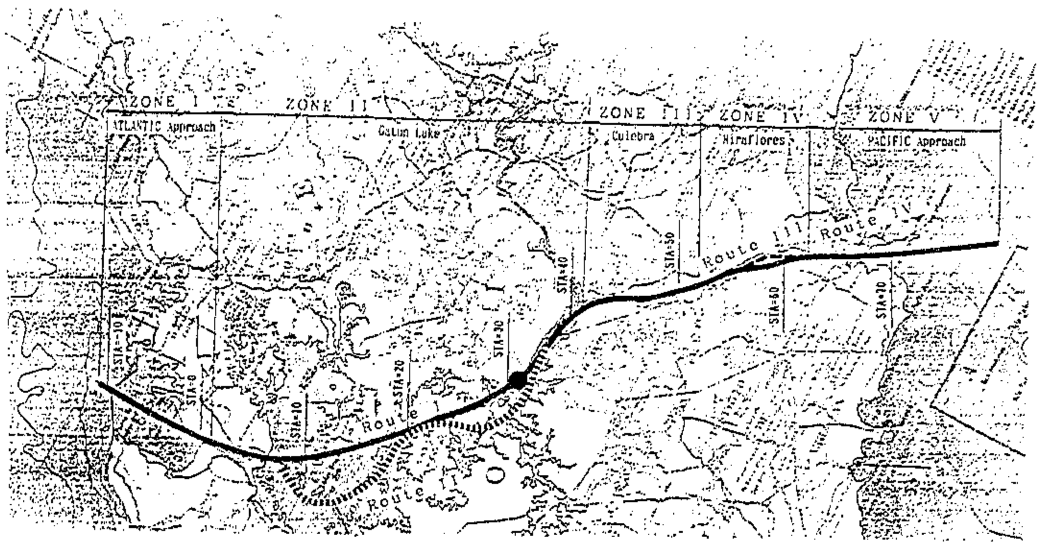


Fig. 3.3.13(2) Cross Section for L-18 Case

L-18

STA. 31+00

GH= 12.0



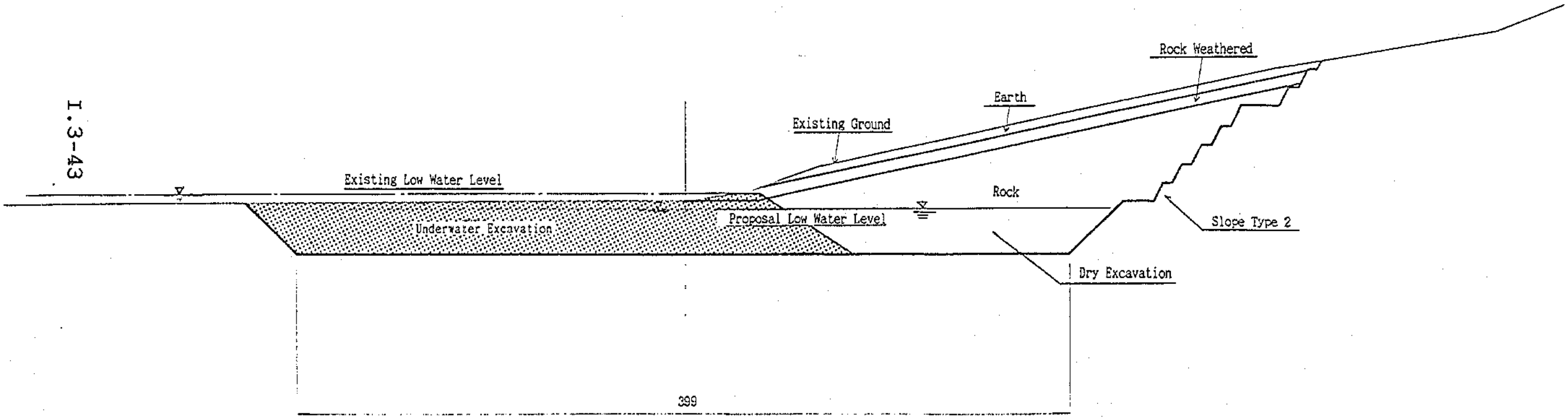
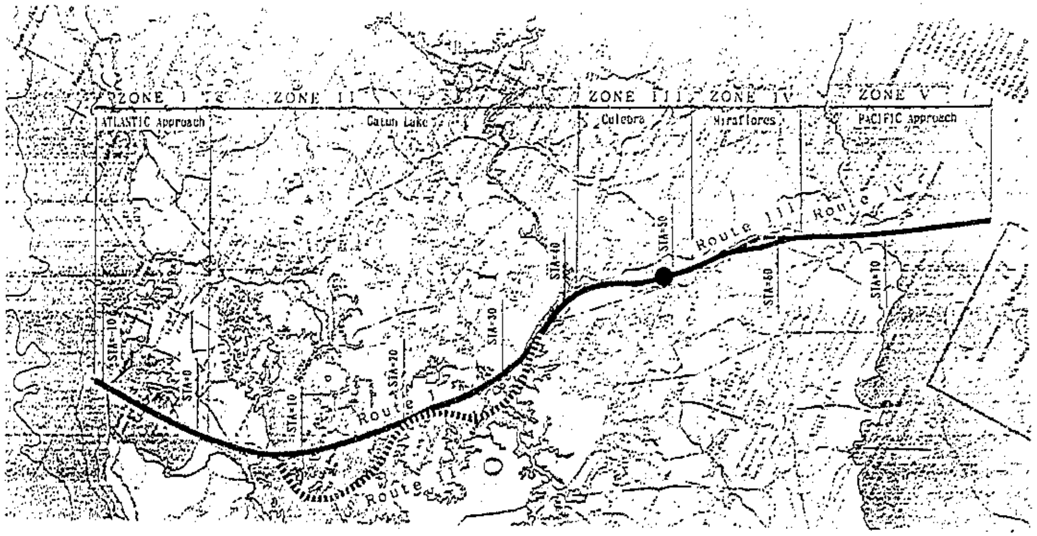


Fig. 3.3.13(3) Cross Section for L-18 Case

L-18

STA. 49+00

GH = 35.0



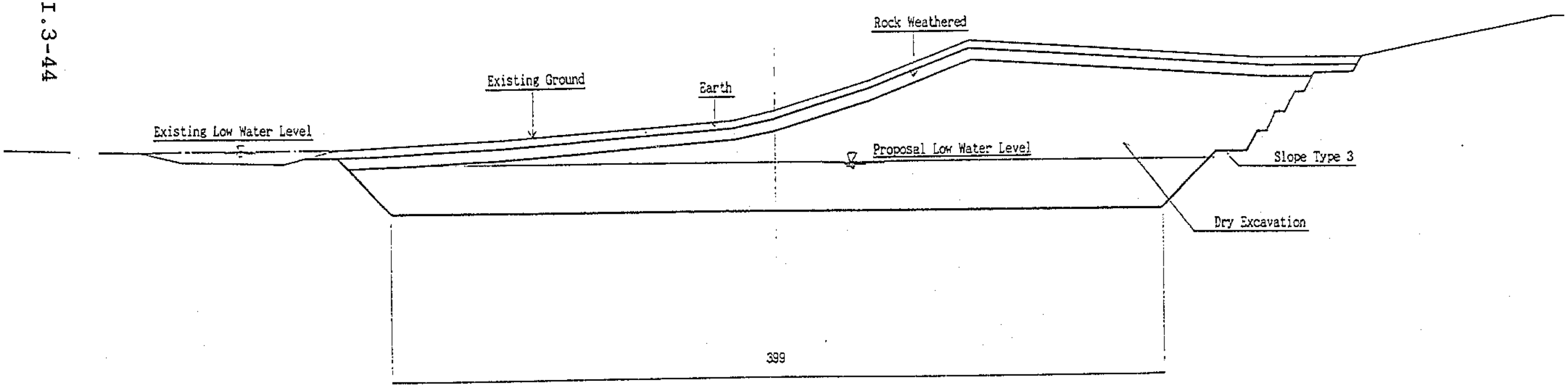
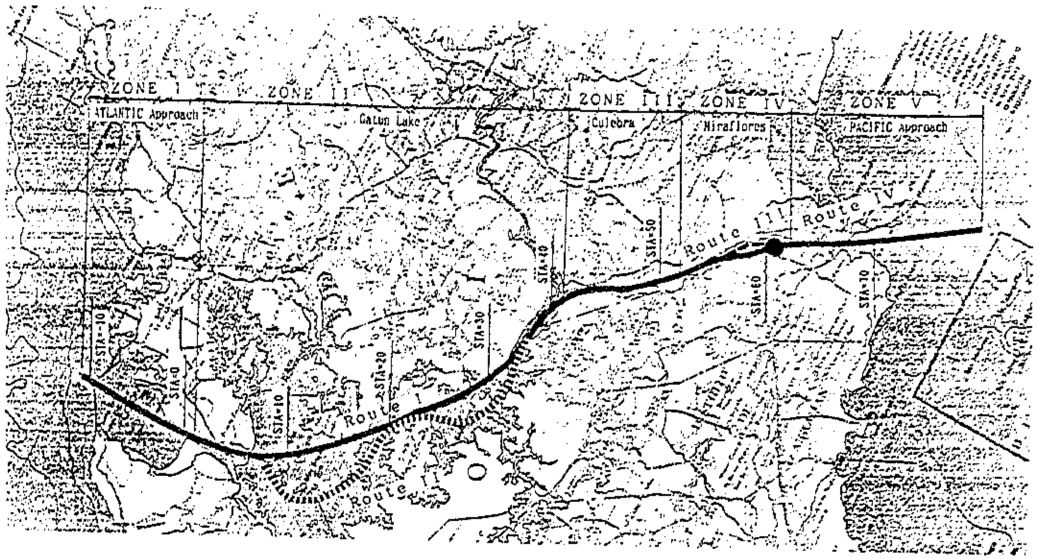


Fig. 3.3.13(4) Cross Section for L-18 Case

L-18

STA 61 00

GH=-7.0



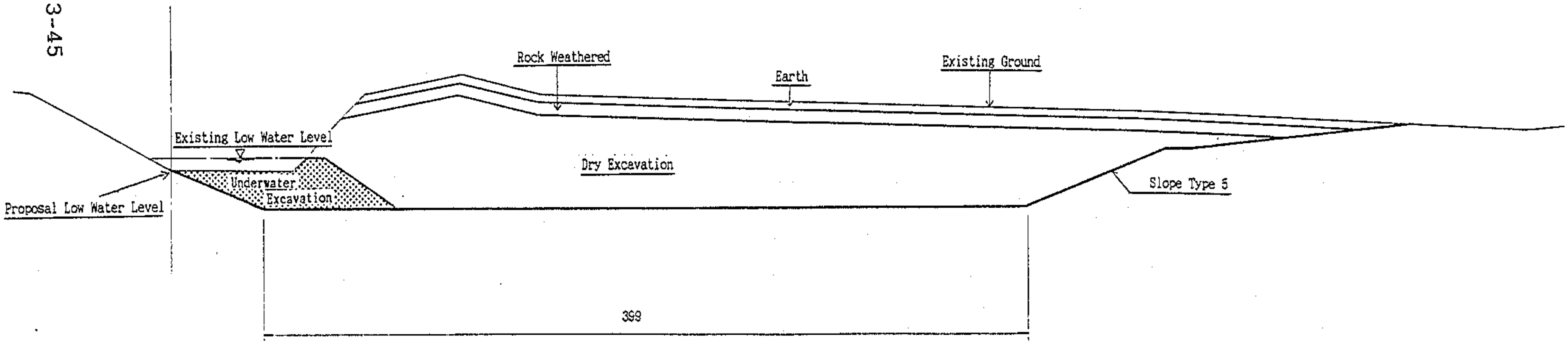


Fig. 3.3.13(5) Cross Section for L-18 Case

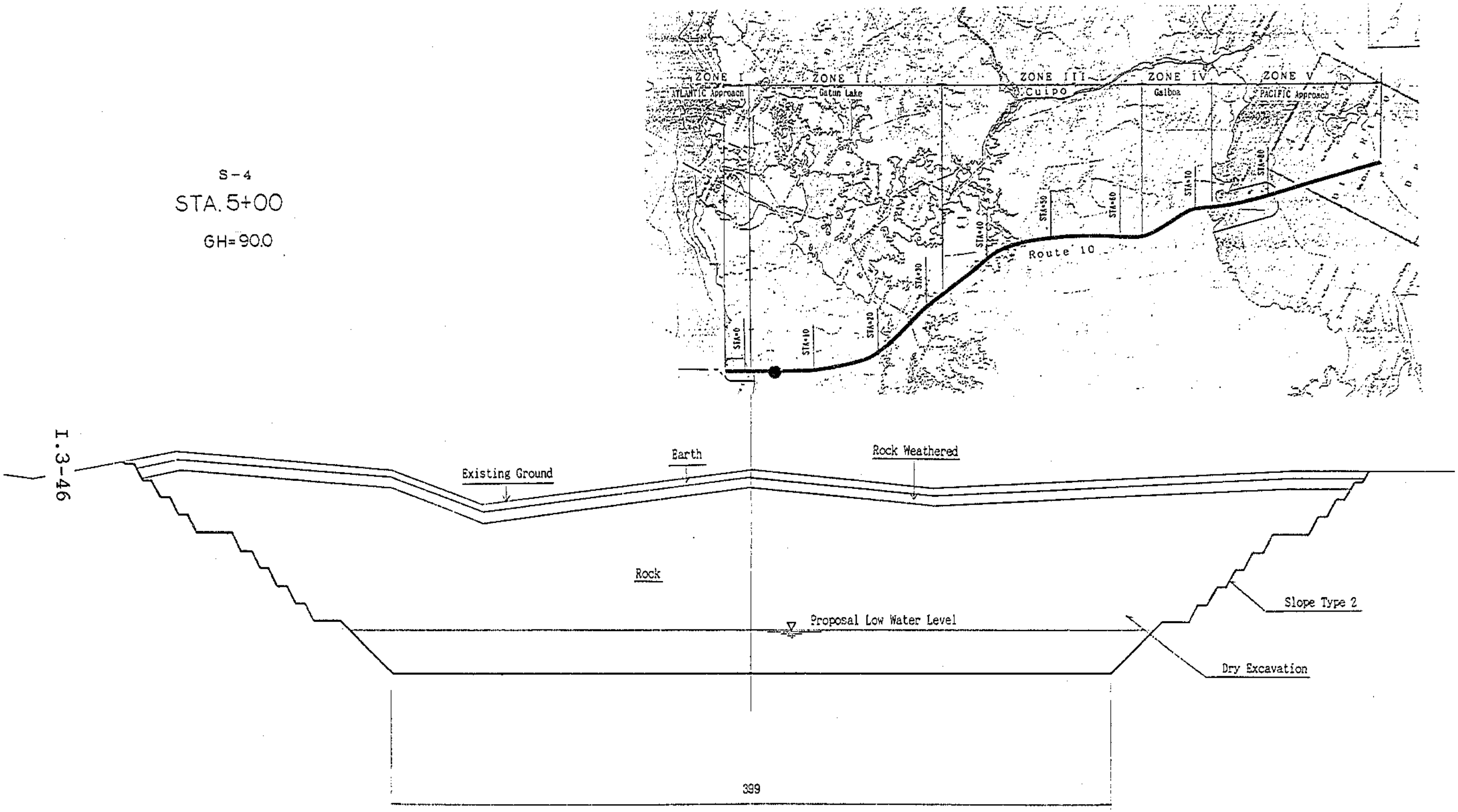


Fig. 3.3.14(1) Cross Section for S-4 Case

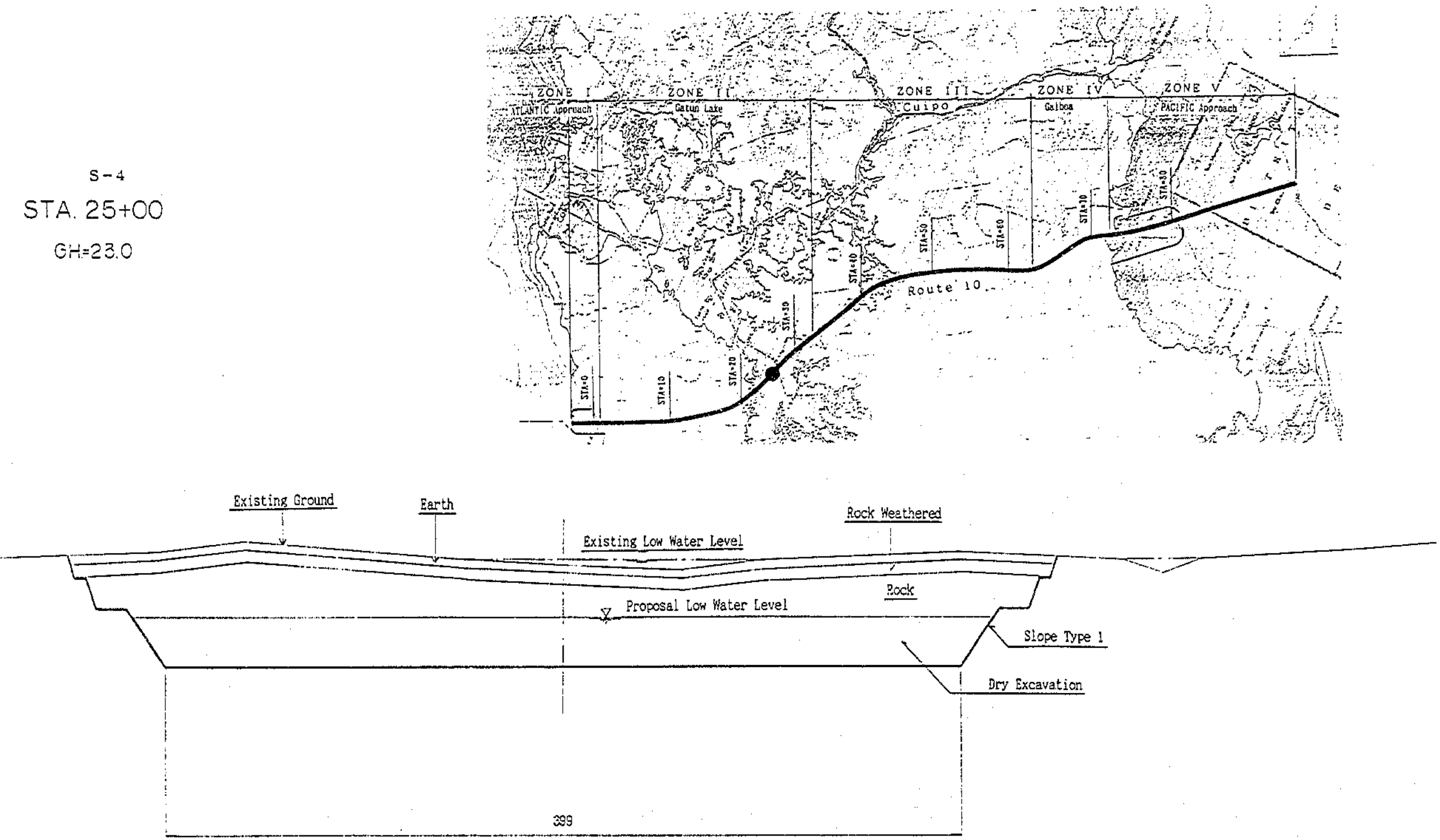
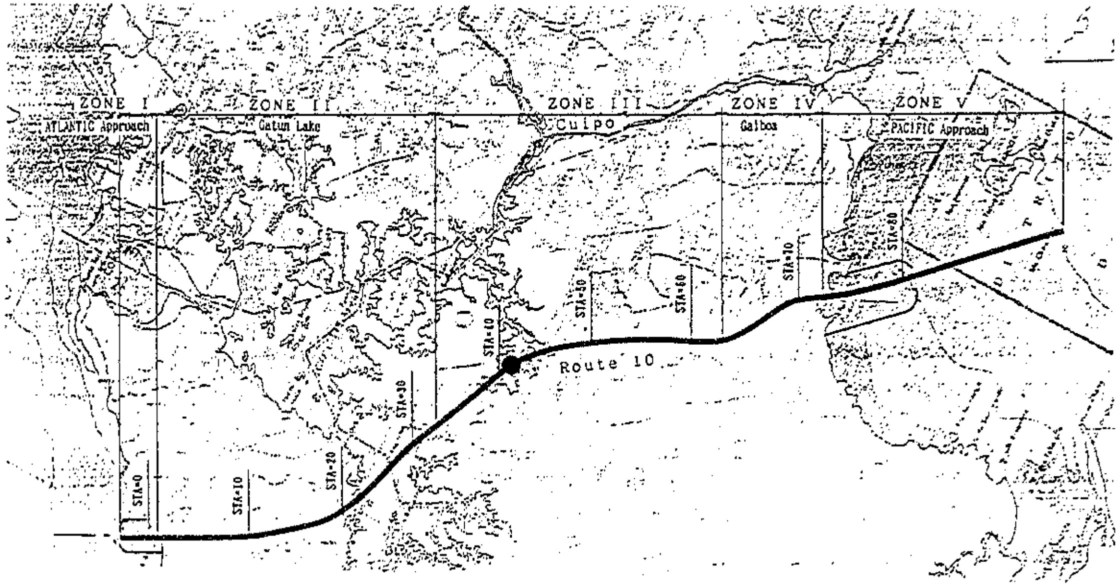


Fig. 3.3.14(2) Cross Section for S-4 Case

S-4

STA. 41+00

GH=35+00



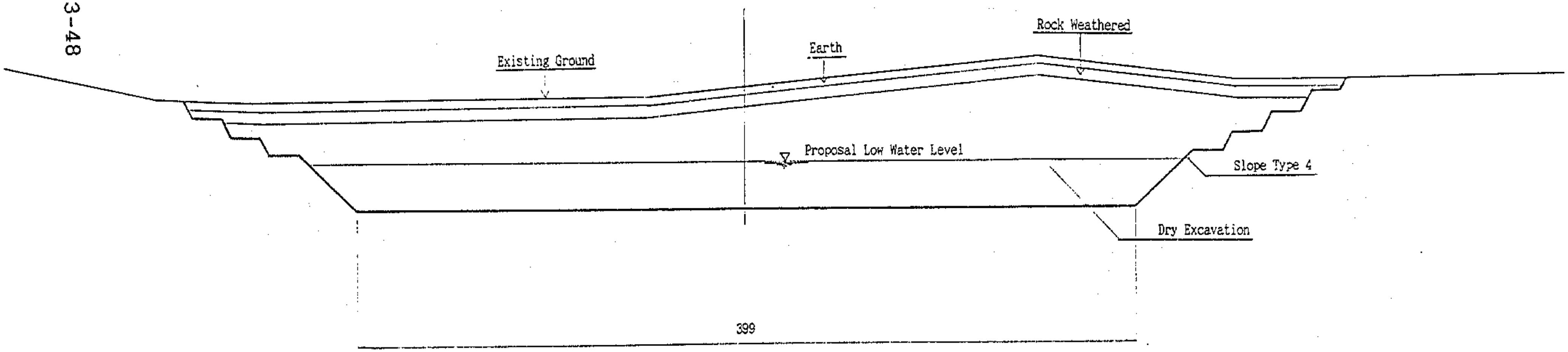


Fig. 3.3.14(3) Cross Section for S-4 Case

3.3.5 Cross-section Preparation

Cross-sections were prepared at a scale of 1:2000 using maps and hydrographic charts. The cross-section locations were chosen giving due consideration to topographical variations.

Maps used

(1) Topographical map (1:25,000 by the Defence Mapping Agency)

(2) Hydrographic map (1:25,000 by IGNTG)

(3) Hydrographic map (1:50,000 by IGNTG)

(4) Panama Canal Hydrographic Survey (1:3,000 and 1:1,000 by P.C.C.)

(5) Plates of Maps and Sections (Maps 1:3,000, Sections 1:1,000 Technical Report S-70-9, by P.C.C)

3.3.6 Excavation Volume

The excavation volume tables were composed according to 37 classifications. The results are presented in the following Table 3.3.1.

Calculation sheets by cross section method of each study case are shown in Appendix 3.

Excavation volume has been also checked by means of mean height method and confirmed to be reasonable.

3.3.7 Dispose Area

Excavated materials are assumed to be disposed with in the distance of 3-4 km in Phase I studies, but the disposal areas will be studied more precisely in Phase 2 studies.

Table 3.3.1(1) Excavation Volume Table

Case L-1 (100,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-10.8 - 1.00	0	2,240,000	0	2,240,000	940,000	10,377,000	5,492,000	2,880,000	19,689,000
II	1.00 - 43.12	16,670,150	59,268,750	6,059,500	81,998,400	14,299,400	14,251,300	3,848,000	0	32,398,700
III	43.12 - 53.00	42,992,814	57,829,897	24,513,991	125,336,702	5,804,951	4,038,597	23,333	0	9,866,881
IV	53.00 - 62.00	63,445,000	33,245,000	10,275,000	106,965,000	705,000	0	0	0	705,000
V	62.00 - 76.30	0		0	0	6,792,800	9,577,400	7,665,000	10,259,800	34,295,000
Total		123,107,964	152,583,647	40,848,491	316,540,102	28,542,151	38,244,297	17,028,333	13,139,800	96,954,581

Case L-2 , L-2' (100,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-10.8 - 1.00	0	2,240,000	0	2,240,000	940,000	10,377,000	5,492,000	5,532,000	22,341,000
II	1.00 - 43.12	18,255,150	59,830,950	5,809,500	83,895,600	22,426,400	18,531,300	4,068,000	0	45,025,700
III	43.12 - 53.00	47,323,051	60,123,558	24,513,991	131,960,600	5,804,951	4,038,597	23,333	0	9,866,881
IV	53.00 - 62.00	67,490,000	33,500,000	10,075,000	111,065,000	705,000	0	0	0	705,000
V	62.00 - 76.30	472,350	30,150	0	502,500	6,792,800	9,577,400	7,665,000	10,259,800	34,295,000
Total		133,540,551	155,724,658	40,398,491	329,663,700	36,669,151	42,524,297	17,248,333	15,791,800	112,233,581

Table 3.3.1(2) Excavation Volume Table

Case L-3 (100,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-10.80 - 1.00	0	2,240,000	0	2,240,000	940,000	10,377,000	5,492,000	5,532,000	22,341,000
II	1.00 - 43.00	42,229,250	15,947,750	9,460,500	67,637,500	48,545,500	56,254,000	20,042,500	20,245,000	145,087,000
III	43.00 - 53.00	132,990,000	20,500,000	14,310,000	167,800,000	22,420,000	740,000	200,000	0	23,360,000
IV	53.00 - 62.00	81,355,000	17,147,500	11,890,000	110,392,500	10,435,000	2,375,000	505,000	0	13,315,000
V	62.00 - 76.30	7,015,000	3,140,000	3,355,000	13,510,000	7,910,000	9,206,000	6,017,500	6,129,000	29,262,500
Total		263,589,250	58,975,250	39,015,500	361,580,000	90,250,500	78,952,000	32,257,000	31,906,000	233,365,500

Case L-4 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.1 - 1.00	0	0	0	0	2,060,000	19,501,500	6,419,500	6,419,500	34,400,500
II	1.00 - 43.12	24,254,738	65,054,398	7,353,000	96,662,136	31,237,800	23,823,800	4,746,000	0	59,807,600
III	43.12 - 53.00	56,658,619	76,376,479	32,724,915	165,760,013	5,804,951	4,038,597	23,333	0	9,866,881
IV	53.00 - 62.00	75,555,000	38,885,000	13,095,000	127,535,000	705,000	0	0	0	705,000
V	62.00 - 79.50	0	0	0	0	9,702,350	27,975,000	10,250,000	13,044,400	60,971,750
Total		156,468,357	180,315,877	53,172,915	389,957,149	49,510,101	75,338,897	21,438,833	19,463,900	165,751,731

Table 3.3.1(3) Excavation Volume Table

Case L-5 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.1 - 1.00	0	0	0	0	2,060,000	19,501,500	6,419,500	6,419,500	34,400,500
II	1.00 - 43.12	26,047,338	65,541,198	7,353,000	98,941,536	40,593,400	32,165,800	4,746,000	0	77,505,200
III	43.12 - 53.00	61,566,221	78,652,420	32,724,915	172,943,556	5,804,951	4,038,597	23,333	0	9,866,881
IV	53.00 - 62.00	80,745,000	39,140,000	13,095,000	132,980,000	705,000	0	0	0	705,000
V	62.00 - 79.50	532,650	30,150	0	562,800	9,702,350	27,975,000	10,250,000	13,044,400	60,971,750
Total		168,891,209	183,363,768	53,172,915	405,427,892	58,865,701	83,680,897	21,438,833	19,463,900	183,449,331

Case L-6 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.10 - 1.00	0	0	0	0	2,060,000	19,501,500	6,419,500	6,419,500	34,400,500
II	1.00 - 43.00	55,742,750	16,985,500	11,837,000	84,565,250	81,505,500	69,124,000	23,070,000	23,192,500	196,892,000
III	43.00 - 53.00	165,840,000	23,270,000	15,810,000	204,920,000	25,655,000	750,000	220,000	0	26,625,000
IV	53.00 - 62.00	103,942,500	19,672,500	13,557,500	137,172,500	12,240,000	2,375,000	345,000	0	14,960,000
V	62.00 - 79.50	11,715,000	4,750,000	3,745,000	20,210,000	13,727,500	18,775,000	8,195,000	8,322,500	49,020,000
Total		337,240,250	64,678,000	44,949,500	446,867,750	135,188,000	110,525,500	38,249,500	37,934,500	321,897,500

Table 3.3.1(4) Excavation Volume Table

Case L-7 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.5 - 1.00	0	0	0	0	20,842,500	21,750,000	8,000,000	8,000,000	58,592,500
II	1.00 - 43.12	37,558,610	76,257,072	9,000,000	122,815,682	77,734,450	38,259,500	8,556,200	688,500	125,238,650
III	43.12 - 53.00	75,097,338	102,671,963	44,148,627	221,917,928	5,804,951	4,038,597	23,333	0	9,866,881
IV	53.00 - 62.00	97,520,000	45,125,000	14,835,000	157,480,000	705,000	0	0	0	705,000
V	62.00 - 83.90	0	0	0	0	37,486,650	41,295,300	14,103,100	17,670,950	110,556,000
Total		210,175,948	224,054,035	67,983,627	502,213,610	142,573,551	105,343,397	30,682,633	26,359,450	304,959,031

Case L-8 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.5 - 1.00	0	0	0	0	20,842,500	21,750,000	8,000,000	8,000,000	58,592,500
II	1.00 - 43.12	39,648,610	76,619,472	9,000,000	125,268,082	93,925,450	41,754,500	7,656,200	688,500	144,024,650
III	43.12 - 53.00	80,870,988	104,985,571	44,148,627	230,005,186	5,804,951	4,038,597	23,333	0	9,866,881
IV	53.00 - 62.00	103,045,000	45,360,000	14,835,000	163,240,000	705,000	0	0	0	705,000
V	62.00 - 83.90	713,550	0	0	713,550	37,486,650	41,265,150	14,083,000	17,650,850	110,485,650
Total		224,278,148	226,965,043	67,983,627	519,226,818	158,764,551	108,808,247	29,762,533	26,339,350	323,674,681

Table 3.3.1(5) Excavation Volume Table

Case L-9 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.50 - 1.00	0	0	0	0	2,060,000	19,987,500	6,577,500	6,577,500	35,202,500
II	1.00 - 43.00	66,865,250	16,198,000	12,927,000	95,990,250	136,615,500	82,699,000	26,995,000	27,117,500	273,427,000
III	43.00 - 53.00	213,875,000	25,945,000	18,090,000	257,910,000	30,555,000	830,000	220,000	0	31,605,000
IV	53.00 - 62.00	136,687,500	22,585,000	15,630,000	174,902,500	16,725,000	2,375,000	345,000	0	19,445,000
V	62.00 - 83.90	18,180,000	6,250,000	4,900,000	29,330,000	29,716,000	33,918,000	11,809,500	11,959,000	87,402,500
Total		435,607,750	70,978,000	51,547,000	558,132,750	215,671,500	139,809,500	45,947,000	45,654,000	447,082,000

Case L-10 (100,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-10.8 - 1.00	0	2,240,000	0	2,240,000	940,000	10,377,000	5,492,000	5,532,000	22,341,000
II	1.00 - 43.12	16,009,750	53,650,950	5,809,500	75,470,200	95,997,400	36,403,300	9,056,000	0	141,456,700
III	43.12 - 53.00	47,323,051	60,123,558	24,513,991	131,960,600	5,804,951	4,038,597	23,333	0	9,866,881
IV	53.00 - 62.00	67,490,000	33,500,000	10,075,000	111,065,000	705,000	0	0	0	705,000
V	62.00 - 76.30	472,350	30,150	0	502,500	6,792,800	9,577,400	7,665,000	10,259,800	34,295,000
Total		131,295,151	149,544,658	40,398,491	321,238,300	110,240,151	60,396,297	22,236,333	15,791,800	208,664,581

Table 3.3.1(6) Excavation Volume Table

Case L-11 (100,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-10.80 - 1.00	0	2,240,000	0	2,240,000	940,000	10,377,000	5,492,000	5,532,000	22,341,000
II	1.00 - 43.00	91,161,750	25,877,750	16,050,500	133,090,000	70,540,500	42,116,500	16,702,500	11,197,500	140,557,000
III	43.00 - 53.00	132,990,000	20,500,000	14,310,000	167,800,000	22,420,000	740,000	200,000	0	23,360,000
IV	53.00 - 62.00	81,355,000	17,147,500	11,890,000	110,392,500	10,435,000	2,375,000	505,000	0	13,315,000
V	62.00 - 76.30	7,015,000	3,140,000	3,355,000	13,510,000	7,910,000	9,206,000	6,017,500	6,129,000	29,262,500
Total		312,521,750	68,905,250	45,605,500	427,032,500	112,245,500	64,814,500	28,917,000	22,858,500	228,835,500

Case L-12 (100,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-10.80 - 1.00	0	0	0	0	940,000	12,617,000	5,492,000	5,532,000	24,581,000
II	1.00 - 37.00	185,349,250	63,602,750	22,020,500	270,972,500	110,810,500	39,141,500	13,312,500	13,347,500	176,612,000
III	37.00 - 47.00	155,405,000	19,455,000	14,750,000	189,610,000	22,930,000	2,610,000	200,000	0	25,740,000
IV	47.00 - 56.00	90,485,000	15,180,000	11,915,000	117,580,000	5,365,000	150,000	180,000	0	5,695,000
V	56.00 - 70.30	45,850,000	19,670,000	13,300,000	78,820,000	18,100,000	5,927,500	2,415,000	3,264,000	29,706,500
Total		477,089,250	117,907,750	61,985,500	656,982,500	158,145,500	60,446,000	21,599,500	22,143,500	262,334,500

Table 3.3.1(7) Excavation Volume Table

Case L-13 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.1 - 1.00	0	0	0	0	2,060,000	19,501,500	6,419,500	6,419,500	34,400,500
II	1.00 - 43.12	19,171,250	53,993,700	7,353,000	80,517,950	127,194,900	43,306,800	10,247,500	0	180,749,200
III	43.12 - 53.00	61,566,221	78,652,420	32,724,915	172,943,556	5,804,951	4,038,597	23,333	0	9,866,881
IV	53.00 - 62.00	80,745,000	39,140,000	13,095,000	132,980,000	705,000	0	0	0	705,000
V	62.00 - 79.50	532,650	30,150	0	562,800	9,702,350	27,975,000	10,250,000	13,044,400	60,971,750
Total		162,015,121	171,816,270	53,172,915	387,004,306	145,467,201	94,821,897	26,940,333	19,463,900	286,693,331

Case L-14 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.10 - 1.00	0	0	0	0	2,060,000	19,501,500	6,419,500	6,419,500	34,400,500
II	1.00 - 43.00	114,815,250	28,300,500	19,327,000	162,442,750	95,678,000	48,691,500	17,727,500	13,827,500	175,924,500
III	43.00 - 53.00	165,840,000	23,270,000	15,810,000	204,920,000	25,655,000	750,000	220,000	0	26,625,000
IV	53.00 - 62.00	103,942,500	19,672,500	13,557,500	137,172,500	12,240,000	2,375,000	345,000	0	14,960,000
V	62.00 - 79.50	11,715,000	4,750,000	3,745,000	20,210,000	13,727,500	18,775,000	8,195,000	8,322,500	49,020,000
Total		396,312,750	75,993,000	52,439,500	524,745,250	149,360,500	90,093,000	32,907,000	28,569,500	300,930,000

Table 3.3.1(8) Excavation Volume Table

Case L-15 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.00 - 1.00	0	0	0	0	2,060,000	19,501,500	6,419,500	6,419,500	34,400,500
II	1.00 - 37.00	217,105,250	34,455,500	24,617,000	276,177,750	148,203,000	46,364,000	15,030,000	15,025,000	224,622,000
III	37.00 - 47.00	176,935,000	21,410,000	14,910,000	213,255,000	22,915,000	610,000	130,000	0	23,655,000
IV	47.00 - 56.00	184,065,000	24,040,000	17,160,000	225,265,000	8,995,000	150,000	195,000	0	9,340,000
V	56.00 - 73.50	56,280,000	20,405,000	10,840,000	87,525,000	26,335,000	14,757,500	4,900,000	4,680,000	50,672,500
Total		634,385,250	100,310,500	67,527,000	802,222,750	208,508,000	81,383,000	26,674,500	26,124,500	342,690,000

Case L-16 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.5 - 1.00	0	0	0	0	20,842,500	21,750,000	8,000,000	8,000,000	58,592,500
II	1.00 - 43.12	31,130,750	58,600,700	9,000,000	98,731,450	208,681,950	49,405,500	13,468,700	688,500	272,244,650
III	43.12 - 53.00	80,870,988	104,985,571	44,148,627	230,005,186	5,804,951	4,038,597	23,333	0	9,866,881
IV	53.00 - 62.00	103,045,000	45,360,000	14,835,000	163,240,000	705,000	0	0	0	705,000
V	62.00 - 83.90	713,550	0	0	713,550	37,486,650	41,295,300	14,083,000	17,650,850	110,515,800
Total		215,760,288	208,946,271	67,983,627	492,690,186	273,521,051	116,489,397	35,575,033	26,339,350	451,924,831

Table 3.3.1(9) Excavation Volume Table

Case L-17 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.50 - 1.00	0	0	0	0	2,060,000	19,987,500	6,577,500	6,577,500	35,202,500
II	1.00 - 43.00	135,855,250	30,290,500	20,697,000	186,842,750	130,770,500	56,346,500	20,542,500	15,982,500	223,642,000
III	43.00 - 53.00	213,875,000	25,875,000	18,090,000	257,840,000	30,555,000	830,000	220,000	0	31,605,000
IV	53.00 - 62.00	135,187,500	22,585,000	15,630,000	173,402,500	16,725,000	2,375,000	345,000	0	19,445,000
V	62.00 - 83.90	18,180,000	6,250,000	4,900,000	29,330,000	29,716,000	33,918,000	11,809,500	11,959,000	87,402,500
Total		503,097,750	85,000,500	59,317,000	647,415,250	209,826,500	113,457,000	39,494,500	34,519,000	397,297,000

Case L-18 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.50 - 1.00	0	0	0	0	20,842,500	21,750,000	8,000,000	8,000,000	58,592,500
II	1.00 - 37.00	278,510,250	74,697,350	29,400,000	382,607,600	198,629,750	51,569,000	17,290,000	17,235,000	284,723,750
III	37.00 - 47.00	241,315,000	26,440,000	18,135,000	285,890,000	31,265,000	830,000	260,000	0	32,355,000
IV	47.00 - 56.00	169,470,000	26,290,000	18,585,000	214,345,000	10,950,000	250,000	325,000	0	11,525,000
V	56.00 - 77.90	79,770,000	18,270,000	37,325,000	135,365,000	65,569,000	24,114,500	7,624,500	7,393,500	104,701,500
Total		769,065,250	145,697,350	103,445,000	1,018,207,600	327,256,250	98,513,500	33,499,500	32,628,500	491,897,750

Table 3.3.1(10) Excavation Volume Table

Case S-1 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-2.50 - 1.00	2,322,500	720,000	480,000	3,522,500	1,487,500	1,750,000	595,000	595,000	4,427,500
II	1.00 - 27.00	117,947,500	92,965,000	44,590,000	255,502,500	0	0	0	0	0
III	27.00 - 53.00	186,610,000	283,470,000	101,010,000	571,090,000	0	0	0	0	0
IV	53.00 - 58.00	0	40,645,000	16,250,000	56,895,000	0	0	0	0	0
V	58.00 - 83.70	0	13,275,000	5,700,000	18,975,000	0	16,558,000	5,678,500	5,678,500	27,915,000
Total		306,880,000	431,075,000	168,030,000	905,985,000	1,487,500	18,308,000	6,273,500	6,273,500	32,342,500

Case S-2 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-2.50 - 1.00	5,225,000	1,320,000	880,000	7,425,000	3,325,000	3,780,000	1,312,500	1,312,500	9,730,000
II	1.00 - 27.00	252,475,000	191,170,000	78,925,000	522,570,000	0	0	0	0	0
III	27.00 - 53.00	263,335,000	508,665,000	161,035,000	933,035,000	0	0	0	0	0
IV	53.00 - 58.00	0	80,675,000	27,125,000	107,800,000	0	0	0	0	0
V	58.00 - 83.70	0	29,265,000	9,075,000	38,340,000	0	36,904,000	12,618,500	12,618,500	62,141,000
Total		521,035,000	811,095,000	277,040,000	1,609,170,000	3,325,000	40,684,000	13,931,000	13,931,000	71,871,000

Table 3.3.1(11) Excavation Volume Table

Case S-3 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-2.85 - 1.00	3,060,000	810,000	540,000	4,410,000	3,003,000	2,252,250	808,500	808,500	6,872,250
II	1.00 - 27.00	146,125,000	122,390,000	50,540,000	319,055,000	0	0	0	0	0
III	27.00 - 53.00	11,845,000	493,588,000	117,750,000	623,183,000	0	0	0	0	0
IV	53.00 - 58.00	0	50,275,000	17,650,000	67,925,000	0	0	0	0	0
V	58.00 - 85.70	0	16,830,000	6,300,000	23,130,000	0	30,371,500	7,213,000	7,213,000	44,797,500
						0				
Total		161,030,000	683,893,000	192,780,000	1,037,703,000	3,003,000	32,623,750	8,021,500	8,021,500	51,669,750

Case S-4 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-2.85 - 1.00	6,970,000	1,560,000	1,040,000	9,570,000	4,966,500	4,889,500	1,674,750	1,674,750	13,205,500
II	1.00 - 27.00	308,725,000	247,915,000	88,950,000	645,590,000	0	0	0	0	0
III	27.00 - 53.00	0	883,785,000	173,580,000	1,057,365,000	0	0	0	0	0
IV	53.00 - 58.00	0	103,300,000	30,250,000	133,550,000	0	0	0	0	0
V	58.00 - 85.70	0	37,260,000	10,050,000	47,310,000	0	68,651,500	15,530,500	15,530,500	99,712,500
Total		315,695,000	1,273,820,000	303,870,000	1,893,385,000	4,966,500	73,541,000	17,205,250	17,205,250	112,918,000

Table 3.3.1(12) Excavation Volume Table

Case S-5 (300,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-2.90 - 1.00	4,825,000	840,000	560,000	6,225,000	3,724,500	2,437,500	858,000	858,000	7,878,000
II	1.00 - 27.00	161,045,000	127,185,000	51,870,000	340,100,000	0	0	0	0	0
III	27.00 - 53.00	191,840,000	362,495,000	134,230,000	688,565,000	0	0	0	0	0
IV	53.00 - 58.00	0	54,185,000	19,400,000	73,585,000	0	0	0	0	0
V	58.00 - 86.70	0	18,225,000	6,450,000	24,675,000	0	37,371,500	7,840,000	7,840,000	53,051,500
Total		357,710,000	562,930,000	212,510,000	1,133,150,000	3,724,500	39,809,000	8,698,000	8,698,000	60,929,500

Case S-6 (300,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-2.90 - 1.00	7,495,000	1,650,000	1,100,000	10,245,000	8,385,000	5,265,000	1,794,000	1,794,000	17,238,000
II	1.00 - 27.00	341,225,000	258,425,000	94,520,000	694,170,000	0	0	0	0	0
III	27.00 - 53.00	308,240,000	652,430,000	197,810,000	1,158,480,000	0	0	0	0	0
IV	53.00 - 58.00	0	111,250,000	31,550,000	142,800,000	0	0	0	0	0
V	58.00 - 86.40	0	40,620,000	10,500,000	51,120,000	0	82,890,000	16,883,000	16,883,000	116,656,000
Total		656,960,000	1,064,375,000	335,480,000	2,056,815,000	8,385,000	88,155,000	18,677,000	18,677,000	133,894,000

Table 3.3.1(13) Excavation Volume Table

Case S-7 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.00 - 1.00	0	0	0	0	1,040,000	9,720,500	3,240,000	3,240,000	17,240,500
II	1.00 - 23.00	28,972,500	8,625,250	6,898,500	44,496,250	68,879,250	20,368,250	7,005,000	6,315,000	102,567,500
III	23.00 - 50.00	513,098,000	62,950,000	43,485,000	619,533,000	38,137,000	8,635,000	4,770,000	1,215,000	52,757,000
IV	50.00 - 54.00	25,420,000	4,195,000	3,140,000	32,755,000	4,920,000	1,940,000	1,240,000	0	8,100,000
V	54.00 - 71.50	1,295,000	565,000	430,000	2,290,000	1,540,000	8,027,500	5,142,500	5,367,500	20,077,500
Total		568,785,500	76,335,250	53,953,500	699,074,250	114,516,250	48,691,250	21,397,500	16,137,500	200,742,500

Case S-8 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.00 - 1.00	0	0	0	0	2,060,000	19,501,500	6,419,500	6,419,500	34,400,500
II	1.00 - 23.00	57,150,250	14,700,500	11,937,000	83,787,750	147,303,000	39,861,500	13,405,000	12,030,000	212,599,500
III	23.00 - 50.00	826,195,000	88,630,000	61,140,000	975,965,000	75,705,000	15,580,000	8,215,000	2,210,000	101,710,000
IV	50.00 - 54.00	48,490,000	8,495,000	5,940,000	62,925,000	10,620,000	2,510,000	1,550,000	0	14,680,000
V	54.00 - 75.90	3,310,000	1,155,000	830,000	5,295,000	4,980,000	23,590,000	11,375,000	11,850,000	51,795,000
Total		935,145,250	112,980,500	79,847,000	1,127,972,750	240,668,000	101,043,000	40,964,500	32,509,500	415,185,000

Table 3.3.1(14) Excavation Volume Table

Case S-9 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.50 - 1.00	0	0	0	0	10,452,500	10,875,000	4,000,000	4,000,000	29,327,500
II	1.00 - 23.00	37,687,000	10,871,500	7,040,000	55,598,500	89,903,000	22,838,500	7,800,000	7,145,000	127,686,500
III	23.00 - 50.00	573,205,000	67,425,000	46,550,000	687,180,000	48,800,000	9,640,000	4,500,000	1,905,000	64,845,000
IV	50.00 - 54.00	30,565,000	4,920,000	3,720,000	39,205,000	7,490,000	2,100,000	1,240,000	0	10,830,000
V	54.00 - 75.90	3,185,000	660,000	570,000	4,415,000	6,499,000	18,631,500	7,343,500	7,732,500	40,206,500
Total		644,642,000	83,876,500	57,880,000	786,398,500	163,144,500	64,085,000	24,883,500	20,782,500	272,895,500

Case S-10 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.50 - 1.00	0	0	0	0	20,842,500	21,750,000	8,000,000	8,000,000	58,592,500
II	1.00 - 23.00	77,882,750	18,593,500	13,590,000	110,066,250	195,337,250	45,186,500	15,530,000	13,860,000	269,913,750
III	23.00 - 50.00	981,205,000	97,150,000	66,450,000	1,144,805,000	97,605,000	17,805,000	8,350,000	3,510,000	127,270,000
IV	50.00 - 54.00	63,010,000	9,820,000	6,925,000	79,755,000	13,600,000	2,670,000	1,660,000	0	17,930,000
V	54.00 - 75.90	4,690,000	1,350,000	965,000	7,005,000	25,558,500	44,544,500	15,849,500	16,304,000	102,256,500
Total		1,126,787,750	126,913,500	87,930,000	1,341,631,250	352,943,250	131,956,000	49,389,500	41,674,000	575,962,750

Table 3.3.1(15) Excavation Volume Table

Case S-11 (300,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.60 - 1.00	0	0	0	0	11,560,000	12,120,000	4,439,000	4,439,000	32,558,000
II	1.00 - 23.00	41,208,000	13,072,500	7,700,000	61,980,500	99,197,000	24,292,500	8,290,000	7,545,000	139,324,500
III	23.00 - 50.00	611,880,000	69,365,000	47,990,000	729,235,000	54,340,000	10,275,000	4,850,000	2,015,000	71,480,000
IV	50.00 - 54.00	32,520,000	5,295,000	3,910,000	41,725,000	8,720,000	2,130,000	1,310,000	0	12,160,000
V	54.00 - 75.20	2,400,000	710,000	550,000	3,660,000	10,400,000	22,716,000	8,296,000	8,648,000	50,060,000
		2								
Total		688,008,000	88,442,500	60,150,000	836,600,500	184,217,000	71,533,500	27,185,000	22,647,000	305,582,500

Case S-12 (300,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.60 - 1.00	0	0	0	0	23,120,000	24,240,000	8,878,000	8,878,000	65,116,000
II	1.00 - 23.00	84,392,000	20,779,000	14,760,000	119,931,000	206,467,000	47,976,000	16,030,000	14,680,000	285,153,000
III	23.00 - 50.00	1,057,945,000	99,485,000	68,045,000	1,225,475,000	107,270,000	19,105,000	9,070,000	3,700,000	139,145,000
IV	50.00 - 54.00	67,930,000	10,390,000	7,235,000	85,555,000	14,650,000	2,700,000	1,750,000	0	19,100,000
V	54.00 - 77.20	5,245,000	1,430,000	1,000,000	7,675,000	34,454,000	49,626,000	17,346,000	17,918,000	119,344,000
Total		1,215,512,000	132,084,000	91,040,000	1,438,636,000	385,961,000	143,647,000	53,074,000	45,176,000	627,858,000

Table 3.3.1(16) Excavation Volume Table

Case S-13 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-2.50 - 1.00	5,225,000	1,320,000	880,000	7,425,000	3,325,000	3,780,000	1,312,500	1,312,500	9,730,000
II	1.00 - 27.00	252,475,000	191,170,000	78,925,000	522,570,000	0	0	0	0	0
III	27.00 - 53.00	186,610,000	283,470,000	101,010,000	571,090,000	0	0	0	0	0
IV	53.00 - 58.00	0	80,675,000	27,125,000	107,800,000	0	0	0	0	0
V	58.00 - 83.70	0	29,265,000	9,075,000	38,340,000	0	36,904,000	12,618,500	12,618,500	62,141,000
Total		444,310,000	585,900,000	217,015,000	1,247,225,000	3,325,000	40,684,000	13,931,000	13,931,000	71,871,000

Case S-14 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-2.90 - 1.00	6,970,000	1,560,000	1,040,000	9,570,000	4,966,500	4,889,500	1,674,750	1,674,750	13,205,500
II	1.00 - 27.00	308,725,000	247,915,000	88,950,000	645,590,000	0	0	0	0	0
III	27.00 - 53.00	11,845,000	493,588,000	117,750,000	623,183,000	0	0	0	0	0
IV	53.00 - 58.00	0	103,300,000	30,250,000	133,550,000	0	0	0	0	0
V	58.00 - 83.70	0	37,260,000	10,050,000	47,310,000	0	68,651,500	15,530,500	15,530,500	99,712,500
Total		327,540,000	883,623,000	248,040,000	1,459,203,000	4,966,500	73,541,000	17,205,250	17,205,250	112,918,000

.1(17) Excavation Volume Table

Case S-15 (300,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-2.90 - 1.00	7,495,000	1,650,000	1,100,000	10,245,000	8,385,000	5,265,000	1,794,000	1,794,000	17,238,000
II	1.00 - 27.00	341,225,000	258,425,000	94,520,000	694,170,000	0	0	0	0	0
III	27.00 - 53.00	191,840,000	362,495,000	134,230,000	688,565,000	0	0	0	0	0
IV	53.00 - 58.00	0	111,250,000	31,550,000	142,800,000	0	0	0	0	0
V	58.00 - 86.40	0	40,620,000	10,500,000	51,120,000	0	82,890,000	16,883,000	16,883,000	116,656,000
Total		540,560,000	774,440,000	271,900,000	1,586,900,000	8,385,000	88,155,000	18,677,000	18,677,000	133,894,000

Case S-16 (150,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.10 - 1.00	0	0	0	0	2,060,000	19,501,500	6,419,500	6,419,500	34,400,500
II	1.00 - 23.00	57,150,250	14,700,500	11,937,000	83,787,750	147,303,000	39,861,500	13,405,000	12,030,000	212,599,500
III	23.00 - 50.00	513,098,000	62,950,000	43,485,000	619,533,000	38,137,000	8,635,000	4,770,000	1,215,000	52,757,000
IV	50.00 - 54.00	48,490,000	8,495,000	5,940,000	62,925,000	10,620,000	2,510,000	1,550,000	0	14,680,000
V	54.00 - 71.50	3,310,000	1,155,000	830,000	5,295,000	4,980,000	23,590,000	11,375,000	11,850,000	51,795,000
Total		622,048,250	87,300,500	62,192,000	771,540,750	203,100,000	94,098,000	37,519,500	31,514,500	366,232,000

Table 3.3.1(18) Excavation Volume Table

Case S-17 (250,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.50 - 1.00	0	0	0	0	20,842,500	21,750,000	8,000,000	8,000,000	58,592,500
II	1.00 - 23.00	77,882,750	18,593,500	13,590,000	110,066,250	195,337,250	45,186,500	15,530,000	13,860,000	269,913,750
III	23.00 - 50.00	573,205,000	67,425,000	46,550,000	687,180,000	48,800,000	9,640,000	4,500,000	1,905,000	64,845,000
IV	50.00 - 54.00	63,010,000	9,820,000	6,925,000	79,755,000	13,600,000	2,670,000	1,660,000	0	17,930,000
V	54.00 - 75.90	4,690,000	1,350,000	965,000	7,005,000	25,558,500	44,544,500	15,849,500	16,304,000	102,256,500
									13,931,000	
Total		718,787,750	97,188,500	68,030,000	884,006,250	304,138,250	123,791,000	45,539,500	40,069,000	513,537,750

Case S-18 (300,000 DWT)

ZONES	STATION	Dry Excavation (m3)				Underwater Excavation (m3)				
		Rock	Weathered	Earth	Total	Rock	Weathered	Loose Material	Clayey Material	Total
I	-11.60 - 1.00	0	0	0	0	23,120,000	24,240,000	8,878,000	8,878,000	65,116,000
II	1.00 - 23.00	84,392,000	20,779,000	14,760,000	119,931,000	206,467,000	47,976,000	16,030,000	14,680,000	285,153,000
III	23.00 - 50.00	611,880,000	69,365,000	47,990,000	729,235,000	54,340,000	10,275,000	4,850,000	2,015,000	71,480,000
IV	50.00 - 54.00	67,930,000	10,390,000	7,235,000	85,555,000	14,650,000	2,700,000	1,750,000	0	19,100,000
V	54.00 - 77.20	5,245,000	1,430,000	1,000,000	7,675,000	34,454,000	49,626,000	17,346,000	17,918,000	119,344,000
Total		769,447,000	101,964,000	70,985,000	942,396,000	333,031,000	134,817,000	48,854,000	43,491,000	560,193,000

CHAPTER 4 - LOCK STRUCTURES AND MECHANICAL EQUIPMENT

4.1 Lock Structures (concrete)

4.1.1 General

The proposed lock site at the Atlantic side is located in the area previously identified for the Gatun Third locks, where excavation was conducted in the early 1940's in an area of simple monoclinal geologic structure. It lies approximately 1 km east of the present Gatun locks (ref: Fig. 4.1.3). In this area the elevations are generally low (averaging about 30 meters) but the terrain is abrupt and irregular.

The lock site area is underlaid by finegrained sandstones and tuffs of the Gatun formation with only a few shallow pockets of Atlantic Muck near the north approach walls. At this site the Gatun formation is more than 400m thick and bedding is massive and uniform with the thickness of some strata in excess of 30m. The foundation rock at the site is correlated with the Gatun sandstone of the existing Gatun locks. The formation was classified as having an allowable bearing capacity of more than 200 ton/m2.

At the Pacific coast side, the lock site takes full advantage of the existing third locks excavation and would be located approximately 900m south of the existing Miraflores locks. The area is characterized by steeply inclined, igneous hills separated by narrow valleys. The elevations of the hills in this area range from approximately 50 to 150m. (ref. Fig. 4.1.4)

The lock structures would be founded entirely in basalt which was classified as having an allowable bearing capacity of more than 500 ton/m2 in the third locks study. The wing walls of the lock would rest in part on the La Boca formation. The La Boca formation consists of silty shales and sandstones of medium hardness and as a whole it is moderately strong. The La Boca formation was classified as having an allowable bearing capacity of 160 ton/m2 at the proposed lock site during the third locks study.

These bearing capacities mentioned above thought to be enough for structure foundations.

4.1.2 Lock Dimensions

Lock chamber dimension are considered for the design with sizes up to 250,000 DWT. Envelope dimensions for the various ship sizes are given in Table 4.1.2. The 300,000 DWT ship is to be used for the sea level canal study cases only. Lock dimensions such as length, width and depth are given in Table 4.1.1.

Table 4.1.1 Dimensions of Lock Chambers

Size (DWT)	L (m)	B (m)	D (m)	Remarks
65,000	304.8 (1,000 ft)	33.5 (110 ft)	12.8 (42 ft)	Existing canal lock dimension
100,000	319	47	19	
150,000	363	54	21	
250,000	428	63	24	

Table 4.1.2 Dimensions of Design Ships

Size (DWT)	L (m)	B (m)	D (m)	Remarks
65,000	295	32	12	Max. Passable Size
100,000	277	43	17	
150,000	316	49	19	
250,000	372	57	22	
300,000	394	61	23	

A typical layout for the lock chambers is shown in Fig. 4.1.1.

Considering the lake water level and the sea level, sill design levels at the Pacific Locks for each study case were adopted as shown in Table 4.1.3. Detailed sketches for the Group A high rise locks have been prepared based on the following sections and are shown in Fig. 4.1.6 and Fig. 4.1.7.

For Low Rise Lock study cases, each dimension is shown in Fig. 4.1.8, Fig. 4.1.9 and Fig 4.1.10.

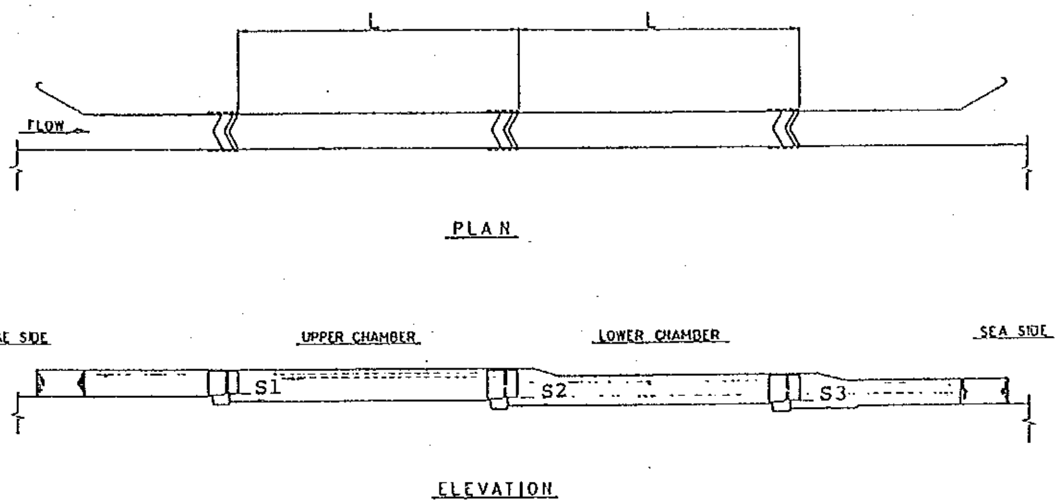


Fig. 4.1.1 Lock Dimension Plan

Table 4.1.3 Sill Elevations for Group A Study Cases

Study Case	Lake Side H.W.L.	Lake Side L.W.L.	Lower Lock H.W.L.	Pacific Coast H.W.L.	Pacific Coast L.W.L.	Sill Elevation Lake (S1)	Sill Elevation L Lock (S2)	Sill Elevation Pacific (S3)
L-1	27.6	26.1	13.7	3.3	-2.7	7.1	-5.3	-21.70
L-2	26.1	24.6	12.9	3.3	-2.7	5.6	-6.1	-21.70
L-4	27.6	26.1	13.7	3.3	-2.7	5.1	-7.3	-23.70
L-5	26.1	24.6	12.9	3.3	-2.7	3.6	-8.1	-23.70
L-7	27.6	26.1	13.7	3.3	-2.7	2.1	-10.3	-26.70
L-8	26.1	24.6	12.9	3.3	-2.7	0.6	-11.1	-26.70
L-10	26.1	24.6	12.9	3.3	-2.7	5.6	-6.1	-21.70
L-13	26.1	24.6	12.9	3.3	-2.7	3.6	-8.1	-23.70
L-16	26.1	24.6	12.9	3.3	-2.7	0.6	-11.1	-26.70

4.1.3 Water Levels and Structure Levels

Wall top and sill top elevations and water levels are schematically shown in Fig. 4.1.2, using study cases L-8 and L-16 as a typical example.

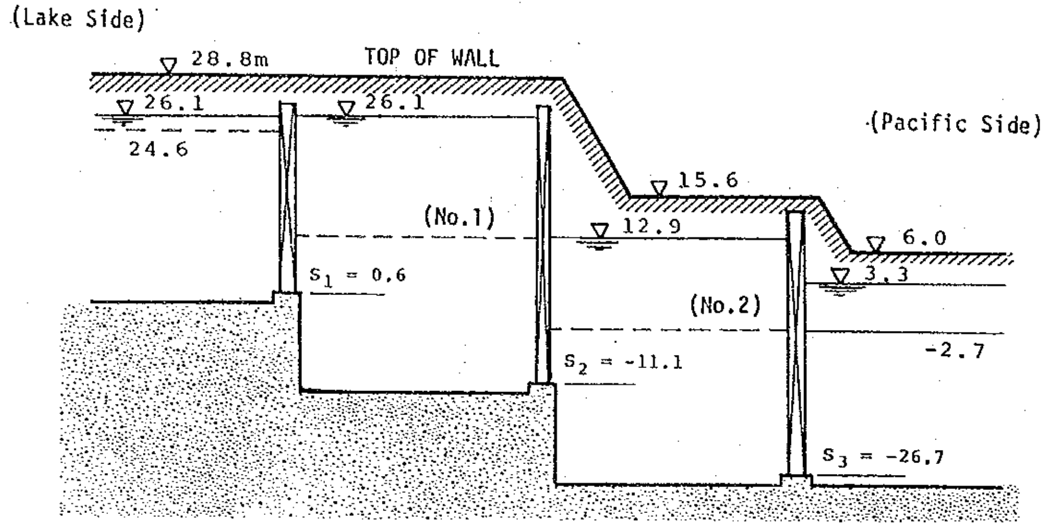


Fig. 4.1.2 Water Levels and Structure Levels

4.1.4 Design Assumptions

(1) Filling and Emptying System

The filling and emptying system adopted for the locks would be a bottom longitudinal tunnel system similar to that developed for the lower Granite Lock on the Snake River in the State of Washington.

The chosen dimension of fillings and emptying tunnel, about 10m x 10m, is decided on the assumption that filling and emptying time is 9 minutes.

(2) Structural Design Concept

All locks and approach walls would be of the gravity type, with cross section varying to meet needs for stability and for enclosure of the hydraulic tunnel system.

All walls would be proportioned so that at the intersection of the base and the foundation, the resultant forces fall within the middle third of the base under normal operating conditions and within the middle half of the base under maintenance and emergency conditions.

4.1.5 Ancillary Facilities

(1) Anchorage Area

For the purpose of mooring ships using the canal anchorage and mooring areas are provided on the upstream side of the new locks on the Pacific Ocean side. In Gatun Lake on the upstream side of the new locks on the Atlantic Ocean side, no such area is required because suitable areas are available in Gatun Lake.

(2) Surge Basin

A hydro dynamic impact by surging phenomena may occur when a canal water pours into a loch chamber in a short time.

The locks proposed at the Pacific Ocean side, a bypass channel on the upstream side of the locks connects back to the main canal. The occurrence of surging in the bypass may cause harmful pitching and rolling in ships when lockage water filling commences.

To reduce the effect of surge on ships a surge basin is proposed in the area of the Rio Cocoli valley.

The surge basin utilizes the natural topography as much as possible. A closure dam would be required at the south-east side of the basin.

(3) Recycling Pond

On both the Pacific and Atlantic Ocean sides, recycling ponds are proposed for the purpose of storing spent lockage water (mainly fresh water) for subsequent recycling by pumping.