E N V I R O N M E N T A L   R E P O R T

PANAMA CANAL GAILLARD CUT WIDENING FEASIBILITY STUDY

Volume 1

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TABLE OF CONTENTS

	Page
TABLE OF CONTENTS	i
LIST OF TABLES	iii
LIST OF FIGURES	iv
LIST OF APPENDICES IN VOLUME 2	v
EXECUTIVE SUMMARY	vi
I. INTRODUCTION	1
II. PURPOSE OF ACTION	4
III. DESCRIPTION OF PROPOSED ACTION	4
A. Scope of Project	4
B. Construction Methodology	6
C. Excavation Operations	8
1. Dry material	10
2. Wet material	12
D. Disposal Operations	13
1. Upland disposal	13
2. Open-water disposal	14
E. Maintenance of Widened Channel	14
IV. DISPOSAL SITE SELECTION	15
A. Upland Sites	15
B. Open-Water Sites	22
V. ENVIRONMENTAL SETTING	24
A. Overview of Project Area	24
B. Air Quality	25
C. Noise	25
D. Water and Sediment Quality	26
1. Surface and groundwater	26
2. Channel and proposed lake disposal area waters	27
3. Sediment	31
E. Vegetation	32
1. Land vegetation	32
2. Aquatic vegetation	36
F. Wildlife	37
1. Mammals	38
2. Reptiles and amphibians	39
3. Birds	40
G. Zooplankton, Fishes and Benthos	41
1. Zooplankton	41
2. Fishes	41
3. Benthos	42
H. Economic and Social Conditions	44
I. Cultural Resources	47
1. Paleontological, archaeological, and historical resources	47
2. Areas of special ecological interest	48

		Page
VI.	POTENTIAL ENVIRONMENTAL IMPACTS	49
	A. Excavation Sites	49
	1. Air quality	49
	2. Noise	49
	3. Water quality	50
	4. Vegetation	52
	5. Zooplankton, fishes and benthos	52
	6. Economic and social conditions	53
	7. Cultural resources	55
	B. Upland Disposal Sites	56
	1. Water quality	56
	2. Vegetation	56
	3. Wildlife	58
	4. Economic and social conditions	59
	5. Cultural resources	60
	C. Open-Water Disposal Sites	60
	1. Water quality	60
	2. Sediment quality	61
	3. Phytoplankton and aquatic macrophytes	62
	4. Wildlife	63
	5. Zooplankton, fishes and benthos	63
	6. Cultural resources	64
VII.	RELATIONSHIP TO LAND-USE PLANS, POLICIES AND CONTROLS	66
VIII.	ALTERNATIVES TO PROPOSED ACTION	67
	A. No Action	67
	B. Tie-up stations	67
	C. Passing lane	68
	D. Partial widening	69
	E. Partial full widening	69
	F. Alternative Methodologies for Dry Material	70
	G. Alternative Methodologies for Wet Material	70
	1. Excavation	70
	2. Disposal	71
IX.	MITIGATION OF UNAVOIDABLE ADVERSE IMPACTS	75
X.	LIST OF CONTRIBUTORS	79
XI.	COORDINATION	81
XII.	FOOTNOTES	82

LIST OF TABLES

		Page
Table 1	Excavation Volumes by Gaillard Cut Sector	11
Table 2	Principal Disposal Site Selection Criteria	16
Table 3	Comparisons of Gaillard Cut Excavation Volumes and Corresponding Upland Disposal Site Capacities	18
Table 4	Water Quality at Proposed Excavation and Open-Water Disposal Sites	29
Table 5	Sediment Quality at Alternative Open-Water Disposal Sites	33
Table 6	Dominant Macrobenthos at Alternative Open-Water Disposal Sites in Gatun Lake	43

LIST OF FIGURES

		Page
Figure 1.	Schematic map of Panama Canal showing Gaillard Cut ...	2
Figure 2.	Gaillard Cut Widening Project Map	5
Figure 3.	Cross section of excavation areas	7
Figure 4.	Gaillard Cut widening construction schedule, based on single contract and optimum construction period to complete all sectors	9
Figure 5.	Map showing Gatun Lake alternative disposal sites (orange) and active Dump 14 (yellow)	23
Figure 6.	Aerial view of Chagres River, at right, entering Canal between Gamboa townsite and north end of Gaillard Cut; mouth of Mandinga River is shown at lower center, across-channel from former Gamboa Penitentiary	28
Figure 7.	Photomap of Gaillard Cut region showing vegetation within the proposed boundaries of excavation and upland disposal, January 1984, scale at 1:10,000 ...	34
Figure 8.	Aerial view at southern portions of Paraiso townsite, showing optimum plan excavation limits (solid line) and contiguous areas (broken line) where structures are subject to removal	45
Figure 9.	Schematic diagram of a dredged material containment area	73

LIST OF APPENDICES IN VOLUME 2

Appendix A	Panama Canal Dredging Frequency
Appendix B	Air Quality Data (Panama Canal Area)
Appendix C	Sound Levels Generated by Selected Excavation Equipment
Appendix D	Water Quality Baseline Data (Panama Canal Area)
Appendix E	Vegetation Survey and Comments on Proposed Upland Disposal Sites
Appendix F	List of Wildlife Recorded from Panamą Canal Watershed
Appendix G	Fish Species Recorded from Gatun Lake, Canal Locks, and Adjacent Drainages
Appendix H	Schematic Diagrams of Benthic Sample Sites: Frijoles Bay A and B; Aojeta Bay; and Pena Blanca Bay
Appendix I	Results of Benthic Macroinvertebrate Sample Analyses on Gatun Lake
Appendix J	The Impact of the Canal Widening Programme on Archaeological Resources (Prehistoric and Historic)
Appendix K	Report on Evaluation of Potential Sites for Dredged Material Disposal (Pest Mangement)

EXECUTIVE SUMMARY

INTRODUCTION. The Gaillard Cut Widening Feasibility Study comprises: a technical simulation analysis, geotechnical studies and cost estimates, an operational analysis, an environmental report, an analysis of financial options, and an economic feasibility analysis. Each of the study elements will be carefully evaluated before a decision can be made to implement a Cut widening program. This summary presents the scope and findings of the environmental report.

BACKGROUND AND PURPOSE OF ACTION. The 50-mile long Panama Canal has offered safe and efficient transit since opening to international maritime trade in 1914. Important features of the Canal system are the man-made Gatun Lake, which forms a large portion of the waterway, three sets of locks that operate by freshwater gravity flows from the lake, and Gaillard Cut, an 8-mile stretch excavated through the Continental Divide, originally at a width of 300 feet. By 1971, the Cut had been widened to its present dimension of 500 feet because of increases in Canal ship traffic. According to recent forecasts, the number of wide beam vessels subject to transit restrictions in the Cut will progressively increase and eventually cause Canal Waters Time to reach unacceptable levels. The proposed project would be a second expansion of that channel area to permit reduction of the restrictions for these vessels and to maintain the Canal's competitive standards of operation, service, and navigational safety.

METHODOLOGY. If the program is approved and funded, excavation and disposal operations, based on the operational analysis, would not begin before 1994 and would require 5 years to completion under the most cost-effective construction schedule or up to 7 or 11 years following other possible construction scenarios. The recommended methodology consists of widening to 630 feet at straight sections and up to 730 feet inside curves; work would proceed almost continuously along the North, Central, and South Sectors of the Cut using conventional land excavation equipment for removal of 22.5 million cubic yards (mcy) of dry material, and dipper dredges and bottom-dump scows for removal of 11.6 mcy of wet material. A team of specialists in engineering, biological, and physical sciences selected 6 of a possible 7 upland (on land) areas, within an average one-mile haul from points of excavation, as preferred sites for disposal of the dry material. All areas served for disposal during construction of the Canal, and at least four have been periodically reactivated while others have been variously used for Canal operations and U.S. Military training exercises. Three alternative disposal sites for wet material were identified near the channel deep in Gatun Lake; the nearest is an average one-way haul of 17 miles from the Cut, and has more than enough capacity for the wet excavation volumes. A series of documents, including baseline surveys and other technical data pertaining to this environmental review, are attached as appendices in Volume 2.

<u>POTENTIAL ENVIRONMENTAL IMPACTS</u>. Proposed excavation and disposal activities and long-term operation of a wider Cut were assessed for probable impacts on air quality, noise, water and sediment quality, vegetation, wildlife, aquatic life, economic and social conditions, and cultural resources. The environmental components identified as subject to greatest disturbance were: water quality; lake benthic

populations; upland vegetation and wildlife; and socioeconomic-related conditions at small parts of a townsite and at military training areas. The potential effects on these components are summarized below:

Water Quality. Material to be removed is predominantly primordial rock, free of harmful contaminants, and resultant water quality effects at excavation and disposal sites essentially would be limited to temporary increases in turbidity. The increases should be similar to those from other improvement or maintenance work at the Canal and far less than experienced in the waterway region due to heavy rains during wet season.

Lake Benthic Populations. There are numerous benthic invertebrate organisms throughout the lake's bottom, but species diversity is very limited and consists mainly of small freshwater clams and snails. Benthos would be covered during open-water disposal, and the communities should re-establish to near existing homogeneous distributions over a relatively short time as previously evidenced at another nearby site.

Upland Vegetation and Wildlife. Vegetation, predominantly grasses, and the small terrestrial wildlife it supports would be more affected at upland disposal than at excavation areas. In all but one of the preferred disposal sites large stands of forest have been circumvented by the selection process, and natural recolonization by pioneer grasses, shrubs and trees is expected to resume after completion of operations; if necessary, measures would be instituted to help restore the vegetation cover. With the slow progression of construction southward, many animals could disperse from both excavation and disposal sites into neighboring comparable habitats, although some would be lost or subjected to crowding and stress. Such impacts would be even less intense and result in correspondingly longer recovery periods following the 7 or 11-year scenarios. Nonetheless, the overall expected impacts of widening on vegetation and wildlife are minor in comparison to the relatively undisturbed and extensive natural resources of the region outside the bounds of the project. The loose, uncovered excavated material at the same time may have a beneficial effect, to the extent it represents preferred nesting ground for reptiles, especially the endangered green iguana.

Socioeconomic-Related Conditions. The analysis showed that excavations in the South Sector of the Cut (Gold Hill to Pedro Miguel Locks) may affect portions of the Paraiso townsite where there are several Panamanian Government buildings and housing units immediately adjacent to the banks of the Canal. Long lead times, with reimbursements to affected parties for relocation should help minimize any disruptions to the quality of life in the community. Upland disposal also would require use of two Canal area localities in the North and Central Sectors, presently licensed to the U.S. Army Garrison-Panama for small arms or artillery training. Under the optimum construction schedule military exercises there would have to be rescheduled or relocated to adjacent available areas, but could resume at the same sites after disposal and not result in a long-term change of training conditions. If an 11-year scenario is implemented, by the time disposal operations reached the Central Sector the affected areas within that region no longer would be under use by the U.S. Military in accordance with treaty-related agreements. The positive impacts of the proposed action appear to substantially outweigh the changes in Gaillard Cut ecosystems and inconveniences associated with relocation. During construction some socioeconomic benefits would accrue from increases in local purchases, services, employment opportunities, and ready availability of high quality fill material to the Government of Panama for productive use. After widening, the fully competitive Canal could continue to provide greater economic advantages to large segments of the Panamanian population.

<u>ALTERNATIVES</u>. There are two types of alternatives to the proposed action. The first considers options to full widening the entire length of the Cut, and the second considers changes in methodology to accomplish a widening action. They are outlined as follows:

<u>Alternatives to Full Widening</u>. The operational analysis investigated the merits of maintaining the status quo (no action), construction of tie-up stations or a passing lane, partial widening (expansion to less than optimum width), and partial full widening (widening to a distance less than the Cut's length). Only one, partial full widening, is considered a reasonable option and would result in fewer and possibly less intensive impacts on the environment.

<u>Alternative Methodologies</u>. Variations in both the excavation and disposal procedures were analyzed in connection with the widening program. It was determined that only employment of large cutterhead-suction dredges instead of dipper dredges for the wet excavations

might prove to be cost effective. Operation of such dredges, which places more material for disposal at upland sites and less in the open-water areas, does not cause significantly different effects than identified under the optimum construction methodology, and adoption depends upon technical and financial factors rather than ecological concerns.

CONCLUSION. Based on findings of this report, widening of Gaillard Cut would not result in a major adverse impact on the natural and human environment within the meaning and intent of the National Environmental Policy Act. The review meets requirements of federal agencies abroad under Executive Order 12114, and is in accordance with conservation commitments of Article VI of the Panama Canal Treaty of 1977. END SUMMARY.

I. INTRODUCTION

The Panama Canal has provided virtually uninterrupted safe and efficient service since opening to international maritime trade in 1914, and still is recognized as one of the most successful achievements in engineering history. The Canal is some 50 miles long from deep water to deep water, and operates by a lock system using freshwater gravity flows from Gatun Lake. Gaillard Cut is an important feature of the Canal; this eight-mile section was excavated through the Continental Divide, originally to a width of 300 feet, and accounted for most of the 260 million cubic yards (mcy) of material removed during the Construction Period. Figure 1 schematically shows Gaillard Cut in relation to Gatun Lake and the Atlantic and Pacific entrances.

Over the years the Canal organization has been committed to maintenance, navigational safety, and modernization needed to competitively meet changing shipping demands. Major improvements to accommodate increases in traffic and larger ships have included widening of the original 300-foot Cut to 500 feet (completed in 1971), straightening navigationally difficult curves in Gatun Lake, extending line-of-site across land obstacles, constructing a tie-up station, and deepening (bottom leveling) of the Canal. At present the navigable channel is more than 700 feet wide in Lake areas, but Gaillard Cut remains a relatively narrow and difficult portion of the waterway.

Long range traffic forecasts indicate that the number of large vessels will progressively grow, and widening of Gaillard Cut again may be required for the Panama Canal to remain competitive. In order

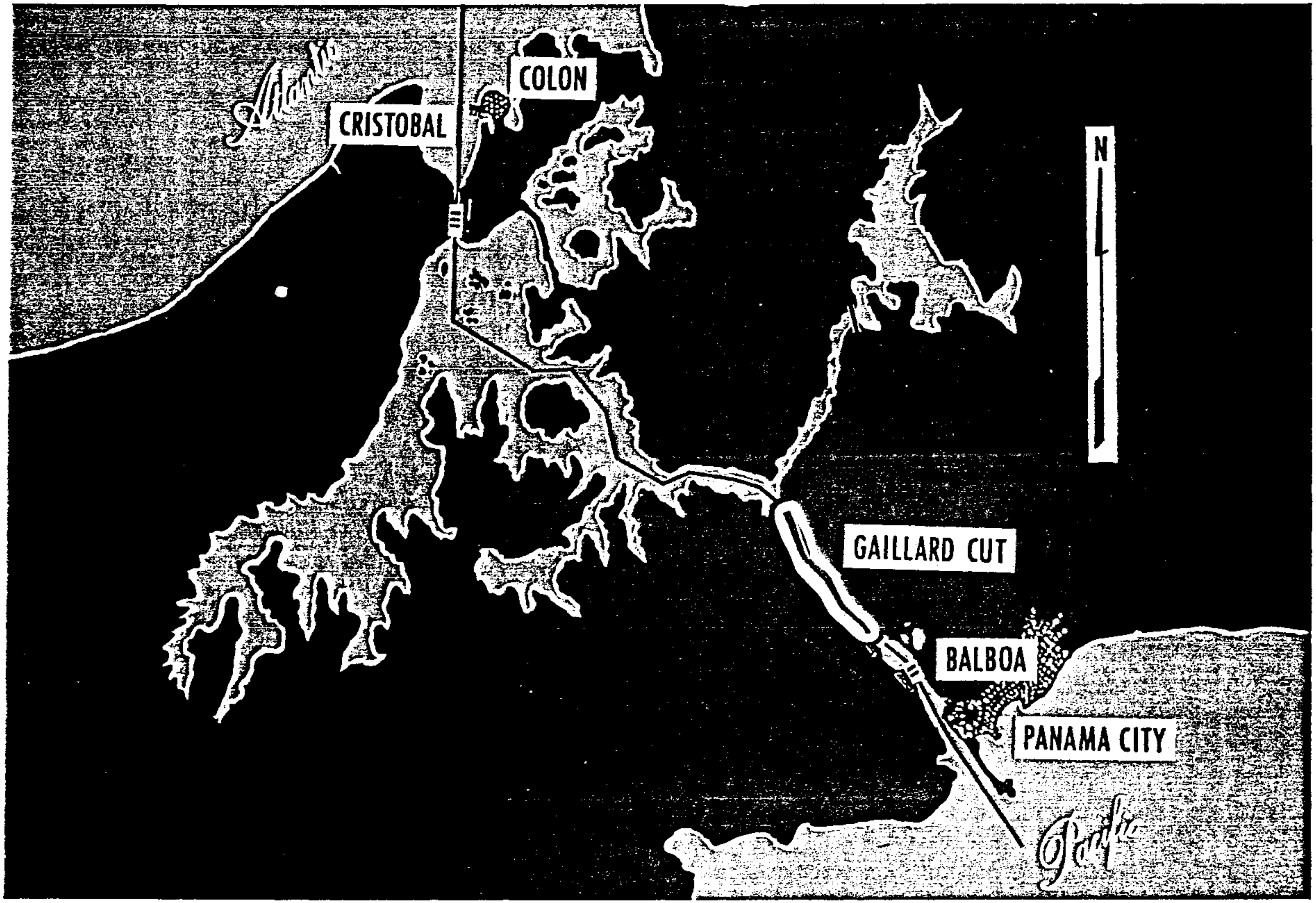


Figure 1. Schematic map of Panama Canal showing Gaillard Cut

to determine feasibility of the widening proposal, a series of studies comprising a technical simulation analysis, geo-technical studies and cost estimtes, an operational analysis, an analysis of financial options, an economic feasibility analysis, and this environmental review will be evaluated. If a Cut widening program is approved and funded, it is estimated, based on current traffic forecasts, that the excavation and disposal operations would not begin before 1994.

Although lead time for the proposed widening action is long, the expected ecological consequences can be reasonably assessed on the basis of available information; the extent of those studies is detailed herein, reflecting a team effort comprised of ecologists and engineers with specialties in biology, botany, chemistry, geology, hydrology and other disciplines. The U.S. Corps of Engineers (USACE) Water Resources Support Center at Fort Belvoir, Virginia participated closely in the development of the environmental review and additional assistance was provided through its Mobile, Alabama District and Waterway's Experiment Station at Vicksburg, Mississippi. Site visits by participating Panama Canal Commission (PCC) specialists were conducted to the recently-completed Tenn-Tom Waterway,[1] and conference/workshops were attended by the preparers which focused on environmental legislation and state-of-art knowledge of the ecological effects of dredging and beneficial uses of dredged material. The environmental study is in agreement with Federal guidelines and procedures established by the Panama Canal Treaty of 1977.[2]

II. PURPOSE OF ACTION

Arrival volume and mix (combination of vessel size) relate directly to Panama Canal efficiency and transit capacity[3]. In past years the dominant factor was total numbers of vessel arrivals; now ship size is becoming more significant because of the limitations imposed by Gaillard Cut. Under existing conditions, wide beam vessels up to PANAMAX-size, built to maximum specifications that the Canal locks can effectively accommodate[4], must be restricted to daylight navigation or to daylight and one-way traffic throughout the Cut's length. The most recent projections have confirmed that the number of Cut-restricted vessels using the Canal will continue to rise and could reach untenable levels by the year 1997. At that point Canal Waters Time, the accepted standard of Canal service to customers, will begin to rise to eventually unacceptable levels.

The purpose of widening is to reduce restrictions by permitting two-way traffic of wide beam vessels in Gaillard Cut. The widening project is designed not only to provide significant increases in long-term capacity for large vessels, but to ensure that the Canal's competitive standards of operation, service and navigational safety are maintained.

III. DESCRIPTION OF PROPOSED ACTION

A. Scope of Project

A map of Gaillard Cut and adjacent areas that shows the maximum excavation and disposal boundaries is attached as Figure 2. The proposal consists of widening the Cut from the existing width

(500 feet) to 630 feet along straight sections, up to 730 feet in curves, and requires excavation and disposal of about 34.1 mcy of earth and rock. Upland disposal sites, each within an average one-mile haul distance from points of excavation, would be used for dry material. Open-water sites are available in Gatun Lake, an approximate haul distance of at least 17 miles, for disposal of the wet material. Upon project completion, established procedures would apply to maintenance of the widened channel.

Further deepening of the Cut is not necessary in connection with the action, as the channel's usable water depth (39.5 feet) meets all expected navigational requirements and can be sustained by the Panama Canal water storage system.[5]

B. Construction Methodology

As shown in the project map (Figure 2), excavation is necessary on one or both banks of seven straight sections (Reaches) and on the inside turn of eight curves (Points of Reach Intersections or P.I.'s) to fully meet width and alignment objectives. Slope designs proposed, where possible, equal or improve the present factors of safety,[6] and most of the excavated slopes would have about the same inclination as before construction in accordance with the diagrammed procedure shown in Figure 3.

For purposes of continuous and phased construction procedure, Gaillard Cut can be divided into sections of approximate equal length: The North Sector (Gamboa to La Pita Hill); Central Sector (La Pita Hill to Gold Hill); and South Sector (Gold Hill to Pedro Miguel Locks). In general, these three segments respectively differ

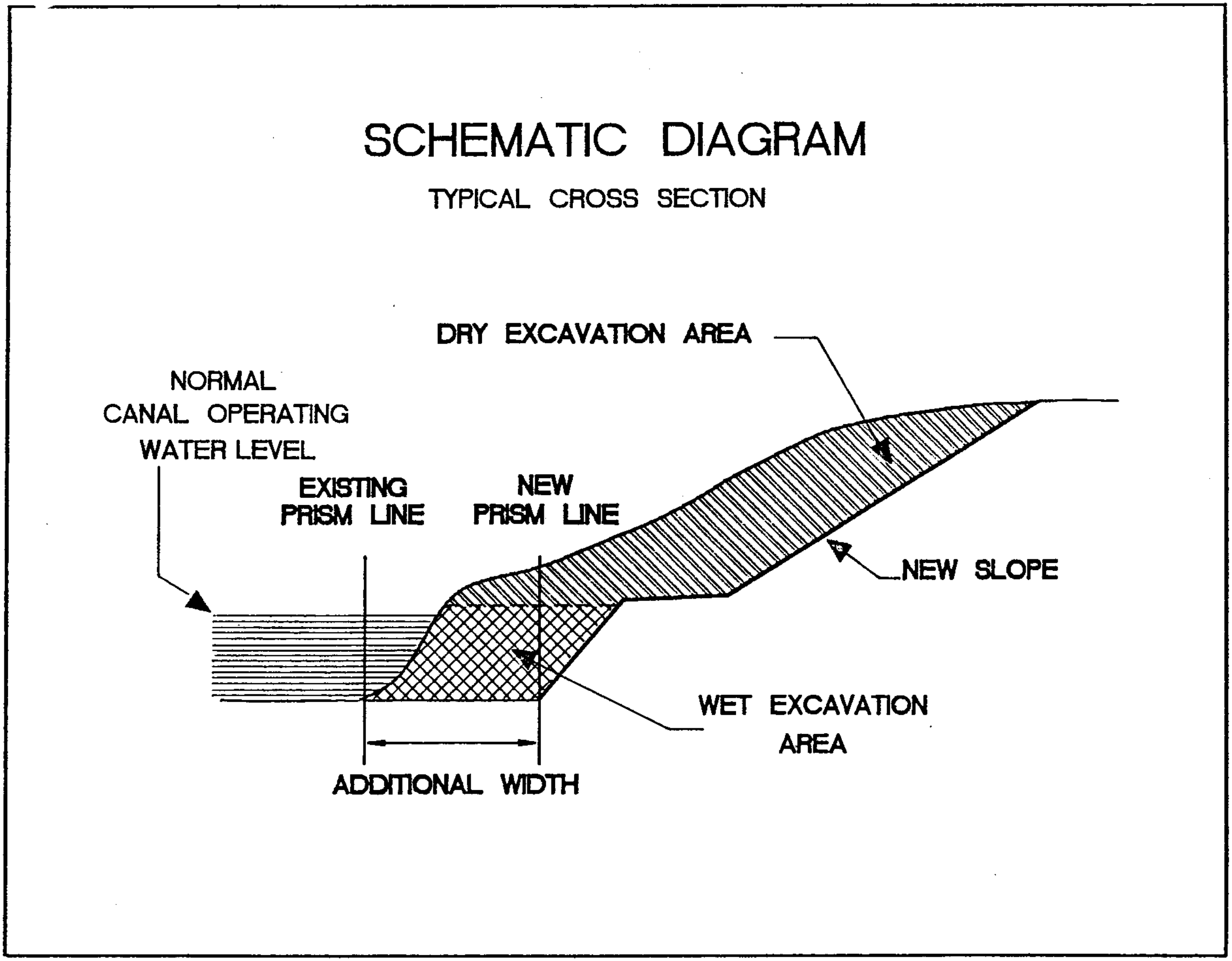


Figure 3. Cross section of excavation areas.

in soil composition (there are approximately 25 geological formations in the Cut), volumes of material to be removed, and slide history. The engineering and operational analyses recommend that work start at the north end of Gaillard Cut and proceed southward, sequentially by sector, until completion. The procedure achieves earliest and greatest advantages to capacity, and minimizes interference with commercial ship traffic during constuction.

Accurate projections on duration and cost of construction cannot be determined until final decisions are reached on project approval, implementation, and the specific engineering requirements. Tentative duration estimates range from a minimum of 5 years up to 7 or 11 years. The lowest cost or optimum construction plan is a 5-year scenario to complete all sectors, and represents the most intensive widening schedule as summarized in Figure 4. All work under this plan assumes a single contract with a large firm; the prime contractor would perform the dry excavations and may subcontract the wet (subaqueous) excavations. Current estimated cost of Cut widening for 5-year construction, including all Canal agency support for contract management, engineering and design, and relocations, is $400M.

C. Excavation Operations

Construction to the recommended widths under the five-year plan should occur generally in two activity waves: first, those related to land-based work; and second, those related to marine-based work. The site-specific dry and wet excavation and disposal procedures depend upon the soil properties and their impacts on slope stability.

Description of Activity	1st Year				2nd Year				3rd Year				4th Year				5th Year			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Mobilization & preparatory work	===	===						===	===											
Clearing & grubbing		===	===	===	===	===	===	===	===	===	===	===	===							
Scraper excavation			===	===	===	===	===	===	===	===										
Drilling & blasting			===	===	===	===	===	===	===	===	===	===	===	===	===	===	===			
Loader/truck excavation				===	===	===	===	===	===	===	===	===	===	===	===	===				
Dipper dredge/scow excavation										===	===	===	===	===	===	===	===	===	===	
Demobilization																	===	===	===	===

Figure 4. Gaillard Cut widening construction schedule, based on single contract and optimum construction period to complete all sectors.

Approximately 25% of the excavations would not require blasting. Where it is necessary, drilling patterns, depths and diameters of drill holes, and types and percentages of explosives would be consistent with ongoing strict safety and engineering standards[7]. The charges used in these types of operations are not expected to exceed 1 lb/cy or 40,000 lbs in a single blast, comparable to other work in the channel.

1. Dry material

All terrain above Canal water level plus five feet (needed as a stable foundation for land-based equipment) is considered dry. These excavations total 22.5 mcy, as detailed by sector in Table 1.

The dry excavations can be performed in two 9-hour shifts/day on a 6-day/week schedule. Although all-weather temporary roads would be opened to minimize delays, working conditions are calculated to be suitable only about 40 weeks per year due to the rainy season in Panama. Clearing and preparation of the excavation sites and access roads employs tractors, bulldozers, graders, and similar equipment assisted by laborers using chain saws and other tools. Removal and movement of the dry material also is largely accommodated by conventional methods, including motor scrapers, push-tractors, rippers, front-end loaders and haul trucks. Vegetation and debris cleared at the areas can be collected at the perimeters, where reasonable, to serve as wildlife cover and a vegetation seeding source during natural weathering and decomposition, is stacked and stoked for burning, or buried at site.

Table 1

Excavation Volumes by Gaillard Cut Sector
(1000's cy)

	Dry Material	Wet Material	Combined Volume*
NORTH SECTOR			
Chagres Crossing (West Bank)	657	1,115	1,772
Bas Obispo Reach (West Bank)	705	1,180	1,885
Las Cascadas Reach (West Bank)	1,044	1,076	2,119
	2,406	3,371	5,776
CENTRAL SECTOR			
Las Cascadas Reach (East Bank)	174	175	348
Cunette Reach (East Bank)	5,147	1,944	7,092
P.I. Empire (West Bank)	34	52	86
Empire Reach (East & West Banks)	3,909	1,812	5,721
Culebra Reach (East & West Banks)	3,339	1,010	4,349
	12,603	4,993	17,596
SOUTH SECTOR			
Gold Hill (East Bank)	2,054	462	2,516
Cucaracha Reach (East Bank)	3,080	809	3,890
P.I. Cartagena (East Bank)	1,518	911	2,429
P.I. Paraiso (East & West Banks)	845	1,027	1,872
	7,497	3,209	10,707
Totals	22,506	11,573	34,079

*Figures may not add across due to independent rounding.

A region of unusual dry excavation and disposal difficulty is Gold Hill on the South Sector east bank. The most practical methodology there, as recommended by USACE experts, may involve pushing off most of the originally estimated 2 mcy to be removed down the north and south faces, for extraction below. However, because access is very limited and the surrounding terrain is so unstable, no firm conclusions have been reached regarding the extent of the Gold Hill contingencies. In October of 1986, after completion of the Cut widening geo-technical studies, a major slope failure occurred adjacent to the south side of Gold Hill following a week of heavy rains on the Isthmus, attesting to existing uncertainties in this portion of the Cut.[8]

2. Wet material

About 11.6 mcy of wet material (Table 1), not economically accessible from land, must be removed with aquatic-based equipment. These wet operations also would begin at the northernmost point, after dry work sufficiently advanced, to proceed southward on a 24-hr/day and 7-day/week schedule throughout the year uninterrupted by rainfall. Excavation by dipper dredges[9] and loading into large bottom-dump scows (4,000-6,000 cy capacity) are viewed by USACE as the most effective proven method for the project. The optimum plan proposes simultaneous operation of two dipper dredges in the Cut; the larger of the two (27 cy capacity) first excavates its portion of the access corridor for a reasonable distance, followed by the smaller dredge (13 cy) to complete the widening. Any small amount of excavation remaining after the dipper dredge work would be removed through normal maintenance procedures. Other support equipment includes tugs, drill boats, derricks, launches, and survey boats.

D. Disposal Operations

With a minor exception[10], dry material as defined would be disposed upland (on land) at nearby sites, and the remaining material transported for open-water disposal in Gatun Lake. These disposal operations are dependent upon the schedules and progression of excavations on either or both banks.

1. Upland disposal

Disposal sites are established only at a prudent distance, usually more than 1,000 feet, from the existing or new channel margins. This practice is designed to reduce overburden and lessen any potential for bank failure. The sites must be of sufficient size to account for expansion or bulking, which occurs when naturally compacted soils are excavated.[11]

Excavated material normally is loaded for hauling to disposal areas using grading equipment, scrapers, front-end loaders, and dump trucks. Access may be provided by existing roads or new temporary haul routes; appropriate precautions are taken during these periods, such as placing safety flagmen at crossings and watering down roadbeds to control dust. Disposal site preparation involves clearing, grading, and associated temporary road construction with inclusion of appropriate storm drains, culverts, bridges, and other structures to assist in year-round access. As in excavation, the vegetation and debris accumulated after clearing the sites and roadways may be moved to the periphery where it can serve as wildlife shelter and seeding sources, or may be buried or stacked and stoked for burning. Disposal normally starts at the lowest portions, with filling as needed toward the highest points at each site. Average maximum fill depth is projected at 50 feet. The material is spread, uniformly compacted, and contoured for drainage, erosion prevention, and, if desired, compatibility with surrounding terrain. Where streams or other watercourses are present, standard good engineering practice involves banking, piping, and diversions to assure that natural drainage patterns are not interrupted.

2. Open-water disposal

The subaqueous material to be dredged consists primarily of boulders and smaller fragmented rock, coarse gravel, and soil. Overdredging and bulking factors increase their total expected wet disposal volume by almost 50%.[12]

Scows loaded by dipper dredge would be towed to deep-water dump sites along the new access corridor while in the Cut, and well away from ship traffic while in Gatun Lake. Haul distances to the nearest alternative range from about 13 miles minimum to 20 miles maximum. Site preparation in the lake is limited to snag and stump removal, if needed for access. Filling to a new water depth of no less than 30 feet (measured at mean lake level) should start at the farthest margins of the site and proceed toward the nearest Canal-side margins.

E. Maintenance of Widened Channel

Maintenance of the widened channel normally would be accomplished by cutter-suction (hydraulic) dredges[13] and consists of the periodic removal of sediment and heavier materials, which accumulate as a result of inflows, bank erosion, ship activity, and the rare slope failures. The Panama Canal Commission has strong in-house capability for maintenance and improvement dredging,[14] and performs all required maintenance throughout the Canal and its entrances; the dredging cycles are listed at Appendix A. The average cycle recommended in Gaillard Cut is six years, and was last accomplished in conjunction with the channel deepening project during 1985. As the widened channel would have similar slope design characteristics, the Cut's ongoing dredging schedules and bank stability and monitoring programs should not change.

Upland disposal areas on the east and west banks and their access roadways have served extensively since Canal construction, and will continue to be used as necessary to accomodate dry spoil that may result primarily from bank stabilization. Wet material from Gaillard Cut also periodically has been disposed upland, in small inlets at the channel's margins, and in a series of Gatun Lake sites. Dump 14, which was established more than 10 years ago, is the currently active lake dump site for barged wet material and has enough capacity to receive long-term maintenance volumes.

V. DISPOSAL SITE SELECTION

A. Upland Sites

At the outset of environmental studies, as many as 16 alternative disposal areas along Gaillard Cut were evaluated by specialists in engineering, biological, and physical sciences, in accordance with all concerns for environmental protection, site design, and management[15]; the principal criteria considered by the review teams are listed in Table 2. Capacity to accommodate the dry material from respective excavation sites in accordance with the

Table 2

Principal Disposal Site Selection Criteria

Engineering Parameters

- Volume of material that can be accommodated (size of area and proposed elevation of fill).
- Haul distance and accessibility from excavation site.
- Site restrictions (right-of-way clearances, presence of navigational aids, buildings, and other structures).
- Drainage pattern considerations.
- Site preparation requirements (clearing, grubbing, and grading).

Environmental Parameters

- Current and past uses of site.
- Presence of wildlife.
- Vegetation types and distribution.
- Presence of watercourses (seasonal tributaries and year-round flows).
- Water quality.
- Proximity to protected areas and communities.
- Cultural and archaeological resources.

optimum construction plan was, of course, the first priority. Emphasis was placed on selecting nearest locations that were previously disturbed or used for disposal; avoided were inhabited or improved lands, training ranges that are potentially dangerous due to unexploded munitions, and areas of unique ecological significance.

A step-down selection process resulted in the seven broadly-defined disposal regions marked on the project map, with potential to receive virtually all (combined) excavated dry and wet materials. The smaller portions shaded on the map were determined most environmentally preferred for disposal, and have dimensions and capacities needed to meet the expected dry volumes (including 25% bulking). Excavation volumes and their corresponding proposed upland disposal sites are compared in Table 3.

The total of seven upland regions and six preferered disposal portions therein needed for optimum disposal methodology can be identified as follows on the project map:

W-1. This west bank alternative lies outside an arm of the Mandinga River and several small tributaries, close to where the river reaches the Panama Canal at the north end of the Cut. The surface of the site measures some 33 acres and haul distance from excavations would average about 0.8 miles. The Gamboa townsite is located 1.4 miles to the North. Parts of W-1 received disposal material in the early 1900's during Canal construction, but apparently not since then; currently there are no specific uses of the land other than occasional military jungle training in connection

Table 3

Comparisons of Gaillard Cut Excavation Volumes and Corresponding Upland Disposal Site Capacities (mcy)

	Sources of Material	Excavation Volumes			Upland Dry Disposal site	Site Capacities**	
		Dry*	Wet	Total		Preferred	Total
West Bank Construction	Chagres Crossing Bas Obispo Reach Las Cascadas Reach	2.4***	3.4	5.8	W-2****	4.4	6.7
	P.I. Empire Empire Reach Culebra Reach	5.2	2.2	7.4	W-3	6.6	10.6
	P.I. Paraiso	0.8	0.8	1.6	W-4	3.7	3.7
East Bank Construction	Empire Reach Cunette Reach Las Cascadas Reach	6.1	2.3	8.4	E-1	7.6	10.3
	Gold Hill Culebra Reach	3.4	0.9	4.3	E-2	4.9	9.6
	P.I. Paraiso P.I. Cartagena Cucaracha Reach	4.6	2.0	6.6	E-3	5.7	7.1

*Portion of excavation disposed upland in accordance with optimum construction methodology.
**Based on average fill depth of 50 feet from lowest to highest points at each site; depths can be increased or decreased as needed to meet specific disposal requirements.
***Includes 0.1 mcy of dry material designated for open-water disposal.
****A last-option (nonpreferred) alternative for part of material disposed at this site is W-1, with additional total capacity estimated at 1.3 mcy.

with the west bank's Empire Range.[16] W-1 is a forested site, selected as a last-option only for wet or dry material from the northernmost areas of proposed channel widening.

<u>W-2</u>. Outermost potential boundaries of W-2 comprise 167 acres, and the portion preferred for dry disposal occupies about two-thirds. Haul distances from expected sources of excavation average 0.7 miles; the preferred disposal area is on the Canal side, where the margins overlap Construction Period disposal sites and resultant flattened terrain is characterized by major clearings. Both intermittent and small permanent streams are present, which contribute to drainage toward the Canal. Most of W-2 is frequently used for military maneuvers.

<u>W-3</u>. This largest upland disposal alternative extends over 262 acres. The preferred area approximates 165 acres and again is dominated by clearings and disturbed second growth vegetation. Average haul is 0.6 miles from the respective points of excavation. W-3's eastern face overlies Construction Period disposal sites and much of the lower terrain at the central part still periodically receives dry fill; Commission records indicate that the most recent disposal operations occurred there in 1983. The principal watercourse is the Camacho River, which forms part of the northern outermost boundary. The area is wholly comprised within Empire Range where large expanses of closely-trimmed grass are maintained in connection with small-arms target practice.

<u>W-4</u>. W-4 is a periodically activated disposal site enclosed by dikes at the southern terminus of Gaillard Cut adjacent to Pedro Miguel Locks. It was first established there more than 15

years ago primarily for disposal of maintenance dredging in the Cut, entrances to the locks, and Miraflores Lake. The entire 93 acres is considered preferred for any disposal operations, and haul distances from the proposed excavations average 0.6 miles. The site accommodates natural drainage of a segment of the Rio Grande River, and supports mostly grasses and limited scrub vegetation that have regrown since last needed for disposal.

E-1. This northernmost east bank location is among the largest prospective sites. About 70% of its 214 acres is considered preferred for disposal, with an average haul of 0.6 miles. Much of the surface is derived from fill deposited during Canal construction, although forest regrowth has occurred throughout most of the area. The environmentally preferred disposal portion was selected on the basis of its most recently disturbed vegetation in closest proximity to the Canal, and to clearings maintained nearby for the Commission's signal station at La Pita Hill and adjacent U.S. Navy Antenna field. There are two perennial streams; the Sardinilla River, which crosses at the northern perimeter, and the Masambi River that forms part of the tentative border at the southern perimeter opposite the small antenna field operated by the Navy. The south side of E-1 falls within an unused treaty-designated Military Area of Coordination connected with those transmission facilities.

E-2. E-2 comprises about 214 acres immediately northeast of Gold Hill, again between the Canal and Gaillard Highway and involving an unused segment of the Military Area of Coordination. Haul distances from this site average 0.7 miles from the proposed excavations at Gold Hill and East Culebra Reach. The northern half is almost level, reflecting its original, extensive use for fill during Canal construction and subsequent landslide stabilization; this preferred disposal portion served as a Navy antenna field until some 12-15 years ago, and now is overgrown by grasses and small scrub vegetation. E-2's principal watercourse is the Obispo River, a year-round, minor tributary of the Canal which passes at the northern boundary.

E-3. E-3 is the southernmost proposed site on the east bank and its limits are entirely on the east side of Gaillard Highway, bordering the Mitras and Las Huertas Hills North about one mile from the Paraiso townsite. Average haul distance to the respective points of excavation also is about one mile, and approximately 95 of the total 146 acres are needed for disposal. The preferred sector is an expanse of dominant grasses, interspersed by other herbaceous plants and small trees, which circumvents secondary forests found at the northeastern and far southern boundaries. Extensive Construction Period filling appears to have interrupted normal drainage along the lowest portions of a perennial watercourse at the site, Canasas Creek, and part of that area now is water-saturated throughout most of the year.

In summary, every upland site considered had served for disposal during construction of the Canal,[17] and at least four since have been periodically reactivated (E-2, W-2, W-3, and W-4), while others have been affected by Canal operation and military training.

B. Open-Water Sites

The total open-water disposal site volume required under the optimum plan is estimated at 17.5 mcy, to accommodate all wet excavations, the limited amount of dry excavations designated for open-water disposal, and expansion (bulking) factors applicable to the dredging processes. Criteria followed for site selection are as listed in Table 2. Originally, seven open-water alternatives were proposed, including several in the deepest and largest regions of Gatun Lake. Three bays, in the vicinity of Dump 14 and Barro Colorado Nature Monument[18], were identified as the only feasible options after consideration of constraints imposed by long haul distance. The three areas are referenced in the map at Figure 5 as follows:

Frijoles Bay. This site lies just North of Dump 14 across the Canal from Barro Colorado Island. The channel and Panama Railroad parallel its southwest and northeast margins, and the Frijoles and Buena Vista Peninsulas determine its southeast and northwest borders. Frijoles Bay is a 16.5-mile average one-way haul from central Gaillard Cut and is the nearest available disposal option that could receive more than all projected dredged volumes. The usable portion of the site has a surface area of approximately 1,008 acres and a total disposal capacity of 22 mcy. For review and comparison purposes, Frijoles Bay can be operationally divided into the two large areas, A and B, shown in the Figure (Part A has 12 mcy capacity and Part B has 10 mcy capacity). A small boat channel is marked with buoys across Part B to provide for continued access between Barro Colorado Island and the Frijoles railroad stop.

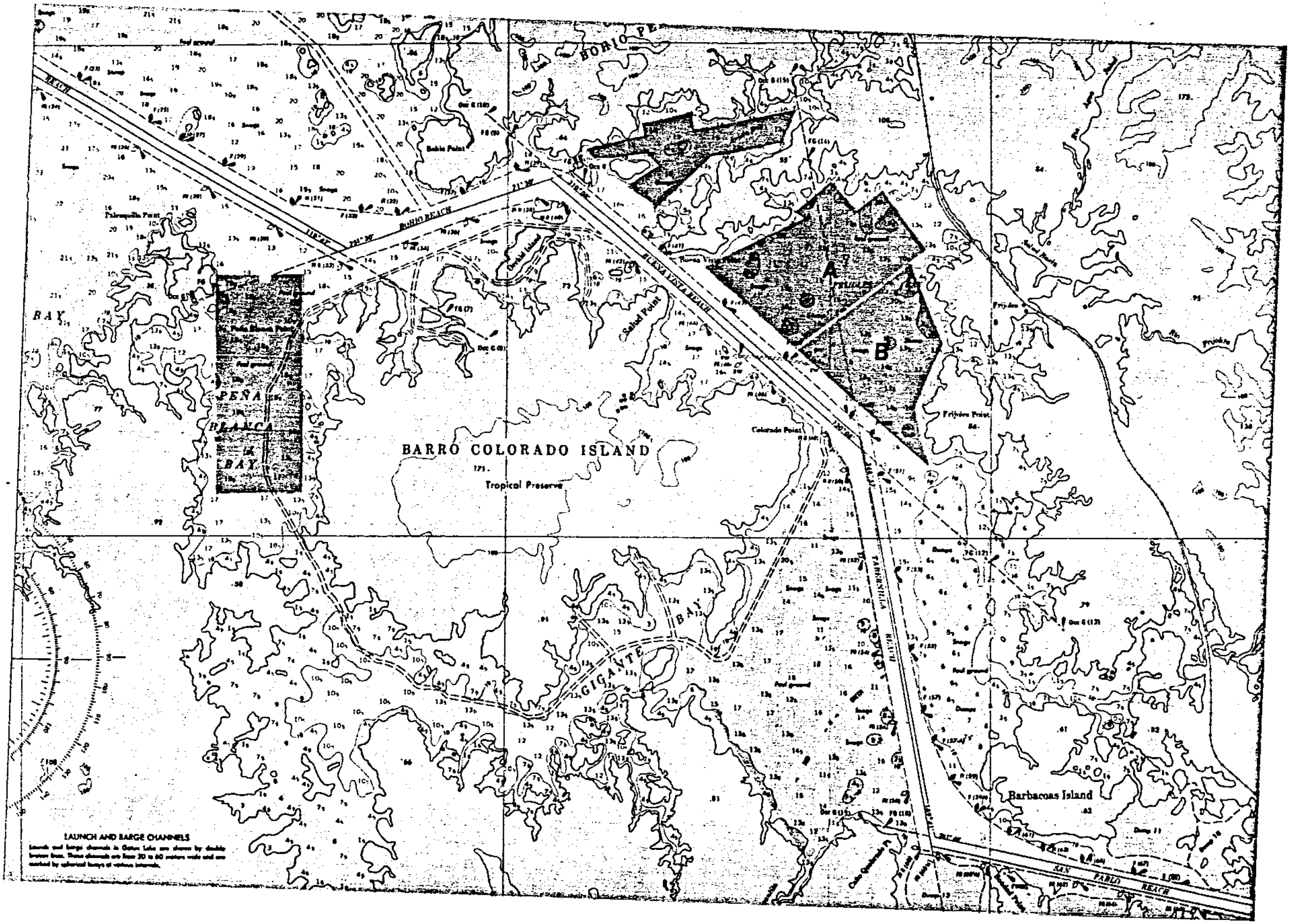


Figure 5. Map showing Gatun Lake alternative disposal sites (orange) and active Dump 14 (yellow).

Aojeta Bay. Aojeta Bay is located on the opposite side of Buena Vista Peninsula, about a one-mile haul farther up channel. This inlet is bordered North by Bohio Peninsula and East, ultimately, by the railroad. The usable portion is relatively small and is calculated at 253 acres with a volume of 6 mcy.

Pena Blanca Bay. This very deep recess of Gatun Lake lies between the west side of Barro Colorado Island and Palenquilla Peninsula. The proposed margins for disposal encompass approximately 611 acres and a usable capacity of 20.7 mcy. While the site is comparable in capacity to Frijoles, the average one-way haul from Gaillard Cut is some six miles farther. A launch and barge access route is maintained across Pena Blanca Bay, and the southern half of the site is outside the Treaty-designated area for operation of the Panama Canal.

VI. ENVIRONMENTAL SETTING

A. Overview of Project Area

Bioclimatic reviews of Panama place the Cut within a Tropical Moist Forest Life Zone.[19] Climate of the zone is characterized by a mean annual rainfall of 71-134 inches and a mean annual temperature of about 26°C. In the Canal area the rainy season usually extends from mid-April to mid-December, and total precipitation diminishes with distance North to South following prevailing northeast winds.

The topography over large segments of the Cut is flattened due to the vast deposits of fill, although there are still numerous conical and irregularly-spaced hills in the region. Terrain is relatively resistant to erosion from stream flowing and weathering, and drainage prevails toward the Canal.

Soils primarily are clayish in texture, acidic, and have a high mineral content. The topsoils typically are shallow and thus can be very fragile when exposed. Important parent rocks in Gaillard Cut, comprised of sedimentary and conglomerate types, have been studied in detail and are reviewed in connection with the geo-technical analysis.

B. Air Quality

Commission records show that suspended particulates and sulfur/nitrogen dioxides are generally at very low concentrations within the Canal area. However, during the dry season (especially the latter part, in the months of March and April) air quality temporarily degrades due to seasonal grass fires that are common throughout Panama and neighboring countries. The stronger dry season winds and low moisture conditions disseminate ashes, smoke, and dust over considerable distances during those periods.

Emmissions from Canal operations and improvements, transiting ships, and other transportation sources are minimal in relation to the overall air quality and have not meaningfully changed in the Canal area for many years. A table summarizing the average high quality of air found in representative Canal localities during a three-year sampling program by the Canal organization is attached at Appendix B.

C. Noise

Background sounds emanating from the routine maintenance and transit activities within the bounds of proposed action generally are not high. Noise levels have increased at specific Cut areas as a result of heavy equipment and blasting operations associated with various improvement projects, including the previous Cut widening, construction of a tie-up station at Paraiso, and channel deepening; attached at Appendix C are principal examples of decibel levels produced by motorized equipment used in these kinds of projects. Frequently louder noises also result from nearby military training activities, the railroad, and Borinquen and Gaillard Highways that are close to parts of the Cut.

D. Water and Sediment Quality

1. Surface and ground water

Hilly terrain that lies within the protected limits of the former Canal Zone is the source of virtually all watercourses that flow across the east and west banks of the Cut. The drainage areas of these perennial and intermittent streams have remained substantially vegetated, and unaffected by urbanization and industry. They are characterized by shallow depths and slow velocities because of the primarily low topography, and ordinarily experience temporary increases in flow and turbidity during the rainy season. The net discharge contributed by the Cut's tributaries is very small in comparison to the influx of waters from the Gatun and Madden Resevoirs and their principal affluents.

Many geological formations in the Canal area, including those in Gaillard Cut, are not porous or permeable enough to provide ground water sources except where fractured and jointed. Such aquifers are often of limited extent and are not favorable for large well development because recharge is extremely slow. There is one potable well in the Cut region, located at the Empire Range to provide water during field training activities.

2. Channel and proposed lake disposal area waters

The waters of Gaillard Cut flow southward and through the Pacific-side locks. Because of this seaward flushing process, the Cut is replenished almost constantly by fresh water. Significant turbidity increases occur during wet season, especially from the Chagres River as shown in Figure 6; however, the coloration changes are primarily due to physical properties rather than degradation of the water's chemical characteristics.[20] Detailed studies by the Canal organization have confirmed that water in the Cut is of good physical and chemical quality throughout the year.[21] Canal water baseline data acquired in 1972, 1975, and 1979 are shown in the table attached at Appendix D. There is one potable water intake in the Cut, at the south end adjacent to the Paraiso townsite, to supply the Miraflores Treatment Plant which serves Pacific-side communities.

A follow-on survey of water quality in Gaillard Cut and proposed alternative open-water disposal sites was performed during 1984 and 1985 as part of the environmental report. Data were obtained from a profile of the water column at each sampling station as summarized in Table 4. These findings, for a broad range of parameters (secchi disk depth, temperature, pH, dissolved oxygen or DO, biochemical oxygen demand or BOD, turbidity, suspended solids, nitrogen, and phosphorous), indicated that water quality in Gaillard Cut has remained comparable to the earlier surveys.

Gatun Lake, one of the largest man-made impoundments in the world, possesses many small bays and a total shoreline of more than 1,000 miles. Its deepest areas lie in the main body North of Barro Colorado Island, where some soundings are over 70 feet. The

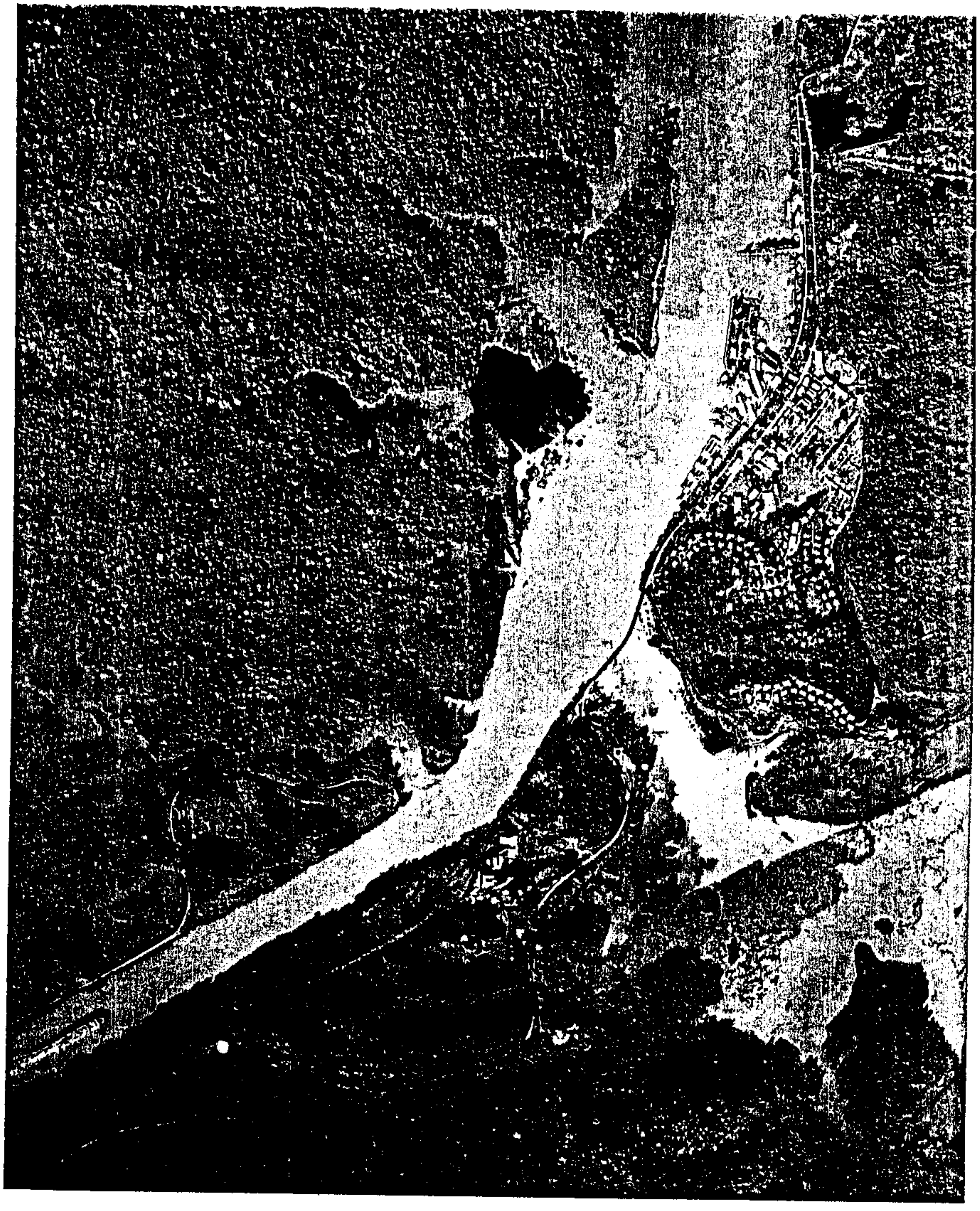


Figure 6. Aerial view of Chagres River, at right, entering Canal between Gamboa townsite and north end of Gaillard Cut; mouth of Mandinga River is shown at lower center, across-channel from former Gamboa Penitentiary. (False infrared photograph at a scale of 1:20,000, taken December 1983.)

Table 4

Water Quality at Proposed Excavation
and Open-Water Disposal Sites*

	Secchi (Feet)	Temperature (°C)	Ph (Units)	DO (mg/l)	BOD (mg/l)	Turbidity (NTU's)	Suspended Solids	Kjeldahl Nitrogen (mg/l)	Ammonia Nitrogen (mg/l)	Total Phosphorous (mg/l)
Gaillard Cut										
North Sector (north end of Cut)	3.50	27.65	7.38	4.65	.88	10.80	7.50	.10	.007	.024
Central Sector (near Gold Hill)	2.50	27.45	7.16	5.00	.24	12.28	6.67	.10	.011	.033
South Sector (Paraiso potable water intake)	4.00	27.70	6.96	4.84	.57	7.19	2.83	.10	.017	.027
Frijoles Bay										
Part A	7.54	28.75	7.42	6.04	.84	17.74	1.50	.10	.01	.03
Part B	6.67	28.80	7.53	5.93	1.31	16.99	.83	.10	.01	.02
Aojeta Bay										
West half	14.00	28.85	7.88	6.45	1.23	.63	1.76	.10	.010	.015
East half	17.00	28.90	7.72	5.83	1.51	.48	.68	.10	.010	.021
Pena Blanca Bay										
North half	12.75	28.75	7.77	6.00	.35	3.98	.52	.10	.01	.01
South half	13.00	29.10	7.78	5.94	.28	2.68	.52	.10	.011	.011
Adjacent Areas										
Dump 14	5.92	28.45	7.48	5.87	1.26	53.01	.28	.11	.04	.09
Barro Colorado Island (across from Frijoles Bay)	7.25	28.75	7.64	6.07	.33	18.26	1.67	.10	.04	.02

*Results are averages based on two testing cycles performed during 1984 and 1985 wet seasons at given locations; each cycle consisted of a sampling profile comprising top, mid and bottom water levels.

waters predominantly are of excellent quality, and have high transparency, low fecal coliform counts, almost neutral pH, and DO levels near saturation with less than 0.5 mg/l difference between top and bottom strata. Water temperatures range from 27.5°to 29.5°C all year, and there are no significant thermoclines because the difference from top to bottom usually is less than 0.4°C. The waters are soft, 35-45 mg/l hardness, and low in alkalinity, less than 40 mg/l. Nutrient content also is low, but sufficient to support a large biomass of aquatic macrophytes (plants). Gatun lake is in a mesotrophic state of eutrophication and thus maintains a high rate of productivity in a well-balanced ecosystem. A detailed limnological review was published by Zaret in 1984.[22]

The principal tributaries of the Gatun Lake Watershed are the Chagres, Trinidad, Ciri, and Gatun Rivers; numerous small streams additionally feed the system. Major turbidity increases can occur seasonally, as was depicted in Figure 6, depending on the amount of rainfall and associated runoff. The channel maintenance dredging operations contribute only small quantities of turbidity overall in relation to such volatile background levels. Turbidity increases associated with inflows from the Chagres River normally will extend North up the channel to Barro Colorado Island, Frijoles Bay, and to a lesser degree, Aojeta Bay. Beyond, there is little evidence of year-round fluctuation in turbidity. The follow-on water quality survey of lake stations was conducted during wet season, and the findings (shown in Table 4) did not indicate any significant changes from the region's average baseline for that time of year.

Water quality differences which appeared between the sampling localities, including readings for secchi disk, BOD, turbidity, and suspended solids, can be attributed to temporary and local impacts of heavy rainfall and close by dredging activities during sampling.

3. Sediment

Minimal sediment has accumulated on the rocky and leveled floor of Gaillard Cut since deepening/maintenance was completed there in 1985. The flushing effect carries solid runoff material into and through this narrow channel towards the locks, so only a relatively thin layer normally is deposited at the bottom. Any sediment present in the Cut is disturbed frequently by ship traffic, causing temporary resuspension in the water column.

Limited testing of sediment composition along the Canal was reported by the agency's 1975 water study. It was stated then that there still is slow decomposing organic matter at lake bottom areas, which probably is related to remnants of the forest inundated when Gatun Lake was formed in 1912. Organic debris is continuously added from the vast weed populations at the shorelines and shallow areas, and is oxidized effectively as a result of the almost daily turnover of these waters. The bottom material is overlaid by the constant deposition of sediment where affected by turbidity, and this sediment, which is silty-clay in texture and olive gray in color, essentially reflects composition of runoff. A very recent, independent report on sediment quality (heavy metals, phosphorus, organic carbon, and total nitrogen) at 80 Gatun Lake localities has confirmed there is a distinctive distribution pattern for most metals along the path of the old Chagres River bed; the concentrations found altogether are rather low, similar to those reported by the Canal organization and can be attributed to geochemical characteristics of the drainage system rather than anthropogenic influences.[23]

Sediment conditions at the alternative lake disposal regions were analyzed for the present study at the time of the follow-on water quality survey, and showed remarkable consistency throughout all potential sites as listed in Table 5. Typically, the material contained approximately 70% montmorillonite (a soft clay mineral) and 30% bentonite, kaolinite, and other clay minerals. The chemistry findings did not reveal any unusual values in metals, volatile solids, nitrogen, oil and grease, or chemical oxygen demand (COD), and are within ranges found in earlier surveys.

E. Vegetation

1. Land vegetation

The country environmental profile prepared by the U.S. Agency for International Development offers a comprehensive report on the terrestrial vegetation of Panama, including the Canal area.[24] A composite photomap of Gaillard Cut prepared for the current study is provided at Figure 7 to show existing vegetation within the limits of proposed excavation and upland disposal. An extraordinary diversity of plant species has been associated with the Canal area,[25] and sections of forest extend up to five miles (the boundary of the former Canal Zone) on either side of the ship channel. However, the distribution of vegetation in the Cut strongly reflects influence of railroad and Canal construction as well as the farming practices associated with those periods. Practically all of the most valuable timber that helped compose the original forest was

Table 5

Sediment Quality at Alternative Open-Water Disposal Sites*

	Volatile Solids	Kjeldahl Nitrogen	Oil and Grease	COD	Hg	Pb	Zn	Fe	Cu
Frijoles Bay									
Part A	11.9	347.5	1709.0	8,792.3	0.11	8.4	120.2	77,941	149.9
Part B	10.3	205.2	763.0	15,721.1	0.04	12.1	119.0	72,597	102.7
Aojeta Bay									
West	12.1	331.1	2065.7	47,653.4	0.09	6.0	100.3	73,069	119.2
East	11.3	253.7	984.4	51,125.8	0.06	12.0	105.5	74,639	114.4
Pena Blanca Bay									
North	14.4	556.1	1107.4	56,920.9	0.06	12.9	122.6	79,972	129.2
South	16.9	474.5	2367.1	79,586.8	0.07	14.4	118.9	89,428	149.9

*Concentrations are expressed in mg/kg except where indicated. Results are averages based on two testing cycles performed during 1984 and 1985 wet seasons at given locations. Samples were obtained using a 6"x6" Ekman Dredge.

removed long ago, and the many fruiting tree species planted since construction now are frequently seen. Canal operations and military training also have contributed to alteration of the natural vegetation processes in Gaillard Cut.

Bank areas and most adjacent slopes already are regularly maintained for a number of activities related to the Canal for lighting, navigational aids, and slope stability. Vegetation close to the channel thus consists primarily of grasses, with some stands of secondary growth particularly along parts of the east side margins.

A vegetation survey was performed at each proposed upland disposal area to assist at the earliest in the site selection process. Appendix E is a condensed report of that study, giving the plant and tree identifications, their distribution, and estimates on abundance. More than 100 species were recorded in the survey, and all represent lowland secondary forest associations found over much of tropical America. Among the grasses were cana silvestre or Vietnam grass (Saccharum spontaneum), faragua (Hyarrhenia rufa) and introduced pasture species, Guinea grass (Panicum maximum), Napier grass (Pennisetum purpureum), and Rhode grass (Chloris gayana). Mixed age plant indicators often seen were guarumo, capulin, malagueto, mangabe, and laurel. The common later secondary tree associations of the region included barrigon, cuajado blanco, verba, jacaranda, Panama tree, gallito, sagrillo, and many more. A number of hardwoods also were observed at the sites, such as guayacan (Tabebvia guayacan and T. rosea), prickly yellow (Zanthoxylum sp.), amarillo real (Terminalia amazonia), zorro (Astronium graveolens), and espave (Anacardium excelsium), but as expected very few were of commercially attractive size. Selective logging throughout the region long ago was further evidenced by the absence or near absence of fine wood trees like cedar (Cedrela odorata) and mahogany (Suwietenia macrophilla), and contrasted with an abundance of mango (Magnifera indica), rose apple (Syzygium jambos), caimito (Chrysophyllum cainito), and other cultivated fruit-bearing species.

With the exception of W-1, and E-1, the proposed areas encompass large sections where grasses and scrub vegetation predominate. Dry season fires sometime occur in such clearings, just as throughout Panama's countryside, but revegetation soon takes place with the onset of the first rains of the wet season. Nearby secondary forests, mainly established on the hilly terrain, normally are not burned. The oldest and most diverse habitats among the proposed disposal boundaries are found at the northernmost sites (W-1 and E-1), apparently because of the slightly higher rainfall and fewer activities disruptive to succession there since construction.

2. Aquatic Vegetation

Steep slopes at the channel margins, relatively deep water depths along the banks, and constant disturbance by transiting ships in the excavation areas do not permit development of aquatic vegetation except in a few small inlets. Small pieces of floating plant mats sometimes move with phytoplankton from the contiguous river and lake waters into and out of the proposed Gaillard Cut project area, southward with the current.

The phytoplankton and macrophyte communities of Gatun Lake have been carefully reviewed by the Canal agency, in connection with an earlier sea-water pumping feasibility analysis.[26] Algal populations were shown to consist of nearly 180 species representing four groups: the Chlorophyta (green algae, including desmids), Bacillariophyta (including diatoms), Cyanophyta (blue-green algae), and Pyrrophyta (including dinoflagellates). Because Gatun Lake waters are thoroughly mixed and lack thermoclines, these phytoplankton are uniformly distributed in the water column. No single species dominates the community thoughout the year, as desmids are most prevalent in the rainy season and diatoms and nannoplankton populations are highest at the end of that period and during dry season. Occasionally, blue-green algae also become locally abundant.

There are at least 28 species of macrophytes identified from Gatun Lake, consisting of submergent, emergent, free-floating, and marginal plants. The dominant species, Hydrilla verticellata, is indigenous to India, but apparently has been in the Canal area for many years and began proliferating in Gatun Lake after year-round water level stabilization was achieved with completion of Madden Dam. Hydrilla maintains dense foliage from within approximately three feet of shore out to depths of 20 feet or slightly more, and its growth must be closely monitored by the Panama Canal Commission.[27] Other pest weeds of importance are water hyacinth (Eichornia crassipes) and water lettuce (Pistia stratiotes); when unchecked these species can form large free-floating mats at river banks and lake shorelines.

F. Wildlife

Attached at Appendix F is Panama's National Institute for Renewable Natural Resources (INRENARE, formerly RENARE) list of the wide variety of animals that may be found within the Panama Canal Watershed and adjacent areas extending to parts of the Cut and margins of Gatun Lake. Additional discussions on the wildlife species characteristic of the former Canal Zone are presented in the Installation EIS prepared for the U.S. Army Garrison-Panama (formerly the 193d Infantry Brigade).[28] Following is an overview of the major taxonomic groups.

1. Mammals

Handley (1966)[29] and Mendez (1970)[30] offer comprehensive descriptions of the mammalian fauna of Panama. Widespread hunting resulted in the near disappearance of certain large animals, including jaguars and other cats, tapirs, deer, capybaras and peccaries from the Canal area and contiguous lands long ago. However, many of the smaller types have remained relatively abundant in the region's protected grass, scrub and forest habitats. The most commonly seen in the project area are coatimundis, opossums, armadillos, sloths, rabbits, bats, raccoons, tree squirrels, marmosets, nequis, agoutis, and other various rodents. INRENARE considers a number of small, terrestrial mammals to be endangered or threatened in Panama (see footnotes to the species list), yet many of them (armadillos, marmosets, nequis, agoutis, etc.) may be locally common especially in the forests of the former Canal Zone. These populations remain protected since treaty implementation, largely due to the designation of national parks (Parque Nacional Soberania, Parque Natural Metropolitano, and Parque Nacional Chagres) and the Barro Colorado Island Nature Monument (see Footnote 18).

The long-tailed otter (Lutra annectens) is a rather uncommon aquatic mammal known to occur in Gatun Lake; however, due to a retiring nature and not particularly good range, it has not been reported as a resident at the alternative lake disposal sites or the Cut's waters. The West Indian Manatee (Trichechus manatee) is another rare aquatic species inhabiting Gatun Lake. This mammal apparently occurred in the Chagres River valley prior to the building of the Canal, but was eliminated later by rural subsistence hunters. Descendants from nine specimens that were stocked during 1964 for Canal weed control are now distributed in various parts of the lake, although there are only infrequent reports of manatee sightings - particularly in Gaillard Cut where there are few aquatic macrophytes.

2. Reptiles and amphibians

Snakes are very numerous in Panama and most of the approximated 130 different kinds, including commonly encountered boas, are not poisonous. Venomous snakes that may occur in the project area comprise both corals and vipers; they are represented by bushmasters, fer-de-lances, hog-nosed and eyelash vipers. Other common reptiles are turtles, lizards, and a variety of frogs, toads, salamanders and other amphibians.

The green iguana (Iguana iguana), protected in Panama because of intense hunting pressure[31], is abundant in the Canal area. Iguanas often are attracted to bare ground for nesting along the banks of rivers and islands, and the shores of Gatun Lake; soft, exposed material at recent excavation and disposal sites also has been sought for egg-laying. The American crocodile (Crocodylus acutus), which is considered endangered throughout Central and South America, is found in limited numbers in the lake and Cut waters, as are populations of the aguja caiman (Caiman crocodylus fuscus).

3. Birds

There is a great diversity of bird life throughout the Isthmus. According to Ridgely (1976),[32] almost 900 species of birds have been sighted in Panama (more than occur in the entire United States and Canada) and approximately 700 breed locally. During the northern autumn and spring periods, migrant passerines and ducks become conspicuous elements of the avifauna. In December, during the annual Christmas count performed by the Panama Audubon Society, more than 200 kinds of birds usually are recorded from the Pacific Canal localities. As with mammals, hunting pressures before controls were instituted years ago reduced a segment of the native population, and there now are few resident wild turkeys, quail, eagles, ducks and many other game and nongame birds in the project area. Terns, herons, egrets, kingfishers, teals and other waterfowl, which formerly preyed on phytophagous fish species, also have been disappearing from Gatun Lake over the past 20 years.[33] Among birds normally encountered in the project area are buzzards, grackles, hummingbirds, kingbirds, robins, wrens, finches, flycatchers, and tanagers.

Some of the many birds listed as endangered or threatened by INRENARE undoubtedly could overfly or visit the upland and aquatic project areas. However the majority of sites selected are very near Canal or military operations, regularly affected by noise and other disturbances, and consequently do not always serve as appropriate habitats for these species.

G. Zooplankton, Fishes and Benthos

The types of aquatic life found in the lake and its contiguous waters are extensively described in several contributing papers to the sea-water pumping feasibility analysis[34] and in the Canal agency's EIS prepared for introduction of the white amur (Ctenopharyngodon idella) into Gatun Lake during 1977.[35] The studies have included population dynamics and relationships to plant ecosystems for the lake's zooplankton, fishes, molluscs, crustaceans, insects and related organisms. An up-to-date compilation of works by Zaret (1984) (see Footnote 22) also provides a detailed account of this most intensively examined of Central American lakes. Following is a summary of the principal nonmammal groups that occur in Gatun Lake.

1. Zooplankton

Virtually all of the zooplankton communities consist of crustaceans and rotifers. The crustaceans are principally represented by cladocerans and copepods, with a brief appearance of decapod shrimp larvae in the plankton early each year. In addition to these limnetic (open water) animals, there is a variety of small benthic crustaceans dominated by paleomonid shrimps.

2. Fishes

The most common freshwater fishes recorded from Gatun Lake represent the families Atherinidae, Characidae, Cichlidae, Goeidae, Eleotridae, Pimelodellidae, and Poecilidae; there are also several marine forms that enter via the locks. The species historically found in the lake proper, the locks and adjacent drainage are listed in Appendix G, although probably many are no longer present or are very rare because of the impact of the accidental introduction of a predatory South American cichlid in 1967 (see Footnote 33).

3. Benthos

Fresh-water bottom-dwelling organisms are principally comprised of populations of molluscs, annelids, and arthropods. At the relatively turbulent and sediment-free bottom of the Cut, establishment of such communities is difficult and limited. In contrast, the conditions of depth, water quality and accumulated sediment in Gatun Lake often favor benthos development. A special study conducted 12 years ago to determine biological impacts of channel deepening, showed that in areas sampled near Barro Colorado Island the molluscs (clams) contributed by far the greatest biomass.[36] As many as 51 bivalves and 70 snails per square meter were recorded, and populations showed remarkable consistency between the sampling stations.

Open-water disposal sites proposed in the current study were surveyed for benthos throughout the approximated boundaries during the March-April period in 1985. Attached at Appendix H are computerized schematic diagrams of those respective sampling efforts at Frijoles, Aojeta and Pena Blanca Bays. A total of 48 representative sediment samples (each a composite of four grabs) was retained for macrobenthos identification and quantification by the Tennessee Valley Authority as contractor. That report is attached at Appendix I and a summary of findings is presented in Table 6. Similar to the earlier observations, most collections at the three bays yielded a prevalent clam (Corbicula sp.), and as many as 50 or

Table 6

Dominant Macrobenthos at Alternative Open-Water Disposal Sites in Gatun Lake March-April 1985*

	Frijoles Bay (25 Samples)**	Aojeta Bay (11 Samples)	Pena Blanca Bay (12 Samples)
MOLLUSCS			
Pelecypods (clams)			
Corbicula sp.			
- Mean number per sample	28.6	15.7	30.8
- Percent of total macrobenthos per site	84.4	79.4	87.5
Gastropods (snails)			
Melanoides tuberculata			
- Mean number per sample	2.2	2.4	1.8
- Percent of total macrobenthos per site	6.4	6.9	5.0
Pyrgophours coronatus			
- Mean number per sample	1.9	1.6	1.2
- Percent of total macrobenthos per sample	5.5	7.8	3.3
ANNELIDS			
Oligochaetes (worms)			
Branchiura sowerbyi			
- Mean number per sample	1.5	0.5	1.3
- Percent of total macrobenthos per site	2.5	2.3	3.8

*Based on identifications of 48 representative samples, each a four-grab composite using a 6"x 6" Ekman Dredge and sieved through standard (No. 50) mesh; 51 additional survey composites examined on-site were consistent with these summarized findings.
**Data combined from 13 samples at Part A and 12 samples at Part B.

more specimens were counted in some samples. Two types of snails (Melanoides tuberculata and Pyrgophours coronatus) and an oligochaete worm (Branchiura sowerbyi) were sporadically observed, but were far less common. Again, there was a relatively uniform distribution of the dominant organisms, both within and between the sites, and at the range of depths surveyed (27-84 feet). Other organisms seen rarely in the samples were waterbugs, caddisflies, midges, isopods and leeches.

H. Economic and Social Conditions

A comprehensive overview of the Canal area's socioeconomic baselines is presented by the former 193d Infantry Brigade's installation EIS (see Footnote 28), while more specific treaty-related changes in local communities, cooperative arrangements between the United States and Panama, and other pertinent matters are addressed in the State Department's 1977 Treaty EIS.[37]

The Canal historically has been an important factor in the local economy, and its role should increase in the year 2000 when full responsibility and control is assumed by the Republic of Panama. Estimated gross income flow into Panama from U.S. Government agencies of the Canal area exceeded $500M in 1985. This flow is exceptionally large when considering the multiplier effect, which conservatively translates into a contribution of over $1B to Panama's economy.

Four small townsites or living areas are within and near the eight-mile Cut region. Portions of one community, Paraiso, lie at the southernmost east banks of the Cut, and are the only populated sites directly affected by optimum widening as shown in Figure 8.

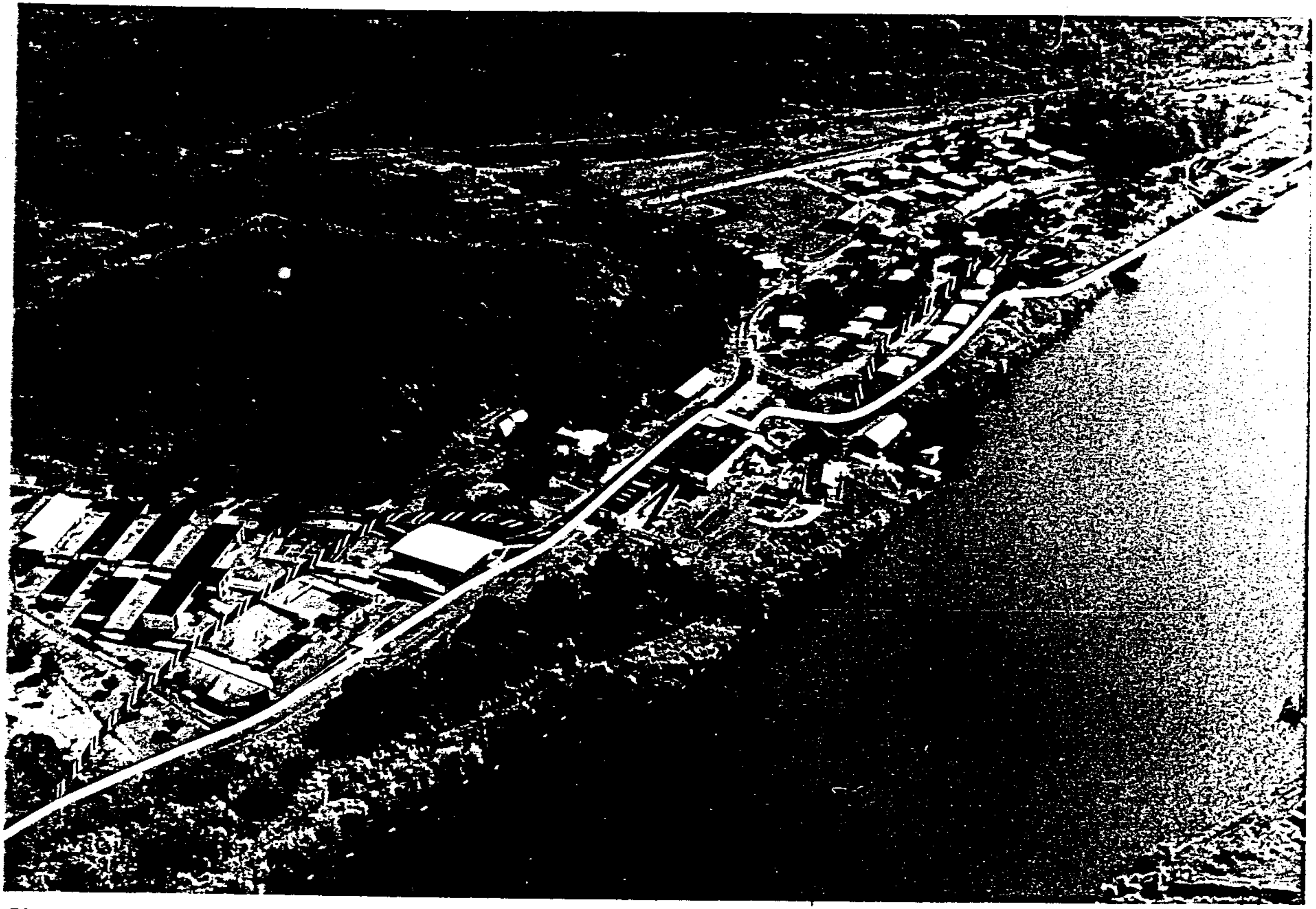


Figure 8. Aerial view at southern portions of Paraiso townsite, showing optimum plan excavation limits (solid line) and contiguous areas (broken line) where structures are subject to removal. (Note - Canal Commission potable water pumping station and line-handler's docking facilities appear on channel margins at right-center and extreme upper-right of photo, respectively.)

Paraiso contains a total of approximately 300 housing units, and is served by elementary school, police station, post office, health clinic, shopette, gas station and other conveniences. Its population mainly is comprised of West Indian descendents or third-country nationals, and many are retired employees of the Canal organization. In accordance with the treaty, Paraiso housing and public buildings are owned and administered by the Ministry of Housing, Republic of Panama, thus residents and shopkeepers are there under rental agreements with the Government of Panama. Facilities retained after treaty by the Commission at the townsite are the raw water intake and pumping station (for Miraflores Water Treatment Plant) at water line below the townsite's Service Center, and a line-handler's dock on the channel South beyond the residential district. The Commission's tie-up station lies across-channel from Paraiso, and also falls within the areas proposed for excavation.

Found at various distances from the Cut outside project bounds are residences at Gamboa and the former Gamboa Penitentiary (now operated by Panama's Defense Forces); Pedro Miguel, a community similar to Paraiso East of Pedro Miguel Locks; and the U.S. Navy Antenna Farm still in operation North of Upland site E-2.

As indicated previously, licensed military training activities connected with Empire Range inside Canal operating areas (across Borinquen Highway on the west bank) constitute a major use of the Cut's lands throughout the life of the treaty. There are no farming or commercial interests throughout the proposed upland bounds of excavation and disposal, and there are no aquatic recreation, commercial or sport fishing interests of any meaning within the project area.

I. Cultural Resources

1. Paleontological, archaeological, and historical resources

Paleontological attributes of the Canal area, including Gaillard Cut, are well-documented from rock and sediment layers.[38] Tertiary period molluscs constitute the bulk of evidence, although fragmented Miocene remains confirm presence some 20 million years ago of primitive deer, large camels, rhinoceroces, rodents, crocodiles, and turtles apparently derived from North American species.

The former Canal Zone circumscribes a variety of sites of archaeological and historical interest dating from the Pre-Columbian, Spanish Colonial and earliest Railway and Canal Construction Periods. These resources were studied by consultant for a Canal widening program implemented in 1975, and the findings which address parts of the proposed project area are attached at Appendix J. Evidence shows that man inhabited the Isthmus at least 11,000 years ago, with numerous human settlements occurring throughout Panama and especially along major watercourses such as the upper reaches of Chagres River. Spanish colonies grew along the Chagres in connection with the trans-Isthmian trade routes, including the Camino Real and Camino de Cruces.[39] It was basically along the same routes that the railroad was built in the mid-1800's, followed by the French Canal efforts during the late 1800's, with construction and successful completion of the waterway in mid-1914 by the United States. Many of the sites, former settlements and other areas pertaining to construction of the Canal, were inundated by creation of Gatun Lake at the time the channel was filled.

A plaque, serving as a monument to Canal construction workers, has been placed on Contractor's Hill near a public lookout on the west bank; while not inside the project bounds, excavation operations could be observed from that point.

An archaeological reconnaissance survey which covers some of the lands proposed for upland disposal was conducted during 1979, on behalf of Panama's National Institute of Culture (INAC) for the U.S. Army training components.[40] Several potential sites of some interest were identified on the west bank, along Mandinga River and parts of Empire Range. However, archaeological evidence was scarce and not considered unique and consisted primarily of stones, fragments of ceramics, and shards. No significant cultural remains have ever been found within the possible upland bounds of the project.

2. Areas of special ecological interest

Parque Nacional Soberania and the Barro Colorado Nature Monument are the principal natural reserves established in the Canal area, and parts of their boundaries lie adjacent to limits of proposed action. The park serves mainly as a sanctuary of Panamanian flora and fauna, and has been recognized officially since 1980. It extends over 22,000 ha east of the railroad, from approximately Obispo River North (following Pipeline Road) to Gatun Lake. Barro Colorado Island, which was formed by impoundment of the Chagres River in 1914, has been a vegetation and wildlife refuge since 1923. The monument, including five adjacent peninsulas, occupies over 5,000 ha, and most are densely forested lands characterized by a rich diversity of wildlife.

VI. POTENTIAL ENVIRONMENTAL IMPACTS

Discussed below are environmental parameters that could be affected by the scope of widening operations.

A. Excavation Sites

1. Air quality

Total suspended particulates and other air pollutants resulting from blasting, earth moving by land equipment, possibly limited burning of cleared vegetation, and related work would tend to increase temporarily in the immediate vicinities of excavation, as well as access road and disposal site preparation, as construction moved from North to South. The projected increases in concentrations of air particulates and sulfur, nitrogen, and carbon oxides are small in relation to the Cut environment and quickly disperse under ambient conditions. The engineering practice of watering down access routes, however, is an important dry season preventive measure against the potentially greater local dust problems that would result during hauls to upland disposal sites.

Over the long term, a widened Gaillard Cut must accommodate a steady increase in large ships, but the slight rise in emissions from them could not be considered ecologically meaningful. The newer large ships and support equipment will carry more efficient pollution controls to further reduce the anticipated marginal air quality effects.

2. Noise

During construction, land and water motor-driven equipment would constitute a potential source of noise heard in the vicinities of excavation, including the Gamboa, Paraiso, and Pedro

Miguel communities and the few housing units associated with the former penitentiary and the Navy antenna farm. This type of noise might have a transitory adverse impact only when southward movement of excavation or transportation activity is in closest proximity, and the levels that would be generated are similar to occasional background sounds that already originate from maintenance and improvement work in the Canal.

Blasting is a particular sound source briefly affecting wider areas. As a normal procedure, use of explosives by the Commission is closely coordinated with Marine Traffic Control (to prevent interference with transiting ships) and is announced well in advance to alert communities at possible hearing distance. The periodic detonations connected with widening would be scheduled only during daylight hours and be restricted to the minimum required at specific sites of excavation as work progressed southward. Nevertheless, it is expected that such discharges could cause little distraction at Gaillard Cut, where similar explosions are produced during Canal maintenance/improvements and are commonly heard from nearby Empire Range.

Any related additional impacts from the increases in size and number of transiting vessels also should be insignificant. The primary sources of ship noise (engine, gears, and propellers) are below waterline or are enclosed within the hull, and comparably low sound levels are associated with transit operations at the locks.

3. Water quality

The effects of dredging are well documented as a result of the leading and extensive research program launched by the Corps of Engineers in 1973.[41] In the absence of contaminants such as in the case of primordial (parent) materials of Gaillard Cut, the main water quality concerns of excavation pertain to temporary increases in turbidity and its effects on aesthetics during the constructon phase. The turbidity generated by dipper dredges results from resuspension, when the bucket strikes or is pulled off the bottom, and from spillage during barge loading. Normally the elevated suspended solid concentrations are confined to the vicinity or are diluted greatly in current flows, and dissipate rapidly when operation ceases.[42] Levels of metallic ions, such as manganese and iron, and ammonium nitrogen, phosphates, and reactive silica that occur in the primordial material increase only briefly in the water column over background conditions with each bucket load. There also are no persistent or well-defined plumes of dissolved metals or nutrients, and any small changes in the physical characteristics of the water disappear rapidly.

Water quality might be slightly affected locally from rainfall and watercourse runoff into the Cut, during or soon after excavation. The potable water intake at Paraiso represents the only reasonable point of concern in the Cut and shall continue to be closely monitored by the Commission for normal filtering requirements and to assure prevention of degradation in quality from any other sources. High turbidity levels are common at the intake area during the wet season without affecting normal water treatment operations.

There are no expected operational-phase water quality impacts of the action, other than the temporary and limited increases in turbidity that would result in the Cut from two-way traffic instead of one-way traffic of the wide-beam vessels.

4. Vegetation

No meaningful short-term or long-term impacts on vegetation could occur at most excavation sites, because flora to be removed largely consist of grasses and early secondary growth that is limited by Canal bank stability and maintenance programs, and perhaps established and trimmed, as necessary, since the last Cut widening completed in 1971. In all instances the affected banks again soon would be quickly revegetated and mostly covered by the first pioneer grass species, predominantly Saccharum, that minimize erosion. The successional growth processes are continuing along these parts of the Canal where not interrupted by dry season fires or by Canal requirements.

5. Zooplankton, fishes and benthos

Zooplankton are dependent on algae for their food, and theoretically may be adversely affected by any process that reduces or otherwise alters species composition of the phytoplankton community. The standing crops or productivity of these microcrustaceans additionally may decrease if very fine suspended sediment is present that clogs their filter-feeding mechanisms. The zooplankton communities that drift through the Cut during excavation should be only slightly and locally affected for the above reasons, because little variation could occur in associated phytoplankton and the predominantly rocky material does not yield widespread fine suspended solids.

The expected low levels of sediment suspension at the excavation sites also should not meaningfully harm fish populations by injury to gill membranes or by a reduction of ability to capture prey. Fishes normally are not threatened by limited turbidity increases, and in any event can quickly retreat from affected areas at will. Previous experience during work in the Canal indicates that the greatest possible temporary impacts on fishes result instead from blasting operations which precede the excavations. The charge sizes necessary for a widening effort can stun or kill small fish in immediate vicinities, but are apparently far less harmful to larger animals such as crocodiles.[43] There are no projected increases in any operational phase impacts on zooplankton and fishes in Gaillard Cut.

Benthic organisms within substrate physically removed from the Cut would be lost, although few are expected to be affected because of unsuitability of that environment due to constant stirring by ship traffic and the periodic disruptions of maintenance dredging. Over the long term, a wider channel essentially represents a much larger, identical bottom habitat for benthos and could then even have a positive impact on their populations.

6. Economic and social conditions

From the outset of the 5-year and longer construction plans, increased opportunities for direct and indirect employment (especially connected with Panama-based contractors performing dry excavations), purchases of materials (fuels, supplies, and various products such as lumber, piping, cement, spare parts, etc.) and all relevant services would contribute to a positive impact on the local economy. Beyond, over the operational phase, Panama, the United States, and maritime trade stand to benefit much more by ongoing efficient, modern and competitive operation of the Canal that may be achieved through timely widening of Gaillard Cut.

Adverse social effects in the Cut area that might be associated with noise or degradation of air and water quality during excavation are not considered meaningful. These changes would be slight and temporary, primarily related to aesthetics and limited to a small radius from the work sites.

If there is full widening in the South Sector, unavoidable additional impacts would occur in the social environment of Paraiso. During construction near that area, some residents would experience periodic disturbances from increases in truck and heavy equipment traffic. Further inconveniences would arise from the temporary or permanent relocations of access routes, several living quarters, stores, offices, facilities and other infrastructure. The affected Government of Panama buildings (shown in Figure 8) are expected to specifically include seven duplexes, a meeting lodge, gas station, gym, pool, and community center; occupants of the center have consisted of a Defense Force unit, health clinic, credit cooperative, snack bar, and shopette. As a part of the total cost of the proposed plan, the Canal agency shall reimburse the Government of Panama for replacement of any such buildings and their attendant structures requiring removal. Very long lead periods would precede any work in the Cut's South Sector, thereby providing the Panamanian Government sufficient time to plan and implement the necessary moves or any other compensation it deems appropriate to best mitigate effects on Paraiso residents. As indicated before, the Paraiso potable water intake, line-handler's dock, and Tie-up station are the principal Canal facilities subject to removal in the vicinity of the townsite.[44] These types of relocations, where appropriate, would be accomplished by PCC with minimum interruption of services to area residents and without compromising the efficient and safe transit of ships. Upon completion of the South Sector excavations, normal social activities, community functions and conveniences should resume and not constitute a long-term negative impact on life quality.

There are similarly no relevant concerns attributable to the operational phase after widening, especially as they pertain to ship accidents and oil spills, or maintenance requirements. Instead, the action yields a waterway that is safer for navigation and less subject to closure from slope failures or other incidents. On balance, widening is expected to represent a major socioeconomic benefit to Panama that far offsets the inconveniences at community level.

7. Cultural resources

The paleontological remains known to potentially occur in strata to be removed are scarce, fragmentary, and have been found elsewhere in Panama. No valued resources pertaining to either the Colonial or Construction eras are expected to be encountered because of the major disturbances already experienced throughout the channel banks, particularly by original digging of the Canal and by subsequent widening.

Although cultural resources would not be potentially affected by the excavation operation, as a precautionary measure experts from INAC's Bureau of Historic Patrimony shall have the opportunity to visit work areas. In accordance with this concern, INAC would be notified immediately in the event that artifacts or other evidence were uncovered during the course of the project and, if appropriate, work may be interrupted by the Canal agency to permit further reconnaissance.

B. Upland Disposal Sites

1. Water quality

Experience from years of maintenance and improvement work in the Cut indicates that during and following upland disposal there may be transitory degradation of stream water quality in the disturbed and contiguous areas; the typical changes primarily involve turbidity, and other minor alterations in pH, conductivity, DO, temperature, and the related parameters.[45] Specific engineering plans developed for each site well in advance of disposal, as an ordinary, practical and environmentally prudent measure, however, should ensure minimal impact. The standard engineering practices were noted to include installation of culverts at stream crossings to avoid blocking natural drainage, as well as grading, contouring, and ditching along haul roads and at the sites to minimize temporary increases in runoff and erosion. Minor negative effects on water quality and other ecological factors, such as invertebrate habitat diversity, would be most evident in the streams during heavy rains before the regrowth of vegetation and should disappear substantially thereafter. There are no expected long-term changes in the aquatic ecosystems of the Cut region as a result of the proposed dry disposal activities.

The well at Empire Range is not within the limits of disposal, and its operation or water quality would not be impacted.

2. Vegetation

Vegetation was considered the environmental factor most susceptible to change by upland disposal, irrespective of construction schedule, and close adherence to site selection criteria was necessary to assure minimum contact with trees, especially older stands of secondary forest. Undoubtedly some large trees will be lost if the project is implemented, but the extent of removal, even at E-1, is very small in comparison to the remaining expanse of forest cover East and West of the channel (see Figure 7). Quality and abundance of the flora are indicative that natural succession historically has been highly effective in the Cut's environment,[46] and it appears that concerted efforts to increase the normal rate of tree establishment in such instances would be unnecessary and costly.

A longer construction period than the 5-year schedule would produce somewhat less intense effects during widening, but at the same time extend any recovery periods. As with excavation areas, revegetation at the disposal sites and their temporary accessess generally should resume immediately by Saccharum and other pioneer species. Where excavation yields a predominance of rock that does not readily support regrowth, more weathered substrates may be used if necessary as topsoil, or fertilizing, seeding, and planting would be employed in coordination with INRENARE to encourage recovery. Prevention of dry season fires, especially at the predominantly grassy sites, is an additional measure that may be taken to minimize interruptions to the natural processes of plant succession where clearing is required.

In summary, relatively limited and peripheral forested areas would be disturbed by the action at most upland sites, and it is reasonably expected that much of the vegetation could return to near pre-existing composition where it reflects the adjacent plant communities. The potential long-range negative impacts overall should not be meaningful in relation to the local and regional environments.

3. Wildlife

Unlike bank excavation areas, which support only small numbers of primarily adventive terrestrial animals, upland disposal habitats can carry more diverse and established populations. Much of the upland wildlife are capable of avoiding the disposal operations, and with gradual progression of excavations southward, noise should first cause dispersion from nearby localities followed by the displacement effects of site preparation and later disposal. The activity probably would result in some permanent migrations away from preferred habitats. Stress also would be induced in certain animals due to territorial requirements, with losses of those that cannot leave and nesting areas. However, since the majority of proposed upland disposal sites and their access routes already are disrupted periodically for disposal, military training, and Canal maintenance, the adverse impacts from widening could not be construed as major and would not measurably impact adversely on total wildlife populations supported in the Cut region.

There are instances of positive effects on wildlife as a result of the action. In particular, disposal, grading, and its related work would generate an abundance of loose exposed soil at all distances from tributaries that could provide temporary additional nesting ground for reptiles, especially the endangered iguanas, crocodiles, and turtles. Other animals may be favored by the protected cover of cleared vegetation pushed to the peripheral areas, and by new habitats created after earliest grass and scrub growth appears after disposal. No rare or endangered species have been reported that could be meaningfully harmed because of the proposed upland disposal operations.

4. Economic and social conditions

Under the optimum 5-year construction plan, the proposed disposal activities West of the channel probably would require temporary relocation of military training scheduled within the bounds of W-2 or W-3 in the North and Central Sectors, respectively. Inconveniences to the U.S. Army Garrison-Panama may involve moving small arms targets and facilities to nearby areas, but do not affect the Empire Range field management buildings and associated infrastructure that are located adjacent to the highway margins of W-3. The same types of military exercises could be resumed at the two affected licensed areas soon after site preparation and disposal proceeded beyond, and thus should not result in a significant long-term change of existing training conditions. There are no anticipated corresponding impacts on Navy transmission operations East of the channel, where the recommended disposal sites E-1 and E-2 at the Central Sector extend into unused Military Area of Coordination. If the longest possible (11-year) construction scenario is implemented, widening work would not reach the Cut's Central Sector until the treaty-related agreements had expired and those areas no longer would be under use by the U.S. military.

Opportunities for uses of the material to be disposed that are beneficial to the human environment have been considered. Good fill material locally in short supply (such as basaltic rock) could be easily accessible at disposal sites, and may be made available to the Republic of Panama for sanitary landfill cover, rail and roadway bedding, or aggregate construction purposes. The greater expanses of level, well-drained terrain created in connection with proposed upland disposal, where consistant with Canal management, also may be suitable for Panama's longer-range reclamation projects, including parks and recreational areas. The implementation of these socioeconomic programs, which is not within the scope of the Canal agency, would depend upon interest expressed by the Government of Panama.

5. Cultural resources

Strict adherence to site selection criteria, a careful literature search, and review of findings with INAC officials have confirmed that there are no known archaeological or historical resources of significance connected with the proposed action. Nevertheless, in accordance with concerns to protect any potential finds of cultural interest, the same measures taken to involve INAC personnel at the excavation sites would extend to the bounds of upland disposal.

C. Open-Water Disposal Sites

1. Water quality

The fate of dredged material in lake environments may be governed by a number of internal and external factors such as sediment concentrations, seasonal changes in weather and related energy shifts, currents, disposal operations and ship traffic.[47] Studies by USACE and others reflecting the many years of research and experience under a mulititude of conditions show, however, that generally few and limited water quality impacts are connected with open-water disposal; the changes in water column from the types of operations proposed are essentially physical in nature and result from creation of mounds and temporarily increased turbidity.[48] The material of Gaillard Cut is free of pollutants, and consists of 80-90% rock and solids with the remaining comprised of clays. Heavier materials which predominate would readily settle to the bottom and only produce minor turbidity plumes at immediate locations. No strong water currents or other disturbances are connected with the three optional disposal sites (at Frijoles, Aojeta, and Pena Blanca Bays) that could widely spread the limited suspended solids. Only small streams feed each of these lake inlets and they are far removed from any off-shore bounds deep enough for disposal.

In summary, water quality at any of the optional locations should not be adversely impacted significantly because the effects would be very localized and disappear quickly, as occurs after disposal operations at nearby Dump 14. The seasonal increases in turbidity at Frijoles Bay, and to some extent at Aojeta described earlier, still represent much greater degradation of water quality than could be generated by disposal from Cut widening. Frijoles Bay, with its large capacity and shortest haul distance, appears to offer the greatest environmental, engineering, and economic advantages among the proposed Gatun Lake areas.

There are no projected long-range effects on water quality at the conclusion of disposal operations.

2. Sediment quality

There is ordinarily very little, if any, release of concentrated or aggregated substances from bottom sediments as a result of open-water disposal.[49] During deposition from scows the sediment is covered, and effectively caps any possible contaminants with new material. The concentrations of potential pollutants in the bottom sediments at the Gatun Lake alternatives nonetheless are low, and have been shown to principally reflect surrounding geology.

Over the long term, the areas used for disposal would eventually return to near-existing bottom conditions by the constant, slow rain of solid particles from naturally-occurring turbidity. This process is accelerated at the Frijoles Bay altenative, where seasonal turbidity is markedly influenced by the Chagres River.

3. Phytoplankton and aquatic macrophytes

Since phytoplankton depend on sunlight for energy, a reduction of sunlight penetration into lake disposal site waters could decrease their productivity. Of course this effect from the project, if even detectable, would be far less than what may result from widespread and substantial longer-term variations in turbidity due to the river flows. The primordial rock and soil to be excavated are not nutrient rich, so any minor increases in nutrient levels at the aquatic disposal sites that could foster algal blooms similarly are not significant.

Aquatic macrophyte populations are not expected to be increased or decreased by the project. The bounds of potential disposal in Gatun Lake do not have existing infestations of aquatic plants because they are too deep. The principal pest in the area, Hydrilla, and other weeds do not develop extensive submersed beds or topped-out surface mats unless clear water depths approximate 20 feet or less, therefore retention of a minimum 30 feet after completion of disposal has been incorporated as a control measure.[50] The low levels of turbidity or nutrients that would occur during the construction phase additionally cause only temporary and marginal effects. There are no projected long-term impacts on aquatic vegetation of Gatun Lake.

4. Wildlife

Manatees, crocodiles, caiman and waterfowl of the lake are not normally found in deep or open-water areas devoid of vegetation, such as the Cut and inside the perimeters proposed for disposal. The animals instead prefer more productive habitats of shallower water and shoreline, where aquatic weeds provide food and shelter for many species. They are often very timid and readily move when disturbed, and would be expected to safely retreat in the few instances they might be encountered during open-water disposal operations. Accordingly, there is no reasonable potential for short or long-term adverse impacts on aquatic wildlife.

5. Zooplankton, fishes and benthos

The possible effects on zooplankton and fishes in Gatun Lake are basically confined to what occurs from the physical effects of turbidity. As discussed previously, the rocky primordial material to be disposed would settle quickly and result in sediment resuspensions of only a limited and temporary nature at the quiet waters of Frijoles, Aojeta or Pena Blanca Bay. Zooplankton should not be meaningfully changed by this turbidity, or by algal blooms because of the low order of suspended nutrients, and fishes could avoid or quickly move away from the areas of disposal activity at will. There are also no projected operational phase impacts on zooplankton and fishes.

Bottom-dwelling communities are most affected by open water disposal, since they are covered wherever the scows release loads of material. Studies have shown that recolonization begins soon thereafter and is achieved at various rates by vertical and lateral migration, and (depending upon the similarity of substrate) reflects the nature of surrounding benthic communities.[51] Zaret earlier investigated such impacts at several disposal sites in the fresh waters of Gatun Lake, and reported that although some temporary changes resulted in the usual composition of benthic molluscs at the sites, the new substrates were quite acceptable to all species (see Footnote 36).

The rocky material from proposed Cut excavations is dissimilar to existing bottom sediment at the alternative open-water sites. Processes of recolonization thus probably would be slower than if like (clay) material were desposited, but balanced by the short-term diversity created by the new habitats. These probable impacts are small in relation to the vast, almost identical portions of the lake bottom unaffected by the project, and in the long term the constant rain of sediments from natural sources would again cover these disposal locations and promote return of the existing homogeneous benthos populations.

6. Cultural resources

Existing records have established that there are no known Pre-Columbian resources of significance that might be affected by disposal at the Gatun Lake alternatives. Among numerous inundated locations of later human activity along the original banks of the Chagres River at that region, there are two that could lie within the radius of proposed action (Frijol and Pena Blanca).[52] However, the previously referenced report by consultant Richard Cooke indicated that any Colonial Period structures at either locality have been considerably modified or destroyed by the railroad and the disturbances that followed in building the Canal, thus subaquatic research or preservation measures cannot be justified. Structures that arose at the same locations during the Construction Period additionally are not considered of particular cultural merit,[53] especially after so many years of sedimentation and Canal-related disturbances, and they are already well-documented by written and graphic records. Based on the given reasons, the environmental review concluded that no meaningful losses of productive or pristine cultural evidence should result during or following open-water disposal.

Areas of special ecological interest, represented by the vegetation and wildlife of Barro Colorado Island, adjacent peninsulas, and shoreline waters of the nature monument are close, but lie outside the bounds of proposed action. The small boat channels at Frijoles and Pena Blanca Bays used to access parts of the monument also would not be changed as a result of the disposal operations, because of the established 30-foot depth margin. During the project there should be only minor and local turbidity effects similar to those seen at Dump 14, which has been in use for many years off the west side of the channel against Barro Colorado Island without apparent negative impacts on the Smithsonian Institute's activities. As a final consideration, before action is taken at a new disposal site in Gatun Lake, scheduling and other pertinent data would be coordinated with the Institute well in advance to avoid or mitigate any unforseen inconveniences and to ensure that planned disposal operations are not inconsistent with the purposes of the monument.

VII. RELATIONSHIP TO LAND USE PLANS, POLICIES AND CONTROLS

The proposed action supports the objectives of the Treaty and implementing documents by ensuring ongoing, effective operation and maintenance of the Canal. The project, which represents the second major effort to widen Gaillard Cut because of changes in ship traffic, would employ essentially the same types of excavation and disposal equipment and methods in effect from the Construction Period. All existing programs pertaining to maintenance and improvement of the waterway (dredging of accumulated silt, stabilization of channel margins, etc.) that have been necessary since the waterway opened in 1914 would continue as before widening.

The bounds of optimum excavation and upland disposal fall entirely within Treaty-defined Canal operating areas, except for the portions of Government of Panama lands that might be affected near the channel's banks at Paraiso and small sections of unused Military Area of Coordination connected with E-1 and E-2. Where licenses have been issued for military training at the proposed west bank sites W-2 and W-3, the agreements will stand throughout the life of the treaty but provide for earlier termination if the lands are needed for Canal purposes.[54] All of the open-water disposal alternatives lie wholly within Canal operating area with exception of the southern half of Pena Blanca Bay. The use of any of these potential disposal sites for purposes of the project would be fully coordinated where necessary with Panama and the Smithsonian Institute, consistent with documents implementing the Treaty.[55]

No major controversies or public concerns have been raised as a result of the recommended action. Pending issues or decisions which could reasonably change, involving refinements in recommended timing or phasing of the operation methodology, ultimate southward limit of Cut excavations, and certain other engineering and contracting procedures, also are not expected to alter the overall findings of this environmental review. The project is structured in a manner that ensures preservation of quality of the natural and human environment, following the well-estabished guidelines of the National Environmental Policy Act (NEPA), Executive Order 12114, and the Panama Canal Treaty (see Footnote 2).

VIII. ALTERNATIVES TO PROPOSED ACTION

A. No Action

No action or postponement maintains the status quo, and does not initiate an immediate physical change in the natural and human environment. However, without timely improvements to existing Gaillard Cut traffic restrictions, the Canal progressively will become congested and less efficient. Loss of revenues and jobs could result if the Canal becomes noncompetitive, which represents a potentially significant long-term adverse impact on the local economy.[56]

Management has the options of reducing the quality of service (increasing Canal Waters Time) or modifying safety-related transit restrictions for wide beam vessels at the Canal. These administrative measures to increase the flow of traffic through Gaillard Cut rather than implementing improvements do not offer long-term solutions.

B. Tie-Up Stations

The existing tie-up station across-channel from Paraiso, North of Pedro Miguel Locks, permits greater utilization of the locks when normal traffic at Gaillard Cut is interrupted due to fog or during turnaround time between northbound and southerbound traffic of restricted vessels. The tie-up station concept is consistent with continuation of one-way traffic in the Cut, and is a method of reducing idle time that occurs between changes in direction. Since this station is used for unrestricted vessels, it does not provide a solution to the problems from the increasing large-vessel transits.

The operational analysis shows that if a second tie-up station is operated in the Central Sector of the Cut, only a minimal theoretical capacity gain could be obtained, and would require sychronization between northbound vessels, southbound vessels, and vessels tieing up at the Paraiso tie-up station. Even minor delays thus would tend to offset any of the possible advantages. The total evaluation of the capacity effect of a second tie-up station, which includes consideration of the increased probability of accidents, more tugboats, and complex scheduling synchronization, forces its rejection as an alternative.

C. Passing Lane

The logical site for a passing lane is North of Gold Hill because it is near the time midpoint of the Cut, and the terrain there is relatively flat with good visibility. Unlike a tie-up station, the passing lane has little advantage and ranks last among the alternatives to full Cut widening. It would compound scheduling difficulties by creating two restricted (although smaller) areas instead of one, and there is no assurance that the perfect synchronization required could ever be achieved. In reality, the passing lane would have to increase to near the full length of the

Cut because of the magnitude of unavoidable scheduling and ship-arrival discrepancies. Finally, the lack of an access corridor during construction would force the barges carrying excavated material to enter the navigation channel and interfere with traffic.

D. Partial Widening

Studies conducted by the Computer Aided Operations Research Facility at Kings Point, New York, as part of the technical simulation analysis, were based on navigational requirements for large 106-foot beam PANAMAX vessels. If the widening dimensions instead were based on a smaller-sized vessel, (e.g., 90-100-foot beam) to achieve partial widening, the major concerns of the forecast could not be addressed. According to the forecast, which shows user trend toward the largest size vessels, this alternative would not achieve the capacity necessary to maintain long-term efficiency of the Canal.

E. Partial Full Widening

Partial full widening is an expansion to the proposed alignments, but for less than the eight-mile length of Gaillard Cut. This type of scenario may be implemented if funds are not available for the entire project because incremental capacity gains could be achieved North to South, although costs by sector would rise since construction would be interrupted and require extensive mobilization. Partial full widening allows greater participation by resources of the Canal agency and/or local contractors.

If the Cut is widened to a point less than its full length, of course the effects on the natural environment in undisturbed sections are avoided. As discussed previously, any longer construction periods, such as those connected with these schedules, would tend to lessen the intensity of environmental disturbances in the project area while increasing the time of recovery. This action also could provide even longer lead times for making the necessary relocations but the ultimate impacts of widening would not change.

F. Alternative Methodologies for Dry Material

Engineering studies performed by USACE on project methodology reviewed all major types of excavation equipment and recommended the most cost effective, efficient means applicable to the local, predominantly rocky, conditions. Among principal alternatives considered for dry material was the employment of large shovel tractors instead of front-end loaders, especially for removal of blasted rock; they were judged much less desirable than loaders due to lower mobility, maneuverability, and higher cost. Other methods that may be conventional elsewhere, including wheel excavators and conveyors, were compared and found unsuitable for this project because of the impractical transportation distances and the anticipated presence of boulders, slabs, and large rock fragments.

There are no reasonable alternative disposal methodologies applicable to the proposed dry construction effort.

G. Alternative Methodologies for Wet Material

1. Excavation

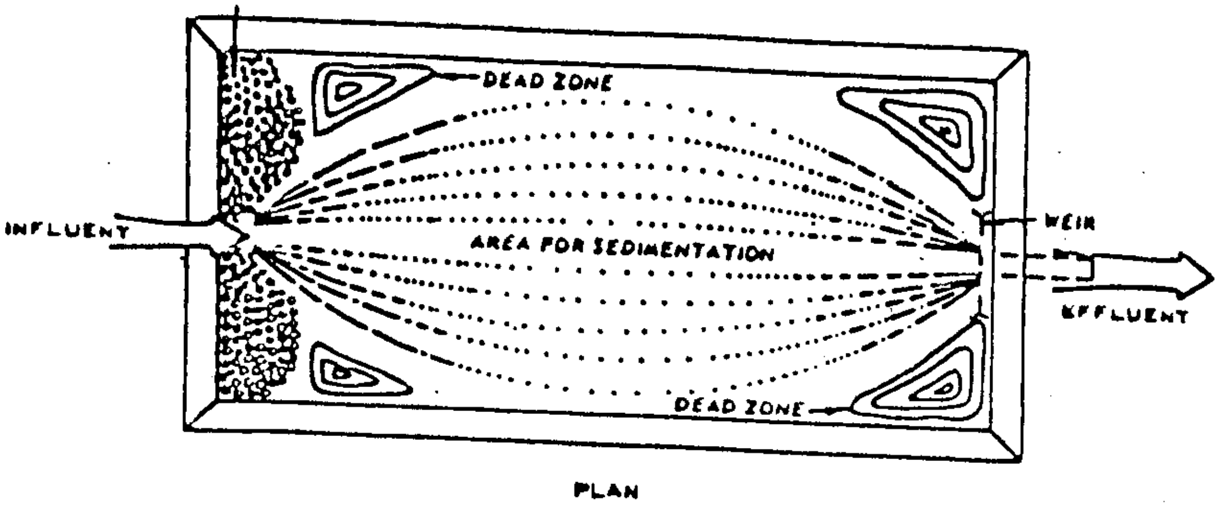
The potential use of backhoes, large draglines, and clamshell dredges to excavate the wet material also was rejected because of inability to handle large boulders and rock fragments that would result from drilling and blasting. However, serious consideration still may be given to large class cutterhead-suction dredges (hydraulic dredges of 10,000-20,000 horsepower with a pipeline discharge 30 inches in diameter or more). This option can be very economical and effective when wet material characteristics permit shearing by cutterhead blades and pick points, and if substantial quantities are to be removed. Cutterhead-suction dredges were not recommended as part of the optimum plan by USACE since there is no prototype information supporting applicability to the wide range of geological formations in the Cut - where large boulders and lenses of hard material are anticipated in many locations. Based on available data, employment of hydraulic dredges on the project is too risky and possibly uneconomical because of mobilization requirements, unpredictable downtime, and uncertainty of the total volume of material that could be accommodated.

If powerful hydraulic dredges become available and prototype information does prove their utility in Gaillard Cut, they still could be implemented because savings in project time and cost may accrue. In the event that this method performed at least a segment of the proposed widening,[57] the ecological consequences identified for wet excavations by dipper dredges remain valid; the effects of operating suction dredges are comparable for the evaluated components (air quality, noise, aquatic ecosystems, socioeconomic conditions, etc.) and probably would produce even fewer changes in excavation site turbidity because of the vacuuming process.

2. Disposal

Relocation of the wet substrate to shallower parts of Gatun Lake that are closer to the proposed excavation areas is not feasible under the optimum plan for several reasons, including inaccessibility to barges, site volume limitations, and adverse effects of possibly enlarging habitats supporting infestations of pest weeds. The channel margins and few partially submerged inlets along the Cut also are not suitable for dumping from barges because of the size and depth constraints.

If hydraulic dredges perform part or all of the proposed widening in place of dipper dredges, suitable open-water sites could not be economically reached and disposal would be accomplished at the same upland alternatives selected for the dry material. All seven upland areas are within routine pumping distance capability from the respective points of excavation, and a discharge pipeline could be deployed temporarily to any of them with little clearing or existing right-of-way preparation. Because of expected grain size variability in the discharge slurry (comprising about 80% water to 20% solids), settlement basins of the type shown in Figure 9 may be necessary to allow sedimentation before drainage of the supernatant water back to the Canal. Such impoundments are designed in accordance with strict engineering guidelines,[58] and are comparable to the existing Canal maintenance disposal sites established at Farfan and Velasquez Fill near the Pacific entrance, Telfer's Fill near the channel's Atlantic entrance, and W-4. The new impoundments, if needed, would be constructed using material from the corresponding dry excavations and still would not extend beyond the maximum site boundaries already reviewed and delineated in the project map. During operation, settlement is regulated by weir and should achieve clearer effluent water (lower turbidity) than found in the vicinities of excavation.[59]



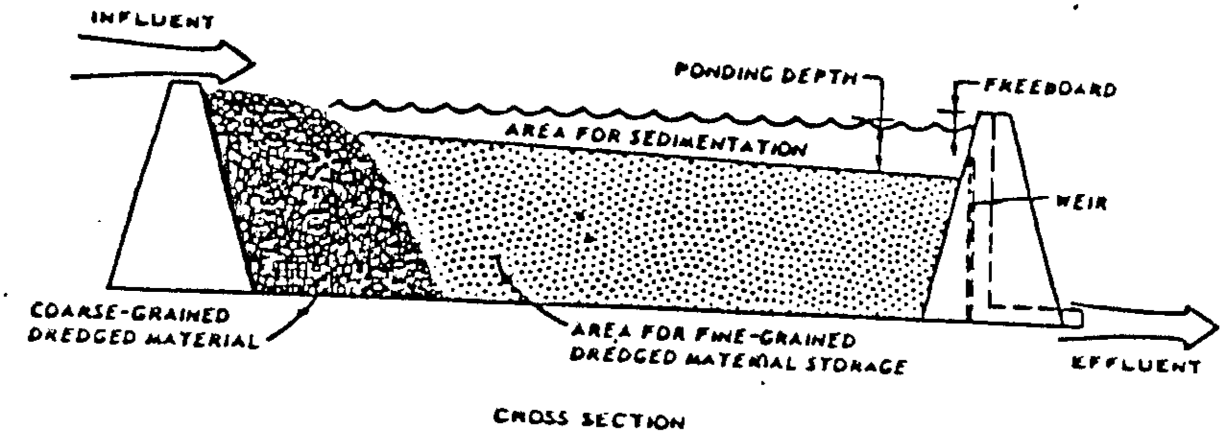


Figure 9. Schematic diagram of a dredged material containment area. (From, Dredging and Dredged Material Disposal, EM 1110-2-5025, 25 March 1983, Department of the Army, Corps of Engineers).

The environmental components affected by upland disposal of hydraulic dredging are among those identified for the dry material (water, vegetation, and wildlife). In cases where wet disposal could be performed at the site effectively without dikes, some sheet flows would be created that cause temporal but not severe increases in erosion and turbidity as the waters return to the Canal through natural watercourses; even fewer changes on water quality should result if diked impoundments are built in accordance with engineering standards.

The principal ecological impacts would derive from using additional upland area for material that otherwise would have been disposed in Gatun Lake. As shown in Table 3, in the very unlikely event that hydraulic dredging could substitute for all dipper dredge work throughout the entire Cut, perhaps near maximum capacities at any of the seven upland alternatives might be claimed for disposal.[60] Although the site selection procedure has ensured least environmental impact for any selected upland disposal action, of course use of the wider margins would require removal of additional dense secondary growth, and more disruption and displacement of wildlife to contiguous forests is unavoidable. This is especially evident at sites W-1 and E-1, where existing vegetation is least disturbed. As a matter of some mitigation, however, disposed slurry should produce a relatively smooth soil base, which promotes even more rapid and diverse recovery of vegetation and soon provides a grassland wildlife habitat, while in the meantime providing optimum nesting ground for iguanas and other reptiles.

The possibility of new impoundments serving as breeding ground for mosquitoes, gnats, and related pest insects was carefully reviewed by sanitation officials and their full report is attached at Appendix K. The study concluded there is no significant pest or vector growth potential associated with wet upland disposal from the Cut because conditions which favor development would not be present (brackish water, high organic content, and fine sediment that produces extensive fissures when dry), coupled with an efficient and experienced vector control program. All cooperative, preventive measures suggested by the sanitation report nonetheless would be closely followed if impoundments are constructed.

In summary, this alternative reduces or averts disposal operations in Gatun Lake, and places that wet material instead within the maximum disposal perimeters established upland by the site selection criteria; the same upland locations served for disposal during construction of the Canal, some since reactivated, and the potentially affected extent of vegetation still is very small in relation to the large remaining adjacent forests. The action therefore does not alter the finding that widening would not result in a major long-term negative impact on the natural or human environment.

IX. MITIGATION OF UNAVOIDABLE ADVERSE IMPACTS

As discussed under Section VII (Potential Environmental Impacts), in the vicinities of aquatic and land-based excavations slight and temporary negative effects would be attributed to degradation of air and water quality, noise increases, and losses of secondary vegetation, small terrestrial animals, and fishes. These effects are not considered environmentally meaningful, and therefore recovery to baseline conditions does not warrant extenuating measures. Of more concern is the potential adverse social impact at Paraiso if there is removal of Government of Panama buildings, including several housing units and convenience facilities. However, in view of the very long lead times and reimbursements of replacement costs to Panamanian authorities, a well-planned program for the necessary relocations to nearby structures should be possible and help maintain the quality of life in the community; the Government of Panama will determine the full extent of these mitigating actions. The area's businesses could benefit during the approach of construction from the influx of project workers and their equipment, especially where providing cafeteria, shopette, gas station, and related services, but of greatest significance is the longer-term economic benefits derived from a competitive Canal that would extend to very large segments of the Panamanian population. An indirect, additional achievement of a wider Cut is a safer channel for transiting ships, which reduces the possibilities of accidents and their associated pollution and virtually eliminates the probability of total closure from major slides.

The upland disposal sites and their access routes would experience only brief changes in air and water quality that are held at a minimum by standard, good engineering practice. Second growth vegetation and small terrestrial forms of wildlife it supports were identified as the most sensitive ecological components during upland disposal. Nonetheless, in all but one of the localities needed under the optimum plan, stands of forest have been mostly circumvented by the site selection process with no significant addition to total cost of the project. The potential vegetation impacts, even if larger upland areas should be needed, were concluded to be small in regional terms, and soon mitigated by natural recolonization of grasses, herbaceous plants, and trees.

With the slow progress of widening southward under the 5, 7, or 11-year schedules, it is expected that some small terrestrial animals would be disturbed or lost during disposal, although where possible habitat development and other beneficial land uses could be implemented consistent with USACE practices.[61] The creation of nesting grounds for the endangered iguana, presented earlier, is a good example of the type of habitat development that would result from the project. Special efforts may be taken by the appropriate and interested local organizations, which include INRENARE, Smithsonian Institute, and the Center for Propagation of Panamanian Endangered Species (CEPEPE), to maintain some east bank areas and W-4 cleared for longer periods to allow reptile breeding where feasible. The west bank disposal locations W-2 and W-3 probably could not be used for these purposes, because U.S. Military small arms and artillery training are expected to resume there after disposal operations during the life of the treaty.

Since large portions of the material to be relocated upland are rocky and hard (especially in excavations from Bas Obispo Reach, Gold Hill, and Nitro Hill), as practicable they could be made available free of charge to the Government of Panama as further mitigation. As noted earlier, there can be many potential productive uses of such fill material locally, in reclamation projects (for parks, industry, and housing), road and railway bedding, or construction in general.

The negative effects connected with the project's open-water dumping from scows do not raise meaningful concern, because they are essentially confined to turbidity increases in the immediate areas, which clear soon after each operation, and burial of bottom-dwelling organisms (predominatly clams and snails). Over the short term the new rocky material disposed could have some positive effect of promoting bottom habitat diversity, but it is apparent with time the natural slow and constant rain of sediments would return the disposal sites to similar existing homogeneous bottom conditions. It has also been determined extremely unlikely that there are submerged archaeological or historical artifacts of interest at the sites, and any remains would not add information of value to well-documented records on the region.

The possibilities were explored for improving fish and waterfowl habitats in connection with open-water disposal, including raising bottom level up to near normal pool by judicious placement of excavated rock and gravel to establish a more productive benthic environment. However, such efforts would promote rapid invasion by unwanted, aggressive aquatic weeds and preclude seeding and planting of the more desirable types. Open water habitat development also seems unnecessary as there is now an abundance of natural lagoons, inlets, and similar wetland systems along the more than 1,000 miles of shoreline of Gatun Lake and many of its islands.

XI. LIST OF CONTRIBUTORS

NAME	DISCIPLINE/EXPERTISE	Role in Compilation of Environmental Report
Dr. David C. Baerg	Environmental and Energy Control Officer, PCC; biological sciences	Leader of Environmental Report team and preparation of document
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Mr. Joseph R. Wilson	Environmental Coordinator, USACE Dredging Division; aquatic biology and environmental compliance	Environmental Report guidance, review, and environmental compliance
Ms. Pastora de Halphen	Geologist, PCC; mining engineering	Coordinator of upland disposal site selection
Mr. George Berman	Chief, Geotechnical Section, PCC; slope stabilization	Engineering designs of excavation and disposal sites
Mr. Ricardo M. Gutierrez	Biologist, PCC: tropical forestry	Appendix E (Vegetation Survey and Comments on Proposed Upland Disposal Sites
Mr. Alfred Chase	Management Analyst, PCC; chemistry	Coordinator of open-water disposal site selection, sediment characterization survey, and collection of macrobenthos
Mr. Wallace P. Murdoch	Biologist, PCC; zoology/aquatic vegetation	Collection of water and sediment samples for chemical analysis; environmental setting of Gatun Lake
Mr. Alfredo Gonzales	Chief Chemist, Water and Labs, PCC; chemistry	Testing of water and sediment chemistry
Mr. Cesar T. Diaz	Chemist, Water and Labs, PCC; chemistry	Testing of water and sediment chemistry
Dr. Melvin M. Boreham	Entomologist, PCC; medical entomology/pest management	Appendix K (Report on Evaluation of Potential Sites for Dredged Material Disposal)

NAME	DISCIPLINE/EXPERTISE	Role in Compilation of Environmental Report
Mr. F. Dewayne Imsand	Environmental Engineer, USACE Mobile District; sedimentology	Upland and open-water site selection criteria; methodology of sediment and macrobenthos sampling surveys
Mr. Thomas W. Toole	Aquatic Biologist, TVA; macrobenthos taxonomy	Appendix I (Report on Taxonomic Analyses of Gatun Lake Benthic Macroinvertebrate Samples)

XI. COORDINATION

In accordance with Treaty Commitments, highest priority was placed on keeping the binational PCC Board of Directors and Joint Commission on the Environment (JCE) well-informed throughout preparation of the environmental analysis. Joint Commissioners inspected the proposed Cut excavation and upland disposal sites as part of the reporting and review process.

The JCE membership is comprised of the Director of INRENARE, Executive Secretary of Panama's National Commission on the Environment (CONAMA), Rector of the University of Panama, and U.S. officials representing the Department of State, conservation interests, and environmental law. Other organizations represented at briefings held for the Joint Commissioners include the Panamanian and U.S. Defense Forces, INAC, Treaty Affairs Office of Panama's Ministry of Foreign Relations, Smithsonian Institute, National Association for the Conservation of Nature, CEPEPE, Association for the Investigation and Propagation of Panamanian Species, and Foundation for National parks and Environment. Separate discussions have been held with the Panama Canal Subcommittee of the Legislative Assembly, INAC representatives, U.S. Army Garrison-Panama field training officials, among other parties.

Upon review of the environmental report by the Agency's Environmental Quality Committee and Board of Directors, the JCE, and other relevant organizations, comments and PCC responses may be incorporated where appropriate, as part of the final approved document. A copy of the report will be available for consultation at the PCC Environmental Office at Balboa Heights, Panama and at the Office of the PCC Secretary in Washington, D.C.

XII. FOOTNOTES

1. Tennessee-Tombigbee (Tenn-Tom) Waterway is USACE's most recent major inland waterway improvement in the United States. The Tenn-Tom was opened in 1985, marking the successful conclusion of a 10-year project which involved excavation of a 300-foot wide navigable channel a distance of 234 miles, and construction of five dams and 10 locks at a total cost of $2 billion.

2. The Environmental Report meets requirements of Executive Order 12114 governing environmental reviews by Federal agencies located outside the United States, and complies with the spirit and intent of Federal laws applicable to waterway improvement activities within the United States, including the National Environmental Policy Act, Clean Water Act, and National Historic Preservation Act. The United States and Republic of Panama are committed to implement the Panama Canal Treaty in a manner consistent with quality of human life while preserving the natural plant and animal resources of Panama. Accordingly, Article VI of the Treaty established the Joint Commission on the Environment (JCE), a binational review body that recommends, as appropriate to both governments, ways to avoid or mitigate adverse ecological impacts which might result pursuant to treaty implementation.

3. Canal capacity represents the number of ships that can transit during a given period, at acceptable levels of service in terms of safety and time in Canal waters (less than 24 hours in Canal waters is considered acceptable). Capacity is a dynamic process influenced by vessel mix and arrival patterns, directly controlled by limitations of the locks structures and their overhaul requirements,

operating restrictions, water supply and storage, scheduling and management of transit operations and other variables. Panama Canal capacity currently ranges from 42-46 ships daily, and theoretically could be increased to about 50 ships per day.

4. Canal locks are 1,000 feet long by 110 feet wide; PANAMAX vessels (50,000-80,000 deadweight tons) have approximate maximum dimensions of 950 by 106 feet.

5. The portion of Panama Canal's reservoir system managed for transit operations totals approximately 365 billion gallons at high water levels in Gatun and Madden Lakes; this includes 100 billion gallons of active storage achieved in the navigational channel itself upon completion of deepening in 1985, which virtually assured the reserve to maintain Canal draft at 39.5 feet even during extended dry periods. Over the past 10 years Canal transits annually have used an average of 665 billion gallons of the water that naturally flows into the sea, and demand is expected to continue at near the same amount because long-term forecasts do not indicate a meaningful increase in the number of vessel arrivals (Canal use of water relates to transits or lockages, not vessel size). The Commission's recently completed hydrological surveys reveal there has been only fractional storage depletion in Madden Reservoir, the Canal water reserve area potentially most affected by siltation. Although the Madden impoundment has been in use some 50 years, cumulative usable/dead storage loss still totals less than 5%, and is far below the levels that could even begin to impact on Canal operations. As a related matter, rainfall patterns at the sources of the drainage water supply (the Canal Watershed) have remained essentially unchanged since measurements began there more than 50 years ago.

6. The present minimum safety factor in Gaillard Cut is 1.2, which has equated to a 95% probability of no failure.

7. The Canal Commission has adopted guidelines of the Occupational Safety and Health Administration to provide and maintain a safe and healthful working environment. All Commission safety standards or, in their absence, Federal and nationally-accepted standards (such as those promulgated by the American National Standard Institute, National Board of Fire Underwriters, National Electric Code, Associated General Contractor's of America, Inc., U.S. Coast Guard, and the Corps of Engineers Manual of General Safety Requirements), whichever highest, are considered as applicable in all operations and methods, including contracted work.

8. The potential for natural structural failures was carefully weighed in all engineering aspects of the Cut widening plan, and a change in slope design has not been recommended by USACE as a result of the landslide; however, the quantities of wet and dry material removed to stabilize the Gold Hill slide should, at the same time, reduce the projected excavation volumes required to widen that area.

9. A dipper dredge essentially is a barge-mounted power shovel that can operate in restricted areas such as Gaillard Cut, and undoubtedly has capability to extract the Cut's variety of wet, hard compacted materials.

10. Dry material (totalling some 145,000 cy) excavated North of Mandinga River on the west bank (the northernmost area) would be dipper-dredged. It is impractical to construct haul roads there and the material is reasonably accessible to the marine-based excavation and disposal equipment.

11. Expansion (bulking) factors vary according to excavation procedure, soil type, presence of rocks, and size of fractured material. This report incorporates a bulking factor of 25% after recompaction at the upland disposal sites.

12. A 7% overdredging and 40% swell (scow measure) are estimated for the composite of wet excavations in Gaillard Cut.

13. Because of its efficiency and versatility, this is the most commonly used dredging vessel in the United States and other countries. It is equipped with a rotating cutter apparatus surrounding the intake end of a suction pipe capable of transporting slurries long distances to upland disposal sites.

14. The Commission's Dredging Division has a wide range of floating equipment, including the recently highly renovated large-class (12,500 hp) hydraulic cutterhead dredge MINDI. This vessel, with a 28-inch suction pipe intake, is equipped for operation under high lift and long discharge pipeline requirements. The Division also has the relatively new 15 cy dipper dredge RIALTO M. CHRISTENSEN, the 13.5 cy dipper dredge CASCADAS, the 7.5 cy clamshell crane GOLIATH, and the drillboat THOR; there are also dump barges, large and small tugs, floating cranes, and other equipment. In addition, the Commission operates a truck-mounted high production terrestrial drill rig which was used in the previous Cut widening efforts.

15. USACE's basic studies and recommendations concerning disposal site selection and operation are reported by Raster, et al., 1978, Development of Procedures for Selecting and Designing Reusable Dredged Material Disposal Sites, Tech. Rept. D-78-22, U.S. Army Waterways Expt. Stat., Vicksburg, Miss.

16. The region known as Empire Range is composed of both Canal Operating Areas leased to the U.S. Army and Military Areas of Coordination. These lands are used by U.S. and Panama Defense Forces for aerial and ground exercises, primarily pistol, rifle and artillery firing, maneuvering and small unit training.

17. Goethals, G. W., 1915, The dry excavation of the Panama Canal, Paper presented at meeting of Int. Eng. Cong., San Francisco, Sept. 1915.

18. Barro Colorado Island is a center of scientific research related to its natural forest habitat in Gatun Lake, and was declared a nature monument by 1977 agreement between the Governments of the United States and Panama. The Smithsonian Tropical Research Institute, as the custodian, also has been granted use of several of the Island's adjacent peninsulas (Bohio, Buena Vista, and Frijoles) and their immediate shoreline waters, consistent with Canal operating area land-use license procedures. The 1977 Panama Canal Treaty additionally assigned the Smithsonian Institute two other adjacent peninsulas (Palenquilla and Gigantito).

19. Tosi, J. A., 1971, Panama: Zonas de Vida, Informe Technico 2, Inventariacion y Demonstraciones Forestales - FO:SF/PANG, UNDP, Roma, 123 pp.

20. Turbidity of water is a measure of the degree of interference with light transmission caused by the numbers and characteristics of suspended solids. Common sources in natural waters are clay and silt particles, organic debris, and mircroorganisms. Normally, turbid waters have no direct ill effects on human consumers, but low turbidity is desirable for aesthetic reasons.

21. Gonzales, A., G. Alvarado-Dupree, and C. T. Diaz, 1975, Canal Zone Water Quality Study Final Report, Water and Laboratories Branch, Maintenance Division, Canal Zone, Volumes I, II and III; Report on Environmental Quality of Surface Water and Ambient Air in Panama Canal Commission Areas, Presented to the Subcommittee on the Panama Canal of the House of Representatives Committee on Merchant Marine and Fisheries, March 18, 1980.

22. Zaret, T. M., 1984, Central American Limnology and Gatun Lake, Panama, In Lakes and Reservoirs, Edited by F. B. Taub, Elsevier Sci. Pub. B.V., Amsterdam, pp. 447-465.

23. Delvalle, D, Geotechnical analysis of bottom sediments from Gatun Lake: A background study, Latin American Colloquium of Geoscience, Berlin, November 19-21, 1986, In Summary of Presentations, Edited by P. Giese, Verlag von Dietrick, Berlin, pp. 119-120.

24. Panama: Country Environment Profile, United States Agency for International Development (USAID), Inter. Sci. Tech. Inst., Inc., Wash., 197 pp.

25. The composition of semideciduous trees of Barro Colorado Island is representative of the region's undisturbed areas. A series of descriptive reports on the Island's vegetation is presented in The Ecology of a Tropical Forest, 1982, Edited by Leigh, E. G., Jr., A. S. Rand, and D. M. Windsor, Smithsonian Inst. Press, Wash., pp. 67-94.

26. The environmental evaluation for this since-rejected possibility of augmenting Gatun Lake levels with sea water was completed in 1974 (Sea Water Pumping Environmental Study - Panama Canal: Information for Biologists Participating in Phase I), and carried the following excellent reports on local aquatic vegetation: Weers, E. T., Fresh

water phytoplankton community, 8 pp; Pasco, R. A., Considerations on effects of salinity on aquatic macrophyte communities growing in Gatun Lake, 12 pp; and Teas, H. J., Shore vegetation, 22 pp.

27. Since 1976, the U.S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi has maintained an aquatic plant control assistance program for the Panama Canal and Gatun Lake. Extensive baseline data have been compiled on the aerial and water-depth distributions of Hydrilla using color infrared photography and field sample collections.

28. Overall Installation Environmental Impact Statement for 193d Infantry Brigade (Canal Zone), VTN Louisiana, Inc., Metairie, 1977.

29. Handley, C. O., Jr., Checklist of the mammals of Panama. In Ectoparasites of Panama, 1966, Edited by R. L. Wenzel and V. J. Tipton, Field Mus. Nat. Hist., Chicago, pp. 753-795.

30. Mendez, E., Los Principales Mamiferos de Panamá, 1970, Edición Privada, 283 pp.

31. Iguanas are prized as a food source, and Dagmar Werner of the Smithsonian Institute has established the Green Iguana Foundation in Panama with financial help from a number of envirомental groups, including the World Wildlife Fund. Their objectives focus on increasing the local iguana populations to a point where they can be raised on farms to serve as a high protein food supplement (Time, October 27, 1986, pg. 39).

32. Ridgely, R., A Guide to the Birds of Panama, 1976, Princeton Univ. Press, 394 pp.

33. Many native fishes, including abundant phytophagous species, were drastically reduced in numbers by the predatory peacock bass (Cichla ocellaris) after its accidental introduction into Gatun Lake during

1967; it is believed that this, in turn, resulted in the disappearance of many waterfowl.

34. Relevant reports include: Greenberg, J., The molluscs of the Panama Canal, 23 pp; Abele, L. G., The decapod crustacean fauna of the Panama Canal and adjacent waters, 21 pp; Hurlbert, S. H., Freshwater zooplankton, 6 pp.; Zaret, T. M., Gatun Lake communities, 9 pp; Hogue, C. L., Possible effects of sea water introductions to the habitats of aquatic insects in Gatun Lake, 62 pp.; and Bozeman, E. L., Jr., and J. M. Dean, Salinity considerations of freshwater fish of the Panama Canal system, 22 pp.

35. Environmental Impact Statement: The Introduction of White Amur into Canal Zone Waters to Control Aquatic Weeds, Prepared by Panama Canal Company, Balboa Heights, Canal Zone, 1977.

36. Zaret, T. M., 1974, Biological Impact Study of the Channel Deepening Project, Panama Canal Company Contract No. PC-2-1512, 22 pp.

37. Final Environmental Impact Statement for the New Panama Canal Treaties, Department of State, December 1977, U.S. Government Printing Office, Washington, D.C.

38. Woodring, W. P., 1957, Geology and Paleontology of Canal Zone and Adjoining Parts of Panama, Geological Survey Professional Paper 306-A, U.S. Government Printing Office, Washington, D.C., 145 pp.; Geological History Gaps Filled, In Panama Canal Review, March 1, 1963.

39. Jaen Suarez, O., 1981, Hombres y Ecologia en Panama, Editorial Universitaria, Smithsonian Tropical Research Institute, Panama.

40. Ortiz-Aguilu, J. J., 1979, Preliminary Results of an Archaeological Reconnaissance Survey of the Areas Under Control of the U.S. 193d Infantry Brigade in the Former Canal Zone, Panama, National Institute of Culture, Panama.

41. In response to long-recognized need for a comprehensive nationwide research effort on effects of dredging, the U.S. Congress authorized the Corps to establish and conduct a 6-year Dredged Material Research Program (DMRP). More than 250 individual, generic studies were completed between 1973 and 1978 as part of the DMRP at a cost of almost $33M, and the findings serve as principal basis for acceptable dredging practice work-wide. Overviews of the DMRP and environmental effects of dredging are presented in the following reports: Saucier, R. A., et al., 1978, Dredged Material Research Program Executive Overview and Detailed Summary, Tech. Rept. DS-78-22, U.S. Army Eng. Waterways Expt. Stat., Vicksburg, Miss; Lazor, R. L. et al., Overview: The environmental effects of Corps dredging programs, In World Dredging & Marine Construction, June 1984; and Murden, W. R., 1984, Dredging and the environment, Dredging & Port Construction, Vol XI (No. 12), pp 17-21.

42. The operation of dredges and their effects are compared in Dredging and Material Disposal, U.S. Army Corps of Engineers Manual, EM 1110-2-5025, 1983.

43. The PCC Dredging Division reports that at least one crocodile learned to follow the drillboat THOR, and immediately after detonations fed on stunned and dead fish. There have never been any reported instances of encountering or harming other large aquatic mammals, including the rare and timid long-tailed otters and West Indian manatees, during blasting conducted for year-round maintenance/improvement.

44. Other principal structures maintained in the Cut that may be relocated involve bank lighting, navigational aids, and cables.

45. Stream water effects of channelization have been well documented by Canter, L. W., 1986, Environmental Impact of Water Resources Projects, Lewis Publishers, Inc., Chelsea, Michigan, 352 pp.

46. De Alba, G. A., Implicaciones ecologicas de las transformaciones geograficas ocasionales por la construccion del Canal de Panama, Revista Loteria, No. 292, July 1980, pp. 74-79, has reviewed historical publications pertaining to Canal area deforestation and recovery; one report cited from the December 4, 1912 issue of the Canal Record stated that 16 mcy of soil and rock were disposed in the jungle at Tavernilla (near Barro Colorado Island), and within 3-4 years abundant vegetation, including trees and shrubs up to 5-6 feet in height, had regrown at the site.

47. Holliday, B. W., 1978, Processes Affecting the Fate of Dredged Material, Tech. Rept. DS-78-2, U.S. Army Eng. Waterways Expt. Stat., Vicksburg, Miss.

48. Useful reports on the scope of investigations especially pertaining to water quality impacts are as follows: Stern, E. M. and W. B. Stickle, 1978, Effects of Turbidity and Suspended Material in Aquatic Environments, Tech. Rept. D-78-21; Wright, T. D., 1978, Aquatic Dredged Material Disposal Impacts, Tech. Rept. DS-78-1; Brannon, J. M. 1978, Evaluation of Dredged Material Pollution Potential, Tech. Rept. DS-78-6, U.S. Army Eng. Waterways Expt. Stat., Vicksburg, Miss; Peddicord, R. K., Impacts of open-water dredged material discharge, Proceedings of the Eleventh Dredging Seminar, October 1979, Texas A&M Univ., CDS Rept. No. 219, pp. 24-48; Lee, G F. and R. A. Jones, 1982, Assessing environmental impacts of open-water disposal of dredged sediment, World Dredging & Marine Construction, Vol. 8 (No.4), pp. 20-22.

49. Burks, S. A. and R. M. Engler, 1978, Water Quality Impacts of Aquatic Dredged Material Disposal, Tech. Rept. DS-78-4, U.S. Army Eng. Waterways Expt. Stat., Vicksburg, Miss.

50. A minimum operational depth of 18 feet or more is required for the types of scows used in the optimum methodology (clearance that allows full opening of bottom scow doors).

51. The impacts of open-water dredged material disposal on benthos and their recolonization potential have been studied extensively bymarine biologists; among representative reports consulted for this analysis are the following: Maurer, D. et al., 1980, Vertical migration and mortality of benthos in dredged material, Part I, Mollusca, Marine Env. Res., Vol. 4, pp. 299-319; Maurer, D. et al., 1982, Vertical migration and mortality of benthos in dredged material, Part III, Polychaeta, Marine Env. Res., Vol. 6, pp. 49-68; Bell, S. S. and D. J. Devlin, 1983, Short-term macrofaunal recolonization of sediment and epibenthic habitats in Tampa Bay, Florida, Bull. Marine Sci., Vol. 33, pp. 102-108; Hirsch, N. D. et al., 1978, Effects of Dredging and Disposal on Aquatic Organisms, Tech. Report DS-78-5, Naval Biosciences Lab., Univ. of Calif., Oakland; Waldichuk, M., 1985, Biological availability of metals to marine organisms, Marine Poll. Bull., Vol. 16, pp. 7-11; and Stern, E. M. and W. B. Stickle, 1978, Effects of Turbidity and Suspended Material in Aquatic Environments, Tech Rept. D-78-21, U.S. Army Eng. Waterways Expt. Stat., Vicksburg, Miss.

52. Small way stations for barge and mule traffic dating back to the mid-1700's.

53. They were related to a working-class communities, consisting primarily of a few wooden or adobe houses and shops; one (Frijol) was used as a train stop during railroad and Canal construction.

54. The Treaty clearly recognizes that the efficiency of the Canal is of special importance to both the Governments of Panama and the United States, and is reflected in Article IV of the Agreement in Implementation of Article III, concerning licensing.

55. See Article V of the Agreement pursuant to Article VI of the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere, for cooperative provisions governing the uses of the nature monument.

56. Among the possible social consequences would be increasing pressures on other sources of income and subsistence like slash-and-burn farming at government lands, including the forested Canal operating areas.

57. Examples of Cut bank areas that may be most suitable for hydraulic dredging are la Pita/Lirio Hills at the North/Central Sectors, because the formations to be excavated are geologically softer in comparison to other very hard formations such as those at Bas Obispo Reach in the North Sector and Gold/Nitro Hills in the South Sector.

58. Hammer, D. P. and E. D. Blackburn, 1977, Design and Construction of Retaining Dikes for Containment of Dredged Material, Tech. Rept. D-77-9, U.S. Army Eng. Waterways Expt. Stat., Vicksburg, Miss.

59. USACE disposal water quality effluent standards have varied widely among the U.S. Corps Districts; while some areas have no set standards, they range to as high as 13 grams/liter above ambient and

50 JTU's above ambient. A summary of Corps studies for predicting effluent quality has been published by Palermo, M. R., Technique developed for prediction of effluent quality in confined disposal areas, World Dredging and Marine Construction, June 1984, pp. 8-9.

60. Total site capacity for wet upland disposal is based on an average dike height not to exceed 50 feet from lowest to highest points; the wet upland disposal allowance for bulking (as with dry material) is approximated at 25%.

61. Beneficial Uses of Dredged Material, U.S. Army Corps of Engineers Manual, EM 1110-2-5026; Coastal Zone Resources Division of Ocean Data Systems, Inc., 1978, Handbook for Terrestrial Wildlife Habitat Development on Dredged Material, Tech. Rept. D-78-37; Spain, P. A. et al., 1978, Guidance for Land Improvement Using Dredged Material, Tech Rept. DS-78-21; Lung, J. D., et al., 1978, Upland and Wetland Habitat Development With Dredged Material: Ecological Considerations, Tech Rept. DS-78-15, U.S. Army Eng. Waterways Expt. Stat., Vicksburg, Miss.

E N V I R O N M E N T A L R E P O R T

PANAMA CANAL GAILLARD CUT WIDENING FEASIBILITY STUDY

Volume 2
(Appendices)

Office of Executive Planning
Panama Canal Commission

March 1987

Appendix A

Panama Canal Dredging Frequency

Location	Average Cycle (Years)
Pacific Entrance	7.5
Balboa Reach	3.5
Miraflores Lake	5
Paraiso Reach	6
Cucaracha Reach	6
Culebra Reach	6
Empire Reach	6
Cunnette Reach	6
Las Cascadas Reach	6
Bas Obispo Reach	6
Chagres Crossing	6
Gamboa Reach	6
Mamei Curve	9
San Pablo Reach	9
Tabernilla Reach	9
Buena Vista Reach	18
Bohio Reach	18
Pena Blanca Reach	Indefinite
Gatun Reach	Indefinite
Gatun Approach	4
Atlantic Entrance	4
Cristobal Anchor, West	3

Appendix B

Air Quality Data
(Panama Canal Area*)

Sampling Station	Suspended Particulates			Sulfur Dioxide			Nitrogen Dioxide		
	1977	1978	1979	1977	1978	1979	1977	1978	1979
Miraflores	38.98	33.60	37.50	12.67	11.49	10.21	21.33	23.08	20.16
Pedro Miguel	44.99	35.87	40.72	7.57	13.69	11.80	27.30	29.11	30.55
Balboa	56.08	48.40	51.24	12.69	19.53	14.21	49.11	45.87	46.32
Madden	55.81	49.31	50.82	5.80	11.42	8.00	16.14	17.75	15.71

*All figures are given in micrograms per cubic meter (ug/m^3). The Environmental Protection Agency primary air quality standards are as follows: suspended particulates, 75 ug/m^3 annual geometric mean; sulfur dioxide, 80 ug/m^3 annual arithmetic mean; nitrogen dioxide, 100 ug/m^3 annual arithmetic mean.

Appendix C

Sound Levels Generated By Selected Excavation Equipment*

Types of Equipment	Decibels Measured At Operator's Position
Cranes	
Diesel-powered, 100 ton	95
Other, various sizes	99-104
Tractors	
Caterpillar D-9, D-8	89-103
Other, diesel-powered	81-95
Graders (with noise abatement)	86
Ditchers	99-104
Rock Drills	112-116
Loaders	98-104
Trucks (with noise abatement)	84

*From: Noise Hazard Evaluation, Sound Level Data of Noise Sources, U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD, January 1975.

Appendix D

Water Quality Baseline Data
(Panama Canal Area*)

Parameter	Gatun Lake**			Gaillard Cut Paraiso Raw Water Intake		
	1972	1975	1979	1972	1975	1979
Temperature (°C)	28.0	28.1	28.1	28.2	28.2	27.2
pH (Unit)	7.3	7.2	7.1	7.0	7.0	7.2
Fecal Coli (Count/100 ml)	31	12	19	112	170	93
DO	6.0	6.2	5.8	5.1	5.8	5.9
BOD (5-Day)	0.64	0.67	0.69	0.55	0.55	0.58
Turbidity (Nephelometric Turbidity Unit)	2.66	3.80	3.12	18.3	20.2	9.5
Alkalinity (mg/l $CaCO_3$)	36	36	35	49	47	50
Fluoride	0.051	0.053	0.049	0.05	0.06	0.06
Ammonia	0.02	0.02	0.02	0.012	0.025	0.030
Kjeldahl Nitrogen	0.1	0.13	0.10	0.20	0.24	0.21
Nitrate-N	0.037	0.039	0.034	0.212	0.223	0.085
Total Phosphorus	0.024	0.026	0.015	0.019	0.023	0.026
Arsenic	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Barium	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Cadium	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Chromium	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Copper	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Iron	124.6	131	138	341	431	450
Lead	<0.040	<0.040	<0.040	<0.040	<0.040	<0.005
Lithium	<0.100	<0.020	<0.020	<0.10	<0.10	<0.10
Manganese	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Mercury	<0.0004	<0.0004	<0.0004	<0.020	<0.020	<0.020
Nickel	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Potassium	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Selenium	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Silver	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Sodium	6.2	6.1	6.2	7.4	7.1	7.4
Zinc	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020

*Annual averages; "<" denotes level below detection limit of test method; Concentrations expressed in mg/l except where indicated.
**Five representative stations.

Appendix E

Vegetation Survey and Comments on Proposed Upland Disposal Sites
Gaillard Cut Widening Feasibility Study

Condensed Report of Study
Performed by
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Engineering and Construction
Bureau, Dredging Division
Panama Canal Commission
October/November, 1985

Summary of Comments

1. Existing forests in the project area are secondary not primary, virgin forests. Throughout the Cut there also is evidence of the previous farming activities, including presence of the cultivated fruit trees Syzygium, Chrysophyllum, and Mangifera,. Late secondary species, Terminalia, Brosimum, Vitex, etc., and abundant Cecropia, Trema, Xylopia, Cordia alliodora, Didymopanax morototoni, and many others, are indicators of mixed ages of vegetation from relatively early to the late secondary stages of succession.

2. All tree species observed in the survey are common to existing lowland forests of tropical america, and the findings on vegetation composition are consistent with previous investigations reported by others.

3. Ecological conditions in the Gaillard Cut region are optimum for natural revegetation. The most aggressive pioneer grasses and light-demanding species that are generally representative of vegetation in surrounding areas initiate the recolonization processes.

4. Time of reestablishment is dependent upon subsequent disturbing activities. Fire is the most upsetting and destructive factor that tends to perpetuate the growth of grasses.

5. Any effort to circumvent the natural invasion of grasses or to increase the rate of tree establishment by reforestation would be costly and impractical. The natural succession processes are more efficient if assisted by precluding grassfires. Reforestation efforts might be recommended only in certain limited instances where justified and where the substrata consist of weathered material derived mostly from the upper soil horizons.

Introduction

This report is based on a series of field inspections conducted in Gaillard Cut proposed disposal areas during October and November of 1985, and provides a general representation of the major vegeta- tion types found. Vegetation was surveyed by direct observation using existing secondary roads, trails, rights-of-way for electrical power transmission and feeder lines and, occasionally, machete paths when closer examination was necessary. These field observations were supplemented with stereoscopic scanning of recent aerial photographs. In addition, annual reports and other documents of the Panama Canal Commission (PCC) collection were consulted to determine the histor- ical events that have influenced structures of the plant communi- ties. Plant species with their approximate relative abundances in the respective study areas are listed with common names in the attached table.

Background and General Description of Gaillard Cut Region

The physiognomy, structure, and distribution of vegetation along the 8-mile Gaillard Cut strongly reflect the impact of man's land-use patterns. In this connection, Taylor (1912) stated that human influ- ence here chiefly was apparent through the destruction of practically all of most valuable timber trees that helped compose the original forest. Activities associated with the Panama Railroad completed in 1851, the French Canal efforts, and the Panama Canal especially have contributed to alteration of natural vegetation processes of Gaillard Cut. Bennett (1929) reported that growing bananas and raising live- stock were very important farm industries of the old Canal Zone and neighboring lands which led to the establishment of introduced pas- tures such as <u>Panicum maximum</u> (Guinea grass), <u>Pennisetum purpureum</u> (Napier grass), and <u>Chloris gayana</u> (Rhode grass). The pastures were extensive and, at one time according to Bennett (1912), supported about 15,000 head of cattle. Other vegetation changes still occur due to necessary Canal improvement work, access roads for operational and maintenance feeder lines, and military training exercises. Unauthorized logging and subsistence agriculture also have impacted on the Cut's vegetation, but the most destructive and disruptive events have been the dry season grass fires.

According to the bioclimatic map of Panama prepared by Tosi (1971), as based on the Holdridge classification system, the entire project area falls within the Tropical Moist Forest Life Zone. This zone is characterized by a mean annual rainfall of 71 inches (1850 mm) to 134 inches (3400 mm) and a mean annual temperature of about 79°F (26°C). On the Isthmus, precipitation generally diminishes with distance from North to South, and there is a marked difference between the Atlantic and Pacific coasts. According to PCC weather records for the period 1930-1984, along the length of Gaillard Cut rainfall ranges from a high mean annual level of near 83 inches in Gamboa at the northern end to a low of 80 inches in Pedro Miguel at the southern end, an average gradient of under 4%. However, rainfall distribution in this area varies considerably; records show that during the 1974-84 period, eight of the years Gamboa received 4-23 inches more than Pedro Miguel and two of the years Pedro Miguel received 7-14 inches more.

According to the soils map developed by Bennett (1929), surfaces are largely of clay texture in the Cut region. At the proposed disposal sites and vicinities, Arraijan and Paraiso clays predominate. These types of clays have various phases depending on local conditions, i.e., a shallow phase that occupies many of the steeper slopes and a thicker phase on low and less broken areas. Bennett reported that vegetation is more vulnerable on the shallow phase of Arraijan clay, particularly during dry seasons. It is obvious that soils have been affected in large areas of the sites and vicinities, as overlying natural horizons have been buried by layers of disposed material. In addition, much of the organic topsoil is washed away in grasslands where there are moderate to steep slopes, especially as a result of first rains following dry season fires that denude the soil surfaces.

Material Disposal Sites

W-1

This alternative upland site on the west bank surrounds an arm of the Mandinga River, near where it enters the Panama Canal at the northernmost portion of the Cut. The approximate surface area is 32.6 acres (13.2 ha) and the average distance from Canal axis is about 0.4 miles. The site lies about 1.4 miles from Gamboa.

The eastern border of W-1 overlaps disposal areas used by the Isthmian Canal Commission for Canal construction in the early 1900's; the soils there thus are derived from introduced material, although probably improved by Mandinga River alluvials. The successional processes at W-1 following construction were not significantly impeded, as is apparent in many other Cut areas. The generally low terrain is influenced by a high water table, and high annual rainfall speeds the processes of weathering disposed material. These factors contribute to accelerated vegetation growth rates and species diversity. The site is dominated (95% of area) by second-growth forest, with species complexes representing early and late secondary successions and a few examples of primary forest trees. Epiphytic growth that is present, i.e., bromeliads, lianas, philodendrons, algae, and lichens, reflects an advanced stage of succession and/or plentiful environmental moisture. The presence of late secondary forest species, including Tabebuia guayacan, T. rosea, and Terminalia amazonia, are compatible with these observations. Volunteer cultivated species in the area, including Chrysophyllum cainito, Syzygium jambos, and Mangifera indica (mango), however, are indicative of past disturbances from farming and related activities.

Similar forest types surround the proposed area except on the Canal side, where early secondary species dominate and the forest is close to pressures of nearby grass invasions due to dry season fires. At the boundaries West and South, wedges of grasses into the site also were observed.

The aquatic boundary of W-1 is typical of abundant inlets found at the margins of Gatun Lake, which serve as habitats for waterfowl and other common terrestrial and aquatic wildlife. Interesting examples seen at the locality included a crocodile in Mandinga River, and large reptile eggs in exposed soil along a roadway (maintained through W-1 by the U.S. Military for training exercises).

W-2

The outermost proposed site boundaries encompass about 166.8 acres. The site is irregularly shaped, with average distance from Canal axis about 0.5 miles. The first-option disposal portion comprises close to two-thirds the acreage; the remaining (East) portions overlap and/or are very close to former disposal areas where soils derive from semi-weathered materials. Both intermittent and small permanent streams occur in the area.

In the clearings preferred for disposal and along roadside borders early secondary vegetation is frequent, evidencing very few examples of late secondary species such as Pseudobombax septenatum. One clearing is a grassland patch dominated by Saccharum spontaneum (an aggressive pioneer probably introduced into Panama from Southeast Asia) and a second open area contains some late species mingled with Guinea grass and Hyparrhenia rufa (faragua grass). The remaining open portions preferred for disposal are shared by disturbed second-growth forest, herbaceous plants, and scattered young softwood trees. The existing grasses readily burn during dry season and exert some stress on the few remaining larger trees.

Vegetation beyond these preferred-disposal segments is disturbed second-growth forest that has characteristics similar to Site W-1. Estimated age of the older specimens is about 70 years, with some trees perhaps more than 100 years old. It is noted that some of these types of large trees, including Ficus spp., Enterolobium cyclocarpum, and others, presumably were left by farmers. In contrast to W-1, the western limits of this forested portion are well drained due to steep slopes, allowing other species such as Apeiba and Cochlospermum to develop.

Among particularly common associated wildlife noted at W-2 were Dasypus novemcinctus (common armadillo) and Nasua nasua (coatimundi). Of interest were the remains of a chamber pot found in the area, as further evidence of human presence during the contruction period.

W-3

The largest potential disposal site is W-3, with a surface of about 261.8 acres. Average distance to Canal axis from this site is approximately 0.6 miles. The principal watercourse is the Camacho River, which establishes a portion of the northern boundary; intermittent water flows also occur in the area.

It was possible to access only part of W-3, accompanied by a Range Officer of the 193d Infantry Brigade, due to active military exercises in the region. The necessary supplemental information pertaining to this site was obtained through recent aerial photographs and maps.

The semi-forested central and southern area portions, some 70 acres mainly involving the area's slopes, are dominated by second-growth species. The remaining, larger preferred-disposal area within W-3 is characterized by grasses and few herbaceous plants, and occupies relatively flat terrain that is regularly trimmed where it serves as a military range.

Forest patches extending into grasslands at the site are good examples of early secondary succession on disposed material from about 1973. However, in this instance there are still many rock outcroppings and loose nonweathered disposed soil material rising 2-4 feet above the adjacent surfaces, which result in excessive drainage of the soil. The small trees dominating the environment thus are mostly <u>Bursera simaruba</u>, a species that also thrives on almost bare rock as observed on the steep bank of the Cut at Gold Hill. Certain lower terrain areas of W-3 are periodically used for upland disposal and, according to PCC records, disposal last occurred some three years ago; the specific sites used have since been invaded by <u>Saccharum</u>.

Part of W-3 overlaps the old Empire and Lirio yards, sites of dry disposal during Canal construction. Obviously, all the sparsely forested vicinities to the North, South, and East have experienced periodic vegetation disturbances for a long period of time. Further, the present training activities probably generate a high potential for fires during dry seasons and as a result favor the development of grasses.

<u>W-4</u>

This site is located at the southern end of proposed excavation near Pedro Miguel locks and occupies some 92.7 acres (37.5 ha). Average distance from Canal axis is about 0.3 miles. W-4 was established many years ago for periodic wet upland disposal requirements of maintenance dredging at the locks approaches and Miraflores Lake. In accordance with standard, good engineering practice using the natural drainage patterns, W-4 is diked to encompass part of the original Rio Grande drainage system. It almost entirely overlays the Arraijan clay soil type according to Bennett's soil map, although in the southeast section there seems to be an area of imperfectly drained clay. This lower part of the site appears to have a high water table because of the river and, possibly, the proximity of Miraflores Lake.

Dominant vegetation types which have returned, mainly at the southeast portion, since the site was last in use are grasses and herbaceous plants. Improved drainage at the higher portions of W-4 also show growth of herbaceous species, as well as scattered small softwood trees and tree seedlings of fire resistant species. Spots of forest relicts have remained only at the western border and northwest corner of the site.

W-4 is probably the site with lowest degree of floristic diversity. As a designated disposal site (containment area) and apparently because of occasional grassland fires, the vegetation cover is held at a relatively early successional stage. A recurrent progression and regression of natural succession similarly occurs in neighboring, contiguous Empire Range areas.

E-1

The limits of this northernmost proposed site on the East Bank lie between the channel and the Panama Railroad, approximating a total of 214 acres. Average distance to Canal axis is about 0.6 miles. Much of the existing surface was deposited during Canal construction, when the area served as a fill. Most of E-1 appears to occur over Arraijan clay of the thicker phase, characteristic of less broken areas. There are now low, broad-topped hills and scattered steep-sided hills present throughout, with comparatively wide stream valleys. The principal year-round watercourses are the Sardinilla River which crosses at the northern tip of the site, and the Masambi River which forms part of the tentative border at the southern portion; small, mostly intermittent flows also are present that form tributaries draining into the Canal.

The preferred-disposal acreage occupies about 70% of the total and involves those portions facing the channel and antenna farm. The forest appears more open or disturbed in these areas, in part because of the proximity to the Canal banks where access roads, rights-of-way for electrical power transmission and feeder lines, and Canal improvement work have favored the invasion of grasses. Along the proposed site border near La Pita Signal Station at the southern end of the site, pockets of early secondary species including *Ochroma pyramidale* and *Didymopanax morototoni*, form dominant stands. More advanced secondary succession is found over the majority of E-1, as indicated by the presence of *Jacaranda copaia*, *Sterculia apetala*, *Pseudobombax*, *Croton* sp., and others, such as *Bursera*, which have wide ecological ranges.

E-2

Site E-2 lies between the Canal and Gaillard Highway, immediately northeast of Gold Hill. The approximate surface area is 212.9 acres, with an average distance of 0.6 miles to Canal axis. Much of the topography of E-2 also has been artificially formed by construction fill material. It is particularly evidenced by largely flat terrain over the entire northern half, the area of preferred disposal, and in southeastern portions, all of which involve former Lirio, Gold Hill and Cucaracha disposal regions. The principal watercourse of the site is the Obispo River; intermittent streams additionally contribute to drainage into the Canal.

Approximately two-thirds of the preferred-disposal area is grassland, dominated by *Panicum* and *Saccharum*. There are small pockets of open forest at the lower waterlogged areas, where presence of large *Erythrina fusca* and *Anacardium excelsum* (espave) trees are evidence of advanced secondary succession. The southern half of E-2 contains a somewhat open second-growth forest, reflecting greater disturbances which have occurred over time in comparison to E-1. In this connection, secondary dirt roads, power transmission lines, rights-of-way and patches of low and saturated soils break the continuity. *Pseudobombax* is a dominant tree in this scattered forest, among other late secondary indicator species, *Vitex gigantea*, *Sapium caudatum*, and *Brosimum alicastrum*. The frequent clearings within the forested portions again are generally dominated by grasses and herbaceous plants.

E-3

This southernmost proposed site on the East Bank encloses about 145.6 acres and averages 0.9 miles from Canal axis. At the southeastern neighboring lands many loose rocks were observed which may be a part of a stony phase mentioned by Bennett. The entire area was extensively used for disposal of material during construction, and since then has remained a valley of rolling topography. Disposal during that period appears to have interrupted some of the normal drainage at the lowest portions of the valley; now, drainage from Cañasas Creek and contributing small flows is predominantly toward the northwest, ultimately discharging into the Canal.

The recommended section for disposal is a large uninterrupted expanse that circumvents forests found at the northeastern and far southern portions of the boundaries. This preferred-disposal portion can be separated into three vegetation complexes: One is a relatively small community of grasses and herbaceous plants; a second, larger complex has grasses and herbaceous plants interspersed with small trees; and the remaining is composed of herbaceous plants, small trees, and early second growth. Faragua, Guinea, and *Saccharum* are the most abundant grasses occurring in these clearings, with certain species becoming more dominant at specific niches, e.g., *Gynerium sagittatum* (wild cane) on the more saturated soils. The forest pockets at E-3 have frequent examples of *Anacardium*, and were observed growing with *Erythrina*, *Elaeis* palms and other species that tolerate water-saturated soils.

The dominance of grasses increases toward the eastern and northern borders. In these sectors, most of the original forest was probably first disturbed during the period of railroad construction. Since then, maintenance activities along the railroad right-of-way apparently have continued to favor grass development in the vicinity.

Among interesting terrestrial wildlife noted at E-3 was a family of *Potos flavus* (kinkajous) and a large *Odocoileus* (deer).

Observations and Comments

The proposed excavation sites also were visited as part of this survey. In general, grasslands prevail on West Bank excavation sites and few patches of second-growth forest additionally occur on East Bank sites. The species observed are already among those listed in Table 1 for respective areas proposed of upland disposal.

Any discussion of past and present disturbances of the Gaillard Cut vegetated areas requires full consideration of the natural successional processes. In this regard, the gradient of annual rainfall decreasing significantly from North to South in most years throughout the Cut, and prevailing winds are important factors. Physical condition of the soil also has a key role, affecting plant uses of water surpluses or defficiencies; compacted or loose rocky soils in areas of normal or low water table retain less water than developed, mature soils. It is also pertinent that forest-type vegetation, as opposed to grass cover, regulates plant-soil water relationships at the deepest possible levels in the soil profile and is particularly important in soil stabilization on steep terrain.

Comments in this report are based, in part, on the plant succession indicators tested by Budowski in forest plots located in Costa Rica and Western Panama. He concluded that "The floristic composition of pioneer communities is limited to a few species of wide natural distribution. There is little variation in the species represented in spite of different soil or climatic conditions."

Large areas of the Cut have been greatly disturbed by the accumulation of disposed materials and by recurrent grass fires. Bennett stressed that, except on the deep and friable clay soils and stream bottoms, after the first month of each dry season much of the grass and brush growth becomes so dry that fires frequently will occur. Within the former disposal areas progressive succession has occurred in patches where conditions are at least marginally suitable, and produce second-growth forests which are generally characterized by persistent shrubs and a few large trees. All sites surveyed in the Cut contain indicators of early second growth. However, in certain areas (including W-1, W-2, and E-1) there are many examples of growth that occur very late in the successional stages.

While species diversity ordinarily changes in accordance with changes in site conditions, i.e., water table, surface drainage, erosion, soil quality, etc., remarkable adaptability is demonstrated by some species. For example, Bursera and Pseudobombax septenatum were seen thriving on almost denuded and steep substrata. At site W-3, a young stand of Bursera is growing on a loose layer of rocks that were disposed there some 10-12 years ago; at the same site Saccharum dominates an area of material disposed some 3 years ago. The aggressive pioneering ability of Saccharum is particularly evident on semi-weathered substrate. Under these conditions few other macrophytes can compete. We note that Richards (1952) listed Saccharum as one of the grasses having an important role in recolonizing the volcanic island of Krakatoa, after its original vegetation had been destroyed. As expected, upland clearings of the Cut that experience recurrent dry season fires display the dominance of grasses like Saccharum, along with fire-resistant trees (pyrophytes), Curatella americana, Byrsonima crassifolia, and Scheelea zonensis.

In some cases, grasslands and farms abandoned after the construction of the Canal had soils of relatively better fertility and, thus, yielded higher vegetation growth rates. Perhaps this is a reason the second-growth forests in sites like E-1 seem older than some of similar ages on the West Bank. Budowski (1961) pointed out that "An increasing number of species and variety in life forms of epiphytes is characteristic of progressive development towards the climax." Such epiphytic growth is most apparent in sites W-1 and E-1, where there is high environmental moisture and there has been little disturbance (interruption of growth) over time.

Budowski (1961) reported that the hardness and weight of wood of trees occupying an area is highly indicative of successional position. Trees representing early stages are soft and light, whereas species characteristic of advanced stages are hard and heavy. Very few hardwoods of commercial size were found in the survey; among those recorded are Tabebuia guayacan, T. rosea, Zanthoxylum sp., Terminalia, Astronium graveolens, and Anacardium. Taylor, some 75 years ago, observed hardwood species growing in the old Canal Zone, but many of these have been practically eliminated. Selective logging before, during, and after Canal construction depleted the existing accessible forests of hardwood and fine wood species. Fine wood trees like Cedrela odorata, found in two sites, have little commercial value due to the excessive branching produced by insect damage.

Tropical lowland environments (as represented in the Cut region), if totally or partially cleared of forest cover, will be fully invaded by pioneer species in a relatively short period of time, within 2-3 years. However, only if annual fires can be prevented from these areas could successional processes eventually reestablish the original forest. Sarmiento et al. (1975) stated that all woody and herbaceous savanna/grassland species are pyrophytes and that forests bordering the cleared areas can remain clean and stable for decades. Thus, frequent fires tend to maintain these environments without further forest regeneration. Saccharum especially appears to play an important role in the process along the Cut; the species displays a wide ecological range--it thrives on hill summits, in close proximity to water bodies, and on immature, excessively drained and meager substrata.

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VEGETATION RECORDED FROM PROPOSED UPLAND DISPOSAL SITES OF GAILLARD CUT

FAMILY	SCIENTIFIC NAME	COMMON NAMES	W-1	W-2	W-3	W-4	E-1	E-2	E-3
ANACARDIACEAE	Anacardium excelsium	Espavé							
	Astronium graveolens	Zorro	C	C	C		C	C	C
	Mangifera indica	Mango						O	
	Spondias mombin	Jobo, Hog plum	O	C	O		C	C	C
ANNONACEAE	Annona reticulata	Anón	C	C	C		C	C	C
	A. spraguey	Toreta	C	C			C	C	C
	Xylopia frutescens	Malagueto	C	C			C		C
	X. sp.	Malagueto	C	C	C		C	C	C
ARACEAE	Dieffenbachia longispatha	Otó de lagarto	C	C			C	C	C
	Philodendron sp.	Philodendron				★			
ARALIACEAE	Didymopanax morototoni	Mangabe, Guarumo de pava	★						
	Sciadodendron excelsum	Jobo, Corroncho de largarto	C	C	C	O	C	C	C
BIGNONIACEAE	Jacaranda copaia	Jacaranda, Cigarrillo						C	C
	Bignonia sp.?	Liana, Bejuco	C	C			C	C	
	Probably Arrabidaea sp.	Bejuco	★	★					
	Tabebuia guayacan	Guayacán	★	★					
	T. rosea	Roble de sabana	C	C			C	C	C
BOMBACACEAE	Ceiba pentandra	Ceiba, Bongo	O						
	Ochroma pyramidale	Balsa, Balso	★					★	
	Pseudobombax septenatum	Barrigón, Ceibo barrigón	C	C	C	C	C	C	C
BORAGINACEAE	Cordia alliodora	Laurel	C	C			C	C	C
BURSERACEAE	Bursera simaruba	Carate, Indio desnudo, Almácigo	C	C		C	C	C	C
CAESALPINIOIDEAE	Cassia multijuga?	Cañafistulo de Montaña, Bronze shower	C	C	C	C	C	C	C
	C. sp.	Cassia					C	C	C
	C. reticulata	Laureño							★
COCHLOSPERMACEAE	Cochlospermum vitifolium	Poro-poro, Brazilian rose						★	
COMBRETACEAE	Terminalia amazonia	Amarillo real	C	C	C	C	C	C	C
CYATHEACEAE	Cyathea sp.	Helecho arbóreo, Tree fern	C	C	C			C	C
CYCLANTHACEAE	Carludovica palmata	Portorrico, Jipi-japa	O	★					★
	Cyclanthes bipartitus	Lengua de buey	C	C	C			C	C
CYPERACEAE	Cyperus sp.	Junco	O	★	★			★	
	Scleria secans?	Cortadera	O	★	★				★
DILLENIACEAE	Curatella americana	Chumico	C	C			C	C	C
	Davilla nitida	Chumiquillo				★		★	★
ELAEOCARPACEAE	Muntingia calabura?	Periquito, Capulín							★
									★

Cont.

FAMILY	SCIENTIFIC NAME	COMMON NAMES	W-1	W-2	W-3	W-4	E-1	E-2	E-3
EUPHORBIACEAE	Croton billbergianus	Sangrillo					C	C	O
	Chamaesyce hirta	Hierba de pollo						*	
	Hevea brasiliensis	Caucho, Rubber tree						*	
	Sapium caudatum	Olivo, Wild fig		C				C	
FLACOURTIACEAE	Hasseltia floribunda	Parimontón, Raspa lengua							*
GESNERIACEAE	Kohleria tubiflora	Undetermined						*	
GRAMINEAE	Chusquea sp.	Carricillo	C	C			C	C	C
	Gynerium sagittatum	Caña blanca, Wild cane			C				C
	Hyparrhenia rufa	Faragua		C	C			C	C
	Panicum grande	Guinea	*						
	P. maximum	Guinea grass		C			C	C	C
	P. purpurascens	Pará grass				*			
	Paspalum sp.	Undetermined		*					
	P. virgatum	Cabezona						*	
	Pennisetum purpureum	Elefante, Napier grass						*	
	Saccharum spontaneum	Caña silvestre, Caña salvaje	O	C	A	A	C	C	VF
	Setaria sp.	Rabo de mono		*				*	*
GUTTIFERAE	Vismia baccifera	Achiotillo, Pintamozo	C	C			C	C	C
LAURACEAE	Ocotea sp.?	Sigua	C	C				C	
	Persea americana	Aguacate						*	
LECYTHIDACEAE	Gustavia sp.	Membrillo	C	C		C	C	C	C
MALPIGNIACEAE	Byrsonima crassifolia	Nance		C	C	C	C	C	C
MARANTHACEAE	Calathea sp.	Calatea	*	*					
MELASTOMATACEAE	Clidemia sp.	Undetermined							
	Miconia argentea	Papelillo	C	C			VF	C	C
	M. sp.?	Dos caras	C	C			C	C	C
MELIACEAE	Cedrela odorata	Cedro, Spanish cedar			*		*	*	
	Trichilia sp.	Alfajía					C	C	
MIMOSOIDEAE	Acacia melanoceras	Cachito							*
	Enterolobium cyclocarpum	Corotú	C	C		C	C	C	C
	Mimosa sp.	Dormidera, Sensitive plant	*	*	*	*	*	*	*
	Inga sp.	Guavo	C	C		C	C	C	C
	Pithecellobium sp.	Pichinde							C
MORACEAE	Brosium alicastrum	Verbá, Berbá						O	O
	Castilla elastica	Hule, Caucho	C	C					
	Cecropia sp.	Guarumo, Trumpet tree	C	C	C	C	C	C	C
	Ficus sp.	Higuerón	C	C	C		C	C	C
	F. sp.	Undetermined	O						
MUSACEAE	Heliconia sp.	Bijao, Chichica	*	*	*	*	*	*	*
	Musa sp.?	Platanillo	*	*			*		
MYRTACEAE	Syzygium jambos	Pomarosa, Rose apple	*	*			*		
	Psidium guajava	Guayaba						*	

Cont.

FAMILY	SCIENTIFIC NAME	COMMON NAMES	W-1	W-2	W-3	W-4	E-1	E-2	E-3
PALMAE	*Acanthorrhiza warscewiczii*	Palma de escoba							*
	Astrocaryum standleyanum	Chonta, Black palm					C	C	C
	Bactris sp.	Caña brava	C						C
	Desmoncus sp.	Matamba							C
	Elaeis oleifera	Corozo, Corocito	C	C			C	C	VF
	Oenocarpus panamanus	Maquenque, Trufa	C	C					
	Roystonea regia	Palmera real		O			C	C	
	Scheelea zonensis	Palma real, Corozo	C	C			C	C	VF
PAPILIONDIDEAE	*Andira inermis*	Almendro de río, Cabbage bark					C	C	
	Crotalaria retusa?	Crotalaria	*	*		*			*
	C. vitellina?	Crotalaria		*					
	Diphysa robinioides	Macano							*
	Erythrina fusca	Gallito, Palo santo	C			C	C	C	C
	Glyricidia sepium	Mata ratón, Balo						*	
	Mucuna pruriens?	Pica-pica		*		*			*
	Ormosia sp.	Peronil	*						
PIPERACEAE	*Piper* sp.	Cordoncillo	*	*			*	*	*
	P. sp.	Hinojo oloroso							*
POLYGONACEAE	*Coccoloba* sp.	Uvero						*	
	Triplaris cumingiana	Vara santa	C	C		C	C	C	C
RUBIACEAE	*Cephaelis* sp.	Undetermined	*	*					
	Genipa americana	Jagua	C				C	C	C
	Isertia sp.?	Undetermined							*
RUTACEAE	*Zanthoxylum* sp.	Arcabú, Prickly yellow	C					C	C
SAPINDACEAE	*Paulinia* sp.?	Bejuco	*	*					
SAPOTACEAE	*Chrysophyllum cainito*	Caimito	C	C					C
SELLAGINELLACEAE	*Selaginella* sp.	Selaginela						*	*
SIMAROUBACEAE	*Simarouba amara*	Aceituno						*	
SOLANACEAE	*Solanum asperum*	Friega platos							*
	S. sp.?	Undetermined							
STERCULIACEAE	*Guazuma ulmifolia*	Guácimo, Bastard cedar	C	C	C	C	C	C	C
	Helicoteres guazumaefolia	Majaguillo, Guácimo torcido		*					
	Sterculia apetala	Panamá, Panama tree		C		C	C	C	
TILIACEAE	*Apeiba tibourbou*	Cortezo, Monkey comb	C	C	C	C	C	C	C
	Luehea speciosa	Guácimo colorado	C	C	C		C	C	C
	L. sp.	Guácimo pacheco	C	C					C
ULMACEAE	*Trema micrantha*	Capulín, Jordancillo	C	C				C	C
VERBENACEAE	*Lantana camara*	Lantana							C
	Vitex gigantea	Cuajado blanco						O	O
VOCHYSIACEAE	*Vochysia herruginea*	Mayo, Yemerí mayo, Pegle					C	C	
ZINGIBERACEAE	*Costus villosissimos*	Caña agria	*	*					*

KEY: O=Occasional; C=Common; VF=Very Frequent; A=Abundant; *=Observed, but numbers not recorded

Appendix F

List of Wildlife Recorded from Panama Canal Watershed

List Of Wildlife Recorded From Panama Canal Watershed
Based On Data Compiled By
National Bureau Of Renewable Natural Resources, Panama, 1984

Class	Order	Scientific Name	Spanish Common Name
Mammalia	Lagomorpha	Sylvilagus brasiliensis	Conejo muleto
	Rodentia	Sciurus granatensis	Ardilla colorada
		S. variegatoides	Ardilla negra
		Coendou rothschildi	Puerco espin
		Hydrochaeris hydrochaeris*	Poncho, Capibara
		Agouti paca*	Conejo pintado
		Dasyprocta punctata*	Neque, Machango
		Proechymis semispinosos	Mocangue
	Carnivora	Urocyon cinereoargenteus	Micho de cerro
		Procyon cancrivorus*	Gato manglatero
		P. lotor*	Gato manglatero
		Nasua nasua	Gato solo
		Lutra annectens (longicaudis?)	Nutria
		Potos flavus	Cosumbi
		Bassaricyon gabbii	Olingo
		Mustela frenata	Comadreja
		Eira barbara	Gato negro
		Galictis vittata	Lobo pollero
		Felis onca*	Tigre, Jaguar
		F. pardalis*	Manigordo
		F. wiedii*	Tigrillo congo
		F. jagouaroundi*	Tigrillo congo
		F. concolor*	Puma
	Sirenia	Trichechus manatus*	Manati
	Perissodactyla	Tapirus bairdii*	Tapir, Macho de monte
	Artiodactyla	Tayassu pecari*	Puerco de monte
		T. tajacu*	Zaino
		Odocoileus virginianus*	Venado de cola blanca
		Mazama americana	Venado colorado
	Primates	Alouata palliata*	Mono aullador
		Ateles geoffroyi*	Mono arana colorado

Class	Order	Scientific Name	Spanish Common Name
Mammalia	Primates (cont.)	Saguinus geoffroyi*	Mono titi
		Aotus trivirgatus*	Mono nocturno, Jujuna
		Cebus capucinus*	Mono cariblanco
	Marsupialia	Didelphis marsupialis	Zorra
		Caluromys derbianus	Zorra roja
	Chiroptera	Desmodus rotundus	Vampiro comun
		Noctilio leporinus	Murcielago pescador
		Diclidurus virgo	Murcielago blanco
		Vampyrum spectrum	Falso vampiro
		Diacmus youngii	Vampiro overo
	Edentata	Myrcecophaga tridactyla#	Oso caballo
		Tamandua tetradactyla	Oso hormiguero
		Cyclopes didactyles*	Tapacacara, Gato balsa
		Bradypus infuscatus	Perezoso de 2 dedos
		Cabassous centralis*	Armadillo rabo de puerco
		Dasypys novemcictus*	Armardillo
Amphibia	Anura	Bufo marinus	Sapo comun
		B. typhonius	Sapo
		Hyla phlebodes	Rana
		H. crepitans	Rana
		Agalychnis callidryas	Rana
		Dendrobates auratus	Rana
		Colestethus nubicola	Rana
		Leptodactylus pentadactylus	Rana
		L. bolivianus	Rana
		Rana warschewitschi	Rana
		Atelopus varius zeteki*	Rana dorada
Reptilia	Apoda	Oscaecilia ochrocephala	Cecilia
	Crocodilia	Crocodylus acutus*	Lagarto aguja
		Caiman crocodylus fuscus*	Babilla
	Squamata	Iguana iguana*	Iguana verde
		Anolis auratus	Lagartija
		A. biporcatus	Lagartija
		Corithophanes cristatus	Camaleon

Class	Order	Scientific Name	Spanish Common Name
Reptilia	Squamata (cont.)	Basiliscus basiliscus	Meracho
		Thecadactylus rapicaudus	Salamenguesa
		Lepidoblepharis sanctaemartea	Salamenguesa
		Mabuya mabouya	Mata caballo
		Gonotodes albogularis	Limpiacasa
		Ameiva ameiva	Borriguero
		A. festiva	Borriguero
		Lachesis muta	Berrugosa
		Bothrops atrox	Berrugosa
		B. schlegelii	Taboba de pestana
		Micrurus mipartitus	Coral
		Boa constrictor	Boa
		Corallus annulatus	Boa
		Rhadinaea decorata	Culebra
		Rhinobothryum bovalli	Falsa coral
		Xenodon vabdocephalus	Culebra
		Clelia clelia	Culebra
Aves	Tinamiformes	Tinamus mayor*	Perdiz de arca
		Crypturellus soui	Perdiz de rastrojo
	Podicipediformes	Podiceps dominicus	Buzo
		Podilymbus podiceps	Buzo
	Pelecaniformes	Annhinga anhinga	Cuervo de aguja
		Pelecanus occidentalis	Pelicano
		Phalacrocorax olivaceus	Pati cuervo
		Fregata magnificens	Tijereta de mar
	Cicorniformes	Butorides virescens	Martinete
		Casmerodios albus	Garza real
		Tigrisoma lineatun	Garza tigre rayada
		Cochlearius cochlearius	Garzota cuchara
		Agami agami	Garza pechicastana
		Ixobrychus exilis	Garza enana
	Anaseriformes	Dendrocygna viduata	Jacamillo
		D. bicolor	Yaguoso colorado
		D. autumnalis*	Guichichi
		Cairina moschata*	Pato real

Class	Order	Scientific Name	Spanish Common Name
Aves	Anaseriformes (cont.)	Anas americana	Pato calvo
		A. platyrhynchos*	Ana de real
		A. cyanoptera	Cerceta colorado
		A. discors	Cerceta ala azul
		A. clypeata	Pato cuchara
		Aythya collaris*	Pato de collar
		A. affinis*	Pato pechiblanco
		Oxyura dominica*	Pato tigre
	Falconiformes	Sarcoramphus papa	Rey de gallinazo
		Cathartes aura	Noneca
		C. burrovianus	Guala
		Coragyps atratus	Gallote
		Elanus leucurus#	Milano
		Elanoides forficatus#	Gavilan tijereta
		Leptodon cayanensis#	Gavilen cabecigris
		Chondrohieraly uncinatus#	Gavilan piquiganchudo
		Harpagus bidentatus#	Gavilan bidente
		Ictinia plumbea#	Gavilan plomizo
		Accipiter superciliosus#	Gavilancito enano
		Buteo magnirostris#	Cuiscui
		B. jamaicensis#	Guaranguao
		B. albonatatus#	Gavilan negro
		Buteogallus antharacinus#	Gavilan cangrejo
		Harpya harpyja#	Harpia
		Spizaetus tyrannus#	Aguila crestuda negra
		Herpetotheres cacinnas#	Vaquero
		Micrastur ruficollis#	Halcon de monte rayado
		M. semitorquatus#	Halcon del monte collarejo
		M. mirandollei#	Halcon gateador
		Daptrius americanus#	Caracara
		Miluago chimachima#	Chimango
		Falco peregrinus*	Halcon peregrino
	Galliformes	Crax rubra	Pavon, Pava rubia
		Penelope purpurascens	Pava cimba
		Ortalis cineiceps	Paisana
		Odontophorus gujanensis	Gallito de monte
		Rhynchortyx cinctus	Gallito de monte menor
		Colinus cristatus	Codorniz
		Odontophorys erythrops	

Class	Order	Scientific Name	Spanish Common Name
Aves	Gruiformes	Aramus guarauna	Carrao
		Armides cajanea	Cocaleca gris
		Gallinula chloropus	Gallineta de agua
		Porphyrula martinica	Polla sultana
		Fulica americana	Gallineta cenicienta
		Heliornis fulica	Patico de agua
	Charadriiformes	Pluvialis dominica	Chorlito dorado
		Charadrius collaris	Turillo
		Caladris canutus	Playero gordo
		Jacana jacana	Gallito de agua barbudo
		Tringa solitaria	Playero solitario
		Actitis macularia	Playerito coleador
		Gallinago gallinago	Agachadiza
		Laros argentatus	Gaviota argentea
		L. pipixcan	Gaviota de franklin
		Chlidonias niger	Gaviotin negro
		Sterna hirundo	Gaviotin comun
	Columbiformes	Columba cayennensis*	Torcaza comun
		C. speciosa*	Paloma escamosa
		C. nigrirostris*	Tres pesos son
		C. talpacoti	Tortolita colorada
		Leptotila verreauxi	Paloma rabiblanca
		Geotrygon veraguensis	Paloma verdusca
	Psittaciformes	Brotogeris jugularis#	Perico piquiblanco
		Pionus menstruus#	Cazanga
		Amazona autumnalis#	Loro mona roja
		A. farinosa#	Loro verde o real
		Ara macao#	Guacamaya bandera
		A. chloroptera#	Guacamaya roja
		A. severa#	Guaquita
		Amazona ochrocephala#	Loro mona amarilla
	Cuculiformes	Piaya minuta	Pajaro ardilla enano
		Crotophaga major	Cocinera
		C. ani	Garrapatero comun
		Dromococcyx phasianellus	Pajaro gallo
		Neomorphus geoffroyi	Hormiguero montanes
		Coccyzus americanus	Cuclillo piqui-amarillo

Class	Order	Scientific Name	Spanish Common Name
Aves	Strigiformes	Otus guatamalae#	Buhito jaspeado
		Lophostrix cristata#	Buho penachudo
		Pulsatrix perspicillata#	Buho de anteojos
		Ciccaba virgata#	Buho montanes
		C. nigrolineata#	Buho blanquinegro
		Tito alba#	Lechuza
	Caprimulgiformes	Lurocalis semitorquatus	Tapacamino selvatico
		Chordeiles acutipennis	Tapacamino menor
		Nyctidromus albicollis	Capacho
		Caprimulgus rufus	Dormilon moreno
	Apodiformes	Chaetura spinicauda	Vencejo de rabadilla blanquecina
		Glaucis hirsuta	Ermitano barbudo
		Threnetes ruckeri	Pico de hoz
		Colibri delphinae	Colibri de coronilla
		Amazilia amabilis	Colibri hermoso
		A. tzacatl	Colibri colicastana
		Chalybura urochrysia	Colibri colibronceado
		Damaphila julie	Colibri pechivioláceo
		Thalurania colombica	Colibri de coronilla
		Klais guimeti	Colibri cabecivioláceo
		Lophornis delattri	Coqueta corona leonada
	Trogoniformes	Trogon massena	Aurora
		T. melanurus	Aurora colilarga
		T. viridis	Tragon de cola blanca
		T. rufus	Tragon gracioso
		T. violaceus	Tragon violaceo
	Coraciformes	Ceryle torquata	Martin pescador grande
		C. alcyon	Martin pescador pasajero
		Chloroceryle americana	Martin pescador verde
		Electron platyrhynchum	Pajaro raqueta piquiancha
		Momotus momota	Pajaro raqueta de coronilla azulada
	Piciformes	Capito maculicoronatus	Capitan corona manchada
		Aulacorynchus prasinus	Currutaco
		Selenidera spectabilis	Pichilingo prieto
		Celeus loricatus	Carpintero prieto
		Campehilus haematogaster	Carpintero acanelado

Class	Order	Scientific Name	Spanish Common Name
Aves	Piciformes (cont.)	Pteroglossus torquata	Pichilingo
		Ramphastos sulfuratus	Paleton
		Piculus callopteros	Carpintero de mejilla rayada
		Dryocopus lineatus	Carpintero real barbirayado
	Passeriformes	Dendrocincla fuliginosa	Trepador pardo
		Decohychura longicaudata	Trepador cola de una
		Dendrocolaptes certhia	Trepador barreteado
		Xiphorphynchus lachrymosus	Trepador listado
		Lepidocolaptes souleyetii	Trepador cabecirayado
		Sclerurus guatemalensis	Raspa hoja
		Thamnophilus punctatus	Pavita hormiguera ceniza
		Thamnistes anabatinus	Hormiguero bermejon
		Dysithamnus punticeps	Hormiguero coronipunteado
		Myrmotherula fulviventris	Hormiguero leonado
		Pittasoma michleri	Merendero
		Chiroxiphia lanceolata	Toledo
		Shiffornis turdinos	Saltarin paralauta
		Sapayoa aenigma	Verdon de montana
		Cotinga nattererii	Cotinga azul mayor
		Sirystes sibilator	Papamosca copeton
		Platyrinchus mystaceus	Piquichato gargantiblanco
		Tolmomyias assimilis	Moscareta amarilleja
		Elaenia chiriquensis	Mononcita
		Ramphocelus dimidiatus	Sangretoro
		Myopagis gaimardii	Monona montaraz
		Leptopogon amaurocephalus	Moscareta cabeciparda
		Ornithion brunneicapillu	
		Trachycineta bicolor	Golondrina
		Neochelidon tibialis	Golondrina
		Thryothorus rufalbus	Ruisenor
		Henicornina leucosticta	Ruisenor
		Mycrobates cinereiventris	Ruisenor
		Vireo altiloquus	Ruisenor
		V. flavoviridis	Ruisenor
		Hylophilus aurantiifrons	Ruisenor
		Cyanerper lucidus	Ruisenor
		Dendroica pensylvanica	Canario
		Wilsonia canadensis	Canario
		Gymnostinops montezuma	Canario
		Cacicus cela	

Class	Order	Scientific Name	Spanish Common Name
Aves	Passeriformes (cont.)	Icterus mesomelas	
		I. galbual	Calandria
		Euphonia anneae	Calandria
		E. minuta	Calandria
		Tangara florida	Calandria
		T. gyrola	Calandria
		Piranga flava	Calandria
		Habia rubica	Calandria
		Tachyphonus delatrii	Calandria
		Heterospingus rubrifrons	Calandria
		Chrysothlypis chrysomelas	
		Saltator maximus	
		S. atriceps	
		Tiaris olivacea	
		Atlapetes brunneinucha	
		Emberizoides herbicola	
		Zonotrichia capensis	

* Endangered
\# Threatened

Appendix G

Fish Species Recorded from Gatun Lake, Canal Locks, and Adjacent Drainages

Fish Species Recorded from Gatun Lake,
Canal Locks, and Adjacent Drainages*

Family	Scientific Name
Primary Consumers	
Astroblepidae	Astroblepus longifilis
Callichthyidae	Hoplosternum thoracatum
Characinidae	Astyanax fasciatus
	A. ruberrimus
	Brycon argenteus
	B. chagrensis
	B. petrosus
	B. striatulus
	Bryconamericus cascajalensis
	B. emperador
	Characidium sp.
	Cheirodon affinis
	Compsura gorgonae
	Ctenolucius hujeta
	Curimata magdalenae
	Gasteropelecus maculatus
	Gephyrocharax atricaudata
	Hoplias microlepis
	Hyphessobrycon panamensis
	Piabucina panamensis
	Roeboides guatamalensis
	R. occidentalis
	Saccoderma sp.
Doradidae	Trachycorystes amblops
Hypopomidae	Hypopomus occidentalis
Loricariidae	Ancistrus chagresi
	Chaetostoma fischeri
	Leptoancistrus canensis
Loricariidae Cont.	Loricaria uracantha
	Plecostomus plecostomus
Pimelodidae	Imparales sp.
	Pimelodella chagresi
	Rhamdia wagneri
Sternopygidae	Eigenmannia virescens
Trichomycteridae	Trichomycterus striatus
Secondary Consumers	
Anguillidae	Anguilla rostrata
Cichlidae	Aequidens coeruleopunctatus
	Cichla ocellaris**
	Cichlasoma maculicauda
	Geophagus crassilabris
	Neotroplus panamensis
Cyprinodontidae	Rivulus brunneus
	R. chucunaque
	R. montium
Poeciliidae	Brachyrhaphis cascajalensis
	B. episcopi
	B. sp.
	Gambusia nicaraguensis
	Neoheterandria tridentiger
	Phallichthys amates
	Poecilia mexicana
	Poeciliopsis elongata
	Priapichthys darienensis

Family	Species
Synbranchidae	*Synbranchus marmoratus*
Peripheral Consumers	
Ariidae	*Arius multiradiatus*
	Felichthys pinnimaculatus
	Galeichthys jordani
	G. seemani
	Netuma oscula
	N. planiceps
	Selenapsis dowi
Atherinidae	*Melaniris chagresi*
Belonidae	*Strongylura marina*
Bothidae	*Citharichthys gilberti*
Carangidae	*Caranx hippos*
	Oligoplites saurus
Centroponidae	*Centropomus armatus*
	C. ensiferus
	C. nigrescens
	C. parallelus
	C. pectinatus
	C. robalito
	C. undecimalis
	C. unionensis
Clupeidae	*Ilisha fuerthii*
	Sardinella stolifera
Elopidae	*Elops saurus*
	Megalops atlanticus
Eleotridae	*Dormitator latifrons*
	D. maculatus
	Eleotris amblyopsis
	E. picta
	E. pisonis
	Euleptoeleotris clarki
	E. shropshirei
	Gobiomorus dormitor
	G. maculatus
	Guavina guavina
	Hemieleotris latifasciatus
	Leptophilypnus fluviatilis
	L. panamensis
Engraulidae	*Anchoa panamensis*
	A. spinifer
	Anchoviella curta
	A. elongata
	A. lucida
Gerridae	*Diapterus peruvianus*
	Eucinostomus argenteus
	Gerres cinereus
Gobiesocidae	*Gobiesox nudus*
Gobiidae	*Awaous tajasica*
	A. transandeanus
	Bathygobius soporator
	Garmannia hildebrandi
	G. homochroma
	Gobionellus microdon
	Microgobius miraflorensis
	Sicydium antillarum
	S. salvini
Lutjanidae	*Lutjanus argentiventris*
	L. aya
	L. colorado
	L. novemfasciatus

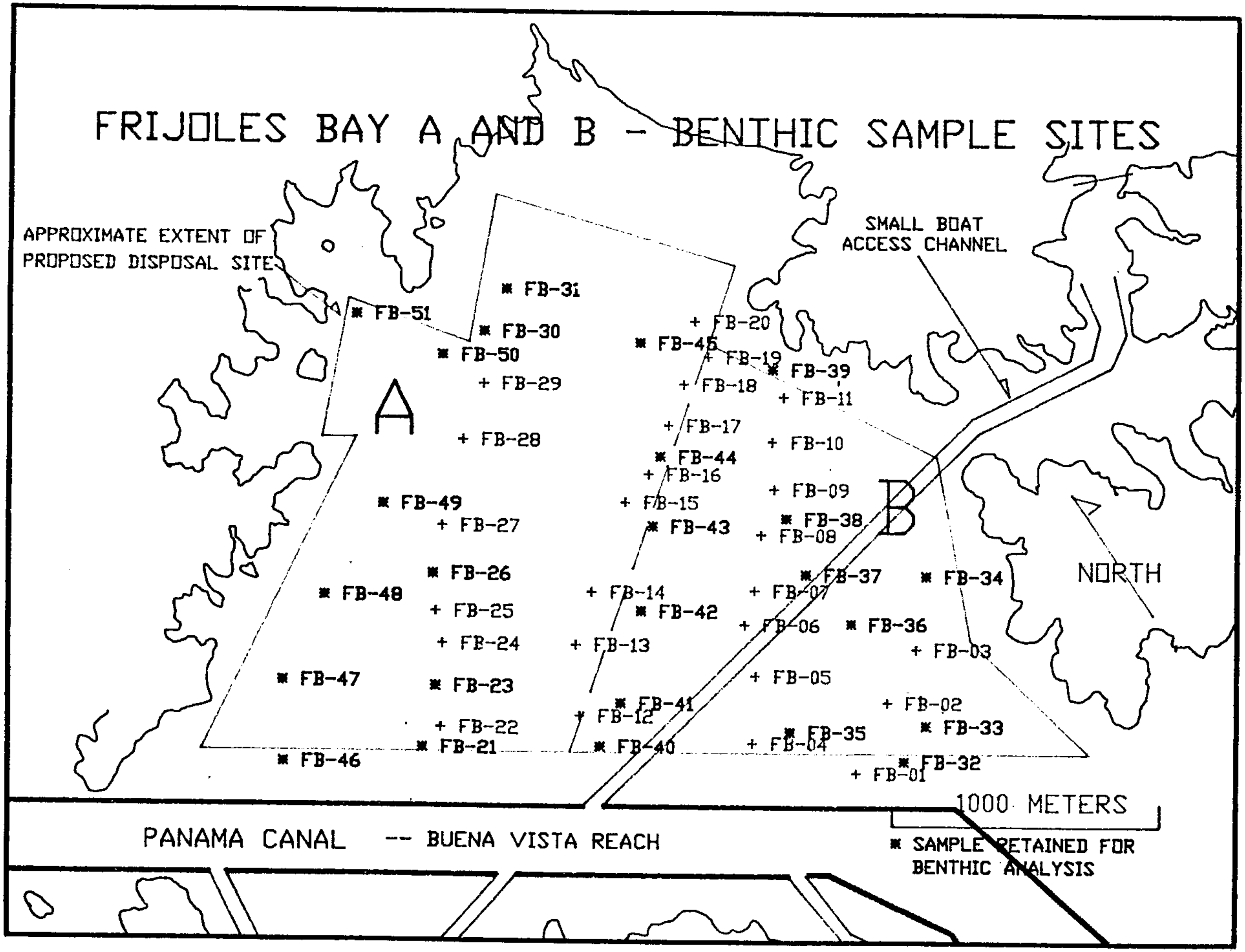
Family	Species
Mugilidae	Agonostomus macracanthus
	A. monticola
	Chaenomugil proboscideus
	Joturus pichardi
	Mugil curema
Pomadasyidae	Pomadasys bayanus
	P. crocro
Pristidae	Pristis microdon
Sciaenidae	Bairdiella ronchus
	Cynoscion albus
	Micropogonias altipinnis
Soleidae	Achirus fluviatilis
	A. mazatlanus
	Trinectes maculatus
Syngnathidae	Oosthethus lineatus
	Pseudophallus mindii
	Syngnathus elcapitanense
Tetraodontidae	Sphoeroides annulatus
	S. testudineus

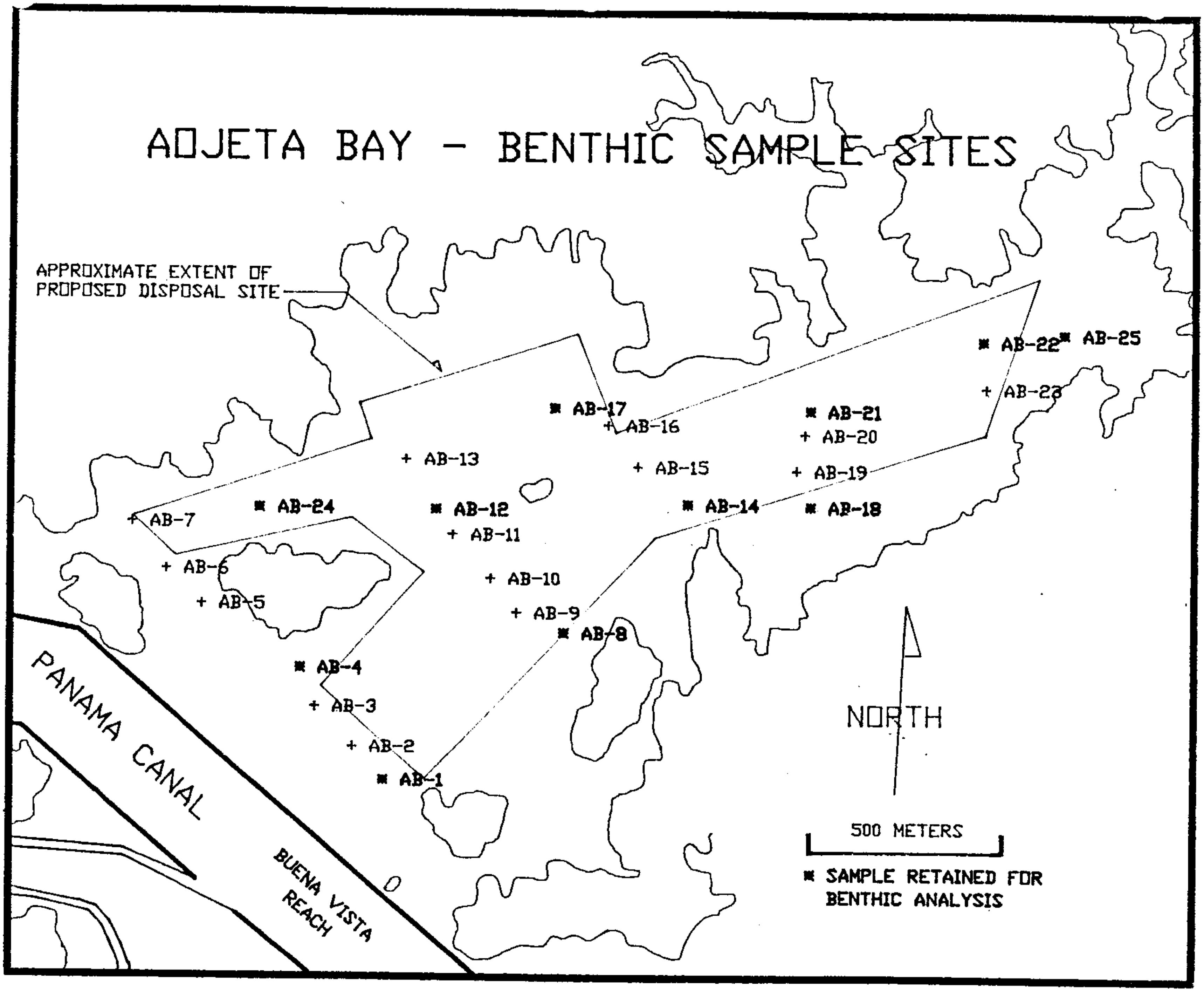
*Tabulated in connection with the 1974 Gatun Lake sea water pumping feasibility study; list does not include the Chinese carp (Ctenopharyngodon idella) introduced in 1977 as a weed control agent, and two species of cichlids (Tilapia nilotica and T. rendalli) that apparently accidentally reached Gatun Lake in 1983 from pond aquaculture facilities.

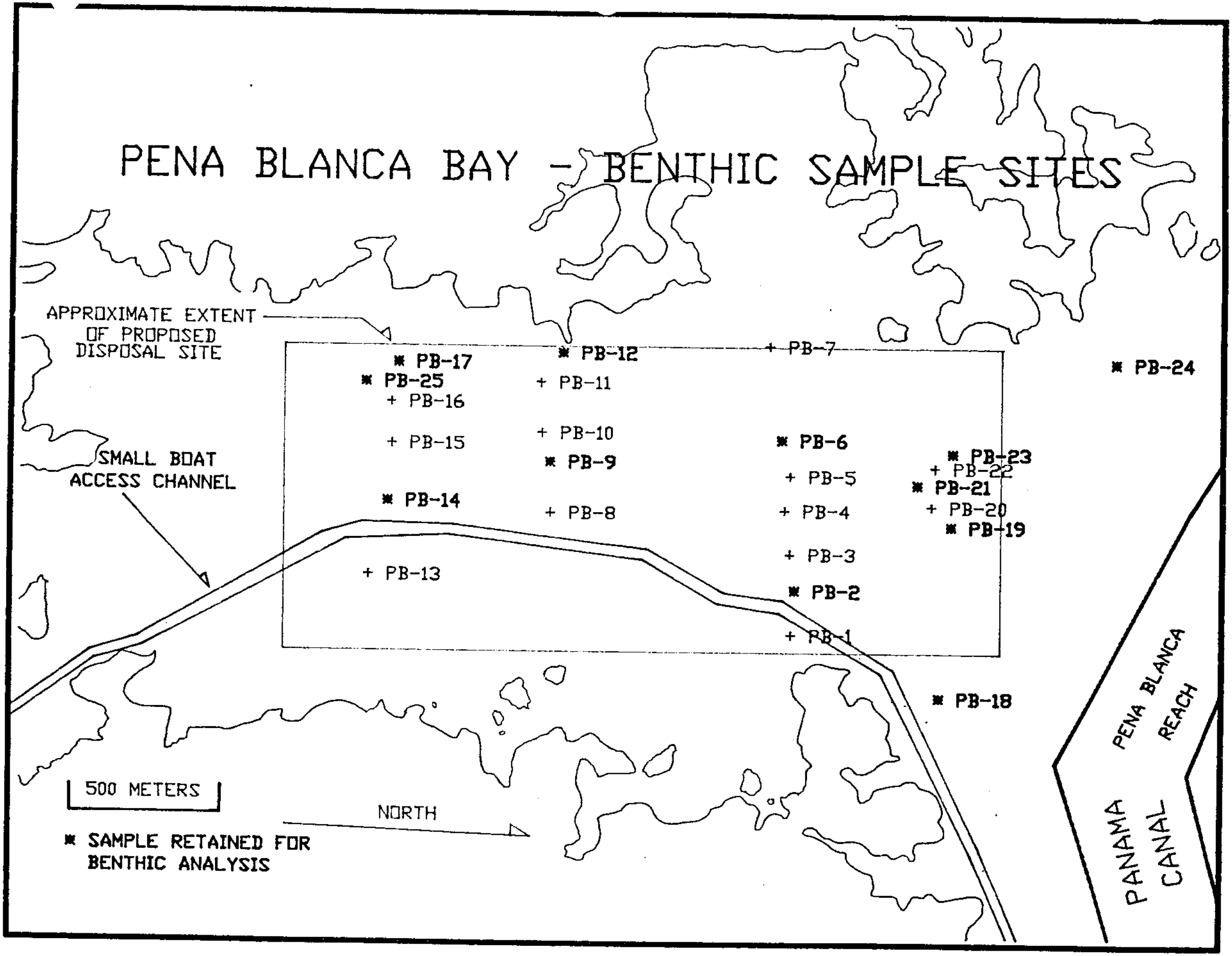
**Accidentally introduced in 1967.

Appendix H

Schematic Diagrams of Benthic Sample Sites: Frijoles Bay A and B; Aojeta Bay; and Pena Blanca Bay


FRIJOLES BAY A AND B - BENTHIC SAMPLE SITES
APPROXIMATE EXTENT OF PROPOSED DISPOSAL SITE
SMALL BOAT ACCESS CHANNEL
A
B
NORTH
FB-31
FB-51
FB-30
FB-50
FB-29
FB-28
FB-49
FB-27
FB-26
FB-48
FB-25
FB-24
FB-47
FB-23
FB-22
FB-21
FB-46
FB-20
FB-45
FB-19
FB-39
FB-18
FB-11
FB-17
FB-10
FB-44
FB-16
FB-09
FB-15
FB-43
FB-38
FB-08
FB-37
FB-34
FB-14
FB-07
FB-42
FB-06
FB-36
FB-13
FB-03
FB-05
FB-41
FB-02
FB-12
FB-33
FB-35
FB-40
FB-04
FB-32
FB-01
1000 METERS
PANAMA CANAL -- BUENA VISTA REACH
* SAMPLE RETAINED FOR BENTHIC ANALYSIS


ADJETA BAY - BENTHIC SAMPLE SITES
APPROXIMATE EXTENT OF PROPOSED DISPOSAL SITE
AB-1
AB-2
AB-3
AB-4
AB-5
AB-6
AB-7
AB-8
AB-9
AB-10
AB-11
AB-12
AB-13
AB-14
AB-15
AB-16
AB-17
AB-18
AB-19
AB-20
AB-21
AB-22
AB-23
AB-24
AB-25
PANAMA CANAL
BUENA VISTA REACH
NORTH
500 METERS
SAMPLE RETAINED FOR BENTHIC ANALYSIS



PENA BLANCA BAY - BENTHIC SAMPLE SITES
APPROXIMATE EXTENT OF PROPOSED DISPOSAL SITE
SMALL BOAT ACCESS CHANNEL
PB-1
PB-2
PB-3
PB-4
PB-5
PB-6
PB-7
PB-8
PB-9
PB-10
PB-11
PB-12
PB-13
PB-14
PB-15
PB-16
PB-17
PB-18
PB-19
PB-20
PB-21
PB-22
PB-23
PB-24
PB-25
PENA BLANCA REACH
PANAMA CANAL
500 METERS
NORTH
* SAMPLE RETAINED FOR BENTHIC ANALYSIS

Appendix I

LABORATORY RESULTS REPORT

RESULTS OF BENTHIC MACROINVERTEBRATE SAMPLE ANALYSES ON GATUN LAKE (PCZ) SAMPLES COLLECTED IN MARCH-MAY, 1985

Taxonomic Analyses by

Roy G. Smith, Jimmy G. Walden, and Larry K. Young

TVA, ONRED, Field Operations, West, Muscle Shoals, AL 35660

Report by

Thomas W. Toole

TVA, ONRED, Field Operations, West, Muscle Shoals, AL 35660

Submitted as Requested Under Contract TV-68176A

Agreement Number WRC-IA-86-2 E8586T003

Between The Tennessee Valley Authority, Office of Natural Resources and Economic Development and the U.S. Army Corps of Engineers Water Resources Support Center

March 1986

INTRODUCTION

As part of contract TV-68176A (Agreement Number WRC-IA-86-2 E8586T003) with the U.S. Army Corps of Engineers, Water Resources Support Center, Ft. Belvoir, Virginia, TVA received for identification and enumeration 48 benthic macroinvertebrate samples from Gatun Lake in the Panama Canal Zone. These samples were collected as part of an EIS on proposed widening of the canal to two lanes for a nine mile stretch through Gatun Lake. This laboratory report is submitted as the final requirement of the contract.

MATERIALS AND METHODS

All samples were washed using a standard No. 50 mesh (300μm) sieve and placed in a large white tray. Organisms were separated from the debris with forceps under a table-mounted magnifier and preserved in 70 percent ethanol. Identifications were made using a dissecting microscope.

Because keys to the fauna of the Panama Canal area were not available, organisms were identified using keys available in the laboratory. Organisms were identified to lowest taxonomic levels that the taxonomists felt were valid using these keys. When several organisms belonging to the same group, such as snails and clams were identified, they were separated into similar groups using characteristics of North America fauna. For instance, the gastropods were separated into four distinct groups based on the following criteria. Snail-1 appeared similar to

Goniobasis sp. Snail-2 was Bulmid in size with a spinous spiral at the periphery of the whorls. Snail-3 resembled *Helisoma trivolis* and snail-4 looked like a smooth Bulmidae. Two clams, one similar to *Corbicula* sp. and the other similar to *Sphaerium* sp., were identified. When counting molluscs, only organisms with flesh in them were counted. A representative sample of each mollusc was sent to Dr. Robert Hershler, Associate Curator, Department of Invertebrate Zoology, Smithsonian Institution for identification and verification that our original separations into similar groups was correct. However, the only specimens of snail-3, snail-4, and clam-2 were lost in the mail. The oligochaetes were tentatively identified as *Branchiura sowerbyi* and sent to E.V.S. Consultants, Seattle, Washington, for verification and the aquatic insects were identified by Dr. Kenneth J. Tennessen, Aquatic Entomologist at TVA.

Analysis of the data were done based upon the two-letter prefix code used for identification of the samples. Those samples with prefix AB were considered from one sampling location, FB from another, and PB from another. Simple statistics were calculated based upon the number of samples collected from each location and results reported as the number of organisms per sample. Calculations for area AB were based on 11 samples; area FB, 25 samples; and area PB, 12 samples. The unsieved sample, PB-19, w s not included in the calculations for area PB.

RESULTS

VERIFICATION

Results of Dr. Hershler's identifications confirmed that we had correctly separated the molluscs and his identifications were as follows:

Snail-1 Melanoides tuberculata (Mullor, 1774)

Snail-2 Pyrgophorus coronatus (Pfeiffer, 1840)

Clam -1 Corbicula sp. (fluminea?)

E.V.S. Consultants confirmed the identification of the oligochaetes as Branchiura sowerbyi.

Some organisms such as the leeches and chironomids were not sent out for identification or verification because they were found in only a few samples and there were very few organisms. Because of this, the level of identification made by TVA personnel was considered adequate by COE for the report.

ALL AREAS

Table 1 lists the mean number per sample of the organisms found at the three locations. The dominant organism at all three areas was Corbicula sp. The mean number per sample was 15.73, 28.64, and 30.83 for areas AB, FB, and PB, resp ctively. Other relatively abundant taxa at all three areas were Melanoides tuberculata, Pyrgophorus coronatus, and Branchiura sowerbyi. The mean number per sample and the standard deviation for

Table 1. Mean Number of Organisms Per Sample Collected at Different Areas in the Panama Canal.

	Area AB	Area FB	Area PB
Mollusca			
Gastropoda			
Melanoides tuberculata	1.36	2.16	1.75
Pyrgophours coronatus	1.55	1.88	1.17
Snail-3		*	
Snail-4		<0.01	
Pelecypoda			
Corbicula sp.	15.73	28.64	30.83
Clam-2		0.16	
Isopoda		<0.01	
Hirudinea	0.01		<0.01
Branchiura sowerbyi	0.27	1.52	0.42
Hemiptera			
Corixidae			<0.01
Trichoptera			
Oecetis sp.		<0.01	
Diptera			
Chironomidae	0.46		
Xestochironomus sp.	0.18		
Chaoboridae		<0.01	

*Specimens were all old shells.

FOWEST 0470K

these four groups are listed in table 2. Figure 1 is a graphical representation of the mean number per sample for these four groups.

Table 3 lists the dominant taxa based upon percentage composition. Figure 2 is a graphical representation of these data. Corbicula sp. was, by far, the dominant organism comprising 79.4, 84.4, and 87.5 percent of the organisms at area AB, area FB, and area PB, respectively. Melanoides tuberculata comprised 6.9, 6.4, and 5.0 percent and P. coronatus comprised 7.8, 5.5, and 3.3 percent. The oligochaete, B. sowerbyi, comprised 2.3, 2.5, and 3.8 with all other organisms comprising 3.6, 1.2, and 0.5 percent, respectively.

AREA AB

In addition to the above organisms, a leech and chironomids were identified from area AB. One chironomid was identified as Xestochironomus sp. and the others would only be keyed to chironomidae. The total number of chironomids found was seven with four being Xestochironomus sp. The leech was identified to the family Hirudinea.

AREA FB

At area FB, two additional snails, snail-3 and snail-4, were identified. An isopod, a Trichoptera, and organisms belonging to the family Chaoboridae were identified. All specimens of snail-3 were old shells and, therefore, were listed as not being counted. The Trichopteran was identified as Oecetis sp. One adult specimen and one larval specimen were found in the samples.

Table 2. Mean Number Per Sample and Standard Deviation of the Four Dominant Taxa Collected from the Panama Canal.

		Area AB	Area FB	Area PB
Corbicula sp.	$\bar{X}$	15.73	28.64	30.83
	S	12.88	43.01	20.36
Melanoides tuberculata	$\bar{X}$	2.36	2.16	1.75
	S	1.29	2.70	1.60
Pyrgophorus coronatus	$\bar{X}$	1.55	1.88	1.17
	S	2.16	3.02	1.19
Branchiura sowerbyi	$\bar{X}$	0.45	1.52	1.33
	S	0.69	3.36	1.78

FOWEST 0471K

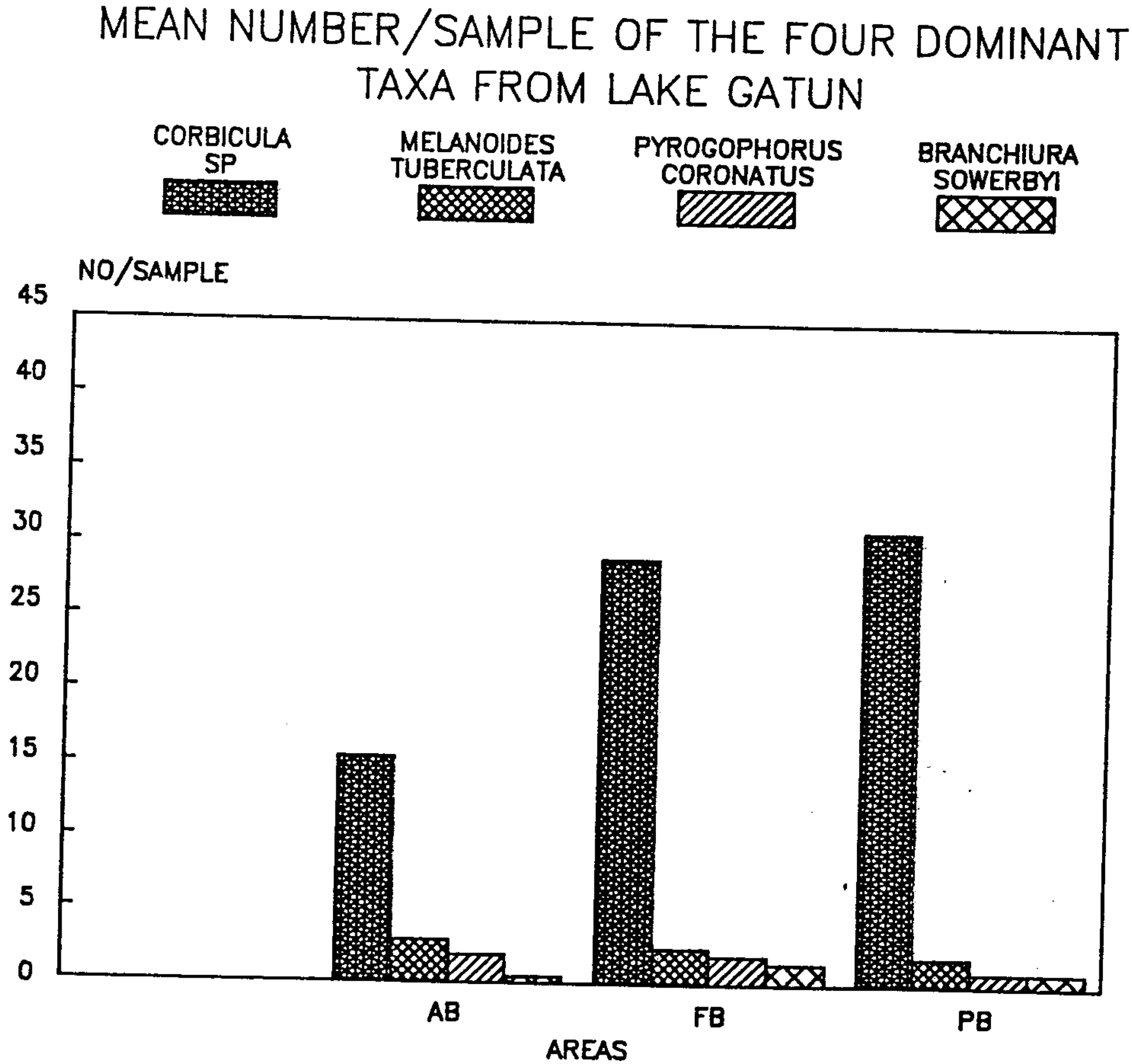


Figure 1. Mean number per sample of the four dominant taxa found at the different sampling areas in Gatun Lake.

Table 3. Percentage Composition of Taxa Collected from Different Areas in the Panama Canal.

	Area AB	Area FB	Area PB
Corbicula sp.	79.4	84.4	87.5
Melanoides tuberculata	6.9	6.4	5.0
Prygophorus coronatus	7.8	5.5	3.3
Branchiura sowerbyi	2.3	2.5	3.8
Other	3.6	1.2	0.5

FOWEST 0472K

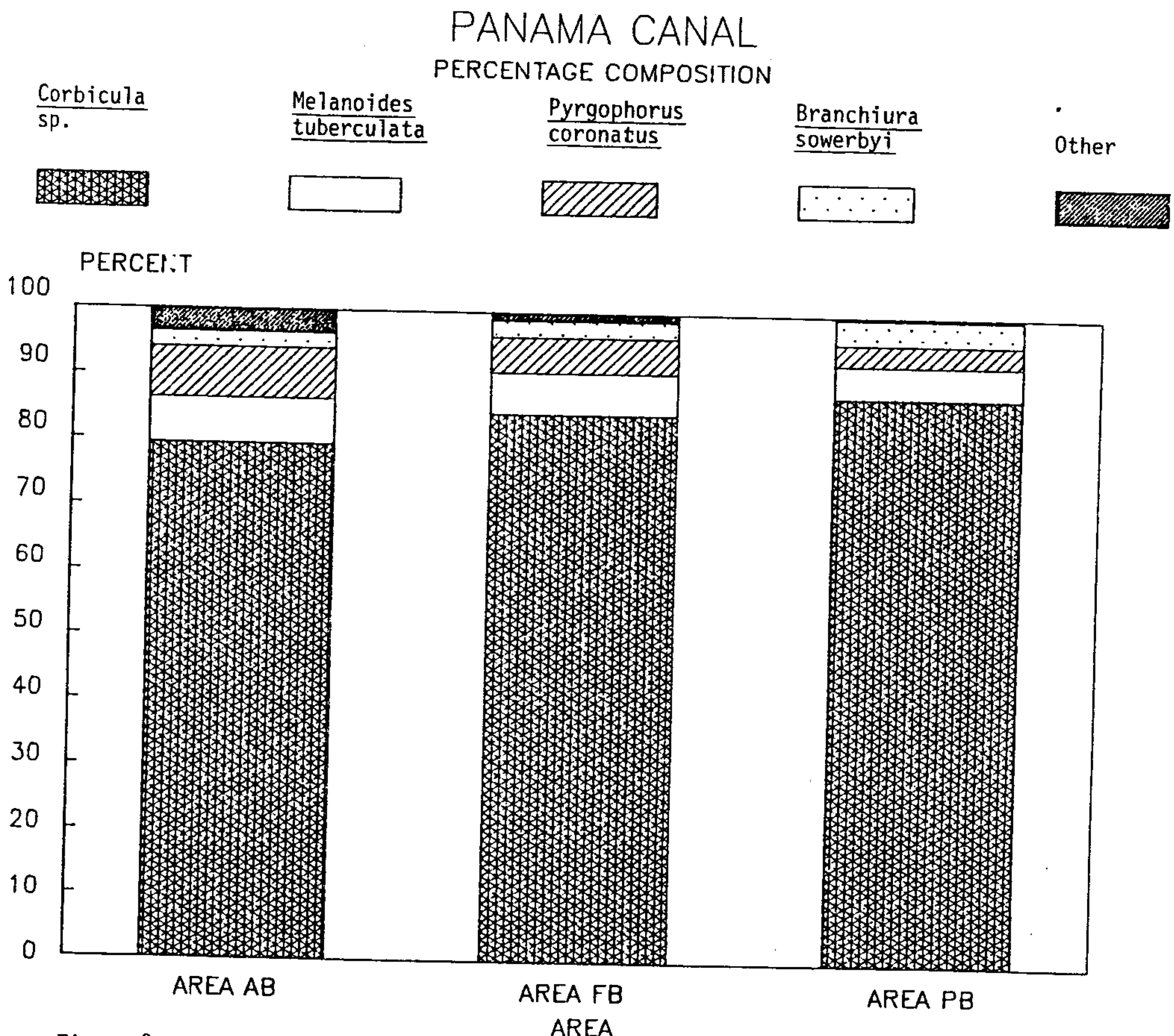


Figure 2. Percentage composition for organisms found at the different sampling areas in the Panama Canal.

AREA PB

An Hemipteran belonging to the family Corixidae, and another leech (Hirudinea) were identified from samples collected in area PB.

Table 4 is a listing of the samples in which all specimens of clams and snails of the listed taxa were old shells. The unsieved sampled PB-19 contained only old specimens of M. tuberculata.

FOWEST 0469K

Table 4. Listing of Samples from the Panama Canal in Which All Specimens of Clams and Snails Found in the Sample Were Old Shells.

Taxon	Sample Identification
Corbicula sp.	PB-18
Melanoides tuberculata	AB-14
	AB-17
	AB-18
	FB-30
	FB-31
	FB-34
	FB-37
	FB-42
	FB-43
	FB-45
	FB-46
	PB-2
	PB-9
	PB-12
	PB-19, Unseived
	PB-21
Pyrogophorus coronatus	FB-40
Snail-3	FB-31
	FB-44

FOWEST 0473K

Appendix J

The Impact of the Canal Widening Programme on Archaeological Resources (Prehistoric and Historic)

Report By
Richard G. Cooke

Prepared Under Contract With the Canal Agency in 1975 for Channel Widening Projects at Curves North of Gaillard Cut

ABSTRACT

Pre-Colombian, Colonial and Recent archaeological deposits have been located in areas to be affected by the Canal widening programme (all in the Chagres river basin). The environmental impact of the programme on these resources has been briefly assessed. Though some sites have, and more will be destroyed by the programme, it is concluded that the existing damage to the materials (by earlier construction and dumping) in most cases outweighs the potential archaeological value of the affected sites. This is deemed to be particularly true in the case of Recent (Railroad and Construction Period) sites, where available documentary and photographic resources are a greater source of information than sub-aquatic or superficial archaeology (the only large site of importance which is not mostly submerged is Gorgona; here, the remaining materials would provide interested students with good information). Some "caveat" are offered about pre-Colombian sites, where lack of stone masonry often conceals valuable information. Suggestions have been made, in the body of the text and the epilogue, concerning the management of cultural resources in the vicinity of the Canal.

Contents

Section A: Archaeological resources (pre-Colombian)

A.1: Introduction

A.2: Pre-Colombian sites in the vicinity of the Canal

A.3: Pre-Colombian archaeological sites located during the cultural survey

- A: de Lesseps Island
- B: the islands in Mamei curve
- C: San Juan island
- D: Gorgona island
- E: Santa Cruz island

A.4: Other pre-Colombian archaeological sites

A.5: The environmental impact of the dredging programme on the pre-Colombian archaeological resources

Section B: Archaeological resources (Colonial period)

B.1: Introduction

B.2: The environmental impact of the Canal widening programme on the Colonial archaeological resources

Section C: Railroad and construction period sites

C.1: Introduction

C.2: Industrial and settlement sites

C.3: Environmental impact on sites of the nineteenth and twentieth centuries

C.4: Recent sites outside the Chagres drainage which will be affected by the Canal widening programme

Section D: Epilogue

A. Archaeological resources (Pre-Colombian)

1. Introduction

The Isthmus of Panama was inhabited by human groups at least as early as 11,000 years ago: projectile points and skin-working tools recovered from the shores of the Rio Chagres (Lake Madden) and from dredge spoil at the Pacific entrance of the Canal, are typologically very similar to examples from Patagonia, Ecuador and Guatemala, which have been dated by C.14 to between 11,000±170 and 10,710±170 B.C. Most of the extant information on subsequent populations comes from the drier, Pacific sector of the Isthmus. Briefly, the known archaeological sequence suggests that, until about 3,000 B.C., the human population was comprised of small bands of hunter-gatherers living seasonally in rock shelters and selected open-sites. About 3,000 B.C., changes in the stone tool inventory and the presence of carbonised remains of plant cultigens on living floors, suggests a gradual adoption of cultivated tree- and root-crops. In some littoral areas of the Pacific (the Gulf of Parita, for example), where protein resources were plentiful and available year-round, settlements were larger (up to ?100 persons) and, presumably, more permanent. At first, the utilisation of domesticates did not affect basic settlement patterns and overall population density; however, in western Chiriqui, agriculture based on seed-, as opposed to root-crops, was responsible for the establishment and rapid expansion of nucleated villages in high mountain valleys by at least 800 B.C. A similar pattern of settlement must have spread over the remainder of the Pacific watershed some time in the first millennium B.C.: densely populated villages in lowland, alluvial zones are well in evidence by 100 A.D., both east and west of Panamá City. Demographic pressures, resulting from the increased productivity of seed ("maize-bean") agriculture and communal fishing in estuarine areas, seem to have been responsible for the establishment, along the Pacific coast, of micro-environmentally defined, mutually belligerent federations of villages, typical of Tropical forest 'rank societies' in general. These 'chiefdoms' were characterised by intense competition for resources within and without the territories, constant raiding and skirmishing and a flexible hierarchical system, based on temporary alliances, rather than rigid social stratification and hereditary dynasties. On the Atlantic side of the Isthmus, the wettest regions (such as Bocas del Toro), could probably never support settlement types more complex than the present-day Guaymi hamlet clusters. However, along some of the larger rivers of the central Caribbean coast (the Indio and the Chagres, for example), the existence of dense agricultural populations is suggested by incomplete data: in the upper Chagres, a seed- and root-crop subsistence is in evidence by at least 70 ± 155 B.C.

2. Pre-Colombian sites in the vicinity of the Canal

No comprehensive professional survey of pre-Colombian archaeological sites has been made in the territory known as the Canal Zone. (Grave-diggers - or 'huaqueros' - residing within the Zone and without, are known to have investigated a number of funerary sites, the majority of undisclosed location.) As the settlement orientation of pre-Colombian groups was decidedly fluviatile, it is probably a truism to state that "any slightly elevated, flood-free location in close proximity to a water-course, will provide evidence of pre-Colombian activities of some nature." The upper reaches of the Chagres river were certainly well populated and it is assumed that several pre-Spanish villages and earlier, more transient settlements, are submerged beneath Lake Gatun.

3. Pre-Colombian archaeological sites located during the cultural survey

A. de Lesseps island

Sheet 4243 IV SE, 626850E-1001475N

The pristine cultural environment of de Lesseps island was disturbed considerably by land-levelling operations undertaken in 1973. In the northern sector of the island, culture-bearing strata have been totally eliminated and the land surface degraded as much as twenty feet. (Humic soil in this area has formed subsequent to the destruction). In the higher, south-west portion, grading has been less extensive and some cultural material was in evidence. An outcrop of volcanics near the present-day summit, might well have been exploited in antiquity for grinding-stones, but no evidence of human interference was noted. At the edge of the escarpment created by the differential grading activity, a small pottery vessel was recovered, embedded in the laterite (fig.1). This appeared to be still in situ - perhaps part of a burial, the topmost part of which has been obliterated. No other artifacts were in association. The vessel had been partly broken by the machinery and is highly weathered. No typological studies have been undertaken in the area: assumed affinities are with the Central Region (west Panamá province to Chiriquí) and a date of manufacture later than 900 A.D. is likely. A search over the (upper) area of less intense grading, revealed only one, possibly pre-Spanish potsherd.

The afore-mentioned materials probably refer to sporadic activities around a convenient, but steep-sided vantage point overlooking the river Chagres. At the western end of the island, where the land surface slopes more gradually towards the lake level, the possibilities of recovering in situ archaeological material are greater; heavy scrub precluded an accurate search at this point.

B. The islands in Mamei Curve

Mamei, west

Sheet 4243 III NE, 635125E-10006745(western point)

This island was completely covered with tall grass and shrub growth and has very steep banks: accurate survey on top of the present-day surface was not possible. Presumably, past grading activities have disturbed or modified the in situ cultural material. On the beach area at the south-western extremity, eight sherds were recovered, that are presumably pre-Colombian (one of two rims is illustrated in fig. 1). A chalcedony core, with bipolar fractures, has long blade, as opposed to flake scars: longer-than-wide, rectangular blades are generally associated in Panamá with at least incipient agricultural activity. Rim type, fig. 1,a, is recovered frequently in eastern Panamá. At Miraflores, Río Bayano, similar forms are associated with C.14 dates spanning 685 to 895 A.D. In the bank of the opposite, north-western beach, a humic layer was located beneath the debris of the latest grading activities. It is overlain by about 30 cms. of laterite, pushed there by the bulldozer blades. It is presumably the provenience of pre-Colombian material found below, on the beach; one sherd of pre-Colombian? manufacture was discovered in situ.

Two of the total of eight sherds, are similar in form to fig.1,a.

Mamei, central

635500E-1007625N

This island has been almost completely eliminated and no survey was attempted.

Mamei, east

635750E-1007625N (western point)

Grading actvities have eradicated the top-soil and shattered mudstone has been spread over the north-eastern extremity. One possible pre-Colombian sherd was found on the north-eastern beach.

Archaeological material found on the three Mamei islands is probably contemporary and representative of a small agricultural settlement on the banks of the Chagres.

C. San Juan Island

637250E-1008500N (northern extremity)

When surveyed in late September, the most northerly part of San Juan island was being cleared by bulldozers; by October 16th., this operation had completely eradicated the *in situ* archaeological remains. To the north of the small isthmus which divides the island into two halves, the original grading uncovered pre-Colombian material in some profusion and had pushed it southwards, where numerous sherds and flakes could be found mixed with humic soil and the remains of a masonry sructure.

A total of 150 undiagnostic and weathered body sherds, 16 necks and rims (fig. 1) and ten flakes of chalcedony, were collected in September. They probably represent the débris of one or a few small houses, most likely accumulated over a short period of time. (Though indications of the pristine stratigraphy have been blurred, there seems never to have been much soil depth). A search to the south of the small isthmus revealed no cultural material; however, forest cover and deep leaf mould prevented a detailed survey.

The same general comment applies to San Juan as to the other neighbouring sites: the cultural material probably relates to a scattered population of agricultural hamlet-units, situated at the higher points along both sides of the river Chagres, in a chronologically random fashion.

D. Gorgona Island

640300E-1007850 N (northern extremity) Sheet 4243 II NW

On the northwestern shore of the island, are some rectangular excavations, measuring about 2 x 4 ft. and between 2½ and 5 ft. deep. Nearby, there was a church in post-Conquest times and would assume that the pits are recent work. Embedded in the wall of one of these cuts, however, was a jasper flake of presumed pre-Colombian manufacture. It was found seemingly in situ in the laterite, about 2 ft. below the surface. Below one of the cuts, one the 'beach', was a "cleaver" of chalcedony: a number of flakes have been struck of both edges of one side of a triangular-sectioned, angular pebble. The only other trace of pre-Colombian activity encountered was a rim sherd illustrated in fig. 1.b. Unless the flake found in the pit wall is of considerable antiquity, it is likely that the extensive and continual Colonial and construction works have utterly destroyed in situ traces of pre-Colonial activity.

E. Santa Cruz Island

641360E-1007525N Sheet 4243 II NW

The most northerly section of Santa Cruz island has been heavily disturbed by earth-moving activities for many years. To the north-west, the surface has been stripped down to the laterite, while in the north-east, the bedrock beneath the laterite has been exposed. Humic soil formation in both these areas is secondary and recent. While grass cover precluded an accurate survey, sherds and lithic materials could be found scattered all over the north-western sector. Erosion has left most of the artifacts on "rain pedestals." About a dozen extremely small and weathered sherds were recovered. 18 flakes of chalcedony are of heterogeneous nature. They were dispersed haphazardly over the studied area and showed no pattern indicative of occupational refuse. They are all probably ex situ. Three of the flakes are large, ?hard-hammer struck from pebble nodules, two of which may have been used aforehand as hammer-stones. One has a pseudo-burin flake extracted and a quadrilateral, pointed edge (a graver?) 14 chalcedony flakes have been randomly struck from irregular-shaped cores. Three show usage wear on various edges. One flake has been struck from a polyhedral blade core. The morphology and few indications of patterns of use are no clue to the relative ages of the stone instruments. Santa Cruz probably represents one of several small communities distributed in suitable localities up and down the Chagres.

4. Other pre-Colombian archaeological sites

In those areas in use, or to be used for dumping on land, the topography, vegetative cover and the nature and extent of past dumping activities, make the accurate location of pre-Colombian sites extremely difficult. Survey suggests that it is doubtful whether there are any pre-Colombian materials of importance either buried beneath the dumps or in close proximity to them: the low-lying and generally swampy terrain is, and probably always has been, unattractive for human settlement. As stated in section A.2, the banks of the Río Chagres were the scenario of constant human activities before the Spanish conquest and scores of sites must have been flooded by the waters of Lake Gatun or obscured by forest cover. It is also likely that many sites remain to be located along the present-day shoreline of the lake, especially at the mouths of water courses.

5. The environmental impact of the dredging programme on the pre-Colombian archaeological resources

A meaningful assessment of the environmental impact of the dredging programme on the pre-Colombian archaeological resources depends on notions of the relative value of the type of cultural material to be affected. It is the consultant's opinion that totally to ignore the importance of even the most superficial survey, is unsound: modern archaeology is concerned primarily with problems of past demography and the most diminutive and transiently utilised sites, are valuable assets. When any future modification to the existing land surface is contemplated in the vicinity of the Canal, it is important to bear in mind the ubiquity of pre-Colombian deposits, which, because they leave behind no masonry remains or saleable items (bottles, for example), are frequently overlooked or intentionally ignored.

Some of the pre-Colombian sites which are situated above the lake level, on areas of land that are within the limits of the Canal widening programme, have either been totally destroyed already (San Juan and Santa Cruz), or irrevocably modified (Mamei, Gorgona and de Lesseps). Of these localities, only San Juan possessed pre-Colombian material in any quantity. A survey more anticipatory of the clearing work would probably not have recovered material of better quality, nor would excavation have clarified problems of stratigraphy or spatial extent (the pre-Colombian deposits at this point had already been considerably modified by post-Conquest activities, specifically the erection of the masonry structure on top of the island, which presumably dates from Construction days). The Mamei curve islands, Gorgona and Santa Cruz had also been heavily disturbed by post-Conquest work: a brief survey suggested that a more intensive study was not warranted. De Lesseps island, which will be totally eradicated at a later date, has been so modified by grading that what little material that has survived _in situ_, was recovered by the consultant or is too damaged to be useful. We do suggest, however, that a brief inspection of the western, lower end of the island be undertaken when the vegetative cover has been stripped.

As regards those pre-Colombian sites already submerged by the Lake, we should make a distinction between those in the immediate vicinity of the Canal and near dumping areas, and those which are situated well away from canal maintenance activities. In the first case, sites will either have been removed or extensively damaged by industrial activities, or be so laden with silt and other débris, that the recovery of whatever material that might have survived, would not be feasible. It is true that, in the past, some pre-Colombian objects have been recovered from dredge spoil (see section A.1): though these might be of interest from a typological point of view, analytically they are almost useless. Structures in the pre-Colombian period were almost exclusively of wood and other rapidly perishable materials; most traces of pre-Colombian activities, other than non-organic artifacts, would have vanished between 1501 and the French canal, and information other than stone- and pottery-tools would not be forthcoming. Though we believe that the recovery of all pre-Colombian material aids in the reconstruction of the total archaeological picture of the Isthmus, we feel that, as regards sites in the immediate vicinity of the Canal channel, the time and expense involved in a submarine search and the monopoly of scarce trained personnel would be disproportionate to the overall archaeological value of such sites. Efforts would be far more profitably spent locating unmodified sites on dry land along the banks of the Chagres river.

When we consider the shoreline of Lake Gatún, well away from Canal operations, the potential value of undisclosed archaeological sites is far greater. When the water level is lowered, innumerable pre-Colombian sites are likely to be exposed just beneath the present-day lake edge, especially where water courses flow into the lake. A similar phenomenon has occurred at Lake Madden, along whose shores literally tons of material have been recovered since the 1930s. The kind of indiscriminate collecting that has been practised around Lake Madden, though socially unavoidable, has helped to limit the scientific value of the exposed material. In this context, we feel that, as soon as the level of Lake Gatun is dropped and the widening and extension of small-boat channels contemplated, an archaeological survey be conducted, as it is vital for materials to be located and studied in as pristine a state as possible.

B. Archaeological resources (Colonial period)

B.1. Introduction

The Río Chagres, or Río de los Lagartos, as it was originally named, was first explored by Hernando de la Serna in 1527. On finding that the river was navigable, de la Serna recommended the construction of a custom-house and a paved road connecting the river to Panamá. (Until this time, overland merchandise travelling to and from Panamá and Nombre de Dios, went by way of the Camino Real). The Cruces Trail was in use by 1533 and it seems that the Custom House was actually constructed in 1536. From this time until the building of the Panamá Railroad, Venta de Cruces, the river Chagres and the trail saw heavy traffic: goods were shipped along the coast from Nombre de Dios in lighters, and up the river in barges to Venta de Cruces, where they were transhipped to a mule train for Panama. At first, harassment by corsairs and bands of "cimaroons" was frequent, but apparently Venta de Cruces was spared a sacking (the town razed by Drake's men in 1573 was Venta de Chagres, contrary to affirmations in the Spanish records, which state that Cruces was destroyed by the English). The Cruces Trail was paved for the first time early in the seventeenth century (? by 1630). To protect the Chagres traffic, the building of a fort at the mouth, San Lorenzo, was begun in 1597; an earthwork defense was built at the junction of the Gatún and Chagres rivers in 1750, when San Lorenzo had proved to be not as impregnable as was imagined. Another fort was built at the mouth of the Trinidad river. In 1720, a plan was proposed to move the Custom-House downriver to Gorgona, situated at the farthest navigable point in the driest part of the dry season. This move was never undertaken, however, the trail to Gorgona was never paved, and Cruces remained the major emporium on the Chagres river.

A number of small settlements grew up along the Chagres river, as ancillaries to the barge and mule trade. Some of these may have been simply chronological extensions of the Indian villages alluded to in Section A, while others were certainly "founded" by bands of cimaroons. The map of the Dutch pirate Exquemeling, dated ?1687, but probably copied from an earlier Spanish map, shows settlements at Tabernilla and Matachín, and perhaps at Ahorca Lagarto and Palo Matías. Gorgona - San Cayetano de Gorgona - is first mentioned in a map of 1729. An undated copy of a ? 18th. century map shows the following riverside settlements: Chagre (at the mouth), Dos Hermanos, Arenal Grande, Bohío Soldado, Bailamono, Peña Blanca, Frijol, Barro Colorado, Barbacoa(s) and Gorgona. A settlement called Trinidad is noted in other 18th. century maps, while the 1750 version of Isaak Trion, adds Juan Gallegos and Vaca Monte to the list. This gradual growth of small settlements along the Chagres obviously reflects the lucrative nature of the Chagres trade.

B.2 The environmental impact of the Canal widening programme on Colonial archaeological resources

It would seem that the only settlements along the Chagres which had masonry structures in Colonial times were Fort San Lorenzo and Venta de Cruces. (The fort at Gatún was an earthwork). This lack of masonry structures obviously limits the conservation of Colonial-age cultural material that might have survived flooding and post-Colonial activities. The fort at the southern junction of the Chagres and Gatún rivers lies directly under the present-day canal entrance to Gatún locks and would not be available for sub-aquatic investigation. Evidence would, besides (as we have inferred) be limited because of the lack of masonry. The site is not near a used or prospective dump area. Of the sites mentioned in the pre-1800 maps, all are either wholly or partially submerged beneath Lake Gatun, except Chagre, at the mouth and part of Gorgona. Ahorca Lagarto, Bohío Soldado, Frijol, Barbacoa, Baila Mono and Matachín were all used as stations when the Panama railroad was built and, while we have no way of telling exactly where the Colonial settlements were in relation to the industrial works, it is quite probable that these villages have been either very considerably modified or totally destroyed by the railroad. Besides, Peña Blanca, Tabernilla and Baila Mono (also the seats of post-Spanish activities) have been largely destroyed by dredging undertaken prior to this report, while Frijol is in the area of a large prospective dump (see section C). Dos Hermanos, Arenal Grande and Trinidad will not be affected by the dumping or dredging.

In sum, one cannot envisage the widening programme's altering or eliminating any Colonial-age site that has not already been subjected to considerable damage by more recent activities. As these sites were all small, and largely working-class communities, without large masonry structures, it is very doubtful whether subaquatic research would recover any pristine remains at all (stratigraphy, one of the primary justifications for excavations on Colonial age village-sites, would be out of the question). Terrestrial dumping areas outside the river Chagres zone, are not known to have affected or to be near any Colonial sites.

C. Railroad and construction period sites

C.1. Introduction

In terms of the degree of actual or prospective damage to archaeological sites, the Canal widening programme will probably affect more material dating from 1850 to the present-day, than to the Pre-Colombian and Colonial periods. This is due to the intense engineering, economic and settlement activity which followed the laying-out of the Panama Railroad in the 1850s. However, the real archaeological value of the endangered or destroyed material must be weighed against a number of factors: i) the damage already perpetrated by the French and American canal workings; ii) past and recent dredging activities; iii) the availability and quality of existing documentary sources.

C.2. Industrial and settlement sites

The Totten map of 1857 lists the following places as stations for the Panamá Railroad on the river Chagres, below Gatún (some of these have already been considered in preceding sections): Ahorca Lagarto, Bohío Soldado, Buena Vista, Frijoles, Tabernilla, Barbacoa, San Pablo, Baila Mono, Juan Grande, Mamei, Gorgona and Matachín. Other settlements, other than stations, are also referred to: Miraflores, La Bruja, Dos Hermanos, Palo Horqueta, Palo Matías, Peña Blanca, Barro Colorado and Palenquilla. By the time the 1900 map was drawn, Massías, Vamos Vamos and Chagrecito have been added to the list.

C.3. Environmental impact on sites of the nineteenth and twentieth centuries

Of the above-mentioned sites, La Bruja, Dos Hermanos, Palo Horqueta, Palo Matías and Ahorca Lagarto are now under the waters of Lake Gatún and will apparently not be further affected by the dredging spoil. Frijoles, also under water, will soon be obscured completely by spoil for Dump 15. The town-and-station site of Tabernilla (in existence at the end of the seventeenth century), will be more completely buried and/or destroyed. (Recent dredging ploughed through part of the town, disgorging artifacts and other remains through the pipes). The Canal Company map of 1905 shows few buildings above the 80 ft. contour. The highest point of the westernmost of the three Mamei Strait islands, was apparently levelled during American construction. The buildings drawn into the 1905 map have probably been eliminated already. (The few sherds of ginger-beer bottles and clouded glass, no doubt refer to activities of this period). The French dug lock workings at the junction of present-day de Lesseps and Barro Colorado islands; what remains of their excavations and machinery will be removed when de Lesseps island is eradicated in 1977. At Juan Grande, mentioned in section A.C.3 as a pre-Colombian site, no structures are acknowledged in the 1905 map, though a concrete building, whose foundations were destroyed in the 1975 grading, was presumably an artifact of the American construction period. The part of San Pablo which is under the lake water, is beneath dumps 10 and 11 and will be covered more completely; Bailamonos will probably be obliterated by the spoil of dumps 7-9. The large construction (and earlier) settlements of Gorgona and Matachín, will be either partially buried or removed by the widening of Gamboa Reach. Chagrecito will probably be completely destroyed or buried by the same work.

Perhaps the most complete loss to the recent history of Panamá will be Frijoles, which will be completely covered by the dump spoil. Nevertheless, years of accumulative dumping in the vicinity and constant fluviatile action, have already left an overload of silt and any attempts at subaquatic salvage would be severely hampered (divers report a visbility of less than five feet and vouch for good working conditions only during the driest part of the dry season). Our comment about Frijoles applies to the other sites of this period which will be buried by dredging spoil: the existing pictorial and graphic documentary sources outweigh the potential information to be gained from subaquatic work, which would, in any case, be especially demanding of time and human resources. A large part of the town of Gorgona lies above the 77-87 ft. contour and those parts which have not been stripped or covered by the recent (1975) grading work, would still be available for study by interested persons after the widening programme. The site survey conducted by the consultant before the October grading operations, found bush cover too dense for more than a cursory appreciation of the archaeological potential of Gorgona. The rectangular cuts mentioned in section A.3.D, supposedly dug in connection with a church, had no direct association other than a stone flake (which is hardly Christian!) Other archaeological remains included late nineteenth and early twentieth century china and glass sherds, scattered over exposed areas of the surface and on the beaches, and, further inland, a series of rubbish dumps which seemed to have been completely disembowelled by amateur "bottle hunters". In October, 1975, about 200 ft. was entirely stripped or covered by bulldozer "push." A second survey made during this work, recovered more recent porcelain sherds. The buildings that have been eliminated by this work at Gorgona, are well documented in the Company records. It is most unlikely that any excavation or survey would add significantly to the existing knowledge of Gorgona: exceptions which spring to mind are the recovery of poorly documented artifacts, industrial and domestic activities and eating habits of different sectors of the community (recently studied in a contemporary context by Rathje and his associates in California). In these cases, certain stratigraphic conditions would be required and it is doubtful whether the northern part of Gorgona island would have met the prerequisites.

The same general comment applies to Matachín as to the other canal-side sites: sub-aquatic work would be feasible, but would be counter-balanced by practical difficulties (murkiness of the water, sedimentation), cost and the poverty of the information recovered in relation to other sources. For this town, as for Gorgona, there are excellent plans and photographic sources. A few other pertinent comments about the potentiality of these sites and others, will be dealt with in the epilogue.

C.4 Recent sites outside the Chagres drainage which will be affected by the Canal-widening programme

No other sites outside the Chagres drainage, dating from the nineteenth and twentieth centuries, are known by the consultant to be in danger from dumping activities; most of the terrestrial dumps, we repeat, are in low-lying and unattractive localities.

E. *Epilogue*

By way of a conclusion, we feel that, when the widening programme is viewed as a whole, the destruction of existing archaeological resources will not remove much information, whose salvage would radically amplify our knowledge of past activities in the Canal area: though some sites will certainly be damaged irrevocably, our conclusions are that the nature of the *in situ* archaeological material, past human interference, accumulative sedimentation and the standard of extant documentary sources, counterbalance the real and potential damage, in the majority of cases. One always has to ask, in the case of sites like Frijoles a number of pertinent questions, if some kind of salvage work is contemplated: i) are there specialists available for the kind of subaquatic work involved? ii) would it be worth the time and expense? iii) would the time and finances involved be more worthwhile applied elsewhere, especially if there are sites still in existence above water? We feel that, from the strictly archaeological point of view, the burying of Frijoles, which is now already well-sedimented, would only obliterate material whose degree of conservation is probably poor and whose historical value has, in the most part, been documented. This is a value judgement of this consultant, however; a problem of salvage archaeology is always to determine whether improved recovery techniques at a later date would alter an assumed impression of what is to be recovered and what is not. Gorgona, the other large construction settlement, has only partly been altered and we repeat that some material will be left *in situ* for interested students.

As regards the pre-Colombian sites, we feel that it is advisable to recommend a greater degree of coordination between the Canal agencies and those entities which are concerned with the safeguard of cultural material in Panama (all work of this nature is coordinated by the Patrimonio Historico del Instituto de Cultura). The consultant's brief field survey managed to rescue some information which, albeit fragmentary, will be of use to pre-historians who might consider reconstructing the pre-Colombian settlement patterns along the Rio Chagres. We repeat that pre-Colombian archaeological material often escapes the eye of untrained observers. Prehistoric sites differ from historic in that only archaeology can recover information from them: once destroyed, the damage is irrevocable. Numbers of sites must suffer, year by year, the fate of San Juan. We suggested that, once the lake level is lowerered, a survey be made (especially in that area which has never been modified by Canal workings and dredging), to determine the location newly exposed material and to decide whether it is of value for subsequent work. We also recommend that construction works in general be reported in advance to ther parties interested in the conservation of cultural material; often, a brief survey, like that undertaken by the consultant, is all that is needed to clear up doubts and record material, which is - as we have seen - frequently *ex situ*.

Appendix K

Report on Evaluaton of Potential Sites
for Dredged Material Disposal
(Pest Management)

Date: July 15, 1985

From: GSAN

Subject: Evaluation of potential sites for dredged material disposal.

To: EPCI

Evaluation of Proposed Dredged Spoil Lagoons as Possible Breeding Areas for Insect Disease Vectors and Biting Pest Insects.

This report is based on Cut widening plan drawing number X-6122-47 which shows proposed excavation sites and areas where dredged spoil lagoons would be constructed on both the East and West Banks of Gaillard Cut. These dredged spoil deposition areas would be enclosed by long earth-rock rubble fill dikes constructed at an average height of 50 feet along the contours indicated in the drawing. The assessment of the insect control aspects of these proposed flooded fresh water lagoons has been a joint effort of the Division Entomologist, the Chief, Sanitation Management Branch, and a Commission Sanitary engineer. The opinions and recommendations are based upon years of experience in planning and directing insect control measures associated with the 250 acre Velasquez Fill spoil dump as well as the 618 acre Telfer's Island spoil dump and 400 acre Far Fan dredged spoil facility.

Assumptions: The following conditions are, based on our best available information, those which will likely be in effect during the proposed Cut widening excavation and dredged spoil deposition within the designated lagoons:

1. The excavation and removal of the earth and rock spoil will be done by a commercial dredging firm contracted by the Panama Canal Commission to carry out this project. The Commission will however, establish how this work is accomplished and in general will provide environmental guidelines to prevent problems which could arise as a result of this work.

2. The deposited spoil will be primarily virgin earth and rock rubble crushed to such a size by the dredge that it will be easily transported to each disposal site through a system of suction dredge pipelines. It is estimated by Commission Soils engineers that the deposits will consist of 80 to 90 percent rock and earth solids, 10 to 20 percent fine mud and suspended colloidal clay, but little, if any, organic matter.

3. The water from the excavation site carrying the dredged spoil material to the deposition sites will have no salt content which might result in a brackish water environment within the lagoons.

4. Dewatering of each deposition lagoon will be controlled through the operation of water spillway stuctures established along the dike

walls to drain the effluent into well designed and maintained drainage systems which lead back into the Canal channel.

5. Roads will be built to and along the top of the dikes of each spoil deposit lagoon so that surveillance and insect control crews can easily reach problem sites should major insect breeding occur within these impoundments.

Historical Perspective:

Although many species of mosquitoes and other biting insects are routinely found during our year-round survey collections, there are only a few which are major vectors of human and animal disease. In addition to these there are a few other species which, due to their explosive breeding potential, are of special concern.

Aedes aegypti, the vector of Yellow Fever and Dengue Fever, although eradicated from Panama, has reinfested port facilities several times in recent years. This species is routinely found here on vessels coming from heavily infested ports along the Caribbean coast. It remains one of the most important transmitters of disease in the Americas.

Another important mosquito species, Anopheles albimanus, the primary vector of malaria in Panama, commonly breeds along the shoreline of Gatun Lake and has been found in considerable numbers in both fresh and brackish water sites on both sides of the Isthmus.

While no malaria has been transmitted in the region of the Panama Canal in the past 10 years, the potential for transmission continues to exist should an imported case of malaria go undetected. To reduce this threat, continuous breeding surveys and control measures are carried out against this species within a one mile perimeter of all Commission townsites.

There have been several past instances where major pest mosquito and Culicoides sand fly outbreaks have been a direct result of the deposition of dredged spoil material into settlement lagoons such as the Velasquez Fill spoil dump and Far Fan Swamp dump on the Pacific side of the Isthmus and the Telfer's Island spoil dump on the Atlantic coast. Insect populations became so great following the pumping of dredged spoil into the Far Fan Swamp in 1968 that the U.S. military brought in special Air Force aerial spray aircraft teams from the U.S. to reduce the hordes of biting gnats which affected the residents and workers at Howard Air Force Base and at Ft. Kobbe. In recent years, local military helicopter spray missions have been required to control flights of Aedes taeniorhynchus mosquitoes emerging from newly dredged deposits within the Velasquez spoil site. Needless to say, these control measures have been expensive and there has been a continuing need to devote manpower and materials to prevent further outbreaks in succeeding years following new dredged spoil depositions.

The main factors which lead to conditions which contribute to a dredged spoil deposition site becoming a breeding site for both mosquitoes and sand flies are:

1. A high percentage of suspended organic matter within the new dredged spoil deposit which provides nutrients for insect breeding. Some spoil mud may have as much as 25 percent organic matter if sewage outfalls are nearby.

2. A high percentage of fine silt and suspended colloidal clay within the main body of the spoil deposit. This results in slow dewatering and greater shrinkage giving rise to deep fissured cracks throughout the surface of the deposit. These fissures may be several feet deep and provide an ideal moisture gradient for oviposition by both mosquitoes and sand flies.

3. A history of past mosquito and sand fly breeding within previous spoil deposits or within swampy areas where new spoil may be deposited. Millions of dormant eggs which may be present in these areas could hatch upon being flooded and create large flights of these insects.

4. Salinity content of the spoil material. The major pests which are produced within dredged spoil fill areas are those species with a preference for, or tolerance of, brackish water environments. *Aedes taeniorhynchus* mosquitoes, breed primarily in saline waters and are very aggressive man-biters which have been known to transmit human disease viruses. They are highly migratory and have been known to invade townsites in great numbers from breeding sites over 20 miles distant. *Anopheles albimanus* mosquitoes are also migratory and

tolerate high levels of salinity such as that found in seepage areas near the dredged spoil deposition sites. Culicoides furens and C.guyanensis sand flies are produced in tremendous numbers within organic saline dredged spoil deposits and are carried by prevailing winds into residential and worksite areas many miles downwind of the site.

Discussion of the Major Factors related to Insect Breeding within the proposed Lagoons.

In the development of standards for the operation of the proposed dredged spoil lagoons, the following facts and observations regarding their potential for breeding vector and pest insects should be taken into account:

1. Although the pumping of dredged spoil into the diked sedimentation lagoons will create potential breeding areas for mosquitoes and sand flies, certain factors will not be present which would be found in a "worst case" situation. The standing water will not be brackish and should not lead to conditions suitable for the breeding of Aedes taeniorhynchus mosquitoes or of Culicoides furens and guyanensis all of which present major problems in saline dredged spoil deposit sites. The deposits will also have a very low organic content thus providing little nutrient to support large populations of insects. And, in that most of the deposited material will be crushed rock and earth with a minimum of fine silt and colloidal material, dewatering of the deposit

should proceed rather rapidly with little shrinkage and without the development of fissures commonly found in deposits made up of fine colloidal silt and clay.

2. The sedimentation of the 10 to 20 percent fine suspended solids in these lagoon systems will require that low water velocities be achieved within the lagoons. However, the lower the water velocity the higher is the potential for mosquito breeding. The fresh water lagoons, would be expected to produce some Culex and Anopheles mosquitoes. These mosquitoes could cause problems should they invade nearby populated areas such as Parque Soberana, Paraiso and Gamboa housing areas. This potential will require that Commission mosquito control resources be assigned to these sites until the lagoons are permanently dry. This may require several months or longer depending upon the cycle of adding new spoil to each site.

3. Water seepage along the perimeter of the dikes may collect in small pools which are hidden by dense vegetation. Such pools would be ideal mosquito breeding sites.

4. Tall vegetation left standing in areas of the lagoons to be flooded following their construction could afford protection for mosquito larvae. Such vegetation may also hinder access by mosquito control crews applying larvicide from small boats.

5. It is not likely that ponding of water within these lagoons will stand long enough to support the growth of aquatic vegetation such as

water hyacinths or water lettuce, however should such vegetation be present, man-biting Mansonia mosquito species could become established within these lagoons. Mansonia titillans, M. leberi and M. dyari are all implicated in the transmission of encephalitis virus to humans and horses.

6. All dikes should be designed with a hard surface access road to the dike and an all weather vehicle road on top of the dike for vehicle access to the spillway and all areas of the lagoon. Unrepaired vehicle ruts in the terrain may also collect and hold sufficient surface water to allow mosquito breeding. Vegetation which becomes rooted along the top and sides of the dikes may hinder vehicle and mosquito control crew access.

7. All Spillway discharges should be channeled to major streams such as the Mandinga River, Pedro Miguel River or the Sardinilla River, rather than being allowed to spread over low ground or to pond below the dikes.

8. Leaks from suction dredge pipelines may also lead to hidden ponding within dense vegetation with a potential for mosquito production.

9. In that all major Culicoides sand fly pest species are limited to saline environments, we do not expect to find sand fly breeding in any of the proposed fresh water sedimentation lagoons.

10. *Aedes aegypti* is not expected to breed in the proposed deposition lagoons, however should man-made refuse and trash accumulate around these and other contractor sites, this mosquito, which almost exclusively breeds in man-made containers, may utilize such refuse accumulations as breeding sites. Breeding by this mosquito has recently been found onboard several transiting vessels, each of which passed within close proximity to the proposed construction areas.

Assessment Conclusions and Recommendations:

1. Upon considering the projected conditions and the discussion of the various factors shown above, major pest and vector insect breeding is not expected to be a problem within any of the 10 proposed dredged spoil deposition / settlement lagoons shown in the engineering drawing provided. This is due primarily to the following: the deposits will not be saline in nature, the vast majority of deposits will be made up of crushed rock and earth with little suspended colloidal or organic matter.

2. However, any body of water, fresh or saline, can provide breeding sites for a variety of mosquitoes. Even though the deposits may not have organic content, the sites themselves will have a certain accumulation of vegetation and humus. This will likely provide enough nutrients to support a certain level of mosquito breeding. Contingency plans covering the weekly monitoring of each site will be drawn up by our Sanitation and Grounds Management Divsion staff prior

to any pumping of spoil material. Lightweight larvicidal oil will normally control such breeding if applied at the right time of the breeding cycle. Therefore, roads will have to be kept in good repair along the top of each dike to facilitate regular access by our Sanitation Branch mosquito surveillance and control crews.

3. The potential for mosquito breeding can be reduced to a minimum by water level control at each lagoon. This will require that a good level of communications be maintained between the contractor and this Division. Dewatering of these deposition sites should proceed as rapidly as possible so that stagnant water is ponded for a relatively short period. The installation of subsurface drainage pipes may allow the dewatering to be accelerated, therefore it may be worthwhile for engineers to consider whether such drainages would be cost-effective if included in the containment lagoon design.

4. The attached diagram graphically shows our main concerns regarding possible problem areas in and around a dredged spoil disposal / settlement lagoon.

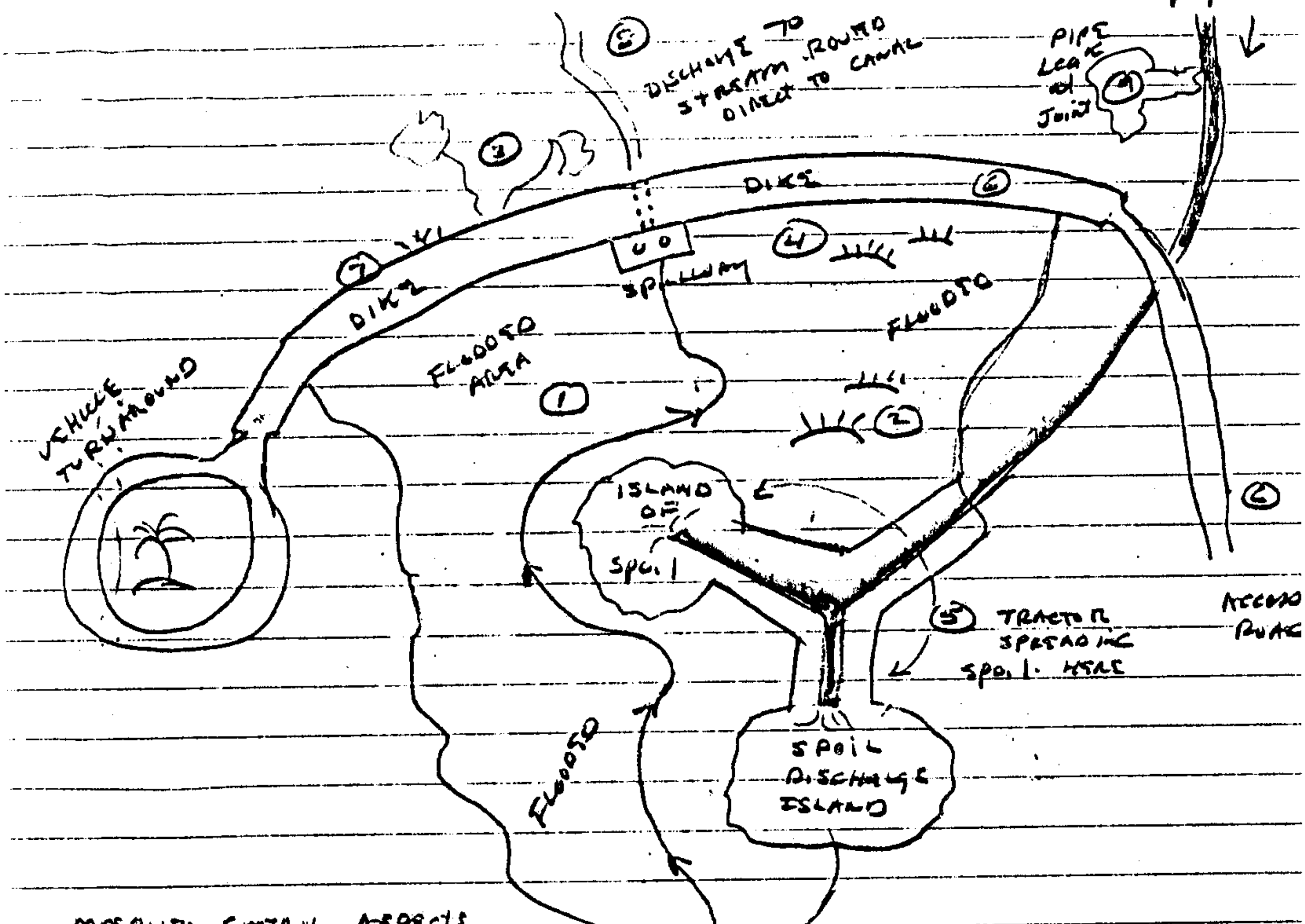
5. In advance of construction, we suggest the establishment of a Dredge Spoil Disposal Site committee which would have members representing the Contracting firm, PCC Dredging Division, PCC Soils Engineering, PCC Environmental Protection, PCC Sanitation / Mosquito Control, and PCC Water Quality Labs. This committee would meet on a regular basis prior to and during the construction of these sites and during the excavation and deposition of the dredged spoil. Such a

committee would provide an excellent mechanism for necessary input prior to dike construction and would provide all concerned with updates on the progress of the excavation and of the need for any corrective measures required during the project.

6. Following the completion of the Cut Widening project, care must be taken to ensure that each dredged deposit site be properly graded and that drainages be constructed within each site to ensure that no ponding of rainwater occurs. Also, all man-made refuse around these sites must be removed in order to prevent breeding by *Aedes aegypti* mosquitoes.

7. Plans regarding vegetation control around and within the deposition sites following the completion of the Cut Widening excavation should be coordinated with the Grounds Management Branch to assure that such additional work can be accomplished within the constraints of their budget.

TYPICAL DREDGED SPOIL LAGOON



<u>MOSQUITO CONTROL ASPECTS</u>

1. Ponded water
2. TALL OR DENSE GROWTH IN FLOODED AREA
3. SEEPAGE FROM DIKE
4. Aquatic growth
5. Vehicle ruts
6. mosquito trucks stuck in mud
7. Very tall grass on dikes
8. Discharge should not pond below dike
9. Pipe leaks