Report to the

# GOVERNMENT OF JAMAICA

# COAL FEASIBILITY STUDY AND FINANCING PLAN

## PHASE II

## VOLUME 1

Prepared for the
Coal Committee of Jamaica

BECHTEL POWER CORPORATION
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REPORT TO THE
GOVERNMENT OF JAMAICA

COAL FEASIBILITY STUDY
AND FINANCING PLAN

PHASE II

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# 1.0 EXECUTIVE SUMMARY

## 1.1 BACKGROUND

During the last 10 years, world oil prices have dramatically impacted the cost of oil imports to Jamaica. In 1981, Jamaica's oil import bill was equal to U.S. $496 million, or 51 percent of Jamaica's export earnings.

In July 1982, realizing the potential foreign exchange benefits associated with the substitution of coal for oil as a fuel for Jamaica's major energy consuming facilities, the Government of Jamaica initiated a study of the feasibility of an oil-to-coal conversion program. The Coal Committee of Jamaica was formed to represent the interests of the various entities involved, and Bechtel was commissioned to perform the study with funds made available through a grant to the Government of Jamaica from the U.S. Trade and Development Program. Work was performed in close coordination with the Committee, the Ministry of Mines and Energy, Jamaica Public Service Company Limited, and PETROCORP.

Phase I of the study was completed in October 1982 and indicated that it is technically and economically attractive for the Government of Jamaica to utilize coal to the maximum extent possible by converting the electric power generating stations at Hunts Bay and Old Harbour and by encouraging the utilization of coal by the alumina production facilities.

This report, which is Phase II of the study, has as its principal objective the assistance of the Coal Committee of Jamaica to identify the preferred option based on the results of Phase I. Using this preferred option, Phase II has the following subobjectives:

- Develop a conceptual design
- Prepare detailed specifications for the principal equipment and obtain pricing from the international marketplace, together with export credit terms
- Develop an infrastructure plan for the coal port
- Develop a project financing plan
- Prepare a plan for implementation of the project.

In the course of the Phase II development, and following inquiries by Bechtel's financial services, and procurement representatives, it was concluded that a very high probability existed that funds to finance the first phase (approximately U.S. $270 million), consisting of Units 2, 3, and 4 of Old Harbour and Unit 6 of Hunts Bay, and the coal port to handle those requirements plus future potential alumina plant conversions, would not be available given present world and local economic conditions. The plan then focused on a low cost alternative based on the conversion of Units 3 and 4 of Old Harbour to provide the capacity to carry the base load and to provide the highest economic rate of return to Jamaica by utilizing the capital investment to the greatest degree possible. The anticipated funding requirement was approximately U.S. $120,000,000 (see Section 2.0).

## 1.2 CONCEPTUAL DESIGN

Section 3.0 describes the conceptual design which has been prepared to verify the technical feasibility of the project and to serve as the basis for detailed engineering and design. The project is technically very feasible. The technologies and equipment utilized have been proven through many decades of use in power generation practice.

Environmental concerns have been addressed, and the design provides for effective controls of the various emissions and in fact actually improves some of the existing conditions (air quality). Equipment has been specified, capital cost estimates have been prepared, preoperational and start-up requirements have been defined and estimated, and incremental operating and maintenance requirements have been defined and evaluated.

Provision has been made to overhaul the existing turbine generator units. Meetings have taken place between General Electric and Jamaica Public Service covering the details of the problems encountered with those machines, and an allowance has been made in the project cost for the rehabilitation of those turbine generators.

Allowance has also been made for a Technical Assistance and Training Program which will support the operation of the units over the first 5 years.

## 1.3 PRICING OF PRINCIPAL EQUIPMENT

As a means of obtaining a high level of confidence in the capital cost estimate and in order to verify the availability of export credit financing, formal requests for quotations were issued to qualified bidders for four packages of equipment - the steam generators, the electrostatic precipitators, the coal handling system, and the ship unloading equipment. Technical and commercial evaluations were prepared and recommendations were made for final negotiation of both prices and financing.

It should be noted that the bidding was very active and competitive and that extremely favorable pricing and credit terms were received for approximately U.S. $36.3 million worth of supply (41 percent of the estimated capital cost). Section 4.0 provides a detailed description of this activity.

## 1.4 COAL PROCUREMENT

Secton 5.0 contains an identification of the required quantity and quality of coal to support Old Harbour Units 3 and 4. Sources have been identified, and estimates for the delivered cost of coal have been prepared. Storage and handling logistics are defined. A coal procurement strategy has been outlined, and the potential for capital plant financing support is discussed.

## 1.5 FINANCIAL ANALYSIS AND FINANCING PLAN

The results of the economic analysis are discussed in Section 6.0. Highlights of the Base Case analysis are as follows:

Basis

| | |
|---|---|
| Date of Initial Operation | 1986 |
| Construction Schedule (Fast-Track) | 2 years |
| Capital Cost Estimate | U.S. $104.8 million |
| Operating Capacity | 70 percent |
| Coal Consumption | 321,400 metric tons/year |
| Oil Consumption (Replaced) | 1.41 million bbl/year |
| Coal Price | U.S. $58.08/metric ton |
| Oil Price | U.S. $28.47/bbl |
| Incremental O&M Costs | U.S. $1.97 million/year |
| Training and Technical Assistance Costs | U.S. $750,000/year - 5 years |
| Financing Plan | 100 percent of capital costs plus IDC as described |
| Fuel Price Escalation | 6 percent per annum starting January 1, 1986 |

Results

| | |
|---|---|
| Cumulative Gross Fuel Savings | U.S. $1067 million |
| Cumulative Net Fuel Savings | U.S. $968 million |
| Average Annual Fuel Savings | U.S. $42.1 million |
| Cumulative Net Cash Flow* | U.S. $766 million |
| Rate of Return | 23.4 percent |
| Payback | 5 years |
| Cumulative Foreign Exchange Savings | U.S. $786 million |
| Average Annual Foreign Exchange Savings | U.S. $342 million |

*Cumulative net cash flow is positive starting in the first year of operation, through the 23-year life of the project.

Sensitivity Analysis

| | |
|---|---|
| Capacity Factor/Rate of Return | 60 percent/20.6 percent<br>70 percent/23.4 percent<br>80 percent/25.8 percent |
| Escalation/Rate of Return | Oil and coal 6 percent/ 23.4 percent<br>Oil and coal 7 percent/ 24.5 percent<br>Oil 7 percent; coal 6 percent/ 25.4 percent |
| Construction Period/Rate of Return | 2 year = 23.4 percent<br>3 year = 22.2 percent |

| | |
|---|---|
| Capital Cost/Rate of Return | +10 percent/21.7 percent<br>-10 percent/25.5 percent |

The project financing plan anticipates the following sources and uses of funds:

| Source | Use | U.S. $ (Millions) |
|---|---|---|
| Inter-American Development Bank | Foreign Procurement, Local Costs, Interest During Construction | 48 |
| Export Credits (OECD) | Foreign Procurement | 47 |
| Export Credits (Non-OECD) | Foreign Procurement, Local Costs | 8 |
| Commercial Bank Loans | Foreign Procurement Down Payments, Interest During Construction | 15 |
| Owner Financing | Working Capital, Local Costs, Interest During Construction | --- |
| | TOTAL | 118 |

Typical rates are shown in Table 6-7.

## 1.6 PROJECT PLAN

The Project Plan, Section 7.0, describes the project organization that is recommended to provide the quality, cost, and schedule control for a project of this magnitude. Included also is a discussion of the balance of plant contracting plan and a suggested financing strategy.

## 1.7 PROJECT EXECUTION

The following summarizes the requirements for execution of the project and references the sections in the report in which the tasks are described in more detail.

- o Notification from the Government of Jamaica of its intent to proceed with the project (Section 6.4)
- o Final negotiations of coal sourcing and of coal company participation (Sections 5.3 and 5.4)
- o Final negotiation of equipment supply prices and placement of orders (Section 4.4)

- Final negotiation of financing and obtaining loan commitments (Section 6.4)
- Finalize with General Electric the plan to rehabilitate Old Harbour Units 3 and 4 turbine generators (Section 3.8)
- Initiation of detailed engineering and procurement activities (Section 3.15)

# 2.0 SELECTION OF PREFERRED OPTION

## 2.1 BACKGROUND - PHASE I

The overall objective of the Coal Feasibility Study, Phase I report was to evaluate the technical and economic feasibility of substituting imported coal for oil as a fuel in the existing electric power and industrial facilities in Jamaica. Based on the results of the study, Bechtel concluded that substitution of coal for fuel oil is an economically sound strategy for the Government of Jamaica.

Specifically, the Phase I study analyzed the utilization of coal for Old Harbour Units 2, 3, and 4 and Hunts Bay Unit 6, together with a coal port and infrastructure plan that would also provide coal to the three alumina companies and the cement company. The cement company had already put in place a plan to utilize coal. The alumina companies had, to varying degrees, studied the utilization of coal and in general agreed on the advantageous aspect of conversion to coal. However, the alumina companies concluded that the large demands for capital for conversion at a period of very low demand and low price for alumina precluded conversion at this time.

Even though conversion of Old Harbour Units 2, 3, and 4 and Hunts Bay Unit 6, together with a coal terminal to supply coal to future alumina plant conversions, was shown to be economically advantageous to the Government of Jamaica, the funds required were on the order of U.S. $270 million.

## 2.2 BACKGROUND - PHASE II

Phase I findings showed a clear advantage for utilization of coal. It was recognized that additional work was required to further define the optimum strategy. Phase II was commissioned with the following tasks:

- Select preferred option
- Perform conceptual design
- Confirm pricing for principal equipment
- Develop infrastructure operating plant (coal sourcing)
- Develop project financing plan
- Identify other actions required for initiation of project
- Prepare project plan

These tasks are reported in detail in this study.

## 2.3 SELECTION OF PREFERRED OPTION

Preliminary, but specific, inquiries on the part of Bechtel's Financial Services and Procurement representatives reported a very high probability that funds to finance the entire first phase (consisting of Units 2, 3, and 4 of Old Harbour Station and Unit 6 of Hunts Bay Station, and the coal port to handle those requirements plus future potential alumina plant conversions) would not be available given present world and local economic conditions. Bechtel recommended an approach that we believe offers a compromise that yields the greatest benefit for the Government of Jamaica, consistent with the possibility of obtaining financing. Bechtel recommended that conversion from oil to coal can be made in several stages; the first stage would be conversion of Units 3 and 4 at Old Harbour Station, together with a minimal coal receiving facility at Old Harbour Station, initially to supply coal only to those two units. The capital cost for this stage was estimated at approximately U.S. $120 million. The present base load of the Jamaica Public Service system is on the order of 120 MW. Units 3 and 4 of Old Harbour Station have a capacity of approximately 137 MW. Therefore, the conversion of Units 3 and 4 of Old Harbour would utilize the capital expenditure to the maximum possible extent, which is a fundamental optimum approach to return an investment.

The entire Phase II plan, which is limited to the conversion of Units 3 and 4 at Old Harbour, is discussed in detail in the following sections of this report.

# 3.0 CONCEPTUAL DESIGN

## 3.1 GENERAL

The existing JPS plant is located on Old Harbour Bay, which is situated on the south coast of Jamaica at approximately latitude 17°54'N and longitude 77°7'W and is approximately 25 miles west of Kingston. The power plant complex consists of four oil-fired units with a total capacity of 230 MWe. Unit 1, which is scheduled to be retired in 1998, is nameplate rated at 33 MWe. Unit 2, which has a Hitachi turbine, is nameplate rated at 60 MWe. Units 3 and 4 have General Electric turbine generators and Foster-Wheeler boilers, and are nameplate rated at 68.5 MWe each. All of the boilers are D type with flat bottoms.

As stated in Section 2.0, the first stage of the coal conversion project would be to modify Units 3 and 4. Two 610,000 pound-per-hour (277,000 kilogram-per-hour) pulverized coal-fired boilers will be installed in parallel with the existing oil-fired boilers. The existing boilers will serve as emergency backup for the coal-fired boilers. All existing oil-fired boilers will be kept intact, along with their piping and accessories. A steam-heated coil will be added to the lower boiler drum to permit these boilers to remain in a standby condition. Provisions will be made to control the Units 3 and 4 turbine generators and auxiliaries from either the existing control room or the new coal-fired boiler control room. The proposed site arrangement is shown in Figure 3-1.

Since there are no air quality emission standards promulgated in Jamaica, the following environmental standards, equivalent to the U.S. air quality standards, were used in the study as a design basis after discussions with Jamaica government officials.

Air Quality Standard

| | |
|---|---|
| $SO_2$ | 80 μg/m$^3$ annual average ground level concentration<br>365 μg/m$^3$ 24-hour average ground level concentration<br>1300 μg/m$^3$ 3-hour average ground level concentration |
| Particulate Matter | 75 μg/m$^3$ annual average ground level concentration<br>260 μg/m$^3$ 24-hour average ground level concentration |
| $NO_x$ | 100 μg/m$^3$ annual average ground level concentration |

Stack Emission Standard

| | |
|---|---|
| Particulates | 0.03 lb/10$^6$ Btu (.0129 g/10$^6$ joules) of heat input |
| $NO_x$ | 0.06 lb/10$^6$ Btu (.0258 g/10$^6$ joules) of heat input |
| Opacity | 20 percent |

The use of coal containing less than 2 percent sulfur along with a stack height conforming to U.S. EPA Good Engineering Practice guidelines reduces the sulfur dioxide ground concentration. Pollutant ground level concentrations from operating the plant were calculated using the U.S. EPA approved model and were compared to the U.S. National Ambient Air Quality Standards. Based on the results of the study, there is an improvement in the local air quality associated with the proposed conversion.

Volume 2, Appendix A, Associated Environmental Impact Assessment, contains detailed analysis of air and water quality, ash disposal site selection, and port dredging waste disposal impact.

## 3.2 SITE FEATURES

### 3.2.1 Site

The new coal-fired boilers will be located on the existing plant property just east of the existing oil-fired boilers. Access to the plant is by secondary road. A complete system of paved plant access roads will be provided for equipment maintenance and ash removal. The main access road will continue to serve the plant. The site plan for the proposed facility is shown on Figure 3-1.

The site slopes gently to the shore and is covered with light vegetation. To be consistent with the existing plant's grade, the entire site will be raised to elevation 7.0 feet. The maximum fill depth is 5 feet. An open drainage system combined with culverts will accommodate all surface runoff. As part of the drainage system, the site will be graded to provide adequate storm drainage. Since the new boilers will be located in the existing parking area, a new paved parking area will be provided.

### 3.2.2 Coal Storage

The coal storage area, which will be located east of the new coal-fired boilers, will also be raised to elevation 7.0 feet. An open drainage system will be provided around the entire coal storage area to collect all coal pile runoff. The drainage system will direct the runoff into a retention basin. The retention basin will retain the runoff for settlement or possible treatment prior to discharge.

### 3.2.3 Ash Disposal

The proposed ash disposal site is located at Kelly's Pen approximately a half mile north of the plant. The 50-acre site is a gently sloping field with light vegetation. A relatively impervious soil layer is expected to limit ground infiltration.

The ash disposal method will consist of trucking the ash to the disposal site and placing the ash in an above-grade landfill. The site will be divided into six 8-acre cells. Only one cell will be filled at a time. Each cell is sized to contain approximately 4 years of fly and bottom ash discharged by the two new boilers. See Figure 3-2 for a typical cell arrangement.

Prior to starting disposal operations, the first cell will be provided with a drainage system design to collect all storm runoff from the ash pile. The collected runoff will be directed into a settling basin. The settling basin is designed to provide adequate retention time to settle out ash sediment prior to discharge into the natural drainage system.

As the ash is collected and piled within the cell area, a combination of water spray and dirt fill will be used to control dust. Once the cell has been filled, the entire ash pile will be covered with a dirt fill and then stabilized with grass or other vegetation. At this point, the settling basin will be removed and a new basin established at the next cell.

## 3.3 PORT FACILITIES

Port facilities suitable for accommodation of coal colliers are not available at the Old Harbour Station. To accommodate the 20,000 dwt coal colliers, new docking facilities and a new dredged channel will be required. A 600-foot-wide by 9000-foot-long approach channel will be dredged to a depth of 30 feet along with a 1500-foot-diameter turning basin. The docking facilities will consist of a 275-foot approach from the shore to the unloading dock. The approach will provide road access and conveyor support. The dock facility will consist of an unloading dock, breasting dolphins, and turning dolphins as required for ship docking and unloading. The docking arrangement and approach channel is shown on Figure 3-3. In the future the channel would be dredged to a depth of 38 feet to accommodate 30,000 dwt colliers.

## 3.4 STRUCTURAL

### 3.4.1 Foundation

The foundation design used in the Phase I study was based on the existing subsurface information provided to Bechtel for Unit 4 of the Old Harbour Station. This information was provided by General Electric and shown on Drawing 7821-71F.

Subsequent to the Phase I study, Bechtel performed three additional borings in the area of the proposed site as shown on the site plan. The data from the new borings confirmed that the foundation used for the Phase I study is still acceptable. A summary of the boring data and foundation design follows.

The soil consists of an upper layer of gray-brown silty sand over a soft and compressible dark gray silty sand. This is followed by a layer of brown silty clay at elevation -25.0 feet. All of these soils have a low blow count, indicating that a deep foundation for all major equipment will be required.

The deep foundation, which has been assumed for all major structures, shall consist of a Raymond step-tapered concrete-filled pile driven into the lower silty clay at elevation -35 to -50 feet. An average pile depth of 50 feet and an allowable capacity of 50 tons (45 metric tons) per pile has been assumed. Actual pile length and capacity will be confirmed by additional subsurface exploration and pile load test.

For shallow foundations, an allowable bearing capacity of 1500 pounds per square foot (.73 kilograms per square centimeter) has been assumed. Due to the compressible soil underlying the site, settlement (even with this relatively light loading) is expected to be in the range of several inches. Therefore, only settlement-tolerant structures should be placed on shallow foundations.

### 3.4.2 Structures

Conceptual design of the structures for this facility was done using American Institute of Steel Construction, American Concrete Institute, and Uniform Building Code requirements. A wind speed of 130 miles per hour (209 kilometers per hour) with gusts of 175 miles per hour (282 kilometers per hour) was assumed for these coastal facilities, and Zone 3 of the Uniform Building Code was assumed for seismic design.

The boiler support will be structural steel braced frames resting on concrete piers and piles. The lateral loads will be transmitted through the bracing system to the foundations. This structure will be open, except for the upper portion at the steam drum area. The tripper room above the coal bunkers will be enclosed to prevent the escape of fugitive coal dust. Coal bunkers will consist of carbon steel plate reinforced with external stiffeners. A stainless steel liner will be provided in the hopper area of the coal bunkers.

All major auxiliary boiler equipment, such as the pulverizer, forced draft fans, and induced-draft fans will be located at grade level. This equipment will be supported by concrete foundations supported on piles.

A common personnel/freight elevator, located between the two coal-fired boilers, will be provided.

The ductwork and breeching will be constructed of carbon steel plate reinforced with external stiffeners. Insulation and lagging will be provided for ducts and breechings with temperatures of more than 140 F (60 C). The ductwork and breeching will be supported by steel frames resting on concrete piers. The precipitator will be supported by a structural steel frame resting on concrete piers and piles. The precipitator will be fixed at selected locations with sliding support as required at the other locations. Platforms and stairs will be provided for access to the operating level. The induced draft fans and motors will be resting on a concrete pedestal and mat that are supported on piles. Monorails and maintenance platforms will be provided for removal of equipment and for maintenance.

The coal conveyors will be supported by steel trusswork spanning approximately 100 feet (30.5 meters). The trusswork will be supported by towers resting on concrete piers and piles. The transfer towers will be of structural steel frames supported on concrete and piles.

A common stack will be constructed of reinforced concrete with a separate steel liner for each unit. The stack height will be approximately 450 feet (137 meters).

The control building will consist of a two-story structure approximately 50 feet by 75 feet. The structure will be of a structural steel frame and siding resting on a concrete and piling foundation.

## 3.5 COAL HANDLING SYSTEM

Coal for the Old Harbour Station will be unloaded from ships and stacked out on storage piles for reclaim and crushing as needed to supply the power plant day bunkers.

### 3.5.1 Coal Unloading and Stackout

Figure 3-4 shows the coal flow diagram for Old Harbour Station. Figure 3-1 shows the coal handling system general arrangement for Old Harbour Station.

A new dock will be constructed to accommodate the ship unloading. An unloader, with an average unloading rate of 600 tons (550 metric tons) per hour, will unload coal from colliers. All other components of the unloading/stackout system are rated for 900 tons (820 metric tons) per hour. The belt conveyors of this system are 30 inches wide and run at 500 feet per minute. The unloader discharges to an 18-metric-ton-capacity surge bin. From the surge bin the coal is carried by a 350-foot-long conveyor, which is equipped with a self-cleaning magnetic separator, to a sampling/stacker tower where it is discharged to a 90-foot-long radial stacker. The conveyor is equipped with a belt scale to weigh the coal received. At the discharge of this belt, a two-stage sampling system collects the as-received coal sample. When the magnetic separator indicates the presence of tramp iron or nonferrous metals, it diverts the rejected material to a rejects bin. Coal from this belt is transferred by a linear motorized stacker with slewing and luffing motions through a 90-foot-long boom to form a kidney-shaped active storage pile of an approximate 25,000-metric-ton capacity sufficient to store the coal from a 20,000-metric-ton collier. This coal would be moved by mobile equipment to the dead storage pile.

### 3.5.2 Coal Reclaim

The coal reclaim system is designed to operate at a maximum of 250 tons (230 metric tons) per hour. Conveyor belts in this system are 24 inches wide and run at 500 feet per minute. Beneath the active storage pile is a reclaim hopper in a linear tunnel which has one "uncoaler" pile activator and reclaim feeder, rated at 230 metric tons per hour. The feeder discharge onto a 250-foot-long conveyor which is equipped with a belt scale to measure the coal for the burn rate and a magnetic separator. This conveyor discharges in the crusher tower into a surge bin. For normal service the coal falls into a 9-metric-ton crusher surge bin and is withdrawn by one vibrating screen which feeds coal larger than 1-1/4 inches to the coal crusher. The coal is reduced to 1-1/4 by 0 inches by the crusher and drops, along with the undersized coal from the vibrating screen, to the plant transfer conveyor. When required, the coal crusher can be bypassed and the coal will fall to the transfer conveyor. The transfer conveyor, a 210-foot-long conveyor with a metal detector, discharges the coal into the vertical silo transfer conveyor. The silo transfer conveyor is an en masse type conveyor located on the south side of Unit 4 coal silo bay. The coal is transferred to the horizontal silo feed conveyor, an en masse type conveyor with eight discharge points, one for each of the boiler coal silos.

Throughout the coal handling system, dust suppression and collection systems are installed where appropriate to control fugitive dust. All conveyors will be covered. Fire protection will be provided for all conveyor belts and coal handling facilities.

## 3.6 BOILER, BOILER DRAFT, AND FLUE GAS SYSTEMS

### 3.6.1 Boiler

To replace the existing oil-fired boilers, two boilers have been selected that are designed to fire bituminous coal and No. 6 fuel oil. The boilers for Units 3 and 4 are each rated at 610,000 pounds per hour (277,000 kilograms per hour), 1300 psig (91.4 kilograms per square centimeter) operating pressure, and 950 F (510 C) steam temperature.

Selection of a typical coal was necessary for sizing equipment. Basic boiler data are presented in Table 3-1. A conceptual boiler outline and equipment arrangement are shown on Figure 3-5.

### 3.6.2 Coal Mills

Four pulverizers, including one as a spare, each rated at 26,000 pounds per hour (11,800 kilograms per hour), will be provided for each boiler. The crushed coal taken from the silos will be fed by the gravimetric feeders at a controlled rate. The hot primary air, which will dry the coal as it is being pulverized and transport it from the grinding chamber through the classifiers, will be supplied from the Ljungstrom air pre-heater, which will also furnish the secondary air for combustion.

### 3.6.3 No. 6 Oil System

Each of the new boilers will be equipped with No. 6 oil burners, fuel heaters, and fuel pumps to achieve full boiler rating while firing No. 6 oil alone. The existing No. 6 oil storage tanks and supply system will be extended to furnish the demand from the new boilers.

### 3.6.4 Oil Ignitors

Oil ignitors using No. 2 fuel oil will be provided for each boiler for initial firing as the boiler is brought up to pressure and temperature and for ignition and flame stablization. The existing No. 2 fuel oil ignition system will be extended to serve the two new boilers, with the existing ignitor oil pumps and storage tanks used for the demand from the new boilers.

3.6.5 Fans

Two 50-percent-capacity forced-draft (FD) fans and two 50-percent-capacity induced-draft (ID) fans will be furnished for each balance draft boiler. The fans will be double inlet, damper controlled, and will be driven by constant speed induction motors. Each pulverizer will be provided with a primary air (PA) fan.

Combustion air will be drawn from the FD fan inlet silencers and will flow through the steam coil air heater and the Ljungstrom air preheater to the furnace windbox. Tempering air for the coal mill system is taken from the FD fan discharge prior to its entering the steam coil air heater, and hot primary air will be taken after the air preheater and mixed prior to entering the PA fan. The ID fan draws the combustion gases from the furnace, through the air prehater and the electrostatic precipitator, and discharges them to the stack thereby maintaining the entire flue gas stream under a negative pressure.

3.6.6 Electrostatic Precipitator

One cold side, rigid frame type precipitator will be provided for each boiler to remove fly ash particulates from the flue gas. It will be located between the air preheater and the induced draft fan. Selection of this type of precipitator was based on the criteria that particulate emissions should not exceed 0.03 pound per million Btu (0.0129 g/$10^6$ joules) of boiler heat input. A cold side, rigid frame precipitator capable of meeting the particulate emission requirements and capable of accommodating both low sulfur and high sulfur coal, constitutes a cost effective and reliable application. Total particulate emissions prior to electrostatic precipitator treatment was calculated assuming:

- The coal and ash analysis used for conceptual design.
- A total of 85 percent of the coal ash as fly ash enters the electrostatic precipitator.

This requires an electrostatic precipitator with a design efficiency of 99.7 percent.

Table 3-2 summarizes the design parameters for the precipitators.

3.6.7 Stack

One stack was selected, with one flue for each new coal-fired boilers. Stack height is 450 feet (137 meters), based on guidelines equivalent to those of the U.S. Environmental Protection Agency. Liner diameters are 8 feet (2.4 meters) at the top, based on a maximum exit velocity of 93 feet per second (28 meters per second) at the full load gas flow.

## 3.7 ASH HANDLING SYSTEM

The ash handling system will collect and handle all ash collected in the bottom ash hoppers, economizer ash hoppers, air preheater hoppers, and precipitator hoppers for each of the two new boilers, for ultimate off-site disposal.

Figure 3-6 shows the preliminary bottom ash handling system flow diagram and Figure 3-7 shows the preliminary fly ash handling system flow diagram.

Ash collected in the system will be disposed of offsite in a landfill. Ash can also be used as an additive in cement processing. Details of the potential use of ash are discussed in Appendix B of the Phase I study.

### 3.7.1 Bottom Ash Handling System

The bottom ash handling system is a mechanical drag chain ash removal system for both bottom and economizer ash evacuation. The system originates at the bottom ash and economizer ash hoppers and extends to the storage facilities.

Ash is collected in the bottom ash hopper located beneath the boiler and in the hoppers located beneath the economizer. The bottom ash hopper is lined with water-cooled refractory and furnished with a seal system to provide a pressure seal between the furnace bottom and the ash hopper. Bottom ash discharges by gravity through isolation gates into a submerged drag chain conveyor. Economizer ash is removed by rotary feeders then discharges by gravity through ash downspouts into the submerged portion of the submerged drag chain conveyor. Isolation gates are provided upstream of the rotary feeders in order to perform on-line maintenance. The inclined portion of the drag chain conveyor is long enough to transport the total ash (bottom and economizer) into the bottom ash storage enclosure. The bottom ash handling system operates continuously. The bottom ash hopper receives the ash from the furnace throat and discharges this ash by gravity into the submerged drag chain conveyor. The bottom ash hopper is provided with four outlets, each with an isolation gate. This allows the boiler to be operated while maintenance is performed on the drag chain conveyor. Quench sprays are located at the top of each hopper to cool the ash collected in the isolation hoppers. Breaker bars are provided above the sloped portion of the hopper to minimize maintenance of the refractory due to possible ash clinkers falling from the boiler superheater section. The bottom ash hopper also incorporates a stainless steel seal trough to provide a water seal between the furnace bottom and the bottom ash hopper. Economizer ash discharges by gravity through the economizer downspouts into the horizontal section of the submerged drag chain conveyor. The vacuum seal between the economizer ash hoppers and the ambient air is maintained by means of rotary seal feeders located beneath the isolation gates. The ash discharged from the drag chain dewatering section will be collected in an enclosed pit and can be removed by mobile equipment and loaded into trucks for offsite disposal.

### 3.7.2 Fly Ash Handling System

The dry fly ash is collected in a total of eight hoppers for each precipitator and two hoppers at the air preheater. The stored ash is periodically evacuated pneumatically to the fly ash silo; it is periodically removed from the silo, wetted to reduce dust, and transported by truck for offsite disposal.

A vacuum-type pneumatic fly ash system is provided as pneumatic conveyor. An 8-inch, disc type, cylinder-operated material intake is provided for each precipitator and air preheater hopper. When the material intake is opened, collected fly ash is dropped by gravity into the vacuum line The flow of ash is aided by the automatic operation of the precipitator hopper vibrators.

A knife gate is located at the end of each row of intakes to provide isolation of that branch when intakes are in the closed position. Fly ash is conveyed to the 10-inch vacuum line from one intake at a time. At the top of the silo and prior to entering the continuous separators, crossover connections with associated knife gates are provided to add flexibility to the system when on-line maintenance is required.

Fly ash is collected from the continuous separators and bag filters and is stored in the fly ash silo. One 25-foot (7.6-meter) diameter, cylindrical fly ash silo of steel plate construction with a storage height of 55 feet (16.8 meters) is provided. It has a storage capacity of 545 metric tons or 72 hours and an overall height of 70 feet (21 meters). The continuous separators, bag filters, and vent filter with its motorized shaker are located in the cylindrical enclosure positioned on top of the silo. The 25-foot-square (9.1-meter-square) unloader equipment room is located directly below the silo. It houses the rotary ash unloaders, fly ash aeration blowers, and fluidizer air heater. An open area for unloading the fly ash into trucks for offsite disposal is provided beneath the unloader equipment room.

The silo floor is provided with two discharge hoppers and fluidizing boxes containing porous blocks. Fluidizing air is piped to the fluidizing boxes in order to move the fly ash to the two discharge hoppers. Under each silo discharge hopper is a cutoff gate, expansion joint, air slide feeder with metering gate, and rotary ash unloader.

One two-stage, cyclone-type, continuous separator will be provided for each unit with a common fly ash silo for the two boilers. Each separator continuously separates transported ash from the conveying air and collects it in the primary and secondary sections of the separator. A cam timer controls an automatic sequence of discharging ash from primary and seconary chambers, through gates, into a lower chamber, and then into the silo.

Self-cleaning, completely automatic, one-stage bag filters are provided in order to obtain 99.9 percent separation of fly ash from the conveying air stream to the atmosphere prior to its discharge, to reduce fugitive dust emission on the site. Each bag filter is provided with the necessary compressed air supply valves, timers, access door, and temperature controller. An automatic air inlet valve allows outside air to enter the filter for cooling if a high temperature is experienced in the bag filter. The bags used are designed for a maximum temperature of 425 F.

## 3.8 MAIN STEAM, FEEDWATER, AND TURBINE GENERATOR SYSTEMS

The existing main steam and feedwater systems will be modified to accommodate the two new coal-fired boilers. Stop and nonreturn valves will be provided at tie-in points to allow the existing boilers to serve as standby boilers. All tie-ins between the existing and new facilities will be made during scheduled maintenance outages of the existing units.

### 3.8.1 Main Steam System

New critical piping will be provided to receive steam from the new coal-fired boilers and to deliver it to each of the existing turbines at a maximum rate of approximately 610,000 pounds per hour (277,000 kilograms per hour) superheated steam.

ASTM A 335, Grade P-12 pipe is used for the main steam lines. An expansion loop will be provided for each unit to absorb the thermal movements. Stop valves required for the system, per the ASME Section 1 Code, will be installed.

### 3.8.2 Feedwater System

Each of the existing boiler feed systems for Units 3 and 4 consists of two boiler feed pumps, and three high pressure heaters. The two 50-percent-capacity boiler feed pumps take suction from the low pressure heater discharge and discharge through the high pressure heaters to the existing boiler economizer.

The new boiler feed systems for the new coal-fired boilers will be tied in on the existing feedwater piping downstream of the high pressure heaters. This will keep the high pressure heaters in service and will allow the feedwater to be preheated by the extraction steam, thereby maintaining the unit efficiency after the conversion.

An attemperation system for each boiler will be provided for the superheated steam temperature control.

Our investigation revealed that the existing boiler feedwater pumps are adequate to supply feedwater to the new coal-fired boilers at the locations shown on Figure 3-8. Byron Jackson, the manufacturer of the existing feedwater pumps for Units 3 and 4, has been contacted. The existing impellers are within 1/16-inch of the maximum size impeller that could be used in these pumps.

The conceptual piping diagram for the combined main steam and feedwater systems is shown on Figure 3-8. The main steam and feedwater systems flow diagram is shown on Figure 3-9.

### 3.8.3 Turbine Generator System

As stated in the previous section, the new boilers will parallel the existing boilers and thereby utilize the existing turbine generators, turbine cycle equipment, and ancillaries. As part of the actual coal conversion project, an allowance of funds has been provided for improving the availability of the existing equipment. Meetings are being held between JPS and General Electric, the manufacturer, in order to:

- Resolve some existing operating problems
- Upgrade instrumentation and provide additional monitoring systems
- Review and modify, where necessary, plant operating and maintenance procedures
- Establish an updated maintenance schedule which may be computerized
- Determine if additional on-site operating and maintenance training are necessary.

### 3.8.4 Closed Cooling Water System

Each boiler will have its individual closed cooling water system separate from the existing unit. The demand by the new boilers exceeds that of the existing system due to the need to cool the FD and ID fans, air preheater, and pulverizing equipment for each new boiler versus the FD fans and air preheater for the existing units. The closed cooling water flow diagram is shown in Figure 3-10.

## 3.9 ELECTRICAL

### 3.9.1 General

The electric power system for each of the new boilers is designed to provide operating flexibility and reliability to ensure continuous operation. The electrical systems are derived from the existing high voltage switchyards to provide a unitized electric power supply for each coal boiler unit. The system can tolerate the loss of a single auxiliary power transformer with no interruption in service. The single-line diagram is shown on Figure 3-11.

### 3.9.2 High Voltage System

A tap from existing line positions is made at the switchyard and connected to the supply side of two new circuit switchers. The load side of these switchers is connected to pot head structures and then to XLPE insulated transmission cables routed underground in duct banks to other pot head structures connected to the line side of the two power step down transformers. These transformers provide 2400 V on the load side and are sized so that either transformer could provide the total power requirements for both coal boilers. This provides for uninterrupted boiler operation in the event of the loss of a single transformer. The power transformers are located in close proximity to the control building where the switchgear is located. The secondary winding of each transformer is connected to its respective medium voltage bus by cables in underground concrete encased duct bank.

Each transformer is provided with a high side load tap changer to ensure good voltage regulation for all operating conditions.

The secondary of each power transformer is grounded through a neutral grounding resistor to limit the fault current in the case of line-to-ground faults.

### 3.9.3 Medium Voltage System

Each boiler unit is provided with a lineup of indoor, metal-clad switchgear which operates at 2400 V. The two switchgear lineups are intertied and designed for fast bus transfer to the adjacent bus when the normal power supply is interrupted. The tie breakers are electrically interlocked to prevent unintentional paralleling of the power transformers. This eliminates the need for current limiting reactors in the bus tie circuits.

The 2400 V switchgear provides power to motors that are 250 horsepower and larger and to the 480 V load center unit substations for distribution to the low voltage equipment. Each 2400 V load is connected to the bus by drawout, stored energy circuit breakers. The circuit breaker cubicles are complete with protective relays, control and test switches, and indicating devices. The switchgear control circuits are rated at 125 V dc.

The remote coal handling loads are supplied by 2400 V feeder cables routed in conduit along the coal conveyors. The 480 V load center unit substations are located in the crusher building and the bulldozer shed.

### 3.9.4 Low Voltage System

The 480 V system provides power for all motor loads less than 250 horsepower and feeds the 120 V system. Load center unit substations are housed in factory-built indoor enclosures and transform the 2400 V supply to 480 V for distribution to motor control centers (MCCs) and the large 460 V motors. Motors between 50 and 250 horspower (exclusive) are powered directly from the load centers, and motors 50 horsepower and smaller are powered from the MCCs. The load centers close to the plant use 125 V dc control circuits. The load centers for the remote coal handling areas use 120 V ac control circuits. The load centers' branch circuits are protected and controlled by low voltage circuit breakers that use solid-state trip devices. The MCC motors are protected and controlled by molded case, circuit breaker type combination starters.

### 3.9.5 125 V dc System

A separate 125 V dc battery system is provided for each boiler addition. This system provides power for circuit breaker operation, annunciators, and selected emergency controls.

### 3.9.6 120 V Vital ac System

A separate inverter is provided for each unit. The inverter is powered from the station battery and supplies ac loads that are critical to the safe and orderly shutdown of the unit upon loss of normal ac power.

The combustion controls, burner management system, process recorders, and other uninterruptible ac loads are powered by this system.

## 3.10 CONTROL AND INSTRUMENTATION

The control building will be located adjacent to the west side of the boilers. A central control room located on the upper floor of the control building will contain the main control consoles and vertical control boards for the two units and appropriate auxiliaries.

The control consoles will be segregated by unit and will contain the boiler flame safety system, pulverizer controls, boiler controls, steam turbine and generator controls, and other controls as needed to provide the operator with the information and equipment necessary to operate the units.

The vertical control boards located in front of the control consoles will contain the opacity monitor recorders, soot blower control panels, fly ash and bottom ash control panels, recorders for historical data, miscellaneous indicators, and annunciators.

The instruments to be supplied for the new boilers will be electronic. To reduce control lag and improve control response, instrument interface with existing pneumatic equipment will utilize electronic transducers.

The local precipitator controls will be duplicated in the main control room. The precipitators will be operable from either location.

Logic cabinets associated with the various systems will be located in the cable spreading room on the ground floor directly beneath the main control room.

The main control room, cable spreading room, and equipment room in the control building will be air conditioned.

Remote controls that are necessary to operate the steam turbine generator set and auxiliaries from the new control room are listed in Table 3-3.

## 3.11 ENVIRONMENTAL IMPACT

(Refer to Appendix A for more complete analysis.)

### 3.11.1 Air Quality Impact Assessment

An air quality impact assessment has been performed for the Old Harbour Plant coal conversion project. Pollutant ground level concentrations from operation of the plant (before and after coal conversion) were calculated using the U.S. EPA approved Industrial Source Complex (ISC) air quality model. Based on the results of the study, there is an improvement in the local air quality associated with the proposed coal conversion. The maximum combined impact of the new units and the existing Units 1 and 2, together with the background pollutant concentrations, represents the total maximum pollutant ground level concentration in the Old Harbour Bay region after coal conversion. Comparisons of this total concentration and the U.S. NAAQS for each pollutant ($SO_2$, TSP, $NO_x$) is shown in Tables 3-4 and 3-5. All calculated pollutant ground level concentrations meet the U.S. NAAQS except the 24-hour average concentration for $SO_2$. However, this value, 382 $\mu g/m^3$ (24-hour), represents a 35 percent reduction in $SO_2$ levels through the replacement of Units 3 and 4 with the new coal-fired units. By limiting the sulfur in the coal to a maximum of 1.88 percent, the U.S. NAAQS 24-hour average ground level concentration of 365 $\mu g/m^3$ will be met. The current operation of oil Units 1 to 4 results in an average concentration of 592 $\mu g/m^3$. This replacement also results in TSP and $NO_x$ total ground level concentrations which do not exceed their applicable U.S. NAAQS and are also representative of improvement in the local air quality.

### 3.11.2 Ash Disposal Site Evaluation

Coal conversion of the Old Harbour Station will result in increased production of ash. Although sale for reuse is the preferred method of ash disposal, until firm arrangements can be made for the sale of ash, landfilling appears to be the most feasible disposal method. The method of transport to the landfill is assumed to be by truck.

The purpose of this study was to identify and evaluate potential ash disposal sites. The site areas were sized to accommodate an annual ash disposal rate of 41,000 metric tons (two 68.5 MWe units) over a unit life of 22 years.

The ash disposal site selection methodology is as described in Appendix A. Based upon this evaluation technique, the three best disposal sites are at Kelleys Pen (Site 1), Palmyra (Site 9), and Occasion Town (Site 3). These sites are highlighted on Figure 3-12.

### 3.11.3 Wastewater Discharge Impact Assessment

The quality and quantity of untreated and treated coal pile runoff were estimated. No other incremental wastewater sources will be associated with coal conversion. Qualitative assessment of the potential incremental aquatic impacts due to coal pile runoff discharge has been evaluated. The analysis shows that the incremental impacts on receiving waters will be minimal outside a limited mixing zone.

### 3.11.4 Port Dredging Impacts

The purpose of this study was to examine the physical and environmental aspects of dredging activities related to potential coal deliveries at Old Harbour, Jamaica. The subject dredging activities at Old Harbour could be carried out in connection with the potential conversion of the steam electric facilities at Old Harbour from oil fuel to coal. The Traverse Group, Inc. (TGI) has examined the dredging impacts under subcontract to Bechtel. Delivery of coal would require dredging of an approach channel and a turning basin at the plant site. Disposal of the initial and maintenance dredge spoil would be required.

This study addressed two major objectives:

a. An initial assessment of the environmental and physical factors that might be associated with the dredging.

b. An identification of alternatives for disposal of the spoil materials.

TGI has identified five alternatives after meeting with various groups in Jamaica and analyzing the site characteristics:

a. Open water disposal.

b. Placement on and/or storage near the Old Harbour public beach, which is badly eroding.

c. Creation of a diked area in the Old Harbour Bay and use of the impounded water for commercial shrimp culture.

d. Disposal on the "land spit" to the southwest of the plant site.

e. Creation of an artificial island that could be used as a wetland wildlife area, with embayment.

TGI recommends a combination of options b and e. The TGI report on port dredging impacts is in Appendix A.

## 3.12 LIST OF MAJOR EQUIPMENT FOR OLD HARBOUR STATION

The following quantities represent a total for two boilers.

| Quantity | Item | Description |
|---|---|---|
| **3.12.1 Steam Generators** | | |
| 2 | Boilers, including: steam drums, water walls, furnaces, superheaters and desuperheaters, economizers, regenerative air heaters, steam air heaters, coal burners, No. 6 oil burners, oil ignitors, steam soot blowing systems, flame monitoring systems, burner controls, steam temperature controls, furnace temperature probes, ductwork, boiler trims, settings, insulation, lagging, and structural steel | Pulverized coal-fired Units 3 and 4 rated at 610,000 pounds/hour (277,000 kg/hour) superheated steam @ 1300 psig, 950 F (91.4 kg/$cm^2$, 510 C) |
| 8 | Coal pulverizers, primary air fans, coal feeders, coal piping, coal valves, and expansion joints | 26,000 pounds/hour (11,800 kg/hour) grinding capacity |
| 8 | Coal bunkers | 24-hour storage capacity |
| 2 | Electrostatic precipitators, including: hoppers and hopper heaters, inlet and outlet nozzles, prewired equipment room with ventilation and air conditioning, and structural steel | |
| 4 | Forced-draft fans, 50 percent capacity, including motors | 100,000 acfm (2,800 $m^3$/minute) |
| 4 | Induced-draft fans, 50 percent capacity, including motors | 155,000 acfm (4,400 $m^3$/min) |
| **3.12.2 Coal Handling System** | | |
| 1 | Ship unloader | 600 tph (550 mtph) average unloading rate |
| 1 | Receiving bin | 20 tons (18 metric tons) |
| 1 | Unloading feeder | 900 tph (820 mtph) |

| Quantity | Item | Description |
|---|---|---|
| 1 | Unloading belt conveyor with belt scale and magnetic separator | 350 ft, 900 tph |
| 1 | Two-stage sampling system | |
| 1 | Radial stacker with telescopic chute | 900 tph |
| 1 | Reclaim pile discharger | |
| 1 | Reclaim feeder | 250 tph (230 mtph) |
| 1 | Reclaim belt conveyor with belt scale and magnetic separator | 250 ft, 250 tph |
| 1 | Crusher surge bin | 10 tons (9 metric tons) |
| 1 | Vibrating screen | 250 tph (230 mtph) |
| 1 | Coal crusher | 250 tph (230 mtph) |
| 1 | Plant transfer belt conveyor with metal detector | 210 ft, 250 tph |
| 1 | Silo transfer Redler conveyor | 130 ft, 250 tph |
| 1 | Silo feed Redler conveyor with motor-operated slide gates | 200 ft, 250 tph |
| 2 | Dust collection systems | |
| 1 | Dust suppression system | |
| 1 lot | Structural steel | |

3.12.3 Fly Ash and Bottom Ash Handling System

| | | |
|---|---|---|
| 1 | Fly ash silo, including two unloaders/conditioners, primary and secondary ash collectors, silo vent filters, aeration blowers, and heaters | Approximately 25 feet (7.6 meters) in diameter x 70 feet (21 meters) high |
| 3 | Mechanical vacuum pumps (one standby), including discharge silencers | 200 hp each |
| 1 Lot | Fly ash intakes, economizer ash intakes, piping and valves, and control panels | |

| Quantity | Item | Description |
|---|---|---|
| 4 | Sump pumps | |
| 2 | Submerged drag chain conveyors with dry bottom ash hoppers and gates | 7.5 hp each |
| 4 | Heat exchangers | |

3.12.4 Fire Protection System

| Quantity | Item | Description |
|---|---|---|
| 1 Lot | Hydrants and hose connections | 2-1/2 inches for yard hydrants, 1-1/2 inches for risers |
| 1 Lot | Sprinkler system, including silo gallery | |
| 1 Lot | Piping and valves | |
| 1 Lot | $CO_2$ blanket system and portable fire extinguishers | |

3.12.5 No. 6 Fuel Oil and Ignitor Oil Systems

| Quantity | Item | Description |
|---|---|---|
| 4 | Burner fuel pumps | |
| 4 | Burner fuel heaters | |
| 1 Lot | Piping and valves | |

3.12.6 Closed Cooling System and Service Water System

| Quantity | Item | Description |
|---|---|---|
| 8 | Pumps | |
| 4 | Heat exchangers | |
| 1 Lot | Piping and valves | |

3.12.7 Service Air and Instrument Air System

| Quantity | Item | Description |
|---|---|---|
| 1 Lot | Piping and valves | |

3.12.8 Boiler Drains and Blowdown System

| Quantity | Item | Description |
|---|---|---|
| 1 Lot | Piping and valves | |
| 2 | Blowdown tanks | Approximately 6 feet (1.83 meters) in diameter x 10 feet (3 meters) high |

| Quantity | Item | Description |
|---|---|---|
| 3.12.9 Main Steam, Feedwater and Attemperation Systems | | |
| 1 Lot | Piping and valves | |
| 3.12.10 HVAC | | |
| 1 Lot | Ventilation and air conditioning equipment for control building | |
| 3.12.11 Electrical Equipment | | |
| 2 | 138 kV circuit-switcher | 1200 A, transformer switching and fault interrupting |
| 2 | Auxiliary power transformers | 138 kV-2.4 kV, 10/12.5, OA/FA, 55 C, ±10 percent load tap changer |
| 2 | Metal-clad switchgears | 2.4 kV, 250 mVA, indoor enclosure<br>Unit 3 - 3000 A bus<br>1-2000 A breaker<br>1-3000 A breaker<br>11-1200 A breakers<br>Unit 4 - 3000 A bus<br>1-3000 A breaker<br>11-1200 A breakers |
| 2 | 138 kV feeders | XLP insulated transmission cables in underground duct banks |
| 2 | Main 2.4 kV feeders | 4-1750 mcm, 5kV cables per phase in underground duct banks |
| 2 | 2.4 kV bus ties | 3-1750 mcm, 5 kV cables per phase in trays |
| 4 | Single-ended load centers | 2.4 kV-480 V, 1000 kVA |
| 2 | Disconnect switches | 2.4 kV, 600 A, located at remote 2.4 kV loads |

| Quantity | Item | Description |
|---|---|---|
| 1 Lot | Medium voltage 5 kV cable (does not include main feeders and bus tie) | 2/0 AWG - 2000 feet (610 meters) (3 phase length) 4/0 - 13,000 feet (4000 meters) |
| 2 | 125 V dc batteries | 860 Ah |
| 2 | Uninterruptible power supplies (inverter) | 15 kVA |
| 2 | Battery chargers | 150 A |
| 1 Lot | Grounding system | |
| 1 Lot | Lighting system | |
| 1 Lot | Communication system | |
| 1 Lot | Raceway system | |
| 1 Lot | 480 V MCCs | |
| 1 Lot | 120 V system | |

## 3.13 CAPITAL COSTS

### 3.13.1 Introduction

The cost and schedule information contained herein is intended to provide capital costs for use in economically assessing the conversion of two of Jamaica's major oil-fired facilities to coal firing at Old Harbour.

This study assumes that the new coal-fired boilers will use the existing facilities to the maximum extent possible. The main steam and feedwater lines associated with the coal-fired boilers will be connected to the existing piping. Likewise, all compressed air and service water will also be drawn from the existing plant. However, a complete new closed cooling water system is required.

Capital costs are shown on Tables 3-6 and 3-7. Table 3-6 displays the summary level costs for the Old Harbour site in U.S. dollars. Table 3-7 displays costs that are anticipated to be payable in Jamaican dollars ($J). The balance which represents foreign dollars is shown in U.S. dollars. Allowances for contingency and escalation are included to yield total project costs for the steam generating facilities. The detailed breakdown of construction/engineering costs by major facilities includes the material, freight, labor, subcontracts, and architect/engineering services.

3.13.2 Development of Capital Costs

Firm, fixed bids were solicited for the boilers, precipitators, coal handling system, and the ship unloader. Erection and freight were priced separately. Additional cost information was provided for the performance bonds, spares, and training. In all cases, costs payable in Jamaican dollars ($J) were identified. The balance was in U.S. dollars ($U.S.).

Capital costs for the balance of plant have been developed by using historical information, standards, and various other parametric estimating techniques. Bechtel recently completed the construction of a coal conversion project located in the Caribbean. The reference project is similar in many respects to the concepts, design, and implementation being considered in this study. A pulverized coal-fired boiler has been constructed to replace the existing oil-fired facility. Much of the existing systems and related equipment is being used by the new boiler, which is also similar to the Jamaica concept. The boilers as well as the critical pipe systems are of similar size and rating. These and other similarities, coupled with the very recent nature of the job, make the reference project an excellent source for comparative pricing.

By comparing the scope and costs for the reference project to the scope of the proposed Jamaica project, appropriate adjustments and modifications were made to account for differences between the two projects. Most of the data for total project cost were developed using modified reference plant costs. For items not comparable with the reference plant scope, pricing from other sources was utilized. Significant items for which the cost was derived from other sources include the dock facilities and the stack.

However, it should be emphasized that approximately 41 percent of the project cost is covered by firm prices based on international competitive bidding.

The following subsections describe the primary components included with each of the major categories shown on Tables 3-6 and 3-7.

3.13.2.1 Dock Facilities

Provision is made to unload coal from ships. Complete construction cost for the dock and a ship unloader is included in this account. Cost for the ship unloader is based on recent vendor information.

3.13.2.2 Site Preparation and Substructures

Included in this category are costs for site preparation, building foundations including piling, general services, and miscellaneous painting. The control building, bulldozer shed, field office, and warehouse are also included along with an allowance for roads, parking, and laydown area preparation. Construction cost for preparation of the first ash disposal cell, an on-site access road, and land acquisition cost have been added. Other service contracts such as soil boring, surveying, and material testing are also included.

3.13.2.3 Onsite Coal Receiving and Handling

Costs are based on vendor information. Costs include all conveyors, bins and chutes, scales, magnetic separators, dust control system, sampling system, towers, a crusher, a stacker, support and miscellaneous steel, instrumentation, and fire protection. In addition, costs are included for all internal and external electrical work including lighting and communication sytems up to an interface point in the vicinity of the coal handling area. Estimated allowances have been made for related foundations in substructure category.

3.13.2.4 Building Superstructures

Included in this account are allowances for building structural and miscellaneous steel, stairways, walkways, and related items in the pulverizer bay area. The cost for a single elevator is also included.

3.13.2.5 Boilers

Vendor supported pricing is used for two 610,000 pound per hour boilers. Included are complete material and labor costs for all pressure and nonpressure parts, complete control systems, structural and miscellaneous steel, air heaters, burner and controls, coal feeders and pulverizers, ductwork, forced draft and induced draft fans, primary air fans, insulation and lagging, and associated trim. In addition, all motors, related control equipment, medium and low voltage distribution equipment, dc battery system, and lighting and communication systems are part of the boiler bid package.

3.13.2.6 Precipitators

Vendor supported pricing has been included for supply and erection of one electrostatic precipitator per boiler. Costs include casing, rapping system, electrodes, transformer/rectifier sets, inlet and outlet nozzles, hoppers with heaters, ductwork, support steel, a control room, and insulation. A complete electrical power and control system is also provided.

3.13.2.7 Stacks

A 450-foot-high concrete stack with an individual steel liner for each boiler is included. Costs include allowances for lighting, access ladders, and platforms.

3.13.2.8 Fly Ash Handling

An allowance has been made for a pneumatic-type fly ash handling system. All associated piping, valves, specialty items, and controls are included along with mechanical vacuum pumps. A single fly ash storage silo with associated unloaders is included.

3.13.2.9 Piping and Mechanical

Major piping systems included are the critical main steam and feedwater systems connecting the new steam generators with the existing main steam and feedwater lines including all necessary isolation valving. Other piping tie-ins include the service and instrument air systems. A fully equipped closed cooling water system and complete bottom ash handling system which uses a drag chain conveyor are included. A complete boiler drains and blowdown system with blowdown tanks is also included. A yard fire loop is included along with all appropriate in-plant fire protection systems. A ventilation and air conditioning system is included for the control facility and the cable spreading room. Hoists, component coolant water heat exchangers, miscellaneous pumps and tanks, chemical feed systems, and hot standby capabilities for the existing oil-fired boilers are also in this category.

3.13.2.10 Electrical and Instrumentation

This category includes all required instrumentation and electrical equipment over and above that provided in the bid packages.

Major electrical equipment contained in this category includes the 138 kV step-down transformers and load centers. Lighting, communications, equipment grounding, and distribution panels are also in this category for the balance of plant. Electrical bulk items such as wire and cable, conduit, and tray for these portions of the electrical system are also included. Allowances are included for field-mounted instruments, water analysis, stack gas monitoring, and control valves.

3.13.3 Assumptions and Qualifications

All cost and schedule information was prepared based on the following assumptions and qualifications:

- Escalation, calculated at 6.5 percent per year to the center of the construction duration, is shown on Tables 3-6 and 3-7. All other costs shown are expressed in August 1983 dollars.

- Taxes and duties are excluded.

- It is assumed that a power source is available in the existing switchyard.

- It is assumed that major portions of the existing facilities' auxiliary systems will be used for the new pulverized coal-fired boilers. Consequently, no provisions are included for items such as air compressors, condensate and feedwater pumps, water treatment systems, circulating water, etc.

- Ultimate disposition of ash will be in an area north of the facilities. Cost of providing the first cell and on-site access road are included.

- An allowance for freight, based on recent experience with a similar Caribbean project, has been included.

- The purchase of coal for start-up testing and initial coal-firing is not included in the capital cost estimate.

- Allowance for funds used during construction has not been included. (However, this sum is included in the project cash flow analysis and rate of return included in the financial section.)

- General and administrative expenses of the owner have been excluded.

- Contingency has been included in order to cover miscellaneous unidentified costs that typically arise during the actual design and construction of a project of this type. This allowance is intended to cover costs that are within the scope of the project. For this estimate, a 10 percent contingency is included for costs that were derived from the reference project and the unloader. The contingency on the unloader reflects the fact that the firm bids received had to be considered invalid. A contingency of 20 percent has been applied to the construction of the dock facilities excluding the unloader. Contingency for the coal handling system, the boilers, and the precipitator for which valid firm fixed bids were received was taken at 3 percent. Contingency on all other costs including the stack, architect-engineer services, and freight is based on a 15 percent factor.

## 3.14 PREOPERATIONAL COSTS

Preoperational expenses are included to cover initial fuel supplies, operator training, spares, initial mobile equipment needs, and upgrade of the existing turbine/generators. Only incremental cost increases over the cost of existing oil-fired facilities and increases over the cost included in the base capital cost estimate are contained in this category. The incremental costs are listed in Table 3-8, and all are in foreign currency.

### 3.14.1 Initial Fuel Supplies

An initial coal pile is included based upon providing a 45-day supply and assuming a 70 percent capacity factor. These requirements translate into 40,000 metric tons of coal which would cost $2,340,000. This is equivalent to reducing the No. 6 fuel oil supply by a 3-week capacity. Since these costs are a tradeoff, ongoing expenses in fuel cost will not increase. Therefore, no additional cost is included in this preoperational expense category.

### 3.14.2 Operator Training

Operator and maintenance training allowance prior to commercial operation is $300,000. Operator and maintenance training allowance of $212,000 for the boiler is provided for in the cost of the bid package included in the capital costs. An additional allowance of $88,000 is made for the balance of plant (BOP). The BOP cost was included in this category.

### 3.14.3 Spare Parts

Cost for spare parts was included in the bid packages for the boiler and the precipitator. On the average, $735,000 was allowed for boiler spares and $70,000 was allowed for precipitator spares in the capital costs. An additional allowance of $250,000 is made for the balance of plant; this is the total cost included for spares in the preoperational expense category.

### 3.14.4 Mobile Equipment

Additional mobile equipment is required to handle ash disposal and coal handling. Three trucks ($50,000 each) and two bulldozers ($225,000 each) are required. The total costs of this equipment equals $600,000.

### 3.14.5 Upgrade Turbine Generator Cycle Equipment

Based on discussions with the manufacturer, an allowance of $500,000 is made to make proper adjustments to the existing turbine generator cycle equipment. This number provides for operator training in the use of any new equipment such as instrumentation and controls.

## 3.15 MILESTONE SUMMARY SCHEDULE

The Engineering/Construction Milestone Summary Schedule (Figure 3-13) was based on commencement of detailed design engineering with the award of contracts for the boiler, precipitator, and coal handling system. This schedule is based upon a fast-track approach to project completion. In addition, the following assumptions were made:

a. No flue gas desulfurization system is required.

b. Existing plant support system are adequate for the new boilers.

c. Adequate construction manpower/resources are available.

d. Licensing/permits can be secured and will not impact the schedule.

e. Financing is available to support licensing, permitting, site geology work, and preliminary engineering required to specify site preparation, piling, and foundations as shown on the schedule.

f. Full financing is available to support the project at release of awards on the boiler, precipitator, and coal handling packages.

g. The award process on the boiler package starts 2 months before job award so that information on foundations will be available to accommodate timing of boiler foundation installation and steel erection.

h. Flexibility is allowed in the bidding process to support a dual approach.

   1. Force account work supplemented with fast-track bidding

   2. International bidding supplemented with A/E-generated material purchase orders necessary to expedite fast-track.

   The first approach would be used for site preparation, piling, foundations, and dock facilities. The second approach would be used such that the fly ash system, the stack, pulverizer bay erection, mechanical equipment installation, critical pipe purchase, piping erection and insulation, the coal unloader, and major electrical equipment would be bid internationally. Supplemental purchase orders would be required on the pulverizer bay area steel, major mechanical equipment, noncritical pipe, and electrical bulks.

i. Detail engineering commences with the award of the major packages for the boiler, the precipitator, and the coal handling system.

j. The owner's project team has been established and is available to support the fast-track schedule at the time of award of the major purchases.

Construction of the two units at Old Harbour is scheduled concurrently. A 3-month lag in the start-up of each Old Harbour unit is scheduled so that only one unit is required to be down at a time.

The critical path for the fast-track begins at the preparation of the site preparation bid package, a month and a half before award of the boiler package; follows through the bid process mobilization, setting of piles, pouring of boiler foundations, the boiler steel erection, erection of pressure parts and ductwork; then through completion of piping (interface portion); and ends with completion of startup. A parallel path occurs on the front end starting with award of the boiler package and follows through the fabrication and delivery of the boiler steel and connects with the overall critical path at boiler erection. This schedule is based on the flexible bidding process as proposed above.

If the international bidding approach, with its lengthy bid evaluation and period of challenge is used exclusively, the critical path would be considerably longer. The new critical path would change after award of the boiler package and switch over to the bid package for foundations. Once foundations were complete the path would change to the boiler steel erection and follow the same residual path as before.

The schedule with strictly international bidding shows a critical path that is 10 months longer than the fast-track approach (see Figure 3-14). On the fast-track schedule, the 10 months was eliminated basically as follows. Eliminating the international bidding process reduces the critical path approximately 6 months. Then allowing for preliminary engineering on the boiler foundations to take place in preaward time frame takes another 4 months off the critical path. To ensure that the full 10-month reduction is maintained, the force-account approach and the supplemental purchase approach was required on certain other items. These were previously identified.

## 3.16 OPERATION AND MAINTENANCE COSTS

Annual operation and maintenance costs include the following categories:

a. Salaries

b. Disposal

c. Coal Handling

d. Spares

e. Auxiliary Power Fuel Cost

f. Miscellaneous Items

g. Technical Assistance and Training

Fuel costs are excluded from this section and are included in Section 6.0. In addition, only incremental costs over and above those applicable to the oil-fired facilities are included. Costs are summarized in Table 3-9.

### 3.16.1 Salaries

The salaries for the additional plant personnel above the present plant staff necessary to operate, maintain the new equipment installed with the coal conversion, and clean the coal and ash handling areas are included in this category. The coal handling system will require an additional five operating positions. This will include one supervisor, one foreman, and three operators handling the equipment and driving the bulldozers, each working the day shift, for a total of five people. The supervisor and foreman will also have responsibility for the ash disposal. The ash handling equipment for offsite disposal of the ash will require two additional operator positions. These operators will work driving trucks during the day shift only. To permit operation of the coal and ash handling system 7 days a week, eight drivers will be required for the five bulldozer and truck positions.

The new coal-fired boilers and auxiliary equipment will require three additional outside operator position. These operators will work three shifts a day, 7 days a week, for a total of 12 additional people. There will also be a requirement for eight additional maintenance positions to work the day shift 5 days a week. Two fitters (mechanical) will be associated with the coal handling area and an additional fitter and electrician will be needed for the boiler and auxiliaries. Each fitter and the electrician will be assisted by a helper.

For proper housekeeping of the coal and ash handling areas of the site, two operator/cleaner positions will work three shifts per day, 7 days a week, for a total of eight additional people.

This is an additional 38 people required for the new coal-fired units. Their individual salary in Jamaican dollars is as follows:

| Position | Number People | Salary ($J) | Total ($J) |
|---|---|---|---|
| Coal Handling Supervisor | 1 | 20,000 | 20,000 |
| Coal Handling Foreman | 1 | 17,000 | 17,000 |
| Drivers (Bulldozers, Trucks) | 8 | 13,000 | 104,000 |
| Boiler Operators | 12 | 13,000 | 156,000 |
| Coal/Ash Handling Operators/Cleaners | 8 | 13,000 | 104,000 |
| Fitters (Mechanical) | 3 | 15,000 | 45,000 |
| Electrician | 1 | 15,000 | 15,000 |
| Helpers | 4 | 12,000 | 48,000 |
| TOTAL | 38 | | 509,000 |

A further element of the additional workers' cost is employee benefits, which are approximately 50 percent of their salaries. The total cost of salaries and benefits is ($J)764,000.

These additional people do not include extra personnel for coal ship unloading; however, it is expected that the unloading can be handled by the present plant staff in conjunction with the additional staffing on an overtime basis. The present schedule would have a coal ship arriving once every 3 weeks for a 1½-day turnaround.

Additional administration costs, if any, are not included in this analysis.

3.16.2 Disposal

Maintenance and fuel costs for the three ash disposal trucks and costs for general upkeep of the ash disposal areas are included in this category. An allowance of $90,000 per year is made to cover these costs.

3.16.3 Coal Handling

This category includes maintenance of the dock facilities and all coal handling equipment. Fuel cost for the bulldozers is included.

A major cost is associated with port maintenance. Dredging of the area is assumed to be required every 5 years at a cost of $1 million. This cost assumes that the local dredge will not be available (there is only one dredge available in Jamaica). An allowance of $200,000 per year is made to cover the cost of providing a dredge from a foreign source.

An additional allowance of $150,000 per year is provided to cover all other operating and maintenance costs for the coal handling equipment except power. Power costs for all facilities are covered in Subsection 3.16.5.

### 3.16.4 Spares

Pulverizer spares are a major cost item. One hundred and twenty thousand dollars per year is budgeted for mill replacement.

Costs for the balance of plant spares are set at $300,000 per year. This includes an incremental increase of $50,000 per year for the turbine generator spares.

### 3.16.5 Auxiliary Power Fuel Cost

A coal-fired boiler of equal size to an oil-fired boiler will require an additional 1 percentage point of nameplate power for auxiliaries' power above the oil-fired boiler. This is due to the coal handling and pulverizing equipment and ash handling equipment not associated with an oil-fired unit.

The cost of this additional auxiliary power fuel requirement was based on the assumed operational schedule stated in Section 5.1 which yields 4,600 hours per year at 100 percent load and 2,360 hours per year at 65 percent load. At the full load condition, the additional power would have to be supplied by oil-fired units for a total fuel cost of $300,000 for the year. At the partial load condition, the additional power would be supplied by operating the coal-fired units at a higher rate for a total fuel cost of $50,000 for the year.

### 3.16.6 Miscellaneous Items

Miscellaneous items include consumables such as chemicals and water, and maintenance materials such as oil and lubricants. An allowance of 20 percent of the other operating and maintenance costs is made.

### 3.16.7 Technical Assistance and Training

This item is an annual allowance of $750,000 to provide on-site, around-the-clock, technical assistance and training supervision. It is assumed that this assistance will be required for only the first 5 years of operation.

TABLE 3-1

BASIC BOILER DATA

| | |
|---|---|
| Type | Natural circulation, non-reheat unit, pulverized coal and No. 6 oil fired, outdoor |
| Superheater outlet pressure | 1300 psig (91.4 kg/cm$^2$) |
| Maximum continuous capacity | 610,000 pounds/hour (277,000 kg/hour) |
| Temperature at superheater outlet | 950 F (510 C) |
| Feedwater inlet temperature | 455 F (235 C) |
| Coal firing rate | 56,000 pounds/hour (25,400 kg/hour) |
| Gas temperature leaving air heater | 300 F (149 C) |
| Air temperature leaving air heater | 560 F (293 C) |
| Excess air | 20 percent |
| Efficiency | 88 percent |
| Air side pressure drop, total | 10 in. w.g. (254 mm w.g.) |
| Draft loss, total | 10 in. w.g. (254 mm w.g.) |
| Flue gas flow | 236,000 acfm (6,680 m$^3$/minute) |

TABLE 3-2

ELECTROSTATIC PRECIPITATOR DESIGN PARAMETERS

Electrostatic precipitator design parameters are listed below.

- 300,000 acfm flue gas flow (includes 50 percent excess air)
- 15 percent ash
- 725 MBtu/hr heat release rate in boiler
- -11.0 in. w.g. at ESP inlet
- .25 to .70 percent heat loss due to unburned carbon
- 300 F exit temperature (corrected)
- 3.5 grains/acf fly ash entering precipitator
- Maximum emissions of 0.03 pound per million Btu
- 455 SCA
- 138,000 sq ft total collection area
- 0.010 grains/acf outlet dust loading
- 99.7 percent ESP efficiency

TABLE 3-3

EQUIPMENT AND CORRESPONDING CONTROL ROOM DEVICES

| Equipment or Item | Control Room Device |
|---|---|
| Steam Turbine | Turbine control insert by GE |
| Stop valve | R/G indicating lights/control switch |
| Control valve | Position indicator |
| Metal and bearing temperatures | Record and alarm |
| Lube oil pumps (3) | R/G/A indicating lights/control switch |
| Lube oil pressure | Indicator |
| Turbine drain valves (5) | R/G indicating lights/control switch |
| Vibration, eccentricity, shaft displacement | Record/alarm |
| Speed (rpm) | Indicator |
| Extraction valves (5) | R/G indicating lights/control switches |
| Emergency Trip (2) | R/G indicating lights/control swtiches |
| Generator | |
| $H_2$ purity | Indicator/alarm |
| $H_2$ cooling pressure | Indicator/alarm |
| Voltage output | Indicator |
| Phase current | Indicator |
| Bearing temperatures | Record/alarm |
| Generator breaker | R/G indicating lights/control switch/ synchronizing panel |
| Condenser | Vacuum indicator |
| Hotwell | Level controller/recorder |
| Condensate makeup | Controller |
| Condensate draw and dump | Controller |
| Condensate pumps (2) | R/G/A indicating lights/control switch |
| Condensate pump discharge pressure | Indicator |
| Condensate pump discharge pH | Indicate/alarm |
| Condensate pump bearing temperatures | Indicate or record/alarm |
| Circulating water temperatures | Indicator |
| Miscellaneous | |
| Main steam line drain valve (1) | R/G indicating light/controller |
| Circulating water pumps (2) | R/G/A indicating lights/control switch |
| Fire pump start (2) | R/G/A indicating lights/control switch |
| Fire system | Alarms (annunciator) |
| Heater level alarms | Annunciator |
| Alarm points (40) | 40 point annunciator |
| Boiler feed pumps (2) | R/G/A indicator lights/control switch |
| Boiler feed pump bearing temperatures | Indicate/alarm |

TABLE 3-4

TOTAL GROUND LEVEL CONCENTRATIONS (μg/m³)

| | Natural Background | | | New Units Plus Units 1 and 2 | | | Total | | | U.S. NAAQS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SO_2$ | TSP | $NO_x$ | $SO_2$* | TSP | $NO_x$ | $SO_2$* | TSP | $NO_x$ | $SO_2$ | TSP | $NO_x$ |
| Annual | 0 | 40 | 0 | 63.4 | 8.4 | 9.5 | 63.4 | 48.4 | 9.5 | 80 | 75 | 100 |
| 24-hour | 0 | 40 | - | 382.3 | 141.7 | - | 382.3 | 181.7 | - | 365 | 260 | - |
| 3-hour | - | - | - | 973.3 | - | - | 973.3 | - | - | 1300 | - | - |

*Based on 2 percent sulfur content of coal

TABLE 3-5

IMPROVEMENT IN LOCAL AIR QUALITY - $SO_2$ IMPACT*

| Averaging Period | New Units Plus Units 1 & 2 ($\mu g/m^3$) | Units 1, 2, 3, 4 ($\mu g/m^3$) | Net Reduction $SO_2$ ($\mu g/m^3$) |
|---|---|---|---|
| Annual | 63.4 | 106.7 | 43.3 |
| 24-hour | 382.3 | 591.9 | 209.6 |
| 3-hour | 973.3 | 1654.4 | 681.1 |

IMPROVEMENT IN LOCAL AIR QUALITY - TSP IMPACT

| Averaging Period | New Units Plus Units 1 & 2 ($\mu g/m^3$) | Existing Units 1, 2, 3, 4 ($\mu g/m^3$) | Net Reduction TSP ($\mu g/m^3$) |
|---|---|---|---|
| Annual | 8.4 | 8.4 | 0 |
| 24-hour | 141.7 | 257.6 | 115.9 |

IMPROVEMENT IN LOCAL AIR QUALITY - $NO_x$ IMPACT

| Averaging Period | New Units Plus Units 1 & 2 ($\mu g/m^3$) | Existing Units 1, 2, 3, 4 ($\mu g/m^3$) | Net Reduction $NO_x$ ($\mu g/m^3$) |
|---|---|---|---|
| Annual | 9.5 | 9.9 | .4 |

*Based on 2 percent sulfur content of coal

TABLE 3-6

CAPITAL COST SUMMARY
STEAM GENERATING FACILITIES
OLD HARBOUR UNITS 3 AND 4
(Dollars in 1,000s, August 1983 Cost Base)

| | Total ($U.S.) |
|---|---|
| Dock Facilities | $ 15,100 |
| Site Preparation and Substructures | 7,200 |
| Onsite Coal Receiving and Handling | 5,000 |
| Building Superstructures | 3,700 |
| Boilers | 29,500 |
| Precipitators | 6,300 |
| Stacks | 3,500 |
| Fly Ash Handling | 1,600 |
| Piping and Mechanical Including Bottom Ash Handling | 9,700 |
| Electrical and Instrumentation | 6,800 |
| Subtotal, Construction/Engineering Cost | $ 88,400 |
| Contingency | 8,000 |
| Land | 30 |
| Subtotal, Project Cost, August 1983 Dollars | $ 96,430 |
| Escalation* | 6,900 |
| Total Cost** Steam Generating Facilities | $103,330 |

*Escalation at 6.5 percent per year to a center of gravity in April 1985.
**Does not include taxes, duties, allowance of funds used during construction (AFUDC), owner administration expenses, and cost for initial coal pile. (Refer to Section 3.14.1). AFUDC is included in the cash flow analysis and rate of return calculations in the financial sections.

TABLE 3-7

CAPITAL COST BREAKOUT
STEAM GENERATING FACILITIES
OLD HARBOUR UNITS 3 AND 4
(Dollars in 1,000s, August 1983 Cost Base)

| | Local ($J)* | Foreign ($U.S.) |
|---|---|---|
| Dock Facilities | $ 5,300 | $12,100 |
| Site Preparation and Substructures | 6,800 | 3,400 |
| Onsite Coal Receiving and Handling | 700 | 4,600 |
| Building Superstructures | 3,700 | 1,600 |
| Boilers | 3,700 | 27,600 |
| Precipitators | - | 6,300 |
| Stacks | - | 3,500 |
| Fly Ash Handling | - | 1,600 |
| Piping and Mechanical Including Bottom Ash Handling | 2,600 | 8,200 |
| Electrical and Instrumentation | 1,900 | 5,700 |
| Subtotal, Construction/Engineering Cost | $24,700 | $74,600 |
| Contingency | 2,500 | 6,600 |
| Land | 50 | - |
| Subtotal, Project Cost, August 1983 Dollars | $27,250 | $81,200 |
| Escalation** | 2,600 | 5,400 |
| Total Cost† Steam Generating Facilities | $29,850 | $86,600 |

*Based on conversion rate of 1 $U.S. = 1.78 $J.
**Escalation at 6.5 percent per year to a center of gravity in April 1985.
†Does not include taxes, duties, AFUDC, owner administration expenses, and cost for initial coal pile.

TABLE 3-8

PREOPERATIONAL CAPITAL EXPENSES

| | Incremental Cost* |
|---|---|
| Initial Fuel Supplies (Tradeoff Equally with Reduced Oil Supply) | - |
| Operator Training** | $ 88,000 |
| Spare Parts | 250,000 |
| Mobile Equipment | 600,000 |
| Upgrade Turbine Generator Cycle Equipment | 500,000 |
| Total Incremental Cost | $1,438,000 |

*Only cost over and above existing expenses for oil-fired facilities and those costs included in the capital cost estimate are included. The total incremental cost is in foreign currency.

**Operator training allowance of $212,000 included in boiler capital cost.

TABLE 3-9

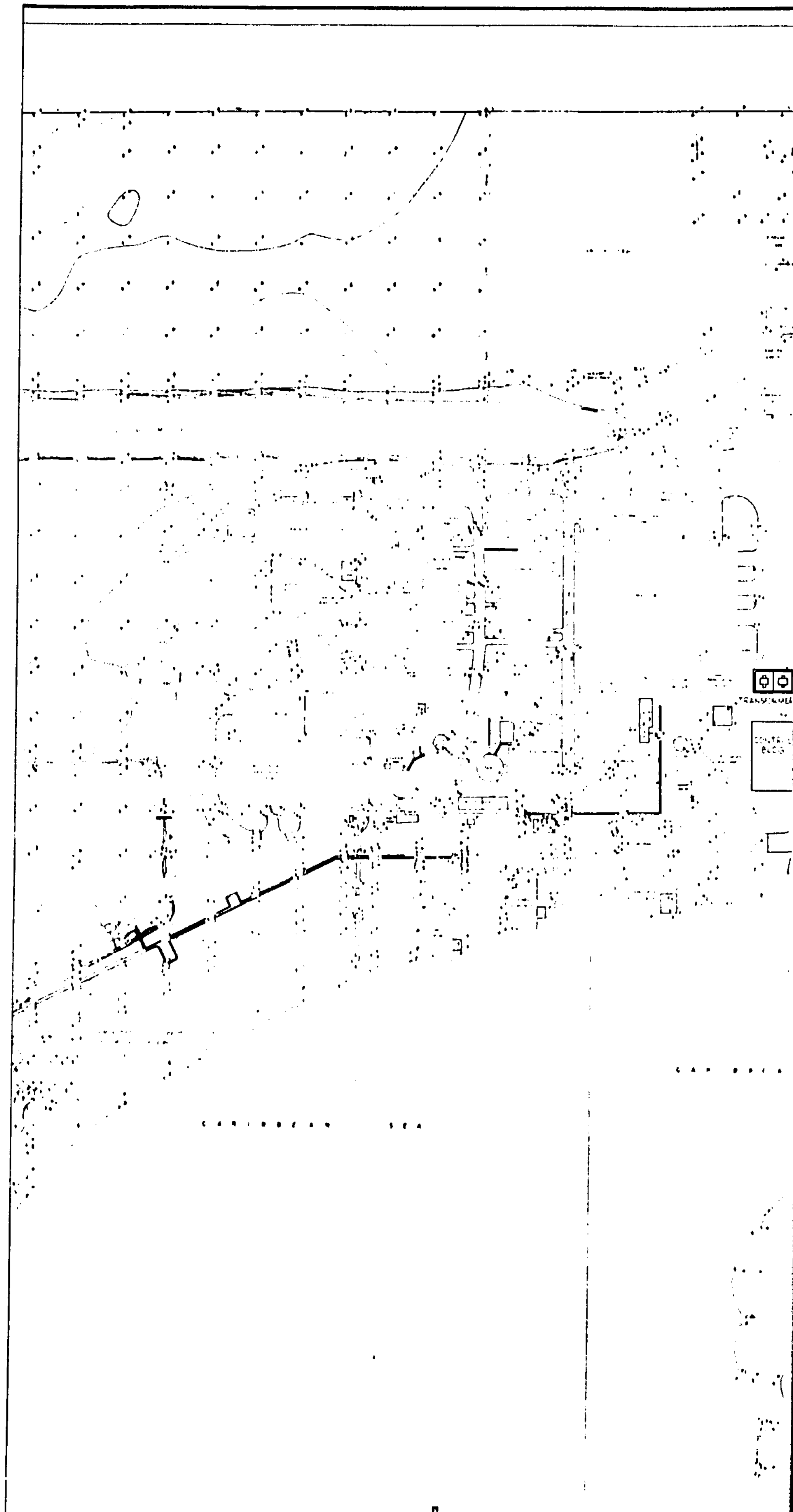
ANNUAL OPERATING AND MAINTENANCE COSTS

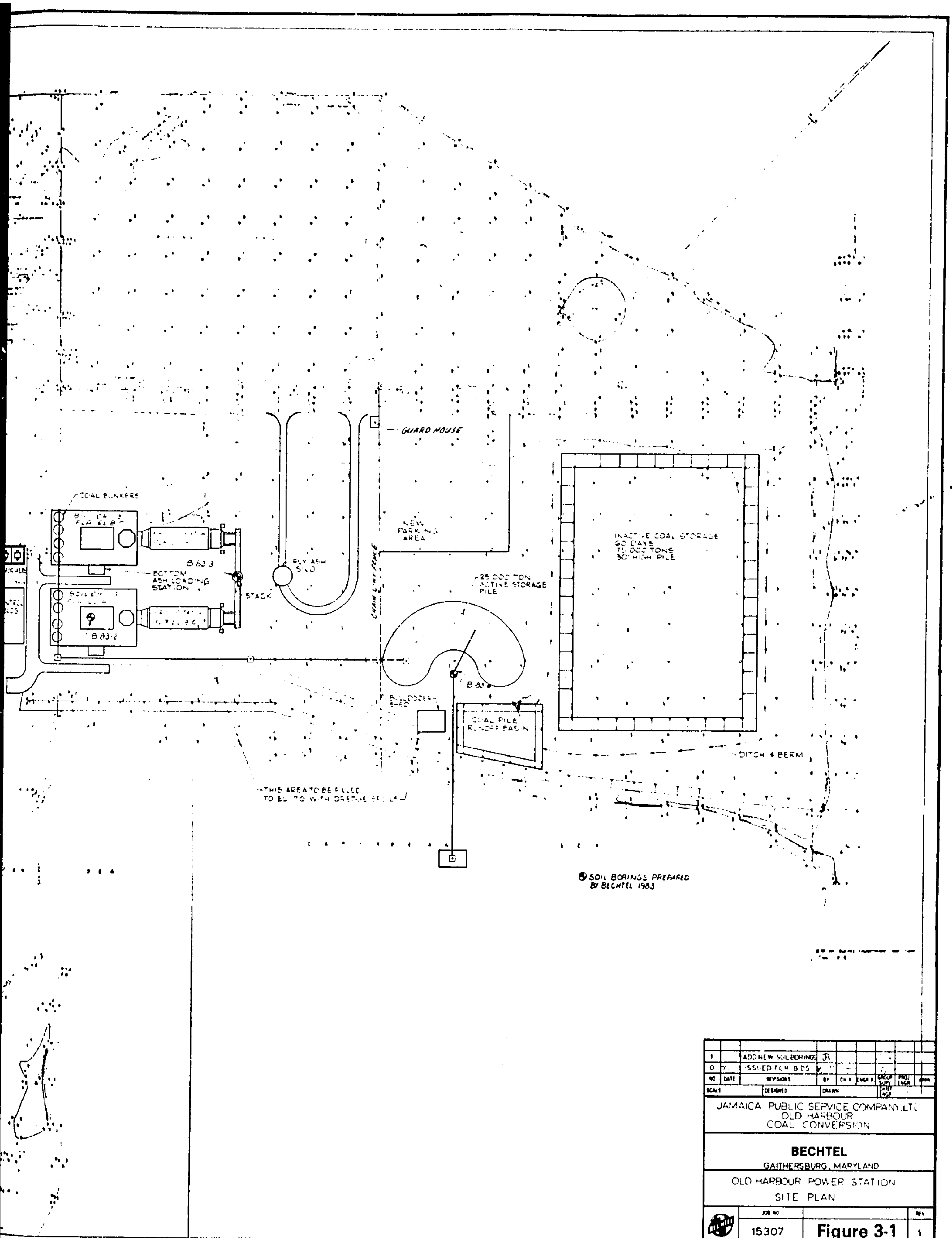
| | Incremental Costs* | | |
|---|---|---|---|
| | Total ($U.S.) | Local Currency ($J) | Foreign Currency ($U.S.) |
| Salaries | 429,000 | 764,000 | - |
| Ash Disposal | 90,000 | - | 90,000 |
| Coal Handling | 350,000 | - | 350,000 |
| Spares | | | |
| Mill Replacement | 120,000 | - | 120,000 |
| BOP Replacement | 300,000 | - | 300,000 |
| Auxiliary Power Fuel Cost | 350,000 | - | 350,000 |
| Miscellaneous Items | 328,000 | - | 328,000 |
| | $1,967,000 | $764,000 | $1,538,000† |
| Technical Assistance and Training** | $ 750,000 | - | $ 750,000 |

*Only costs over and above operation of the oil-fired facilities are included.

**Technical assistance and training for the first 5 years of operation.

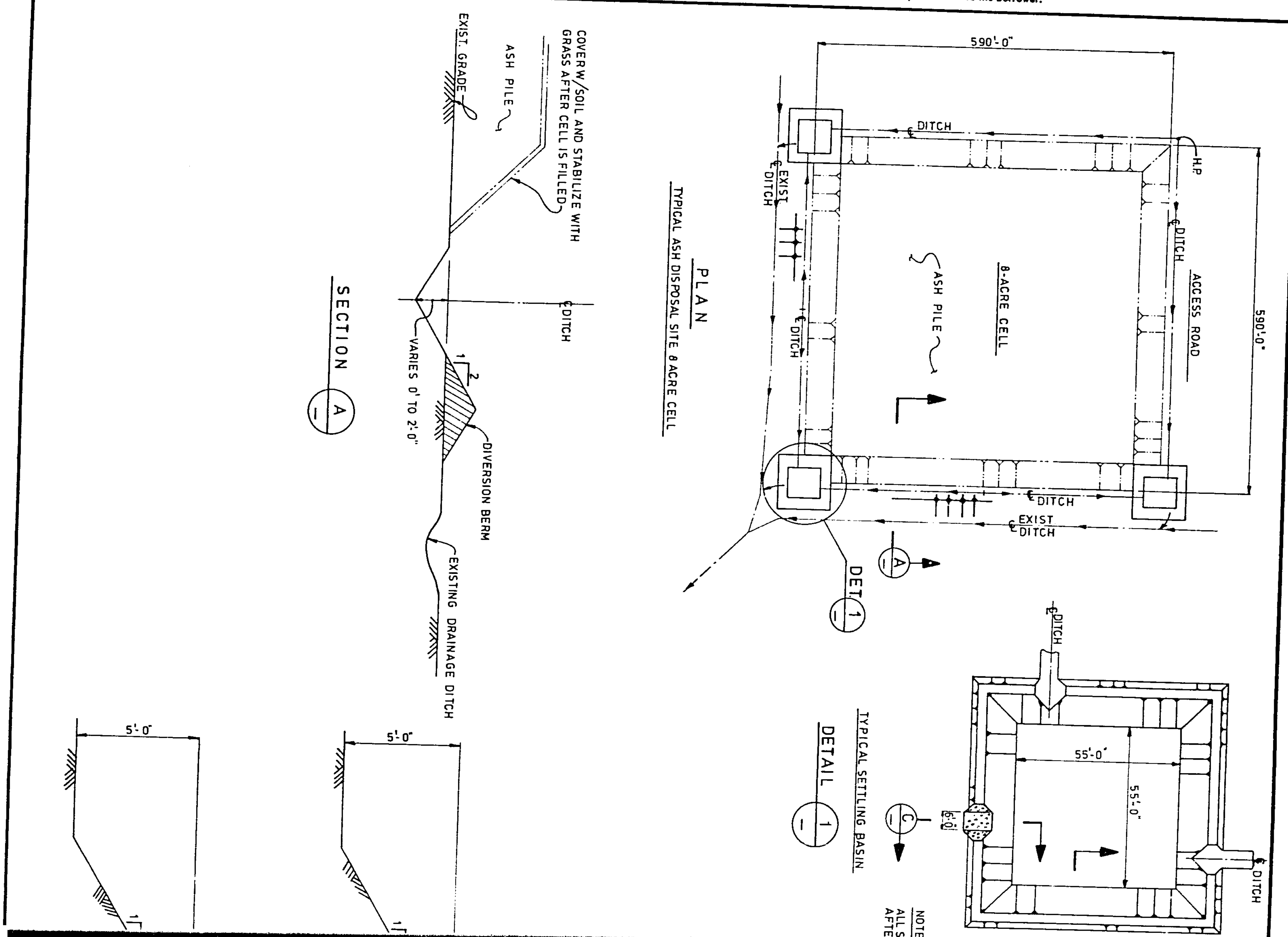
†This U.S. dollar content will have to be available on an annual basis as foreign currency for the life of the coal-fired boilers.

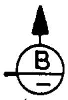




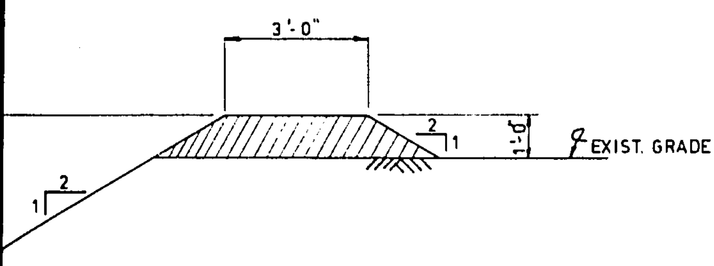
COAL BUNKERS
BOTTOM ASH LOADING STATION
STACK
FLY ASH SILO
GUARD HOUSE
NEW PARKING AREA
CHAIN LINK FENCE
25,000 TON ACTIVE STORAGE PILE
INACTIVE COAL STORAGE
60 DAYS
75,000 TONS
30' HIGH PILE
BULLDOZER SHED
COAL PILE RUNOFF BASIN
DITCH & BERM
SOIL BORINGS PREPARED BY BECHTEL 1983
ADD NEW SOIL BORINGS
ISSUED FOR BIDS
NO
DATE
REVISIONS
BY
SCALE
DESIGNED
DRAWN
JAMAICA PUBLIC SERVICE COMPANY, LTD
OLD HARBOUR
COAL CONVERSION
BECHTEL
GAITHERSBURG, MARYLAND
OLD HARBOUR POWER STATION
SITE PLAN
JOB NO
15307
REV
1


Figure 3-1

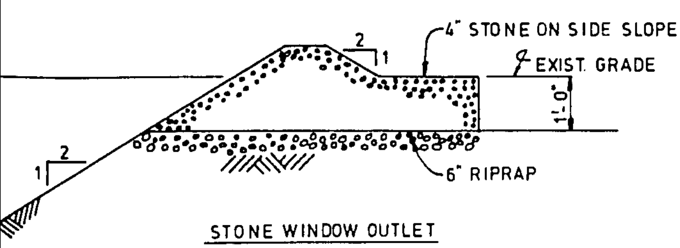

590'-0"
DITCH
H.P.
EXIST DITCH
DITCH
ACCESS ROAD
8-ACRE CELL
ASH PILE
590'-0"
EXIST DITCH
DET. 1
A
PLAN
TYPICAL ASH DISPOSAL SITE 8 ACRE CELL
COVER W/SOIL AND STABILIZE WITH GRASS AFTER CELL IS FILLED
ASH PILE
EXIST. GRADE
DITCH
VARIES 0' TO 2'-0"
DIVERSION BERM
EXISTING DRAINAGE DITCH
SECTION A
DITCH
55'-0"
55'-0"
6'-0"
C
TYPICAL SETTLING BASIN
DETAIL 1
NOTE
ALL S
AFTE
5'-0"
5'-0"




TE:
L SETTLING BASINS TO BE REMOVED
TER ASH PILE IS COVERED & SEEDED




SECTION B




STONE WINDOW OUTLET

SECTION C

| NO | DATE | REVISIONS | BY | CHKD | DES SH SUPV | ENGR | PROJ ENGR | APPR |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
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| A | | ISSUED FOR REPORT | R | – | | | | |

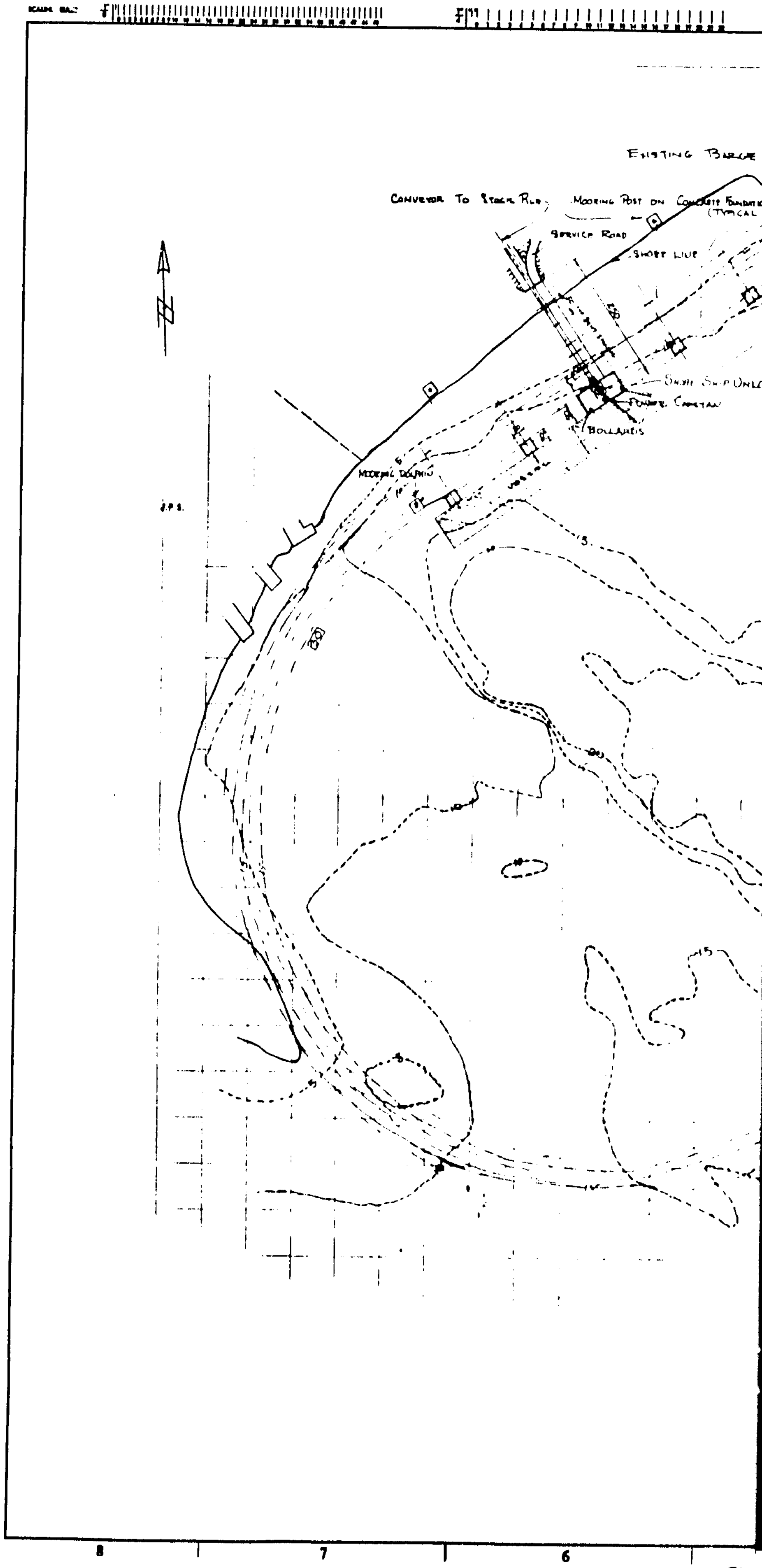
SCALE | DATE | DESIGNED | DRAWN Rawlings | CHIEF ENGR

**BECHTEL**
GAITHERSBURG, MARYLAND

GOVERNMENT OF JAMAICA
COAL FEASIBILITY STUDY PHASE II

ASH DISPOSAL SITE DETAILS

| JOB No. | | REV. |
|---|---|---|
| 15307 | **Figure 3-2** | A |



Existing Barge
Mooring Post on
(Typical
Service Road
Bollards
Mooring Dolphin
8
7
6

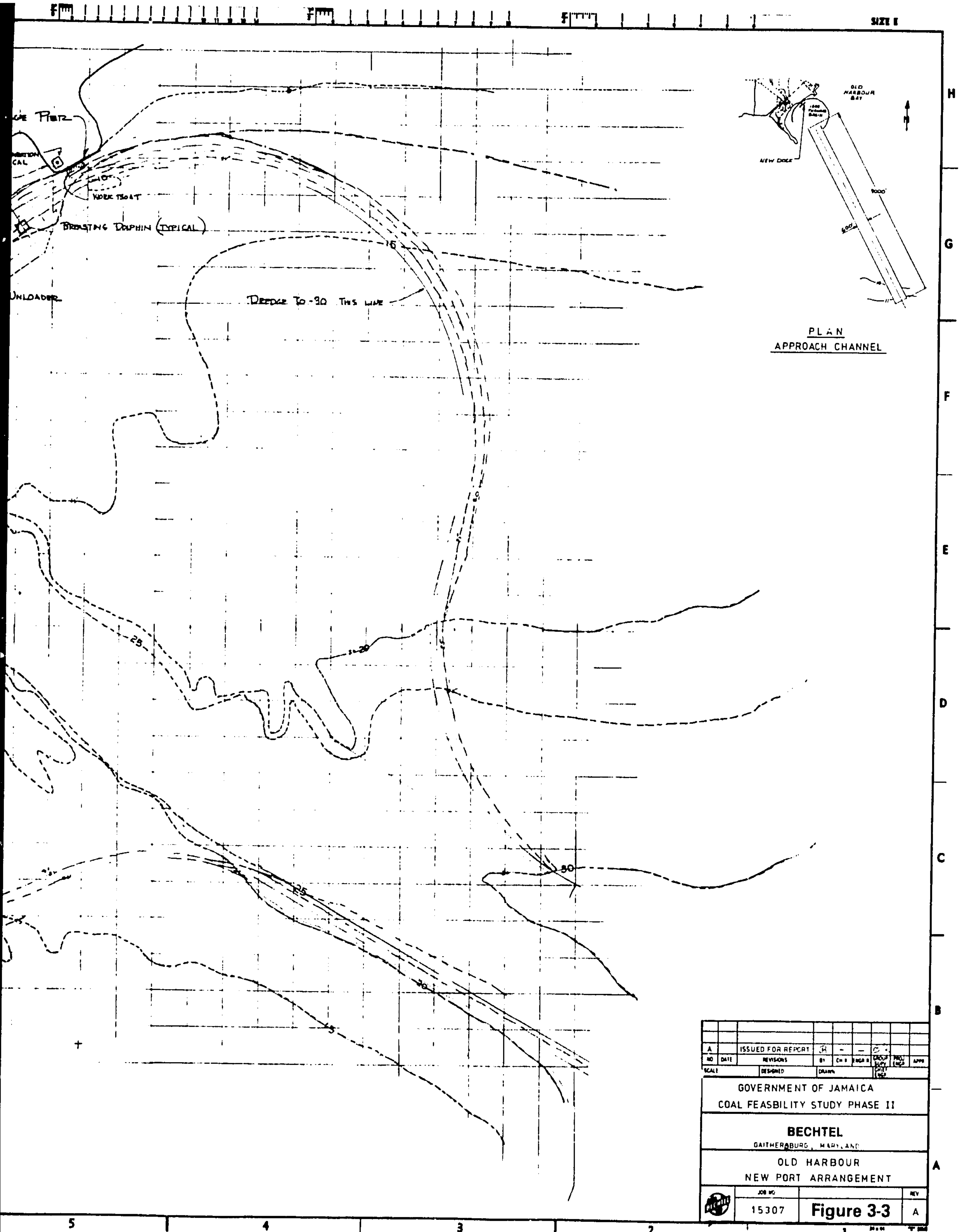
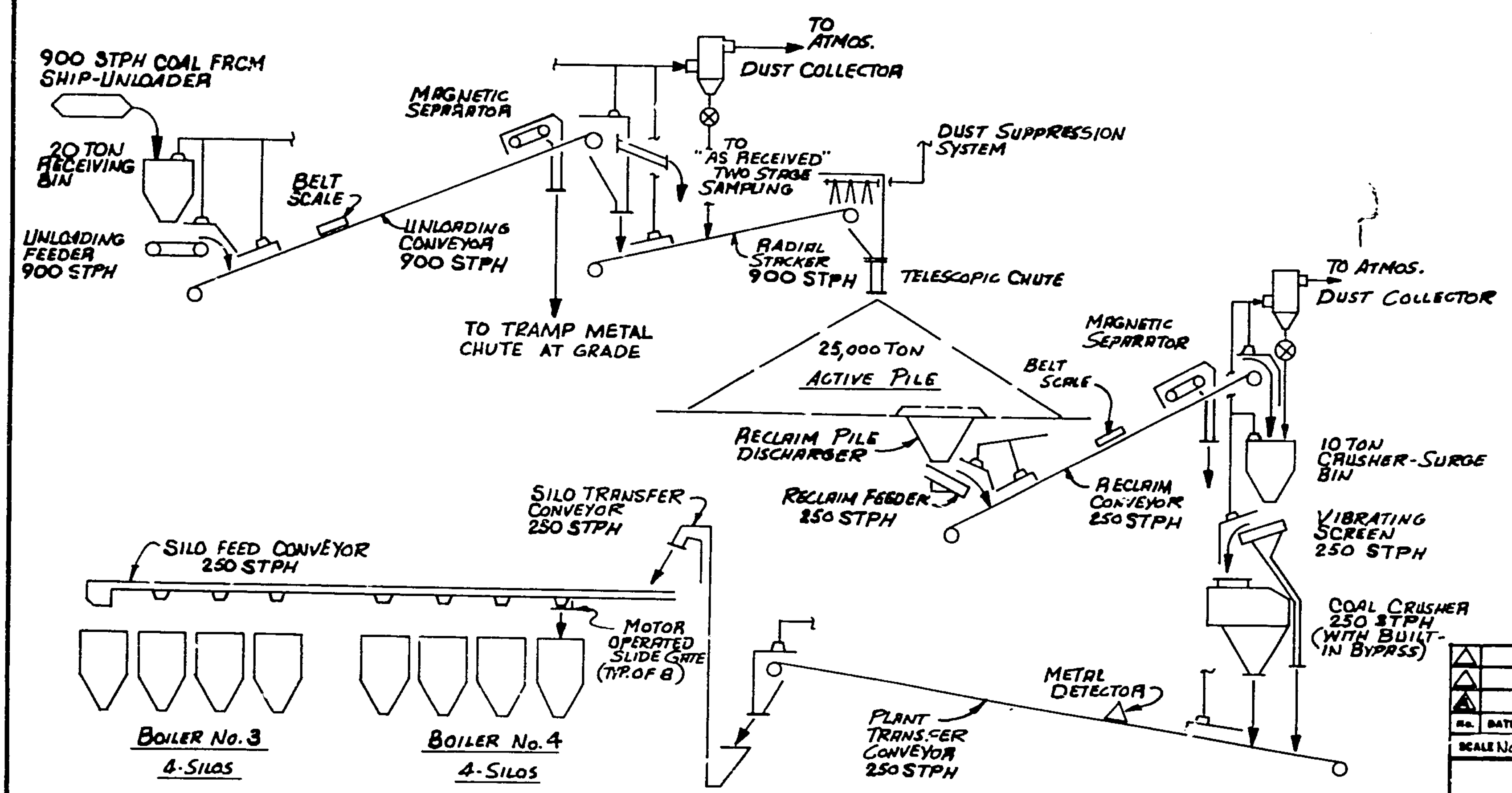

PIER
BREASTING DOLPHIN (TYPICAL)
WORK BOAT
UNLOADER
DREDGE TO -30 THIS LINE
OLD HARBOUR BAY
NEW DOCK
PLAN
APPROACH CHANNEL
SIZE E
ISSUED FOR REPORT
GOVERNMENT OF JAMAICA
COAL FEASBILITY STUDY PHASE II
BECHTEL
GAITHERSBURG, MARYLAND
OLD HARBOUR
NEW PORT ARRANGEMENT
15307

Figure 3-3




| No. | DATE | REVISIONS | BY | CH'K | DES. SUPV. | ENG'R | PROJ. ENGR. |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | ISSUED FOR REPORT | JR | | | | |

SCALE None | DESIGNED JBA | DRAWN | CHIEF ENGR.

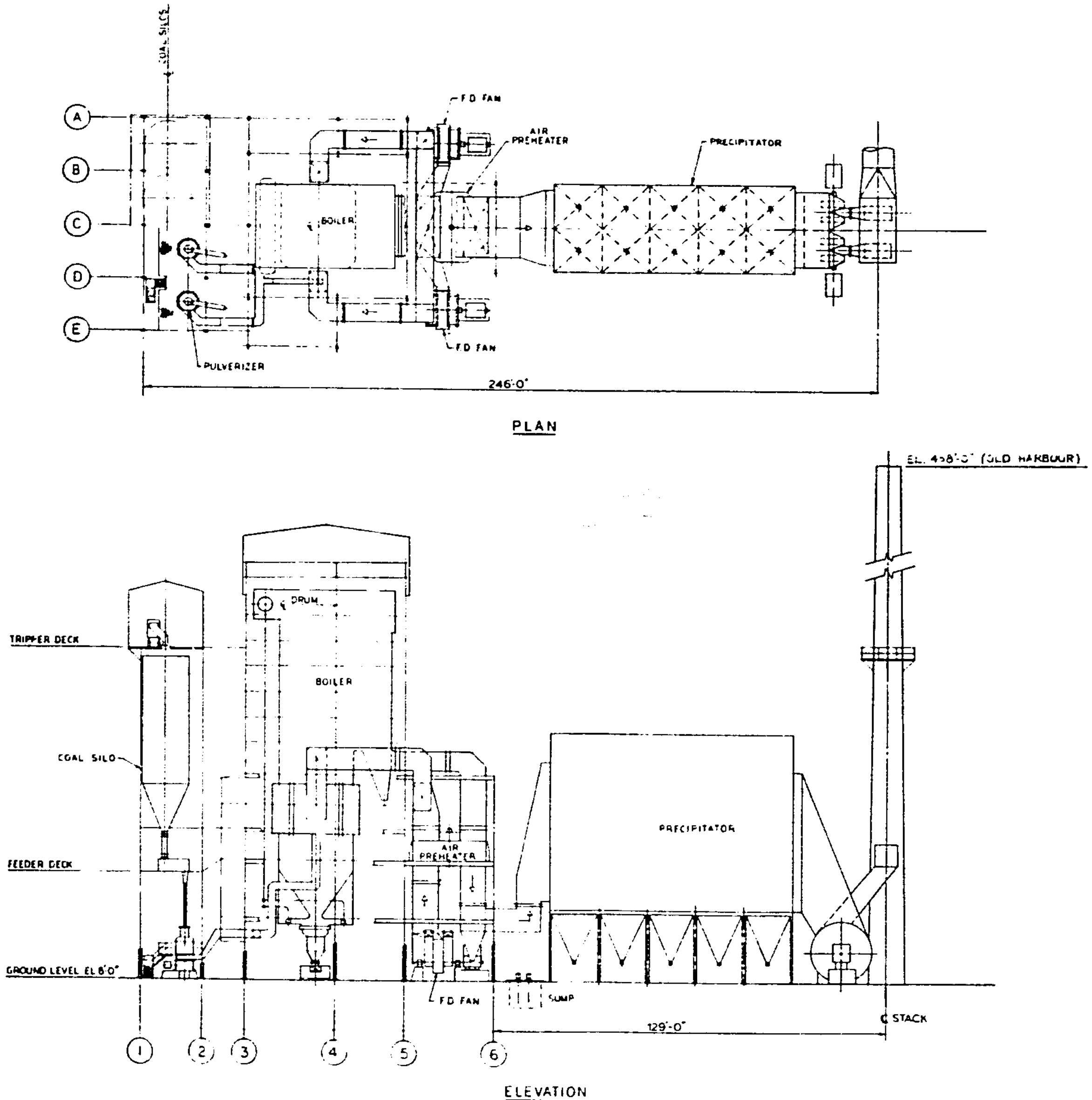
**BECHTEL**
GAITHERSBURG, MD.

GOVERNMENT OF JAMAICA
COAL FEASIBILITY STUDY PHASE

COAL HANDLING SYSTEM
FLOW DIAGRAM

JOB No. 15307

Figure 3-4

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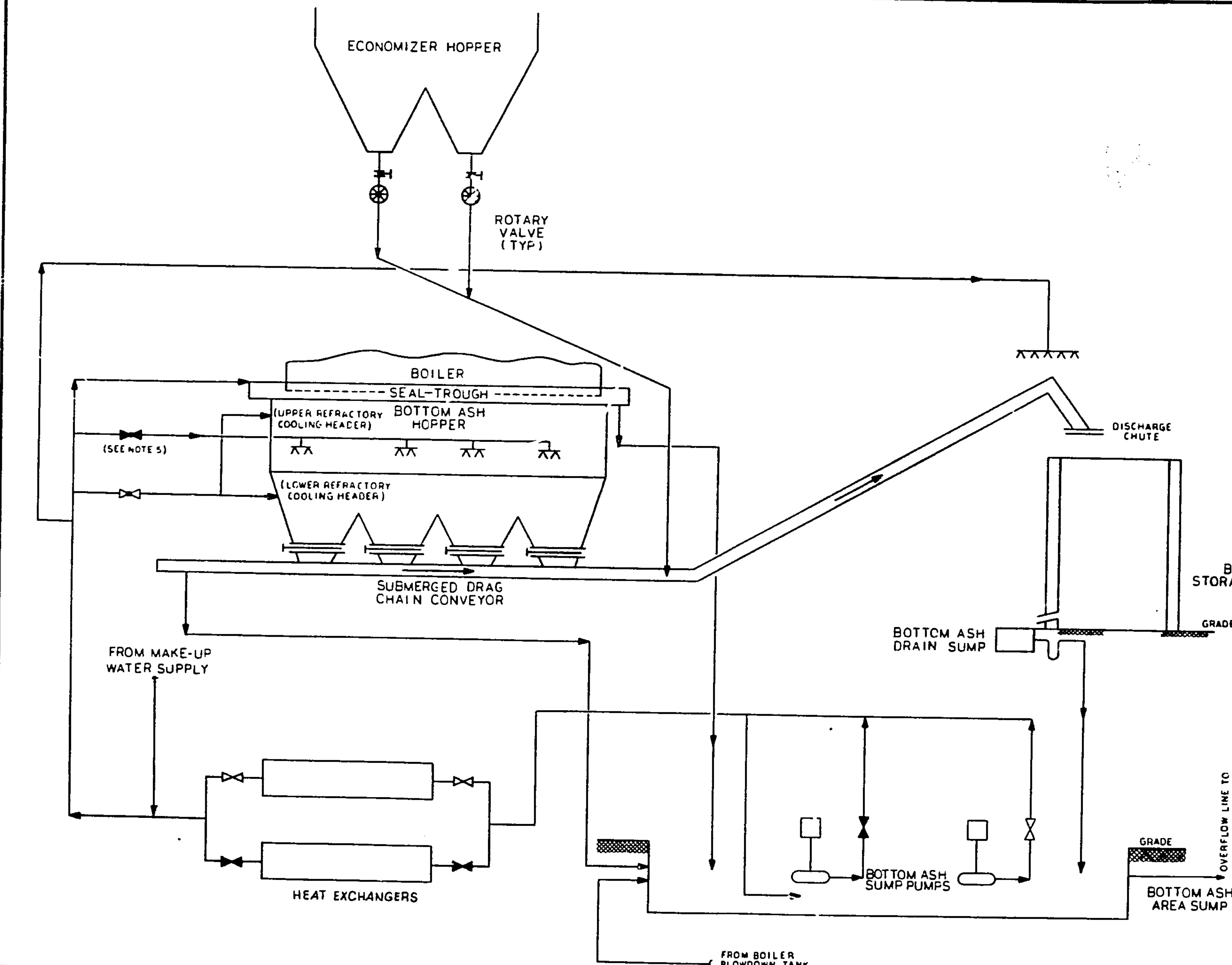
| NO | DATE | REVISIONS | BY | CHK | ENGR'R | GROUP SUPV | PROJ ENGR | APPR |
| SCALE | | DESIGNED | | DRAWN | | CHIEF ENGR | | |

JAMAICA PUBLIC SERVICE COMPANY LTD
OLD HARBOUR COAL CONVERSION

**BECHTEL**
GAITHERSBURG, MARYLAND

OLD HARBOUR POWER STATION
PRELIMINARY BOILER ARRANGEMENT

| JOB NO | | REV |
|---|---|---|
| 15307 | **Figure 3-5** | 0 |




## NOTES

1. FLUSHING CONNECTION TO REACH SEALTROUGH ON EACH SIDE.
2. INITIAL FILL OF SYSTEM WILL BE BY USE OF HOSE LINES TO THE BOTTOM ASH AREA SUMP AND SUBMERGED DRAG CHAIN CONVEYOR.
3. PUMP B SHOWN IN STAND-BY MODE.
4. HEAT EXCHANGER B SHOWN IN STAND-BY MODE.
5. THE QUENCH SPRAY HEADER IS MANUALLY INITIATED TO COOL THE ASH WHICH COLLECTS IN THE HOPPERS WHEN THE SUBMERGED DRAG CHAIN CONVEYOR IS DOWN FOR MAINTENANCE AND THE HOPPERS ARE ISOLATED. COOLING WATER TO THE UPPER AND LOWER REFRACTORY IS NOT REQUIRED DURING QUENCH SPRAY OPERATIONS.

| | | | |
|---|---|---|---|
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Scale: NONE

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GAITHERSBURG, MARYLAND

GOVERNMENT OF JAMAICA
COAL FEASIBILITY STUDY PHASE II

SYSTEM FLOW DIAGRAM
BOTTOM ASH HANDLING SYSTEM
TYPICAL FOR 1 UNIT

| JOB No. | | REV. |
|---|---|---|
| 15307 | **Figure 3-6** | A |

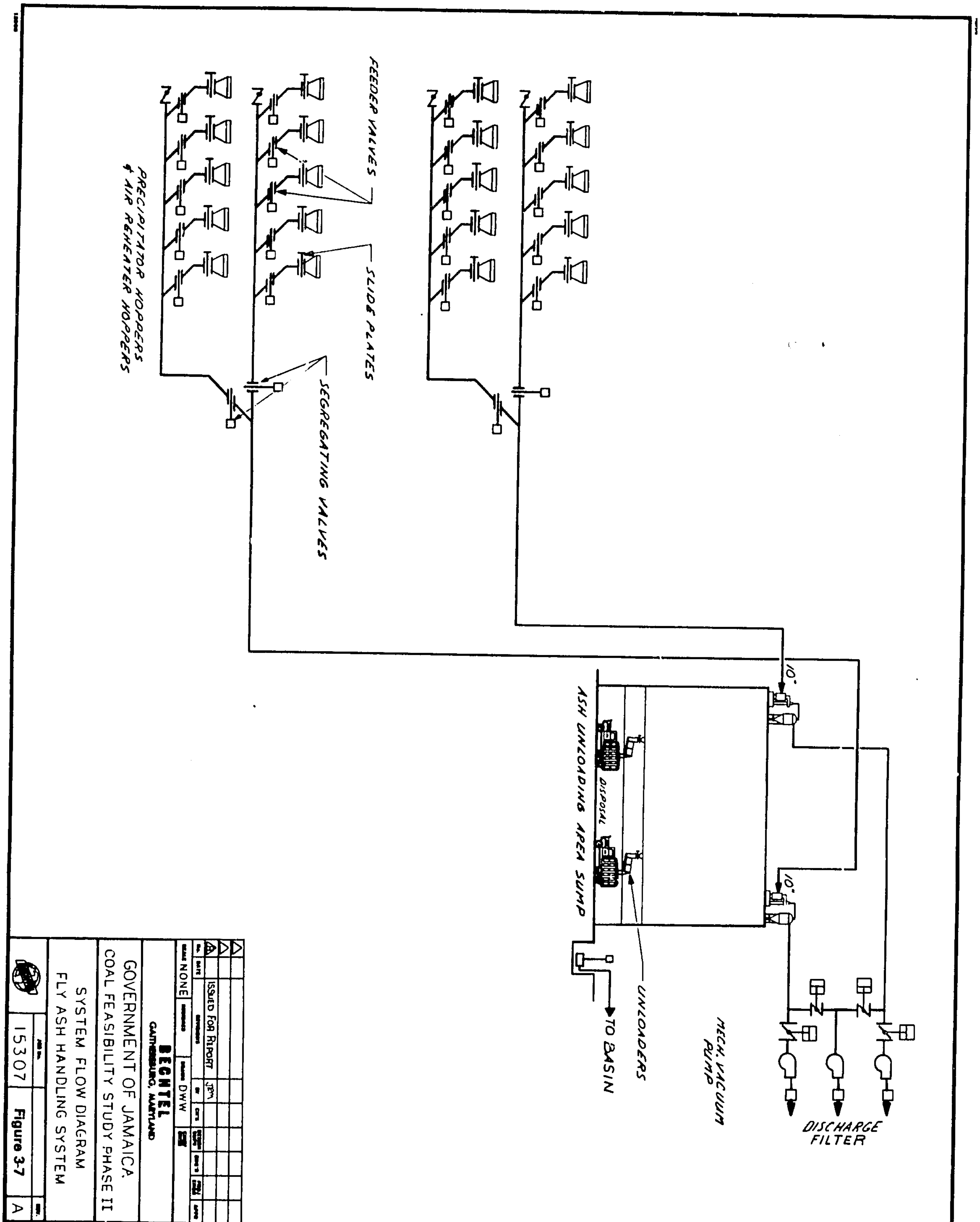
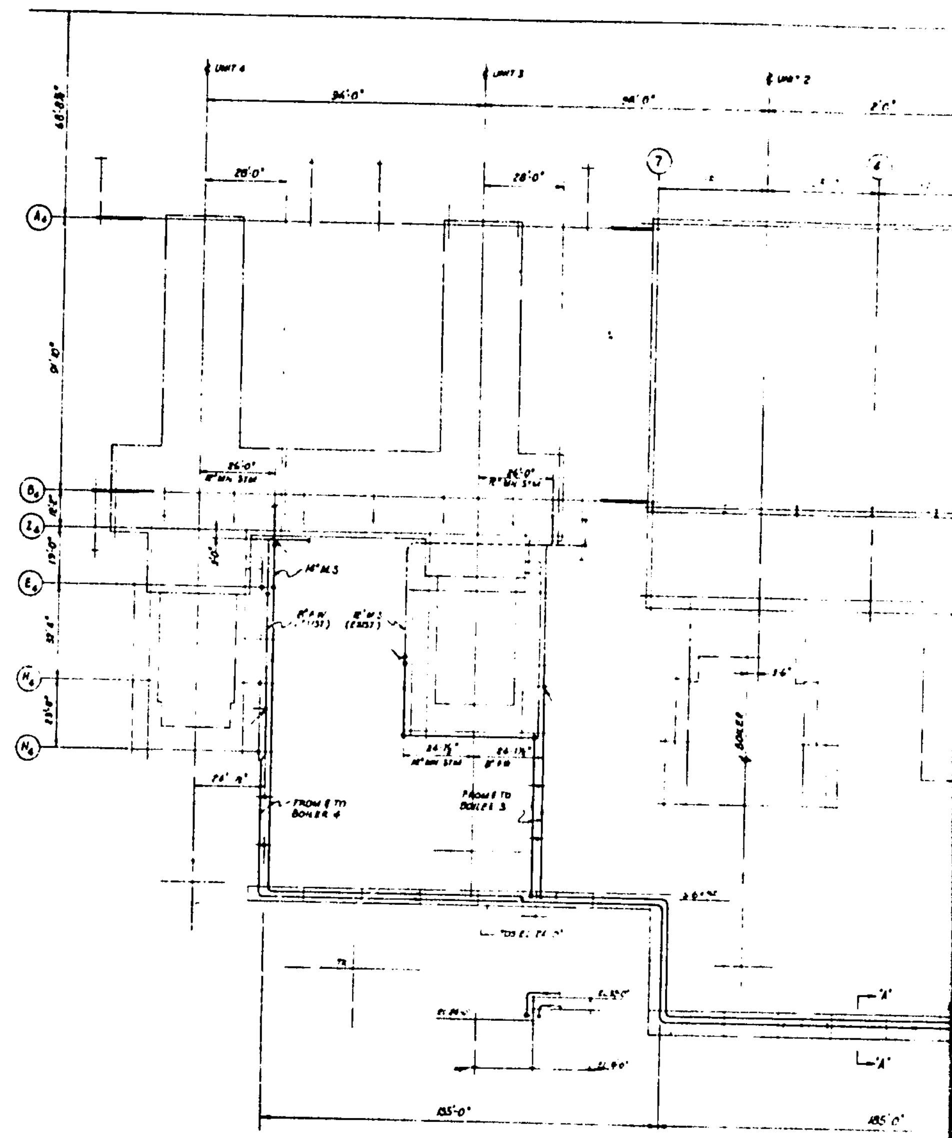
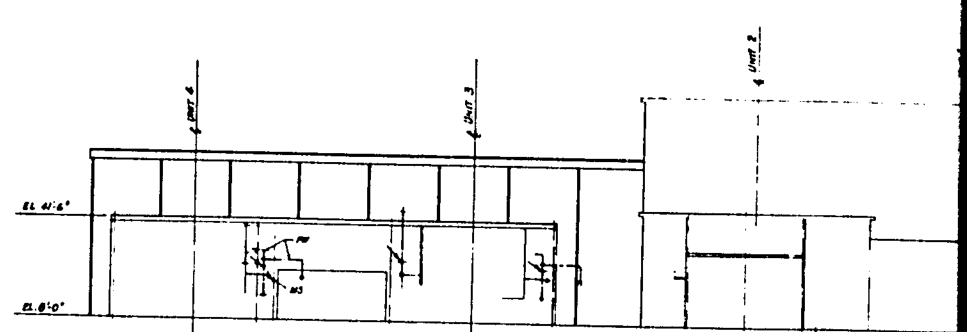

FEEDER VALVES
SLIDE PLATES
SEGREGATING VALVES
PRECIPITATOR HOPPERS
& AIR REHEATER HOPPERS
10"
10"
ASH UNLOADING AREA SUMP
DISPOSAL
UNLOADERS
TO BASIN
MECH. VACUUM PUMP
DISCHARGE FILTER
ISSUED FOR REPORT
SCALE NONE
DRAWN DWW
BECHTEL
GAITHERSBURG, MARYLAND
GOVERNMENT OF JAMAICA
COAL FEASIBILITY STUDY PHASE II
SYSTEM FLOW DIAGRAM
FLY ASH HANDLING SYSTEM
15307
A

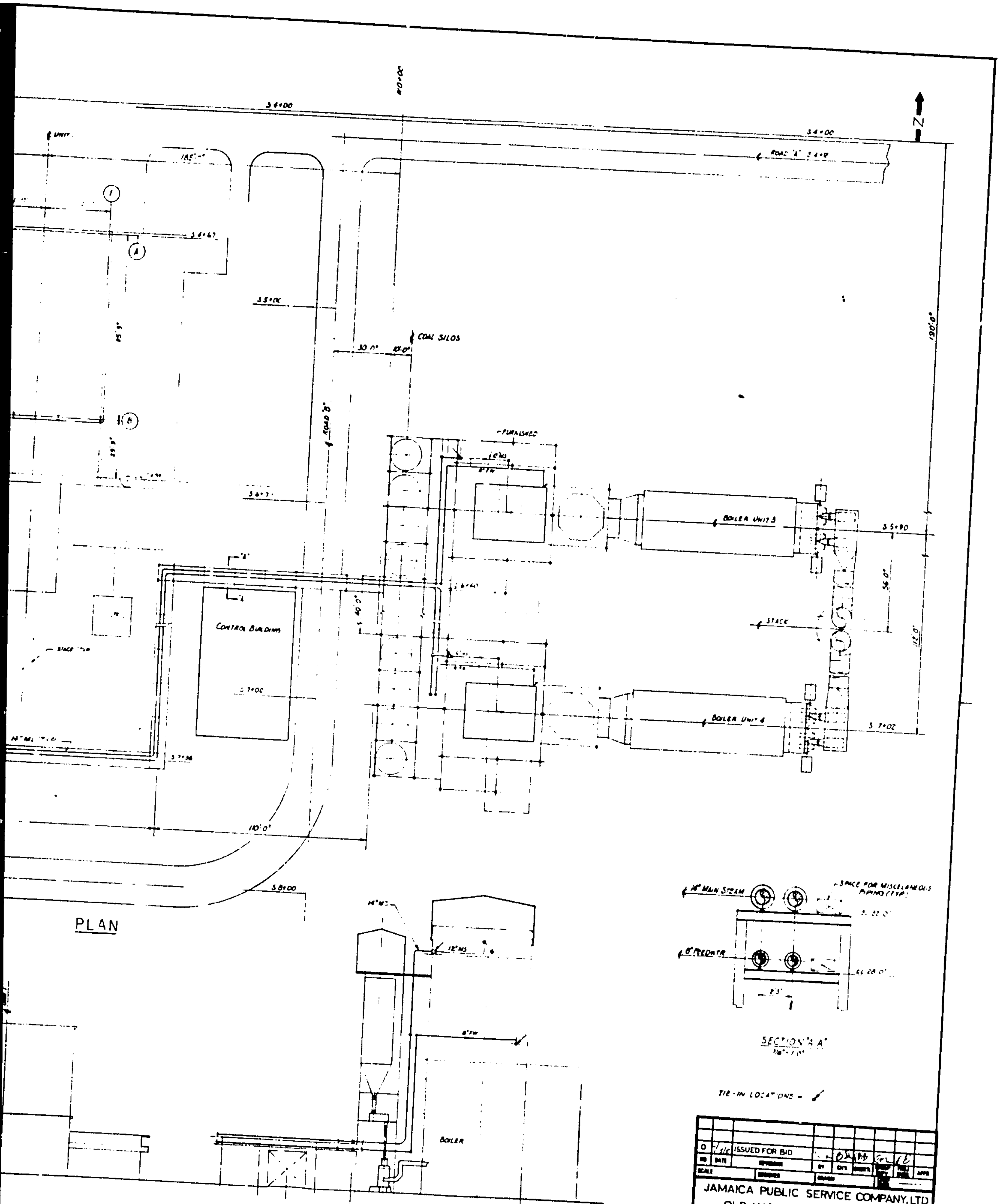
Figure 3-7



UNIT 4
UNIT 3
28'-0"
28'-0"
FROM ℄ TO BOILER 4
FROM ℄ TO BOILER 3
BOILER
135'-0"
135'-0"

UNIT 4
UNIT 3
UNIT 2
MS



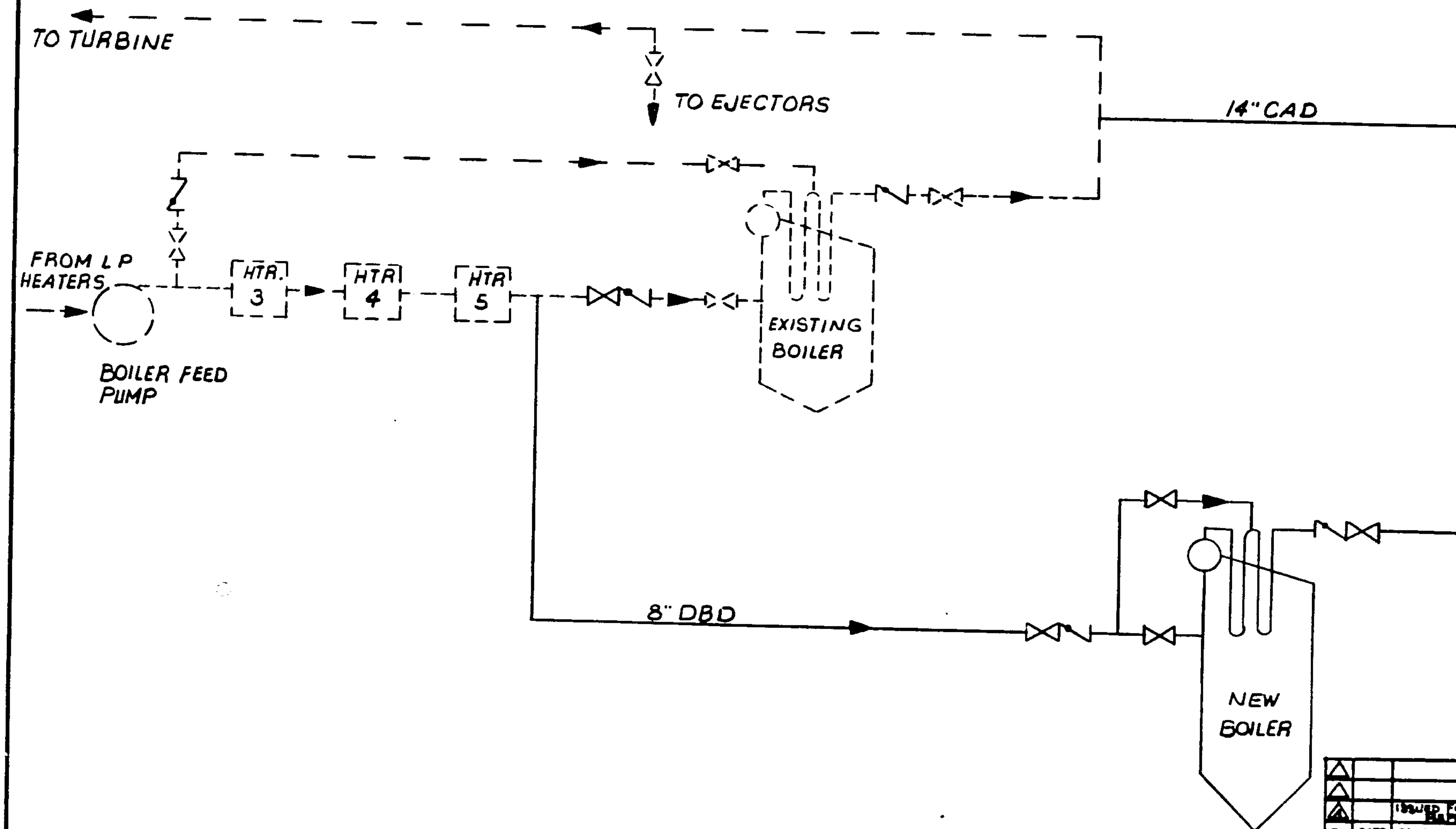

| | | | | | |
|---|---|---|---|---|---|
| 0 | | ISSUED FOR BID | | | |
| NO | DATE | REVISIONS | BY | CHK'D | APPR |

JAMAICA PUBLIC SERVICE COMPANY, LTD
OLD HARBOUR COAL CONVERSION

**BECHTEL**
GAITHERSBURG, MARYLAND

OLD HARBOUR POWER STATION
MAIN STEAM AND FEEDWATER ROUTING

| JOB NO. | DRAWING NO. | REV |
|---|---|---|
| 15307 | Figure 3-8 | 0 |

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| No. | DATE | REVISIONS | BY | CH'K | DES. SUPV. | ENG'R | PROJ. ENGR. | APPD |

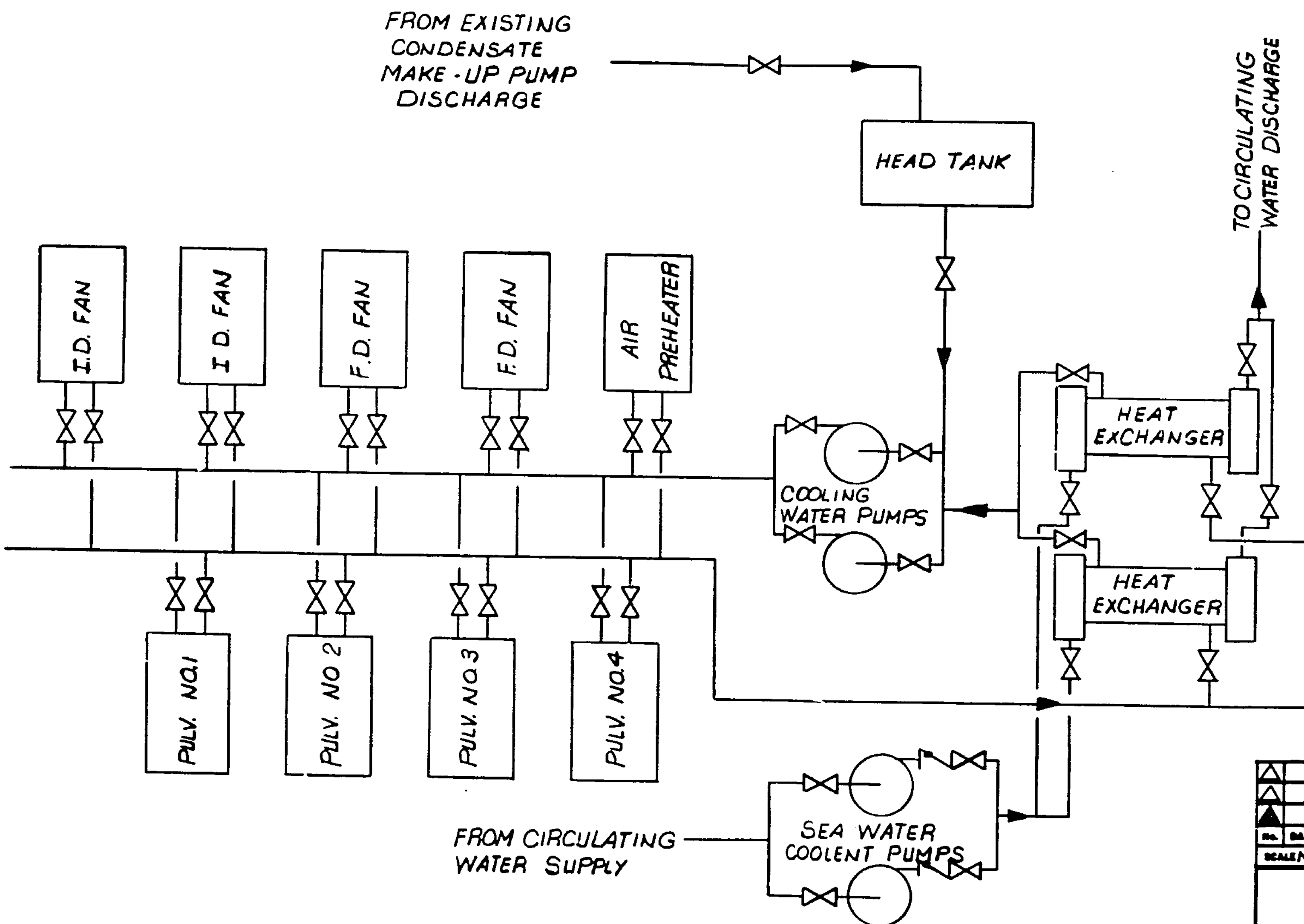
SCALE NONE | DESIGNED | DRAWN JR | CHIEF ENGR.

**BECHTEL**
GAITHERSBURG, MD.

GOVERNMENT OF JAMAICA
COAL FEASIBILITY STUDY PHASE II

MAIN STEAM AND FEEDWATER SYSTEM
FLOW DIAGRAM

| JOB No. | | REV. |
|---|---|---|
| 15307 | Figure 3-5 | A |




| No. | DATE | REVISIONS | BY | CH'K | | ENG'R | PROJ. ENGR. | APPD |
|---|---|---|---|---|---|---|---|---|
| | | ISSUED FOR REPORT | JR | | | | | |

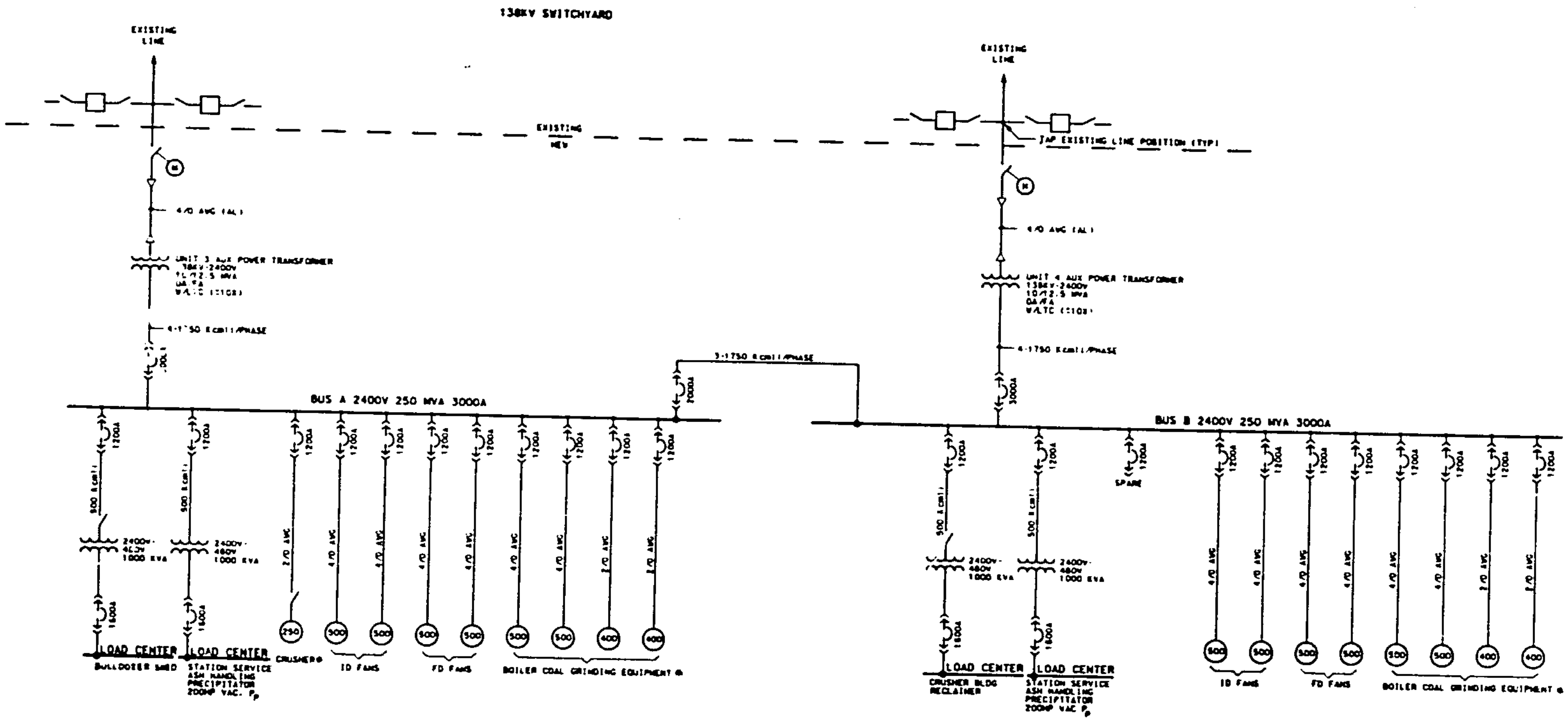
SCALE NONE | DESIGNED | DRAWN JR | CHIEF ENGR.

**BECHTEL**
GAITHERSBURG, MD.

GOVERNMENT OF JAMAICA
COAL FEASIBILITY STUDY PHASE II

CLOSED COOLING WATER SYSTEM
FLOW DIAGRAM

| JOB No. | | REV. |
|---|---|---|
| 15307 | Figure 3-10 | A |




NOTE

- THE EQUIPMENT LISTED AS BOILER COAL GRINDING, AND THE 250HP CRUSHER, ARE BASED ON A COMPOSITE OF VARIOUS MANUFACTURERS EQUIPMENT. WHEN SPECIFIC MANUFACTURERS ARE SELECTED THESE HORSEPOWER & BREAKER LOADINGS WILL BE ADJUSTED ACCORDINGLY. MOTORS UNDER 250HP WILL BE SUPPLIED FROM 480V LOADCENTERS OR MCC'S.

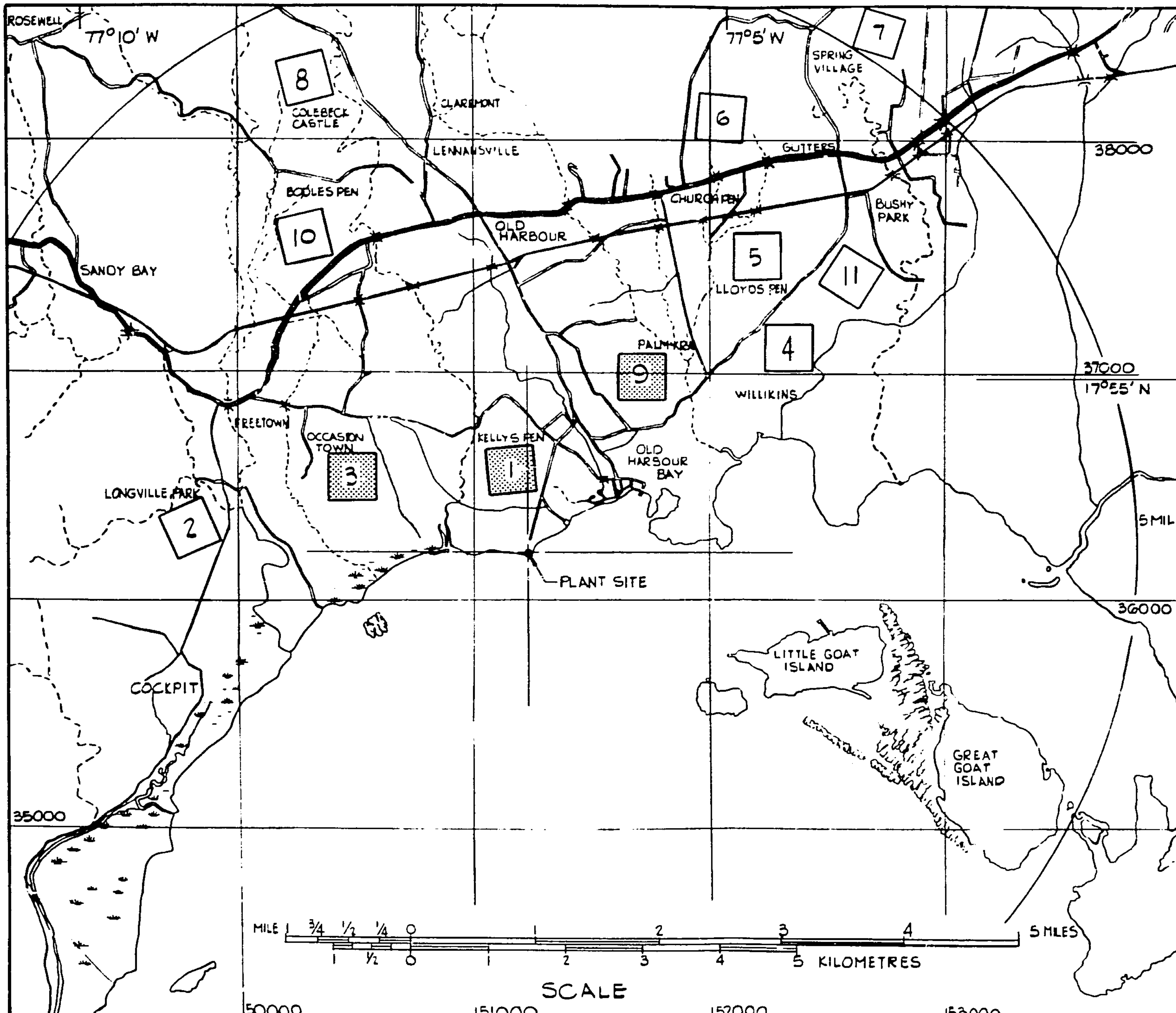
| | |
|---|---|
| △ | ISSUED FOR REPORT |

**BECHTEL**
GAITHERSBURG, MARYLAND

GOVERNMENT OF JAMAICA
COAL FEASIBILITY STUDY PHASE 2

SINGLE LINE DIAGRAM
OLD HARBOUR POWER STATION

| JOB NO. | | REV. |
|---|---|---|
| 15307 | Figure 3-11 | A |




| No | DATE | REVISIONS | BY | CH'K | DES SUPV | ENG'R | PROJ ENGR | APP |
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SCALE — DESIGNED — DRAWN J. Slater CHIEF ENGR

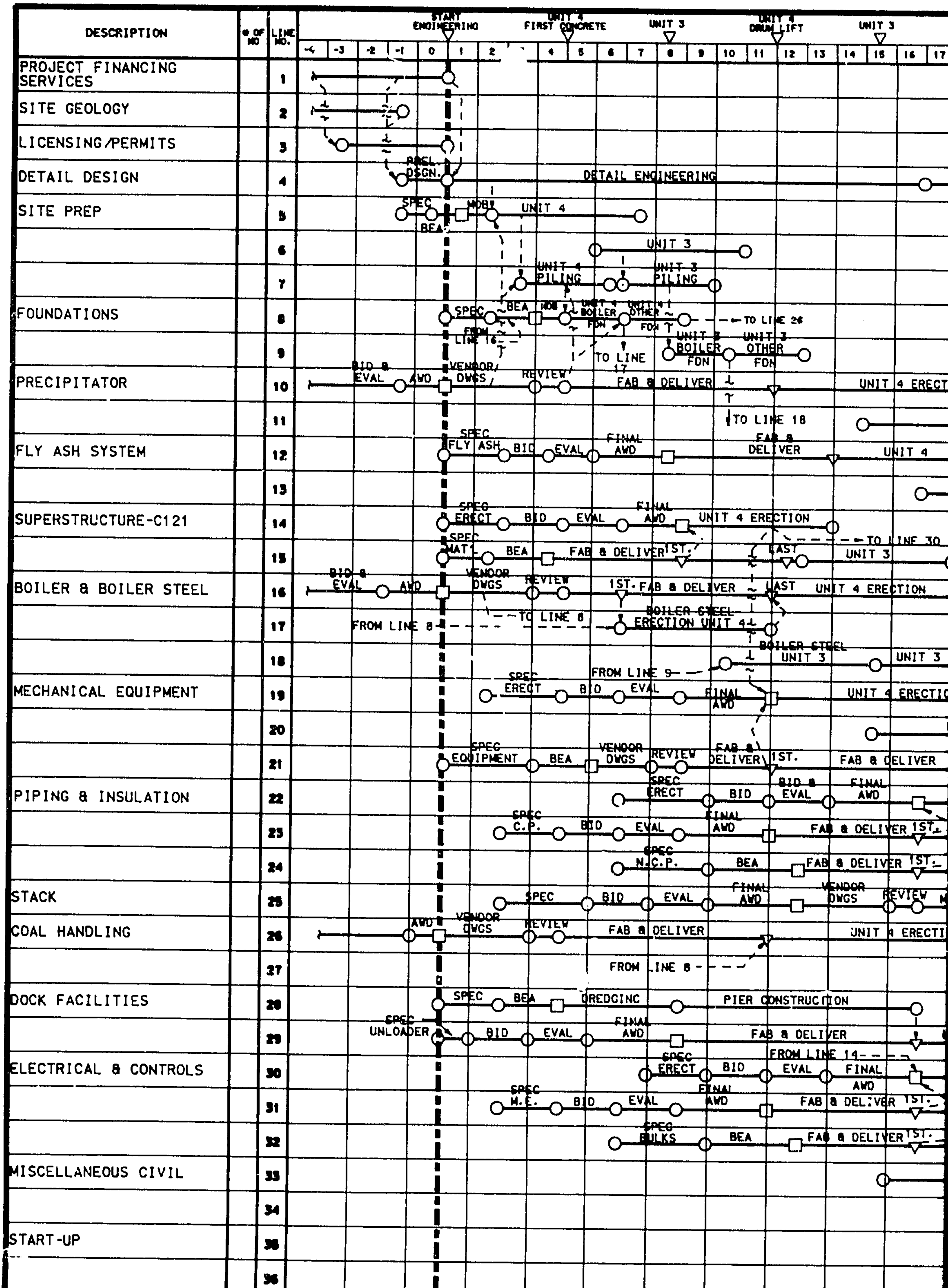
**BECHTEL**
GAITHERSBURG, MD.

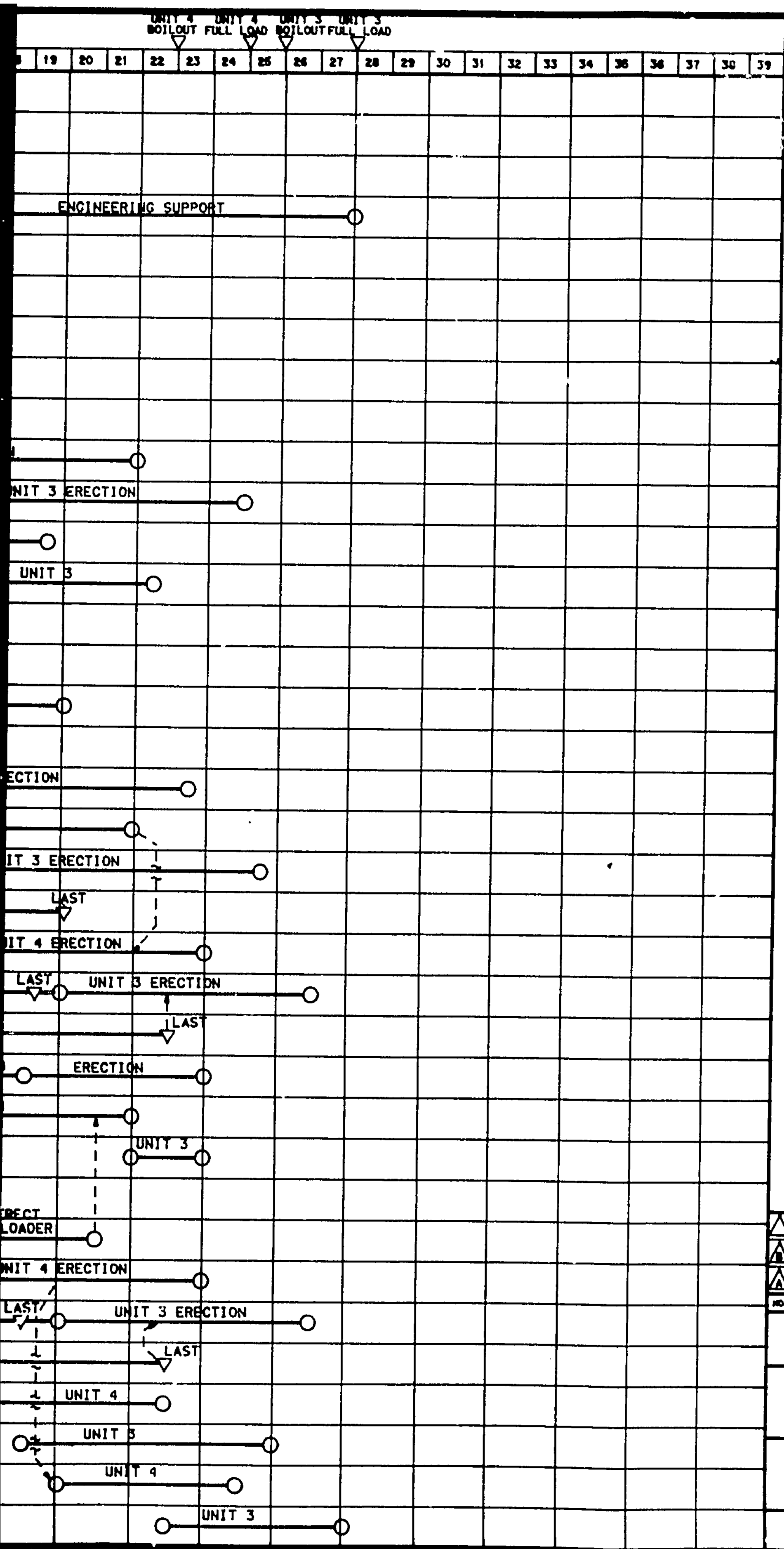
GOVERNMENT OF JAMAICA
OLD HARBOUR PLANT
COAL CONVERSION STUDY

ALTERNATIVE
ASH DISPOSAL SITES

JOB No. | Figure 3-12 | REV

N59143


DESCRIPTION
# OF NO
LINE NO.
START ENGINEERING
UNIT 4 FIRST CONCRETE
UNIT 3
UNIT 4 DRUM LIFT
UNIT 3
-4 -3 -2 -1 0 1 2 4 5 6 7 8 9 10 11 12 13 14 15 16 17
PROJECT FINANCING SERVICES 1
SITE GEOLOGY 2
LICENSING/PERMITS 3
DETAIL DESIGN 4
PREL. DSGN.
DETAIL ENGINEERING
SITE PREP 5
SPEC
MOBE
BEA
UNIT 4
6
UNIT 3
7
UNIT 4 PILING
UNIT 3 PILING
FOUNDATIONS 8
SPEC
BEA
MOB
UNIT 4 BOILER FDN
UNIT 4 OTHER FDN
TO LINE 26
9
FROM LINE 16
UNIT 3 BOILER FDN
UNIT 3 OTHER FDN
TO LINE 17
PRECIPITATOR 10
BID & EVAL
AWD
VENDOR DWGS
REVIEW
FAB & DELIVER
UNIT 4 ERECT
11
TO LINE 18
FLY ASH SYSTEM 12
SPEC FLY ASH
BID
EVAL
FINAL AWD
FAB & DELIVER
UNIT 4
13
SUPERSTRUCTURE-C121 14
SPEC ERECT
BID
EVAL
FINAL AWD
UNIT 4 ERECTION
15
SPEC MAT'L
BEA
FAB & DELIVER
1ST.
LAST
TO LINE 30
UNIT 3
BOILER & BOILER STEEL 16
BID & EVAL
AWD
VENDOR DWGS
REVIEW
1ST.
FAB & DELIVER
LAST
UNIT 4 ERECTION
17
FROM LINE 8
TO LINE 8
BOILER STEEL ERECTION UNIT 4
18
BOILER STEEL UNIT 3
UNIT 3
MECHANICAL EQUIPMENT 19
SPEC ERECT
BID
EVAL
FROM LINE 9
FINAL AWD
UNIT 4 ERECTION
20
21
SPEC EQUIPMENT
BEA
VENDOR DWGS
REVIEW
FAB & DELIVER
1ST.
FAB & DELIVER
PIPING & INSULATION 22
SPEC ERECT
BID
BID & EVAL
FINAL AWD
23
SPEC C.P.
BID
EVAL
FINAL AWD
FAB & DELIVER
1ST.
24
SPEC N.C.P.
BEA
FAB & DELIVER
1ST.
STACK 25
SPEC
BID
EVAL
FINAL AWD
VENDOR DWGS
REVIEW
COAL HANDLING 26
AWD
VENDOR DWGS
REVIEW
FAB & DELIVER
UNIT 4 ERECTI
27
FROM LINE 8
DOCK FACILITIES 28
SPEC
BEA
DREDGING
PIER CONSTRUCTION
29
SPEC UNLOADER
BID
EVAL
FINAL AWD
FAB & DELIVER
ELECTRICAL & CONTROLS 30
SPEC ERECT
BID
EVAL
FINAL AWD
FROM LINE 14
31
SPEC M.E.
BID
EVAL
FINAL AWD
FAB & DELIVER
1ST.
32
SPEC BULKS
BEA
FAB & DELIVER
1ST.
MISCELLANEOUS CIVIL 33
34
START-UP 35
36




## LEGEND

- ◯ ENGINEERING / CONSTRUCTION
- ☐ PROCUREMENT
- ▽ DELIVERY
- ▽ MILESTONE

## NOTES:

1. NO FLUE GAS DESULPHURIZATION SYSTEM.
2. ALL EXISTING PLANT SUPPORT FACILITIES FOR NEW BOILERS
3. PHASE II ENGINEERING ACTRIVITIES TO INCLUDE: SITE GEOLOGY COMPLETE, COAL HANDLING SYSTEM, BOILER & PRECIPITATOR, VENDORS SELECTED, CONSTRUCTION / MANPOWER RESOURCES AVAILABLE.

AWD - AWARD
BEA - BID, EVALUATE, AWARD
CP - CRITICAL PIPE
NCP - NONCRITICAL PIPE
FDN - FOUNDATION
ME - MAJOR EQUIPMENT

**FIGURE 3-13**

| NO. | DATE | REVISION | BY | CHK'D | SUPP ENGR | ENGR | PROC | CONST | PROJ |
|---|---|---|---|---|---|---|---|---|---|
| 3 | | | | | | | | | |
| 2 | | ISSUE FOR PHASE II STUDY (DRAFT) | | | | | | | |
| 1 | | ISSUE FOR PHASE I STUDY | RG | MK | | | | | |

**COAL CONVERSION OLD HARBOUR STATION**

**JAMAICAN MINISTRY OF MINING & ENERGY**

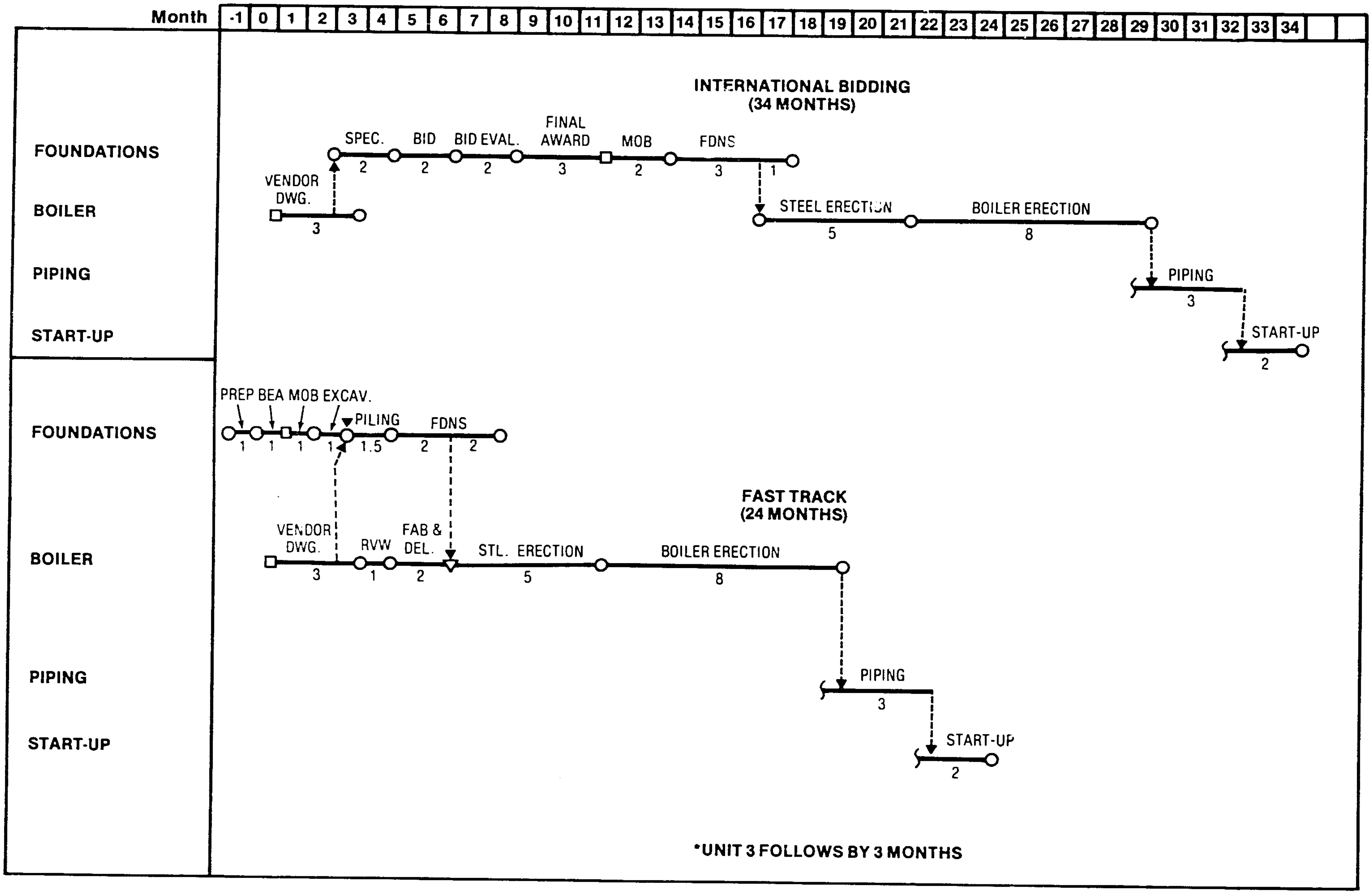
**ENGINEERING / CONSTRUCTION MILESTONE SCHEDULE**

| JOB NO. | DRAWING NO. | REV |
|---|---|---|
| 15307 | MSS-1 | B |

DFN=QS1:(50,8) JAMSS1.DGN

**FIGURE 3-14**

**COMPARISON OF CRITICAL PATHS (UNIT 4 ONLY)***




*UNIT 3 FOLLOWS BY 3 MONTHS

# 4.0 PRICING OF PRINCIPAL EQUIPMENT

## 4.1 GENERAL

An essential element in the refinement of capital costs identified in the Phase I study was the confirmation of principal equipment costs. Even more crucial in determining project viability was the identification of financing sources and costs related to the purchase and installation of such equipment. In order to obtain valid data rather than budgetary information only, the following procedures and documents were developed and utilized:

- o Detailed specifications were written for supply and erection of the steam boilers, electrostatic precipitators, coal handling system, and ship unloader.

- o Inquiries were made on an international basis in developing bidder lists consisting of firms with requisite qualifications, an indicated capability of supplying export credit financing, and interest in the project.

- o Bid documents were developed containing the preferred terms and invitations issued to obtain competitive bids from an international base with a wide spectrum of financing sources. The bid invitations requested that proposals include firm pricing for supply and erection, a financial proposal, appropriate technical data, and a validity period of 180 days from the due date. The bid documents clearly advised prospective bidders that any awards would be contingent upon receipt of final financing arrangements by the owner (JPS) and final project approval by the Government of Jamaica.

The following 14 bidders with country of origin were invited to submit proposals for the steam generator:

Ansaldo S.P.A. (Italy)
Babcock Power Limited (England)
Babcock & Wilcox International, Inc. (U.S.A./Canada)
Combustion Engineering, Inc. (U.S.A.)
CBC Industrias Pesedas S.A. (Brazil)
Franco Tosi Industriale S.P.A. (Italy)
GASA-Gureel Arajuo Industria E. Commercio, S.A. (Brazil)
Hyundai Corporation (Korea)
Lancaster-Distral Group (U.S.A./Colombia)
Marubeni American Corp. (Japan)
Mecanicas, Inc. (Spain)
Mitsubishi Heavy Industries, Ltd. (Japan)
Samsung Shipbuilding & Heavy Industries, Co., Ltd. (Korea)
Sumitomo Corporation (Riley-Mitsui Consortium) (U.S.A./Japan)

These bidders were given 10 weeks to prepare their technical offering and 12 weeks to complete their commercial offering.

The following nine b'dders responded to the bid invitation for the steam generator:

Ansaldo S.P.A.
Babcock Power Limited
Babcock & Wilcox International, Inc.
Combustion Engineering
Franco Tosi Industriale S.P.A
Lancaster-Distral Group
Marubeni American Corp.
Samsung Shipbuilding & Heavy Industries Co., Ltd.
Sumitomo Corporation (Riley-Mitsui Consortium)

The following 14 bidders with country of origin were invited to submit proposals for the coal handling system:

Ansaldo North America, Inc. (Italy)
Babcock-Moxey, Ltd. (England)
Dravo-Wellman Company (U.S.A.)
Combustion Engineering, Inc. (U.S.A.)
FMC Corporation (U.S.A.)
Hyundai Corporation (Korea)
Lancaster-Distral Group (U.S.A./Colombia)
Marubeni American Corporation (Japan)
Mecanicas, Inc. (Spain)
Midwest Conveyor Company, Inc. (U.S.A.)
PACECO, Inc. (U.S.A.)
PHB Weserhutte, Inc.-PWH (U.S.A./West Germany)
Samsung Shipbuilding & Heavy Industries Co., Ltd. (Korea)
Sumitomo Corporation (Riley-Mitsui Consortium) (U.S.A./Japan)

These bidders were given 8 weeks to prepare their technical and commercial offerings. The following four bidders responded to the bid invitation for the coal handling system:

Ansaldo S.P.A.
Babcock-Moxey, Ltd.
FMC Corporation
Lancaster-Distral Group
Samsung Shipbuilding & Heavy Industries Co., Ltd.

The following 12 bidders with country of origin were invited to submit proposals for the electrostatic precipitator:

Babcock & Wilcox International, Inc. (U.S.A./Canada)
CBC Industrias Pesedas S.A. (Brazil)
Combustion Engineering, Inc. (U.S.A.)
Dresser Industries, Inc. (Lodge-Cottrell) (U.S.A.)
Environmental Elements Corporation (U.S.A.)
Flakt Industri - A.B. (Sweden)
General Electric Environmental Services, Inc. (U.S.A.)
Lancaster-Distral Group (U.S.A./Colombia)
Marubeni America Corporation (Japan)
Mecanicas, Inc. (Spain)
Research-Cottrell (Head Wrightson) (U.S.A./England)
Sumitomo Corporation (Riley-Mitsui Consortium) (U.S.A./Japan)

These bidders were given 8 weeks to prepare their technical and commercial offerings. The following seven bidders responded to the bid invitation for the electrostatic precipitator:

Babcock & Wilcox International, Inc.
Combustion Engineering, Inc.
Dresser Industries, Inc. (Lodge-Cottrell)
Flakt Industri - A.B.
General Electric Environmental Services, Inc.
Lancaster-Distral
Research-Cottrell (Head Wrightson)

The following 14 bidders with country of origin were invited to submit proposals for the ship unloader:

Ansaldo North America, Inc. (Italy)
Babcock-Moxey, Ltd. (England)
Combustion Engineering, Inc. (U.S.A.)
Dravo-Wellman Company (U.S.A.)
FMC Corporation (U.S.A.)
Hyundai Corporation (Korea)
Marubeni America Corporation (Japan)
Mecanicas, Inc. (Spain)
Midwest Conveyor Company, Inc. (U.S.A.)
PACECO, Inc. (U.S.A)
PHB Weserhutte, Inc.-PWH (U.S.A./West Germany)
SALWICO, Inc. (U.S.A./Sweden)
Samsung Shipbuilding & Heavy Industries Co., Ltd. (Korea)
Sumitomo Corporation (Riley-Mitsui Consortium) (U.S.A./Japan)

These bidders were given 8 weeks to prepare their technical and commercial offerings. The following three bidders responded to the bid invitation for the ship unloader:

Babcock-Moxey, Ltd.
PACECO, Inc.
PHB Weserhutte, Inc.-PWH

Proposals received were subjected to preliminary technical, financial, and commercial review to select those for further consideration and detailed evaluation by Engineering, Financial Services, and Procurement. The methodology utilized in these evaluations, results, and recommended courses of action are contained in the following three sections of this chapter:

- Technical Analysis
- Financing Proposal Analysis
- Commercial Analysis and Recommendations

SECTIONS 4.2, 4.3, AND 4.4 HAVE BEEN DELETED FROM THIS COPY OF THE REPORT TO MAINTAIN CONFIDENTIALITY OF THE BIDDERS' PROPOSALS.

TABLES 4-1 THROUGH 4-12 HAVE BEEN DELETED FROM THIS COPY OF THE REPORT TO MAINTAIN CONFIDENTIALITY OF THE BIDDERS' PROPOSALS

# 5.0 COAL PROCUREMENT

## 5.1 COAL REQUIREMENTS

The initial stage in the oil-to-coal conversion is to convert Old Harbour Station Units 3 and 4. Each new coal-fired boiler will require 26 metric tons per hour at maximum continuous rating (assuming 12,500 Btu/pound coal, which is average for the coals offered by the coal suppliers). Annual coal requirements are based upon an overall plant capacity factor of 70 percent and the following annual operating schedule:

| Plant Load, MW | Percent of MCR | Operating Hours |
|---|---|---|
| 68.5 | 100 | 4600 |
| 44.5 | 65 | 2360 |
| 0 | 0 | 1800 |

Annual coal requirements for both boilers operating at 70 percent capacity factor is 321,400 metric tons. The port facilities and coal unloading system described in subsection 3.5.1 can easily handle 1,200,000 metric tons of coal per year by modifying the coal storage area and stackout system. The coal reclaim system described in Subsection 3.5.2 can supply coal to Old Harbour Units 3 and 4 and a future boiler for Unit 2 by extending the horizontal silo feed conveyor.

The Caribbean Cement Company annual coal requirements of 120,000 metric tons would be shipped directly to Caribbean Cement Company facilities and not pass through Old Harbour. Plans for the use of coal in the alumina producing facilities have been delayed due to the existing market demand for alumina. Table 6-1 in the Phase I report projected annual coal requirements for the alumina industry of 1,280,000 metric tons. In addition, new coal-fired steam generating units for the Jamaica Public Service Company system could increase annual coal requirements.

The Old Harbour coal terminal can be expanded in the future to accommodate increased coal consumption in Jamaica. The channel depth would be increased to permit larger ships. A parallel coal unloading system with larger capacity and capability for direct barge loading could be added for transshipment to other coal users in Jamaica. The future coal unloading conveyor would transport coal north of the proposed coal handling storage area. Rail loading facilities would be provided at the north coal terminal.

## 5.2 COAL STORAGE

The coal yard has provisions for an inactive coal pile of 75,000 metric tons. This quantity can store sufficient coal to fire both boilers at full load for 60 days or at a 70 percent capacity factor for 85 days. The active coal pile has been sized for 25,000 metric tons to permit unloading of the 20,000 metric ton coal ships onto the active pile.

Although the inactive pile can store sufficient coal for 85 days, careful stockpile management could reduce the normal quantity of coal stored, particularly since standby oil firing capability for both boilers is available. The coal pile would be at maximum capacity prior to coal suppliers' contract expiration dates for union miners and transportation workers. Contract expiration dates occur every 3 years. The normal inactive pile would contain considerably less coal. Bechtel suggests that the normal inactive pile should contain 40,000 metric tons, which is sufficient for 45 days at a 70 percent capacity factor.

## 5.3 COAL PROCUREMENT

A discussion on the quality of coal to be purchased can be found on Pages 6-2, 6-3, and 6-4 in the Phase I report. Based on quotations from U.S. coal suppliers received in 1982 and consideration of factors affecting the plant operation and environment, a coal specification such as the following has been used for obtaining coal quotations:

| | Nominal | Extreme |
|---|---|---|
| Heat valve (HHV), Btu/lb | 12,500 | 11,500 min. |
| Sulfur, percent | 1.0-1.5 | 0.6-2.0 max. |
| Ash, percent | 10.0 | 15.0 max. |
| Moisture, percent | 6.0 | 10.0 max. |
| Volatile matter, percent | 33.0 | 30 to 36 |
| Ash softening temperature, F (reducing) | 2400 | 2200 min. |
| Hardgrove Grindability Index | 60 | 50 min. |

This specification represents a reasonable compromise of cost, environmental impact, ash quantity, and boiler plant impact. The specification listed is compatible with coal found in eastern United States, Colombian, and British mines.

A letter of inquiry was sent to 12 producers of bituminous coal. The producers included several U.S. suppliers that offered coal at competitive prices and quality last year plus two additional U.S. coal suppliers, two coal suppliers from Colombia, and the National Coal Board of Great Britain (see Table 5-1).

A total of 11 written expressions of interest involving 15 coal properties were received. Each of the companies demonstrates reserves capable of supplying 330,000 metric tons per year. Table 5-2 displays approximate coal data as provided by the responding coal companies. Data should be regarded as comparative and subject to considerable variation, even among different samples from the same mine.

The coal procurement strategy recommended is based upon one long-term contract which should provide the majority of the requirements, with spot purchases serving to correct stockpile size and offset irregularities in coal usage as well as take advantage of favorable short-term price fluctuations. During recent years, spot purchase prices have been lower than contract prices due to an excess supply of coal. This excess supply of coal in the United States is due to world recession, bulging U.S. utility stockpiles, and the strong U.S. dollar. Spot purchases should provide up to 20 percent of the total requirement.

Contractual conditions are perceived to be highly negotiable and only provide a limited price protection. All coal companies insist on an escalation clause, which would effectively pass on cost increases due to material and labor escalation regulatory restrictions, and tax changes. Reopener contract clauses every 1 to 5 years are also required. The intent of this clause is to adjust for market price changes in the long-term contract.

The delivered cost (per million Btu) of coal provides a good benchmark for comparing alternative coal purchases. To some extent, it corrects the distorted cost per ton values for differing freight cost, moisture content, ash content, and heating value.

All U.S. coal suppliers provided coal prices at the mine or coal preparation plant, freight rates to a U.S. port, and port charges for loading ships. The price per million Btu FOB U.S. port ranges from $1.80 to $2.30 per million Btu. Neither Colombian coal supplier would provide a coal price. However, a Colombian coal supplier stated that their price would be relative to the market price for comparable U.S. coal at the point of delivery. The National Coal Board price for coal is $1.65 per million Btu, FOB Immingham, England. Table 5-3 shows the comparative coal costs, FOB port of export for the United States and Great Britain coal suppliers. Bechtel would expect considerable additional negotiation to be in order prior to contract execution because the current market is still a buyer's market and potential suppliers would not be expected to present their lowest quotations to this inquiry.

## 5.4 COAL PORT FINANCING

The letter of inquiry to the coal producers invited them to provide the financing for the unloading berth for the colliers and the dredging of the ship channel. Approximately half of the coal producers or suppliers expressed some interest in future financing or investment in the coal terminal.

One coal supplier might be interested in an equity participation of up to 50 percent of the total coal terminal investment required or the new coal terminal to be developed at Old Harbour Station. This participation may involve either providing equipment, engineering services, and supplies, or providing the funds required.

A second supplier is working closely with the Pan Jamaican Investment Trust, Ltd. and Pan Caribbean Merchant Bank of Jamaica to explore several possible alternatives for port financing.

A third supplier might consider an arrangement that permits extended payment terms. The benefit to Jamaica for delayed payment plan is to provide a working capital fund with which Jamaica could retire the short-term debt of the coal terminal. A surcharge to the coal price would be added to cover this company's financing costs.

A fourth supplier is receptive to sharing lease, joint venture, partnership or other business arrangements under which the coal port facility would be operated. This arrangement is subject to further discussions and agreements. They are also receptive to financing the proposed coal terminal and adjusting the price of coal in a long-term contract to recoup its financing over the term of the agreement. They suggest that discussions be held with the Government of Jamaica concerning a joint mining venture, which would yield significant benefits.

A fifth company would be pleased to assist the Government of Jamaica in providing financing for the coal terminal and would also be willing to assist in any other portion of the total coal conversion projects. This company will need to review the detailed project analysis and projections and then would be in a position to discuss financing alternatives.

A sixth coal supplier is not interested in financing the coal terminal, but expressed an interest in equity participation. Financing of the coal terminal is under consideration by the seventh company, but at present no decision has been made regarding equity participation.

## 5.5 COAL TRANSPORTATION

To minimize capital cost requirements for the initial stage of the coal conversion project, the channel to Old Harbour Power Station will be dredged to an initial depth of 30 feet. Colliers in the 20,000 dwt range would be utilized to transport coal from either the United States or Colombia. Ships would arrive at Old Harbour at 3-week-intervals.

Spot charter rates from the United States to the Caribbean area for gearless ships of this size are presently less than U.S. $7 per metric ton. A consensus of what normal 3-to-5-year present charter rates run for vessels in the 20,000 dwt range is U.S. $9.00 per metric ton for ocean transport from the United States to Jamaica. This estimate could easily vary depending upon the state of the charter market at a particular time, length of the charter period, and the specific type and size of the ship.

The distance between Colombia and Jamaica is about 500 nautical miles compared to about 1200 to 1400 nautical miles between the United States and Jamaica. Transport costs per metric ton would be approximately U.S. $7.00 to Jamaica from Colombia.

In addition, a Jamaica port cost of U.S. $0.40 per metric ton was added as a charge for delivery of coal at the Jamaica port to cover port operating costs.

For the purposes of this study, ocean transportation was assumed to be in gearless vessels. This assumption was made because this type of vessel is common in international boat trades. The use of self-unloading vessels, which are much less common, would increase ocean transport cost by U.S. $1.50 per metric ton. This additional annual cost of U.S. $482,000 for freight in self-unloading ships is comparable to the annualized cost of a shore-sideship-unloader. Hence, ready availability of gearless vessels for time charter, and the known technology of shore-side unloading offer a system with maximum flexibility in handling coal from various sources in different vessel types. This position could change depending on the concessions or offers made by coal suppliers in the final negotiation.

## 5.6 FUEL PRICE

The fuel savings projected in the Financing Plan, Section 6.0 are based on oil costs reported on August 1, 1983 in Platts Oilgram for 2.8 percent sulfur Caribbean cargoes, and coal costs from current published listings.*

The current price of oil used in this study is $28.47 per barrel at the JPS plant at Old Harbour, based on information received from the Petroleum Corporation of Jamaica regarding charges for handling, insurance, losses and other miscellaneous expenses, and the published price for 2.8 percent sulfur Caribbean cargoes of $25.00 per barrel. The $28.47 oil price equates to $4.52 per million Btu at Old Harbour.

Coal price was determined by adjusting the published export spot steam coal price for 12,000 Btu/lb, 1.5 percent sulfur, 12 percent ash coal at Hampton Roads/Norfolk, Virginia, U.S.A.

The following adjustments were made to the base coal price of $42.00 per metric ton:

- $1.75 added for coal at 12,500 Btu/lb higher heating value
- $5.10 added for average difference between spot and term contract prices for complaince coal
- ($1.02) credit for purchasing 20 percent of coal at spot prices.
- $0.85 added for port loading fees
- $9.00 estimated for ocean shipping to Old Harbour port
- $0.40 allowed for Jamaica port fee.

The current price for coal used in this study is $58.08 per metric ton, Jamaica. This price equates to $2.11 per million Btu at Old Harbour.

The coal and oil prices for this study are assumed to be firm through December 31, 1985.

*Coal Week, August 1, 1983, page 5

TABLE 5-1

LIST OF COAL COMPANIES CONTACTED

| Company | Address |
|---|---|
| Atlantic Export Corporation | 1700 19th Street, N.W.<br>Washington, D.C. 20009 |
| Carbocol (Carbonas de Colombia S.A.) | CRA 7 No. 31-10-P12<br>Bogota, Columbia |
| Columbia Coal Gasification Corporation* | 340-17 Street<br>Ashland, Kentucky 41101 |
| Consolidated Coal Company | Consol Plaza<br>Pittsburgh, Pennsylvania, 15241 |
| Diamond Shamrock Coal Sales Corporation | 1200 First Security Plaza<br>Lexington, Kentucky, 40506 |
| Esso Inter-America, Inc.<br>(Cerrejon, Colombia Coal) | 396 Alhambra Circle<br>Coral Gables, Florida 33134 |
| Inter-Mountain Coals, Inc.<br>(AMVEST Corporation) | One Boars Head Place<br>P.O. Box 5347<br>Charlottesville, Virginia 22905 |
| Kentucky Export Resources<br>Authority, Inc. | Suite 1505, Vine Center<br>333 West Vine Street<br>Lexington, Kentucky 40507 |
| MAPCO, Inc. | 1437 South Boulder Avenue<br>Tulsa, Oklahoma 74119 |
| Marine Coal Sales, Inc.<br>(Ziegler Coal Corporation) | 9011 North Meridian Street<br>Indianapolis, Indiana 46260 |
| National Coal Board | Hobart House, Grosvenor Place<br>London Seix 7AE, England |
| Pittston Coal Export Corporation | One Pickwick Plaza<br>Greenwich, Connecticut 06830 |

*Verbal request.

## TABLE 5-2

## COMPARATIVE COAL AND ASH ANALYSIS FOR TENDERED COAL PROPERTIES

| COMPANY AND MINE | Carbocol Cerrejon Zone North | Columbia Coal Gas Daisy | Consolidated Westland II | Dia Sham Paragon No. 1 | Dia Sham Lundale/ MacGregor | Esso I-A Cerrejon | Inter-Mtn Glamorgan | Ky Ex Res Big Sandy Coop | MAPCO Martiki | Marine C.S. Elkhorn No. 3 | Marine C.S. Illinois No. 6 | Marine C.S. Secor Seam | N.C.B. Immingham Blended | Pittston Badger/ Grand Badger | Pittston Rum Creek |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PROXIMATE ANALYSIS, WT%** | | | | | | | | | | | | | | | |
| Moisture | 9.2 | 8 | 5-7 | 5.0 | 6.0 | 9.2 | 6-8 | 8-9 | 6.7 | 4.04 | 10.20 | 4.75 | 11-12 | 6-7 | 6-7 |
| Volatile Matter | 34.9 | 30-36 | 33-38 | 31.5 | 33.5 | 34.9 | 31-33 | 25-35 | 32.4 | 36.13 | 30.34 | 34.30 | 30 | 35 | 33-34 |
| Fixed Carbon | 47.9 | 44-55 | 45-54 | 51.0 | 48.0 | 47.9 | 49-55 | 44-55 | 52.8 | 55.0 | 53.75 | 54.55 | 47-49 | 46 | 49-51 |
| Ash | 8.0 | 8-12 | 8-10 | 12.5 | 12.5 | 8.0 | 8-10 | 12 | 8.1 | 4.83 | 5.71 | 3.40 | 10-11 | 13 | 10 |
| HHV, Btu/lb | 11,900 | 12,000 | 12,900 | 12,600 | 12,300 | 11,900 | 12,500 | 12,000 | 12,500 | 13,896 | 12,083 | 13,308 | 11,800 | 12,500 | 12,500 |
| HGI | 48 | 52-57 | N/A | 53 | 50 | 48 | 56-63 | 48 | 45 | N/A | 60 | N/A | 57 | 53 | 48-50 |
| **ULTIMATE ANALYSIS, WT%** | | | | | | | | | | | | | | | |
| Carbon | 67.8 | 70.84 | 73.13 | 69.93 | 71.72 | 67.8 | 74.46 | N/A | 69.05 | 79.55 | 69.47 | 74.38 | 66.38 | 70.0 | 71.13 |
| Hydrogen | 4.6 | 4.60 | 5.00 | 4.53 | 4.50 | 4.6 | 4.90 | N/A | 5.51 | 4.48 | 4.44 | 4.86 | 4.13 | 4.8 | 4.67 |
| Oxygen | 8.57 | 5.45 | 5.09 | 4.83 | 3.44 | 8.57 | 5.46 | N/A | 8.56 | 4.05 | 7.62 | 6.10 | 4.59 | 3.7 | 5.24 |
| Nitrogen | 1.2 | 1.38 | 1.49 | 1.44 | 1.16 | 1.2 | 1.37 | N/A | 1.47 | 1.71 | 0.98 | 1.79 | 1.40 | 1.2 | 1.37 |
| Sulfur | 0.6 | 1.50 | 2.01 | 1.60 | 0.6 | 0.6 | 1.44 | 1 | 0.93 | 1.25 | 0.99 | 1.45 | 1 5 | 1.3 | 0.85 |
| Moisture | 9.2 | 8.0 | 5.00 | 5.0 | 6.0 | 9.2 | 7.0 | 9 | 6.65 | 4.04 | 10.20 | 4.75 | 11.5 | 5.8 | 6.50 |
| Ash | 8.0 | 8.0 | 8.27 | 12.5 | 12.5 | 8.0 | 5.37 | 12 | 7.75 | 4.83 | 5.77 | 6.40 | 10.5 | 13.0 | 10.0 |
| Chlorine | 0.03 | 0.23 | 0.01 | 0.17 | 0.03 | 0.03 | N/A | N/A | 0.08 | 0.09 | 0.53 | 0.26 | N/A | 0.2 | 0.24 |
| **ASH FUSION TEMP (REDUCING), F** | | | | | | | | | | | | | | | |
| ID | 2260 | 2400 | N/A | 2420 | 2800 | 2260 | N/A | 2400 | 2800 + | 2290 | 2145 | N/A | 2120 | N/A | 2800 + |
| ST | 2380 | N/A | 2300 | 2570 | 2890 | 2380 | 2500 | N/A | 2800 + | 2415 | 2265 | N/A | N/A | 2400 | 2800 + |
| HT | 2465 | N/A | N/A | 2630 | 2970 | 2465 | N/A | N/A | 2800 + | 2525 | 2393 | N/A | 2480 | N/A | 2800 + |
| FT | 2555 | N/A | N/A | 2650 | 2990 | 2555 | N/A | N/A | 2800 + | 2585 | 2525 | N/A | 2550 | N/A | 2800 + |
| **ASH ANALYSIS, WT%** | | | | | | | | | | | | | | | |
| $SiO_2$ | N/A | 44 | 50.37 | 52.33 | 55.67 | 62.7 | 40.39 | N/A | 54.07 | 45.29 | 52.64 | N/A | 49.8 | 44.31 | 51.18 |
| $Al_2O_3$ | N/A | 30 | 23.13 | 26.07 | 32.71 | 19.0 | 29.04 | N/A | 31.20 | 25.98 | 24.88 | N/A | 27.0 | 35.58 | 32.74 |
| $Fe_2O_3$ | N/A | 15 | 16.35 | 12.65 | 3.89 | 7.9 | 23.09 | N/A | 7.39 | 16.37 | 12.10 | N/A | 11.8 | 8.68 | 7.45 |
| $CaO$ | N/A | 1.6 | 2.51 | 0.97 | 0.58 | 2.0 | 1.89 | N/A | 1.65 | 2.46 | 1.78 | N/A | 2.3 | 2.13 | 2.49 |
| $MgO$ | N/A | 0.7 | 0.55 | 1.18 | 0.79 | 1.8 | 0.95 | N/A | 0.99 | 1.21 | 0.99 | N/A | 1.5 | 0.19 | 0.79 |
| $Na_2O$ | N/A | 0.6 | 0.58 | 0.58 | 0.61 | 1.1 | 0.62 | N/A | 0.34 | 1.39 | 1.62 | N/A | 1.6 | 0.13 | 0.35 |
| $K_2O$ | N/A | 2.2 | 1.78 | 3.55 | 2.16 | 1.9 | 1.84 | N/A | 1.94 | 1.71 | 2.27 | N/A | 3.0 | 1.47 | 1.61 |
| $TiO_2$ | N/A | 1.5 | 1.52 | 1.30 | 1.28 | 0.8 | 1.67 | N/A | 1.34 | 1.55 | 1.20 | N/A | 0.9 | 1.73 | 1.43 |
| $P_2O_5$ | N/A | 0.4 | 0.47 | 0.06 | 0.16 | 0.2 | 0.37 | N/A | 0.16 | 0.38 | N/A | N/A | 0.36 | 0.47 | 0.12 |
| $SO_3$ | N/A | 1.75 | 2.04 | 1.17 | 0.32 | 1.9 | 0.10 | N/A | 0.71 | 2.73 | N/A | N/A | 1.7 | 2.27 | 1.67 |
| Not Accounted For | N/A | 2.25 | 0.70 | 0.14 | 1.83 | 0.7 | 0.04 | N/A | 0.21 | 0.93 | 2.52 | N/A | 0.04 | 3.04 | 0.20 |

# TABLE 5-3

## COMPARATIVE COAL COSTS, FOB PORT OF EXPORT

| BIDDER<br>MINE<br>LOCATION | Carbocol | Columbia Coal Gasification<br>Daisy Preparation Plant<br>Daisy, W. Va. | Consolidated Coal<br>Westland II (Typical)<br>Southwester, Pa. - Northern W. Va. | Diamond Shamrock<br>Paragon No. 1<br>Man, Logan Co., W. Va. | Diamond Shamrock<br>Lundale/MacGregor<br>Man, Logan Co., W. Va. | Esso Inter-America<br>Cerrejon<br>Colombia | Inter-Mountain Coals<br>Glamorgan<br>Wise, Wise Co., Va. | Kentucky Export Resources<br>Auth. Big Sandy Cooperative<br>Pike Co., Letcher Co., Kentucky | MAPCO Coals, Inc.<br>Martiki<br>Martin Co., Kentucky | Marine Coal Sales<br>Elkhorn No. 3<br>East Kentucky | Marine Coal Sales<br>Illinois No. 6<br>Illinois | Marine Coal Sales<br>Secor Seam<br>Oklahoma | National Coal Board<br>Immingham Blended<br>England | Pittston Coal Export<br>Badger/Grand Badger<br>Meridan, Ours Mill, W. Va. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HHV (BTU PER POUND) | 11,900 | 12,000 | 12,900 | 12,600 | 12,300 | 11,900 | 12,500 | 12,000 | 12,500 | 13,896 | 12,083 | 13,308 | 11,800 | 12,500 |
| FOB MINE PRICE<br>Per Metric Ton | None Quoted | $39.14 | $39.69 | $36.38 | $36.38 | None Quoted* | $36.38 | $27.50 | $39.69 | $44.10 | $37.49 | $46.31 | $42.86 | $37.49 |
| Per Million Btu | | $ 1.48 | $ 1.40 | $ 1.31 | $ 1.34 | | $ 1.32 | $ 1.15 | $ 1.59 | $ 1.44 | $ 1.41 | $ 1.58 | $ 1.65<br>£28.00 | $ 1.36 |
| RAIL/BARGE AND COST | | C&O RR to Newport News, Va. | Conrail RR to Baltimore Md. | C&O RR to Newport News, Va. | C&O RR to Newport News, Va. | Included in Mine Price | Southern RR to Charleston, S.C. | Truck to Ashland, Ky., Barge to New Orleans, La. | Norfolk & Western RR to Lanberts Pt., Va. | Rail to Ohio, R. Barge to New Orleans, La. | Rail to Miss., R. Barge to New Orleans, La. | Truck to Arkansas, R. Barge to New Orleans, La. | Included in Above Price | B&O RR to Curtis Bay, Md. |
| Per Metric Ton | | $17.00 | $12.46 | $17.04 | $17.04 | — | $14.31 | $15.50 | $17.33 | $15.40 | $11.36 | $ 6.62 | — | $16.37 |
| Per Million Btu | | $ 0.64 | $ 0.44 | $ 0.61 | $ 0.63 | — | $ 0.52 | $ 0.65 | $ 0.69 | $ 0.50 | $ 0.43 | $ 0.23 | — | $ 0.59 |
| PORT AND PORT COST | Portete, Colombia | Newport News, Va. | Baltimore, Md. | Newport News, Va. | Newport News, Va. | Portete, Colombia Included Above | Charleston, S.C. | New Orleans, La. Included Above | Norfolk, Va. | New Orleans, La. | New Orleans, La. | New Orleans, La. | Immingham, England Included Above | Baltimore, Md. |
| Per Metric Ton | | $ 0.85 | $ 3.31 | $ 0.85 | $ 0.85 | | $ 2.76 | | $ 0.56 | $ 2.48 | $ 2.48 | $ 2.48 | | $ 0.85 |
| Per Million Btu | | $ 0.03 | $ 0.12 | $ 0.03 | $ 0.03 | | $ 0.10 | | $ 0.02 | $ 0.08 | $ 0.09 | $ 0.08 | | $ 0.03 |
| TOTAL PRICE, FOB SHIP PORT OF EXPORT PER MILLION Btu | | (2.15) | (1.96) | (1.95) | (2.00) | | (1.94) | (1.80) | (2.30) | (2.02) | (1.93) | (1.89) | (1.65) | (2.01) |

*Comparable to U.S. Market Price

# 6.0 FINANCIAL ANALYSIS AND FINANCING PLAN

## 6.1 INTRODUCTION AND SUMMARY

This chapter presents the financial analysis of the project as well as the interest that has been expressed by various financial institutions to fund its implementation. In addition, a project financing plan is developed as well as a strategy for implementing the plan.

Results of the engineering, environmental, and financial analyses reported in this study support the preliminary conclusions of the Phase I study, i.e., the conversion from oil to coal of Old Harbour Units 3 and 4 is technically feasible and is economically a sound strategy for Jamaica. On the basis of the financing proposals received in support of bids for the major project components, and through extensive discussions with senior officials at the Inter-American Development Bank, the World Bank and other financial institutions, it is Bechtel's judgement that financing for this project can be arranged on favorable terms.

The analyses presented in this study demonstrate that under conservative assumptions, the potential savings from the conversion of oil to coal justify the capital investment required. The Base Case indicates that during their remaining life, Old Harbour Units 3 and 4 will generate cumulative net fuel savings, after incremental operating, maintenance, and technical assistance costs, of $968 million. This results in a favorable internal rate of return for the Base Case of 23.4 percent. Since this is substantially above the economic cost of capital in Jamaica estimated by the World Bank at 11 percent, it can be concluded that the project is economically viable under the assumptions of the Base Case. The payback period for the project, when all capital costs can be recovered from accumulated income, is about 5 years. The project produces a positive cumulative cash flow after debt service from the first year of operations.

A series of sensitivity analyses performed on the Base Case demonstrate that the project produces a satisfactory rate of return, has a reasonably short payout, and generates more than enough cash flow to cover all incremental operating costs and debt service obligations under very pessimistic scenarios. For example, assuming 0 percent annual escalation in oil prices, coal prices, and operating and maintenance costs, the rate of return decreases to 16.9 percent, the net fuel savings decrease to $446 million, and the payback period is lengthened to about 6 years.

A financing plan has been developed and used to prepare pro forma financial statements for the project and to perform the financial analyses. Details of the specific financing offers with comments are included in Section 4.3, the bid evaluation portion of this study.

Table 6-1 presents a summary of the sources of funds used in the preparation of the financing plan and cash flow analyses.

## 6.2 METHODOLOGY

An integral part of the cost estimating process for this project was the solicitation of international competitive bids from qualified suppliers on four packages for the supply and erection of the boilers, electrostatic precipitators, coal handling system and ship unloader. Since the availability of project financing is a critical objective of the Jamaica Coal Committee, each bidder was specifically requested to provide a financing package in support of its bid. This was designed to accomplish the following purposes:

- o Identify at the earliest possible stage of the study whether financing from export credit agencies was likely to be available for the project since this was identified as a key source of project financing.

- o Provide a realistic basis for the development of a financing plan for the project and the financial model for analysis of the project's pro forma cash flows.

- o Enable the evaluation of bids utilizing technical, financial, and commercial criteria.

- o Permit the development of a detailed financing strategy to obtain definitive financing commitments for implementation of the project if and when it is determined to be technically, economically, and financially viable and the Jamaica Coal Committee decides to proceed.

Financial projections were made for the project utilizing the capital and operating cost estimates presented in the study, coal and oil quantity consumption at different operating levels, oil and coal price assumptions, and the preliminary financing plan outlined in Section 6.4. Capital expenditures, including interest during construction, are presented in the statement of sources and uses of funds during the construction period (Table 6-8). Annual revenues from fuel savings and debt service are shown in cash flow statements from start-up in 1986 to the year 2008 (Table 6-9). Debt service obligations in each operating period are shown in Table 6-10. These financial statements provide a useful way to examine profitability, year-to-year liquidity, and sensitivity to differences in underlying assumptions (e.g., operating capacity, differences in price projections, and capital cost estimate).

## 6.3 ECONOMICS OF CONVERSION

The oil-to-coal conversion project considered in this study is part of an overall national strategy to develop a more efficient energy base and to fortify Jamaica's balance of payments by reducing the amount of foreign exchange devoted to the importation of fuel. On a strict Btu basis using current fuel prices for coal and oil delivered to the Old Harbour power plant, considerable savings can be realized through generating electric power with coal rather than oil. The objective is to determine whether the substantial capital investment required to convert Old Harbour Units 3 and 4 from oil to coal burning is justified by the savings of foreign exchange to the national economy.

The analyses presented in this study indicate that under conservative assumptions, the potential savings from the conversion of oil to coal justify the capital investment required.

### 6.3.1 Economic Assumptions

The Base Case analyses for the project are based upon conservative assumptions for fuel consumption, fuel prices of oil and coal, capital costs, and project financing. Details of the capital cost estimates and the financing plan are presented in Sections 3.13 and 6.4, respectively. The assumptions are summarized in Table 6-2.

Fuel consumption and operating and maintenance costs are based on the assumption that the plant will operate at only 70 percent capacity. Since a comprehensive maintenance and operations training program as well as technical assistance for 5 years are integral parts of this project and included in the costs, it is Bechtel's opinion that operating capacity could be above 70 percent, thus improving project economics. The sensitivity analyses presented in Subsection 6.3.3 illustrate the impact on the project's rate of return if the operating capacity for the Base Case is as low as 60 percent or as high as 80 percent.

The methodology for the selection of oil and coal prices is described in Section 5.6. These prices have been used in the Base Case and escalated at 6 percent per annum from start-up of operations in 1986 to 2008. Similarly, operating and maintenance (O&M) costs have been estimated for the year of project start-up and escalated at 6 percent per annum to 2008. Sensitivity analyses have been performed to determine the impact of alternate oil and coal price changes over the life of the project. These are presented in Subsection 6.3.3, and a complete set of pro forma cash flows for the Conservative Case with 0 percent escalation of oil, coal, and O&M costs is presented for comparative purposes in Tables 6-11 through 6-13.

### 6.3.2 Results

Tables 6-8 through 6-10 present the pro forma financial statements for the Base Case. The financial and economic viability of the project is indicated by its internal rate of return, by its ability to generate foreign exchange savings greater than the foreign exchange outlays required to cover all debt service obligations and incremental O&M costs, by the cumulative foreign exchange savings created by the project, and by the project's payback period.

The simple payback period is defined as the minimum time necessary for all capital costs (excluding financing costs) to be recovered from accumulated income.

Table 6-3 summarizes the Base Case results. The Base Case indicates that during the estimated project operating life of 23 years (1986 to 2008), the project will generate cumulative net fuel savings, after incremental O&M cost, of $968.4 million or an average of $42.1 million per year. Annual savings begin in 1986 at about $20 million and grow to $75 million in 2008. After deducting debt service payments, the net cumulative cash flow created by the project is $766 million. This results in an internal rate of return for the Base Case of 23.4 percent. This is above the economic cost of capital in Jamaica estimated by the World Bank at 11 percent, thus indicating that the project is economically viable under the conservative assumptions of the Base Case.

6.3.3 Sensitivity Analyses

A series of sensitivity analyses has been performed on the results of the Base Case to determine the effects of variations in several of the assumptions used in making the projections. This includes an evaluation of the impact on the Base Case results of future escalation in oil and coal prices at 0 percent, 6 percent, and 7 percent per annum in any combination and at capacity factors of 60 percent, 70 percent and 80 percent. The results of these analyses are presented in Figures 6-1 and 6-2.

Figure 6-1 illustrates the change in the project's internal rate of return resulting from various percentage changes in coal prices, oil prices, capacity utilization (i.e., quantities of fuel consumed and O&M costs), and capital costs. These factors vary independently of one another, and the graph was constructed under the assumption that all other factors are held constant when any one of them is changed. For example, if capital costs were to increase by 10 percent, the rate of return would decrease to 21.7 percent from the 23.4 percent of the Base Case.

Figure 6-1 demonstrates that the rate of return is most sensitive to variations in fuel prices and relatively less sensitive to variations in capital cost and capacity factor.

Figure 6-2 presents the impact of changes in one or more variables simultaneously on the project's rate of return. Escalation in fuel prices is compounded over the 23-year projection horizon, at rates which can be different for oil or coal prices. Tracing the arrows around the graph indicates that the Base Case assumptions for 6 percent price escalation for oil and coal and 70 percent capacity utilization results in a 23.4 percent rate of return. Similarly, results can be determined for any combination of price changes and capacity factors either directly or by extrapolation.

The cash flow schedules contained in Table 6-12 present the detailed financial results of one set of conservative sensitivity analyses which demonstrates the impact of annual price increases of 0 percent for coal, 0 percent for oil, and 0 percent for O&M costs on all other project parameters. From the perspective of the IDB or World Bank, this would be considered the "real" price and "real" rate of return analysis. Some of the data from the Base Case and various sensitivity analyses are summarized in Table 6-4.

A sensitivity analysis was also performed on the project construction schedule to determine the financial advantages of utilizing a fast track, 2-year construction schedule versus a 3-year conventional construction management schedule. The sensitivity analysis used the same assumptions as the Base Case except for capital costs and financing plan. The alternate financing plan was based on slightly different assumptions of a 6-month grace period after completion, rather than 1 year, and a larger IDB loan ($55 million) plus owner equity of about $5 million to fund the added IDC and somewhat higher capital cost. Results of this case indicate an increase of about $11 million in the financed capital cost to $129.5 million and somewhat lower ROR than for the fast-track Base Case (see Table 6-4). Under the 3-year case, the project experiences a slight negative cumulative cash flow (less than $1 million) in the third and fourth years after start-up.

It can be concluded from Table 6-4, the supporting schedules, and the sensitivity analyses that the project produces a satisfactory rate of return, has a reasonably short payout, and generates more than enough cash flow to cover all incremental operating costs and debt service obligations the Base Case and other more pessimistic assumptions.

## 6.4 PROJECT FINANCING

Based on the financing proposals submitted in support of bids on the project's major components, and extensive discussions with official and private financial institutions in the United States and abroad, Bechtel has developed a financing plan designed to meet the following objectives:

- o Identify financing for as much of the project cost as possible at this stage, including material and labor costs incurred in Jamaica, and interest and fees accrued during the construction period.
- o Establish a debt repayment schedule consistent with the project's capacity to generate foreign currency benefits from fuel savings.
- o Minimize the cost and interest rate uncertainty of borrowing by utilizing relatively low cost, fixed rate, long-term financing whenever possible.

### 6.4.1 Financing Sources

Bechtel has developed a financing plan based on the expressions of interest to participate in the financing for this project received from the Inter-American Development Bank, export credit agencies in potential supplier countries, potential suppliers, and international commercial banks. The terms and conditions utilized in the financing plan and cash flow projections are those indicated in expressions of interest received from financial institutions in support of this project. Some of the financing proposals supporting particular supplier bids contained more favorable terms than those utilized in this study. These proposals have not all been used in the development of the financing plan. Therefore, we believe it can be safely assumed that the financing parameters outlined in the following subsections have a conservative bias and can probably be improved upon in subsequent negotiations.

Given the problems many countries have been facing concerning foreign debt repayments, international commercial banks and export credit agencies have become extremely selective in extending new credits to countries facing balance of payments problems and shortages of foreign exchange. Many international financing sources have expressed some reluctance toward extending additional amounts of credit to Jamaica at this time. However, the participation in a project of a multilateral financial institution such as the Inter-American Development Bank or World Bank will often give sufficient reassurance to hesitant lenders to participate as cofinanciers in projects to which they might otherwise not lend.

Bechtel believes that this is the case with the Jamaican oil-to-coal conversion project under the current economic conditions, and therefore we consider the willingness of the Inter-American Development Bank to make a major commitment to the project to be very important in attracting lenders to cover the balance of the project costs.

6.4.1.1 Inter-American Development Bank

The availability of funds under favorable terms and conditions makes an institutional lender such as the Inter-American Development Bank (IDB) an attractive source of funding for Jamaica. A series of meetings has been held among representatives of Bechtel, the Jamaica Coal Committee and senior officials of the IDB to explore the Bank's interest in making a major funding commitment to the project. These meetings confirmed that the Bank is very interested in this project since it feels that the substitution of coal for oil is a viable option for Caribbean nations seeking to reduce their foreign exchange outlays for electric power generation.

IDB has tentatively included this project in its 1984 lending program for Jamaica subject to receipt of a formal request for funding from the Government of Jamaica, the satisfactory appraisal of the project by the Bank's staff, and approval by the IDB Board of Directors.

The Bank has indicated that, if approved, it would consider funding up to 50 to 55 percent of the capital cost of the project. Prevailing applicable IDB terms are repayment over 10 years following a 5-year grace period; financing of interest during construction; interest at 11 percent per annum; plus various commitment and loan management fees. For purposes of this study, Bechtel has assumed that the IDB loan will amount to about $48 million extended on the terms outlined previously. It is possible that the interest rate will be reduced to around 10 percent by the time any loan is finalized.

6.4.1.2 Export Credits

Export credits tie financial commitments by various countries to their participation as suppliers of goods and services to the project. The availability and terms of export credits are often major factors in the selection of procurement sources. Expressions of interest or preliminary commitments to finance a portion of this project were received from suppliers in Colombia, Italy, Japan, Korea, and the United States. Details of the specific financing offers and an analysis are included in the bid evaluation sections of this study.

Several other countries may be willing to provide export credit financing in support of their exporters when the project has reached a further stage of development and formal applications for financing are made, if desired, by the Government of Jamaica. These countries could include Canada and the United Kingdom where suppliers of technically acceptable equipment are located.

Basic terms of export credits extended by OECD member countries have been set through a consensus agreement which is adjusted from time to time. The terms in effect as of September 30, 1983 that are applicable to long-term export credits extended to Jamaica are as follows:

- Amount of Financing - Up to 85 percent of the value of the goods and services to be exported plus the foreign currency portion of any erection costs.

- Interest Rate - 11.35 percent fixed per annum for U.S. dollar denominated loans and 8.7 percent per annum for loans denominated in Japanese yen. These rates are currently under negotiation and may be reduced by approximately 0.6 percent prior to the time when export credit commitments are finalized for the project.

- Repayment Terms - Total repayment period of up to 10 years following the construction period. Repayment of principal is generally in equal semiannual installments commencing 6 to 12 months after project completion. For purposes of the analyses of this project, it was assumed that loans would be repaid in 17 equal semiannual installments commencing 36 months after start of construction. Total term is therefore 11½ years. Most of the bidders offered loan repayment terms of about this duration.

Within the framework of the consensus agreement, there is considerable flexibility to vary many of the terms and conditions. For example, some export credit agencies will agree to finance interest during construction, local costs, and the downpayments. In reality, the gentlemen's agreement against offering repayment terms and interest rates that are more favorable than the consensus terms through "mixed credits" is often violated in competitive situations.

The export credit agencies in non-OECD member countries including Korea and Colombia are not parties to the consensus agreements. The terms and conditions offered by these countries in support of their supplier bids for this project are more favorable in many respects than OECD consensus terms. In particular, the interest rate is lower by about 2 to 3 percent, and they are willing to finance interest during construction, downpayments, and some local costs.

It is Bechtel's experience that the export credit agency of one country is often willing to match better terms and conditions offered by the agency of a competing country for similar goods and services. Consequently, the strategy adopted in calling for limited international competitive bids and multinational procurement should help to optimize the terms applicable to the final financing plan.

6.4.1.3 International Bank Loans

For the finance plan presented here, it is assumed that export credits can be arranged to cover up to 85 percent of the foreign sourced goods and services used in the project. The amount of export financing actually utilized will depend on many factors including the amount and timing of availability of loans from the IDB, export credit coverage, and the availability of concessionary financing from any of the supplier countries. A certain portion of foreign currency costs, such as interest during construction and downpayments for foreign goods and services financed by export credit agencies, is not likely to be covered from any of these sources and will probably need to be financed by loans from one or more international commercial banks.

The amount of international commercial bank financing available for Jamaican projects is currently limited, and therefore dependence on the availability of these loans for this project has been minimized. Commercial banks are often eager to participate with export credit agencies from their respective countries in financing viable projects, and Bechtel sees no problem in raising limited amounts of commercial bank financing in conjunction with the export credits for this project. Many of the suppliers have indicated a willingness by their bankers to provide financing for the 15 percent downpayments not financed by the export credit agency, as well as financing for interest during construction.

For purposes of the cash flows presented in this study, commercial bank loans are assumed to carry an interest rate of 1-1/2 percent per annum above the London Interbank Offered Rate (LIBOR) with the total interest charged on the loans averaging 13 percent per annum. Management fees are assumed to be 1.5 percent payable at loan signing. Loan repayment is assumed to be in 10 equal semiannual installments commencing 6 months after completion of the project with a total loan term of 7½ years. The maximum amount of the commercial bank loan utilized in the financing plan has been limited to $15 million which should be available in conjunction with the export credit financing.

6.4.1.4 Owner Financing

A small percentage of the total project cost may not be covered from any of the aforementioned sources of international financing and may need to be funded either from equity contributions by the project sponsor, or raised from Jamaican dollar borrowings in the local market. These costs are likely to include any increased working capital requirements, some of the local currency construction costs, and possibly some of the interest during construction if the amount of international commercial bank funding proves to be insufficient.

It should be noted that some lenders may only be interested in participating in the project if the government or project sponsor is willing to invest some of its own funds. The amount may be very small, only 5 to 10 percent of total project cost, but the importance for these lenders of some equity participation is to demonstrate the priority of the project in the overall development plans of the country and utility.

It may be possible to attract a certain amount of foreign investment capital for a portion of the coal handling infrastructure needed by the project. Several coal companies which have expressed an interest in selling contract coal to fuel the project have also indicated a willingness to consider investing in or financing the necessary port developments and coal unloading equipment. One method suggested for recovering this investment, which appears feasible, would be through a surcharge on each ton of coal delivered.

Since these proposals are still at an early stage of discussion, this type of foreign investment has not been included in development of the preliminary financing plan. However, this certainly appears to be a potentially attractive way to reduce the overall debt financing or owner equity investment required for the project.

6.4.2 Financing Plan

Table 6-5 summarizes the breakdown of project capital costs presented in Section 3.13. The financing plan was developed to cover 100 percent of project costs including interest and financing fees during construction. The foreign currency capital costs represent foreign sourced equipment, materials, and services eligible for export credit financing. A portion of these contracts may also be financed by the IDB. Some of the local costs for erection of major project components may also be covered by export credit financing. However, the financing plan assumes that most of the local costs will be funded by the IDB.

Table 6-6 summarizes the sources and uses of funds used in the development of the financing plan and for the cash flow analyses presented in Tables 6-8 through 6-13.

Table 6-7 summarizes the financing terms for each funding source discussed previously and for those used in the cash flow analyses. The terms are outlined in greater detail in Subsection 6.4.3.

Note that the split of export credits between OECD and non-OECD member countries can only be determined when suppliers are selected and negotiations are completed. The amount of non-OECD financing was minimized at this stage to assure conservatism in the financing plan.

Similarly, some of the financing identified as IDB financing could be provided by export credits or vice versa, since the amounts indicated for each of these sources are less than the maximum amount likely to be available to cover foreign sourced goods and services. In developing the plan to "fast-track" the project construction schedule, certain contract packages on the early critical path will likely have to be funded from the export credit agencies, since their procurement procedures are more flexible and IDB's bidding requirements may not conform to the project schedule - this is why Bechtel has assumed that less than the maximum amount of IDB financing potentially available will actually be used for the project.

This overlap of sources of financing will provide flexibility in determining and negotiating the optimal financing plan for the project.

6.4.3 Pro Forma Financial Model Base Case Assumptions

6.4.3.1 Sources of Funds

a. Export Credit I for $24.5 million covers 85 percent of the foreign costs of the boiler, estimated at $29 million. Drawdown is according to estimated disbursement schedule.

b. Export Credit II for $8 million covers 100 percent of the estimated foreign costs of items to be procured in non-OECD countries (e.g., Colombia, Korea). This may include the coal handling system, electrostatic precipitator, or other equipment for the project.

c. Export Credit III for $22 million covers 85 percent of other foreign sourced equipment and services procured from OECD member countries including items such as architect-engineer services, electrical and controls, piping and mechanical, stack, fly and ash handling equipment, dock facilities, building superstructure, etc., up to a maximum of $22 million. The amount has been arbitrarily capped to permit maximum utilization of the $55 million anticipated loan from the Inter-American Development Bank.

d. Bank Credit of $15 million covers the 15 percent downpayments on the foreign costs not financed by Export Credits I and III, ($7.8 million) plus interest during construction on Export Credits I, II, and III and the Bank Credit. This credit is disbursed as needed to cover payments of these amounts.

e. IFI Credit of $48 million represents somewhat less than the amount expected to be available from the Inter-American Development Bank for the project (approximately 50 percent of total project cost). The loan covers foreign sourced procurement not covered by the Export Credits or Bank Credit ($26 million) plus local costs ($17 million) as well as IDC and fees on this credit of about $5 million. For purposes of this analyses, funds are disbursed as local costs and foreign costs not covered by other funding sources are incurred. In actual operation, the IFI loan will finance specific contract packages let through international competitive bidding.

f. Equity funds may be needed to cover the balance of project costs not funded from any of the above sources. This could include a portion of interest during construction, local costs, and working capital. For the Base Case, this has been estimated at zero. Use of equity funds or other local financing could reduce the amount of project debt and improve the project cash flows in the early years of operation.

6.4.3.2 Terms and Conditions

a. Export Credits I and III - OECD Consensus Terms

- o Repayment - 17 equal semiannual installments beginning after 3-year grace period. Total term 12 years
- o Interest - 11.35 percent per annum (p.a.) fixed
- o Management Fee - 1/2 percent p.a. on undisbursed amount of the loan facility

b. Export Credit II - Non-OECD Consensus Terms

- o Repayment - 12 equal semiannual installments commencing after 5-year grace period
- o Interest - 9.0 percent p.a. fixed
- o Management Fee - 1 percent flat
- o Commitment Fee - 1/2 percent p.a. on undisbursed amount of the loan facility

c. IFI Credit

- o Repayment - 20 equal semiannual installments commencing after 5-year grace period. Total term 15 years
- o Interest - 11.0 percent p.a. fixed
- o Management Fee - 1 percent flat
- o Commitment Fee - 1.25 percent p.a. on undisbursed amount of the commitment



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- o Interest during construction and financing fees financed by drawings under the IFI credit facility

d. Commercial Bank Credit

- o Repayment - 10 equal semiannual installments commencing after 2½-year grace period
- o Interest - 1-1/2 percent above the London Interbank Offered Rate (LIBOR) adjustable every 6 months. For purposes of this study, LIBOR was assumed to average 11-1/2 percent p.a.; therefore, the total interest rate is 13 percent p.a.
- o Management Fee - 1-1/2 percent flat
- o Commitment Fee - 1/2 percent p.a. on undisbursed amount of the commitment

TABLE 6-1

FINANCING SOURCES

| | |
|---|---|
| Inter-American Development Bank | $ 48 million |
| Export Credits (OECD) | 47 million |
| Export Credits (Non-OECD) | 8 million |
| Commercial Bank Loans | 15 million |
| Other Financing (Equity, Domestic Loans, or Foreign Investment) | 0 |
| TOTAL | $118 million |

## TABLE 6-2

## BASE CASE ASSUMPTIONS

| | |
|---|---|
| Fast-Track Construction Schedule | 2 years |
| Capital Cost Estimate | $104.8 million |
| Operating Capacity | 70 percent |
| Coal Consumption | 321,400 metric tons/year |
| Oil Consumption | 1.41 million bbl/year |
| Coal Price (August 1, 1983) | $58.08/metric ton escalated @ 6 percent per annum beginning January 1, 1986 |
| Oil Price (August 1, 1983) | $28.47/bbl escalated @ 6 percent per annum beginning January 1, 1986 |
| Incremental O&M Costs | $1.97 million/year escalated @ 6 percent per annum beginning January 1, 1986 |
| Technical Assistance and Training Costs | $750,000/year beginning 1986 for 5 years |
| Financing Plan | 100 percent of capital costs plus IDC, as described |

TABLE 6-3

BASE CASE SUMMARY RESULTS

| | |
|---|---|
| Total Estimated Capital Cost (Includes IDC and Contingency) | $ 118.1 million |
| Gross Fuel Savings | $ 1067 million |
| Cumulative Net Fuel Savings | $ 968 million |
| Average Annual Fuel Savings | $ 42.1 million |
| Cumulative Net Cash Flow (After Debt Service) | $ 766 million |
| Rate of Return | 23.4 percent |
| Payback | 5 years |

TABLE 6-4

SUMMARY SENSITIVITY RESULTS

| Case | Coal Escalation, Percent | Oil Escalation, Percent | Capacity Factor, Percent | ROR | Payback, Years | Cumulative Cash Flow ($ Millions) |
|---|---|---|---|---|---|---|
| Base Case | 6 | 6 | 70 | 23.4 | 5 | 766 |
| No Escalation Case | 0 | 0 | 70 | 16.9* | 6 | 244 |
| Alt. Base Case 2 | 6 | 7 | 70 | 25.4 | 5 | 1,052 |
| Alt. Base Case 3 | 7 | 7 | 70 | 24.5 | 5 | 913 |
| Capital Cost + 10 percent | 6 | 6 | 70 | 21.7 | 5 | 745 |
| High Capacity Case | 6 | 6 | 80 | 25.8 | 5 | 902 |
| Low Capacity Case | 6 | 6 | 60 | 20.6 | 6 | 626 |
| 3-Year Construction Case | 6 | 6 | 70 | 22.2 | 5 | 742 |

*"Real" rate of return

## TABLE 6-5

## CAPITAL COST BREAKDOWN
(Millions of U.S. Dollars)

| | | |
|---|---|---|
| Foreign Currency Capital Costs | $79.2 | |
| + Contingency | 7.4 | |
| Subtotal, Foreign Costs | | 86.6 |
| Local Currency Capital Costs | 15.2 | |
| + Contingency | 1.6 | |
| Subtotal, Local Costs | | 16.8 |
| Other Preoperational Costs | | 1.4 |
| Total, Capital Cost | | 104.8 |
| Interest During Construction and Financing Fees | | 13.3 |
| Total, Financed Project Cost | | 118.1 |

TABLE 6-6

SOURCES AND USES OF FUNDS

| Sources | Uses | Amount |
|---|---|---|
| Inter-American Development Bank | Foreign Procurement, Local Costs, Interest During Construction | $ 48 million |
| Export Credits (OECD) | Foreign Procurement | 47 million |
| Export Credits (Non-OECD) | Foreign Procurement, Local Costs | 8 million |
| Commercial Bank Loans | Foreign Procurement Downpayments, Interest During Construction | 15 million |
| Owner Financing (Equity, Domestic Loans, or Foreign Investment) | Working Capital, Local Costs and IDC Not Covered Above | --- |
| TOTAL | | $118 million |

TABLE 6-7

FINANCING TERMS

| Source | Interest Rate, Percent | Total Term, Years | Grace Period, Years |
|---|---|---|---|
| Inter-American Development Bank | 11.0 | 15 | 5 |
| Export Credits (OECD Members) | 11.35 | 11½ | 3 |
| Export Credits Non-OECD Members) | 9.0 | 11 | 5 |
| Commercial Banks | LIBOR + 1½* | 7½ | 2½ |

*Assumed to average a total of 13 percent per annum for the life of the loans.

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BASE CASE--FAST TRACK

Table 6-8

JAMAICA COAL STUDY
OLD HARBOUR UNITS 3 & 4 CONVERSION
SOURCES AND USES OF FUNDS DURING CONSTRUCTION

(THOUSANDS OF DOLLARS)

| | 1984-1 | 1984-2 | 1985-1 | 1985-2 | TOTAL |
|---|---|---|---|---|---|
| SOURCES | | | | | |
| EXPORT CREDIT I (BOILER) | 3675.0 | 6125.0 | 10290.0 | 4410.0 | 24500.0 |
| EXPORT CREDIT II | 800.0 | 1840.0 | 3360.0 | 2000.0 | 8000.0 |
| EXPORT CREDIT III | 2200.0 | 5060.0 | 9240.0 | 5500.0 | 22000.0 |
| INT'L FINANCIAL INSTITUTION | 2175.1 | 7240.0 | 17115.1 | 22042.6 | 48572.7 |
| BANK CREDIT | 3226.0 | 5079.9 | 6694.0 | - | 15000.0 |
| EQUITY | - | - | - | - | - |
| TOTAL SOURCES | 12076.1 | 25344.9 | 46699.1 | 33952.6 | 118072.7 |
| USES | | | | | |
| FOREIGN CAPITAL COSTS | 7920.0 | 18216.0 | 33264.0 | 19800.0 | 79200.0 |
| LOCAL CAPITAL COSTS | 1213.5 | 3337.2 | 6067.6 | 4550.7 | 15169.0 |
| FOREIGN CONTINGENCY COSTS | 740.0 | 1702.0 | 3108.0 | 1850.0 | 7400.0 |
| LOCAL CONTINGENCY COSTS | 125.8 | 346.1 | 629.2 | 471.9 | 1573.0 |
| PREOPERATIONAL EXPENSES | - | - | - | 1438.0 | 1438.0 |
| NET WORKING CAPITAL CHANGE | - | - | - | - | - |
| SUBTOTAL | 9999.4 | 23601.2 | 43068.8 | 28110.6 | 104780.0 |
| FINANCING FEES | | | | | |
| COMMITMENT FEES | | | | | |
| EXPORT CREDIT I (.5%) | 56.7 | 44.4 | 23.9 | 5.5 | 130.5 |
| EXPORT CREDIT II (.5%) | 19.0 | 15.7 | 9.2 | 2.5 | 46.4 |
| EXPORT CREDIT III (.5%) | 52.3 | 43.2 | 25.3 | 6.9 | 127.6 |
| INT'L FINANCIAL INSTITUTION (1.25%) | 339.8 | 309.4 | 235.1 | 115.7 | 1000.1 |
| BANK CREDIT (.5%) | 36.2 | 27.0 | 12.4 | - | 75.6 |
| MGMT/INS. FEES | | | | | |
| EXPORT CREDIT I (1%) | 245.0 | - | - | - | 245.0 |
| EXPORT CREDIT II (1%) | 80.0 | - | - | - | 80.0 |
| EXPORT CREDIT III (1%) | 220.0 | - | - | - | 220.0 |
| INT'L FINANCIAL INSTITUTION (1%) | 550.0 | - | - | - | 550.0 |
| BANK CREDIT (1.5%) | 225.0 | - | - | - | 225.0 |
| INTEREST DURING CONSTRUCTION | | | | | |
| EXPORT CREDIT I (11.35%) | 104.3 | 382.4 | 848.1 | 1265.2 | 2600.0 |
| EXPORT CREDIT II (9.0%) | 18.0 | 77.4 | 194.4 | 315.0 | 604.8 |
| EXPORT CREDIT III (11.35%) | 62.4 | 268.4 | 674.2 | 1092.4 | 2097.5 |
| INT'L FINANCIAL INSTITUTION (11%) | 34.4 | 301.9 | 955.7 | 2007.0 | 3299.0 |
| BANK CREDIT (13%) | 33.7 | 273.8 | 651.9 | 1031.8 | 1991.3 |
| SUB-TOTAL FINANCING COSTS | 2076.7 | 1743.6 | 3630.3 | 5842.0 | 13292.7 |
| TOTAL USES OF FUNDS | 12076.1 | 25344.9 | 46699.1 | 33952.6 | 118072.7 |

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BASE CASE--FAST TRACK



JAMAICA COAL STUDY
OLD HARBOUR UNITS 3 & 4 CONVERSION
OPERATING PERIOD CASH FLOW STATEMENT

(THOUSANDS OF DOLLARS)

| | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FUEL SAVINGS: | | | | | | | | | | | | | | |
| ANNUAL OIL CONSUMPTION, MMBBL | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| OIL COST/BBL AT STATION | 30.2 | 32.0 | 34.0 | 36.1 | 38.3 | 40.6 | 43.1 | 45.7 | 48.5 | 51.4 | 54.6 | , 57.9 | 61.4 | 65.1 |
| ANNUAL OIL COST | 41967.2 | 44523.0 | 47234.4 | 50111.0 | 53162.8 | 56400.4 | 59835.2 | 63479.1 | 67345.0 | 71446.3 | 75797.4 | 80413.5 | 85310.6 | 90506.1 |
| PROJECTED COAL CONSUMPTION, MT (000) | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 |
| COAL COST/MT AT STATION | 61.6 | 65.4 | 69.4 | 73.6 | 78.1 | 82.8 | 87.9 | 93.2 | 98.9 | 104.9 | 111.3 | 118.1 | 125.5 | 132.9 |
| ANNUAL COAL COST | 19515.3 | 20703.8 | 21964.7 | 23302.3 | 24721.4 | 26227.0 | 27824.2 | 29518.7 | 31316.4 | 33223.5 | 35246.8 | 37393.4 | 39670.6 | 42086.6 |
| GROSS ANNUAL FUEL SAVINGS | 22451.9 | 23819.2 | 25269.8 | 26808.7 | 28441.3 | 30173.4 | 32011.0 | 33960.5 | 36028.6 | 38222.8 | 40550.6 | 43020.1 | 45640.0 | 43419.5 |
| LESS: INCREASED ANN OPERATING & MAINT | | | | | | | | | | | | | | |
| -FOREIGN CURRENCY COSTS | 1598.5 | 1695.8 | 1799.1 | 1906.7 | 2024.9 | 2148.2 | 2279.1 | 2417.9 | 2565.1 | 2721.3 | 2887.1 | 3062.9 | 3249.4 | 3447.3 |
| -LOCAL CURRENCY COSTS | 402.5 | 427.0 | 453.0 | 480.6 | 509.9 | 540.9 | 573.9 | 608.8 | 645.9 | 685.2 | 727.0 | 771.2 | 818.2 | 868.0 |
| TECHNICAL ASSIST & TRAINING | 750.0 | 750.0 | 750.0 | 750.0 | 750.0 | - | - | - | - | - | - | - | - | - |
| NET ANNUAL FUEL SAVINGS | 19700.9 | 20946.3 | 22267.6 | 23669.4 | 25156.6 | 27484.3 | 29158.1 | 30333.8 | 32817.6 | 34816.2 | 36936.5 | 39186.0 | 41572.4 | 44104.2 |
| LESS: DEBT SERVICE | | | | | | | | | | | | | | |
| PRINCIPAL REPAYMENTS | | | | | | | | | | | | | | |
| EXPORT CREDIT I | - | 2882.4 | 2882.4 | 2882.4 | 2882.4 | 2882.4 | 2882.4 | 2882.4 | 2882.4 | 1441.2 | - | - | - | - |
| EXPORT CREDIT II | - | - | - | 1333.3 | 1333.3 | 1333.3 | 1333.3 | 1333.3 | 1333.3 | - | - | - | - | - |
| EXPORT CREDIT III | - | 2588.2 | 2588.2 | 2588.2 | 2588.2 | 2588.2 | 2588.2 | 2588.2 | 2588.2 | 1294.1 | - | - | - | - |
| INT'L FINANCIAL INSTITUTION | - | - | - | 4857.3 | 4857.3 | 4857.3 | 4857.3 | 4857.3 | 4857.3 | 4857.3 | 4857.3 | 4857.3 | 4857.3 | - |
| BANK CREDIT | 1500.0 | 3000.0 | 3000.0 | 3000.0 | 3000.0 | 1500.0 | - | - | - | - | - | - | - | - |
| SUBTOTAL | 1500.0 | 8470.6 | 8470.6 | 14661.2 | 14661.2 | 13161.2 | 11661.2 | 11661.2 | 11661.2 | 7592.6 | 4857.3 | 4857.3 | 4857.3 | - |
| INTEREST DURING OPERATION | | | | | | | | | | | | | | |
| EXPORT CREDIT I | 2780.8 | 2699.0 | 2371.8 | 2044.7 | 1717.5 | 1390.4 | 1063.2 | 736.1 | 408.9 | 81.8 | - | - | - | - |
| EXPORT CREDIT II | 720.0 | 720.0 | 720.0 | 690.0 | 570.0 | 450.0 | 330.0 | 210.0 | 90.0 | - | - | - | - | - |
| EXPORT CREDIT III | 2497.0 | 2423.6 | 2129.8 | 1836.0 | 1542.3 | 1248.5 | 954.7 | 661.0 | 367.2 | 73.4 | - | - | - | - |
| INT'L FINANCIAL INSTITUTION | 5343.0 | 5343.0 | 5343.0 | 5209.4 | 4675.1 | 4140.8 | 3606.5 | 3072.2 | 2537.9 | 2003.6 | 1469.3 | 935.0 | 400.7 | - |
| BANK CREDIT | 1950.0 | 1657.5 | 1267.5 | 877.5 | 487.5 | 97.5 | - | - | - | - | - | - | - | - |
| SUBTOTAL | 13290.8 | 12843.0 | 11832.1 | 10657.6 | 8992.4 | 7327.2 | 5954.5 | 4679.3 | 3404.1 | 2158.9 | 1469.3 | 935.0 | 400.7 | - |
| TOTAL DEBT SERVICE | 14790.8 | 21313.6 | 20302.7 | 25318.8 | 23653.6 | 20488.4 | 17615.7 | 16340.5 | 15065.3 | 9751.4 | 6326.6 | 5792.3 | 5258.0 | - |
| NET CASH FLOW | 4910.1 | (367.3) | 1964.9 | (1649.4) | 1502.9 | 6995.9 | 11542.4 | 14593.3 | 17752.4 | 25064.8 | 30610.0 | 33393.7 | 36314.4 | 44104.2 |
| CUM NET CASH FLOW | 4910.1 | 4542.8 | 6507.8 | 4858.4 | 6361.3 | 13357.2 | 24899.5 | 39492.9 | 57245.2 | 82310.1 | 112920.0 | 146313.7 | 182628.1 | 226732.3 |
| LOAN PRINCIPAL O/S | 116572.7 | 108102.1 | 99631.8 | 84970.4 | 70309.2 | 57148.0 | 45486.8 | 33825.6 | 22184.4 | 14571.8 | 9714.5 | 4857.3 | - | - |
| NET FOREIGN EXCHANGE SAVINGS | 5312.6 | 59.7 | 2418.0 | (1168.8) | 2012.8 | 7536.8 | 12116.2 | 15202.1 | 18398.3 | 25750.0 | 31336.9 | 34164.9 | 37132.6 | 44972.2 |
| DEBT SERVICE COVERAGE RATIO | 133.2 % | 98.3 % | 109.7 % | 93.5 % | 106.4 % | 134.1 % | 165.5 % | 189.3 % | 217.8 | 357.0 % | 583.8 % | 676.5 % | 790.7 % | 10E7 |
| INTERNAL RATE OF RETURN | 23.4 % | | | | | | | | | | | | | |
| NET PRESENT VALUE @ 5% | 361082.1 | | | | | | | | | | | | | |
| @ 10% | 156145.6 | | | | | | | | | | | | | |
| @ 15% | 63621.1 | | | | | | | | | | | | | |
| @ 20% | 17901.8 | | | | | | | | | | | | | |
| @ 25% | (6444.5) | | | | | | | | | | | | | |

Table 6-9



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BASE CASE--FAST TRACK

JAMAICA COAL STUDY
OLD HARBOUR UNITS 3 & 4 CONVERSION
OPERATING PERIOD CASH FLOW STATEMENT

(THOUSANDS OF DOLLARS)

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| FUEL SAVINGS: | | | | | | | | | | |
| ANNUAL OIL CONSUMPTION, MMBBL | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 32.4 |
| OIL COST/BBL AT STATION | 69.1 | 73.3 | 77.8 | 82.5 | 87.5 | 92.9 | 98.5 | 104.5 | 110.9 | - |
| ANNUAL OIL COST | 96017.9 | 101865.4 | 108069.0 | 114650.4 | 121632.6 | 129040.0 | 136898.5 | 145235.7 | 154080.5 | 1995022 |
| PROJECTED COAL CONSUMPTION, MT (000) | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 7392.2 |
| COAL COST/MT AT STATION | 141.0 | 149.6 | 158.7 | 168.3 | 178.6 | 189.5 | 201.0 | 213.2 | 226.2 | - |
| ANNUAL COAL COST | 44649.6 | 47368.8 | 50253.6 | 53314.0 | 56560.8 | 60005.4 | 63659.7 | 67536.6 | 71649.6 | 927712.9 |
| GROSS ANNUAL FUEL SAVINGS | 51368.2 | 54496.6 | 57815.4 | 61336.4 | 65071.7 | 69034.6 | 73238.8 | 77699.1 | 82430.9 | 1067309 |
| LESS: INCREASED ANN OPERATING & MAINT | | | | | | | | | | |
| -FOREIGN CURRENCY COSTS | 3657.2 | 3880.0 | 4116.3 | 4366.9 | 4632.9 | 4915.0 | 5214.3 | 5531.9 | 5868.8 | 75988.6 |
| -LOCAL CURRENCY COSTS | 920.9 | 977.0 | 1036.5 | 1099.6 | 1166.6 | 1237.6 | 1313.0 | 1392.9 | 1477.8 | 19133.8 |
| TECHNICAL ASSIST & TRAINING | - | - | - | - | - | - | - | - | - | 3750.0 |
| NET ANNUAL FUEL SAVINGS | 46790.1 | 49639.6 | 52662.7 | 55869.8 | 59272.3 | 62882.0 | 66711.5 | 70774.2 | 75084.4 | 968436.6 |
| LESS: DEBT SERVICE | | | | | | | | | | |
| PRINCIPAL REPAYMENTS | | | | | | | | | | |
| EXPORT CREDIT I | - | - | - | - | - | - | - | - | - | 24500.0 |
| EXPORT CREDIT II | - | - | - | - | - | - | - | - | - | 8000.0 |
| EXPORT CREDIT III | - | - | - | - | - | - | - | - | - | 22000.0 |
| INT'L FINANCIAL INSTITUTION | - | - | - | - | - | - | - | - | - | 48572.7 |
| BANK CREDIT | - | - | - | - | - | - | - | - | - | 15000.0 |
| SUBTOTAL | - | - | - | - | - | - | - | - | - | 118072.7 |
| INTEREST DURING OPERATION | | | | | | | | | | |
| EXPORT CREDIT I | - | - | - | - | - | - | - | - | - | 15294.1 |
| EXPORT CREDIT II | - | - | - | - | - | - | - | - | - | 4500.0 |
| EXPORT CREDIT III | - | - | - | - | - | - | - | - | - | 13733.5 |
| INT'L FINANCIAL INSTITUTION | - | - | - | - | - | - | - | - | - | 44079.8 |
| BANK CREDIT | - | - | - | - | - | - | - | - | - | 6337.5 |
| SUBTOTAL | - | - | - | - | - | - | - | - | - | 83944.9 |
| TOTAL DEBT SERVICE | - | - | - | - | - | - | - | - | - | 202017.6 |
| NET CASH FLOW | 46790.1 | 49639.6 | 52662.7 | 55869.8 | 59272.3 | 62882.0 | 66711.5 | 70774.2 | 75084.4 | 766419.0 |
| CUM NET CASH FLOW | 273522.4 | 323162.0 | 375824.7 | 431694.6 | 490966.9 | 553848.9 | 620560.4 | 691334.6 | 766419.0 | - |
| LOAN PRINCIPAL O/S | - | - | - | - | - | - | - | - | - | - |
| NET FOREIGN EXCHANGE SAVINGS | 47711.0 | 50616.6 | 53699.2 | 56969.4 | 60438.9 | 64119.6 | 68024.5 | 72167.2 | 76562.2 | 785552.9 |
| DEBT SERVICE COVERAGE RATIO | 10E7 | 10E7 | 10E7 | 10E7 | 10E7 | 10E7 | 10E7 | 10E7 | 10E7 | - |

Table 6-10

09/23/83 10:56
BASE CASE--FAST TRACK

JAMAICA COAL STUDY
OLD HARBOUR UNITS 3 & 4 CONVERSION
DEBT SERVICE AMORTIZATION SCHEDULE

(THOUSANDS OF DOLLARS)

| | ECI PRIN | ECI INT | ECII PRIN | ECII INT | ECIII PRIN | ECIII INT | IDB PRIN | IDB INT | BC PRIN | BC INT | TOTAL DS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | - | 1390.4 | - | 360.0 | - | 1248.5 | - | 2671.5 | - | 975.0 | 6645.4 |
| 6 | - | 1390.4 | - | 360.0 | - | 1248.5 | - | 2671.5 | 1500.0 | 975.0 | 8145.4 |
| 7 | 1441.2 | 1390.4 | - | 360.0 | 1294.1 | 1248.5 | - | 2671.5 | 1500.0 | 877.5 | 10783.2 |
| 8 | 1441.2 | 1308.6 | - | 360.0 | 1294.1 | 1175.1 | - | 2671.5 | 1500.0 | 780.0 | 10530.4 |
| 9 | 1441.2 | 1226.8 | - | 360.0 | 1294.1 | 1101.6 | - | 2671.5 | 1500.0 | 682.5 | 10277.7 |
| 10 | 1441.2 | 1145.0 | - | 360.0 | 1294.1 | 1028.2 | - | 2671.5 | 1500.0 | 585.0 | 10025.0 |
| 11 | 1441.2 | 1063.2 | 666.7 | 360.0 | 1294.1 | 954.7 | 2428.6 | 2671.5 | 1500.0 | 487.5 | 12867.6 |
| 12 | 1441.2 | 981.4 | 666.7 | 330.0 | 1294.1 | 881.3 | 2428.6 | 2537.9 | 1500.0 | 390.0 | 12451.3 |
| 13 | 1441.2 | 899.7 | 666.7 | 300.0 | 1294.1 | 807.9 | 2428.6 | 2404.4 | 1500.0 | 292.5 | 12035.0 |
| 14 | 1441.2 | 817.9 | 666.7 | 270.0 | 1294.1 | 734.4 | 2428.6 | 2270.8 | 1500.0 | 195.0 | 11618.7 |
| 15 | 1441.2 | 736.1 | 666.7 | 240.0 | 1294.1 | 661.0 | 2428.6 | 2137.2 | 1500.0 | 97.5 | 11202.3 |
| 16 | 1441.2 | 654.3 | 666.7 | 210.0 | 1294.1 | 587.5 | 2428.6 | 2003.6 | - | - | 9286.0 |
| 17 | 1441.2 | 572.5 | 666.7 | 180.0 | 1294.1 | 514.1 | 2428.6 | 1870.1 | - | - | 8967.2 |
| 18 | 1441.2 | 490.7 | 666.7 | 150.0 | 1294.1 | 440.6 | 2428.6 | 1736.5 | - | - | 8648.4 |
| 19 | 1441.2 | 408.9 | 666.7 | 120.0 | 1294.1 | 367.2 | 2428.6 | 1602.9 | - | - | 8329.6 |
| 20 | 1441.2 | 327.1 | 666.7 | 90.0 | 1294.1 | 293.8 | 2428.6 | 1469.3 | - | - | 8010.8 |
| 21 | 1441.2 | 245.4 | 666.7 | 60.0 | 1294.1 | 220.3 | 2428.6 | 1335.8 | - | - | 7692.0 |
| 22 | 1441.2 | 163.6 | 666.7 | 30.0 | 1294.1 | 146.9 | 2428.6 | 1202.2 | - | - | 7373.2 |
| 23 | 1441.2 | 81.8 | - | - | 1294.1 | 73.4 | 2428.6 | 1068.6 | - | - | 6387.8 |
| 24 | - | - | - | - | - | - | 2428.6 | 935.0 | - | - | 3363.7 |
| 25 | - | - | - | - | - | - | 2428.6 | 801.5 | - | - | 3230.1 |
| 26 | - | - | - | - | - | - | 2428.6 | 667.9 | - | - | 3096.5 |
| 27 | - | - | - | - | - | - | 2428.6 | 534.3 | - | - | 2962.9 |
| 28 | - | - | - | - | - | - | 2428.6 | 400.7 | - | - | 2829.4 |
| 29 | - | - | - | - | - | - | 2428.6 | 267.2 | - | - | 2695.8 |
| 30 | - | - | - | - | - | - | 2428.6 | 133.6 | - | - | 2562.2 |
| 31 | - | - | - | - | - | - | - | - | - | - | - |
| 32 | - | - | - | - | - | - | - | - | - | - | - |
| 33 | - | - | - | - | - | - | - | - | - | - | - |
| 34 | - | - | - | - | - | - | - | - | - | - | - |
| 35 | - | - | - | - | - | - | - | - | - | - | - |
| 36 | - | - | - | - | - | - | - | - | - | - | - |
| 37 | - | - | - | - | - | - | - | - | - | - | - |
| 38 | - | - | - | - | - | - | - | - | - | - | - |
| 39 | - | - | - | - | - | - | - | - | - | - | - |
| 40 | - | - | - | - | - | - | - | - | - | - | - |
| 41 | - | - | - | - | - | - | - | - | - | - | - |
| 42 | - | - | - | - | - | - | - | - | - | - | - |
| 43 | - | - | - | - | - | - | - | - | - | - | - |
| 44 | - | - | - | - | - | - | - | - | - | - | - |
| 45 | - | - | - | - | - | - | - | - | - | - | - |
| 46 | - | - | - | - | - | - | - | - | - | - | - |
| 47 | - | - | - | - | - | - | - | - | - | - | - |
| 48 | - | - | - | - | - | - | - | - | - | - | - |
| 49 | - | - | - | - | - | - | - | - | - | - | - |
| 50 | - | - | - | - | - | - | - | - | - | - | - |
| TOTAL | 24500.0 | 15294.1 | 8000.0 | 4500.0 | 22000.0 | 13733.5 | 48572.7 | 44079.8 | 15000.0 | 6337.5 | 202017.6 |

Table 6-11

09/23/83 11:17
NO ESCALATION CASE--FAST TRACK

JAMAICA COAL STUDY
OLD HARBOUR UNITS 3 & 4 CONVERSION
SOURCES AND USES OF FUNDS DURING CONSTRUCTION

(THOUSANDS OF DOLLARS)

| | 1984-1 | 1984-2 | 1985-1 | 1985-2 | TOTAL |
|---|---|---|---|---|---|
| **SOURCES** | | | | | |
| EXPORT CREDIT I (BOILER) | 3675.0 | 6125.0 | 10290.0 | 4410.0 | 24500.0 |
| EXPORT CREDIT II | 800.0 | 1840.0 | 3360.0 | 2000.0 | 8000.0 |
| EXPORT CREDIT III | 2200.0 | 5060.0 | 9240.0 | 5500.0 | 22000.0 |
| INT'L FINANCIAL INSTITUTION | 2175.1 | 7240.0 | 17115.1 | 22042.6 | 48572.7 |
| BANK CREDIT | 3226.0 | 5079.9 | 6694.0 | - | 15000.0 |
| EQUITY | - | - | - | - | - |
| TOTAL SOURCES | 12076.1 | 25344.9 | 46699.1 | 33952.6 | 118072.7 |
| **USES** | | | | | |
| FOREIGN CAPITAL COSTS | 7920.0 | 18216.0 | 33264.0 | 19800.0 | 79200.0 |
| LOCAL CAPITAL COSTS | 1213.5 | 3337.2 | 6067.6 | 4550.7 | 15169.0 |
| FOREIGN CONTINGENCY COSTS | 740.0 | 1702.0 | 3108.0 | 1850.0 | 7400.0 |
| LOCAL CONTINGENCY COSTS | 125.8 | 346.1 | 629.2 | 471.9 | 1573.0 |
| PREOPERATIONAL EXPENSES | - | - | - | 1438.0 | 1438.0 |
| NET WORKING CAPITAL CHANGE | - | - | - | - | - |
| SUBTOTAL | 9999.4 | 23601.2 | 43068.8 | 28110.6 | 104780.0 |
| FINANCING FEES | | | | | |
| COMMITMENT FEES | | | | | |
| EXPORT CREDIT I (.5%) | 56.7 | 44.4 | 23.9 | 5.5 | 130.5 |
| EXPORT CREDIT II (.5%) | 19.0 | 15.7 | 9.2 | 2.5 | 46.4 |
| EXPORT CREDIT III (.5%) | 52.3 | 43.2 | 25.3 | 6.9 | 127.6 |
| INT'L FINANCIAL INSTITUTION (1.25%) | 339.8 | 309.4 | 235.1 | 115.7 | 1000.1 |
| BANK CREDIT (.5%) | 36.2 | 27.0 | 12.4 | - | 75.6 |
| MGMT/INS. FEES | | | | | |
| EXPORT CREDIT I (1%) | 245.0 | - | - | - | 245.0 |
| EXPORT CREDIT II (1%) | 80.0 | - | - | - | 80.0 |
| EXPORT CREDIT III (1%) | 220.0 | - | - | - | 220.0 |
| INT'L FINANCIAL INSTITUTION (1%) | 550.0 | - | - | - | 550.0 |
| BANK CREDIT (1.5%) | 225.0 | - | - | - | 225.0 |
| INTEREST DURING CONSTRUCTION | | | | | |
| EXPORT CREDIT I (11.35%) | 104.3 | 382.4 | 848.1 | 1265.2 | 2600.0 |
| EXPORT CREDIT II (9.0%) | 18.0 | 77.4 | 194.4 | 315.0 | 604.8 |
| EXPORT CREDIT III (11.35%) | 62.4 | 268.4 | 674.2 | 1092.4 | 2097.5 |
| INT'L FINANCIAL INSTITUTION (11%) | 34.4 | 301.9 | 955.7 | 2007.0 | 3299.0 |
| BANK CREDIT (13%) | 33.7 | 273.8 | 651.9 | 1031.8 | 1991.3 |
| SUB-TOTAL FINANCING COSTS | 2076.7 | 1743.6 | 3630.3 | 5842.0 | 13292.7 |
| TOTAL USES OF FUNDS | 12076.1 | 25344.9 | 46699.1 | 33952.6 | 118072.7 |

Table 6-12

09/23/83 11:17
NO ESCALATION CASE--FAST TRACK



JAMAICA COAL STUDY
OLD HARBOUR UNITS 3 & 4 CONVERSION
OPERATING PERIOD CASH FLOW STATEMENT

(THOUSANDS OF DOLLARS)

| | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|
| IEL SAVINGS: | | | | | | | |
| INUAL OIL CONSUMPTION, MMBBL | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| L COST/BBL AT STATION | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 |
| INUAL OIL COST | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 |
| IOJECTED COAL CONSUMPTION, MT (000) | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 |
| IAL COST/MT AT STATION | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 |
| INUAL COAL COST | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 |
| OSS ANNUAL FUEL SAVINGS | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 |
| SS: INCREASED ANN OPERATING & MAINT | | | | | | | |
| -FOREIGN CURRENCY COSTS | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 |
| -LOCAL CURRENCY COSTS | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 |
| CHNICAL ASSIST & TRAINING | 750.0 | 750.0 | 750.0 | 750.0 | 750.0 | - | - |
| T ANNUAL FUEL SAVINGS | 18811.8 | 18811.8 | 18811.8 | 18811.8 | 18811.8 | 19561.8 | 19561.8 |
| SS: DEBT SERVICE | | | | | | | |
| PRINCIPAL REPAYMENTS | | | | | | | |
| EXPORT CREDIT I | - | 2882.4 | 2882.4 | 2882.4 | 2882.4 | 2882.4 | 2882.4 |
| EXPORT CREDIT II | - | - | - | 1333.3 | 1333.3 | 1333.3 | 1333.3 |
| EXPORT CREDIT III | - | 2588.2 | 2588.2 | 2588.2 | 2588.2 | 2588.2 | 2588.2 |
| INT'L FINANCIAL INSTITUTION | - | - | - | 4857.3 | 4857.3 | 4857.3 | 4857.3 |
| BANK CREDIT | 1500.0 | 3000.0 | 3000.0 | 3000.0 | 3000.0 | 1500.0 | - |
| SUBTOTAL | 1500.0 | 8470.6 | 8470.6 | 14661.2 | 14661.2 | 13161.2 | 11661.2 |
| INTEREST DURING OPERATION | | | | | | | |
| EXPORT CREDIT I | 2780.8 | 2699.0 | 2371.8 | 2044.7 | 1717.5 | 1390.4 | 1063.2 |
| EXPORT CREDIT II | 720.0 | 720.0 | 720.0 | 690.0 | 570.0 | 450.0 | 330.0 |
| EXPORT CREDIT III | 2497.0 | 2423.6 | 2129.8 | 1836.0 | 1542.3 | 1248.5 | 954.7 |
| INT'L FINANCIAL INSTITUTION | 5343.0 | 5343.0 | 5343.0 | 5209.4 | 4675.1 | 4140.8 | 3606.5 |
| BANK CREDIT | 1950.0 | 1657.5 | 1267.5 | 877.5 | 487.5 | 97.5 | - |
| SUBTOTAL | 13290.8 | 12843.0 | 11832.1 | 10657.6 | 8992.4 | 7327.2 | 5954.5 |
| TAL DEBT SERVICE | 14790.8 | 21313.6 | 20302.7 | 25318.8 | 23653.6 | 20488.4 | 17615.7 |
| T CASH FLOW | 4021.0 | (2501.8) | (1490.9) | (6507.0) | (4841.8) | (926.6) | 1946.1 |
| 4 NET CASH FLOW | 4021.0 | 1519.2 | 28.3 | (6478.7) | (11320.5) | (12247.2) | (10301.0) |
| AN PRINCIPAL O/S | 116572.7 | 108102.1 | 99631.6 | 84970.4 | 70309.2 | 57148.0 | 45486.8 |
| T FOREIGN EXCHANGE SAVINGS | 4406.0 | (2116.8) | (1105.9) | (6122.0) | (4456.8) | (541.6) | 2331.1 |
| 3T SERVICE COVERAGE RATIO | 127.2 % | 88.3 % | 92.7 % | 74.3 % | 79.5 % | 95.5 % | 111.0 % |
| TERNAL RATE OF RETURN | 16.9 % | | | | | | |
| T PRESENT VALUE @ 5% | 141540.6 | | | | | | |
| @ 10% | 53157.8 | | | | | | |
| @ 15% | 10077.8 | | | | | | |
| @ 20% | (12622.5) | | | | | | |
| @ 25% | (25279.5) | | | | | | |

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|
| IEL SAVINGS: | | | | | | | |
| INUAL OIL CONSUMPTION, MMBBL | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| L COST/BBL AT STATION | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 |
| INUAL OIL COST | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 |
| IOJECTED COAL CONSUMPTION, MT (000) | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 |
| IAL COST/MT AT STATION | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 |
| INUAL COAL COST | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 |
| OSS ANNUAL FUEL SAVINGS | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 |
| SS: INCREASED ANN OPERATING & MAINT | | | | | | | |
| -FOREIGN CURRENCY COSTS | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 |
| -LOCAL CURRENCY COSTS | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 |
| CHNICAL ASSIST & TRAINING | - | - | - | - | - | - | - |
| T ANNUAL FUEL SAVINGS | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 |
| SS: DEBT SERVICE | | | | | | | |
| PRINCIPAL REPAYMENTS | | | | | | | |
| EXPORT CREDIT I | 2882.4 | 2882.4 | 1441.2 | - | - | - | - |
| EXPORT CREDIT II | 1333.3 | 1333.3 | - | - | - | - | - |
| EXPORT CREDIT III | 2588.2 | 2588.2 | 1294.1 | - | - | - | - |
| INT'L FINANCIAL INSTITUTION | 4857.3 | 4857.3 | 4857.3 | 4857.3 | 4857.3 | 4857.3 | - |
| BANK CREDIT | - | - | - | - | - | - | - |
| SUBTOTAL | 11661.2 | 11661.2 | 7592.6 | 4857.3 | 4857.3 | 4857.3 | - |
| INTEREST DURING OPERATION | | | | | | | |
| EXPORT CREDIT I | 736.1 | 408.9 | 81.8 | - | - | - | - |
| EXPORT CREDIT II | 210.0 | 90.0 | - | - | - | - | - |
| EXPORT CREDIT III | 661.0 | 367.2 | 73.4 | - | - | - | - |
| INT'L FINANCIAL INSTITUTION | 3072.2 | 2537.9 | 2003.6 | 1469.3 | 935.0 | 400.7 | - |
| BANK CREDIT | - | - | - | - | - | - | - |
| SUBTOTAL | 4679.3 | 3404.1 | 2158.9 | 1469.3 | 935.0 | 400.7 | - |
| TAL DEBT SERVICE | 16340.5 | 15065.3 | 9751.4 | 6326.6 | 5792.3 | 5258.0 | - |
| T CASH FLOW | 3221.3 | 4496.5 | 9810.4 | 13235.2 | 13769.5 | 14303.8 | 19561.8 |
| 4 NET CASH FLOW | (7079.7) | (2583.2) | 7227.2 | 20462.4 | 34231.8 | 48535.6 | 68097.4 |
| AN PRINCIPAL O/S | 33825.6 | 22164.4 | 14571.8 | 9714.5 | 4857.3 | - | - |
| T FOREIGN EXCHANGE SAVINGS | 3606.3 | 4881.5 | 10195.4 | 13620.2 | 14154.5 | 14688.8 | 19946.8 |
| 3T SERVICE COVERAGE RATIO | 119.7 % | 129.8 | 200.6 % | 309.2 % | 337.7 % | 372.0 % | |

Table 6-12



09/23/83 11:17
NO ESCALATION CASE--FAST TRACK

JAMAICA COAL STUDY
OLD HARBOUR UNITS 3 & 4 CONVERSION
OPERATING PERIOD CASH FLOW STATEMENT

(THOUSANDS OF DOLLARS)

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| FUEL SAVINGS: | | | | | | | | | | |
| ANNUAL OIL CONSUMPTION, MMBBL | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 32.4 |
| OIL COST/BBL AT STATION | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | - |
| ANNUAL OIL COST | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 40142.7 | 923282.1 |
| PROJECTED COAL CONSUMPTION, MT (000) | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 321.4 | 7392.2 |
| COAL COST/MT AT STATION | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 | 58.1 | - |
| ANNUAL COAL COST | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 18666.9 | 429339.0 |
| GROSS ANNUAL FUEL SAVINGS | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 21475.8 | 493943.1 |
| LESS: INCREASED ANN OPERATING & MAINT | | | | | | | | | | |
| -FOREIGN CURRENCY COSTS | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 1529.0 | 35167.0 |
| -LOCAL CURRENCY COSTS | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 | 385.0 | 8855.0 |
| TECHNICAL ASSIST & TRAINING | - | - | - | - | - | - | - | - | - | 3750.0 |
| NET ANNUAL FUEL SAVINGS | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 448171.1 |
| LESS: DEBT SERVICE | | | | | | | | | | |
| PRINCIPAL REPAYMENTS | | | | | | | | | | |
| EXPORT CREDIT I | - | - | - | - | - | - | - | - | - | 24500.0 |
| EXPORT CREDIT II | - | - | - | - | - | - | - | - | - | 8000.0 |
| EXPORT CREDIT III | - | - | - | - | - | - | - | - | - | 22000.0 |
| INT'L FINANCIAL INSTITUTION | - | - | - | - | - | - | - | - | - | 48572.7 |
| BANK CREDIT | - | - | - | - | - | - | - | - | - | 15000.0 |
| SUBTOTAL | - | - | - | - | - | - | - | - | - | 118072.7 |
| INTEREST DURING OPERATION | | | | | | | | | | |
| EXPORT CREDIT I | - | - | - | - | - | - | - | - | - | 15294.1 |
| EXPORT CREDIT II | - | - | - | - | - | - | - | - | - | 4500.0 |
| EXPORT CREDIT III | - | - | - | - | - | - | - | - | - | 13733.5 |
| INT'L FINANCIAL INSTITUTION | - | - | - | - | - | - | - | - | - | 44079.8 |
| BANK CREDIT | - | - | - | - | - | - | - | - | - | 6337.5 |
| SUBTOTAL | - | - | - | - | - | - | - | - | - | 83944.9 |
| TOTAL DEBT SERVICE | - | - | - | - | - | - | - | - | - | 202017.6 |
| NET CASH FLOW | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 19561.8 | 244153.5 |
| CUM NET CASH FLOW | 87659.2 | 107221.0 | 126782.8 | 146344.6 | 165906.4 | 185468.1 | 205029.9 | 224591.7 | 244153.5 | - |
| LOAN PRINCIPAL O/S | - | - | - | - | - | - | - | - | - | - |
| NET FOREIGN EXCHANGE SAVINGS | 19946.8 | 19946.8 | 19946.8 | 19946.8 | 19946.8 | 19946.8 | 19946.8 | 19946.8 | 19946.8 | 253008.5 |
| DEBT SERVICE COVERAGE RATIO | | | | | | | | | | - |

Table 6-13

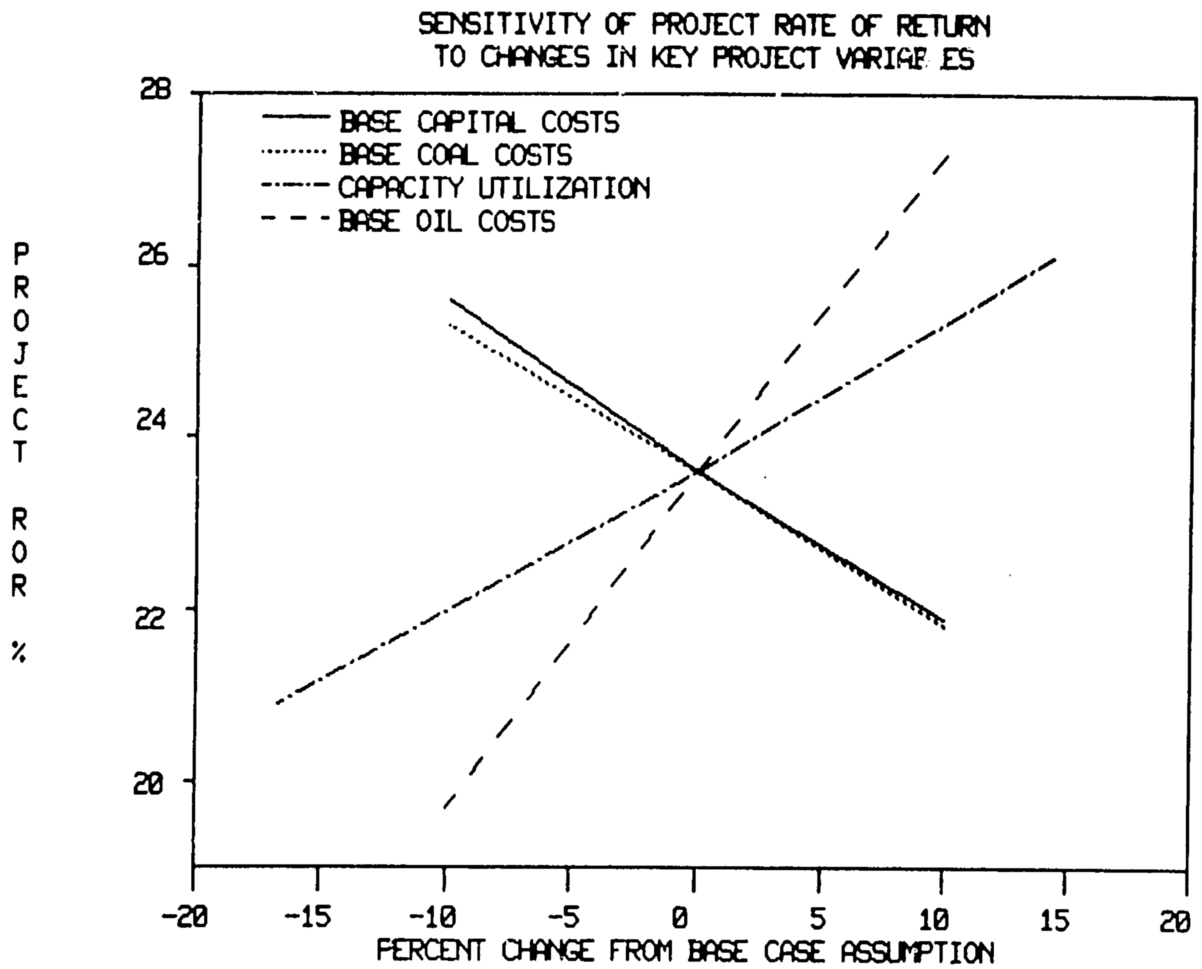
09/23/83 11:18
NO ESCALATION CASE--FAST TRACK

JAMAICA COAL STUDY
OLD HARBOUR UNITS 3 & 4 CONVERSION
DEBT SERVICE AMORTIZATION SCHEDULE

(THOUSANDS OF DOLLARS)

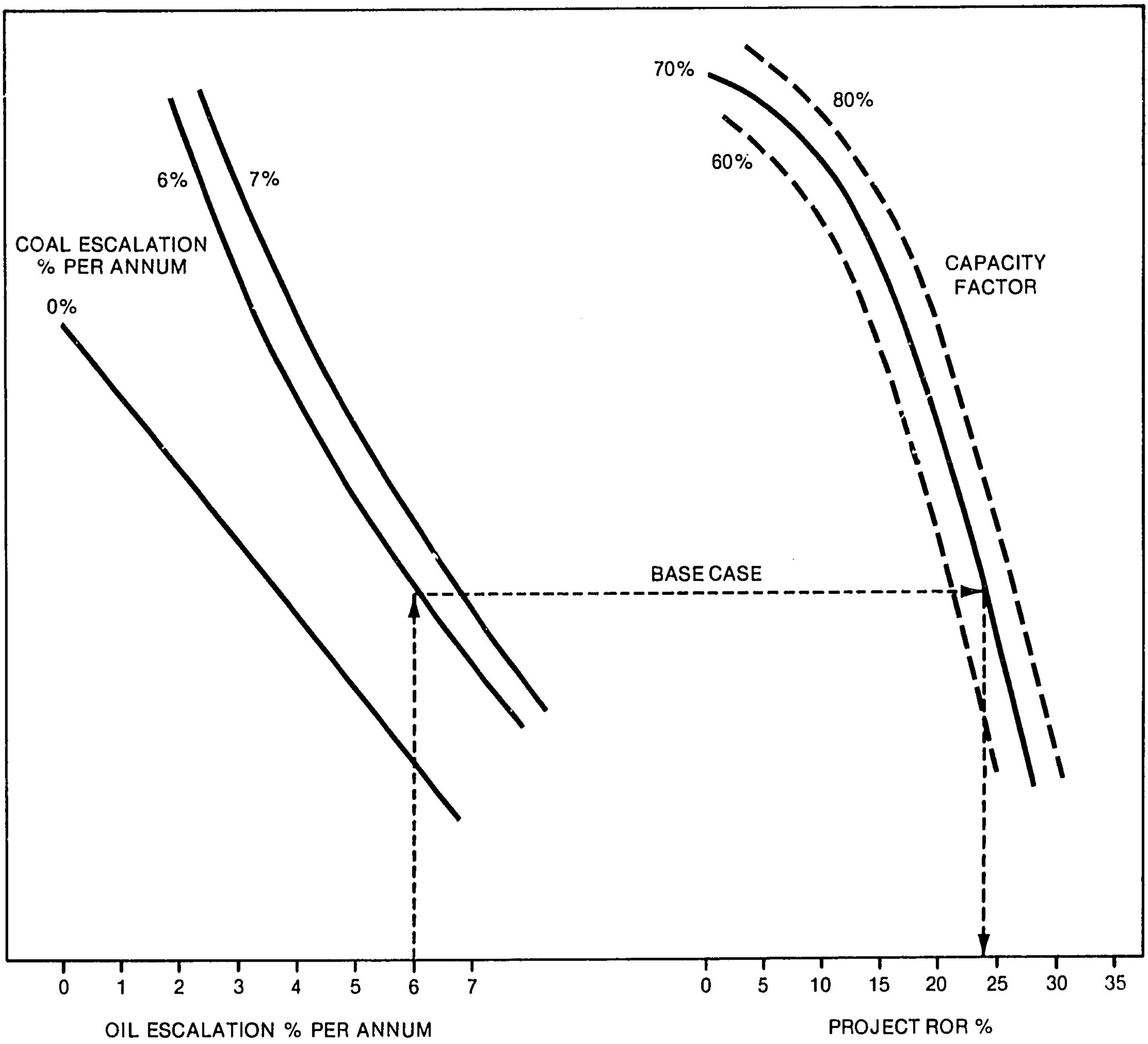
| | ECI PRIN | ECI INT | ECII PRIN | ECII INT | ECIII PRIN | ECIII INT | IDB PRIN | IDB INT | BC PRIN | BC INT | TOTAL DS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | - | 1390.4 | - | 360.0 | - | 1248.5 | - | 2671.5 | - | 975.0 | 6645.4 |
| 6 | - | 1390.4 | - | 360.0 | - | 1248.5 | - | 2671.5 | 1500.0 | 975.0 | 8145.4 |
| 7 | 1441.2 | 1390.4 | - | 360.0 | 1294.1 | 1248.5 | - | 2671.5 | 1500.0 | 877.5 | 10783.2 |
| 8 | 1441.2 | 1308.6 | - | 360.0 | 1294.1 | 1175.1 | - | 2671.5 | 1500.0 | 780.0 | 10530.4 |
| 9 | 1441.2 | 1226.8 | - | 360.0 | 1294.1 | 1101.6 | - | 2671.5 | 1500.0 | 682.5 | 10277.7 |
| 10 | 1441.2 | 1145.0 | - | 360.0 | 1294.1 | 1028.2 | - | 2671.5 | 1500.0 | 585.0 | 10025.0 |
| 11 | 1441.2 | 1063.2 | 666.7 | 360.0 | 1294.1 | 954.7 | 2428.6 | 2671.5 | 1500.0 | 487.5 | 12867.6 |
| 12 | 1441.2 | 981.4 | 666.7 | 330.0 | 1294.1 | 881.3 | 2428.6 | 2537.9 | 1500.0 | 390.0 | 12451.3 |
| 13 | 1441.2 | 899.7 | 666.7 | 300.0 | 1294.1 | 807.9 | 2428.6 | 2404.4 | 1500.0 | 292.5 | 12035.0 |
| 14 | 1441.2 | 817.9 | 666.7 | 270.0 | 1294.1 | 734.4 | 2428.6 | 2270.8 | 1500.0 | 195.0 | 11618.7 |
| 15 | 1441.2 | 736.1 | 666.7 | 240.0 | 1294.1 | 661.0 | 2428.6 | 2137.2 | 1500.0 | 97.5 | 11202.3 |
| 16 | 1441.2 | 654.3 | 666.7 | 210.0 | 1294.1 | 587.5 | 2428.6 | 2003.6 | - | - | 9286.0 |
| 17 | 1441.2 | 572.5 | 666.7 | 180.0 | 1294.1 | 514.1 | 2428.6 | 1870.1 | - | - | 8967.2 |
| 18 | 1441.2 | 490.7 | 666.7 | 150.0 | 1294.1 | 440.6 | 2428.6 | 1736.5 | - | - | 8648.4 |
| 19 | 1441.2 | 408.9 | 666.7 | 120.0 | 1294.1 | 367.2 | 2428.6 | 1602.9 | - | - | 8329.6 |
| 20 | 1441.2 | 327.1 | 666.7 | 90.0 | 1294.1 | 293.8 | 2428.6 | 1469.3 | - | - | 8010.8 |
| 21 | 1441.2 | 245.4 | 666.7 | 60.0 | 1294.1 | 220.3 | 2428.6 | 1335.8 | - | - | 7692.0 |
| 22 | 1441.2 | 163.6 | 666.7 | 30.0 | 1294.1 | 146.9 | 2428.6 | 1202.2 | - | - | 7373.2 |
| 23 | 1441.2 | 81.8 | - | - | 1294.1 | 73.4 | 2428.6 | 1068.6 | - | - | 6387.8 |
| 24 | - | - | - | - | - | - | 2428.6 | 935.0 | - | - | 3363.7 |
| 25 | - | - | - | - | - | - | 2428.6 | 801.5 | - | - | 3230.1 |
| 26 | - | - | - | - | - | - | 2428.6 | 667.9 | - | - | 3096.5 |
| 27 | - | - | - | - | - | - | 2428.6 | 534.3 | - | - | 2962.9 |
| 28 | - | - | - | - | - | - | 2428.6 | 400.7 | - | - | 2829.4 |
| 29 | - | - | - | - | - | - | 2428.6 | 267.2 | - | - | 2695.8 |
| 30 | - | - | - | - | - | - | 2428.6 | 133.6 | - | - | 2562.2 |
| 31 | - | - | - | - | - | - | - | - | - | - | - |
| 32 | - | - | - | - | - | - | - | - | - | - | - |
| 33 | - | - | - | - | - | - | - | - | - | - | - |
| 34 | - | - | - | - | - | - | - | - | - | - | - |
| 35 | - | - | - | - | - | - | - | - | - | - | - |
| 36 | - | - | - | - | - | - | - | - | - | - | - |
| 37 | - | - | - | - | - | - | - | - | - | - | - |
| 38 | - | - | - | - | - | - | - | - | - | - | - |
| 39 | - | - | - | - | - | - | - | - | - | - | - |
| 40 | - | - | - | - | - | - | - | - | - | - | - |
| 41 | - | - | - | - | - | - | - | - | - | - | - |
| 42 | - | - | - | - | - | - | - | - | - | - | - |
| 43 | - | - | - | - | - | - | - | - | - | - | - |
| 44 | - | - | - | - | - | - | - | - | - | - | - |
| 45 | - | - | - | - | - | - | - | - | - | - | - |
| 46 | - | - | - | - | - | - | - | - | - | - | - |
| 47 | - | - | - | - | - | - | - | - | - | - | - |
| 48 | - | - | - | - | - | - | - | - | - | - | - |
| 49 | - | - | - | - | - | - | - | - | - | - | - |
| 50 | - | - | - | - | - | - | - | - | - | - | - |
| TOTAL | 24500.0 | 15294.1 | 8000.0 | 4500.0 | 22000.0 | 13733.5 | 48572.7 | 44079.8 | 15000.0 | 6337.5 | 202017.6 |

**FIGURE 6-1**



SENSITIVITY OF PROJECT RATE OF RETURN
TO CHANGES IN KEY PROJECT VARIABLES
BASE CAPITAL COSTS
BASE COAL COSTS
CAPACITY UTILIZATION
BASE OIL COSTS
PROJECT ROR %
28
26
24
22
20
-20
-15
-10
-5
0
5
10
15
20
PERCENT CHANGE FROM BASE CASE ASSUMPTION

**FIGURE 6-2**
**SENSITIVITY OF PROJECT RATE OF RETURN TO FUEL PRICE ESCALATION AND CAPACITY FACTOR**



# 7.0 PROJECT PLAN

## 7.1 PROJECT MANAGEMENT ORGANIZATION

For a project of this size and complexity, there are many critical factors to be continuously monitored, such as cost, schedule, quality, and contractor performance. To maintain control of the project performance, the project management concept is almost universally considered to be optimum. In this concept the project organization functions as a team with the Project Manager as the team leader. He is assisted by a Project Engineer, Project Procurement Manager, Project Cost and Schedule Supervisor, Project Construction Manager, and Project Start-Up Supervisor.

This project team is directly responsible to the Project Manager. As the focal point, his prime function is the coordination of all the activities of the project from conception through completion. Under his direction, project schedules are developed and manpower requirements and total project cost are estimated, based on a defined scope of work. According to established procedures, these schedules and estimates are continuously monitored and any deviations identified. The Project Manager has the responsibility and authority to take necessary corrective action.

The project management organization and interfaces are shown in Figure 7-1.

## 7.2 CONSTRUCTION MANAGEMENT

When carefully structured on a complex project, the construction management approach to construction can result in the most competitive cost. This concept has already been applied to the furnish and erect specifications for the boilers, electrostatic precipitators, and coal handling system for the Old Harbour conversion. This approach requires careful scoping of the contracts to permit sufficient engineering time to develop complete plans and specifications. The more complete the packages, the more real is the competition for "hard money" contracts. In this fashion much of the commercial risk will be assumed by the successful bidder on each contract. This is a distinct advantage over a situation in which a contract is awarded for a task on a target basis, with undeveloped scope and schedule, and then is subject to changing conditions throughout the life of the contract.

In a "fast-track" type of project, which may be the optimum approach for Old Harbour, a modified construction management approach is required in which the critical path of the project is established. In the case of Old Harbour, this is the boiler fabrication, delivery, and erection period. Construction packages will then be prepared and competitively bid for all activities that can fall within the prescribed critical path. In some activities (for example, the boiler foundations), the normal cycle of engineering, specifications, bid, and award on a construction management basis would fall outside of the boiler critical path. In this case engineering will begin using preliminary boiler column loadings. This would permit placement of an order for the pipe piles, and ordering of any pile-driving equipment that may be required from offshore sources. The data would also be sufficient at this point to obtain bids for driving the piles on a per-foot basis. Engineering would obtain boiler loading data to permit final design while the contractor is mobilizing. This example is typical of several areas that will require a modification to stay within the boiler critical path. It is expected that the fast-track schedule shown on Figure 3-13 will also require the modified approach in the electrical installation and pipe erection.

## 7.3 PROJECT CONTROLS

### 7.3.1 Project Control System Overview

Much of the planning for the project should be initiated prior to the actual construction phase. This will ensure that construction will start in an efficient manner and will help avoid costly delays caused by not having long lead time materials and documentation on site to support the proper construction sequence. Since this type of planning is included in the overall project controls, much of the following discussion of major control components includes references to controls that are beyond the scope of controls considered for construction only. These controls are based on the assumption (as is the case for Old Harbour) that the project budget will be established in advance and that the appropriate level of project estimates to support the control system will be developed.

### 7.3.2 Project Control System Components

The major components of the Project Control System recommended for the the Old Harbour Project are as follows. Each is described in the following commentary.

a. Project Schedules

b. Trend Program

c. Labor Productivity Analysis and Control

d. Bulk Commodity Inventory Control

e. Material and Contract Control

f. Detail Design Control and Schedule Integration

g. Change Control Program

#### 7.3.2.1 Project Schedules

In order to control the project schedule, a well-defined hierarchy of schedules is recommended. The starting point is an integrated summary schedule (Figure 3-13) which indicates major milestones and shows critical relationships between engineering, procurement, and construction. This Level I schedule establishes the framework for developing more detailed schedules and is used to report schedule status to management throughout the life of the project.

Level II schedules, which show more detail and are the starting point for the detailed work plans of the contractors' superintendents, can also be developed prior to the award of contracts. These schedules integrate engineering, procurement, and construction.

7.3.2.2 Trend Program

The trend program is an integral part of the Project Control System, designed to track and control project scope, cost, and schedule. The trend program involves constant monitoring of the project and is dynamic--it exposes pending decisions and their related impacts early enough to minimize negative impacts. It is a decision-making tool in which timeliness of identifying and resolving trends is the key element.

The key activities of a successful trend program include:

- Establish an initial trend base control budget (project estimate)

- Hold regularly scheduled project team trend meetings to discuss potential budget deviations, to solve problems promptly and make necessary decisions

- Document all potential budget deviations through the participation of all project team members, who are experienced in design/construction review and are able to recognize problems

- Provide monthly summary report of trends to the joint project team.

When these activities are accomplished, the trend program will provide a constant projection of total project cost and schedule. In addition, changes from the original defined scope of the project are continuously documented, and their impact on cost and schedule is evaluated. Contractor change requests can be anticipated and documented in advance to avoid surprises.

7.3.2.3 Labor Productivity Analysis and Control

Labor control is effected in the field by constant monitoring of job-hours, costs, and quantities, which are translated into a format that can be compared with the budget.

Budget unit job-hours for field labor can be established. Performance curves which compare actual unit job-hour rates to the budget rate at various stages of progress should be developed. Labor unit job-hours are monitored by comparing the unit job-hours spent to date with the budget unit job-hours by commodity for total project and for each major contract. Deviations and trends are identified, and experience and special studies are applied to accomplish control. This monitoring approach identifies early indications of when a contractor is in trouble, sometimes before the contractor is aware of any problems. Also, more accurate projections of estimated costs to complete the work are available.

### 7.3.2.4 Quantity Inventory Control

Bulk commodity tracking is the thread that ties the cost and schedule reporting system together, including the ties of quantities to the appropriate level schedules. Quantity takeoffs are initiated when engineering design is sufficient and continue until completion of engineering. The quantity data become more definitive as design engineering progresses, i.e., estimated quantities are compared to takeoff, and finally, actual installed quantities. Forecast cost and schedule are revised and updated as deviations from the budgeted quantities are identified and reported in the trend program.

Standard identification of commodities will be required among the various contractors to minimize interface problems and ensure consistent and accurate reporting. The quantity tracking program will also support the contract packaging and bid process and will aid in the control of contract changes due to quantity variations.

### 7.3.2.5 Material and Contract Control

A cost and schedule budget should be prepared for each material requisition based on quantity and cost data from the most recent estimate. This budget allows engineering and procurement to assess the quotations received from various contractors, with significant deviations being noted in the trend reports.

All project material and subcontract costs and commitments are continually recorded and accumulated through their appropriate cost codes. A cost engineering group implements and monitors the cost and commitment program for the project. The program provides a quick and economical means for accumulating and categorizing project material and contract costs.

Reports recommended for procurement control include a status of material requisitions throughout the bid cycle, and a status of major equipment and materials after purchase order or contract award through site delivery. These types of reports are used by the procurement group for detailed expediting of vendors, contractors, and the project team.

As part of the contract bid evaluation and review process, independent equivalent scope of supply estimates should be prepared for use in comparison with the submitted bids for scope and pricing consistency. Possible savings are identified and the results and updates of these estimates are continued through the change order control and trend programs.

#### 7.3.2.6 Detail Design Control and Schedule Integration

The control of detail design and its integration with project schedule should be accomplished early in the project in order to support the construction program. Drawings, specifications, licensing, studies, and other tasks are formulated into a detailed engineering work plan and budget which are monitored and forecast continuously in terms of job-hours and schedule.

The designers, equipment suppliers, and contractors' schedules should be integrated. All specifications and drawings associated with a contract package should be identified and tracked. Exception reports allow the joint project team to know which key documents are missing before the package is formed so that incomplete packages are not let for bid. The drawings, specifications, etc., developed by contractors can also be integrated into a detail design control program as contracts are awarded.

#### 7.3.2.7 Change Control Program

A comprehensive and assertive change control program is an essential part of the overall Project Control System, encompassing scope monitoring from contract pre-award through closeout. The major components of the change control program include:

- Engineering Design/Field Change Notcies. These identify in detail the scope of a change and whether it was initiated by the contractor or the joint project team.

- Equivalent Scope Estimates. These estimates of a change order allow the client to negotiate from a position of strength when the contractor submits its proposal to do the work.

- Contract Change Log. The log allows the client to keep abreast of all changes to a contract at any point in time and to constantly be aware of the status and value of all pending changes.

- The Contract Admendment Process. The process is simplified and more thorough because of effective control of changes.

- Trending. This occurs continuously even after contract award and allows contract change requests to be anticipated and the client advised several months in advance. Incorporation of the change control program with the trend program keeps the client current on the latest status of project cost and schedule.

### 7.4 BALANCE OF PLANT CONTRACTING PLAN

It is envisioned that the remaining major contracts and purchase orders for supply and erection or supply of services only would be originated at the engineer's offices or from the jobsite during the construction effort. Potential sources would include those countries from which firms have been awarded principal equipment, and others on the previous bidders lists, if qualified. Participation of the Inter-American Development Bank (IDB) could influence development of subsequent bidders lists. By dividing this project into easily definable work packages, the opportunity for Jamaican firms to participate directly should be maximized.

Competitive bids will be requested. Terms of such invitations will be modified if necessary to accommodate participation of IDB, Export-Import Bank, or other financial institutions.

The major contract and purchase order items that would be committed individually are as follows:

- Piling
- Concrete Foundation
- Coal Unloading Pier
- Chimney
- Site Development
- General Mechanical
- Control Building and Auxiliary Bay Structural Steel
- Coal Day Silos
- Personnel/Freight Elevator
- Bottom Ash System
- Fly Ash System
- General Electrical and Instrumentation

The contracts for general mechanical and general electrical and instrumentation will be structured to include all possible materials (e.g., valves, piping, instruments) to allow the subcontractors to maximize their purchases from the local marketplace. Where necessary to support a fast-track schedule, material and equipment will be procured separately from installation contracts and provided as owner-furnished items. When justifiable, sole source procurement may be used to enhance the project schedule.

## 7.5 SUGGESTED FINANCING STRATEGY

The following financing strategy was developed by Bechtel Financing Services, Inc. based on its worldwide experience in assisting clients to obtain export credit, international development bank financing, and commercial bank financing for projects over the last 15 years. Bechtel is prepared to assit the Coal Committee of Jamaica to obtain financing for implementation of this strategy under Phase III of the Coal Conversion Study.

a. Upon preliminary approval of the project by appropriate Government of Jamaica authorities, formal application should be made to the Inter-American Development Bank for funding to cover 50 to 55 percent of project cost. This is likely to be the most important source of funding for the project, and considerable time will be needed for IDB's project appraisal. Participation by other lenders is likely to be contingent on IDB participation.

b. A matrix of the maximum amount of potential project procurement of goods and services from each individual country should be developed. This should include the recommended suppliers on the major equipment packages plus the balance of plant that can also be potentially sourced from each of these countries.

c. A series of presentations to the export credit agencies and government officials in each country identified in Item b should be made. Documentation should be presented to each agency in the form of a project financing brochure. The brochure should include details on the project plan, scheduling, economic analysis, and financing plan as well as a formal request for funding for the maximum potential procurement from each country. These presentations should be organized in coordination with at least one potential supplier in each country and should be undertaken in parallel with the technical and commercial negotiations.

d. In discussions with each export credit agency, evidence of the favorable financing terms received from other agencies should be presented to encourage a competitive matching of the most favorable terms. Attempts should be made to negotiate additional concessions with respect to financing downpayments, interest during construction, local costs related to supply and erection, and limited procurement from other countries. These types of favorable concessions have been granted on other projects, particularly by the Japanese.

e. If the technical and commercial evaluations warrant further discussions with suppliers in Italy and Japan, formal applications should be made to these governments for concessionary financing as recommended by the suppliers.

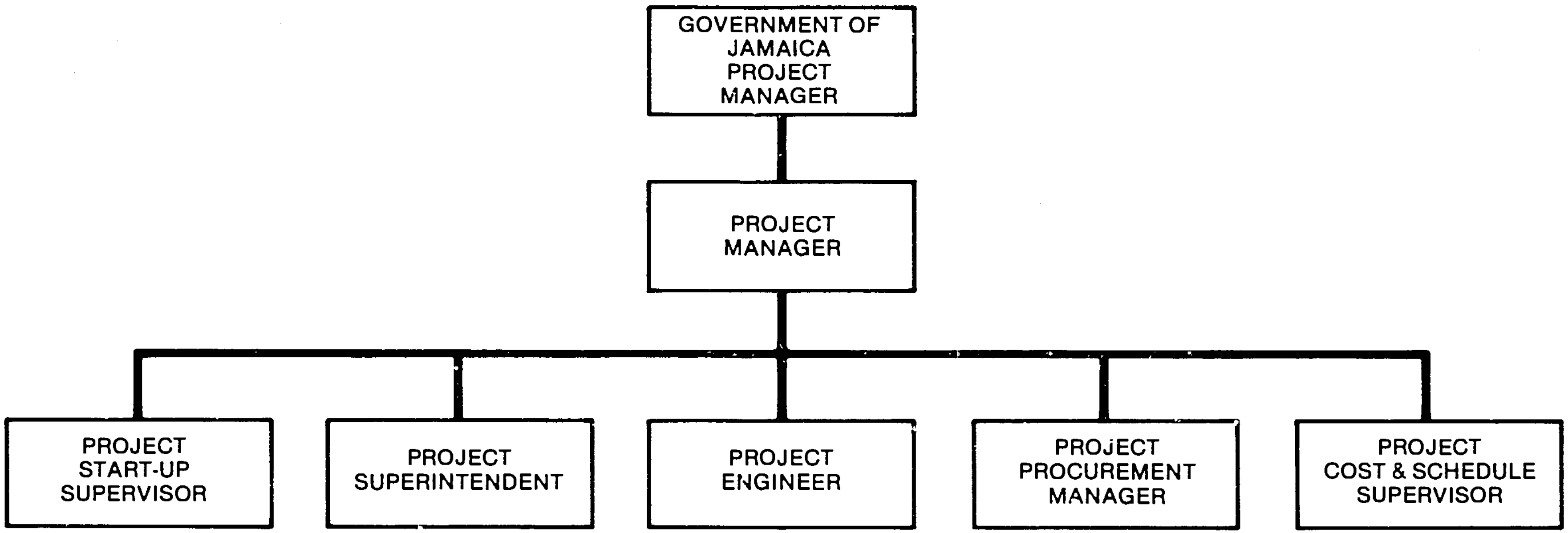
f. Commercial bank financing can often be arranged in conjunction with export credits, in situations where banks may otherwise be unwilling to lend. This linkage should be utilized to the extent needed to encourage commercial bank participation to cover any financing gaps. It is recommended that contacts with the commercial banks be deferred until the IDB becomes formally involved in the project and much of the project financing is committed by export credit agencies and the IDB. This will identify clearly the amount of commercial bank financing actually needed and minimize the payment of commercial bank commitment fees.

g. A final financing plan should be developed based on the commitments obtained from the IDB, the export credit agencies, and the commercial banks. A revised set of project cash flow projections should be prepared to ascertain the impact of the final financing plan on the project's economic and financial viability.

h. Loan negotiations with each selected financial institution should be concluded.

**FIGURE 7-1**

**PROJECT MANAGEMENT ORGANIZATION**



Report to the

GOVERNMENT OF JAMAICA

# COAL FEASIBILITY STUDY AND FINANCING PLAN

PHASE II

VOLUME 2

APPENDIX A

# ASSOCIATED ENVIRONMENTAL IMPACT ASSESSMENT

Prepared for the
Coal Committee of Jamaica

BECHTEL POWER CORPORATION
September 1983
Reference No. 15307-002

120

GOVERNMENT OF JAMAICA

OLD HARBOUR PLANT

ASSOCIATED ENVIRONMENTAL IMPACT ASSESSMENT

## INTRODUCTION

Conversion of the Old Harbour Station to coal-firing by addition of two new coal-fired boilers operating in parallel with the existing oil-fired boilers, Units 1 and 2, was determined to be technically feasible and economically attractive in the Coal Feasibility Study, Phase I of the project. The existing plant consists of four oil-fired units with a total capacity of 222 MWe, Unit 1 at 30 MWe, Unit 2 at 60 MWe, and Units 3 and 4 at 66 MWe each. Thd heat input to each new boiler is 720 x $10^6$ Btu/hr at full load and it will have the same steam output capacity as that of the existing oil-fired boilers, Units 3 and 4. Once the new boilers are in operation, the oil-fired boilers (Units 3 and 4) will be used as an emergency backup only. The small oil-fired Units 1 and 2 will continue to operate with the new boilers.

Following is a summary of the associated environmental impact assessment for the addition of two new coal units. The associated environmental assessment has been performed for potential air quality impacts, ash disposal site evaluation, potential wastewater discharge impacts and port dredging impacts.

## SUMMARY

1. Air Quality Impact Assessment

An air quality impact assessment has been performed for the Old Harbour Plant coal conversion project. Pollutant ground level concentrations from operation of the plant (before and after coal conversion) were calculated using the U.S. EPA approved Industrial Source Complex (ISC) air quality model.

Based on the results of the study, there is an improvement in the local air quality associated with the proposed coal conversion. The maximum combined impact of the new units and the existing units 1 and 2, together with the background pollutant concentrations, represents the total maximum pollutant ground level concentration in the Old Harbour Bay region after coal conversion. Comparisons of this total concentration and the U.S. NAAQS for each pollutant ($SO_2$, TSP, $NO_X$) is shown in Table 1. As shown in Tables 1 & 2, all calculated pollutant ground level concentrations meet the U.S. NAAQS except the 24-hour average concentration of $SO_2$. However, this exceedance, 382 $\mu g/m^3$ (24-hour) represents a 35% reduction in $SO_2$ levels through the replacement of Units 3 and 4 with the new coal-fired units. The current operation of oil units 1-4 results in an average concentration of 592 $\mu g/m^3$. This replacement also results in TSP and $NO_X$ total ground level concentrations which do not exceed their applicable U.S. NAAQS and are also representative of improvement in the local air quality.

2. Ash Disposal Site Evaluation

Coal conversion of the Old Harbour Station will result in increased production of ash. Although sale of reuse is the preferred method of ash disposal, until firm arrangements can be made for the sale of ash, landfilling appears to be the most feasible disposal method. The method of transport to the landfill is assumed to be by truck.

The purpose of this study was to identify and evaluate potential ash disposal sites. The site areas were sized to accommodate an annual ash disposal rate of 41,000 metric tons (2 - 66 MWe units) over a unit life of 22 years.

The disposal site selection methodology consists of 3 distinct steps.

Step 1 - Regional Screening

Step 2 - Site Identification

Step 3 - Site Evaluation and Rating

During Step 1, avoidance areas were identified on base maps. The avoidance criteria included: areas of known faults, recharge zones, urban areas, etc. Step 2 consisted of two phases (A) Identification of 11 potential disposal site areas on the base maps (b) field reconnaissance of the 11 potential sites. A conservative estimate of 100 acres was used for the potential site area. Step 3 included a detailed evaluation of the 11 sites based on their engineering and environmental characteristics. These characteristics included:

(A) Engineering - transportation, site preparation drainage and geology

(B) Environmental - ecology, water resources, land use and aesthetics.

Each site was given a rating ($R_i$) for each of the above 8 criteria. Each of the criteria was then weighted ($WF_i$) according to significance. The sum of the engineering weighted ratings was multiplied by .6 and added to the environmental weighted ratings multiplied by .4. This sum was the overall rating for each site. Based on this evaluation technique, 3 sites were selected as best suited for ash disposal. These sites are highlighted on Figure 1.

3. Wastewater Discharge Impact Assessment

The quality and quantity of untreated and treated coal pile runoff were estimated. No other incremental wastewater sources will be associated with coal conversion. Qualitative assessment of the potential, incremental aquatic impacts due to coal pile runoff discharge has been evaluated. The analysis shows that the incremental impacts on receiving waters will be minimal outside a limited mixing zone.

4. Port Dredging Impacts

The purpose of this study was to examine the physical and environmental aspects of dredging activities related to potential coal deliveries at Old Harbour, Jamaica. The subject dredging activities at Old Harbour could be carried out in connection with the potential conversion of the steam electric facilities at Old Harbour from oil fuel to coal. The Traverse Group, Inc. (TGI), has examined the dredging impacts under subcontract to Bechtel. Delivery of coal would require dredging of an approach channel and a turning basin at the plant site. Disposal of the initial and maintenance dredge spoil would be required.

This study addressed two major objectives:

1. An initial assessment of the environmental and physical factors that might be associated with the dredging.
2. An identification of alternatives for disposal of the spoil materials.

TGI has recommended the following alternatives for disposal of spoil materials after meeting with various groups in Jamaica:

a. Use of dredge spoil for the Old Harbour public beach

b. Expansion of "land spit" to the west of the plant

c. Creation of diked pond areas for possible mariculture operation

TABLE 1

TOTAL GROUND LEVEL CONCENTRATIONS ($\mu g/m^3$)

| | Natural Background | | | New Units + Units 1 and 2 | | | Total | | | U.S. NAAQS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SO_2$ | TSP | $NO_x$ | $SO_2$ | TSP | $NO_x$ | $SO_2$ | TSP | $NO_x$ | $SO_2$ | TSP | $NO_x$ |
| Annual | 0 | 40 | 0 | 63.4 | 8.4 | 9.5 | 63.4 | 48.4 | 9.5 | 80 | 75 | 100 |
| 24-hour | 0 | 40 | - | 382.3 | 141.7 | - | 382.3 | 181.7 | - | 365 | 260 | - |
| 3-hour | - | - | - | 973.3 | - | - | 973.3 | - | - | 1300 | - | - |

TABLE 2

## IMPROVEMENT IN LOCAL AIR QUALITY - $SO_2$ IMPACT

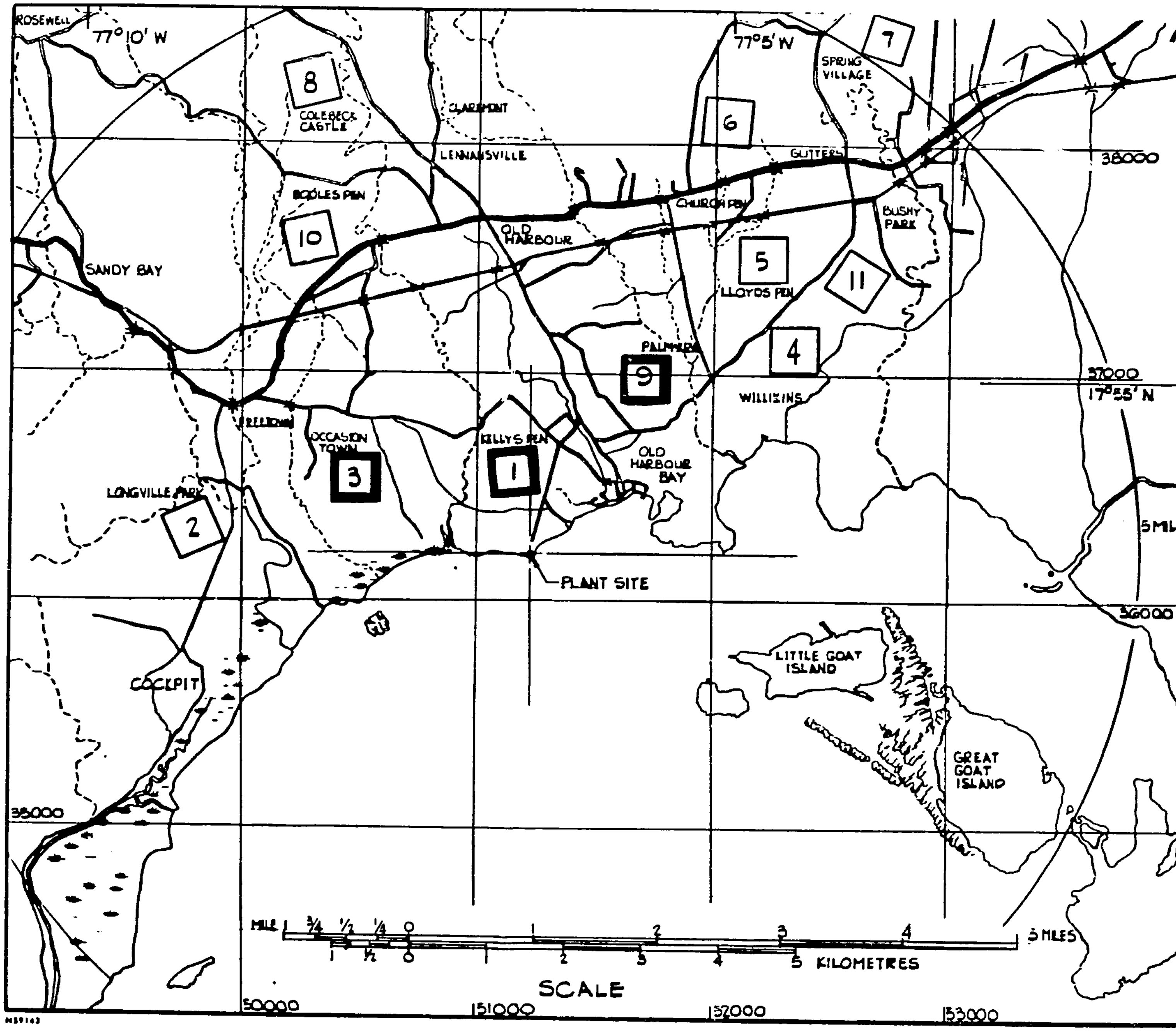
| Averaging Period | New Units + Units 1 & 2 ($\mu g/m^3$) | Units 1, 2, 3, 4 ($\mu g/m^3$) | Net Reduction $SO_2$ ($\mu g/m^3$) |
|---|---|---|---|
| Annual | 63.4 | 106.7 | 43.3 |
| 24-hour | 382.3 | 591.9 | 209.6 |
| 3-hour | 973.3 | 1654.4 | 681.1 |

## IMPROVEMENT IN LOCAL AIR QUALITY - TSP IMPACT

| Averaging Period | New Units + Units 1 & 2 ($\mu g/m^3$) | Existing Units 1, 2, 3, 4 ($\mu g/m^3$) | Net Reduction TSP ($\mu g/m^3$) |
|---|---|---|---|
| Annual | 8.4 | 8.4 | 0 |
| 24-hour | 141.7 | 257.6 | 115.9 |

## IMPROVEMENT IN LOCAL AIR QUALITY - $NO_x$ IMPACT

| Averaging Period | New Units + Units 1 & 2 ($\mu g/m^3$) | Existing Units 1, 2, 3, 4 ($\mu g/m^3$) | Net Reduction $NO_x$ ($\mu g/m^3$) |
|---|---|---|---|
| Annual | 9.5 | 9.9 | .4 |




| No. | DATE | REVISIONS | BY | CH'K | DES SUPV | ENG'R | PROJ ENGR | APPR |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

SCALE — DESIGNED — DRAWN E Slater CHIEF ENGR

**BECHTEL**
GAITHERSBURG, MD.

GOVERNMENT OF JAMAICA
OLD HARBOUR PLANT
COAL CONVERSION STUDY

ALTERNATIVE
ASH DISPOSAL SITES

JOB No. | DRAWING No. FIG.-1 | REV.



M59163

GOVERNMENT OF JAMAICA

OLD HARBOUR PLANT

COAL CONVERSION PROJECT

# ASSOCIATED ENVIRONMENTAL IMPACT ASSESSMENT

# AIR QUALITY

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## 1.0 INTRODUCTION

Conversion of the Old Harbour Station to coal-firing by addition of two new coal-fired boilers operating in parallel with the existing oil-fired boilers, Units 1 and 2, was determined to be technically feasible and economically attractive in the Coal Feasibility Study, Phase I of the project. The existing plant consists of four oil-fired units with a total capacity of 222 MWe, Unit 1 at 30 MWe, Unit 2 at 60 MWe, and Units 3 and 4 at 66 MWe each. The heat input to each new boiler is 720 x $10^6$ Btu/hr at full load and it will have the same steam output capacity as that of the existing oil-fired boilers, Units 3 and 4. Once the new boilers are in operation, the oil-fired boilers (Units 3 and 4) will be used as an emergency backup only. The small oil-fired Units 1 and 2 will continue to operate with the new boilers.

The purpose of this study is to evaluate incremental air quality impacts, if any, resulting from operation of the new coal facility. Ground level concentrations of pollutants emitted from the existing and/or new facilities will be determined through diffusion modeling. A Good Engineering Practice (GEP) stack height will be determined and used for the new facility to avoid excessive ground level concentrations of air pollutants due to adverse downwash effects caused by nearby structures.

## 2.0 PLANT DESCRIPTION

### 2.1 SITE DESCRIPTION

The Old Harbour station is located on the south side of the island on Old Harbour Bay, approximately 25 miles west of Kingston. The geographical location of the station is latitude 17° 54'N and longitude 77° 7'W. Docking facilities are not available at the site, and the railroad and the main highway are approximately two miles north of the site. Secondary roads lead into the plant. Old Harbour, the nearest town, is about 3.5 miles north of the Station.

The site is relatively flat and it is covered with light vegetation. The existing plant elevation varies from sea level at the shoreline to an elevation of 8.0 feet inland. The plant grade is approximately 7.0 feet above mean sea level (MSL).

### 2.2 PLANT AND FUEL DATA

The new coal-fired facility will be located to the northeast of the existing plant (see Figure 2.2-1). As a result of the conversion, steam from the two new coal-fired boilers will replace the steam from the existing oil-fired boilers Nos. 3 and 4.. Relevant plant data for the existing and planned facility are given in Tables 2.2-1 and 2.2-2, respectively. For the new coal-fired boilers, particulate emissions are controlled by electrostatic precipitators (ESP) with 99.7 percent efficiency.

The new boilers will be designed to fire coal with a maximum sulfur content of two percent. Proximate and ultimate analyses of coal which are used as the design basis for boiler and other equipment are given in Table 2.2-3.

TABLE 2.2-1

PLANT DATA - EXISTING FACILITY

| Item | Unit No. 1 | Unit No. 2 | Unit No. 3 | Unit No. 4 |
|---|---|---|---|---|
| Design Capacity, MWe | 30 | 60 | 66 | 66 |
| Oil-Firing Rate, lb/hr | 18,580 | 37,160 | 40,600 | 40,600 |
| Boiler Heat Input, $10^6$ Btu/hr | 346.3 | 692.7 | 756.8 | 756.8 |
| Stack Height, ft. | 150 | 150 | 158.6 | 158.6 |
| Stack Diameter, ft. | 6.0 | 7.5 | 10.0 | 10.0 |
| Flue Gas Velocity, ft/sec | 62 | 79 | 48.8 | 48.8 |
| Stack Gas Temperatures, °F | 270 | 270 | 270 | 270 |
| Stack Gas Rate, 1,000 acfm | 105 | 210 | 230 | 230 |

TABLE 2.2-2

PLANT DATA - PLANNED FACILITY

| Item | Unit No. 1 | Unit No. 2 | Coal* Unit A | Coal* Unit B |
|---|---|---|---|---|
| Design Capacity, MWe | 30 | 60 | 66 | 66 |
| Fuel | Oil | Oil | Coal | Coal |
| Fuel Firing Rate, lb/hr | 18,580 | 37,160 | 61,000 | 61,000 |
| Boiler Heat Input, $10^6$ Btu/hr | 346.3 | 692.7 | 720.0 | 720.0 |
| Stack Height, ft. | 150 | 150 | 450 | 450 |
| Stack Diameter, ft. | 6 | 7.5 | 8 | 8 |
| Flue Gas Velocity, ft/sec | 62 | 79 | 93 | 93 |
| Stack Gas Temperature, °F | 270 | 270 | 270 | 270 |
| Stack Gas Rate, 1,000 acfm | 105 | 210 | 280 | 280 |

* Common stack for Units A & B.

TABLE 2.2-3

DESIGN BASIS FUEL DATA

COAL

| Proximate Analysis | |
|---|---|
| Constituent | Weight (%) |
| Fixed carbon, % | 50.3 |
| Volatile matter, % | 35.7 |
| Ash, % | 8.0 |
| Moisture, % | 6.0 |
| Higher heating value, Btu/lb | 12,700 |
| Heating Value, Btu/lb | 12,700 |

| Ultimate Analysis | |
|---|---|
| Constituent | Weight (%) |
| Moisture, % | 6.0 |
| Carbon, % | 69.7 |
| Hydrogen, % | 4.9 |
| Nitrogen, % | 1.3 |
| Sulfur, % | 2.0 |
| Ash, % | 8.0 |
| Oxygen, % (diff.) | 8.1 |

OIL

| | |
|---|---|
| Heating Value, Btu/lb | 18,641 |
| Maximum Sulfur, Weight Percent | 3.0 |

## 2.3 EMISSION SOURCES

Air pollutant emission rates from the facility before and after the coal conversion are estimated. Existing Units 1 through 4 burn residual oil containing maximum of 3 percent sulfur. As a result of the conversion, steam from the two new coal-fired boilers replaces the steam from oil-fired Units 3 and 4. Emission rates of particulates, $SO_e$, and $NO_x$ for the existing and the planned facilities are given in Tables 2.3-1 and 2.3-2, respectively. Particulates from coal-fired units are removed by ESP of 99.7 percent removal efficiency. Also, fugitive particulate emissions result from coal handling activities such as barge unloading, coal conveying and transfer points, coal storage, coal reclaiming, and fly ash handling. Particulate emissions will be controlled by currently available engineering practices such as wet supression, dust collection with fabric filters, telescopic chutes, under-pile reclaiming, etc. Table 2.3-3 summarizes controlled fugitive particulate emissions for all transfer points shown in Figure 2.2-2.

## TABLE 2.3-1

## AIR POLLUTANT EMISSION DATA - EXISTING FACILITY

| Pollutant | Controlled Emission Rates, lb/hr | | | |
|---|---|---|---|---|
| | Unit 1 | Unit 2 | Unit 3 | Unit 4 |
| Particulate | 76 | 152 | 166 | 166 |
| Sulfur Dioxide | 1,115 | 2,230 | 2,436 | 2,436 |
| Nitrogen Oxides | 104 | 208 | 227 | 227 |

## TABLE 2.3-2

## AIR POLLUTANT EMISSION RATES - PLANNED FACILITY

| Pollutant | Controlled Emission Rates, lb/hr | | | |
|---|---|---|---|---|
| | Oil Unit 1 | Oil Unit 2 | Coal Unit A | Coal Unit B |
| Particulate | 76 | 152 | 21.8 | 21.8 |
| Sulfur Dioxide | 1,115 | 2,230 | 2,286 | 2,286 |
| Nitrogen Oxides | 104 | 208 | 435.5 | 435.5 |

## TABLE 2.3-3

## FUGITIVE PARTICULATE EMISSIONS

| No. | Source | Control Measures | Controlled Emissions lb/day |
|---|---|---|---|
| 1 | Barge Unloading | Wet Supression, Dust Collection | 5.19 |
| 2 | Stacker Tower | Dust Collection, Enclosure | 3.46 |
| 3 | Active Coal Storage | Wet Supression, Telescopic Chute, Underpipe Reclaim | 28. |
| 4 | Crusher Tower | Dust Collection, Enclosure | 0.48 |
| 5 | Transfer Tower | Dust Collection, Enclosure | 0.10 |
| 6 | Silo-Feed Conveyor | Dust Collection, Enclosure | 0.19 |
| 7 | Inactive Coal Storage | Compaction, Wet Supression | 0.9 |
| 8 | Fly-Ash Silo | Wet Supression, Dust Collection | 11.8 |

## 2.4 GEP STACK HEIGHT

An empirical equation, based on the dimensions of the nearby structures, was used to determine the GEP stack height:

$$H_S = H_B + 1.5L \qquad \text{Ref. (1)}$$

where:

$H_S$ = GEP stack height

$H_B$ = height of the nearby structure

$L$ = height ($H_B$) or width (W) of the structure, whichever is less.

The methodology is provided and discussed by the U.S. EPA Good Engineering Practice Stack Height Guidelines (EPA 450/4-80-023, 1981).

A nearby structure is defined as a structure that would cause stack plume downwash. Based on the site arrangement, the nearby structures are the new boiler building and its associated coal silo.

The greatest justifiable stack height based on the conceptual design of the new facility and using the above equation is 450 feet. Therefore, the GEP stack height for the Old Harbour Station coal-fired facility is 450 feet.

## 3.0 AIR QUALITY REVIEW

### 3.1 AMBIENT AIR QUALITY STANDARDS

Air pollution emissions from burning coal consist primarily of particulate matter (PM), sulfur dioxide ($SO_2$), and nitrogen oxides ($NO_x$). Other contaminants such as carbon monoxide and hydrocarbons are also emitted in the combustion process but in amounts that are relatively small in terms of ambient air quality.

Since there are no published air quality emissions standards promulgated in Jamaica, the following environmental standards, equivalent to U.S. air quality standards, were used in the study as a design basis after discussions with Jamaica government officials as reported in the Phase I Study.

Air Quality Standard

| | | |
|---|---|---|
| $SO_2$ | 80 $\mu g/m^3$ | Annual average ground level concentration |
| | 365 $\mu g/m^3$ | 24-hour average ground level concentration |
| | 1300 $\mu g/m^3$ | 3-hour average ground level concentration |
| PM | 75 $\mu g/m^3$ | Annual average ground level concentration |
| | 260 $\mu g/m^3$ | 24-hour average ground level concentration |
| $NO_x$ | 100 $\mu g/m^3$ | Annual average ground level concentration |

The short-term (3-hour and 24-hour) air quality standards are allowed to be exceeded once a year.

## 3.2 DISPERSION MODELING

### 3.2.1 Data Base

#### 3.2.1.1 Meteorological Data

For the purpose of air quality dispersion modeling, a survey was conducted to identify the most representative and best available surface and upper air meteorology data for the plant site.

The only station that records upper air data in Jamaica is Palisadoes Airport which is about 25 miles east-northeast of the Old Harbour Station. The airport is situated south of Kingston, near the Caribbean Sea. Its proximity to the sea offers it atmospheric dispersion conditions similar to that of the coastal Old Harbour Station. Data are available from 1956 to 1975. The closest station, that has surface observations which are representative of the atmospheric dispersion conditions at the plant site, is an old Air Force station located in Vernam which is approximately 18 miles west of the Old Harbour Bay. Surface data are available from 1973 to 1980. Thus the concurrent years of surface and upper air data are 1973-1975. Three years of meteorological observations are considered adequate to represent the year-to-year variation of atmospheric conditions. Both surface and upper air data were obtained from the U.S. National Climatic Center. This data was processed for compatibility with EPA-approved dispersion models.

There were a good deal of missing data in both the selected surface and upper air data bases. After a careful examination of the new data base, the most complete and concurrent one year of records for both sets of data was determined to be the period from 9/1/73 through 8/31/74. Since it is a requirement to use data for each hour of a given year to execute the air quality program, the identified data set was further edited for completeness. When a mixing height record was missing, it was replaced by an appropriate average value (morning or afternoon) calculated from the past two days of records. If an hour of surface data was missing, it was replaced by the last available hour of good data. The justification for this replacement scheme is that over small time intervals (few hours), meteorological conditions do not vary greatly. If there is a large gap of missing data, more than 12 hours, the whole day was replaced by the last available day. This situation only arise twice within the year of data selected. In a statistical sense, the replacement is insignificant. The validity of the air quality impact assessment will not be affected.

3.2.1.2 Emissions

The pollutant emission rates from the new boilers and the existing oil-fired boilers were already discussed in Section 2.3 and are given in Tables 2.3-1 through 2.3-3. There are no major industrial sources in the vicinity of the station.

3.2.1.3 Terrain

Terrain surrounding the plant site gradually rises from sea level at the edge of the Caribbean Sea to 100 feet above mean sea level approximately three miles north of the site. Elevated terrain greater than 500 feet is located five miles north of the plant. Local terrain is tabulated in Table 3.2-1.

TABLE 3.2-1

TERRAIN ELEVATIONS (FEET, MSL)

DISTANCE (km)

| Direction | 1.0 | 2.0 | 3.0 | 5.0 | 8.0 | 12.0 | 16.0 |
|---|---|---|---|---|---|---|---|
| N | 20 | 30 | 50 | 100 | 700 | 625 | 625 |
| NNE | 15 | 25 | 35 | 65 | 450 | 500 | 625 |
| NE | 10 | 15 | 25 | 60 | 90 | 250 | 275 |
| ENE | 0 | 10 | 10 | 15 | 35 | 40 | 50 |
| E | 0 | 0 | 0 | 0 | 15 | 250 | 125 |
| ESE | 0 | 0 | 0 | 50 | 250 | 0 | 0 |
| SE | 0 | 0 | 0 | 0 | 50 | 0 | 0 |
| SSE | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| S | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SSW | 0 | 0 | 0 | 0 | 0 | 0 | 25 |
| SW | 0 | 0 | 0 | 0 | 25 | 500 | 50 |
| WSW | 0 | 0 | 10 | 100 | 250 | 300 | 75 |
| W | 10 | 10 | 25 | 100 | 260 | 250 | 200 |
| WNW | 15 | 25 | 40 | 60 | 200 | 250 | 250 |
| NW | 20 | 35 | 55 | 100 | 375 | 450 | 750 |
| NNW | 25 | 35 | 60 | 100 | 200 | 900 | 1250 |

NOTES:

1. Plant grade elevation: 7 feet, MSL



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### 3.2.2 Dispersion Model

To determine if the operation of the new boilers will cause a violation of any of the U.S. Ambient Air Quality Standards as given in Section 3.1, the air quality review includes atmospheric dispersion modeling. The EPA Industrial Source Complex (ISC) model was chosen to perform both the existing and new source air quality analyses. The ISC model is capable of modeling noncollocated, point, area, and line sources simultaneously and predicting their combined impacts. Appendix A is devoted to a more detailed model description. The following is a brief description of the ISC model:

The ISC dispersion model is a steady-state Gaussian plume model, designed to assess the air quality impact of emissions from a wide variety of sources associated with an industrial complex. The ISC model was developed specifically to include the following modeling features:

1. Concentration averaging times ranging from 1 hour to 1 year.
2. Physical separation of multiple sources.
3. A variation of wind speed with height wind-profile exponent law.
4. Plume rise due to buoyancy and/or momentum as a function of downwind distance.
5. Difference in terrain elevation of receptors.
6. Aerodynamic building wake effects.
7. Wind blown emissions.
8. Multiple, noncollocated, point, area, line, and volume sources with variable emission rates.
9. Gravitational settling and dry deposition of particulates.

TABLE 3.2-2

SITE BOUNDARY RECEPTORS

| Direction (degrees) | Distance (ft) | Direction (degrees) | Distance (ft) |
|---|---|---|---|
| 10 | 680 | 190 | 580 |
| 20 | 800 | 200 | 580 |
| 30 | 830 | 210 | 800 |
| 40 | 860 | 220 | 1170 |
| 50 | 890 | 230 | 1200 |
| 60 | 920 | 240 | 1230 |
| 70 | 940 | 250 | 1270 |
| 80 | 600 | 260 | 1100 |
| 90 | 380 | 270 | 950 |
| 100 | 330 | 280 | 800 |
| 110 | 260 | 290 | 700 |
| 120 | 240 | 300 | 680 |
| 130 | 220 | 310 | 670 |
| 140 | 230 | 320 | 650 |
| 150 | 240 | 330 | 650 |
| 160 | 240 | 340 | 650 |
| 170 | 260 | 350 | 670 |
| 180 | 460 | 360 | 680 |

Note:

1. Direction 360 degree is true north.



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### 3.2.3 Dispersion Methods

#### 3.2.3.1 Receptor Grids

The ISC model provides either rectangular or polar receptor grids. In this analysis, a polar grid system was utilized with the new stack at the center of the grid. The grid system used to calculate pollutant ground level concentrations consists of 9 rings spaced at distances of 0.75, 1.0, 1.5, 2.0, 3.0, 5.0, 8.0, 12.0, and 16.0 km, and on each ring a receptor is placed every 10 degrees. This grid system provided adequate spacial resolution of the pollutant concentrations. Additional, dense receptor grids were located at the Old Harbour plant site boundary to determine the impact of low level onsite fugitive dust sources. Tabel 3.2-2 lists locations of the site boundary receptors. Since the ISC model is unable to calculate dispersion parameters for receptors located less than 100 meters from any emission source, nearby receptors between ESE and S of the plant were positioned slightly beyond the actual site boundary.

#### 3.2.3.2 Source Configurations

In the analysis, all applicable emission sources were modeled as point sources, except for the coal unloading areas and storage which were treated as area sources.

#### 3.2.3.3 Terrain

The ISC model allows for a limited simulation of terrain features. The model limits terrain to be no higher than the height of the lowest emission source and no lower than the base height of the lowest emission source. The area close to the new facility is mostly flat to gently rolling. The new boiler stack is 450 feet high and the existing stacks are 150 feet high. Therefore, terrain elevations higher than 150 feet were artifically lowered to 150 feet. As shown from Table 3.2-1, this situation arises five miles away from the site and beyond. The approach taken under-predicts the ground level concentration of the emitted pollutants; however, it does not affect the determination of the maximum air quality impact which is expected to occur closer to the plant, i.e., one or two miles from the pollutant source.

For fugitive emission modeling, dispersion estimates were calculated using a polar receptor grid system centered at the new stack. An additional 36 receptors were also placed along the site boundary. Due to the ISC model requirement that maximum terrain heights must be less than or equal to the height of the lowest emission source, flat terrain was assumed in modeling of the figutive emissions. This treatment provides a reasonable approximation of the fugitive impact. Most of the fugitive emissions were low level releases (e.g., coal unloading, coal storage pile, ash handling, etc.) whose maximum ground impact is expected to occur very close to the site, i.e., within two miles of the station. Since the terrain within two miles of the station (see Table 3.2-1) is flat to gentle rolling, the flat terrain assumption for fugitive emissions modeling does not affect the determination of the maximum ground level fugitive impact.

#### 3.2.3.4 Fallout and Surface Reflection

For TSP concentration calculations, the ISC model allows the use of a fallout function to simulate plume depletion with distance. The rate at which particulate matter falls out from a plume is dependent on the size of the particles. Actual TSP emissions contain a spectrum of sizes. Since there is no defined particle size distribution spectrum available, a medium particle size of 20 microns (Ref. 2) was assumed for all particulate emissions. The fall velocity and surface reflection for this size of particle are 5 cm/sec and 62.5 percent (Ref. 3), respectively.

## 4.0 AIR QUALITY IMPACT ANALYSIS

### 4.1 EXISTING AIR QUALITY

Jamaica is under the influence of the easterly tradewinds throughout the year. The rugged terrain produces wide local variations in wind speed and channeling effects. Land and sea breeze effects are important for the coastal plant site. The tradewinds are modified somewhat by land and sea breezes. Wind speeds at night are lower than the daytime wind speeds. Hurricanes and tropical storms are frequent during the summer and early autumn. The annual mean wind speed analyzed from the Vernam surface data is 7.9 mph. Monthly and annual wind distributions collected at the meteorological station are given in Tables 4.1-1 through 4.1-19. In general, the ventilation/dispersion capability of the plant site area is considered to be good. There are no industrial complexes near the plant site. The closest town is Old Harbour, which is approximately 3.5 miles northwest of the station. In summary, the plant area can be classified as having a rural, marine environment.

Characterization of the existing air quality for the Old Harbour Station site area involved using the typical U.S. east coast rural area TSP estimate of 40 $\mu g/m^3$ (Ref. 4) to represent the natural background TSP concentration. The sum of this background concentration and the TSP impact from operation of the Old Harbour Station oil-fired units was used as a measure of the existing TSP level in the area. Since the only major source of $SO_2$ and $NO_x$ in the site area is the existing Old Harbour Station, the $SO_2$ and $NO_x$ impact from operation of the station is considered to be representative of the local existing $SO_2$ and $NO_x$ level.

The $SO_2$, TSP and $NO_x$ impacts from operation of the existing oil-fired boilers were modeled using the ISC model and based on emission rates given in Table 2.3-1.

TABLE 4.1-1

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

| | Relative Frequency Distribution | | | | | Station = 78397 | Period: 1974 - 1975 |
|---|---|---|---|---|---|---|---|
| | Ann. | Speed (KTS) | | | | | |
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .010768 | .000571 | .000000 | .000000 | .000000 | .000000 | .011338 |
| NNE | .002154 | .000114 | .000000 | .000000 | .000000 | .000000 | .002268 |
| NE | .008957 | .000114 | .000000 | .000000 | .000000 | .000000 | .009071 |
| ENE | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| E | .008614 | .000457 | .000000 | .000000 | .000000 | .000000 | .009071 |
| ESE | .006461 | .000342 | .C00000 | .000000 | .000000 | .000000 | .006803 |
| SE | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| SSE | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| S | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| SSW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| SW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| WSW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| W | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| WNW | .013035 | .000571 | .000000 | .000000 | .000000 | .000000 | .013606 |
| NW | .013149 | .000457 | .000000 | .000000 | .000000 | .000000 | .013606 |
| NNW | .017685 | .000457 | .000000 | .000000 | .000000 | .000000 | .018141 |
| Total | .080822 | .003082 | .000000 | .000000 | .000000 | .000000 | .082904 |

Relative frequency of occurence of A stability = .083904.

Relative frequency of calms distributed above with A stability = .079680.

TABLE 4.1-2

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

| | Relative Frequency Distribution | | | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| | Ann. | | Speed (KTS) | | | | |
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .012199 | .002854 | .000571 | .000000 | .000000 | .000000 | .015624 |
| NNE | .002769 | .000457 | .000342 | .000000 | .000000 | .000000 | .003568 |
| NE | .003273 | .0001027 | .000342 | .000000 | .000000 | .000000 | .004643 |
| ENE | .005928 | .001598 | .00342 | .000000 | .000000 | .000000 | .007869 |
| E | .011188 | .004224 | .003425 | .000228 | .000000 | .000000 | .019064 |
| ESE | .006921 | .002397 | .002169 | .000342 | .000000 | .000000 | .011830 |
| SE | .001694 | .000457 | .000000 | .000114 | .000000 | .000000 | .002265 |
| SSE | .000488 | .000228 | .000000 | .000000 | .000000 | .000000 | .000717 |
| S | .001465 | .000685 | .000228 | .000000 | .000000 | .000000 | .002379 |
| SSW | .000733 | .000342 | .000114 | .000000 | .000000 | .000000 | .001189 |
| SW | .000733 | .000342 | .000000 | .000000 | .000000 | .000000 | .001075 |
| WSW | .001824 | .000685 | .000000 | .000000 | .000000 | .000000 | .002509 |
| W | .005196 | .001256 | .000685 | .000000 | .000000 | .000000 | .007136 |
| WNW | .006873 | .001370 | .000457 | .000000 | .000000 | .000000 | .008700 |
| NW | .010521 | .002740 | .001826 | .000000 | .000000 | .000000 | .015087 |
| NNW | .013925 | .003995 | .001484 | .000000 | .000000 | .000000 | .019404 |
| Total | .085731 | .024658 | .011986 | .000685 | .000000 | .000000 | .123059 |

Relative frequency of occurence of B stability = .123059.

Relative frequency of calms distributed above with B stability = .075228.

TABLE 4.1-3

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

| | Ann. | Relative Frequency Distribution Speed (KTS) | | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .008019 | .003196 | .003311 | .000114 | .000000 | .000000 | .014640 |
| NNE | .003828 | .001370 | .000571 | .000000 | .000000 | .000000 | .005768 |
| NE | .002186 | .001370 | .000799 | .000114 | .000000 | .000000 | .004469 |
| ENE | .002824 | .001826 | .001484 | .000228 | .000000 | .000000 | .006363 |
| E | .007903 | .004680 | .013356 | .006963 | .000114 | .000000 | .033017 |
| ESE | .004009 | .002283 | .009247 | .003653 | .000000 | .000000 | .019191 |
| SE | .001594 | .001142 | .001256 | .00342 | .00342 | .000000 | .004676 |
| SSE | .000159 | .000114 | .000114 | .000000 | .000000 | .000000 | .000388 |
| S | .001594 | .001142 | .000228 | .000000 | .000000 | .000000 | .002964 |
| SSW | .000478 | .000342 | .000457 | .000000 | .000000 | .000000 | .001277 |
| SW | .000319 | .000228 | .000114 | .000000 | .000000 | .000000 | .000661 |
| WSW | .001230 | .000685 | .000342 | .000000 | .000000 | .000000 | .002257 |
| W | .002574 | .001256 | .000913 | .000000 | .000000 | .000000 | .004743 |
| WNW | .004282 | .002283 | .001142 | .000000 | .000000 | .000000 | .007707 |
| NW | .007085 | .003311 | .003425 | .000000 | .000000 | .000000 | .013820 |
| NNW | .011162 | .005251 | .003881 | .000457 | .000000 | .000000 | .020751 |
| Total | .059247 | .030479 | .040639 | .011872 | .000457 | .000000 | .142694 |

Relative frequency of occurence of C stability - .142694.

Relative frequency of calms distributed above with C stability - .052283.

TABLE 4.1-4

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

| | Relative Frequency Distribution | | | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| | Ann. | | Speed (KTS) | | | | |
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .003251 | .002511 | .004795 | .002283 | .000457 | .000114 | .013411 |
| NNE | .001303 | .000913 | .000457 | .000228 | .000228 | .000000 | .003129 |
| NE | .000967 | .001027 | .001826 | .000685 | .000000 | .000114 | .004620 |
| ENE | 001182 | .001256 | .006963 | .006393 | .001370 | .000114 | .017278 |
| E | .002479 | .002397 | .021689 | .048059 | .015525 | .001256 | .091405 |
| ESE | .001303 | .000913 | .020205 | .084589 | .060160 | .012443 | .179614 |
| SE | .000645 | .000685 | .009247 | .027740 | .018379 | .002169 | .058864 |
| SSE | .000544 | .000342 | .004909 | .002854 | .001598 | .000799 | .011046 |
| S | .001075 | .001142 | .002397 | .000571 | .000114 | .000114 | .005413 |
| SSW | .000215 | .000228 | .000799 | .000228 | .000000 | .000000 | .001471 |
| SW | .000107 | .000114 | .000913 | .000342 | .000000 | .000000 | .001477 |
| WSW | .000107 | .000114 | .000457 | .000000 | .000114 | .000000 | .000792 |
| W | .000974 | .000799 | .001484 | .000685 | .000342 | .000000 | .004284 |
| WNW | .001619 | .001484 | .002511 | .000913 | .000228 | .000000 | .006755 |
| NW | .005085 | .004224 | .003767 | .000228 | .000114 | .000000 | .013418 |
| NNW | .005971 | .004224 | .007306 | .003311 | .001256 | .000228 | .022295 |
| Total | .026826 | .022374 | .089726 | .179110 | .099886 | .017352 | .435274 |

Relative frequency of occurence of D stability = .435274.

Relative frequency of calms distributed above with D stability = .023858.

TABLE 4.1-5

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

| | Relative Frequency Distribution | | | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| | Ann. | Speed (KTS) | | | | | |
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .003154 | .004566 | .000799 | .000000 | .000000 | .000000 | .008519 |
| NNE | .001295 | .001826 | .000114 | .000000 | .000000 | .000000 | .003235 |
| NE | .000415 | .000571 | .000114 | .000000 | .000000 | .000000 | .001100 |
| ENE | .001080 | .001712 | .000342 | .000114 | .000000 | .000000 | .003249 |
| E | .002647 | .004909 | .001941 | .000685 | .000114 | .000000 | .010296 |
| ESE | .002533 | .005023 | .002283 | .003995 | .001027 | .000114 | .014976 |
| SE | .001904 | .004338 | .005708 | .002169 | .000228 | .000114 | .014461 |
| SSE | .003708 | .008447 | .002511 | .000114 | .000000 | .000000 | .014781 |
| S | .003572 | .007763 | .001256 | .000000 | .000000 | .000000 | .012590 |
| SSW | .002205 | .005023 | .000571 | .000114 | .000000 | .000000 | .007912 |
| SW | .000665 | .001142 | .000114 | .000000 | .000000 | .000000 | .001921 |
| WSW | .000415 | .000571 | .000000 | .000000 | .000000 | .000000 | .000986 |
| W | .001517 | .003082 | .000342 | .000114 | .000000 | .000000 | .005056 |
| WNW | .001395 | .002055 | .000799 | .000000 | .000114 | .000000 | .004363 |
| NW | .003190 | .005023 | .000571 | .000000 | .000000 | .000000 | .008784 |
| NNW | .003296 | .003767 | .001484 | .000000 | .000114 | .000000 | .008661 |
| **Total** | .032991 | .059817 | .018950 | .007306 | .001598 | .000228 | .120890 |

Relative frequency of occurence of E stability = .120890.

Relative frequency of calms distributed above with E stability = .028311.

TABLE 4.1-6

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

| | Relative Frequency Distribution | | | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| | Ann. | | Speed (KTS) | | | | |
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .005124 | .000228 | .000000 | .000000 | .000000 | .000000 | .005352 |
| NNE | .001670 | .000114 | .000000 | .000000 | .000000 | .000000 | .001784 |
| NE | .000892 | .000000 | .000000 | .000000 | .000000 | .000000 | .000892 |
| ENE | .003008 | .000114 | .000114 | .000000 | .000000 | .000000 | .003236 |
| E | .002448 | .000228 | .000342 | .000114 | .000000 | .000000 | .003133 |
| ESE | .006565 | .000571 | .000457 | .000114 | .000000 | .000000 | .007707 |
| SE | .005113 | .000685 | .000571 | .000571 | .000114 | .000000 | .007054 |
| SSE | .010765 | .002169 | .000342 | .000000 | .000000 | .000000 | .013276 |
| S | .010890 | .001598 | .000000 | .000000 | .000000 | .000000 | .012488 |
| SSW | .007871 | .001941 | .000000 | .000000 | .000000 | .000000 | .009812 |
| SW | .002665 | .000457 | .000000 | .000114 | .000000 | .000000 | .003236 |
| WSW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| W | .004335 | .000571 | .000000 | .000000 | .000000 | .000000 | .000000 |
| WNW | .008681 | .000685 | .000114 | .000000 | .000000 | .000000 | .009480 |
| NW | .005102 | .001142 | .000000 | .000000 | .000000 | .000000 | .006244 |
| NNW | .004895 | .000457 | .000228 | .000000 | .000000 | .000000 | .005580 |
| Total | .080023 | .010959 | .002169 | .000913 | .000114 | .000000 | .094178 |

Relative frequency of occurence of F stability = .094178.

Relative frequency of calms distributed above with F stability = .067694.

TABLE 4.1- 7

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | JAN. | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .002699 | .017544 | .013495 | .000000 | .000000 | .000000 | .033738 |
| NNE | .001350 | .002699 | .000000 | .000000 | .000000 | .000000 | .004049 |
| NE | .000000 | .005398 | .001350 | .000000 | .000000 | .000000 | .006748 |
| ENE | .002699 | .008097 | .008097 | .008097 | .001350 | .000000 | .028340 |
| E | .001350 | .013495 | .031039 | .049933 | .018893 | .002699 | .117409 |
| ESE | .000000 | .010796 | .026991 | .076923 | .037787 | .004049 | .156545 |
| SE | .000000 | .008097 | .013495 | .024291 | .009447 | .000000 | .055331 |
| SSE | .005398 | .004049 | .001350 | .000000 | .000000 | .000000 | .010796 |
| S | .000000 | .010796 | .004049 | .000000 | .000000 | .000000 | .014845 |
| SSW | .000000 | .009447 | .000000 | .000000 | .000000 | .000000 | .009447 |
| SW | .000000 | .004049 | .000000 | .000000 | .000000 | .000000 | .004049 |
| WSW | .001350 | .005398 | .005398 | .000000 | .000000 | .000000 | .012146 |
| W | .004049 | .017544 | .000000 | .000000 | .000000 | .000000 | .021592 |
| WNW | .000000 | .002699 | .005398 | .001350 | .002699 | .000000 | .012146 |
| NW | .004049 | .013495 | .002699 | .000000 | .000000 | .000000 | .020243 |
| NNW | .001350 | .031039 | .018893 | .001350 | .000000 | .000000 | .052632 |
| CALM | .439946 | | | | | | |
| Total | .464238 | .164642 | .132254 | .161943 | .070175 | .006748 | |

Total number of observations for the Month of Jan. was 741.00

TABLE 4.1- 8

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | FEB. | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .000000 | .034125 | .026706 | .011869 | .000000 | .000000 | .072700 |
| NNE | .001484 | .005935 | .001484 | .000000 | .000000 | .000000 | .008902 |
| NE | .000000 | .005935 | .000000 | .000000 | .000000 | .000000 | .005935 |
| ENE | .000000 | .000000 | .000000 | .004451 | .000000 | .000000 | .004451 |
| E | .002967 | .022255 | .020772 | .026706 | .002967 | .000000 | .075668 |
| ESE | .000000 | .014837 | .020772 | .077151 | .048961 | .017804 | .179525 |
| SE | .000000 | .005935 | .013353 | .020772 | .001484 | .000000 | .041543 |
| SSE | .000000 | .025223 | .016320 | .002967 | .000000 | .000000 | .044510 |
| S | .000000 | .014837 | .008902 | .000000 | .000000 | .001484 | .025223 |
| SSW | .000000 | .010386 | .001484 | .000000 | .000000 | .000000 | .011869 |
| SW | .002967 | .002967 | .001484 | .000000 | .000000 | .000000 | .007418 |
| WSW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| W | .000000 | .002967 | .004451 | .001484 | .000000 | .000000 | .008902 |
| WNW | .004451 | .011869 | .019288 | .001484 | .000000 | .000000 | .037092 |
| NW | .002967 | .025223 | .002967 | .000000 | .000000 | .000000 | .031157 |
| NNW | .007418 | .023739 | .029674 | .016320 | .000000 | .000000 | .077151 |
| CALM | .367953 | | | | | | |
| Total | .390208 | .206231 | .167656 | .163205 | .053412 | .019288 | |

Total number of observations for the Month of Feb. was 674.00



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TABLE 4.1- 9

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | MAR. | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .004032 | .010753 | .022849 | .001344 | .000000 | .000000 | .038978 |
| NNE | .005376 | .018817 | .001344 | .000000 | .000000 | .000000 | .025538 |
| NE | .000000 | .008065 | .013441 | .001344 | .000000 | .000000 | .022849 |
| ENE | .000000 | .005376 | .006720 | .000000 | .000000 | .000000 | .012097 |
| E | .002688 | .025538 | .006720 | .008065 | .008065 | .000000 | .051075 |
| ESE | .001344 | .028266 | .037634 | .033602 | .017473 | .000000 | .118280 |
| SE | .005376 | .022849 | .041667 | .043011 | .012097 | .001344 | .126344 |
| SSE | .000000 | .008065 | .026882 | .022849 | .014785 | .002688 | .075269 |
| S | .000000 | .012097 | .017473 | .005376 | .000000 | .000000 | .034946 |
| SSW | .000000 | .005376 | .005376 | .001344 | .000000 | .000000 | .012097 |
| SW | .000000 | .000000 | .004032 | .001344 | .000000 | .000000 | .005376 |
| WSW | .000000 | .001344 | .001344 | .000000 | .000000 | .000000 | .002688 |
| W | .005376 | .005376 | .001344 | .004032 | .000000 | .000000 | .016129 |
| WNW | .000000 | .005376 | .002688 | .001344 | .001344 | .000000 | .010753 |
| NW | .001344 | .000000 | .005376 | .000000 | .000000 | .000000 | .006720 |
| NNW | .001344 | .014785 | .014785 | .000000 | .000000 | .000000 | .030914 |
| CALM | .409946 | | | | | | |
| Total | .436828 | .172043 | .209677 | .123656 | .053763 | .004032 | |

Total number of observations for the Month of Mar. was 744.00.



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TABLE 4.1-10

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | APR. | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .002778 | .004167 | .001389 | .001389 | .000000 | .000000 | .009722 |
| NNE | .002778 | .002778 | .001389 | .001389 | .000000 | .000000 | .008333 |
| NE | .000000 | .000000 | .001389 | .000000 | .000000 | .000000 | .001389 |
| ENE | .000000 | .001389 | .000000 | .000000 | .000000 | .000000 | .001389 |
| E | .004167 | .022222 | .077778 | .043056 | .002778 | .000000 | .150000 |
| ESE | .002778 | .013889 | .027778 | .116667 | .083333 | .016667 | .261111 |
| SE | .001389 | .002778 | .022222 | .026389 | .045833 | .001389 | .100000 |
| SSE | .000000 | .005556 | .004167 | .000000 | .000000 | .006944 | .016667 |
| S | .006944 | .027778 | .000000 | .000000 | .000000 | .000000 | .034722 |
| SSW | .000000 | .008333 | .006944 | .000000 | .000000 | .000000 | .015278 |
| SW | .000000 | .001389 | .000000 | .000000 | .000000 | .000000 | .001389 |
| WSW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| W | .000000 | .001389 | .004167 | .000000 | .000000 | .000000 | .005556 |
| WNW | .001389 | .006944 | .001389 | .000000 | .000000 | .000000 | .009722 |
| NW | .005556 | .011111 | .000000 | .000000 | .000000 | .000000 | .016667 |
| NNW | .006944 | .008333 | .018056 | .000000 | .000000 | .000000 | .033333 |
| CALM | .334722 | | | | | | |
| Total | .369444 | .118056 | .166667 | .188889 | .131944 | .025000 | |

Total number of observations for the Month of Apr. was 720.00

TABLE 4.1-11

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | MAY | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .009409 | .014785 | .000000 | .000000 | .000000 | .000000 | .024194 |
| NNE | .004032 | .001344 | .002688 | .000000 | .000000 | .000000 | .008065 |
| NE | .000000 | .001344 | .001344 | .000000 | .000000 | .000000 | .002688 |
| ENE | .001344 | .000000 | .002688 | .000000 | .000000 | .000000 | .004032 |
| E | .006720 | .025538 | .041667 | .063172 | .008065 | .001344 | .146505 |
| ESE | .006720 | .017473 | .060484 | .194892 | .073925 | .012097 | .365591 |
| SE | .002688 | .010753 | .030914 | .061828 | .041667 | .004032 | .151882 |
| SSE | .000000 | .018817 | .013441 | .001344 | .000000 | .000000 | .033602 |
| S | .002688 | .008065 | .005376 | .000000 | .001344 | .000000 | .017473 |
| SSW | .000000 | .001344 | .004032 | .000000 | .000000 | .000000 | .005376 |
| SW | .000000 | .001344 | .000000 | .000000 | .000000 | .000000 | .001344 |
| WSW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| W | .002688 | .001344 | .000000 | .000000 | .000000 | .000000 | .004032 |
| WNW | .002688 | .005376 | .000000 | .000000 | .000000 | .000000 | .008065 |
| NW | .001344 | .002688 | .000000 | .000000 | .000000 | .000000 | .004032 |
| NNW | .004032 | .014785 | .002688 | .000000 | .000000 | .000000 | .021505 |
| CALM | .201613 | | | | | | |
| Total | .145968 | .125000 | .165323 | .321237 | .125000 | .017473 | |

Total number of observations for the Month of May was 744.00

TABLE 4.1-12

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution (Wind Rose)

| Direction | JUNE 1 - 3 | Speed (KTS) 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | Station = 78397 21 | Period: 1974-1975 Total |
|---|---|---|---|---|---|---|---|
| N | .005556 | .009722 | .001389 | .000000 | .000000 | .000000 | .016667 |
| NNE | .004167 | .002778 | .000000 | .000000 | .000000 | .000000 | .006944 |
| NE | .005556 | .005556 | .000000 | .000000 | .000000 | .000000 | .011111 |
| ENE | .001389 | .015278 | .001389 | .002778 | .000000 | .000000 | .020833 |
| E | .001389 | .013889 | .051389 | .122222 | .030556 | .001389 | .220833 |
| ESE | .002778 | .009722 | .047222 | .204167 | .134722 | .022222 | .420833 |
| SE | .000000 | .000000 | .994167 | .051389 | .054167 | .001389 | .111111 |
| SSE | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| S | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| SSW | .000000 | .005556 | .000000 | .000000 | .000000 | .000000 | .005556 |
| SW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| WSW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| W | .000000 | .011111 | .000000 | .000000 | .000000 | .000000 | .011111 |
| WNW | .005556 | .004167 | .000000 | .000000 | .000000 | .000000 | .009722 |
| NW | .001389 | .006944 | .004167 | .000000 | .000000 | .000000 | .012500 |
| NNW | .001389 | .008333 | .002778 | .000000 | .000000 | .000000 | .012500 |
| CALM | .140278 | | | | | | |
| Total | .169444 | .093056 | .112500 | .380556 | .219444 | .025000 | |

Total number of observations for the Month of June was 720.00

TABLE 4.1- 13

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | JULY | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .005376 | .020161 | .000000 | .000000 | .000000 | .000000 | .025538 |
| NNE | .002688 | .002688 | .002688 | .000000 | .000000 | .000000 | .008065 |
| NE | .001344 | .001344 | .000000 | .000000 | .000000 | .000000 | .002688 |
| ENE | .004032 | .009409 | .001344 | .000000 | .000000 | .000000 | .014785 |
| E | .001344 | .014785 | .048387 | .079301 | .020161 | .000000 | .163978 |
| ESE | .002688 | .006720 | .030914 | .123656 | .134409 | .033602 | .331989 |
| SE | .000000 | .000000 | .005376 | .045699 | .021505 | .004032 | .076613 |
| SSE | .001344 | .002688 | .001344 | .000000 | .000000 | .000000 | .005376 |
| S | .000000 | .001344 | .000000 | .000000 | .000000 | .000000 | .001344 |
| SSW | .000000 | .004032 | .000000 | .000000 | .000000 | .000000 | .004032 |
| SW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| WSW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| W | .002688 | .005376 | .000000 | .002688 | .000000 | .000000 | .010753 |
| WNW | .012097 | .010753 | .000000 | .000000 | .000000 | .000000 | .022849 |
| NW | .009409 | .008065 | .008065 | .000000 | .000000 | .000000 | .025538 |
| NNW | .010753 | .017473 | .010753 | .000000 | .000000 | .000000 | .038978 |
| CALM | .267473 | | | | | | |
| Total | .321237 | .104839 | .108871 | .251344 | .176075 | .037634 | |

Total number of observations for the Month of July was 744.00



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TABLE 4.1-14

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | AUG. | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .008065 | .009409 | .001344 | .000000 | .000000 | .001344 | .020161 |
| NNE | .000000 | .005376 | .001344 | .000000 | .002688 | .000000 | .009409 |
| NE | .004032 | .002688 | .000000 | .000000 | .000000 | .000000 | .006720 |
| ENE | .002688 | .005376 | .013441 | .002688 | .001344 | .000000 | .025538 |
| E | .001344 | .013441 | .059140 | .107527 | .030914 | .002688 | .215054 |
| ESE | .000000 | .001344 | .038978 | .095430 | .110215 | .026882 | .272849 |
| SE | .000000 | .002688 | .000000 | .020161 | .021505 | .013441 | .057796 |
| SSE | .000000 | .004032 | .002688 | .000000 | .000000 | .000000 | .006720 |
| S | .001344 | .002688 | .000000 | .000000 | .000000 | .000000 | .004032 |
| SSW | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| SW | .000000 | .000000 | .000000 | .001344 | .000000 | .000000 | .001344 |
| WSW | .001344 | .004032 | .000000 | .000000 | .000000 | .000000 | .005376 |
| W | .000000 | .001344 | .001344 | .000000 | .000000 | .000000 | .002688 |
| WNW | .006720 | .010753 | .001344 | .000000 | .000000 | .000000 | .018817 |
| NW | .005376 | .209570 | .009409 | .001344 | .000000 | .000000 | .045699 |
| NNW | .008065 | .012097 | .002688 | .004032 | .000000 | .001344 | .028226 |
| CALM | .279570 | | | | | | |
| Total | .318548 | .104839 | .131720 | .232527 | .166667 | .045699 | |

Total number of observations for the Month of Aug. was 744.00.

TABLE 4.1-15

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| Direction | SEPT. 1 - 3 | Speed (KTS) 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | Station = 78397 21 | Period: 1974-1975 Total |
|---|---|---|---|---|---|---|---|
| N | .002778 | .004167 | .001389 | .001389 | .000000 | .000000 | .009722 |
| NNE | .000000 | .002778 | .001389 | .000000 | .000000 | .000000 | .004167 |
| NE | .002778 | .004167 | .009722 | .006944 | .000000 | .000000 | .023611 |
| ENE | .001389 | .011111 | .044444 | .045833 | .011111 | .000000 | .113889 |
| E | .001389 | .015278 | .077778 | .075000 | .048611 | .005556 | .223611 |
| ESE | .002778 | .012500 | .026389 | .019444 | .018056 | .008333 | .087500 |
| SE | .001389 | .000000 | .029167 | .002778 | .000000 | .000000 | .033333 |
| SSE | .000000 | .006944 | .004167 | .004167 | .001389 | .000000 | .016667 |
| S | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 | .000000 |
| SSW | .000000 | .000000 | .001389 | .000000 | .000000 | .000000 | .001389 |
| SW | .000000 | .002778 | .002778 | .000000 | .000000 | .000000 | .005556 |
| WSW | .000000 | .000000 | .002778 | .000000 | .000000 | .000000 | .002778 |
| W | .006944 | .018056 | .012500 | .00±389 | .000000 | .000000 | .028889 |
| WNW | .004167 | .026389 | .015278 | .001389 | .000000 | .000000 | .047222 |
| NW | .005556 | .031944 | .043058 | .000000 | .001389 | .000000 | .081944 |
| NNW | .008333 | .006944 | .005556 | .000000 | .000000 | .000000 | .020833 |
| CALM | .188889 | | | | | | |
| Total | .326389 | .143056 | .277778 | .158333 | .080556 | .013889 | |

Total number of observations for the Month of Sept. was 720.00.

TABLE 4.1-16

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | OCT. | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .008065 | .008065 | .006720 | .000000 | .000000 | .000000 | .022849 |
| NNE | .004032 | .002688 | .001344 | .000000 | .000000 | .000000 | .008065 |
| NE | .000000 | .004032 | .006720 | .001344 | .000000 | .001344 | .013441 |
| ENE | .002688 | .008065 | .028226 | .013441 | .002688 | .001344 | .045452 |
| E | .000000 | .020161 | .033602 | .063172 | .016129 | .001344 | .134409 |
| ESE | .009409 | .005376 | .041667 | .034946 | .010753 | .005376 | .107527 |
| SE | .001344 | .025538 | .013441 | .016129 | .001344 | .001344 | .059140 |
| SSE | .002688 | .014785 | .008065 | .004032 | .000000 | .000000 | .029570 |
| S | .000000 | .008065 | .008065 | .001344 | .000000 | .000000 | .017473 |
| SSW | .001344 | .000000 | .004032 | .000000 | .000000 | .000000 | .005376 |
| SW | .001344 | .001344 | .000000 | .000000 | .000000 | .000000 | .002688 |
| WSW | .000000 | .006720 | .000000 | .000000 | .000000 | .000000 | .006720 |
| W | .002688 | .013441 | .010753 | .000000 | .000000 | .000000 | .026882 |
| WNW | .001344 | .012097 | .005376 | .000000 | .000000 | .000000 | .018817 |
| NW | .004032 | .020161 | .030914 | .000000 | .000000 | .000000 | .055108 |
| NNW | .014785 | .029570 | .018817 | ..001344 | .000000 | .001344 | .065860 |
| CALM | .369624 | | | | | | |
| Total | .423387 | .180108 | .217742 | .135753 | .030914 | .012097 | |

Total number of observations for the Month of Oct. was 744.00.

TABLE 4.1-17

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | NOV. | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .006944 | .016667 | .015278 | .005556 | .000000 | .000000 | .044444 |
| NNE | .001389 | .006944 | .002778 | .001389 | .000000 | .000000 | .012500 |
| NE | .000000 | .004167 | .002778 | .000000 | .000000 | .000000 | .006944 |
| ENE | .005556 | .009722 | .002778 | .004167 | .000000 | .000000 | .022222 |
| E | .002778 | .004167 | .022222 | .019444 | .001389 | .000000 | .050000 |
| ESE | .000000 | .004167 | .034722 | .069444 | .052778 | .004167 | .165278 |
| SE | .000000 | .001389 | .006944 | .016667 | .016667 | .000000 | .041667 |
| SSE | .004167 | .025000 | .005556 | .000000 | .000000 | .000000 | .034722 |
| S | .004167 | .047222 | .004167 | .000000 | .000000 | .000000 | .055556 |
| SSW | .000000 | .022222 | .000000 | .000000 | .000000 | .000000 | .022222 |
| SW | .000000 | .012500 | .005556 | .000000 | .000000 | .000000 | .018056 |
| WSW | .000000 | .006944 | .000000 | .000000 | .000000 | .000000 | .006944 |
| W | .000000 | .004167 | .006944 | .000000 | .000000 | .000000 | .011111 |
| WNW | .009722 | .004167 | .011111 | .005556 | .000000 | .000000 | .030556 |
| NW | .005556 | .031944 | .008333 | .000000 | .000000 | .000000 | .045833 |
| NNW | .009722 | .016667 | .020833 | .004167 | .000000 | .000000 | .051389 |
| CALM | .380558 | | | | | | |
| Total | .430556 | .218056 | .150000 | .126389 | .070833 | .004167 | |

Total number of observations for the Month of Nov. was 720.00.



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TABLE 4.1-18

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | DEC. | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .013423 | .018792 | .024161 | .008054 | .005369 | .000000 | .069799 |
| NNE | .000000 | .002685 | .001342 | .000000 | .000000 | .000000 | .004027 |
| NE | .000000 | .006711 | .000000 | .000000 | .000000 | .000000 | .006711 |
| ENE | .000000 | .004027 | .001342 | .000000 | .000000 | .000000 | .005369 |
| E | .000000 | .012081 | .018792 | .013423 | .000000 | .000000 | .044295 |
| ESE | .002685 | .013423 | .017450 | .065772 | .012081 | .000000 | .111409 |
| SE | .000000 | .006711 | .020134 | .040268 | .002685 | .000000 | .069799 |
| SSE | .001342 | .021477 | .010738 | .000000 | .002685 | .000000 | .036242 |
| S | .005369 | .016107 | .001342 | .000000 | .000000 | .000000 | .022819 |
| SSW | .005369 | .028188 | .000000 | .002685 | .000000 | .000000 | .036242 |
| SW | .001342 | .001342 | .000000 | .002685 | .000000 | .000000 | .005369 |
| WSW | .001342 | .000000 | .000000 | .000000 | .001342 | .000000 | .002685 |
| W | .000000 | .001342 | .000000 | .000000 | .004027 | .000000 | .005369 |
| WNW | .000000 | .001342 | .000000 | .000000 | .000000 | .000000 | .001342 |
| NW | .006711 | .022819 | .000000 | .001342 | .000000 | .000000 | .030872 |
| NNW | .008054 | .033557 | .028188 | .018792 | .016107 | .000000 | .104698 |
| CALM | .442953 | | | | | | |
| Total | .488591 | .190604 | .123490 | .153020 | .044295 | .000000 | |

Total number of observations for the Month of Dec. was 745.00.

TABLE 4.1-19

SUMMARY METEOROLOGICAL DATA JAMAICA 9/73 TO 8/74

Joint Wind Frequency Distribution
(Wind Rose)

| | ANN. | | Speed (KTS) | | | Station = 78397 | Period: 1974-1975 |
|---|---|---|---|---|---|---|---|
| Direction | 1 - 3 | 4 - 6 | 7 - 10 | 11 - 16 | 17 - 21 | 21 | Total |
| N | .005822 | .013927 | .009475 | .002397 | .000457 | .000114 | .032192 |
| NNE | .002283 | .004795 | .001484 | .000228 | .000228 | .000000 | .009018 |
| NE | .001142 | .004110 | .003082 | .000799 | .000000 | .000114 | .009247 |
| ENE | .001826 | .006507 | .009247 | .006735 | .001370 | .000114 | .025799 |
| E | .002169 | .016895 | .040753 | .056050 | .015753 | .001256 | .132877 |
| ESE | .002626 | .011530 | .034361 | .092694 | .061187 | .012557 | .214954 |
| SE | .001027 | .007306 | .016781 | .030936 | .019064 | .002283 | .077397 |
| SSE | .001256 | .011301 | .007877 | .002968 | .001598 | .000799 | .025799 |
| S | .001712 | .012329 | .004110 | .000571 | .000114 | .000114 | .018950 |
| SSW | .000571 | .007877 | .001941 | .000342 | .000000 | .000000 | .010731 |
| SW | .000457 | .002283 | .001142 | .000457 | .000000 | .000000 | .004338 |
| WSW | .000342 | .002055 | .000799 | .000000 | .000114 | .000000 | .003311 |
| W | .002055 | .006963 | .003425 | .000799 | .000342 | .000000 | .013584 |
| WNW | .003995 | .008447 | .005023 | .000913 | .000342 | .000000 | .018721 |
| NW | .004452 | .016895 | .009589 | .000228 | .000114 | .000000 | .031279 |
| NNW | .006849 | .018151 | .014384 | .003767 | .001370 | .000228 | .044749 |
| CALM | .327055 | | | | | | |
| Total | .365639 | .151370 | .163470 | .199886 | .102055 | .017580 | |

Total number of observations for the year was 8760.00.



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## 4.2 NEW FACILITY PROJECTED AIR QUALITY

This section describes the projected air quality impacts due to the operation of the proposed new coal-fired facility. In the analysis, the facility's two new boilers, served by a common 450 foot stack, were assumed to operate at full load continuously to identify the maximum air quality impact. Ground level concentrations of $SO_2$, TSP, and NOx resulting from operation of the new facility were modeled with the EPA ISC dispersion model on new plant emission data listed in Tables 2.3-1 and 2.3-2, and best available meteorological data (1974) described in Section 3.2.1.

Due to the incomplete nature of the meteorological data base, only one year of good data was available for use in the dispersion modeling. Consequently, the highest ground concentration was used instead of the second highest concentration in the discussion of the maximum air quality impact.

### 4.2.1 Sulfur Dioxide ($SO_2$)

The maximum annual, 24-hour and 3-hour average $SO_2$ ground level concentrations (on land) resulting from emissions from the new boiler stack were 9.5 $\mu g/m^3$, 100.7 $\mu g/m^3$, 557.0 $\mu g/m^3$, respectively. These maximum annual, 24-hour and 3-hour average concentrations occurred respectively at the following locations relative to the new stack, 5,000 meters-west, 1,500 meters-east, 1,500 meters-east. Results are summarized in Table 4.2-1.

### 4.2.2 Total Suspended Particulates (TSP)

The maximum annual and 24-hour average TSP ground level concentrations (on land) resulting from emissions from the new boiler stack and fugitive sources associated with the new facility were 8.4 $\mu g/m^3$ and 141.7 $\mu g/m^3$ respectively. Note the maximum TSP impacts from the stack emissions and fugitive sources do not occur at the same location, and therefore, the impacts are not additive. The maximum fugitive impacts occur near the site boundary (300 meters-SE) where stack particulate contributions are negligible. Fugitive impacts fall to negligible values at the location of the maximum stack particulate contributions, 12,500 meters to the west. As maximum stack particulate impacts are less than the maximum fugitive impacts, the fugitive impacts are used to represent the maximum TSP gound level concentrations. Results are as summarized in Table 4.2-1.



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### 4.2.3 Nitrous Oxide $NO_x$

The maximum annual $NO_x$ ground level concentration (on land) resulting from emissions from the new boiler stack was 1.8 $\mu g/m^3$ and was located 5,000 meters west of the stack. Results are summarized in Table 4.2-1.

TABLE 4.2-1

MAXIMUM PREDICTED GROUND LEVEL CONCENTRATION
FROM THE NEW COAL-FIRED UNITS ($\mu g/m^3$)

| Averaging Period | Pollutants | | |
|---|---|---|---|
| | $SO_2$ | TSP(1) | $NO_x$ |
| Annual | 9.5 | 8.4 | 1.8 |
| 24-hour | 100.7 | 141.7 | - |
| 3-hour | 557.0 | - | - |

Note:

(1) Maximum impact caused by fugitive emissions.

## 4.3 IMPROVEMENT OF LOCAL AIR QUALITY

Existing oil-fired units 3 and 4 will not operate after the two new coal-fired units begin commercial operation. Therefore, existing oil-fired units 1 and 2 will be the only units that will operate concurrently with the new units. As the coal-fired units will emit less $SO_2$ and TSP pollutants than the existing units 3 and 4, and effluents are released from a taller stack, there will be an improvement in local air quality.

To assess the local air quality improvement, the maximum combined impacts from operation of the new units and units 1 and 2, and the maximum combined impacts from operation of existing units 1, 2, 3 and 4 were modeled with ISC. The improvement in air quality is measured by the net reduction in ground level concentrations from replacing units 3 and 4 with the new coal-fired units. Results are summarized in Tables 4.3-1 through 4.3-3.

TABLE 4.3-1

IMPROVEMENT IN LOCAL AIR QUALITY - $SO_2$ IMPACT

| Averaging Period | New Units + Units 1 & 2 ($\mu g/m^3$) | Units 1, 2, 3, 4 ($\mu g/m^3$) | Net Reduction $SO_2$ ($\mu g/m^3$) |
|---|---|---|---|
| Annual | 63.4 | 106.7 | 43.3 |
| 24-hour | 382.3 | 591.9 | 209.6 |
| 3-hour | 973.3 | 1654.4 | 681.1 |

TABLE 4.3-2

IMPROVEMENT IN LOCAL AIR QUALITY - TSP IMPACT

| Averaging Period | New Units + Units 1 & 2 ($\mu g/m^3$) | Existing Units 1, 2, 3, 4 ($\mu g/m^3$) | Net Reduction TSP ($\mu g/m^3$) |
|---|---|---|---|
| Annual | 8.4 | 8.4 | 0 |
| 24-hour | 141.7 | 257.6 | 115.9 |

TABLE 4.3-3

IMPROVEMENT IN LOCAL AIR QUALITY - $NO_x$ IMPACT

| Averaging Period | New Units + Units 1 & 2 ($\mu g/m^3$) | Existing Units 1, 2, 3, 4 ($\mu g/m^3$) | Net Reduction $NO_x$ ($\mu g/m^3$) |
|---|---|---|---|
| Annual | 9.5 | 9.9 | .4 |

## 4.4 CONCLUSION

The maximum combined impact of the new units and the existing units 1 and 2, together with the background pollutant concentrations, represent the total maximum pollutant ground level concentration in the Old Harbour Bay region. Comparisons of this total concentration and the U.S. NAAQS for each pollutant ($SO_2$, TSP, $NO_x$) is shown in Table 4.4-1.

As shown in Table 4.4-1, all calculated pollutant ground level concentrations meet the U.S. NAAQS except the 24-hour average concentration for $SO_2$. However, this exceedance, 382 $\mu g/m^3$ 24-hour average, represents a 35% reduction in $SO_2$ levels through the replacement of units 3 and 4 with the new coal-fired units. This replacement also results in TSP and $NO_x$ total ground level concentrations which do not exceed their applicable U.S. NAAQS and are also representative of improvement in the local air quality.

TABLE 4.4-1

TOTAL GROUND LEVEL CONCENTRATIONS ($\mu g/m^3$)

| | Natural Background | | | New Units + Units 1 and 2 | | | Total | | | U.S. NAAQS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SO_2$ | TSP | $NO_x$ | $SO_2$ | TSP | $NO_x$ | $SO_2$ | TSP | $NO_x$ | $SO_2$ | TSP | $NO_x$ |
| Annual | 0 | 40 | 0 | 63.4 | 8.4 | 9.5 | 63.4 | 48.4 | 9.5 | 80 | 75 | 100 |
| 24-hour | 0 | 40 | - | 382.3 | 141.7 | - | 382.3 | 181.7 | - | 365 | 260 | - |
| 3-hour | - | - | - | 973.3 | - | - | 973.3 | - | - | 1300 | - | - |

REFERENCES

1. Environmental Protection Agency, 1981, "Guidelines for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations)," EPA Report No. EPA 450/4-80-023, USEPA Office of Air Quality Planning and Standards.

2. PEDCO Environmental, Inc., 1978, "Survey of Fugitive Dust from Coal Mines," EPA Region 8, Report No. EPA-90811-78-003.

3. Environmental Protection Agency, 1979, "Industrial Source Complex (ISC) Dispersion Model User's Guide, Vol. 1," EPA Report No. EPA-450/4-79-030, U.S. Environmental Protection Agency, Research Triangle Park, N.C.

4. Environmental Protection Agency, 1980, "Guidelines on Air Quality Models," QAQPS Guidelines Series, U.S. Environmental Protection Agency, Research Triangle Park, N.C.



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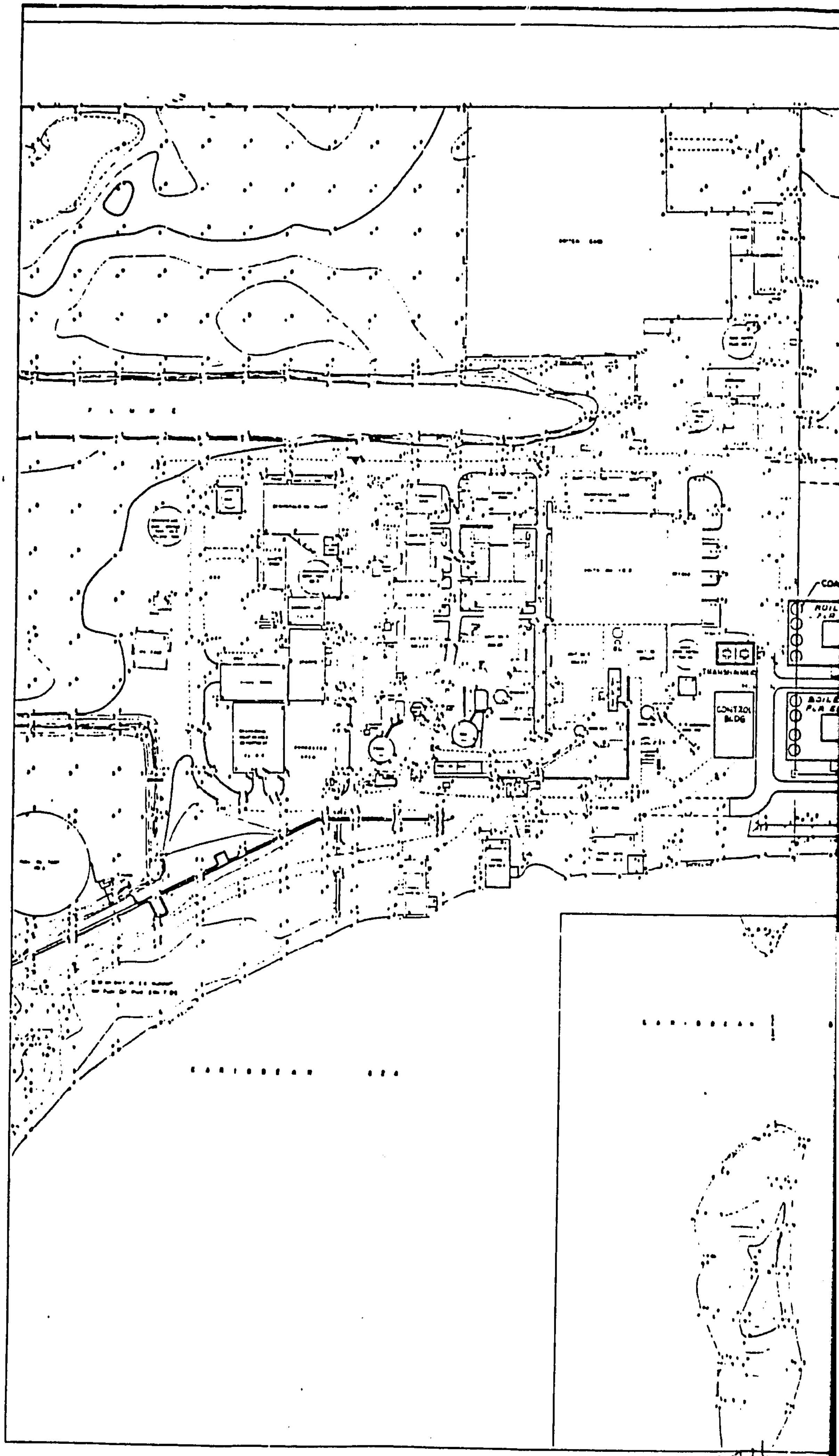

CONTROL BLDG

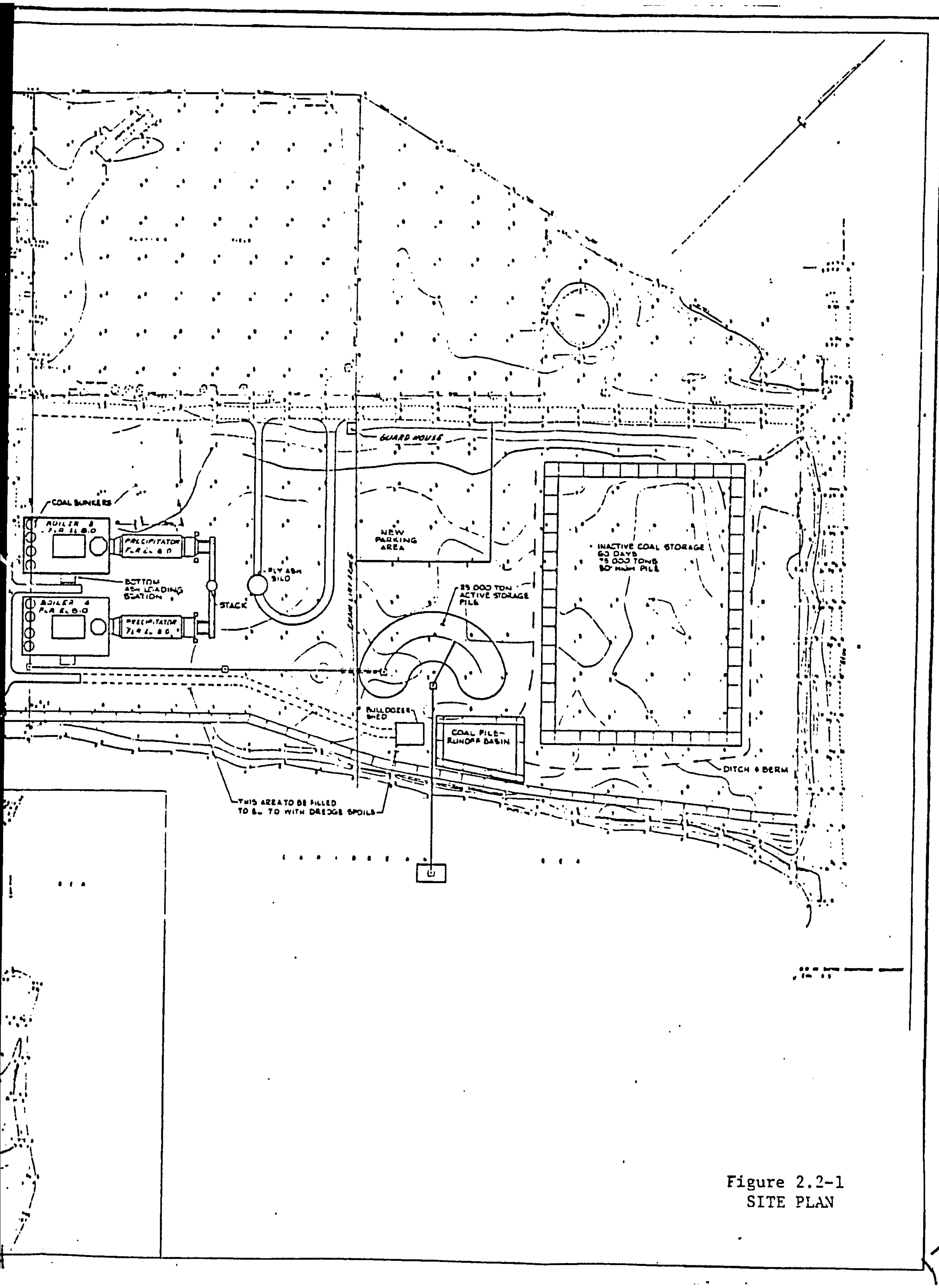
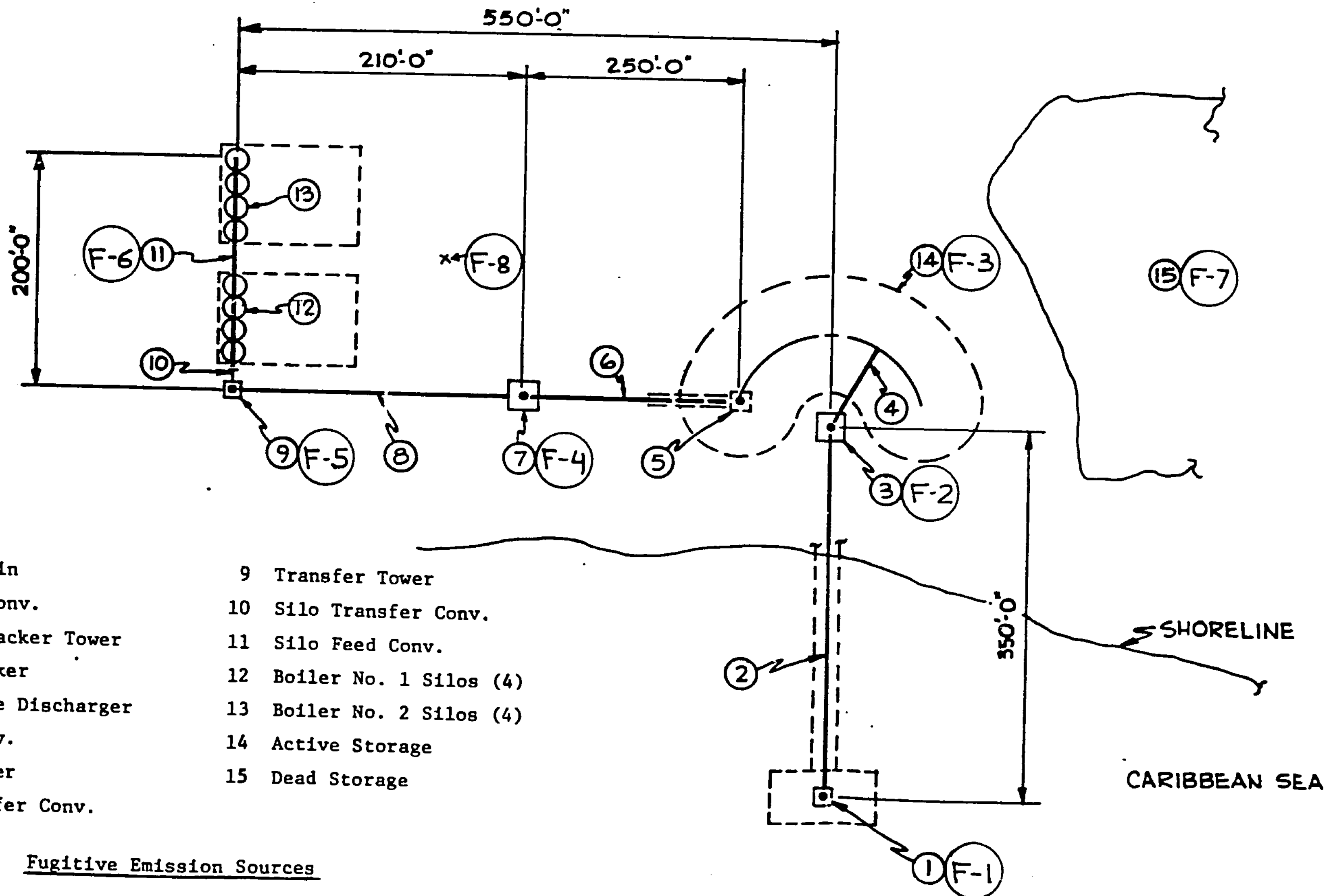



Figure 2.2-1
SITE PLAN




1 Receiving Bin
2 Unloading Conv.
3 Sampling/Stacker Tower
4 Radial Stacker
5 Reclaim Pile Discharger
6 Reclaim Conv.
7 Crusher Tower
8 Plant Transfer Conv.
9 Transfer Tower
10 Silo Transfer Conv.
11 Silo Feed Conv.
12 Boiler No. 1 Silos (4)
13 Boiler No. 2 Silos (4)
14 Active Storage
15 Dead Storage

<u>Fugitive Emission Sources</u>

F-1 Barge Unloading
F-2 Stacker Tower
F-3 Active Coal Storage
F-4 Crusher Tower
F-5 Transfer Tower
F-6 Silo Feed Conveyor
F-7 Inactive Coal Storage
F-8 Fly Ash Silo

# APPENDIX A

# AIR QUALITY MODEL TECHNICAL DESCRIPTION

## A.1 GENERAL

The Industrial Source Complex (ISC) Dispersion Model is an advanced Gaussian plume model. The technical discussion contained in this section assumes that the reader is already familiar with the theory and concepts of Gaussian plume models. Readers who lack a fundamental knowledge of the basic concepts of Gaussian plume modeling are referred to Section 2 of the User's Manual for the Single Source (CRSTER) Model (EPA, 1977) or to other references such as Meteorology and Atomic Energy (Slade, 1968) or the Workbook of Atmospheric Dispersion Estimates (Turner, 1970).

TABLE A-1

**HOURLY METEOROLOGICAL INPUTS REQUIRED BY THE ISC SHORT-TERM MODEL PROGRAM**

| Parameter | Definition |
|---|---|
| $\bar{u}_1$ | Mean wind speed in meters per second (m/sec) at height $z_1$ (default value for $z_1$ is 10 meters) |
| AFVR | Average random flow vector (direction toward which the wind is blowing) |
| p | Wind-profile exponent (default values assigned on the basis of stability; see Table 2-2) |
| $T_a$ | Ambient air temperature in degrees Kelvin ($^{\circ}$K) |
| $H_m$ | Depth of surface mixing layer (meters), developed from twice-daily mixing height estimates by the meteorological preprocessor program |
| Stability | Pasquill stability category (1 = A, 2 = B, etc.) |
| $\frac{\partial \Theta}{\partial z}$ | Vertical potential temperature gradient in degrees Kelvin per meter (default values assigned on the basis of stability; see Table A-2). |



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## A.2 MODEL INPUT DATA

### A.2.1 Meteorological Input Data

#### A.2.1.1 Meteorological Inputs for the ISC Short-Term (ISCST) Model Program

Table A-1 gives the hourly meteorological inputs required by the ISC Model short-term computer program (ISCST). These inputs include the mean wind speed measured at height $z_1$, the direction toward which the wind is blowing, the wind-profile exponent, the ambient air temperature, the Pasquill stability category and the vertical potential temperature gradient. In general, these inputs are developed from concurrent surface and upper-air meteorological data by the same preprocessor program as used by the Single Source (CRSTER) Model. If the preprocessed meteorological data are used, the user may input, for each combination of wind-speed and Pasquill stability categories, site-specific values of the wind-profile exponent and the vertical potential temperature gradient. If the user does not input site-specific wind-profile exponents and vertical potential temperature gradients, the ISC Model uses the default values given in Table A-2. The inputs listed in Table A-1 may also be developed by the user from observed hourly meteorological data and input by card deck. In these cases, the direction from which the wind is blowing must be reversed 180 degrees to conform with the average flow vector (the direction toward which the wind is blowing) generated by the meteorological preprocessor program.

It should be noted that concentrations calculated using Gaussian dispersion models are inversely proportional to the mean wind speed and thus the calculated concentrations approach infinity as the mean wind speed approaches zero (calm). Also, there is no basis for estimating wind direction during periods of calm winds. The meteorological preprocessor program arbitrarily sets the wind speed equal to 1 meter per second if the observed wind speed is less than 1 meter per second and, in the case of calm winds, sets the wind direction equal to the value reported for the last non-calm hour. Thus, considerable uncertainties exist in the results of model calculations for hours with calm winds, especially if a series of consecutive calm hours occurs. In this case, the preprocessor program assumes a single persistent wind direction for the duration of the period of calm winds. Concentrations calculated for such periods may significantly overestimate the concentrations that can actually



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be expected to occur. Consequently, it is recommended that the ISCST user examine the preprocessed meteorological data for the periods with calculated maximum short-term concentrations to ensure that the results are not determined by an arbitrary assumption. Periods of persistent calm winds may be recognized by the combination of a constant wind direction with a wind speed of exactly 1.0 meter per second.

The ISCST program has a rural and two urban options. In the Rural Mode, rural mixing heights and the $\sigma_y$ and $\sigma_z$ values for the indicated stability category are used in the calculations. Urban mixing heights are used in both urban modes. In Urban Mode 1, the stable E and F stability categories are redefined as neutral D stability following current EPA guidance. In Urban Mode 2, the E and F stability categories are combined and the $\sigma_y$ and $\sigma_z$ values for the stability category one step are more unstable than the indicated category are used in the calculations. For example, the $\sigma_y$ and $\sigma_z$ values for C stability are used in calculations for D stability in Urban Mode 2. Table A-3 gives the dispersion coefficients used in each mode.

The Rural Mode is usually selected for industrial source complexes located in rural areas. However, the urban options may also be considered in modeling an industrial source complex located in a rural area if the source complex is large and contains numerous tall buildings and/or large heat sources (for example, coke ovens). An urban mode is appropriate for these cases in order to account for the enhanced turbulence generated during stable meteorological conditions by the surface roughness elements and/or heat sources. If an urban mode is appropriate, Urban Mode 1 is recommended for most situations. Urban Mode 2 is primarily recommended for area sources in urban areas. Urban Mode 2 should not be used for stack sources in modeling studies for regulatory purposes.

TABLE A-2

DEFAULT VALUES FOR THE WIND-PROFILE EXPONENTS AND VERTICAL POTENTIAL TEMPERATURE GRADIENTS

| Pasquill Stability Category | Wind-Profile Exponent p | Vertical Potential Temperature Gradient (°K/m) |
|---|---|---|
| A | 0.10 | 0.000 |
| B | 0.15 | 0.000 |
| C | 0.20 | 0.000 |
| D | 0.25 | 0.000 |
| E | 0.30 | 0.020 |
| F | 0.30 | 0.035 |



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### A.2.2 Source Input Data

Table A-4 summarizes the source input data requirements of the ISC Dispersion Model computer programs. As shown by the table, there are three source types: stack, volume and area. The volume source option is also used to simulate line sources. Source elevations above mean sea level and source locations with respect to a user-specified origin are required for all sources. If the Universal Transverse Mercator (UTM) coordinate system is used to define receptor locations, UTM coordinates are also used to define source locations. Otherwise, the origin of the receptor array (either polar or Cartesian) is usually placed at the location of the most significant pollutant source within the industrial source complex. The X and Y coordinates of the other sources with respect to this origin are then obtained from a plant layout drawn to scale. The X axis is positive to the east and the Y axis is positive to the north.

The pollutant emission rate is also required for each source. If the pollutant is depleted by any mechanism that can be described by time-dependent exponential decay, the user may enter a decay coefficient $\psi$. The parameters $\phi_n$, $V_{sn}$ and $\gamma_n$ are not required if concentration or deposition calculations are being made for particulates with appreciable gravitational settling velocities (diameters greater than about 20 micrometers). Particulate emissions from each source can be divided by the user into a maximum of 20 gravitational settling-velocity categories. Emission rates used by the short-term model program ISCST may be held constant or may be varied as follows:

- By hour of the day
- By season or month
- By hour of the day and season
- By wind-speed and stability categories (applies to fugitive sources of wind-blown dust)

Emission rates used by the long-term model program ISCLT may be annual average rates or may be varied by season or by wind-speed and stability categories.

Additional source inputs required for stacks include the physical stack height, the stack exit velocity, the stack inner diameter and the stack exit temperature. For an area source or a volume source, the dimensions of the source and the effective emission height are entered in place of these parameters. If a stack is located on or adjacent to a building and the stack height to building height ratio is less than 2.5, the length (L) and width (W) of the building are required as source inputs in order to include aerodynamic wake effects in the model calculations. The building wake effects option is automatically exercised if building dimensions are entered.

TABLE A-3

**PASQUILL-GIFFORD DISPERSION COEFFICIENTS USED BY THE ISC MODEL IN THE RURAL AND URBAN MODES**

| Actual Pasquill Stability Category* | Pasquill Stability Category for the $\sigma_y, \sigma_z$ Values Used in ISC Model Calculations | | |
|---|---|---|---|
| | Rural Mode | Urban Mode 1 | Urban Mode 2 |
| A | A | A | A |
| B | B | B | A |
| C | C | C | B |
| D | D | D | C |
| E | E | D | D |
| F | F | D | D |

*The ISCST program redefines extremely stable G stability as very stable F stability.



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TABLE A-4

SOURCE INPUTS REQUIRED BY THE ISC MODEL PROGRAMS

| Parameter | Definition |
|---|---|
| **Stacks** | |
| $Q$ | Pollutant emission rate for concentration calculations (mass per unit time) |
| $Q_T$ | Total pollutant emissions during the time period $T$ for which deposition is calculated (mass) |
| $\psi$ | Pollutant decay coefficient (seconds$^{-1}$) |
| $X$, $Y$ | $X$ and $Y$ coordinates of the stack (meters) |
| $Z_s$ | Elevation of base of stack (meters above mean sea level) |
| $h$ | Stack height (meters) |
| $V_s$ | Stack exit velocity (meters per second) |
| $d$ | Stack inner diameter (meters) |
| $T_s$ | Stack exit temperature (degrees Kelvin) |
| $\phi_n$ | Mass fraction of particulates in the $n^{th}$ settling-velocity category |
| $V_{sn}$ | Gravitational settling velocity for particulates in the $n^{th}$ settling-velocity category (meters per second) |
| $\gamma_n$ | Surface reflection coefficient for particulates in the $n^{th}$ settling-velocity category |
| $h_b$ | Height of building adjacent to the stack (meters) |



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TABLE A-4 (Continued)

| Parameter | Definition |
| --- | --- |
| W | Width of building adjacent to the stack (meters) |
| L | Length of building adjacent to the stack (meters) |
| <u>Volume Source (Line Source)</u> | |
| Q | Same definition as for stacks |
| $Q_T$ | Same definition as for stacks |
| $\psi$ | Same definition as for stacks |
| X, Y | X and Y coordinates of the center of the volume source or of each volume source used to represent a line source (meters) |
| $Z_s$ | Elevation of the ground surface at the point of the center of each volume source (meters above mean sea level) |
| H | Height of the center of each volume source above the ground surface (meters) |
| $\sigma_{yo}$ | Initial horizontal dimension (meters) |
| $\sigma_{zo}$ | Initial vertical dimension (meters) |
| $\phi_n$ | Same definition as for stacks |
| $V_{sn}$ | Same definition as for stacks |
| $\gamma_n$ | Same definition as for stacks |
| <u>Area Source</u> | |
| $Q_A$ | Pollutant emission rate for concentration calculations (mass per unit time per unit area) |



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TABLE A-4 (Continued)

| Parameters | Definition |
|---|---|
| $Q_{A\tau}$ | Total pollutant emissions during the time period $\tau$ for which deposition is calculated (mass per unit area) |
| $\psi$ | Same definition as for stacks |
| X, Y | X and Y coordinates of the southwest corner of the square area source (meters) |
| $Z_s$ | Elevation of the area source (meters above mean sea level) |
| H | Effective emission height of the area source (meters) |
| $x_o$ | Width of the square area source (meters) |
| $\phi_n$ | Same definition as for stacks |
| $V_{sn}$ | Same definition as for stacks |
| $\gamma_n$ | Same definition as for stacks |

### A.2.3 Receptor Data

The ISC Dispersion Model computer program allow the user to select either a Cartesian (X, Y) or a polar (r, θ) receptor grid system. In the Cartesian system, the X-axis is positive to the east of a user-specified origin and the Y-axis is positive to the north. In the polar system, r is the radial distance measured from the user-specified origin and the angle θ (azimuth bearing) is measured clockwise from north. If pollutant emissions are dominated by a single source or by a group of sources in close proximity, a polar coordinate system with its origin at the location of the dominant source or sources is the preferred receptor grid system. However, if the industrial source complex is comprised of multiple sources that are not located at the same point, a Cartesian coordinate system is usually more convenient. Additionally, if the Universal Transverse Mercator (UTM) coordinate system is used to define source locations and/or to extract the elevations of receptor points from USGS topographic maps, the UTM system can also be used in the ISC Model calculations. Discrete (arbitrarily placed) receptor points corresponding to the locations of air quality monitors, elevated terrain features, the property boundaries of the industrial source complex or other points of interest can be used with either coordinate system.

In the polar coordinate system, receptor points are usually spaced at 10-degree intervals on concentric rings. Thus, there are 36 receptors on each ring. The radial distances from the origin to the receptor rings are user selected and are generally set equal to the distances to the expected maximum ground-level concentrations for the major pollutant sources under the most frequent stability and wind-speed combinations. Estimates of these distances can be obtained from the PTMAX computer program (Turner and Busse, 1973) or from preliminary calculations using the ISCST computer program. The maximum number of receptor points is determined by factors such as the number of sources and the desired output. An example of a polar receptor array is shown in Figure A-1.

In the Cartesian coordinate system, the X and Y coordinates of the receptors are specified by the user. The spacing of gird points is not required to be uniform so that the density of grid points can be greatest in the area of the expected maximum ground-level concentrations. For example, assume that an industrial source complex is comprised of a number of major sources, contained within a 1-kilometer square, whose maximum ground-level concentrations are expected to occur at downwind distances ranging from 500 to 1000 meters. The Cartesian receptor grind {X and & = 0, ±200, ±400, ±600, ±800, ±1,000, ±1,200, ±1,500, ±2,000, ±3,000} illustrated in Figure A-2 provides a dense spacing of grid points in the areas where the highest concentrations are expected to occur. As shown by Figure A-2, use of the Cartesian system requires that some of the receptor points be located within the property of the source complex. Also, some of the receptors may be located within 100 meters of an individual source. If a receptor is located within 100 meters of a source, a warning message is printed and concentrations are not calculated for the source-receptor combination. The 100-meter restriction, which arises from the fact that the Pasquill-Gifford curves begin at 100 meters, is not a problem in this case because the concentrations of concern are the concentrations calculated at and beyond the property boundaries of the source complex. Comparison of Figures A-1 and A-2 shows that, for the hypothetical industrial source complex described above, the Cartesian receptor array is more likely to detect the maximum concentrations produced by the combined emissions from the various sources within the industrial source complex than is the polar receptor array.

As noted above, discrete (arbitrarily spaced) receptor points may be entered using either a polar or a Cartesian coordinate system. In general, discrete receptor points are placed at the locations of air quality monitors, the boundaries of the property of an industrial source complex or at other points of interest. However, discrete receptor points can be used for many purposes. For example, assume that a proposed coal-fired power plant will be located approximately 30 kilometers from a National Park that is a Class I (pristine air quality) area and that it is desired to determine whether the 3-hour and 24-hour Class I Non-Deterioration Increments for $SO_2$ will be exceeded on more than 18 days per year. The angular dimensions of the areas within which the 3-hour and 24-hour Class I Non-Deterioration Increments for

$SO_2$ are exceeded are usually less than 10 degrees. It follows that a polar coordinate system with a 10-degree angular separation of receptors is not adequate to detect all occurrences of 3-hour and 24-hour $SO_2$ concentrations above the short-term Class I $SO_2$ Increments. The user may therefore wish to place discrete receptors at 1-degree intervals along the boundary of and within the Class I area.

If model calculations are to be made for an industrial source complex located in complex terrain, the elevation above mean sea level of each receptor must be input. If the elevation of any receptor exceeds the height of any stack or the effective emission height of any volume source, an error message is printed and program execution is terminated.



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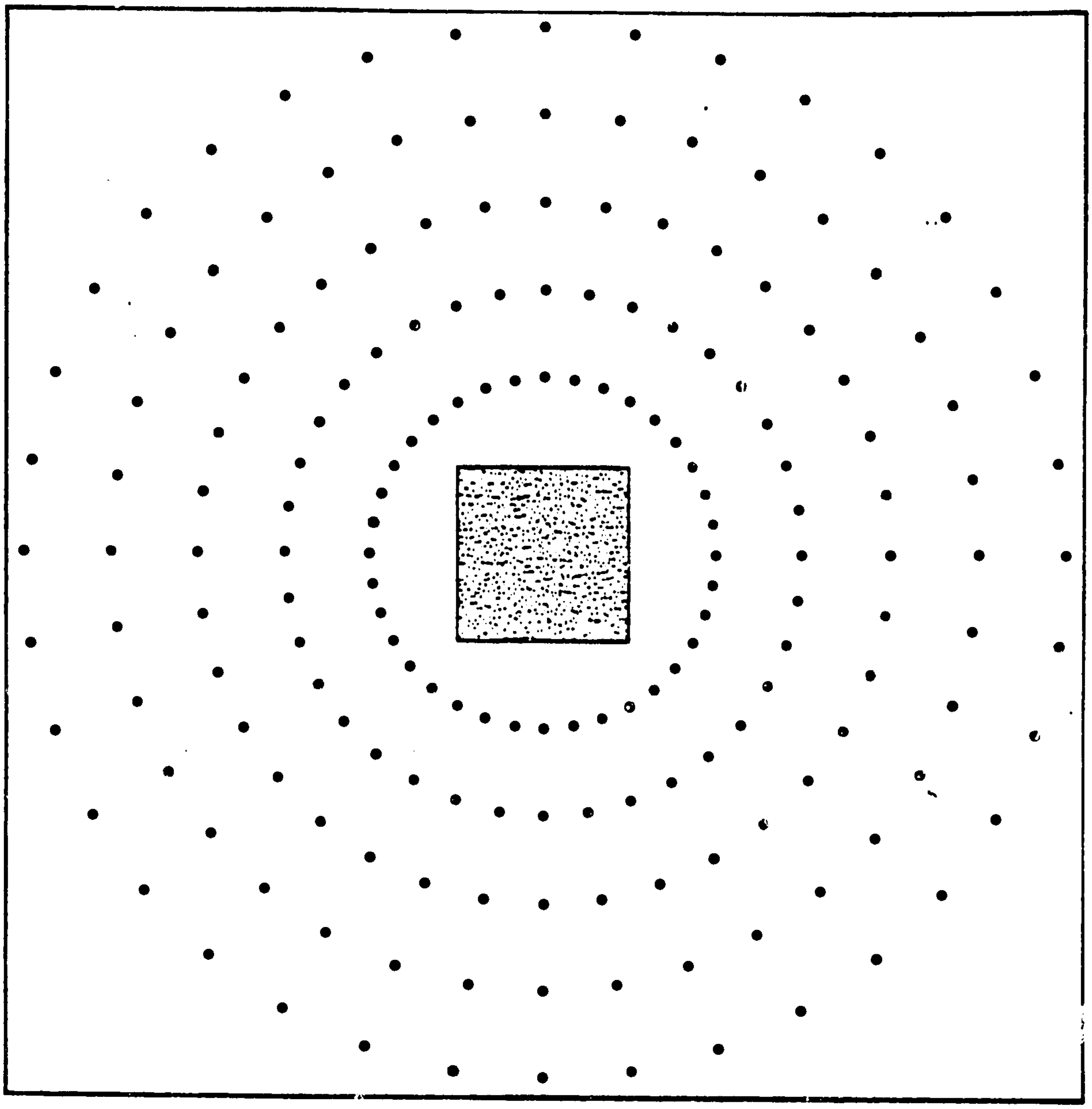

FIGURE A-1. Example of a polar receptor grid. The stippled area shows the property of a hypothetical industrial source complex.

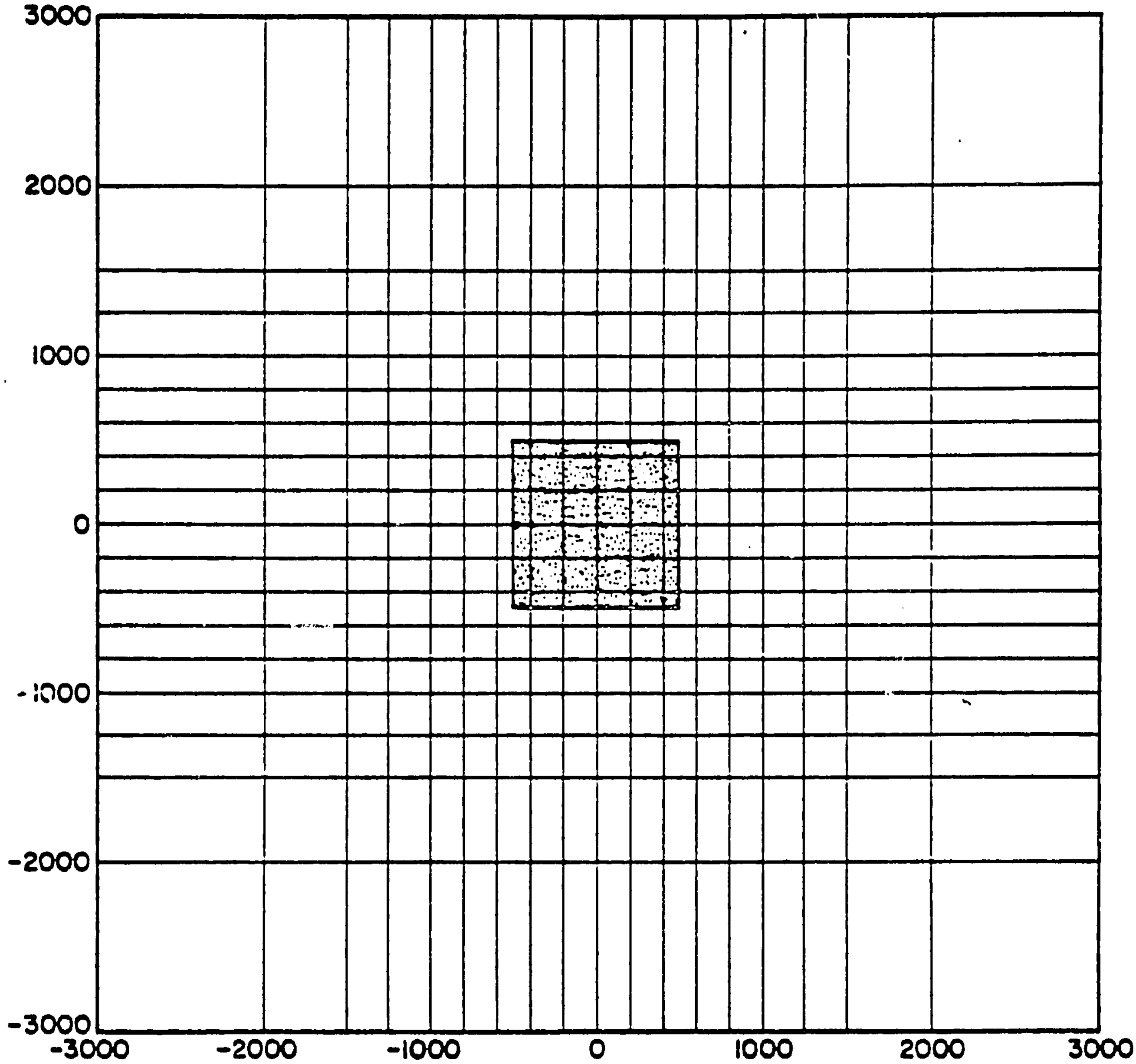


FIGURE A-2. Example of an irregularly-spaced Cartesian receptor grid. The stippled area shows the property of a hypothetical industrial source complex.



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A.3 PLUME RISE FORMULAS

The effective stack height H of a plume with momentum and/or thermal buoyancy is given by the sum of the physical stack height h and the plume rise $\Delta h$. The ISC Model programs use the generalized Briggs (1971, 1975) plume-rise equations. Parameters used in these equations are defined as follows:

$$F_m = \left(T_a/T_s\right) V_s^2 \, d^2/4 \qquad \text{(A-1)}$$

$$F = \begin{cases} F' = \dfrac{g\, V_s\, d^2}{4} \left(1 - T_a/T_s\right) & ; F' > F_c \\ 0 & ; F' \leq F_c \end{cases} \qquad \text{(A-2a)}$$

$$F_c = \begin{cases} 0.0727\ (V_s d)^{4/3} & ; F' \leq 55\ m^4/sec^3 \\ 0.0141\ (V_s d)^{5/3} & ; F' > 55\ m^4/sec^3 \end{cases} \qquad \text{(A-2b)}$$

$$\beta_j = \left(1/3 + \frac{\bar{u}\{h\}}{V_s}\right) \qquad \text{(A-3)}$$

where

$F_m$ = momentum flux term

$F$ = buoyancy flux term

$F_c$ = buoyancy flux below which plume rise is due to momentum only

$\beta_j$ = jet entrainment coefficient

$T_a$ = ambient air temperature (°K)

$T_s$ = stack exit temperature (°K), input as zero for a pure momentum source

$V_s$ = stack exit velocity (m/sec), input as zero if no plume rise is to be calculated

$d$ = stack inner diameter (m)

$g$ = acceleration due to gravity (9.8 $m/sec^2$)

$\bar{u}(h)$ = mean wind speed (m/sec) at emission height h

If the vertical potential temperature gradient is less than or equal to zero (the default value for the A, B, C and D Pasquill stability categories), plume rise $\Delta h_N$ due to buoyancy and/or momentum at downwind distance x is given by

$$\Delta h_N\{x\} = \left[ \frac{3F_m\, x'}{\beta_j^2\, \bar{u}\{h\}^2} + \frac{3F\, x'^2}{2\beta_1^2\, \bar{u}\{h\}^3} \right]^{1/3} \qquad \text{(A-4)}$$

$$x' = \left\{ \begin{array}{lll} x & ; & x < 3.5\, x^* \text{ and } F > 0 \\ x & ; & x < \dfrac{4d\left(V_s + 3\bar{u}\{h\}\right)^2}{V_s\, \bar{u}\{h\}} \text{ and } F = 0 \\ 3.5\, x^* & ; & x \geq 3.5\, x^* \text{ and } F > 0 \\ \dfrac{4d\left(V_s + 3\bar{u}\{h\}\right)^2}{V_s\, \bar{u}\{h\}} & ; & x \geq \dfrac{4d\left(V_s + 3\bar{u}\{h\}\right)^2}{V_s\, \bar{u}\{h\}} \text{ and } F = 0 \end{array} \right\} \qquad \text{(A-5)}$$

$$x^* = \left\{ \begin{array}{l} 14\, F^{5/8}; \quad F \leq 55\ m^4/sec^3 \\ 34\, F^{2/5}; \quad F > 55\ m^4/sec^3 \end{array} \right\} \qquad \text{(A-6)}$$

where the default value for the adiabatic entrainment coefficient $\beta_1$ is 0.6 (Briggs, 1975). It should be noted that Equation (A-4) is a theoretical formulation. At present, sufficient experimental data to determine the validity of the final plume rises yielded by Equation (A-4) for non-buoyant plumes are not available.

If the vertical potential temperature gradient is positive, plume rise $\Delta h_S$ at downwind distance x is given by

$$\Delta h_s\{x\} = \left[ \frac{3F_m}{\beta_j^2 \bar{u}\{h\} S^{1/2}} \sin\left(S^{1/2} x'/\bar{u}\{h\}\right) + \frac{3F}{\beta_2^2 \bar{u}\{h\} S} \left(1 - \cos\left(S^{1/2} x'/\bar{u}\{h\}\right)\right)\right]^{1/3} \quad \text{(A-7)}$$

$$x' = \begin{cases} x & ; \; x < \pi \bar{u}\{h\} S^{-1/2} \text{ and } F > 0 \\ x & ; \; x < \frac{\pi}{2} \bar{u}\{h\} S^{-1/2} \text{ and } F = 0 \\ \pi \bar{u}\{h\} S^{-1/2} & ; \; x \geq \pi \bar{u}\{h\} S^{-1/2} \text{ and } F > 0 \\ \frac{\pi}{2} \bar{u}\{h\} S^{-1/2} & ; \; x \geq \frac{\pi}{2} \bar{u}\{h\} S^{-1/2} \text{ and } F = 0 \end{cases} \quad \text{(A-8)}$$

$$S = \frac{g}{T_a} \frac{\partial \theta}{\partial z} \quad \text{(A-9)}$$

where

S = stability parameter

$\frac{\partial \theta}{\partial z}$ = vertical potential temperature gradient (the default value is 0.020°K/m for E stability and 0.035°K/m for F stability)

The default value for the stable entrainment coefficient $\beta_2$ is 0.6 (Briggs, 1975). It should be noted that, if the buoyancy parameter F is equal to zero and $\Delta h_s\{x\}$ is greater than $3V_s d/\bar{u}\{h\}$, the ISC Model programs set $\Delta h_s\{x\}$ equal to $3V_s d/\bar{u}\{h\}$. Equation (A-7) is a theoretical formulation. In the case of non-buoyant plumes, sufficient experimental data to determine the validity of the final plume rises calculated by Equation (A-7) currently are not available.

It is important to note that the calculation of plume rise as a function of downwind distance is an ISC Model option. If the ISC Model programs are not directed to calculate plume rise as a function of downwind distance, the program will assume that the final plume rise applies at all downwind distances. The final plume rise with an adiabatic or unstable thermal stratification is given by Equation (A-4) with x' set equal to the maximum value allowed by Equation (A-5). Similarly, the final plume rise with a stable thermal stratification is given by Equation (A-7) with x' set equal to the maximum value allowed by Equation (A-8)

A wind-profile exponent law is used to adjust the mean wind speed $\bar{u}_1$ from the wind system measurement height $z_1$ (default value of 10 meters) to the emission height h. This law is of the form

$$\bar{u}_h = \bar{u}_1 \left(\frac{h}{z_1}\right)^p \qquad \text{(A-10)}$$

where p is the wind-profile exponent. The default values for p are given in Table A-2.

As an option, the user may direct the ISC Model programs to consider stack-tip downwash for all stacks following the suggestions of Briggs (1973). The physical stack height h is replaced by an adjusted stack height h', which is defined as

$$h' = \begin{cases} h & ; \; V_s \geq 1.5\,\bar{u}\{h\} \\ h + 2\left[V_s/\bar{u}\{h\} - 1.5\right]d\,; & V_s < 1.5\,\bar{u}\{h\} \end{cases} \qquad \text{(A-11)}$$

The user is cautioned that Equation (A-11) is based on data obtained in an aeronautical wind tunnel airstream turbulence and without proper Froude number scaling for buoyancy effects (see Halitsky, 1978). Additionally, the published data upc which Equation (A-11) is based (Sherlock and Stalker, 1941) refer to the downward displacement of the lower plume boundary rather than to the downward displacement of the plume centerline.

## A.4 THE ISC SHORT-TERM DISPERSION MODEL EQUATIONS

### A.4.1 Stack Emissions

The ISC short-term concentration model for stacks uses the steady-state Gaussian plume equation for a continuous elevated source. For each stack and each hour, the origin of the stack's coordinate system is placed at the ground surface at the base of the stack. The x axis is positive in the downwind direction, the y axis is crosswind (normal) to the x axis and the z axis extends vertically. The fixed receptor locations are converted to each stack's coordinate system for each hourly concentration calculation. The hourly concentrations calculated for each stack at each receptor are summed to obtain the total concentration produced at each receptor by the combined stack emissions.

The hourly ground-level concentration at downwind distance x and crosswind distance y is given by

$$\chi\{x,y\} = \frac{KQ}{\pi \bar{u}\{h\} \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \quad \text{(A-12)}$$

{Vertical Term} {Decay Term}

where

$Q$ = pollutant emission rate (mass per unit time)

$K$ = a scaling coefficient to convert calculated concentrations to desired units (default value of $1 \times 10^6$ for Q in g/sec and concentration in $\mu g/m^3$)

$\sigma_y$, $\sigma_z$ = standard deviation of lateral, vertical concentration distribution (m)

$\bar{u}\{h\}$ = mean wind speed (m/sec) at stack height h

Equation (A-12) includes a Vertical Term, a Decay Term, and dispersion coefficients ($\sigma_y$ and $\sigma_z$). The dispersion coefficients a ' the Vertical Term are discussed below. It should be noted that the Vertical Term includes the effects of source elevation, plume rise, limited mixing in the vertical, and the gravitational settling and dry disposition of larger particulates (particulates with diameters greater than about 20 micrometers).

The Decay Term, which is a simple method of accounting for pollutant removal by physical or chemical processes, is of the form

$$\{\text{Decay Term}\} = \exp\left[-\psi\ x/\bar{u}\{h\}\right] \qquad \text{(A-13)}$$

where

For example, if $T_{1/2}$ is the pollutant half life in seconds, the user can obtain $\psi$ from the relationship

$$\psi = \frac{0.693}{T_{1/2}} \qquad \text{(A-14)}$$

The default value for $\psi$ is zero. That is, decay is not considered in the model calculation unless $\psi$ is specified.

In addition to stack emissions, the ISC short-term concentration model considers emissions from area and volume sources. The volume-source option is also used to simulate line sources. These model options are described in Section A.4.2. Section A.4.3 gives the optional algorithms for calculating dry deposition for stack, area and volume sources.

### A.4.1.1 The Dispersion Coefficients

a. Point Source Dispersion Coefficients. Equations that approximately fit the Pasquill-Gifford curves (Turner, 1970) are used to calculate $\sigma_y$ and $\sigma_z$. The equations used to calculate $\sigma_y$ are of the form

$$\sigma_y = 465.11628\ x\ \tan(TH) \qquad \text{(A-15)}$$

$$TH = 0.017453293\ (c - d\ \ln x) \qquad \text{(A-16)}$$

where the downwind distance x is in kilometers in Equations (A-15 and (A-16); the coefficients c and d are listed in Table A-5. The equation used to calculate      is of the form

$$\sigma_z = ax^b \tag{A-17}$$

where the downwind distance x is in kilometers in Equation (A-17) and the coefficients a and b are given in Table A-6.

TABLE A-5

**PARAMETERS USED TO CALCULATE $\sigma_y$**

| Pasquill Stability Category | $\sigma_y = 465.11628\ x(km)\ \tan(TH)$ $TH = 0.017453293\ (c - d \ln(x(km)))$ . | |
|---|---|---|
| | c | d |
| A | 24.1670 | 2.5334 |
| B | 18.3330 | 1.8096 |
| C | 12.5000 | 1.0857 |
| D | 8.3330 | 0.72382 |
| E | 6.2500 | 0.54287 |
| F | 4.1667 | 0.36191 |



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TABLE A-6

**PARAMETERS USED TO CALCULATE $\sigma_z$**

| Pasquill Stability Category | x (km) | $\sigma_z = a\, x(km)^b$ a | b |
|---|---|---|---|
| A* | 0.10 - 0.15 | 158.080 | 1.05420 |
| | 0.16 - 0.20 | 170.220 | 1.09320 |
| | 0.21 - 0.25 | 179.520 | 1.12620 |
| | 0.26 - 0.30 | 217.410 | 1.26440 |
| | 0.31 - 0.40 | 258.890 | 1.40940 |
| | 0.41 - 0.50 | 346.750 | 1.72830 |
| | 0.51 - 3.11 | 453.850 | 2.11660 |
| | >3.11 | ** | ** |
| B* | 0.10 - 0.20 | 90.673 | 0.93198 |
| | 0.21 - 0.40 | 98.483 | 0.98332 |
| | >0.40 | 109.300 | 1.09710 |
| C* | >0.10 | 61.141 | 0.91465 |
| D | 0.10 - 0.30 | 34.459 | 0.86974 |
| | 0.31 - 1.00 | 32.093 | 0.81066 |
| | 1.01 - 3.00 | 32.093 | 0.64403 |
| | 3.01 - 10.00 | 33.504 | 0.60486 |
| | 10.01 - 30.00 | 36.650 | 0.56589 |
| | >30.00 | 44.053 | 0.51179 |

*If the calculated value of $\sigma_z$ exceeds 5000 m, $\sigma_z$ is set to 5000 m.

**$\sigma_z$ is equal to 5000 m.

TABLE A-6 (Continued)

| Pasquill Stability Category | x (km) | $\sigma_z = a\,x(km)^b$ | |
|---|---|---|---|
| | | a | b |
| E | 0.10 - 0.30 | 23.331 | 0.81956 |
| | 0.31 - 1.00 | 21.628 | 0.75660 |
| | 1.01 - 2.00 | 21.628 | 0.63077 |
| | 2.01 - 4.00 | 22.534 | 0.57154 |
| | 4.01 - 10.00 | 24.703 | 0.50527 |
| | 10.01 - 20.00 | 26.970 | 0.46713 |
| | 20.01 - 40.00 | 35.420 | 0.37615 |
| | >40.00 | 47.618 | 0.29592 |
| F | 0.10 - 0.20 | 15.209 | 0.81558 |
| | 0.21 - 0.70 | 14.457 | 0.78407 |
| | 0.71 - 1.00 | 13.953 | 0.68465 |
| | 1.01 - 2.00 | 13.953 | 0.63227 |
| | 2.01 - 3.00 | 14.823 | 0.54503 |
| | 3.01 - 7.00 | 16.187 | 0.46490 |
| | 7.01 - 15.00 | 17.836 | 0.41507 |
| | 15.01 - 30.00 | 22.651 | 0.32681 |
| | 30.01 - 60.00 | 27.074 | 0.27436 |
| | >60.00 | 34.219 | 0.21716 |

b. Downwind and Crosswind Distances. As noted in Section A.2.3, the ISC Model uses either a polar or a Cartesian receptor grid as specified by the user. In the polar coordinate system, the radial coordinate of the point $(r, \theta)$ is measured from the user-specified origin and angular coordinate $\theta$ is measured clockwise from north. In the Cartesian coordinate system, the X axis is positive to the east of the user-specified origin and the Y axis is positive to the north. For either type of receptor grid, the user must define the location of each source with respect to the origin of the grid using Cartesian coordinates. In the polar coordinate system, the X and Y coordinates of a receptor at the point $(r, \theta)$ are given by

$$X(R) = r \sin \theta \qquad \text{(A-18)}$$

$$Y(R) = r \cos \theta \qquad \text{(A-19)}$$

If the X and Y coordinates of the sources are X(S) and Y(S), the downwind distance x to the receptor is give by

$$x = -\left(X(R) - X(S)\right) \sin DD - \left(Y(R) - Y(S)\right) \cos DD \qquad \text{(A-20)}$$

where DD is the direction from which the wind is blowing. If any receptor is located within 100 meters of a source, a warning message is printed and no concentrations are calculated for the source-receptor combination. The crosswind distance y to the receptor (see Equation (A-12)) is given by

$$y = -\left(Y(R) - Y(S)\right) \sin DD + \left(X(R) - X(S)\right) \cos DD \qquad \text{(A-21)}$$

c. Lateral and Vertical Virtual Distances. Equations (A-15) through (A-17) define the dispersion coefficients for an ideal point source. However, volume sources have initial lateral and vertical dimensions. Also, as discussed below, building wake effects can enhance the initial growth of stack plumes. In these cases, lateral ($x_y$) and vertical ($x_z$) virtual distances are added by the ISC Model to the actual downwind distance x for the $\sigma_y$ and $\sigma_z$ calculations. The lateral virtual distance in kilometers is given by

$$x_y(\text{km}) = \left(\frac{\sigma_{yo}\ (\text{m})}{p}\right)^{1/q} \qquad \text{(A-22)}$$

where the stability-dependent coefficients p and q are given in Table A-7 and $\sigma_{yo}$ is the standard deviation of the lateral concentration distribution at the source. Similarly, the vertical virtual distance in kilometers is given by

$$x_z\ (\text{km}) = \left(\frac{\sigma_{zo}\ (\text{m})}{a}\right)^{1/b} \qquad \text{(A-23)}$$



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where the coefficients a and b are obtained from Table A-8 and $\sigma_{zo}$ is the standard deviation of the vertical concentration distribution at the source. It is important to note that the ISC Model programs check to ensure that the $x_z$ used to calculate $\sigma_z\{x+x_z\}$ is the $x_z$ calculated using the coefficients a and b that correspond to the distance category specified by the quantity $(x + x_z)$.

d. Procedure Used to Account for the Effects of Building Wakes on Effluent Dispersion. The procedures used by the ISC Model to account for the effects of the aerodynamic wakes and eddies produced by plant buildings and structures on plume dispersion follow the suggestions of Huber and Snyder (1976) and Huber(1977). Their suggestions are principally based on the results of wind-tunnel experiments using a model building with a crosswind dimension double that of the building height. The atmospheric turbulence simulated in the wind-tunnel experiments was intermediate between the turbulent intensity associated with the slightly unstable Pasquill C category and the turbulent intensity associated with the neutral D category. Thus, the data reported by Huber and Snyder reflect a specific stability, building shape and building orientation with respect to the mean wind direction. It follows that the ISC Model wake-effects evaluation procedures may not be strictly applicable to all situations. However, the suggestions of Huber and Snyder are based on the best available data and are used by the ISC Model as interim procedures until additional data becomes available.

The wake-effects evaluation procedures may be applied by the user to any stack on or adjacent to a building. The distance-dependent plume rise option generally should be used with the building wake effects option. Additionally, because the effects of stack-tip downwash (see Equation (A-11)) are implicitly included in the building wake effects option, the stack-tip downwash option normally should not be used in combination with the building wake effects option. The first step in the wake-effects evaluation procedures used by the ISC Model programs is to calculate the plume rise due to momentum alone at a distance of two building heights downwind from the stack. Equation (A-4) or Equation (A-7) with the buoyancy parameter F set equal to zero is used to calculate this momentum rise. If the plume height, given by the sum of the stack height and the momentum rise at a downwind distance of two building heights, is greater than either 2.5 building heights ($2.5\ h_b + 1.5\ h_w$), the

TABLE A-7

COEFFICIENTS USED TO CALCULATE
LATERAL VIRTUAL DISTANCES

| Pasquill Stability Category | $x_y = \left(\frac{\sigma_{yo}}{p}\right)^{1/q}$ | |
|---|---|---|
| | p | q |
| A | 209.14 | 0.890 |
| B | 154.46 | 0.902 |
| C | 103.26 | 0.917 |
| D | 68.26 | 0.919 |
| E | 51.06 | 0.921 |
| F | 33.92 | 0.919 |

plume is assumed to be unaffected by the building wake. Otherwise, the plume is assumed to be affected by the building wake.

The ISC Model programs account for the effects of building wakes by modifying $\sigma_z$ for plumes from stacks with plume height to building height ratios greater than 1.2 (but less than 2.5) and by modifying both $\sigma_y$ and $\sigma_z$ for plumes with plume height to building height ratios less than or equal to 1.2. The plume height used in the plume height to stack height ratios is the same plume height used to determine if the plume is affected by the building wake. The ISC Model defines buildings as squat ($h_w \geq h_b$) or tall ($h_w < h_b$). The building width $h_w$ is approximated by the diameter of a circle with an area equal to the horizontal area of the building. The ISC Model includes a general procedure for modifying $\sigma_z$ and $\sigma_y$ at distances greater than 3 $h_b$ for squat buildings or 2 $h_w$ for tall buildings. The air flow in the building cavity region is both highly turbulent and generally recirculating. The ISC Model is not appropriate for estimating concentrations within such regions. The ISC Model assumption that this recirculating cavity region extends to a downwind distance of 3 $h_b$ for a squat building or 3 $h_w$ for a tall building is most appropriate for a building whose width is not much greater than its height. The ISC Model user is cautioned that, for other types of buildings, receptors located at downwind distances of 3 $h_b$ (squat buildings) or 3 $h_w$ (tall buildings) may be within the recirculating region. Some guidance and techniques for estimating concentrations very near buildings can be found in Barry (1964), Halitsky (1963) and Vincent (1977). The downwash procedure found in Budney (1977) may also be used to obtain a "worst-case" estimate.

The modified equation for a squat building is given by

$$\sigma_z' = \begin{cases} 0.7h_b(m) + 0.067\,[x(m) - 3h_b(m)]; & 3h_b(m) \quad x(m) \quad 10h_b(m) \\ \sigma_z \{x(km) + x_z(km)\} & ; \quad x(m) \geq 10h_b(m) \end{cases} \tag{A-24}$$

where the building height $h_b$ is in meters. For a tall building, Huber (1977) suggests that the width scale $h_w$ replace $h_b$ in Equation (A-24).

The modified $\sigma_z$ equation for a tall building is then given by

$$\sigma_z' = \begin{cases} 0.7h_w(m) + 0.067\left[x(m) - 3h_w(m)\right] & : \quad 3h_w < x(m) < 10h_w(m) \\ \sigma_z\left\{x(km) + x_z(km)\right\} & ; \quad x(m) \geq 10h_w(m) \end{cases} \qquad \text{(A-25)}$$

where $h_w$ is in meters. It is important to note that $\sigma_z'$ is not permitted to be less than the point source value given by Equation (A-17), a condition that may occur with the A and B stability categories.

The vertical virgual distance $x_z$ is added to the actual downwind distance x at downwind distances beyond $10h_b$ (squat buildings) or $10h_w$ (tall buildings) in order to account for the enhanced initial plume growth caused by the building wake. Equations (A-17) and (A-24) can be combined to derive the vertical virtual distance $x_z$ for a squat building. First, it follows from Equation (A-24) that $\sigma_z$ is equal to $1.2h_b$ at a downwind distance of $10h_b$ in meters or 0.01 $h_b$ in kilometers. Thus, $x_z$ for a squat building is obtained from Equation (A-17) as follows:

$$\sigma_z\left\{0.01h_b\right\} = 1.2h_b = a\left(0.01h_b + x_z\right)^b \qquad \text{(A-26)}$$

$$x_z = \left(\frac{1.2h_b}{a}\right)^{1/b} - 0.01h_b \qquad \text{(A-27)}$$

where the stability-dependent constants a and b are given in Table A-6. Similarly, the vertical virtual distance for tall buildings is given by

$$x_z = \left(\frac{1.2h_w}{a}\right)^{1/b} - 0.01h_w \qquad \text{(A-28)}$$

For a squat building with a building width to building height ratio $h_w/h_b$ less than or equal to 5, the modified $\sigma_y$ equation is given by

$$\sigma_y' = \begin{cases} 0.35h_w(m) + 0.067\left[x(m) - 3h_b(m)\right] & ; \quad 3h_b < x(m) < 10h_b(m) \\ \sigma_y\left\{x(km) + x_y(km)\right\} & ; \quad x(m) \geq 10h_b(m) \end{cases} \qquad \text{(A-29)}$$

with the lateral virtual distance $x_y$ given by

$$x_y = \left(\frac{0.35h_w + 0.5h_b}{p}\right)^{1/q} - 0.01h_b \qquad \text{(A-30)}$$

The stability-dependent coefficients p and q are given in Table A-7.

For building width to building height ratios $h_w/h_b$ greater than 5, the presently available data are insufficient to provide general equations for . For a building that is much wider than it is tall and a stack located toward the center of the building (i.e., away from either end), only the height scale is considered to be significant. The modified $\sigma_y$ equation for a squat building is then given by

$$\sigma_y' = \begin{cases} 0.35h_b(m) + 0.067\left[x(m) - 3h_b(m)\right] & ; \quad 3h_b < x(m) < 10h_b(m) \\ \sigma_y\left\{x(km) + x_y(km)\right\} & ; \quad x(m) \geq 10h_b(m) \end{cases} \qquad \text{(A-31)}$$

with the lateral virtual distance $x_y$ given by

$$x_y = \left(\frac{0.85h_b}{p}\right)^{1/q} - 0.01h_b \qquad \text{(A-32)}$$

For $h_w/h_b$ greater than 5 and a stack located laterally within about 2.5 $h_b$ of the end of the building, lateral plume spread is affected by the flow around the end of the building. With end effects, the enhancement in the initial lateral spread is assumed not to exceed that given by Equation (A-29) with $h_w$ replaced by $5h_b$. The modified $\sigma_y$ equation is given by

$$\sigma_y' = \begin{cases} 1.75h_b(m) + 0.067\left[x(m) - 3h_b(m)\right] & ; \quad 3h_b < x(m) < 10h_b(m) \\ \sigma_y\left\{x(m) + x_y(km)\right\} & ; \quad x(m) \geq 10h_b(m) \end{cases} \qquad \text{(A-33)}$$

$$x_y = \left(\frac{2.25h_b}{p}\right)^{1/q} - 0.01h_b \qquad \text{(A-34)}$$

The upper and lower bounds of the concentrations that can be expected to occur near a building are determined respectively by Equations (A-31) and (A-33). The user must specify whether Equation (A-31)or Equation (A-33) is to be used in the model calculations. In the absence of user instructions, the ISC Model uses Equation (A-31) if the building width to building height ratio $h_w/h_b$ exceeds 5.

Although Equation (A-31) provides the highest concentration estimates for squat buildings with building width to building height ratios $h_w/h_b$ greater than 5, the equation is applicable only to a stack located near the center of the building when the wind direction is perpendicular to the long side of the building (i.e., when the air flow over the portion of the building containing the source is two dimensional). Thus, Equation (A-33) generally is more appropriate than Equation (A-31). It is believed that Equation (A-31) and (A-33) provide reasonable limits on the extent of the lateral enhancement of dispersion and that these equations are adequate until additional data are available to evaluate the flow near very wide buildings.

The modified $\sigma_y$ equation for a tall building is given by

$$\sigma_y' = \begin{cases} 0.35h_w(m) + 0.067\left[x(m) - 3h_w\right]; & 3h_w < x(m) < 10h_w \\ \sigma_y\left\{x(km) + x_y(km)\right\} & ; \quad x(m) \geq 10h_w \end{cases} \tag{A-35}$$

$$x_y = \left(\frac{0.85h_w}{p}\right)^{1/q} - 0.01h_w \tag{A-36}$$

Because the Pasquill-Gifford $\sigma_y$ and $\sigma_z$ curves begin at a downwind distance of 100 meters, the ISC Model programs print a warning message and do not calculate concentrations for any source-receptor combination where the source-receptor separation is less than the maximum of 100 meters or $3h_b$ for a squat building or $3h_w$ for a tall building. It should be noted that, for certain combinations of stability and building height and/or width, the vertical and/or lateral plume dimensions indicated for a point source by the Pasquill-Gifford curves at a downwind distance of ten building heights or widths can exceed the values given by Equation (A-24) or (A-25) and by Equation (A-29), (A-31) or (A-32). Consequently, the ISC Model programs do not permit the virtual distances $x_y$ and $x_z$ to be less than zero.

It is important to note that the use of a single effective building width $h_w$ for all wind directions is a simplification that is required to enable the ISC Model computer programs to operate within the constraints imposed on the programs without sacrificing other desired ISC Model features. The effective building width $h_w$ affects $\sigma_z$ for tall buildings ($h_w < h_b$) and $\sigma_y$ for squat buildings ($h_w \geq h_b$) with plume height to building height ratios less than or equal to 1.2. Tall buildings typically have lengths and widths that are equivalent so that the use of one value of $h_w$ for all wind directions does not significantly affect the accuracy of the calculations. However, the use of one value of $h_w$ for squat buildings with plume height to building height ratios less than or equal to 1.2 affects the accuracy of the calculations near the source if the building length is large in comparison with the building width. For example, if the building height and width are approximately the same and the building length is equal to five building widths, the ISC Model at a downwind distance of $10h_b$ underestimates the centerline concentration or deposition by about 40 percent for winds parallel to the building's long side and overestimates the centerline concentration (or deposition) by about 60 percent for winds normal to the building's long side. Thus, the user should exercise caution in interpreting the results of concentration (or deposition) calculations for receptors located near a squat building if the stack height to building height ratio is less than or equal to 1.2.



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The recommended procedure for calculating accurate concentration (or deposition) values for receptors located near squat buildings consists of two phases. First, the appropriate ISC Model program is executed using the effective building width $h_w$ derived from the building length and width. Second, the ISC Model calculations are repeated for the receptors near the source with highest calculated concentration (or deposition) values using receptor-specific values of $h_w$. For example, assume that the ISCST program is used with a year of sequential hourly data to calculate maximum 24-hour average concentrations and that the highest calculated concentrations occur at Receptor A on Julian Day 18 and at Receptor B on Julian Day 352. The crosswind building with $h_w$ associated with the wind directions required to transport emissions to Receptors A and B may be obtained from a scale drawing of the building. The ISCST program is then executed for Receptor A only on Day 18 only using the appropriate $h_w$ value for Receptor A. Similarly, the ISCST program is executed for Receptor B only on Day 352 only using the appropriate $h_w$ value for Receptor B.

A.4.1.2 The Vertical Term

a. The Vertical Term for Gases and Small Particulates. In general, the effects on ambient concentrations of gravitational settling and dry deposition can be neglected for gaseous pollutants and small particulates (diameters less than about 20 micrometers). The Vertical Term is then given by

$$\{\text{Vertical Term}\} = \left\{ \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] + \sum_{i=1}^{\infty}\left[\exp\left[-\frac{1}{2}\left(\frac{2iH_m - H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{2iH_m + H}{\sigma_z}\right)^2\right]\right]\right\} \qquad \text{(A-37)}$$



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where

$H$ = effective stack height = sum of actual stack height h (m) and buoyant rise $\Delta h$ (m)

$H_m$ = mixing height (m)

The infinite series term in Equation (A-37) accounts for the effects of the restriction on vertical plume growth at the top of the surface mixing layer. As shown by Figure A-3, the method of image sources is used to account for multiple reflections of the plume from the ground surface and at the top of the surface mixing layer. It should be noted that, if the effective stack height H exceeds the mixing height $H_m$, the plume is assumed to remain elevated and the ground-level concentration is set equal to zero.

Equation (A-37) assumes that the mixing height in rural and urban areas is known for all stability categories. As explained below, the meteorological preprocessor program uses mixing heights derived from twice-daily mixing heights calculated using the Holzworth (1972) procedures. These mixing heights are believed to be representative, at least on the average, of mixing heights in urban areas under all stabilities and of mixing heights in rural areas during periods of unstable or neutral stability. However, because the Holzworth minimum mixing heights are intended to include the heat island effect for urban areas, their applicability to rural areas during periods of stable meteorological conditions (E or F stability) is questionable. Consequently, the ISC Model in the Rural Mode currently deletes the infinite series term in Equation (A-37) for the E and F stability categories.

The Vertical Term defined by Equation (A-37) changes the form of the vertical concentration distribution from Gaussian to rectangular (uniform concentration within the surface mixing layer) at long downwind distances. Consequently, in order to reduce computational time without a loss of accuracy, Equation (A-12) is changed to the form

$$\chi\{x,y\} = \frac{KQ}{\sqrt{2\pi}\ \bar{u}\{h\}\sigma_y H_m} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\{\text{Decay Term}\} \qquad \text{(A-38)}$$

at downwind distances where the $\sigma_z/H_m$ ratio is greater than or equal to 1.6.



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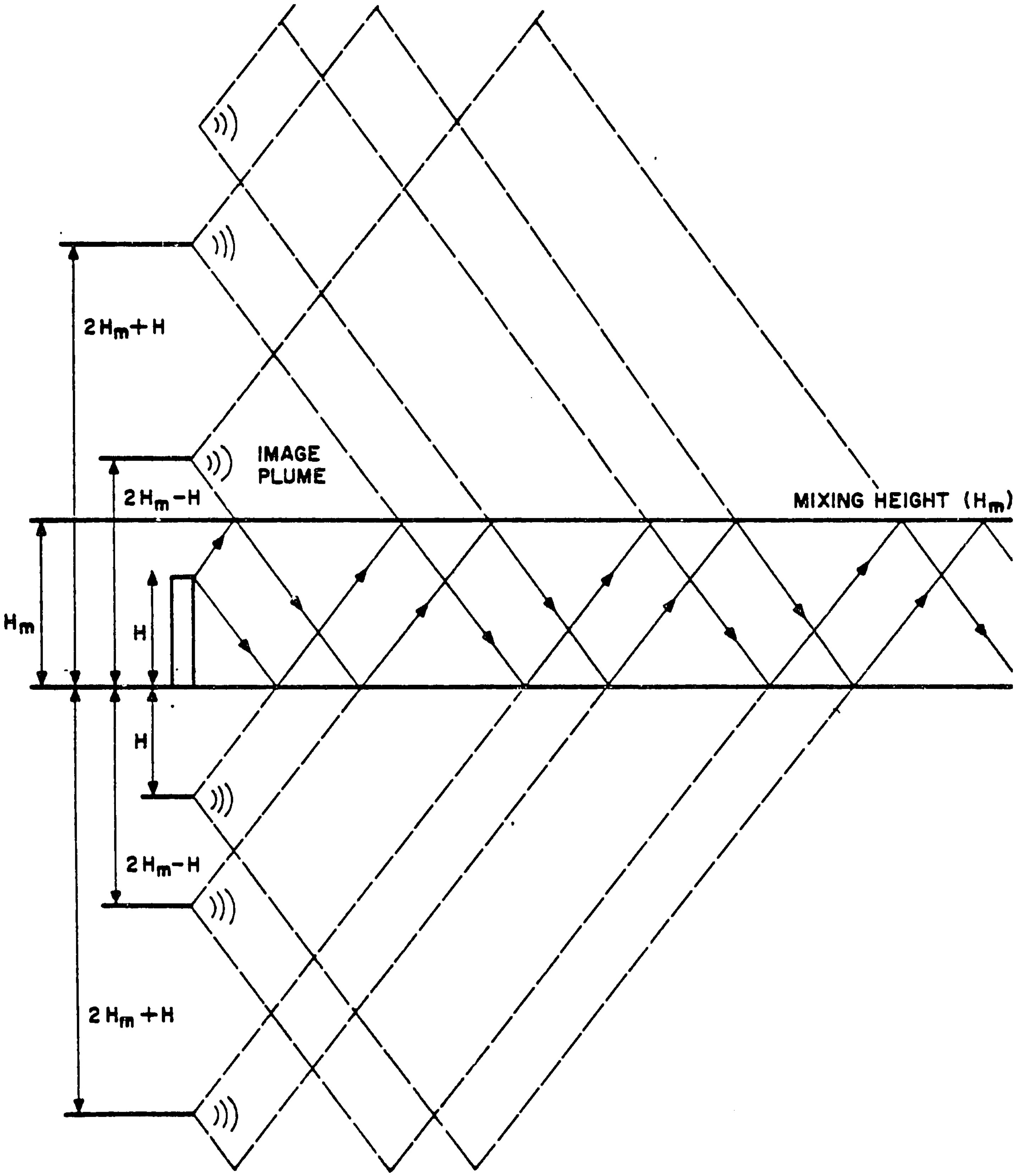


FIGURE A-4. The method of multiple plume images used to simulate plume reflection in the ISC Model.



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The meteorological preprocessor program used by the ISC short-term model (see Appendix G) uses an interpolation scheme to assign hourly rural or urban mixing heights on the basis of the early morning and afternoon mixing heights calculated using the Holzworth (1972) procedures. The procedures used to interpolate hourly mixing heights in urban and rural areas are illustrated in Figure A-4, where

$H_m\{max\}$ = maximum mixing height on a given day

$H_m\{min\}$ = minimum mixing height on a given day

MN = midnight

SR = sunrise

SS = sunset

The interpolation procedures are functions of the stability category for the hour before sunrise. If the hour before sunrise is neutral, the mixing heights that apply are indicated by the dashed lines labeled neutral in Figure A-4. If the hour before sunset is stable, the mixing heights that apply are indicated by the dashed lines labeled stable. It should be pointed out that there is a discontinuity in the rural mixing height at sunrise if the preceding hour is stable. As explained above, because of the uncertainties about the applicability of Holzworth mixing heights to rural areas during periods of E and F stability, the ISC Model in the Rural Mode ignores the interpolated mixing heights for E and F stabilities and effectively sets the mixing height equal to infinity.

b. The Vertical Term in Complex Terrain. The ISC Model makes the following assumption about plume behavior in complex terrain:

- The plume axis remains at the plume stabilization height above mean sea level as it passes over elevated terrain
- The mixing height is terrain following
- The wind speed is a function of height above the surface (see Equation (A-10))

Thus, a modified plume stabilization height H' is substituted for the effective stack height H in the Vertical Term given by Equation (A-37). For example, the effective plume stabilization height at the point (X, Y) is given by

$$H'\{X,Y\} = h + \Delta h + z_s - z\{X,Y\} \qquad \text{(A-39)}$$



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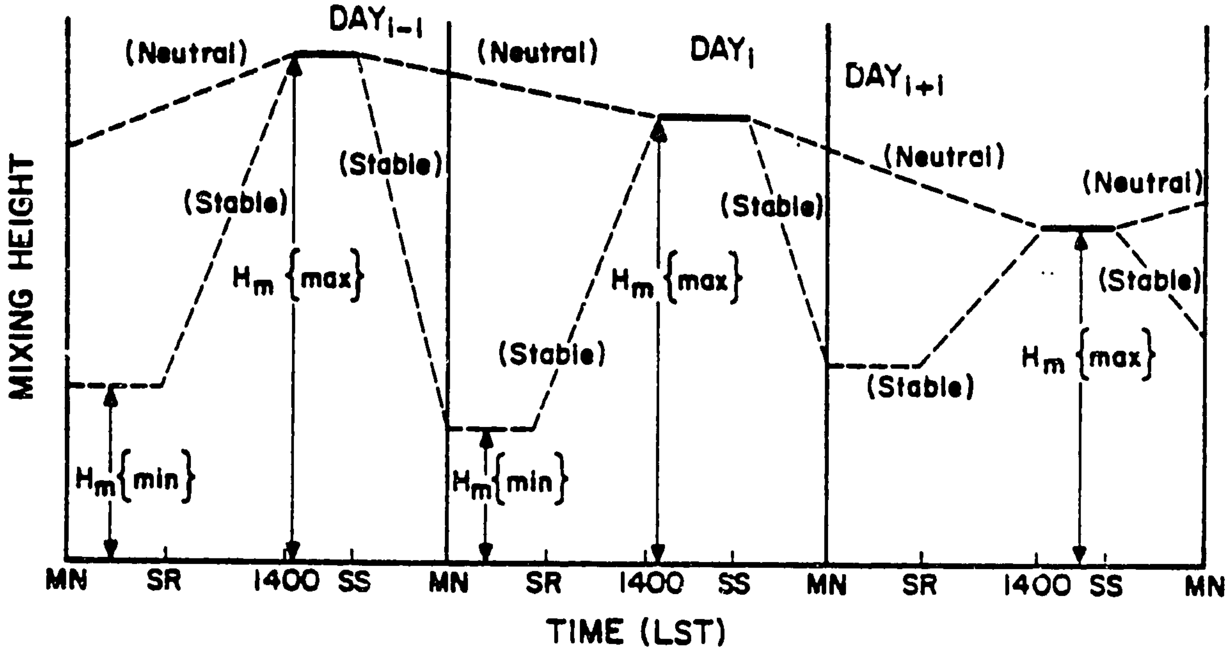
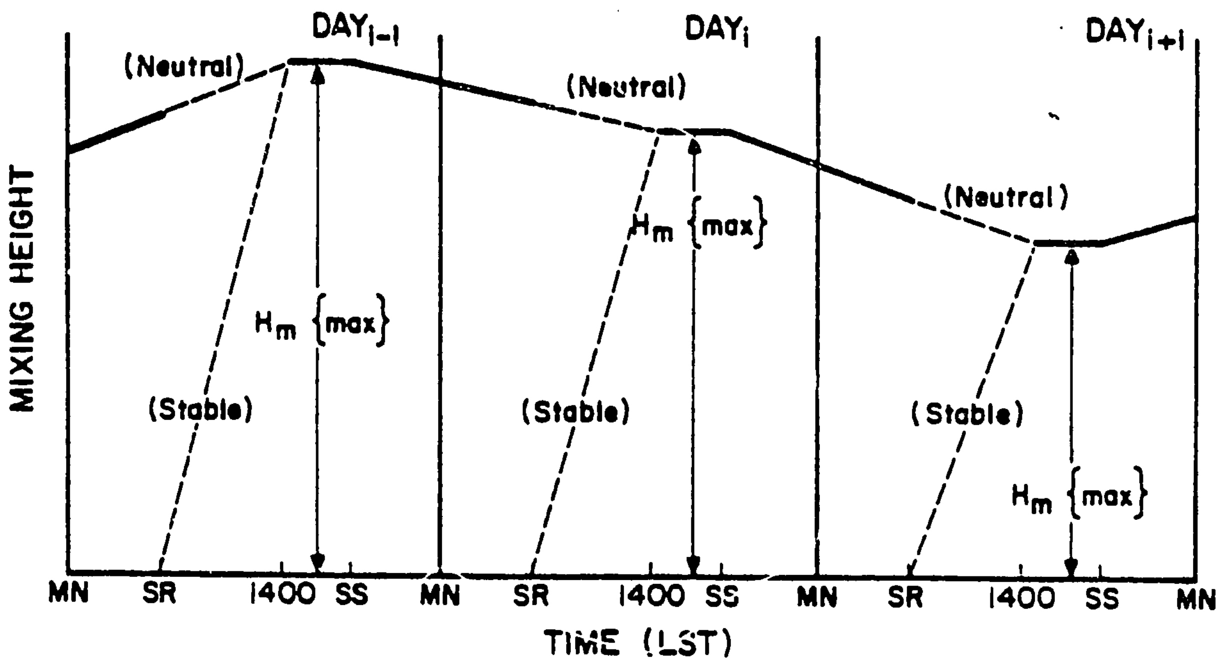



(a) Urban Mixing Heights




(b) Rural Mixing Heights

FIGURE A-4. Schematic illustration of (a) urban and (b) rural mixing height interpolation procedures.

where

$z_s$ = height above mean sea level of the base of the stack

$z\{X,Y\}$ = height above mean sea level of the point (X,Y)

It should be noted that, if the terrain height ($z\{X,Y\} - z_s$) exceeds h for a stack or H for a volume source (see Section A.4.2), the computer program prints an error message and terminates execution. Also, if the receptor elevation is less than the stack base elevation, the receptor elevation is set equal to the stack base elevation by the computer program. Figure A-5 illustrates the terrain-adjustment procedures used by the ISC Model.

c. <u>The Vertical Term for Large Particulates</u>. The dispersion of particulates or droplets with significant gravitational settling velocities differs from that of gaseous pollutants and small particulates in that the larger particulates are brought to the surface by the combined processes of atmospheric turbulence and gravitational settling. Additionally, gaseous pollutants and small particulates tend to be reflected from the surface, while larger particulates that come in contact with the surface may be completely or partically retained at the surface. The ISC Model Vertical Term for large particulates includes the effects of both gravitational settling and dry deposiion. Gravitational settling is assumed to result in a tilted plume with the plume axis inclined to the horizontal at an angle given by arctan ($V_s/\bar{u}$) where $V_s$ is the gravitational settling velocity. A user-specified fraction $\gamma$ of the material that reaches the ground surface by the combined processes of gravitational settling and atmospheric turbulence is assumed to be reflected from the surface. Figure A-6 illustrates the vertical concentration profiles for complete reflection from the surface ($\gamma$ equal to unity), 50-percent reflection from the surface ($\gamma$ equal to 0.5) and complete retention at the surface ($\gamma$ equal to zero).

For a given particulate source, the user must subdivide the total particulate emissions into N settling-velocity categories (the maximum value of N is 20). The ground-level concentration of particulates with settling velocity $V_{sn}$ is given by Equation (A-12) with the Vertical Term defined as (Dumbauld and Bjorklund, 1975).

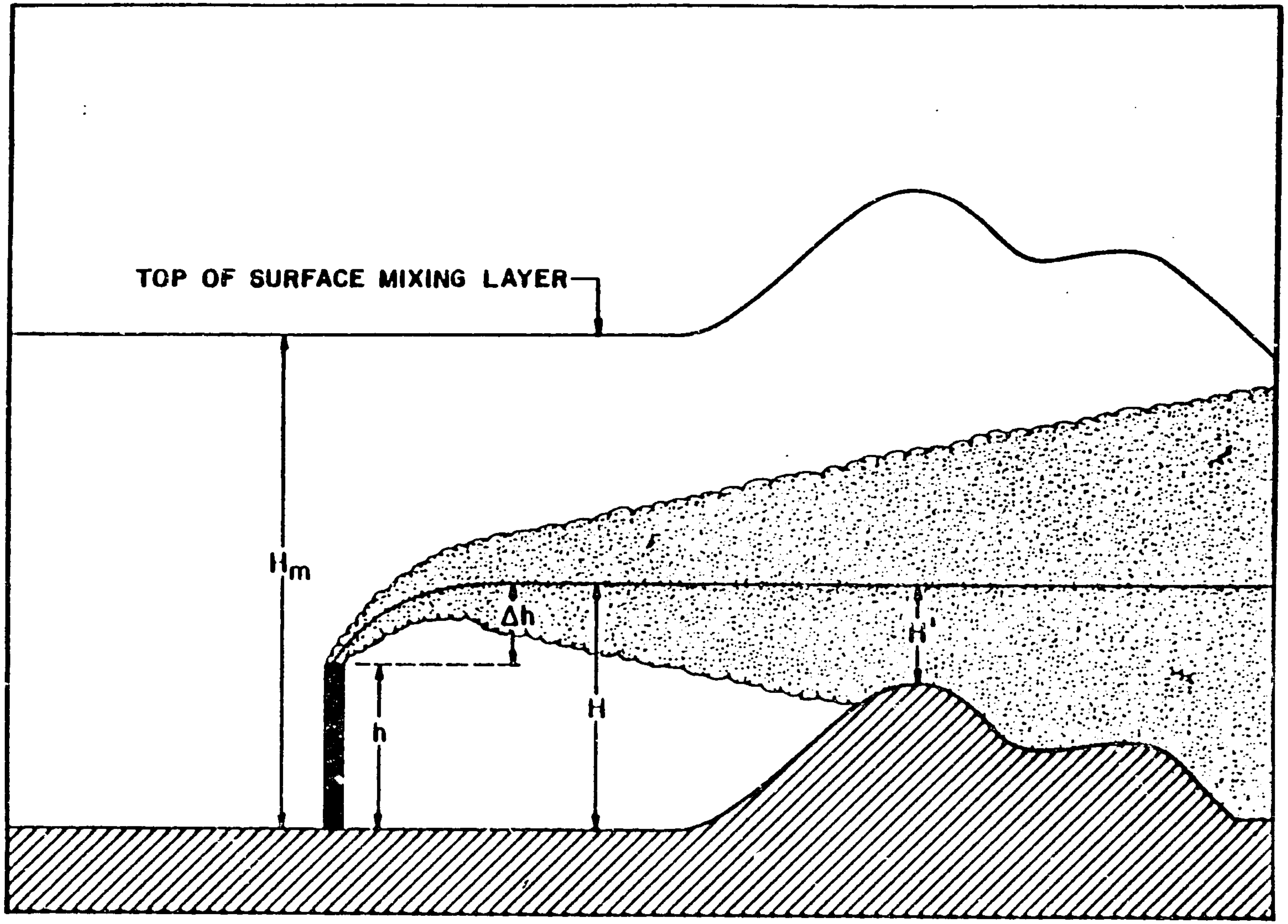



FIGURE A-5. Illustration of plume behavior in complex terrain assumed by the ISC Model.

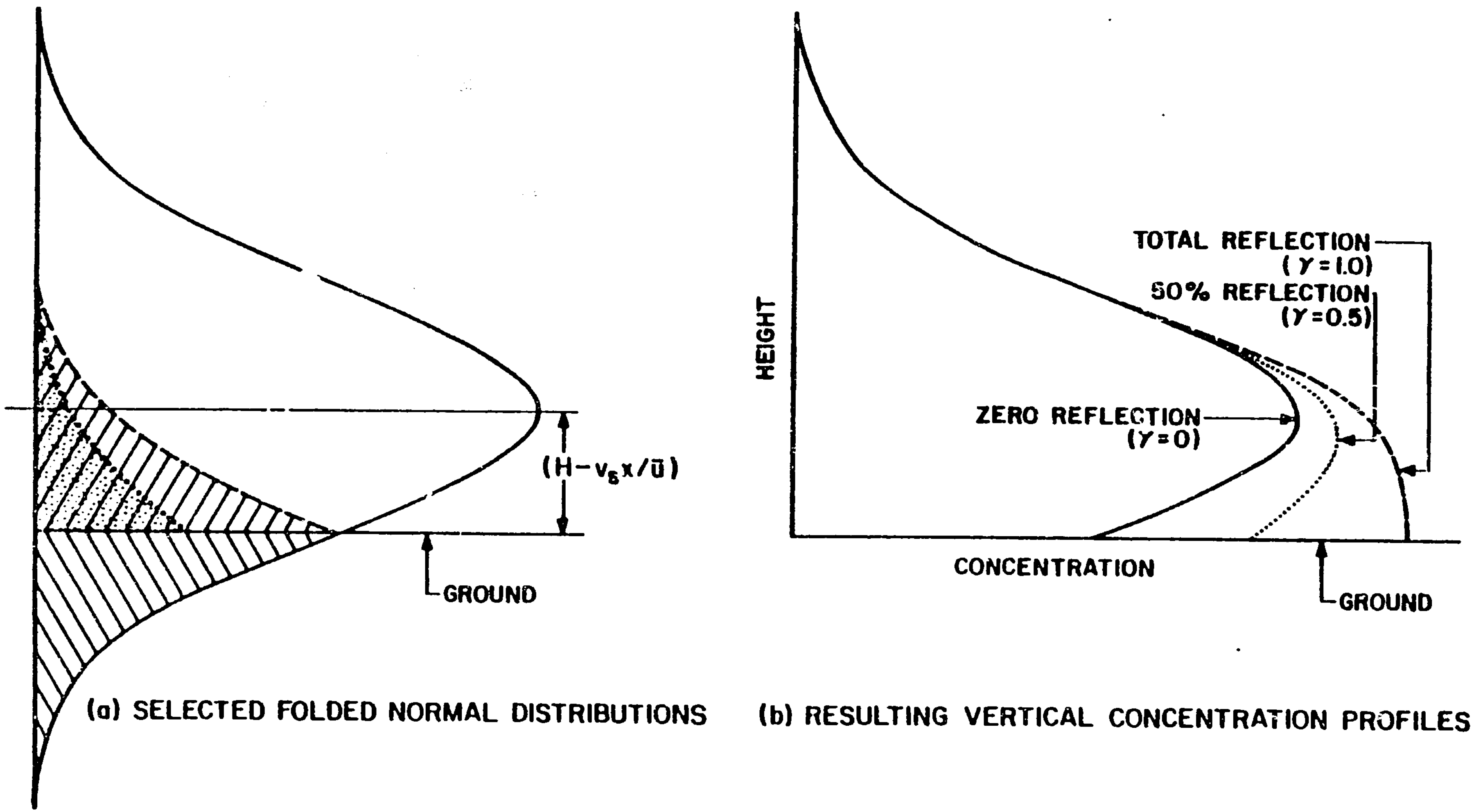



FIGURE A-6. **Illustration of vertical concentration profiles for reflection coefficients of 0, 0.5 and 1.0.**

$$\{\text{Vertical Term}\} = \frac{\phi_n}{2}\left\{\sum_{i=0}^{\infty}\left[\gamma_n^i \exp\left[-\frac{1}{2}\left(\frac{2iH_m - H + (V_{sn}x/\bar{u}\{h\})}{\sigma_z}\right)^2\right]\right.\right.$$

$$+ \gamma_n^{i+1} \exp\left[-\frac{1}{2}\left(\frac{2iH_m + H - (V_{sn}x/\bar{u}\{h\})}{\sigma_z}\right)^2\right]\Bigg]$$

$$+ \sum_{i=1}^{\infty}\left[\gamma_n^i \exp\left[-\frac{1}{2}\left(\frac{2iH_m + H - (V_{sn}x/\bar{u}\{h\})}{\sigma_z}\right)^2\right]\right.$$

$$\left.\left. + \gamma_n^{i-1} \exp\left[-\frac{1}{2}\left(\frac{2iH_m - H + (V_{sn}x/\bar{u}\{h\})}{\sigma_z}\right)^2\right]\right]\right\} \qquad \text{(A-40)}$$

where

$\phi_n$ = mass fraction of particulates in the $n^{th}$ settling-velocity category

$\gamma_n$ = reflection coefficient for particulates in the $n^{th}$ settling-velocity category (set equal to unity for complete reflection)

$V_{sn}$ = settling velocity of particulates in the $n^{th}$ settling-velocity category.

For convenience, $0^0$ is defined to be unity in Equation (A-40). The total concentration is computed by the program by summing over the N settling-velocity categories. The optional algorithm used to calculate dry deposition is discussed in Section A.4.3.

Use of Equation (A-40) requires a knowledge of both the particulate size distribution and the density of the particulates emitted by each source. The total particulate emissions for each source are subdivided by the user into a maximum of 20 categories and the gravitational settling velocity is calculated for the mass-mean diameter of each category. The mass-mean diameter is given by

$$\bar{d} = \left[\frac{d_2^3 + d_1^2 d_2 + d_1 d_2^2 + d_1^3}{4}\right]^{1/3} \qquad \text{(A-41)}$$

where $d_1$ and $d_2$ are the lower and upper bounds of the particle-size category. McDonald (1960) gives simple techniques for calculating the gravitational settling velocity for all sizes of particulates. For particulates with a density on the order of 1 gram per cubic centimeter and diameters less than about 80 micrometers, the settling velocity is given by

$$V_s = \frac{2\rho g r^2}{9\mu} \qquad \text{(A-42)}$$

where

$V_s$ = settling velocity ($cm \cdot sec^{-1}$)

$\rho$ = particle density ($gm \cdot cm^{-3}$)

$g$ = acceleration due to gravity ($980\ cm \cdot sec^{-2}$)

$r$ = particle radius (cm)

$\mu$ = absolute viscosity of air ($\mu \sim 1.83 \times 10^{-4}\ gm \cdot cm^{-1} \cdot sec^{-1}$)

It should be noted that the settling velocity calculated using Equation (A-42) must be converted by the user from centimeters per second to meters per second for use in the model calculations.

The reflection coefficient $\gamma_n$ can be estimated for each particle-size category using Figure A-7 and the settling velocity calculated for the mass-mean diameter. If it is desired to include the effects of gravitational settling in calculating ambient particulate concentrations while at the same time excluding the effects of deposition, $\gamma_n$ should be set equal to unity for all settling velocities. On the other hand, if it is desired to calculate maximum possible deposition, $\gamma_n$ should be set equal to zero for all settling velocities. The effects of dry deposition for gaseous pollutants may be estimated by settling velocity $V_{sn}$ equal to zero and the reflected coefficient $\gamma_n$ equal to the amount of material assumed to be reflected from the surface. For example, if 20 percent of a gaseous pollutant that reaches the surface is assumed to be retained at the surface by vegetation uptake or other mechanisms, $\gamma_n$ is equal to 0.8.

The derivation of Equation (A-40) assumes that the terrain is flat or gently rolling. Consequently, the gravitational settling and dry deposition options cannot be used for sources located in complex terrain without violating mass continuity. However, the effects of gravitational settling alone can be estimated for sources located in complex terrain by setting $\gamma_n$ equal to unity for each settling velocity category. This procedure will tend to overestimate ground-level concentrations, especially at the longer downwind distances, because it neglects the effects of dry deposition.

It should be noted that Equation (A-40) assumes that $\sigma_z$ is a continuous function of downwind distance. Also, Equation (A-40) does not simplify for $\sigma_z/H_m$ greater than 1.6 as does Equation (A-37). As shown by Table A-8, $\sigma_z$ for the very unstable A stability category attains a maximum value of 5,000 meters at 3.11 kilometers. Because Equation (A-40) requires that $\sigma_z$ be a continuous function of distance, the coefficients a and b given in Table A-8 for A stability and the 0.51 to 3.11-kilometer range are used by the ISC Model in calculations beyond 3.11 kilometers. Consequently, this introduces uncertainties in the results of the calculations beyond 3.11 kilometers for A stability.

### A.4.2 Area, Volume and Line Source Emissions

#### A.4.2.1 General

The area and volume sources options of the ISC Model are used to simulate the effects of emissions from a wide variety of industrial sources. In general, the ISC area source model is used to simulate the effects of fugitive emissions from sources such as storage piles and slag dumps. The ISC volume source model is used to simulate the effects of emissions from sources such as building roof monitors and line sources (for example, conveyor belts and rail lines).

#### A.4.2.2 The Short-Term Area Source Model

The ISC area source model is based on the equation for a finite crosswind line source. Individual area sources are required to have the same north-south and east-west dimensions. However, as shown by Figure A-8, the effects of an area source with an irregular shape can be simulated by dividing the area source into multiple squares that approximate the geometry of the area source. Note that the size of the individual area sources in Figure A-8 varies; the only requirement is that each area source must be square. The ground-level concentration at downwind distance x (measured from the downwind edge of the area source) and crosswind distance y is given by

$$\chi\{x,y\} = \frac{KQ_A\, x_o}{\sqrt{2\pi}\, \bar{u}\{h\}\, \sigma_z} \left\{\text{Vertical Term}\right\} \left\{\text{erf}\left(\frac{x_o'/2 + y}{\sqrt{2}\,\sigma_y}\right) + \text{erf}\left(\frac{x_o'/2 - y}{\sqrt{2}\,\sigma_y}\right)\right\} \left\{\text{Decay Term}\right\} \tag{A-43}$$

where

$Q_A$ = area source emission rate (mass per unit area per unit time)

$x_o$ = length of the side of the area source (m)

$x_o'$ = effective crosswind width = $2x_o/\sqrt{\pi}$

and the Vertical Term is given by Equation (A-37) or Equation (A-40) with the effective emission height H assigned by the user. In general, H should be set equal to the physical height of the source of fugitive emissions. For example, the emission height H of a slag dump is the physical height of the slag dump. A vertical virtual distance, given by $x_o$ in kilometers, is added to the actual downwind x for the $\sigma_z$ calculations. If a receptor is located within $x_o'/2$ plus 100 meters of the center of an area source, a warning message is printed and no concentrations are calculated for the source-receptor combination. However, program execution is not terminated.

It is recommended that, if the separation between an area source and a receptor is less than the side of the area source $x_o$, the area source be subdivided into smaller area sources. If the source-receptor separation is less than $x_o$, the ISC Model tends to overpredict the area source concentration. The degree of overprediction is a function of stability, the orientation of the receptor with respect to the area source and the mean wind direction. However, the degree of overprediction near the area source rarely exceeds about 30 percent.

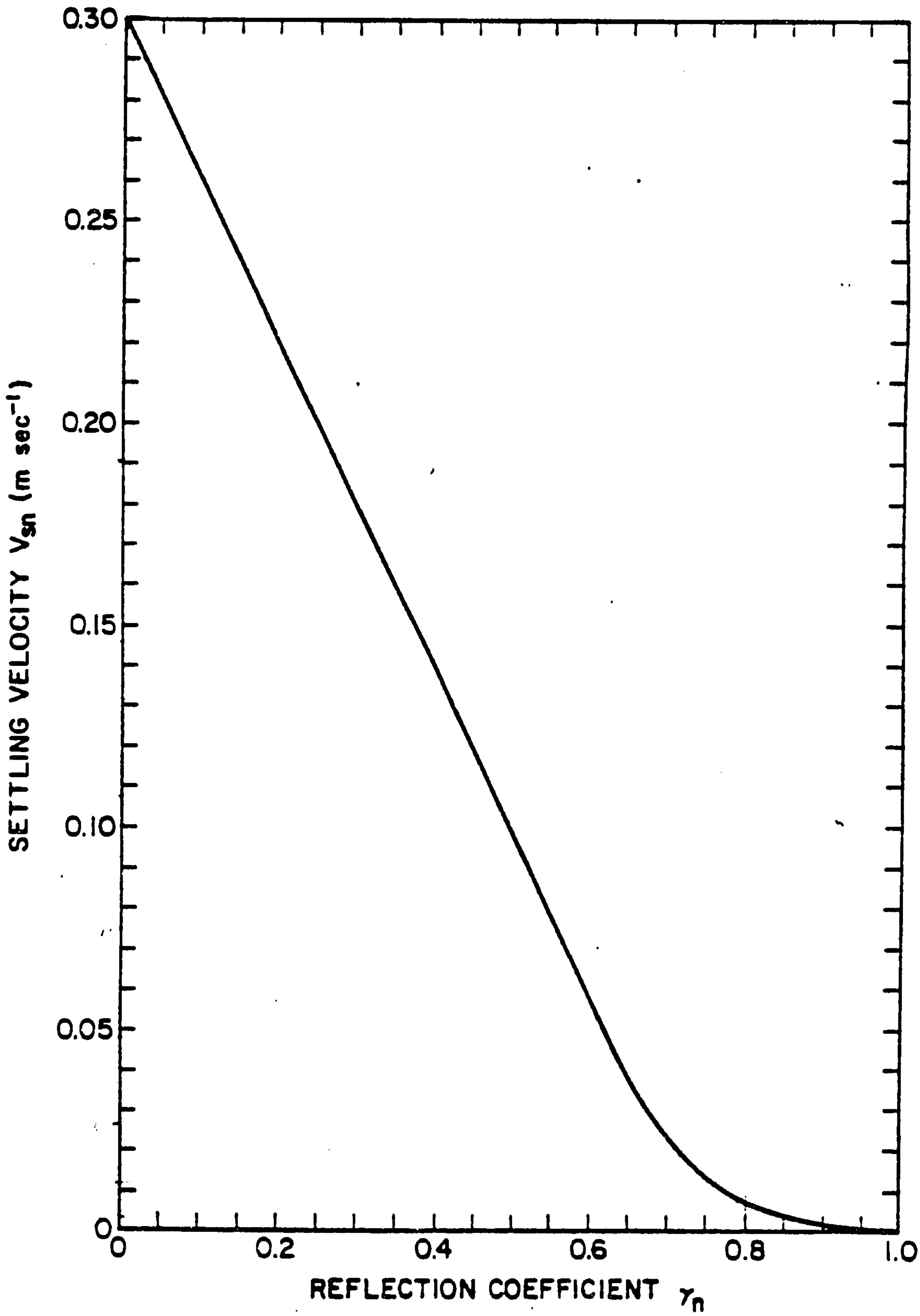



FIGURE A-7. Relationship between the gravitational settling velocity $V_{sn}$ and the reflection coefficient $\gamma_n$ suggested by Dumbauld, et al. (1976).

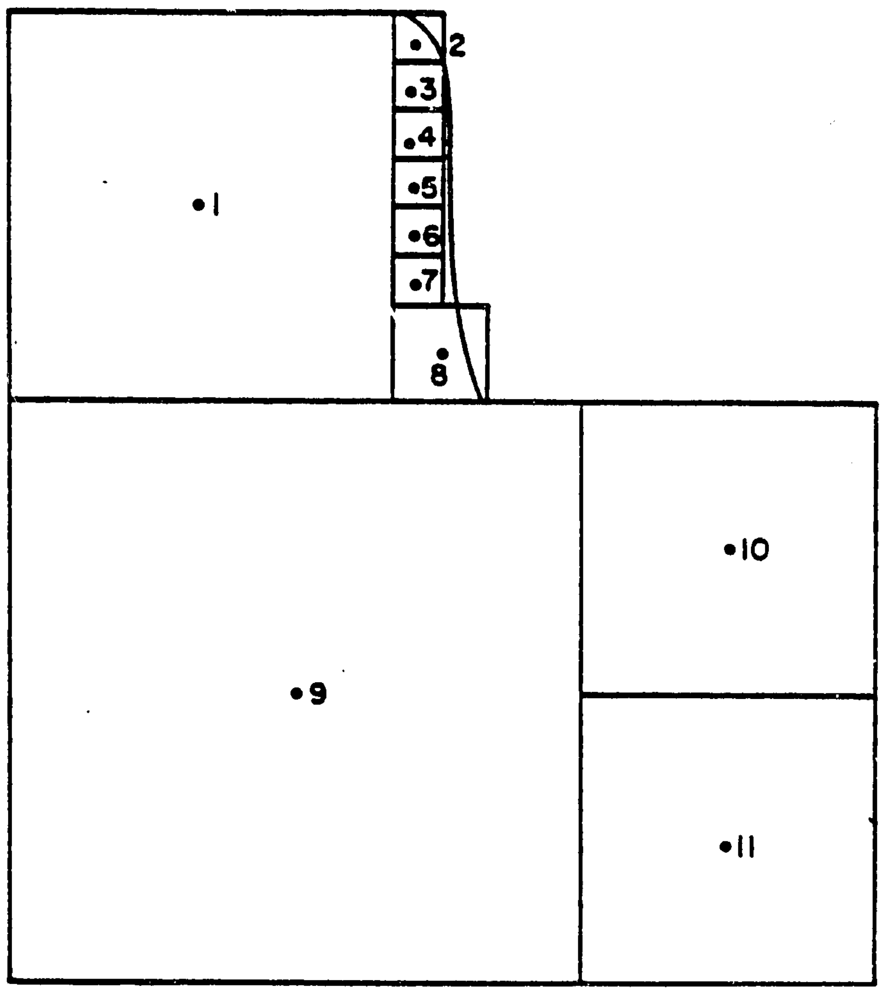



Figure A-8. Representation of an irregularly shaped area source by 11 square area sources.

### A.4.3 The ISC Short-Term Dry Deposition Model

#### A.4.3.1 General

The Industrial Source Complex short-term dry deposition model is based on the Dumbauld, et al. (1976) deposition model. The Dumbault, et al. model, which is an advanced version of the Cramer, et al. (1972) deposition model, assumes that a user-specified fraction $\gamma_n$ of the material that comes into contact with the ground surface by the combined processes of atmospheric turbulence and gravitational settling is reflected from the surface (see Section A.4.1.2.c) The reflection coefficient $\gamma_n$, which is a function of settling velocity and the ground surface for particulates and of the ground surface for gaseous pollutants, is analogous in purpose to the deposition velocity used in other deposition models. The Cramer et al. (1972) deposition model has closely matched ground-level deposition patterns for droplets with diameters above about 30 micrometers, while the more generalized Dumbauld, et al. (1976) deposition model has closely matched observed deposition patterns for both large and small droplets.

Section A.4.1.2.c discusses the selection of the reflection coefficient $\gamma_n$ as well as the computation of the gravitational settling velocity $V_{sn}$. The ISC dry deposition model should not be applied to sources located in complex terrain. Also, as noted in Section A.4.1.2.c, uncertainties in the deposition calcualtions are likely for the A stability category if deposition calculations are made at downwind distances greater than 3.11 kilometers. Deposition and ambient concentration calculations cannot be made in a single program execution. In an individual computer run, the ISC Model calculates either concentration (including the effects of gravitational settling and dry deposition) or dry deposition.

#### A.4.3.2 Stack and Volume Source Emissions

Deposition for particulates in the $n^{th}$ settling-velocity category or a gaseous pollutant with zero settling velocity $V_{sn}$ and a reflection coefficient $\gamma_n$ is given by

$$
\begin{aligned}
DFP_n\{x,y\} = {} & \frac{KQ_\tau (1-\gamma_n)\phi_n}{2\pi \sigma_y \sigma_z x} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-\psi\, x/\bar{u}\{h\}\right] \\
& \left\{\left[\bar{b}H + (1-\bar{b})\, V_{sn}\, x/\bar{u}\{h\}\right] \exp\left[-\frac{1}{2}\left(\frac{H - V_{sn}\, x/\bar{u}\{h\}}{\sigma_z}\right)^2\right]\right. \\
& + \sum_{i=1}^{\infty}\left[\gamma^{i-1}\left[\bar{b}\,(2iH_m - H) - (1-b)\, V_{sn}\, x/\bar{u}\{h\}\right]\right. \\
& \exp\left[-\frac{1}{2}\left(\frac{2iH_m - H + V_{sn} x/\bar{u}\{h\}}{\sigma_z}\right)^2\right] \\
& + \gamma^{i}\left[\bar{b}\left(2iH_m + H\right) + \left(1-\bar{b}\right) V_{sn} x/\bar{u}\{h\}\right] \\
& \left.\left.\exp\left[-\frac{1}{2}\left(\frac{2iH_m + H - V_{sn} x/\bar{u}\{h\}}{\sigma_z}\right)^2\right]\right]\right\}
\end{aligned}
\qquad \text{(A-44)}
$$

The parameter $Q_\tau$ is the total amount of material emitted during the time period $\tau$ for which the deposition calculation is made. For example, $Q_\tau$ is the total amount of material emitted during a 1-hour period if an hourly deposition is calculated. For time periods longer than an hour, the program sums the deposition calculated for each hour to obtain the total deposition. For convenience, $0^0$ is defined to be unity in Equation (A-44). The coefficient $\bar{b}$ is the average value of the exponent b for the interval between the source and the downwind distance x (see Table A-6).

A.4.3.3 Area Source Emissions

For area source emissions, the first line of Equation (A-44) is changed to the form

$$\mathrm{DEP}_n\{x,y\} = \frac{KQ_{A\tau}\, x_o\, (1 - \gamma_n)\, \phi_n}{\sqrt{2\pi}\, \sigma_z\, x} \left\{ \mathrm{erf}\left(\frac{x_o'/2 + y}{\sqrt{2}\, \sigma_y}\right) + \mathrm{erf}\left(\frac{x_o'/2 - y}{\sqrt{2}\, \sigma_y}\right) \right\} \exp\left[-\psi\, x/\bar{u}\{h\}\right] \qquad \text{(A-45)}$$

The parameter $Q_{A\tau}$ is the total mass per unit area emitted over the time period $\tau$ for which deposition is calculated.

GOVERNMENT OF JAMAICA

OLD HARBOUR PLANT

COAL CONVERSION STUDY

# ASSOCIATED ENVIRONMENTAL IMPACT ASSESSMENT

# ASH DISPOSAL SITE SELECTION

## TABLE OF CONTENTS

## 1.0 INTRODUCTION

In the Coal Feasibility Study (Phase I) of this project, conversion of the Old Harbour Station to coal-firing was determined to be technically and economically feasible. The existing plant consists of four oil-fired units with a total output rating of 222 MWe (Unit 1 = 30 MWe; Unit 2 = 60 MWe; Unit 3 = 66 MWe; Unit 4 = 66 MWe). Coal conversion for this facility consists of the addition of two new coal-fired boilers with a combined output rating of 132 MWe (66 MWe each). Once the new coal-fired boilers are in operation, oil-fired units 3 and 4 will be used as an emergency backup only. Oil fired units 1 and 2 will continue to operate normally.

Since the acreage required for ash disposal is not available on-site, for the purposes of this study, coal ash is assumed to be impounded off-site. The method of transport has been assumed to be by truck. Although sluicing or pneumatic conveying of the ash are alternatives to trucking, a detailed economic/engineering/environmental analysis should be conducted to determine if these alternatives are viable. This analysis will be included in the detailed design phase of this project.

As discussed in Appendix B of the Phase I report, the preferred method of ash disposal is sale for reuse (fill material, cement, bricks, etc.). Until firm arrangements can be made for the sale of the ash, landfilling appears to be the most feasible method of disposal. Landfilling will also allow for ash reclamation should a market for sale be developed in the future. An area of approximately 30 to 40 acres will be required to accommodate the disposed ash over the 22 year plant life.

## 2.0 PURPOSE

The purpose of this study is to identify and evaluate potential disposal sites for the flyash and bottom ash collected from the proposed new coal-fired boilers. The ash disposal site will be sized to accommodate an annual ash disposal rate of 41,000 metric tons from both units over a life of 22 years.

## 3.0 METHODOLOGY

The ash disposal site selection methodology consists of three distinct steps:

Step 1 - Regional screening

Step 2 - Site identification

Step 3 - Site evaluation and ranking

During each step, the Bechtel siting team met with concerned Jamaican environmental and regulatory agencies to inform each of the siting approach, preliminary findings and site evaluations. At each phase, input received from the agencies was incorporated to facilitate preparation of the siting report. A list of agencies contacted is included in Table 3-1.

### 3.1

Step 1 - Regional Screening

The first action taken under Step 1 involved delineation of the site area boundary. Examination of 1:50,000 and 1:25,000 scale topographic maps prepared by the Jamaican Government resulted in a determination that due to limited number of paved roads and rapidly rising terrain elevation to the north, the study area should be limited to the area encompased by a circle of radius ten miles centered at the existing Old Harbour plant site.

The next action taken under Step 1 involved the identification of avoidance areas on the base maps. The avoidance criteria used for this purpose included:

(1) Areas of known active faults

(2) Areas of known karst terrain potential

(3) Recharge zones of potable water supply aquifers

(4) Areas within 1,000 feet of wells used to produce water for human or animal consumption



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(5) Areas within 500 year floodplains

(6) Areas known to contain threatened or endangered species

(7) Known wildlife refuge, natural preserves, scientific study areas, unique ecological habitats

(8) Urban areas, traffic corridors, utility ROW's

(9) National and local parks, recreational areas and preserves

(10) Historical and archaeological sites

(11) Prime agricultural land

Based on data available through literature, the above avoidance criteria were used to delineate avoidance areas on the base maps. Jamaican regulatory/ environmental authorities were contacted during the week of May 29 to June 3 and informed of the avoidance area criteria and 10 mile radius area selection. This completed Step 1.

## 3.2 Step 2 - Site Identification

Step 2 involved two distinct phases:

(A) Identification of potential disposal site areas on the base maps

(B) Field reconnaisance of the potential sites

Following the identification of avoidance areas as outlined in Step 1, remaining land areas were then analyzed to identify potential disposal site areas. The identification of site areas was based on the following factors:

- Topography. Areas with rolling terrain and minimum slopes were considered desirable.
- Capacity. Areas capable of holding the designed capacity, with no major requirement for excavation, grading, or site preparation were considered suitable.

- Location. Areas should be close to a major access road, and at a reasonable distance from avoidance areas
- Drainage. Areas identified as requiring minimal efforts to control drainage were considered desirable.

The area required to dispose of 41,000 metric tons/year (two units) over a 22 year unit life was determined to be 30 to 40 acres. To allow additional room for the site area preparation, equipment storage, etc., a conservative estimate of 100 acres was used for the potential site area.

Following the examination of eligible areas, and taking the above factors into consideration, eleven potential sites were then identified and located on the base map. Due to the lack of paved roads and the quickly rising terrain, it was decided to locate as many sites as possible below road A-2.

To facilitate Step 3 - Site Evaluation, a study team comprised of four environmental/geotechnical specialists conducted a field investigation of the eleven sites identified above. During this investigation, several sites were reoriented and one new site not previously identified was added. Figure 1 shows the eleven sites evaluated in Step 3.

To assist the reader in Step 3, a site name has been given to each of the eleven sites. These names were determined arbitrarily by the siting team and are based on the nearest geographical feature (county, town, etc.).

| | | | |
|---|---|---|---|
| Site 1 | Kellys Pen | Site 6 | Church Pen |
| Site 2 | Longville Park | Site 7 | Spring Village |
| Site 3 | Occasion Town | Site 8 | Colebeck Castle |
| Site 4 | Willikins Estate | Site 9 | Palmyra |
| Site 5 | Lloyds Pen | Site 10 | Bodles Pen |
| | | Site 11 | Bushy Park |

Jamaican regulatory/environmental authorities were infomred of the eleven potential site areas and copies of a figure showing the potential sites was distributed.

### 3.3 Step 3 - Site Evaluation and Criteria

Criteria:

The eleven potential site areas were then evaluated based on their engineering and environmental characteristics. The environmental characteristics included sociological considerations.

The evaluation criteria included

A. Engineering Criteria: transportation, site preparation, drainage, geology.

B. Environmental Criteria: ecology, water resources, land use (including air quality and noise), aesthetics.

A more detailed discussion of the individual criteria follows.

#### 3.3.1 Engineering Criteria

The engineering criteria used to evaluate the identified site areas are described in the following paragraphs. Since site areas rather than specific locations were identified, evaluation criteria relating to site capacity and cover material availability were not included. These criteria require the identification of specific site locations.



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3.3.1.1 Transportation

The accessibility of the site area and its distance from the Old Harbour plant were considered in this criterion. Solid wastes were assumed to be transported by truck from Old Harbour plant to the disposal site.

The transportation distance is considered a major cost factor in the disposal operation. Depending on the site area location, capital investment and commitments to operating expenditure will vary greatly from one site area to another as trasnportation distance varies. In addition, transporting the waste may result in other secondary effects such as noise, traffic congestion, and air pollution.

The site areas were evaluated using the following rating system:

Site Area Characteristics

(A) Accessibility

| Criteria | Rating |
|---|---|
| Site is currently inaccessible, new roads are required | 1 |
| Site is currently accessible, roads must be upgraded, Route A-2 must be crossed | 2 |
| Site is currently accessible, roads must be upgraded, Route A-2 is not crossed | 3 |
| Site is currently accessible, roads are good, Route A-2 is not crossed | 4 |

(B) Distance from Site

| Criteria | Rating |
|---|---|
| (1) More than 3 miles | 1 |
| (2) Between 2 to 3 miles | 2 |
| (3) Between 1 to 2 miles | 3 |
| (4) Less than 1 mile | 4 |

3.3.1.2 Site Preparation

Prior to disposal, preparation of the site including clearing of vegetation, removal of structures, realignment of rights-of-way, removal of topsoil, and preparation of subsoil will be required. These preparation activities could constitute a major cost factor and could create other environmental effects.

The following rating scale was used to evaluate site areas:

| Site Area Characteristics | Rating |
|---|---|
| (1) Site is steeply sloped; over 75% of area is heavily forested with some structures on site | 1 |
| (2) Site requires significant amount of earthwork and other construction to establish suitable area for ash disposal; 25-75% forested | 2 |
| (3) Site requires some earthwork and other consideration to establish suitable area for ash disposal; less than 25% forested | 3 |
| (4) Site requires minimal work prior to ash disposal; minimal forested areas on site | 4 |

### 3.3.1.3 Drainage

This criterion evaluated identified potential site areas in accordance with estimated potential effort to manage drainage runoff at the site.

| Site Area Characteristics | | Rating |
|---|---|---|
| (1) | Over 50% of drainage basin is upstream of site; site area slopes over 10% with high erosion potential | 1 |
| (2) | Slopes moderate at 5-10% | 2 |
| (3) | Drainage basin is basically within the disposal site (minimum diversion required) | 3 |
| (4) | Site relatively flat | 4 |

### 3.3.1.4 Geology

The geological siting characteristics listed below were used to evaluate the ability of the subsurface materials to support the weight of the ash pile without slope failure or excessive settlement. In addition, the siting characteristics identified those subsurface conditions that affect the amount and rate of potential leachate movement leaving the ash pile in order that impacts on groundwater resources can be assessed.

| Site Area Characteristics | | Rating |
|---|---|---|
| (1) | Site underlain by limestone deposits with active karst or karst potential | 1 |
| (2) | Site underlain by permeable sand and is a groundwater recharge area | 2 |
| (3) | Site underlain by limestone or other rock without karst potential | 3 |
| (4) | Site underlain by relatively impervious soils | 4 |

### 3.3.2 Environmental Criteria

#### 3.3.2.1 ECOLOGY

A. Terrestrial Ecology

Since some terrestrial habitat will be lost during development of the ash disposal area, it is important to avoid areas that are ecologically valuable, either because of the vegetation or wildlife present. The terrestrial criteria listed below gives emphasis to protected species of wildlife and unique habitats or vegetative associations; further ecological diversity in terms of the interspersion of different habitat types is also recognized as an important consideration. The ratings for each site were derived from the following: (1) a visit to each site, (2) discussions with Miss Ann Haynes of the Natural Resource Conservation Department and Dr. Ivan Goodbody of the University of the West Indies, (3) review of topographic maps at scales of 1:12,500 and 1:50,000 and 1980 aerial photography at a scale of 1:50,000, and (4) Reference 1T. (See Section 4.2)

| Terrestrial Site Characteristics | Rating |
|---|---|
| (1) high potential for threatened or endangered species. Unique habitats (e.g., undisturbed forest) or significant wetlands are found onsite. | 1 |
| (2) endangered species or unique habitats are adjacent to the site, and/or the site contains a diversity of natural habitat types. | 2 |
| (3) site is moderately diverse in terms of both native and/or agricultural vegetation. | 3 |
| (4) site has little or no diversity of either native or agricultural vegetation. | 4 |

## B. Aquatic Ecology

Under this criterion, candidate sites were evaluated on the potential impact they will have on Old Harbour Bay, local aquaculture resources and adjacent streams if they are developed as an ash disposal area. Portland Bight, of which Old Harbour Bay is a part, is the most significant aquatic system in the area; it is important as a fishing resource and as habitat for a number of protected species. The aquaculture of tilapia is being undertaken in the area as an additional food source under the sponsorship of the Ministry of Agriculture; its importance is also reflected in the rating system set forth below.

Sources of information used in arriving at a rating for each site include onsite reconnaissance, review of both topographic maps (at scales of 1:12,500 and 1:50,000) and 1980 aerial photography (at a scale of 1:50,000), discussions with Roy MooYoung of the Inland Fishery Department and Miss Ann Haynes of the Natural Resource Conservation Department, and several publications (Refs. 1Aq, 3Aq, 4Aq, and 5Aq).

| Aquatic Site Characteristics | Rating |
|---|---|
| (1) protected species or important naturally-occurring commercial fisheries potentially found onsite or within one-half mile downstream (i.e., waters of Portland Bight); site is within one-half mile of the proposed Portland Ridge and Bight National Park. | 1 |
| (2) site is within one-half to one mile upstream from the above resources; aquaculture ponds either occur on or are planned for the site. | 2 |
| (3) site is greater than one mile upstream of resources listed in (1) or within one-half mile upstream of a pond; site is adjacent to a stream. | 3 |

| | Rating |
|---|---|
| (4) site is not directly drained by, nor is it adjacent to a stream or water body; there are no ponds within one mile downstream. | 4 |

The ecology rating is the sum of the terrestrial and aquatic ecology ratings.

### 3.3.2.2 LAND USE

The evaluation of this criterion is based on a reconnaissance of each site and the use of both topographic maps (at a scale of 1:12,500 and 1:50,000) and 1980 aerial photography (at a scale of 1:50,000). In terms of agricultural land use, it should be noted that lands farmed by the Ministry of Agriculture are rated lower than other farmland due to its probable importance in forwarding agriculture in the country. Unimproved pasture, or ruinate land, while being put to an agriculature use is given a higher rating since it has, compared with other agricultural land, a very low productivity.

Aquaculture ponds, which are, of course, a form of agriculture, are considered under the heading Aquatic Ecology. With regard to residences, it should be noted although a site may not be adjacent to a population center a number of houses may none-the-less be located near the site.

| Site Area Characteristics | Rating |
|---|---|
| (1) site is within one-half mile of a population center or is being farmed by the Ministry of Agriculture. | 1 |
| (2) site is between one-half and one mile of a population center, or is in active agriculture (i.e., cultivated or in improved pasture). | 2 |
| (3) site is between one-half and one mile of a population center or onsite land use includes both active agricultural land and unimproved pasture (i.e., ruinate). | 3 |
| (4) site is greater than one mile from a population center or the site is used as unimproved pasture (i.e., ruinate). | 4 |

### 3.3.2.3 WATER RESOURCES

The evaluation of the solid waste disposal facility effects on surface waters was primarily based on the presence of surface water bodies (i.e., streams, ponds, wetlands, impoundments, canals) on or in close proximity to the potential site area. The potential for reduction, disturbance, or contamination of these resources was also considered. The presence of groundwater resources at the site area was evaluated with respect to possible effects on aquifiers resulting from construction activities. In addition, the potential for impacting surface and groundwater quality and quantity was also evaluated.

| Site Area Characteristics | Rating |
|---|---|
| (1) site area is within the flood plains or in close proximity to a potential aquifer recharge area (0-1/2 mile). | 1 |
| (2) potential for large volume of drainage runoff to pass through the site; possible flood potential. | 2 |
| (3) potential for moderate volume of drainage runoff to pass through the site; minor flood potential. | 3 |
| (4) no surface water body identified on the site; flood potential is minimal. | 4 |

### 3.3.2.4 AESTHETICS

Under this criterion, candidate site areas were evaluated with respect to the degree of visual impact that they will have on the surrounding landscape and estimated number of viewers. Aesthetic resources are essentially the visual quality components of a given landscape unit as perceived by people.

The specific site characteristics used to rate each site are listed below. The actual analysis was based on a reconnaissance of each site, review of topographic maps (at scales of 1:12,500 and 1:50,000) and 1980 aerial photography (at a scale of 1:50,000), and Reference 1A.

| Aesthetics Site Characteristics | Rating |
|---|---|
| (1) adjacent land uses include residential, tourist, or commercial; site is within, or visible from, a recognized scenic viewshed and cannot be effectively screened. | 1 |
| (2) as above; in addition, site may border a 1st class road. However, it can be screened from view. | 2 |
| (3) site is not adjacent to, but is visible from, residential, tourist, or commercial land uses and can be effectively screened; site is within, or visible from, a recognized scenic viewshed, but can be effectively screened. | 3 |
| (4) site is adjacent to or within industrialized land uses or other highly disturbed classifications. | 4 |

## 4.0 RATING

The summary of the site selection evaluation is given in Table 4.1. For each of the two major evaluation criteria (Environmental and Engineering), an evaluation factor (EF) was determined. The basis for the EFs is discussed in Sections 4.1 and 4.2. The evaluation factor for each criteria is the sum of the products of the ratings (r) and the weighting factors (WF) for each of the various subcriteria used to evaluate the sites. The EF is indicative of the overall engineering and environmental worth of each site and is calculated as follows:

(A) $EF_1 = \sum_{i=1}^{i=n} R_i \times WF_i$

(B) $EF_2 = \sum_{i=1}^{i=n} R_i \times WF_i$

where $EF_1$ = Engineering Evaluation Factor

$EF_2$ = Environmental Evaluation Factor

i = subcriterion used in the evaluation

n = total number of subcriterion used

The ratings (R) indicate the relative magnitude of each criterion for each site. A rating of 1, 2, 3 or 4 can be given to each site for each criterion with four being the most desirable rating for each criterion.

The WF's indicate the relative significance of the various criteria. The more important parameters are given the highest value of weight in determining the ratings.

Based on Bechtel's experience with similar siting studies, the overall evaluation factor (OEF) for each site is best determined by allocating a criteria weighting (CW) of 60% to engineering and 40% to environmental. Accordingly, the overall evaluation factor for each site is determined by the formula:

$$OEF = CW_1 \times EF_1 + CW_2 \times EF_2$$

or

$$OEF = .6\ EF_1 + .4\ EF_2$$

4.1 Engineering Subcriteria

To review, the following engineering subcriteria were selected as significant in determining the engineering evaluation factor (EF):

A. Transportation

B. Site Preparation

C. Drainage

D. Geology

### 4.1.1 Transportation

(A) Accessibility

Site 1 is easily accessible from a paved road and was rated 4.

Sites 2, 3, 4, 5, 9 and 11 are currently accessible and south of A2. Access roads to each of these sites need improvement. All seven sites were rated 3.

Sites 6, 7, 8 and 10 were currently accessible but north of Route A2. Access roads to each of the 4 sites need improvement. All 4 of these sites were rated 2.

(B) Distance From Site

Site 1 is less than one mile from the site and was rated 4.

Sites 3 and 9 are less than 2 miles from the site and were rated 3.

Sites 2, 4 and 5 were less than 3 miles from the site and were rated 2.

The remaining sites were more than 3 miles from the site and were rated 1.

### 4.1.2 Site Preparation

The requirements for site preparation prior to ash disposal are based on good engineering practice and criteria developed using environmental considerations. For example, if pervious soil conditions and the potential for recharge to a ground water aquifer exists, a liner may be required to minimize the movement of leachate into the groundwater. Construction of the liner would increase the cost of site preparation.

The site preparation evaluation is based on two primary characteristics:

(1) vegetation - which determines the amount of clearing required, and

(2) topography and site layout - which determines the amount of earthwork and other construction required.

The evaluation of the sites to determine the amount and type of vegetative cover which would need to be removed during site preparation was based on field reconnaisance of each site and review of aerial photographs. In general, none of the sites have major forest cover with most of the vegetation consisting of scrub brush. Accordingly, the site ratings were developed primarily from a consideration of topography and site layout. One factor which led to a low rating for a number of sites was the potential need for a liner for sites located north of the Jamaica National Railway line. Although detailed field investigation, including borings, of specific sites would be needed to confirm the necessity for a liner, the potential that a liner would be required is included in establishing the ratings. Site 3 is the only site rated 4 due to the expected minimal amount of work required to develop the site. A rating of 3 was assigned to sites 1, 2 and 9, indicating a greater amount of earthwork, diversion of surface water and other construction activities are required. All other sites were rated 2 based on the site preparation requirements if a liner would need to be installed.

### 4.1.3 Drainage

All sites are located on the alluvial plain which is flanked north and west by limestone hills and on the south by the Caribbean Sea. The relief of the plain is small rising gradually from the sea to approximately Elevation 200 feet at the base of the limestone hills north of Colbeck. The plain is disected by several small streams (Bowers Gully and Krasers Gully) and generally dry gullies. Site 9 is crossed in its northeast corner by Krasers Gully and the other sites generally are crossed by small gullies or field drainage ditches which serve to remove surface water generated by intense precipitation. Studies performed by the Government of Jamaica (Preliminary Hazard Assessment Map) show the entire alluvial plain to be subject to flooding in lower areas due to intense precipitation and also subject to storm surge flooding up to Elevation +20 feet.

The ratings shown on Table 4-1 were established based on examination of topographic maps of the area and visual reconnaissance of each site. All sites were assigned a rating of 3 indicating similar minimal division of existing surface water flow paths may be required. This can be accomplished by a relatively minor amount of grading during site preparation or selection of a specific disposal location within the site area to avoid existing surface water flow paths. In addition the site grading will fill any local low areas to promote runoff from areas adjacent to the ash pile. It should be noted that a small area of Site 1 and about 40 percent of Site 4 are below the Elevation 20 contour. These areas within the site will either be avoided, diked or raised to protect against storm surge flooding.

#### 4.1.4 Geology

All ash disposal sites are located on the alluvial plain consisting of quaternary age deposits of gravel, sand and clay. Based on the avoidance criteria described in Section 3.1, sites were not located in areas of active faults, known karst (sinkhole) terrain or other areas of questionable soil support capability. Therefore all sites are similar and acceptable in their ability to support the weight of the ash pile without the potential for slope stability failure or excessive settlement of the ash materials.

The geologic assessment therefore concentrated on a determination of the characteristics that could impact the use of the ground water resources in the area.[1G] Primarily more favorable sites are located in areas where the subsurface materials have a low permeability in order to:

- Retard or prevent movement of potential leachate from the ash pile into usable aquifers.
- Reduce any contaminent by absorption or filtration, thus minimizing the rate at which they enter usable aquifers.

In addition, more favorable sites are located so ground water flow lines do not reach usable aquifers or that sufficient dilution to safe levels is reached before a water resource is reached.

The assessment of the geologic and hydrogeologic conditions and the ratings for the sites were derived from the following:

1. Study of obtained geologic literature
2. A visit to, and observation of, pertinent characteristics of each site

3. Discussions with individuals familiar with geologic and hydrogeologic conditions in Jamica.

4. Obtaining and review of unpublished information concerning geologic structure, subsurface conditions, water well locations and type, and ground water levels in the area of the sites.

As shown on Table 4-1, the sites were divided into two rating categories. Sites 2, 5, 6, 7, 8, 10 and 11 are located in the norther portion of the alluvial plain and considering the distribution and depth of existing water wells may be located over an aquifer recharge area for domestic and industrial water supply. These sites are therefore assigned a rating of 2. Sites 1, 3, 4 and 9 are located in areas reported to be underlain by relatively impervious soils and are down gradient with respect to ground water flow direction. These sites are therefore assigned a rating of 4.

Reference:

1G. Wright, R. M., Hydrogeological Criteria for Evaluating Solid-Waste Disposal Sites in Jamaica. The Journal of the Scientific Research Council of Jamaica; 1972.



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4.2 Environmental Subcriteria

The following environmental subcriteria were selected as significant in determining the environmental evaluation factor ($EF_2$):

A. Ecology

B. Land Use

C. Aesthetics

D. Water Resources

4.2.1 Ecology

A. Terrestrial

In general terms, the vegetation of the alluvial plains of the southern coast of Jamaica has been classified as cultivated areas and induced savanna, secondary communities, and thorn scrub (Ref. 1T). Within the first cateogry, sugar cane is the predominate crop in the Old Harbour area; induced savannas in the region consist of grass and guango trees (Samonea saman). Some of the areas designated below as improved pasture could be considered induced savannas; these areas are typically fenced. Secondary communities are those areas that have types of vegetation which develop after burning, catch cropping, and abandonment. This land is often referred to as ruinate (Ref. 1T). Some ruinate land in the area surveyed is heavily grazed and some only lightly grazed, giving rise to differences in ground cover. Typically, this land is not fenced. It is referred to as unimproved pasture in the discussions of the individual sites. Thorn scrub communities were not obsered on any of the sites under study.



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While there are no specific terrestrial studies of the Old Harbour area, observations and knowledge of experts indicate that there are no protected terrestrial species found there (Ref. 2T and 3T). The Jamaican crocodile, is considered under aquatic ecology.

As noted in Table 4-1, there is little difference in the rating given the various sites. In fact, only one site, Number 11 was rated 3; all others were given a rating of 4. While some minor differences exist between sites given a rating of 4, these were relatively small and would not greatly impact the standing of sites from an ecological point of view. It should be noted that terrestrial ecology was not viewed as a significant issue by those persons interviewed (Ref. 2T and 3T).

Site 11 is rated as 3 based on the fact that some diversity occurred on the site. Present on this site were areas of improved pasture, sugar cane, coconut trees, and some areas of tall grass.

Sites 1, 2 and 9 can be classified as unimproved pasture. Site 2 was not grazed to the same extent as Sites 1 and 9: thus the ground cover was not as sparse. Site 1 appeared to have some small marshy areas (the two observed were less than 1 acre each) and a few larger trees. Sites 1 and 9 each appear to nave a drainage ditch crossing them. As noted above, while some variation exists, the sites are none-the-less not very diverse.

Of the remaining sites, Numbers 4 and 7 consisted of 60 to 70 percent sugar cane and 30 to 40 percent pasture. In the case of site 4, the pasture appeared to be unimproved; while in the case of site 7, it appeared to be improved. Sites 3, 5, 6, 8, and 10 were devoted almost entirely to agricultural use, either for grazing or crops. Two of these sites, Number 6 and 10, are part of Ministry of Agriculture farms.

## References


1T Asprey, G. F. and R. G. Robbins. 1953. The Vegetation of Jamaica. Ecol. Monographs, Vol. 23: 359-412.

2T Miss Ann Haynes. NRCD. Personal communication. June 6, 1983.

3T Dr. Ivan Goodbody, Chairman, Zoology Department, University of the West Indies. Personal Communication. June 6, 1983.

## B. Aquatic Ecology

The Portland Bight area represents an important aquatic resource in Jamaica. Fishing in the area is important as is reflected by the fact that Old Harbour Bay is the largest fishing beach, in terms of the number of boats, in the country (Ref. 1Aq). It should be noted, however, that the most heavily fished areas of the bight are further south, as opposed to along the shore of Old Harbour Bay (Ref. 2Aq).

The open waters of the Portland Bight and the various bays and mangrove swamps surrounding it are also important habitats for a number of protected species. These include the Jamaican crocodile and West Indian manatee. A number of sea turtles currently recommended for protection, including the hawksbill, Kemps, Atlantic Ridley, and green have also been sighted, as has the Atlantic bottle-nosed dolphin (Ref. 3Aq). Crocodiles utilize the mangrove habitat lining Portland Bight (Ref. 4Aq), while the manatee, sea turtles, and dolphins forage in the open water; Galleon Harbour is especially important in this regard (Refs. 2Aq. and 3Aq.). Sea turtles also nest along some of the beaches of Portland Bight (Ref. 2Aq.). The importance of the area with respect to aquatic life in general is reflected in the fact that the Portland Ridge and Bight National Park is planned to encompass most coastal areas and nearly all waters within the region (Ref. 5Aq.). It should be noted that the proposed park boundary does not include lands or waters immediately offshore between the Alcan Bauxite Plant and the town of Old Harbour Bay.

A second important aquatic resource found in the area of study is aquaculture ponds. Tilapia, which is the species grown in local aquaculture projects, mature in 9 to 12 weeks; after this time, the ponds are drained, harvested, refilled, and restocked (Ref. 6Ag).

The distance of a proposed disposal site from the bay was used to aid in determining its relative rating. However, it should be noted that even though one site may be rated 1 for purposes of the present study, this does not mean that it is excluded from further consideration for development. Rather it signifies that it is less desirable than other higher rated sites in regard to aquatic ecology. If, in the final analysis, a site with a low aquatic rating is selected, possible further study and implementation of appropriate mitigation measures may be indicated.

Sites numbers 1, 2, 3 and 4 are all rated 1. Each of these sites is within one-half mile of either the bay or swampland bordering it. It should be noted that the points of measurement are those which give the shortest distance. If the actual disposal area were placed within the opposite corner of a site, it could fall further away from the bay by about another quarter-mile.

Sites 6, 9 and 10 are all rated 2. Sites 5 and 12 both appear (based on aerial photo interpretation) to have ponds on them which are conservatively assumed to be used for aquaculture. Site 11 is given a rating of 2 based on the fact that it is within one mile of Old Harbour Bay and the wetlands bordering it.

Sites 5, 8 and 11 are each given a rating of 3. Numbers 4 and 15 are each adjacent to a stream, while Site 8 is located within one-half mile upstream of a pond. Site 6 is rated 4 since there does not appear to be any significant waterbodies on or adjacent to it; there are no ponds within one mile downstream from its boundaries.

References

1Ag. Sahney, A.K. 1981. Sample Survey of the Fishing Industry In Jamaica. Ministry of Agriculture, Kingston, Jamaica.

2Ag. Miss Ann Haynes. NRCD. Personal Communication, June 6, 1983.

3Ag. Fairbairn, P. W. AND A. M. Haynes. No date. Jamaican Surveys of the West Indian Manatee (Trichechus manatus), Dolphin (Tursiops truncatus), Sea turtles (Families Cheloniidae and Dermochelydae), and Booby Terns (Family Laridae). NRCH. Kingston, Jamaica.

4AQ. Garrich, L. and C. Swaby. No date. The Jamaican Crocodile (Crocodylus acutus): Endangered Jamaican Animals Information Sheet Number One.

5AQ. Ministry of Finance and Planning. 19__. A National Physical Plan for Jamaica.

6AQ. Mr. Roy MooYoung, Inland Fisheries Department. Personal Communication. June 2, 1983 and letter dated June 9, 1983.

### 4.2.2 Land Use

Sites 1, 6, 7 and 10 are all given a rating of 1. For sites 6 and 10 this is based on the fact that both fall on agricultural land currently being farmed by the Ministry of Agriculture. Sites 1 and 7 are both within one-half mile of a population center; Spring Village and Old Harbour Bay, respectively.

Sites 3, 5, 8 and 11 have all been given a rating of 2. In each case these sites are currently used exclusively for agricultural purposes. In addition site 4 is between one-half and one mile from Church Pen.

Sites 4 and 9 are rated as 3. Site 4 is given this rating based on the fact that it is not totally devoted to productive agricultural use since about 30 to 40 percent of the land was judged to be unimproved pasture. Site 9 is between one-half and one mile from the town of Old Harbour and Old Harbour Bay. Site 2 was given a rating of 4. This site is not near any population centers, nor is it currently being used for agricultural purposes. Based on topographic maps this site was once used for sugar cane production; however, it is currently covered with cashaw and grasses. It appeared to be only lightly grazed; only a few goats were observed onsite and the grasses were not cropped back as was the case for sites 1 and 9.

4.2.3 Aesthetics

Only one site, Number 8, is rated 1. This rating is based on the fact that Colbeck Castle is located within about 1,500 feet (southeast) of the proposed site. Further, because the castle sits on raised ground, it is felt that the site could not be effectively screened. Colbeck Castle was built in the 17th century; and although it is not currently developed as a tourist attraction, it could be rated as a Category 1 or 2 (intensive use area and general recreational use area, respectively) in the future, if and when it is restored (Ref. 1A).

Potential disposal sites 1, 2, 6 and 10 are all rated 2. Site 2 is adjacent to Route B12, which is currently rated as a scenic highway (Ref. 1A). As noted in Reference 1A, care should be taken to prevent obstruction of the view from the road. The site is rated 2, as opposed to 1 since if the disposal area itself were placed away from the road and effectively screened with vegetation, it would tend to blend into the hillside located to the west of the site. Thus, the general view from the road would not be significantly impacted.

Sites 1, 6 and 10 are rated as 2 since they are adjacent to residential areas and/or 1st class highway. Site 6 is just north of Church Pen and Highway A2 and so is potentially visible to a large number of people. Site 10 is also immediately north of Highway A2. Site 1 while not near a major highway, is adjacent to some housing to the south and a section of the town of Old Harbour Bay to the north. Although these sites may initially be highly visible, a vegetative screen should be reasonably effective in lessening their visual impact.

All remaining sites (3, 4, 5, 7, 9 and 11) are classified as 3. It should be noted that there may be some scattered residences near these sites; however, they are not adjacent to towns or larger groups of houses. A vegetative screen should aid in lessening the visual impact of these sites.

## References

1A Ministry of Finance and Planning. 1979. A National Physical Plan for Jamaica. Parks, Recreation, and Conservation, pp. 93-109.



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4.2.4 Water Resources

As discussed in Section 4.1.3, all sites are located on the alluvial plain which is disected by small streams and dry gullies. Due to the slight relief, areas of the alluvial plain are subject to local flooding during periods of intense precipitation. The northern portion of the area (north of the Jamaica Railway Corporation trackage) is utilized by numerous wells to provide water for domestic and farming/industrial uses. The wells to the north are completed within the underlying limestone, while to the south the wells are completed in the alluvial sands and gravels.

The ratings shown on Table 4-1 were mainly based on information obtained from the Water Resources Department, supplemented by: (1) geologic literature; (2) topographic maps; (3) air photos of the area; and (4) a reconnaissance of the area. The ratings were derived by combining the potential effects of ash disposal on both the ground and surface water resources in the area.

A rating of 3 was assigned to Sites 1, 2, 3 and 9. These sites are located to the south and down-gradient of the portion of the alluvial plain used to supply groundwater. In addition, with the planned extent of site preparation, flooding potential can be minimized. Site 4 is assigned a rating of 2 due to the large portion of the site area that is below Elevation +20 feet and therefore is subject to storm surge flooding. The remainder of the sites are rated 1 due to their location over or in close proximity to the aquifer that supplies most of the groundwater in the Old Harbour area.

## 5.0 WEIGHTING FACTORS

### 5.1 Engineering

Of the four engineering subcriteria, transportation was considered to be the most significant and was assigned a weighting factor ($WF_i$) of .40. This was due primarily to the marginal road conditions and associated capital and operating costs as well as to a consideration of potential environmental impacts such as noise, dust, etc. Site preparation was given a $WF_i$ of .30 again due to the potentially high associated capital and operating costs and potential environmental impacts to ground water. Geology was given a $WF_i$ of .20, since most of the geologically significant areas were excluded in Step 1. Drainage was assigned a $WF_i$ of .10 since all sites were rated equivalent.

### 5.2 Environmental

Of the 4 environmental criteria, ecology was considered to be the most significant and assigned a $WF_i$ of .40. This resulted primarily from the concerns related to drainage/leachate impacts on the bay ecrosystem. Water resources was given a $WF_i$ of .30 since aquaculture and other water sources are considered valuable resources. Land Use was given a $WF_i$ of .20 since agricultural lands are considered a significant resource requiring protection. Aesthetics was given a $WF_i$ of .10.

## 6.0 RESULTS

Each of the 11 candidate sites was evaluated using the ratings described in Section 4.0. Then, engineering and environmental evaluation factors ($EF_1$ and $EF_2$) were determined using the weighting factors described in



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Section 5.0. Finally, the overall evaluation factor (OEF) was determined for each site using the formula:

$$OEF = .6EF_1 + .4EF_2$$

The sites were then normalized and ranked numerically in descending order. See Table 4-1. Based on this ranking, the three sites which appear to be best suited for ash disposal are:

1. Site No. 1 - Near Kelly's Pen
2. Site No. 9 - Near Palmyra
3. Site No. 3 - Near Occasion Town



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## SELECTED SITE DESCRIPTIONS

Kellys Pen (Site 1)

Advantages

The ash disposal site near Kellys Pen is south of Road A2 and is closest to the generating facility and easily accessible; thus minimizing the transportation costs and associated impacts such as truck noise and fugitive dust. The site is relatively flat with few trees. A liner is not expected to be required since the site is reported to be underlain by relatively impervious soils. Drainage and terrestrial ecology are not significant factors at any of the sites. The site is located to the south and down-gradient of ground water sources

Disadvantages

The site is located relatively close to a residential area. It is also the closest site to Old Harbour Bay; however, since it is not subject to flooding and is underlain by impervious soil, aquatic impacts are not anticipated.

Palmyra (Site 9)

Advantages

The ash disposal site near Palmyra is south of Road A2 within two miles of the generating facility resulting in low transportation costs and minimal associated environmental impacts. Access to the site needs some improvement but is generally good. The site is generally flat with few trees. Due to its location (south of the railroad), a liner is not anticipated since the site is reported to be underlain with relatively impervious soil. The site is down-gradient of ground water sources. Terrestrial ecology and drainage are not significant factors for any of the sites. The site is not used for agricultural purposes and it is 1-1½ miles from the closest population center.

Disadvantages

The site is relatively close to Old Harbour Bay and residential area; however, since the site is underlain by relatively impervious soils and is not subject to flood, aquatic impacts are not anticipated.

Occasion Town (Site 3)

Advantages

The ash disposal site near Occasion Town is within two miles of the generating facility south of Road A2 resulting in low transportation costs and associated environmental impacts. Access to the site needs some improvement but is generally good. The site is flat with few trees and will require the least amount of site preparation of all sites considered. No liner is anticipated since the site is reported to be underlain by relatively impervious soils. The site is located to the south and down-gradient of the ground water sources. Terrestrial ecology and drainage are not significant factors. The site is more than 2 miles from the closest population center.

Disadvantages

The site is currently being used for agriculture. In addition, the site is located with 1/2 mile of the bay; however, since the site is not subject to flooding and since it is reported to be underlain by impervious soils, aquatic impact is not anticipated.



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TABLE 3-1

JAMAICAN GOVERNMENTAL AGENCIES CONTACTED

1. Natural Resources Conservation Department - Ministry of Mining of Jamaica.

2. Environmental Control Division - Ministry of Health of Jamaica.

3. Inland Fishery Division - Department of Agriculture.

4. Geology Division - Ministry of Mining of Jamaica.

5. Water Resources Division - Ministry of Local Government



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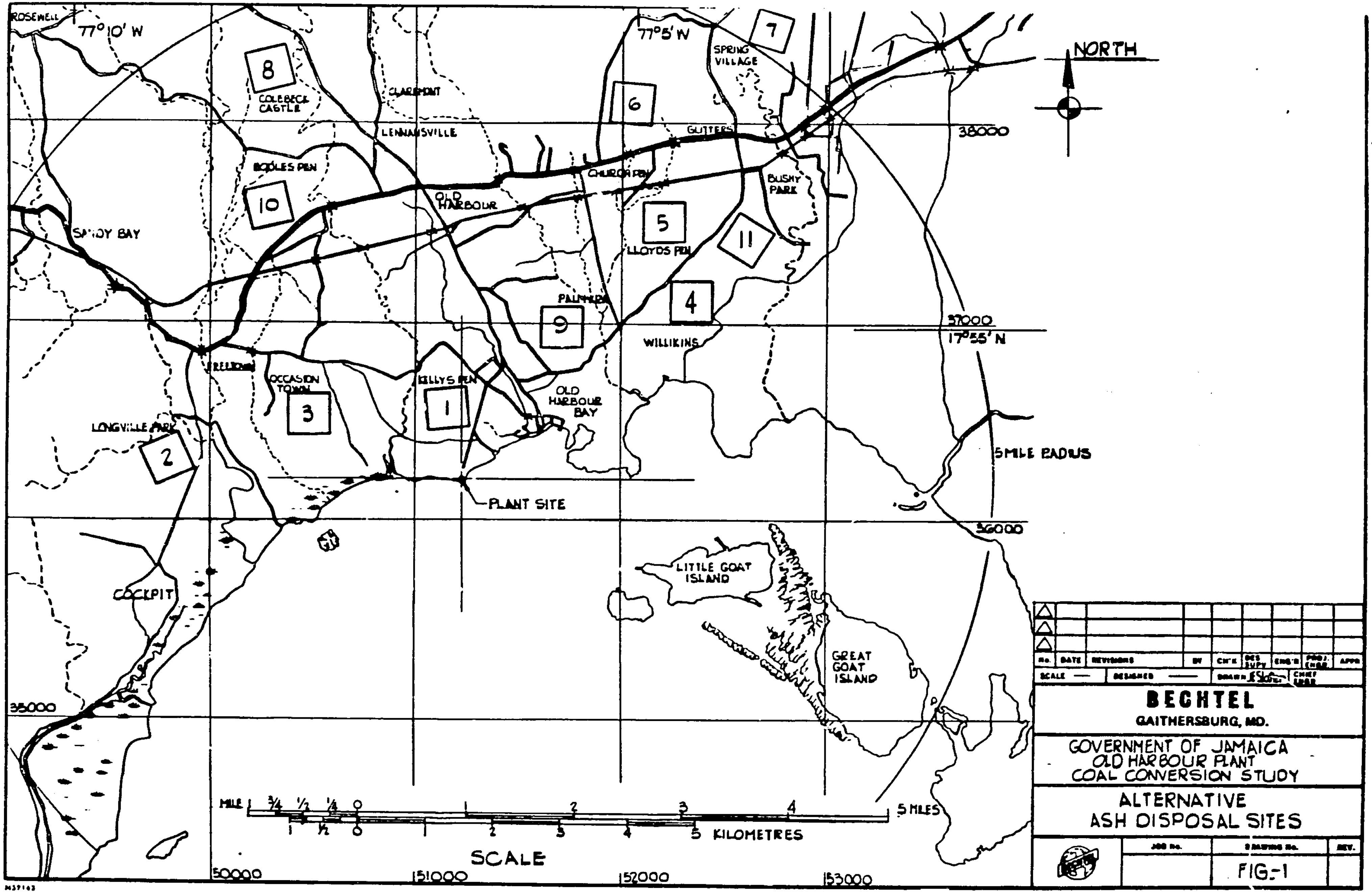
TABLE 4-1

SITE RATING EVALUATION

| CRITERIA | SITE 1 $R_i$ | x $WF_i$ | = $EF_i$ | SITE 2 $R_i$ | $WF_i$ | $EF_i$ | SITE 3 $R_i$ | $WF_i$ | $EF_i$ | SITE 4 $R_i$ | $WF_i$ | $EF_i$ | SITE 5 $R_i$ | $WF_i$ | $EF_i$ | SITE 6 $R_i$ | $WF_i$ | $EF_i$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (8)Transportation | 8 | .4 | 3.2 | 5 | .4 | 2 | 6 | .4 | 2.4 | 5 | .4 | .2 | 3 | .4 | 1.2 | 3 | .4 | 1.2 |
| ENGINEERING (4)Site Preparation | 3 | .3 | .9 | 3 | .3 | .9 | 4 | .3 | 1.2 | 2 | .3 | .6 | 2 | .3 | .6 | 2 | .3 | .6 |
| ENGINEERING Drainage(4) | 3 | .1 | .3 | 3 | .1 | .3 | 3 | .1 | .3 | 3 | .1 | .3 | 3 | .1 | .3 | 3 | .1 | .3 |
| ENGINEERING Geology (4) | 4 | .2 | .8 | 2 | .2 | .4 | 4 | .2 | .8 | 4 | .2 | .8 | 2 | .2 | .4 | 2 | .2 | .4 |
| ENGINEERING EF (max. possible=5.6) | | | 5.2 | | | 3.6 | | | 4.7 | | | 3.7 | | | 3.3 | | | 2.5 |
| ENVIRONMENTAL Ecology (8) | 5 | .4 | 2.0 | 5 | .4 | 2.0 | 5 | .4 | 2.0 | 5 | .4 | 2.0 | 7 | .4 | 2.8 | 6 | .4 | 2.4 |
| ENVIRONMENTAL Water (4) Resources | 3 | .3 | .9 | 3 | .3 | .9 | 3 | .3 | .9 | 2 | .3 | .6 | 1 | .3 | .3 | 1 | .3 | .3 |
| ENVIRONMENTAL Land Use (4) | 1 | .2 | .2 | 4 | .2 | .8 | 2 | .2 | .4 | 3 | .2 | .6 | 2 | .2 | .4 | 1 | .2 | .2 |
| ENVIRONMENTAL Aesthetics (4) | 2 | .1 | .2 | 2 | .1 | .2 | 3 | .1 | .3 | 3 | .1 | .3 | 3 | .1 | .3 | 2 | .1 | .2 |
| ENVIRONMENTAL $EF_2$ (max. possible = 5.6) | | | 3.3 | | | 3.9 | | | 3.6 | | | 3.5 | | | 3.8 | | | 3.1 |
| OEF (max. possible = 5.6 | | | 4.44 | | | 3.72 | | | 4.26 | | | 3.62 | | | 3.50 | | | 2.74 |
| Normalized (x 100/5.6) | | | (79) #1 | | | (66) #4 | | | (76) #3 | | | (65) | | | (62.5) | | | (49) |

| CRITERIA | SITE 7 $R_i$ | $WF_i$ | $EF_i$ | SITE 8 $R_i$ | $WF_i$ | $EF_i$ | SITE 9 $R_i$ | $WF_i$ | $EF_i$ | SITE 10 $R_i$ | $WF_i$ | $EF_i$ | SITE 11 $R_i$ | $WF_i$ | $EF_i$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (8)Transportation | 3 | .4 | 1.2 | 3 | .4 | 1.2 | 6 | .4 | 2.4 | 3 | .4 | 1.2 | 4 | .4 | 1.6 |
| ENGINEERING (4)Site Preparation | 2 | .3 | .6 | 2 | .3 | .6 | 3 | .3 | .9 | 2 | .3 | .6 | 2 | .3 | .6 |
| ENGINEERING Drainage(4) | 3 | .1 | .3 | 3 | .1 | .3 | 3 | .1 | .3 | 3 | .1 | .3 | 3 | .1 | .3 |
| ENGINEERING Geology (4) | 2 | .2 | .4 | 2 | .2 | .4 | 4 | .2 | .8 | 2 | .2 | .4 | 2 | .2 | .4 |
| ENGINEERING EF (max. possible=5.6) | | | 2.5 | | | 2.5 | | | 4.4 | | | 2.5 | | | 2.9 |
| ENVIRONMENTAL Ecology (8) | 8 | .4 | 3.2 | 7 | .4 | 2.8 | 6 | .4 | 2.4 | 6 | .4 | 2.4 | 6 | .4 | 2.4 |
| ENVIRONMENTAL Water (4) Resources | 1 | .3 | .3 | 1 | .3 | .3 | 3 | .3 | .9 | 1 | .3 | .3 | 1 | .3 | .3 |
| ENVIRONMENTAL Land Use (4) | 1 | .2 | .2 | 2 | .2 | .4 | 3 | .2 | .6 | 1 | .2 | .2 | 2 | .2 | .4 |
| ENVIRONMENTAL Aesthetics (4) | 3 | .1 | .3 | 1 | .1 | .1 | 3 | .1 | .3 | 2 | .1 | .2 | 3 | .1 | .3 |
| ENVIRONMENTAL $EF_2$ (max. possible = 5.6) | | | 4.0 | | | 3.6 | | | 4.2 | | | 3.1 | | | 3.4 |
| OEF (max. possible = 5.6 | | | 3.1 | | | 2.94 | | | 4.32 | | | 2.74 | | | 2.94 |
| Normalized (x 100/5.6) | | | (55) | | | (53) | | | (77) #2 | | | (49) | | | (55) |

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SCALE — DESIGNED —— DRAWN ESL CHIEF ENGR

**BECHTEL**
GAITHERSBURG, MD.

GOVERNMENT OF JAMAICA
OLD HARBOUR PLANT
COAL CONVERSION STUDY

ALTERNATIVE
ASH DISPOSAL SITES

JOB No. | DRAWING No. | REV.

FIG-1

GOVERNMENT OF JAMAICA

OLD HARBOUR PLANT

COAL CONVERSION STUDY

ASSOCIATED ENVIRONMENTAL IMPACT ASSESSMENT

WATER QUALITY

## TABLE OF CONTENTS

# 1.0 INTRODUCTION

## 1.1 SITE DESCRIPTION

The Old Harbour Station is located on the south side of the island on the coast adjoining Old Harbour Bay, approximately 25 miles west of Kingston. The geographical location of the station is latitude 17° 54'N and longitude 77° 7'W. Docking facilities are not available at the site. Secondary roads lead into the plant. Old Harbour, the nearest town, lies about 3.5 miles north of the station.

The site is relatively flat and is covered with light vegetation. The existing plant elevation varies from sea level at the shoreline to an elevation of 8.0 feet inland. The plant grade is approximately 7.0 feet above mean sea level (MSL).

## 1.2 PLANT DESCRIPTION

In the Coal Feasibility Study (Phase I) of this project, conversion of the Old Harbour Station to coal firing was determined to be technically and economically feasible. The existing plant consists of four oil-fired units with a total output rating of 220 MWe (Unit 1 = 30 MWe; Unit 2 = 60 MWe; Unit 3 = 66 MWe; Unit 4 = 66 MWe). Coal conversion for this facility consists of the addition of two new coal-fired boilers with a combined output rating of 132 MWe (66 MWe each). Once the new coal-fired units are operational, oil-fired units 3 and 4 (132 MWe) will be used for emergency backup only. Oil-fired units 1 and 2 (90 MWe) will continue to operate normally.

The purpose of this study is to evaluate potential water quality impacts resulting from construction and operation of the new coal units.



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## 2.0 PLANT WASTEWATER STREAMS

### 2.1 CONSTRUCTION - INCREMENTAL WATER AND WASTEWATER STREAMS

#### 2.1.1 Construction Water Use Requirements

All water required during construction of the new coal units will be supplied from existing wells. The amount of water required during construction is expected to be small.

#### 2.1.2 Construction Wastewater Streams

The coal pile runoff basin will be constructed early and will be utilized to collect runoff during grading, excavation and construction for settling of suspended solids before discharge to the harbor through the existing discharge canal. In addition, wastewater from dewatering operations will be directed to the coal pile runoff basin for settling of suspended solids.

### 2.2 OPERATION - INCREMENTAL WATER AND WASTEWATER STREAMS

#### 2.2.1 Operational Water Use

Clean plant makeup water will continue to be supplied from existing wells and the amount of well water required will be comparable to that required by the existing Oil Units 3 and 4.

#### 2.2.2 Operational Wastewater Discharge

The conversion of Units 3 and 4 from oil to coal will create only one new waste stream - coal pile runoff. All other plant waste streams: water streatment wastes, boiler blowdown, plant floor drains and neutralized boiler cleaning wastes, will be of comparable quantity and quality to the waste streams from Oil Units 3 and 4 and will continue to be discharged with the once through cooling water, maybe the existing discharge canal. Plant runoff from all other areas of the site except the coal pile will continue to be by natural drainage. Ash from the new coal units will be disposed of off-site. Coal pile runoff will be collected and treated before discharge to meet EPA Steam Electric Power Effluent Guidelines for coal pile runoff. The coal pile runoff basin will be designed to hold the design storm (10 year, 24 hour). Coal pile runoff will be collected in a lined basin, neutralized to pH 6-9, and held in the basin until the suspended solids have settled to at least 50 mg/l. The basin will be lined to prohibit untreated water from escaping from the basin and entering the surrounding soil and/or groundwater. Although coal pile runoff can be a large quantity of water (800,000 gallons for the design storm), it will be held in the basin and discharged gradually to minimize the impacts in the discharge area. Basin discharge pumps are designed for a 50 gpm pumping rate and pump the basin effluent to the bay as shown in Figure 1. During runoff retention in the basin, suspended solids in the water will settle to the bottom of the basin. The basin floor will be cleaned periodically and collected solids will be disposed of offsite. The estimated quality of typical coal pile run-off before and after treatment is given in Table 1.



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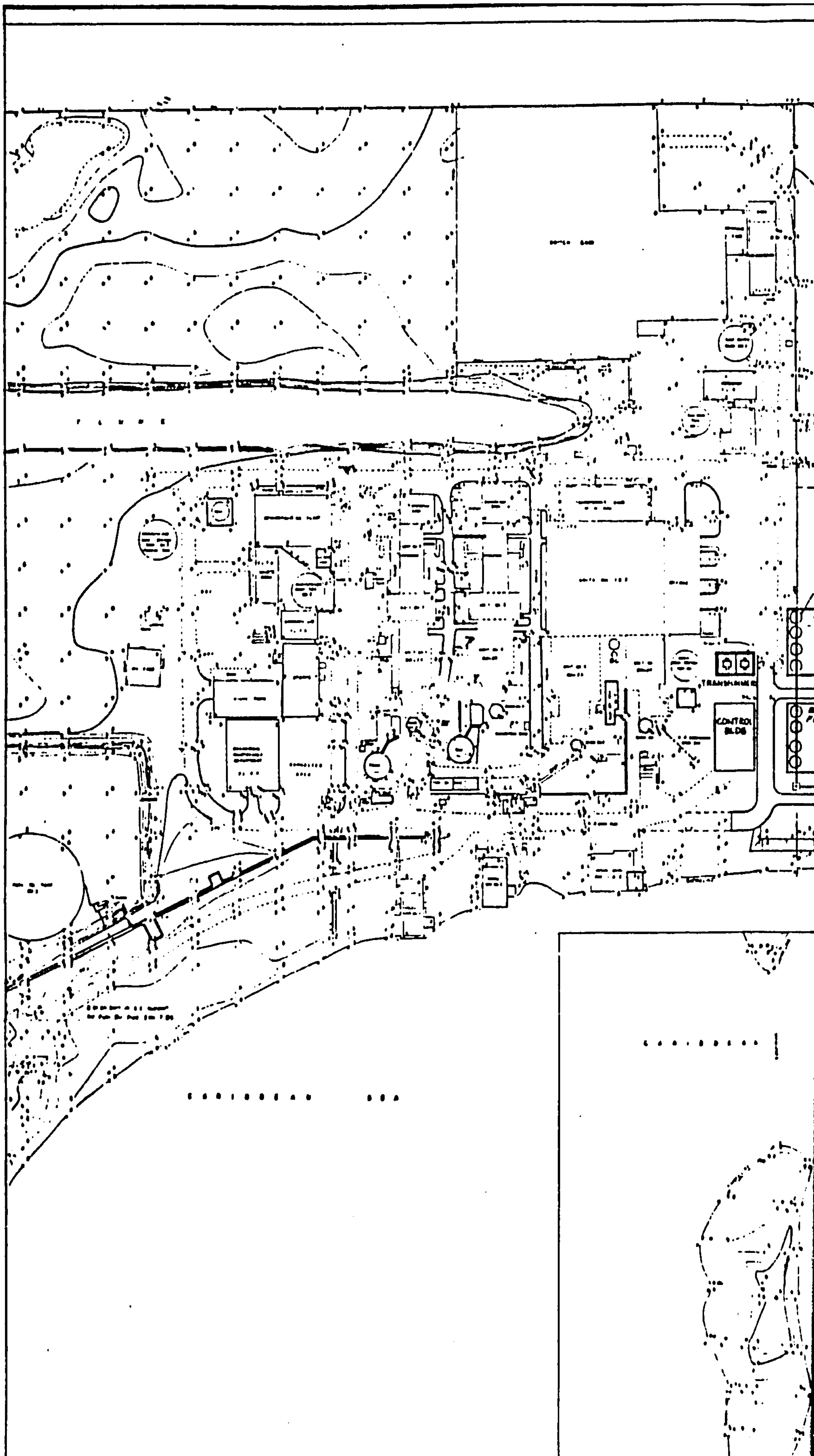
TABLE 1

TYPICAL COAL PILE RUNOFF

| Parameter | Concentration (mg/l) Before Treatment* EPA median | Before Treatment* Range | After Treatment** EPA median |
|---|---|---|---|
| total dissolved solids | 5800 | 700-44000 | 5800 |
| total suspended solids | 610 | 20-3300 | <50 |
| total hardness(CaCO3) | 1109 | 130-1850 | 1431 |
| alkalinity (CaCO3) | 14 | 15-80 | 150 |
| acidity (CaCO3) | 10 | 10-27800 | 0.1 |
| copper | 1.8 | 1.6-3.9 | 0.9 |
| sodium | 1260 | 160-1260 | 1260 |
| zinc | 1.6 | 0.06-23.0 | 0.8 |
| aluminum (total) | 1200 | 825-1200 | 15 |
| aluminum (dissolved) | 1200 | - | 0.76 |
| sulfate | 5231 | 130-20000 | 5231 |
| phosphorus | 0.7 | 0.2-1.2 | 0.7 |
| iron | 0.9 | 0.4-2.0 | 0.45 |
| chloride | 139 | 20-480 | 139 |
| nitrate | 1.8 | 0.3-2.3 | 1.8 |
| ammonia | 0.35 | 0.35-1.8 | 0.35 |
| BOD | 3 | 3-10 | 3 |
| COD | 1000 | 100-1000 | 500 |
| turbidity (JTU) | 8 | 6-605 | 0.7 |
| pH | 3 | 2.8-7.8 | 7 |

*Sources: (1) Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for Steam Electric Powerplants, EPA 440-1-73/029, March 1974.
(2) Steam Electric Power Generating, EPA 440/1-74-029a.
(3) "Coal pile environmental impact problems", POLLUTION ENGINEERING, July 1981, pages 35-36.

**Treatment: Lime neutralization and sedimentation.


CONTROL BLDG

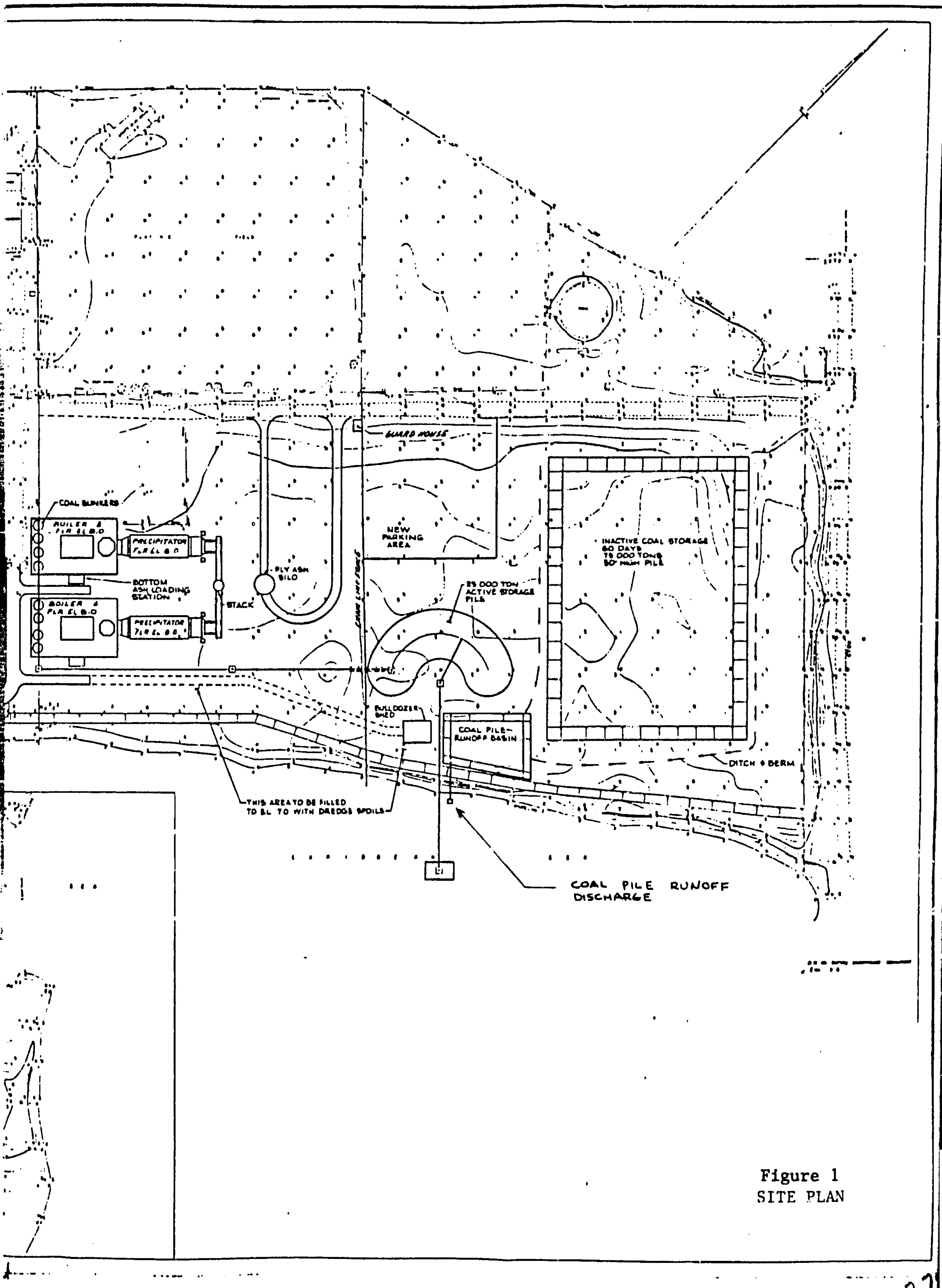



Figure 1
SITE PLAN

## 3.0 WATER QUALITY IMPACTS

Potential water quality impacts are associated with both construction and operation phases of the coal conversion of Old Harbour Station. Construction impacts are generally temporary in nature, lasting only during the construction period; operation impacts, however, can be long-term lasting throughout the lifetime of the facility.

### 3.1 CONSTRUCTION

Potential sources of impact to the aquatic resources of Old Harbour Bay during coal conversion are runoff from disturbed areas and dewatering of certain deep foundations. These impacts are not expected to be significant, given the relatively short duration of the construction period and the lack of extensive and widespread earthmoving required for the conversion. Runoff could be expected to carry both leached nutrients and suspended sediment. Water derived from dewatering activities is traditionally relatively free of sediments, however, it could contain dissolved nutrients. As noted in Section 2.1, a basin will be constructed into which site runoff and water from dewatering will be directed before it is released into the bay. As a result, much of the sediment in the runoff will settle out, thus decreasing loading in the basin effluent. Nutrients leached from disturbed soils usually consist of nitrogen and phosphorous forms which are capable of stimulating enrichment of the receiving water body. The amount of both sediment and nutrients reaching Old Harbour Bay will depend largely upon retention time in the sedimentation basin. It should be noted that effluent released from the sediment retention basin will be intermittent, varying largely with the amount of precipitation, thus enrichment, would largely be a temporary phenomenon. While site runoff effects should be small compared to those of dredging, the discussion presented in the Report On The Impacts of Dredging to Old Harbour Bay are generally applicable.

## 3.2 OPERATION

Coal pile runoff is considered the major source of potential impact during facility operation. Of those constituents of coal pile runoff which are listed in Table 1, only copper and zinc are released at levels (prior to mixing) which could potentially be harmful to aquatic life. These are discussed separately below. There are, however, a number of factors that should act to mitigate any significant adverse impacts.

As noted in Section 2.2, after the runoff is collected and treated it will be released at a rate of 50 gpm. The rate is, of course, quite small when compared to the receiving body, Old Harbour Bay. In connection with the discharge, it should be noted that it will be intermittent in nature. During the dry season little or no coal pile runoff will enter the bay. During the rainy season, however, the discharge will occur as often as is necessary to maintain storage capacity in the treatment basin. Because of the intermittent nature of the discharge, it is unlikely any chronic, or long term, impacts to acquatic biota will occur.

When discharge water reaches the waters of Old Harbour Bay they will, of course, mix with them. This mixing should occur within a reasonably confined area and result in the dilution of the constituents of the coal pile runoff to levels that are not harmful to aquatic life. The number of dilutions needed for the chemical elements of concern are discussed below.

The United States Environmental Protection Agency (U.S.EPA) has established aquatic life criteria for a number of trace elements and chemicals, including copper and zinc (Refs. 1 and 2). The criterion for copper with regard to the protection of saltwater aquatic life is 0.004 mg/l as a 24-hour average; the concentration should not exceed 0.023 mg/l at any time (Ref. 1). Considering



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that the level in the discharge is estimated as 0.1 mg/l, about 8 dilutions or less would be needed to bring the levels of copper to the U.S. EPA recommended level that should not be exceeded at any time and about 5 dilutions to the 24-hour average. While 8 dilutions could be excessive under some circumstances, for example, large discharges to small bodies of water, this is not the case at present since considering a discharge rate of 50 gpm, only 350 gpm of water would be needed to reach 8 dilutions. Thus, the mixing zone can be expected to be relatively small.

With regard to zinc, the U.S. EPA has established saltwater aquatic life criteria which state that total recoverable zinc should not exceed 0.058 mg/l as a 24-hour average and 0.17 mg/l at anytime (Ref. 2). Considering that the level of zinc is estimated as 0.8 mg/l in the coal pile runoff, dilution factors of about 4 and 3 would be required, respectively. These factors are well within the 8 dilutions for copper discussed above.

No information is available on the makeup of the aquatic community in the immediate vicinity of the proposed discharge; therefore, the listing of important commercial species caught on the south shelf of Jamaica (Table 2, Ref. 3) was compared with experimental data on copper and zinc toxicity compiled by the U.S. EPA (Refs. 1 and 2). It should be noted that scientific nomenclature is not used in Reference 3; thus, direct comparisons are not possible. However, comparisons can be made between related forms.

Table 2 Aq. Important commercial species of the southern shelf of Jamaica. (From Ref. 3)

| Species | Pounds |
|---|---|
| Herring Sprat | 1,276,650 |
| Snapper | 1,151,951 |
| Parrot | 954,627 |
| Grunt | 648,224 |
| Jack Fish | 380,008 |
| Lobster | 310,193 |
| Goat Fish | 291,462 |
| King and Wahoo | 129,585 |
| Mullet | 93,253 |
| Grupper and Hines | 89,468 |
| Turtle | 62,228 |
| Tuna and Bonito | 59,679 |
| Trigger | 56,376 |
| Mackerel | 56,367 |
| Gogglf Eye | 42,651 |
| Shrimp | 21,383 |
| Dolphin | 2,578 |
| Other | 1,344,672 |

Copper has been found to be toxic (96-hour LC50) to American lobster (Homarus americanus) larvae and adults at levels of 0.048 and 0.10 mg/l respectively; the 96-hour LC50 for brown shrimp (Crangon crangon) larvae is 0.33 mg/l (Ref. 1). With respect to zinc, the 96-hour LC50 value for American lobster larvae is 0.175 mg/l (Ref. 2). These values (for both copper and zinc) would be greater than those found outside the 8 dilution mixing zone discussed above, thus lobster and shrimp would be unlikely to be significantly effected by coal pile runoff.

## 5.0 CONCLUSION

The activities associated with construction and operation of the new coal units are not expected to produce significant changes in water quality for the following reasons:

1. Oil units 3 and 4 will not normally be operated;
2. The construction of the new coal units will have minimal disruptive effects on the site, since most of the areas involved were previously distrubed during construction of the oil units;
3. During construction, runoff and dewatering streams will be routed to a lined basin for sedimentation prior to discharge;
4. The only new wastewater stream during operation will be coal pile runoff which will be directed to a lined basin for sedimentation and pH adjustment prior to discharge;
5. The wastewater discharged from the basin will be intermittent;
6. The mixing zone will be relatively small.

References


1. United States Environmental Protection Agency. 1980. Ambient Water Quality Criteria for Copper. NTIS No. PB 81-117475. Washington, D.C.
2. United States Environmental Protection Agency. 1980. Ambient Water Quality Criteria for Zinc. NTIS No. PBS 81-117897. Washington, D.C.
3. Sahney, A.F. 1982. Simple Survey of the Fishing Industry in Jamaica - 1981. Ministry of Agriculture. Kingston, Jamaica.




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# JAMAICA COAL CONVERSION STUDY

## PORT DREDGING IMPACTS
## ANALYSIS: I

Submitted to

Bechtel Power Corporation
Gaithersburg, Maryland

Submitted by

The Traverse Group, Inc.
2480 Gale Road
Ann Arbor, Michigan 48105

July 30, 1983

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# I. INTRODUCTION

This study examines the physical and environmental aspects of dredging activities related to potential coal deliveries at Old Harbour, Jamaica. The dredging activities would be carried out in connection with the potential construction of two 66 MW coal fired steam electric boilers at the Jamaica Public Service (JPS) Old Harbour site. The project would allow two oil fired boilers to be retired to standby status. The study of the fuel conversion feasibility is being conducted by Bechtel Power Corporation of Gaithersburg, Maryland, under contract to the Jamaica Public Service Company, Ltd. The Traverse Group, Inc. (TGI) is examining the dredging segment of the feasibility project, under subcontract to Bechtel. Delivery of coal would require dredging of an approach channel and a turning basin at the plant site as well as disposal of the initial and maintenance dredge spoil.

The present plan is to dredge an approach channel to the site that would accommodate small vessels of approximately 15,000 to 20,000 DWT carrying coal to be discharged at the plant site. Bechtel's transportation division in San Francisco estimated that approximately 1.5 to 1.75 million cubic meters of material would have to be dredged initially. Further, approximately 60,000 cubic meters will be needed to raise the elevation of the site to 2.1 meters above MSL. This would leave approximately 1.4 to 1.6

million cubic meters of spoil to be placed elsewhere.

Maintenance dredging volumes have not been estimated by Bechtel at this time, presumably due to lack of any information on currents, littoral drift, surface sediment characteristics and general coastal wave climate, all of which will affect the amount of channel filling or shoaling in the area of the unloading dock and approach channel. This point bears upon the question of environmental effects of dredging since the amount of maintenance dredge spoil could determine the level of impacts associated with that activity.

The TGI study addresses two major objectives:

1. An initial assessment of the environmental and physical factors that might be associated with the dredging.

2. An identification of alternatives for disposal of the spoil materials.

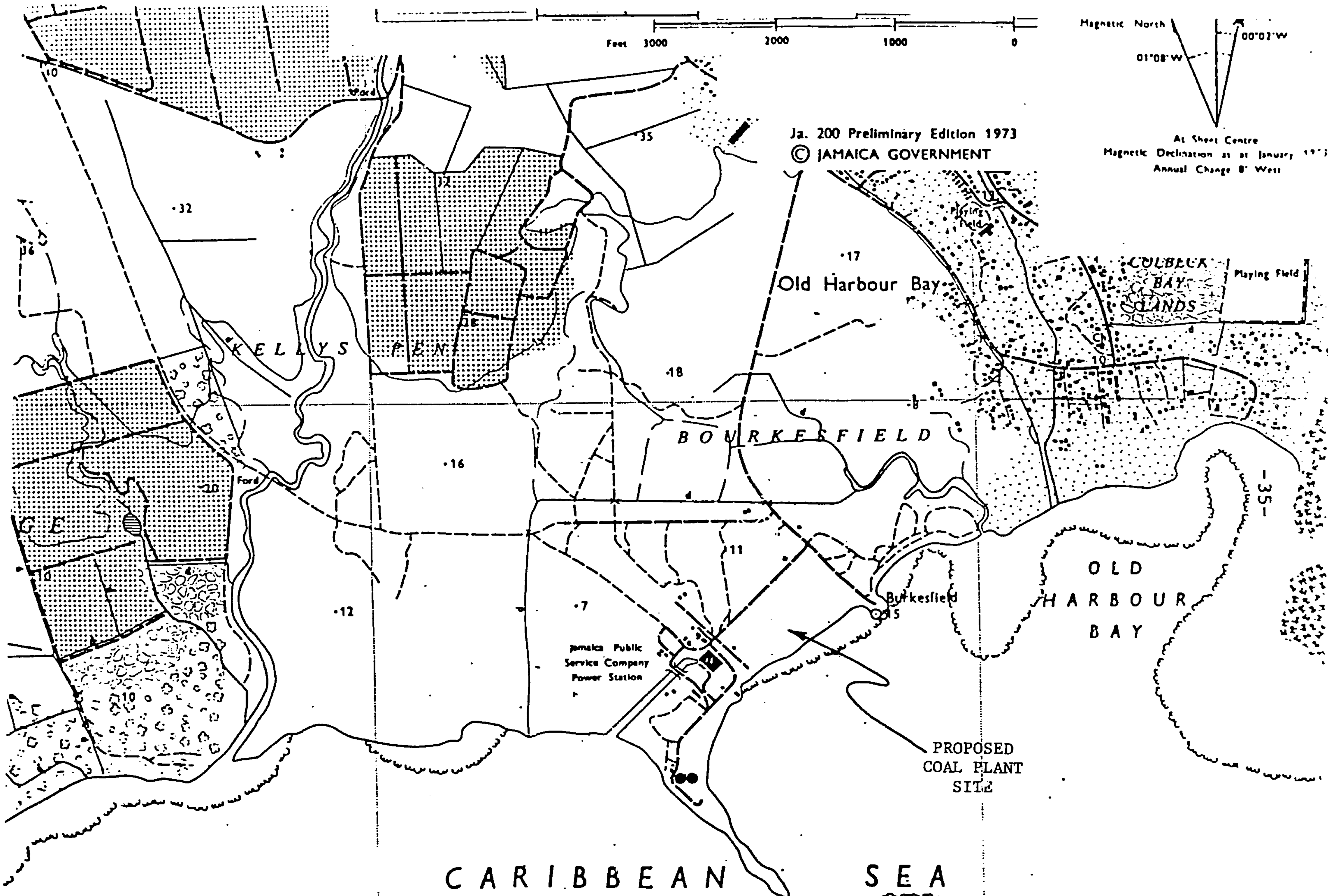
The study began on April 15 and was concluded August 7, 1983. The study consisted of a field trip to inspect the site and meetings with various agencies and individuals in Jamaica involved in the conduct or regulation of dredging, electricity production, and environmental, marine, and physical sciences (see Personal Communications list at the end of this report). A literature search for available documents and studies was also undertaken. This report describes and analyzes the findings of the site visit and of the information gathered during the literature search.

The environmental aspects of this preliminary investigation include both the effects of the proposed dredging on the biological and physical environment of the area and the interaction of the environment of the area with the proposed dredging activities; thus, the determination of environmental effects must include an analysis of the physical environment, such as waves and currents, and how this environment both affects and is affected by the dredging activities. (e.g., movement of sediments in an around the dredging activities is determined by the nature of the coastal physical processes).

In the process of examining coastal processes, dredging and spoil disposal in Old Harbour Bay, a number of questions were raised concerning the interaction between the proposed onshore and pier facilities and the coastal processes. These questions also affect the potential location of the channel, maintenance, and dredging and spoil disposal alternatives. The impacts of hurricanes, high waves, tsunamis, and the location of the proposed wharf/causeway are discussed in Section IV. Recommendations for further coastal processes analysis are included.

## II. GENERAL DESCRIPTION OF THE OLD HARBOUR SITE AND AREA

The proposed project would be sited immediately to the northeast of the present steam electric generating plant. Two coal fired steam boilers, active and inactive coal storage and unloading facilities would be located at the site.


Feet 3000 2000 1000 0
Magnetic North
00°02'W
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At Sheet Centre
Magnetic Declination as at January 1973
Annual Change 8' West
Ja. 200 Preliminary Edition 1973
© JAMAICA GOVERNMENT
Old Harbour Bay
COLBECK BAY LANDS
Playing Field
KELLYS PEN
BOURKESFIELD
Burkesfield
Ford
Jamaica Public Service Company Power Station
OLD HARBOUR BAY
PROPOSED COAL PLANT SITE
CARIBBEAN SEA

The site is located on Old Harbour Bay, one of several large bays in the Portland Bight on the south coast of Jamaica. Portland Bight is situated southwest of Kingston Harbor; the two bodies of water separated by the Hellshire Peninsula. The upland area is mainly agricultural with sugar cane predominating (Site Visit, 1983).

The hydrography of Old Harbour Bay is generally shallow with depths near the plant site (0-300 feet from shore) of 9 to 14 feet and from 300 to 3000 feet from shore, approximately 14 to 28 feet in depth (Survey Dept, Gov't. of Jamaica, 1981).

TGI found no quantitative information on the subsurface geology of the submerged bottoms in Old Harbour. Verbal descriptions (Earl Munroe, Station Manager, May 13, 1983) and inspections (TGI, May, 1983) of old dredge spoils indicate a general bottom sand or silt layer with sublayers of clay, sand, and coral. No definitive information on rock formations subsurface to the dredge area could be located.

The meteorological conditions and coastal wave climate are predominantly from the southeast. The local coastal processes in Old Harbour are controlled by these conditions, but are complex and are discussed in Section III.

The electric plant site, including the new site for coal boilers, consists of sand and clay fill material (Bechtel, 1983). This fill was placed at the site in 1939-1940 by the U.S. Navy as part of a seaplane base facility construction program at Little Goat Island (approximately two miles to the SE of the plant site)

(Captain Jennings, Fisheries Division, personal comm., 1983; Dr. Vincent Transano, U.S. Navy, personal comm., 1983). The general topography of the JPS site is now flat with an average elevation of approximately 2-1/2 to 3 feet or less above mean sea level (MSL). This fact means that the proposed coal boiler site is currently barely above sea level as material has been excavated from the site for fill elsewhere on the JPS plant site area. Material at the coal facilities site has been bulldozed to the edge of the shore to form a 3-4 foot berm.

Verbal reports and discussion with Navy staff in California and Washington indicate that a channel was dredged at the existing plant site (Dr. Vincent Transano, NAVFAC, June, 1983). A 1981 survey (Jamaica Survey Dept.) shows what appears to be a 26-foot deep channel running from the SE towards the existing water intake structure at the power plant.

Apparently, during the Navy program at Goat Island, two structures were constructed on each side of the present plant site extending out several thousands of feet seaward (Pers. comm., Captain Jennings, Marine Fisheries Division, 1983). One evidence of this is the westerly "sand spit" that is present at the site. The fact that this "spit" is not changing in size or shape (Survey Dept, 1958, 1972) indicates that it may, in reality, not be a spit, but what is left of the structure built by the Navy project. Whether these structures, if they were indeed built, were breakwaters or causeways to the island is not known. They may be important with respect to potential dredging activities.

Discussions with NAVFAC staff indicate that some of the original Goat Island project drawings show what appears to be a causeway from Goat Island to the area of the present power plant site.

There is very little data available on the present environmental parameters in Old Harbour Bay. Extensive contacts and review of files yielded very limited results. The marine environment of Old Harbour Bay has not been surveyed or documented (personal communication with NRCD, ECD, Marine Fisheries, and University of West Indies staff, 1983) The harbor, however, is typical of the bays on the south coast with some coral reef formations and seagrass beds near shore. The old British Admiralty hydrographic chart (1962) indicates that a line of coral reefs extends from just off the current JPS plant westward to Port Esquivel.

Water quality in the bay has not been monitored (Thorhaug, 1983; pers. comm., Paul Carroll, Don Rose, NRCD, May 16, 1983); the nearest system with any water quality data is Kingston Harbour which is under much more intensive use as a receiving water for industrial and domestic waste. Runoff into Old Harbour probably is high in nitrates, phosphates, and possibly chlorinated hydrocarbons from agricultural activities in the upland drainage area (based on discussions with NRCD staff and site observation of gullies and streams adjoining the JPS site). The available environmental and ecological data for Old Harbour Bay pertinent to proposed dredge and fill operations is summarized in Section VI.

The dredging operation conducted at the AlCan facility in

Port Esquivel is somewhat similiar to Old Harbour and involves both open water disposal and land disposal of dredge spoil but the operations at Port Esquivel have not been studied and/or monitored over the years. Therefore, little information of use at Old Harbour has been gathered. Evidently, no formal licenses or analyses were required for that initial and maintenance dredge program. Port Esquivel was dredged in 1951-2 before the enactment of laws such as the Beach Control Act of 1956. (Mason, 1957; Calvin Cottrell, Beach Control Authority, 1983, personal comm.). The only formal study that could be found concerning the Old Harbour area was one concerning sea grass beds in the area (Thorhaug, 1983).

## III. COASTAL PROCESSES IN OLD HARBOUR BAY

There is very little data on the coastal processes of Old Harbour Bay, particularly in the area of the proposed project site. However, it is possible to make a preliminary assessment of the coastal processes based on assumptions made from the limited data available from a variety of sources (e.g., old reports near Port Esquivel; progress reports of ongoing research near the discharge channel of the existing plant; and a series of maps/charts, personal interviews, site visits).

The primary waves in the area appear to be small (1-3 feet) and to be generated by the local predominantly ESE-SE winds. These waves directly approach the shoreline with little or no refraction. Swells off the Caribbean Sea appear to be effectively dissipated by the time they reach Old Harbour Bay as a result of the cays and bathymetry at the entrance to Portland Bight. The size of potential storm waves is unknown, so it is not possible to predict the frequency and/or magnitude of storm events at the site. Interviews conducted with on-site and other knowledgeable personnel indicate that the area is generally fairly quiet (Personal comm., Dr. Winston Freckleton, NRCD, and Derrick Gardener, JPS, 1983).

The lack of reliable storm data also made it impossible to predict the level of risk from sea level changes due to storms; i.e., storm surges, especially from hurricanes. Port Royal, at the entrance to Kingston Harbor, recorded an 18-foot surge in 1722 and Kingston and Old Harbour suffered severe damage in 1744. (Pers. Comm., Keith Ford, Office of Disaster Preparedness (ODP), 1983) These surges were probably associated with hurricanes, but the data are sparse. Following the 1744 event which destroyed Old Harbour, the town was relocated on higher ground at its present location. A more recent study by the Jamaica Public Service (JPS) predicted that a 20-foot storm surge was possible at their Hunts Bay Plant. Therefore, it appears quite possible that storm surges of this level could occur, but again, the level of risk is unknown.

Hurricanes are generated in the Atlantic and move in a westerly direction through the Caribbean. The hurricane season is June to November with the highest risk in August. Jamaica is not located on a main hurricane track and is seldom hit directly.

However, combinations of high winds and torrential rains have wreaked severe flood damage. Only 16 hurricanes between 1880 and 1980 have struck the island. The most serious occurred in 1880, 1886, 1917, 1944, 1951 and 1980 (ODP, 1983; Braatz, 1981). Most of the hurricanes move westward along the north coast, so that since 1880 Kingston and the southeast coast have been hit only twice (once in 1951). The most recent hurricane, Hurricane Allen, struck Jamaica on August 6, 1980, leaving in its wake 8 persons dead, hundreds homeless, and extensive damage to crops, roads and buildings. The parishes of Portland and St. Mary, on the northeast coast, were the hardest hit (ODP, 1983).

Damaging rains are associated with tropical storms, hurricanes, and "northers" (cold winter air waves which mainly affect Jamaica's northern side). However, in 1979, the wettest year of the decade, four periods of high rainfall occurred and caused extensive flooding and movement of earth and marl, particularly in the southwestern end of the island. The estimated damage was U.S. $100 million (ODP & U.S. Office of Foreign Disaster Assistance, 1983).

The records on tsunami events are also sparse, but a recently produced hazards map for Jamaica shows that the proposed plant site has a "moderate" risk of tsunamis (ODP, 1983). That is, this site has a lower risk than the north coast of the island because of the presence of the Cayman Trough on that side of the island. This trough marks the boundary between the American and Caribbean Plates which definitely increases the risk of earthquakes and, therefore, tsunamis on that side. From a geology map for Jamaica (Geological Survey Division, 1958), there is a fault running parallel to the coast in the Mid-Eocene to Lower Miocene White Limestone Formation which may be buried under the coastal Quaternary alluvium at the proposed plant site. Furthermore, Little Goat Island to the Southeast of the site in Old Harbour Bay is primarily a "raised coral reef" of Quaternary age. This island may represent an extension of the fault where geologically recent activity raised the reef, a different fault entirely, or the result of an earlier and higher stand of sea level. In any case, the number, location, type, and seismic activity along faults in the area is unknown which further complicates the assessment of tsunami risks at the site. However, we suspect that the seismic and the tsunami risks are acceptable at this site in terms of the life of the plant.

The tidal range along the entire Jamaican coast is low, on the order of one to two feet. While the bathymetry in the Portland Bight and Old Harbour Bay may increase this range slightly, the change is not considered to be significant. The importance of the tides lies in the currents they generate.

The water currents in the Portland Bight and Old Harbour area are the result of several driving forces: tides, waves, general oceanic circulation, and the outfall plume at the JPS power plant site. Of interest to this project are tidal and wave driven currents. As with the previous factors, little is known about the circulation patterns in Old Harbour Bay. Although the tidal currents may not be strong, they could be important in terms of dredging impacts, spoil disposal, and on-land construction because they would be a major factor in the distribution of suspended sediments from these sources.

A little more can be determined about the littoral currents. To the west of the old Navy breakwater (west of the proposed plant site), the net littoral current sets to the west. An inspection of maps of the area shows that the mouths of streams entering the sea are diverted to the west. This phenomenon is caused by the deposition of littoral drift from the littoral currents. This observation is supported by at least two reports: Mason (1957) and Thorhaug (1983). Mason examined the shoaling problem at Port Esquivel and concluded that the shoaling material - primarily mud - was coming from the east. Furthermore, he cited the shoreline changes in the spit to the west created by the spoil from the dredging of the channel for Port Esquivel. His cited and predicted shoreline changes are the direct result of a westward moving littoral drift and current.

To the east of Bourkefield Wharf, the littoral current appears to be easterly setting. A 1957 map (Jamaica Survey Dept.) of the plant site and vicinity shows a long spit along the shore at the village of Old Harbour Bay. This spit is attached to the mainland at its western end which suggests that it is, or was, building to the east. Furthermore, the mangrove area farther east provides data which supports this apparent littoral current flow direction. On the west side of this mangrove area there is a

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lagoon which has what appears to be a baymouth bar growing southward across the opening to the lagoon. As this reach is east of the spit cited above (although the coast has turned 90 degrees and runs N-S), the baymouth bar may represent deposition of littoral drift carried by the easterly littoral currents.

If the littoral currents set easterly east of Bourkefield Wharf (east of the plant site) and set westerly west of the old Navy breakwater/spit (west of the plant site), then a nodal zone exists in the vicinity of the plant. Furthermore, it is an "exit" or "erosional" nodal zone; i.e., all of the littoral drift moves away from a point on the coast. A nodal zone, then, represents a change in the direction of littoral drift movement. In this case, if an exit nodal zone exists in the vicinity of the plant, then the plant site may be subject to somewhat higher erosional stresses than might normally be expected. Exactly where this nodal zone exists cannot be determined from the existing available data.

The problem of shoaling at the intakes to the present plant suggests that the nodal point may be at Bourkefield Wharf. The shoal which forms at the easterly intake (No. 1) appears to be primarily sand while the shoal which forms at the westerly intakes (Nos. 3 and 4) appears to be primarily mud (Discussions with JPS Old Harbour Plant Staff, 1983). This distribution of shoaling material from sand to mud from east to west suggests a westerly setting littoral current whose capacity is reduced from east to west. That is, as the current moves along the shoreline, sand is deposited first and muds last. Presently, the cause for this loss of capacity is speculative, but an examination of the bathymetry at the plant site suggests a possible cause (Jamaica Survey Dept., 1981). Just east of the plant site is an old, relatively deep, channel which was apparently originally dredged by the U.S. Navy. The bottom widens into a large shallow area just west of this channel. A littoral current flowing westerly would be compressed into a relatively narrow band at the head of the channel and then it would spread out relatively rapidly which would slow its velocity, reduce its capacity, and cause it to deposit any material it was carrying. The heavier material would deposit first and then the lighter material. The source for this material would have to be east of the channel; i.e., near Bourkefield Wharf. If the waves are approaching almost directly at the shoreline in this area, they would tend to focus on Bourkefield Wharf as it would act similarly to a headland. The littoral currents would flow away from this "headland" and carry material to the west or east on the west or east sides, respectively. The general trend of the shorelines at Bourkefield Wharf support this suggestion. However, the nature and rate of shoreline change to the west of the wharf are unknown at this time, so it is unknown whether this area could be a source area for the shoaling material at the intakes. Furthermore, it is unknown what influence the channel has on the wave refraction pattern vis-a-vis the Bourkefield Wharf "headland."

A second potential source for the shoaling material is the offshore areas. Longer period waves tend to move bottom materials toward shore; in effect, they rebuild beaches eroded by the shorter period storm waves. There are several problems with this hypothesis, however. First, the direction of movement caused by the longer period waves is directly onshore which does not allow for the alongshore change in material from sand to mud. Second, as stated earlier in this section, it appears unlikely that the required swell conditions exist in Old Harbour Bay which would allow any significant contribution of material in this fashion. Thirdly, the exact nature of the bottom materials offshore of the plant site is unknown, so it is unknown whether this area could be a source area.

With respect to offshore materials, the only reliable data for any location in the vicinity are to be found in the Frederick Snare Corporation report (1952, A. D. Quinn, author). This report was written as part of the design sequence for the pier at Port Esquivel. Quinn indicates in the boring logs for the offshore holes that the surface material on the bottom is sand/pea gravel varying in thickness from 0-6 feet and averaging about 3 feet. This layer is underlain by generally stiff clays to considerable depths. The shallowest depth reported for possible bedrock is 54 feet below the surface. If similar conditions exist at the proposed site, then bedrock should pose no problems for dredging. However, it is unknown whether these conditions are similar offshore of the plant site. If these conditions do hold, then there is a potential for considerable short term, high turbidity conditions in the water column during dredging. The Quinn/Snare report is also quite old and it is possible for conditions to have changed considerably over time. Furthermore, there is not a reliable, large scale time series of hydrographic charts available so it was not possible to determine the nature, magnitude, or location of bathymetric changes over time. Thus, it was not possible to address potential shoaling problems in the proposed channel or at the proposed causeway.

There is also very little data currently available on shoreline changes in the vicinity of the plant. The only reported change was erosion at the public beach east of the site. The magnitude, duration, or material flows are all unknown at this time. However, the potential for erosion at the site exists and should be carefully considered as various factors will affect the magnitude of the problem; e.g., the causeway, the channel, any shore protection, land alterations, etc.

One last note: sea level is rising world wide (in some locations as much as 1/2 inch/yr or about 15 inches over a 30-year project life) (U.S. Army Coastal Engineering Research Center, 1977). The rate of sea level rise at Old Harbour Bay is unknown (it does vary from site to site) and it may pose a future problem. However, the rate of rise at the site must be of the same order of magnitude as elsewhere, so it seems very improbable that this factor will pose a problem during the life of the plant.

## IV. FACILITIES/COASTAL PROCESSES INTERACTIONS

The interaction between the proposed onshore and dock/pier facilities and the coastal processes of Old Harbour Bay is important not only for the onshore and pier facilities, but also for dredging and spoil disposal activities.

As stated in Section III above, little is known about the coastal processes in Old Harbour Bay. This situation makes it very difficult to describe the likely effects resulting from the interaction of the facilities with the coastal processes. Therefore, this section is intended primarily to raise those questions which must be addressed as part of the final design process for the proposed facilities and dredging activities. None of the effects discussed below are beyond the range of feasible current engineering solutions.

The risk of waves and surges from hurricanes is real, but the magnitude of the risk is unknown. If the 20-foot surge calculated for Hunts Bay is possible and this represents the 100-year level, then there is a 30 percent chance of such a surge occurring during a 30 year project life. Furthermore, the high waves associated with a hurricane would occur on top of this surge. Therefore, hurricane effects should be considered during the design phase.

Tsunamis can be very damaging (note the recent disaster in northwest Japan). Furthermore, they can travel large distances (up to 10,000 miles) in a matter of hours. This means that the

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generating earthquake does not have to occur near Jamaica. The entire Caribbean Basin is earthquake prone, so tsunamis could come from anywhere in the Basin. In a relatively enclosed area such as Old Harbour Bay, tsunami effects are increased significantly. Although we suspect this risk is small at this site, it should also be considered during the design phase.

The proposed channel, turning basin, and causeway/wharf also pose potential problems. The channel and turning basin will change the existing wave refraction and shoaling patterns. Potentially, this means that higher waves are possible and they could be directed at the unloading wharf and surrounding shoreline. No refraction study has been attempted as there are no wave data for Old Harbour Bay, and because it was beyond the scope of this study.

The proposed causeway/wharf could have beneficial and adverse impacts at the same time. Depending on the littoral current/drift patterns, it could eliminate the shoaling problems at intakes 1, 3 and 4 by blocking the transport of material along the shoreline. This beneficial effect could be offset, however, if the littoral currents do flow east to west on the west side of Bourkefield Wharf. The causeway would act like a large groin by trapping material on its east side and causing erosion on its west side due to the east side material flow blockage. If the currents flow west to east, then this "groin effect" will reverse sides which will further aggravate the shoaling problems at the intakes. In either case, it may be necessary to provide shore erosion protection in this area.

The blockage of littoral drift will create another problem: shoaling in the turning basin. This effect is well described by Mason (1957) for Port Esquivel. As the littoral drift is blocked, it will be carried along the causeway and deposited in a shoal near the unloading wharf. In addition, material will build up along and seaward from the shoreline, eventually affecting the turning basin.

Thus, there are several factors related to coastal processes in Old Harbour Bay which must be considered as part of the design process for the facilities and dredging. These include:

1. hurricane effects
2. tsunami effects and level of risk
3. wave refraction analysis
   (This analysis will provide critical input for the determination of the direction and magnitude of the littoral currents and drift; size, location, elevation and thickness of armor stone on the causeway; shoreline erosion protection requirements; shoaling and scouring patterns; and potential current patterns in Old Harbour Bay.)
4. littoral current/drift analysis
5. design wave calculations (which will determine the causeway, wharf, and shoreline protection needs)
6. erosion and sedimentation.

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## V. ENVIRONMENTAL DATA AND CONCERNS

As outlined in Section VI below, dredge and fill activities can affect changes in water quality and the conduct of aquatic life (benthic communities, seagrass beds, coral reefs, and fisheries). This section presents the available descriptive and quantitative data concerning the environmental indicators of Old Harbour Bay. In addition, the basis for environmental regulation and licensing of coastal developments by the Government of Jamaica is outlined.

A recent report summarizes the status of Jamaica's littoral (Braatz, 1981):

> Jamaica's coastline is a valuable resource as it provides the island's coastal fishery and recreation areas of great value. In addition, coral reefs and mangrove swamps provide protection of the land from storms and important breeding grounds for aquatic species. The quality of the coastal area has declined in recent years. Development along the coast has destroyed wetlands; rivers with high sediment loads emptying into the coastal areas have damaged coral reefs; dumping of domestic sewage, industrial wastes and oil from ship's bilges has polluted coastal waters; and overfishing has depleted the fish stock of the coastal fishery. The nearshore fishing grounds have been overfished, yet the fishing boats are not large enough to reach the offshore grounds which have a greater fishing potential. Almost all the fish caught comes from the coastal areas; comparatively little is from off-shore fishing grounds and almost none from inland fisheries. Jamaica imports almost half the fish it consumes.

A 1968 UNDP-sponsored study which formed the basis of the *National Physical Plan 1970-1990* included a review of the needs and capabilities of Jamaica regarding establishment of recreational areas and national parks. The entire Portland Bight and Ridge area is earmarked for consideration as a national park because of numerous mangrove forests, cays, islands, and reefs within the bight. The Portland Bight also encompasses the largest fishing village in Jamaica (by number of boats) at Old Harbour, three bauxite loading ports, and the Old Harbour JPS site. The Bight is, therefore, of ecological and economic importance to Jamaica.

## A. WATER QUALTIY

Water quality in Old Harbour Bay has not been monitored, according to NRCD, ECD, and university staff. The only available data are six samplings of water quality indicators taken between December 5, 1981 and February 3, 1982 in connection with an NRCD study for IOCARIBBE (UN) on disposal of floating oil. This sampling program was of too short a duration to provide useful water quality indicators. In addition, testing was inconsistent; results were not obtained for each of the indicators during each sampling trip.

Water quality testing and monitoring has been conducted for several Kingston Harbour studies (Wade, et al, 1972), but the metropolitan effluent entering Kingston Harbour is very different from the agricultural effluent entering Old Harbour Bay.

It was learned that there may be reason to believe that upland agricultural practices may contribute to chemical runoff in the Old Harbour area watershed (Discussions with Marine Fisheries, NRCD, and site observations, 1983). Whether this is, indeed, true and whether or not any materials of this nature have been entering Old Harbour Bay and accoumulating in sediments is not known. There is essentially no quantitative data on bottom sediments and materials in Old Harbour Bay (Discussions with several people at NRCD, ECD, JPS, and Dr. Ivan Goodbody, Univ. West Indies, 1983). No analysis of bottom sediments for chemical and biological components has been done (NRCD, ECD, JPS, Dr. Goodbody, 1983).

However, the numerous cane sugar and rum factories in Jamaica are serious polluters. Several sugar cane plants and estates are located in the Old Harbour area and discharge into creeks and gullies. Evidence of agricultural processing runoff can be observed in the creeks and gullies to the north of the JPS plant (Captain Jennings of Marine Fisheries and site visit observations, 1983). The discharge of "dunder" waste from rum manufacturing into streams and rivers is the most significant problem associated with the cane industry. The dunder, originating from molasses fermentation after the distillation of rum, is high in sugar, alcohols and yeast. It can impart bad odor and taste to the water, and its high BOD can cause anoxic conditions.

In general, there is evidence that stream quality is declining in Jamaica. Monitoring of coastal area streams has revealed a high proportion of streams with excess nutrient loading, high biological oxygen demand (BOD) resulting in oxygen depletion in the water, excess algal growth, turbidity, discoloration, and bacterial contaminatio (Braatz, 1981; Varma, 1972; Jamaica NPA, 1979.)

## B. AQUATIC LIFE

Benthic communities, bottom vegetation such as sea-grass beds, coral reef ecology, and fisheries are indicators of aquatic life in Old Harbour Bay. No studies have been conducted on zooplankton, phytoplankton, or benthic organisms for Old Harbour Bay or the Portland Bight area. The only studies of benthos on the south coast of Jamaica concern Kingston Harbour (UWI, 1973; Goodbody, 1970; Wade, 1972). The Kingston Harbour studies may indicate which species are likely to be present in Old Harbour Bay. However, dominant species, numbers, and diversity are likely to be very different in the two areas as Kingston Harbour receives the effluents of the city of Kingston.

Seagrass beds have important food web or production and water quality functions in the nearshore marine ecosystem in Jamaica (Greenway, 1977 and Thorhaug, 1983). The only study of grass beds in the Portland Bight or Old Harbour Bay is an ongoing NRCD - Florida International University study (Thorhaug, 1983). The study examined a 90' x 30' plot directly in the path of the thermal effluent of the JPS power plant.

> The existing vegetation is in almost classic thermal plume alignment. A large barren area of sand exists several thousand feet seaward from the thermal effluent. The next zone is patchy Halodule in a tongue shape along shore. The third zone is medium density

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> *Halodule*. Zone four is patchy *Thalassia* in *Halodule* beds; zone five is almost pure *Thalassia*; and zone six is mixed *Syringodium* and *Thalassia*. This zonation is caused by the thermal plume and the thermal tolerances of the seagrass species: as the heated water cools as it flows away from its source, the more heat tolerant successional species grades into the less heat tolerant climax species. The zones look like widening arcs radiating from the core plumes (Thorhaug, 1983).

The site study indicates that *Halodule*, *Thalassia*, and *Syringodium* grass beds are likely to exist throughout Old Harbour Bay.

A line of coral reefs is located in Old Harbour Bay from just off the spit of land at the JPS site westward past Port Esquivel. The productivity and condition of these reefs is not known (according to Dr. Jeremy Woodley, Director, Discovery Bay Marine Laboratory). Site observation of the dredge spoils and the British Admiralty hydrograph chart indicate that the channel for Port Esquivel was dredged directly through those reefs. However, the old channel dredged by the U.S. Navy at the JPS plant appears to be just east of the beginning of the line of reefs.

Old Harbour Fishing Village, located about 1/4 to 1/2 mile east of the JPS site, is among the most important fish landing sites in Jamaica. The *Sample Survey of the Fishing Industry in Jamaica - 1981* breaks down the annual catch by type of fish and fishing ground (e.g., North Shelf, South Shelf, Pedro Bank, and Other Bank) not by fishing village. However, the number of boats per village gives an indication of the percentage of catch landed at each village. The Old Harbour Bay village has 203 (195 mechanized) of the 308 boats in St. Catherine's parish, by far the largest number of boats per village in Jamaica. Most of the "mechanized" boats in Jamaica are narrow 20-25 foot fiberglass "canoe type" boats powered by outboard motors. About 10 percent of Jamaica's total catch is landed at Old Harbour Fishing Village. Average annual value of catch per boat on the south shelf is $11,187 (Jamaican), from an average of 5,430 lbs/boat/yr.

Discussion with Marine Fisheries staff of the Ministry of Agriculture indicate that most of the fish landed at Old Harbour are caught farther out in Portland Bight (rather than Old Harbour Bay) and on the Pedro Bank, an oceanic bank situated due south of Jamaica. However, some fishing reportedly occurs along the coral reefs in Old Harbour Bay itself (Discussions with Captain Jennings, Marine Fisheries Division, 1983).

The type of gear used on Old Harbour Fishing Village boats is almost entirely for pot (150) or net (50) fishing. Trapping with pots, practiced in shallow (20-130 ft. deep) waters, is the most common method in Jamaica. Net fishing with seine or gill nets for small pelagic fish is done in sheltered shallow areas (Survey of the Fishing Industry in Jamaica, 1981).

Herring sprat, snapper, parrot fish, grunt, jackfish, and goat fish are the most commonly caught fish on the south bank of Jamaica (which includes Portland Bight and Old Harbour Bay).

## C. GOVERNMENT LICENSES AND REVIEWS REQUIRED FOR DREDGE AND FILL ACTIVITIES IN COASTAL AREAS

Dredge and fill activities in the coastal zone are regulated and licensed by various government ministries under Jamaican law. The Harbour Master, NRCD, and ECD all have license or project review authorities or responsibilities concerning coastal structures and dredge and fill activities.

### Harbour Master

A license for dredge and fill activities in coastal areas must be obtained from the Port Authority of Jamaica (under the Harbours Act of 1874 - since amended). Licenses are issued by the Harbour Master.

### Beach Control Authority

A Beach Control Authority License must be obtained for any proposed disturbance of the shore, beach, foreshore, or overlying waters or floor of the sea under the Beach Control Act of 1956. The Beach Control Authority is now a division of NRCD. The applicant should write a letter to the Beach Control Authority outlining the proposed action. Issuance of the license usually takes one to four weeks according to Mr. Calvin Cotrell, Director, Beach Control Authority. The license must be signed by the chairman of the Natural Resources Conservation Authority, the Board overseeing NRCD.

Mr. Cottrell's major concern is that the small public bathing beach immediately to the east, adjacent to the proposed site, not be adversely affected by the proposed dredging. He agreed that sand nourishment from dredge spoils may improve the eroding bathing beach.

## Environmental Control Division

The Environmental Control Division (ECD) of the Ministry of Health operates under both a statutory and a Cabinet directive. The ECD was established in 1973 by the Cabinet with statutory authorities for public health included in the Public Health Act.

The Public Health Act mandates that discharge of a liquid or solid that is injurious to health is illegal. In addition, the Cabinet gave ECD responsibility to control pollution that might affect public health. This second directive has not yet evolved into a separate statute. But a "general acceptance" of this responsibility exists, according to Mr. Ted Aldrich, ECD director (pers. comm., 1983). In effect, the ECD's jurisdiction is over quality control of drinking water and beaches, domestic sewerage and industrial waste water under control, solid waste disposal, and occupational health programs. (Braatz, 1981)

ECD would require a letter from JPS explaining the proposed dredge and spoil activities and any environmental impact studies conducted for the activity. ECD does not have a formal environmental impact assessment procedure or a checklist of items to be included in the letter. Upon receipt of the letter, ECD would make an assessment (no formal "procedures" are used in such an assessment according to Mr. Aldrich; the procedures vary depending upon the case) and approve or disapprove of the proposed action or suggest modifications for approval, according to Mr. Aldrich.

## VI. EFFECTS OF DREDGING

The present plan is to dredge an approach channel to the site that would accommodate small vessels of approximately 15,000 to 20,000 DWT carrying coal to be discharged at the plant site. Bechtel's transportation division in San Francisco estimated that approximately 1.5 to 1.75 million cubic meters of material would have to be dredged initially. Further, approximately 60,000 cubic meters will be needed to raise the elevation of the site to 2.1 meters above MSL. This would leave approximately 1.4 to 1.6 million cubic meters of spoil to be placed elsewhere.

Maintenance dredging volumes have not been estimated by Bechtel at this time, presumably due to lack of any information on currents, littoral drift, surface sediment characteristics and general coastal wave climate, all of which will affect the amount of channel filling or shoaling in the area of the unloading dock and approach channel. This point bears upon the question of environmental effects of dredging since the amount of maintenance dredge spoil could determine the level of impacts associated with that activity.

**A. General Effects of Dredging Activities**

The environmental effects of dredging in Old Harbour Bay can be associated with two categories of dredging activities: 1) the mechanical process of extracting and moving the bottom materials and 2) the transport and final disposal of the spoil material. One set of mechanisms, the coastal processes, controls how these activities affect the environment.

In category 1), the major issue is the release and potential dispersion of various types of sediment material into the water column. Two general types of effects can be identified with this type of dispersion and resuspension of solids:

a. if chemical or biological pollutants are present in the bottom sediments, they could be re-released to the water column, either in original form or in other molecular or ionic states. If such substances are toxic to the flora and fauna of the area, or to humans (e.g., through body contact during swimming at the nearby bathing beach or from contaminated fish), environmental issues may arise;

b. the resuspension or release of inert materials to the water column could occur; e.g., an increase in turbidity in the water column which, under certain circumstances, could have physical effects on benthic organisms or higher trophic level organisms in the water column.

In both cases, a) and b), the specific nature of the area being dredged will have a significant bearing on the fate of materials released by dredging; e.g., waves and currents as well as the hydrography of the area. The magnitude and duration of dredging will, of course, have a strong effect on the intensity of any environmental consequences of dredging. The type of dredging

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equipment used will have a direct effect; e.g., suction, suction cutterhead, dustpan, etc.

Thus, in attempting to even preliminarily assess the impact of dredging, one must determine three sets of information: 1) the present level of pollutants, if any, in the area to be dredged, 2) the prevailing water current patterns in the area, both surface and subsurface currents, and 3) the location of ecologically productive areas, such as grass beds and coral reefs.

It is anticipated that a cutterhead dredge is going to be required for the dredging at the Old Harbour site. The turbidity generated by a cutterhead is usually in the vicinity of the cutter. The levels of turbidity are directly related to the type and quantity of material cut and not picked up by the suction. The amount of material supplied by the cutter to the suction is controlled mainly by the rate of cutter rotation, the thickness of the cut, and the swing rate of the dredge. The ability of the dredge's suction to pick up the cut material determines the amount of material that remains on the bottom or suspended in the water column. In addition, turbidity may also be caused by sloughing of material from the sides of vertical cuts, inefficient operational techniques, and the prop wash from the tender.

Turbidity level control will depend upon the limits desired to minimize impacts. Suspended solids levels can vary widely in the vicinity of the cutter head, depending upon the above factors, and can range from 50 to 1000 mg/l depending also on material type (Krenkel et al, 1976).

There has been extensive research in the U.S. on the impacts of dredging on the environment. According to the U.S. Army Corps of Engineers Waterways Experiment Station, "...traditional fears of water quality degradation resulting from the resuspension of dredged material during dredging and disposal operations are for the most part unfounded" (Brannon, J.M., 1980).

The impact associated with depressed levels of dissolved oxygen has also been of some concern, due to the very high oxygen demand associated with fine-grained dredged material slurry (Barnard, W.D., 1978). However, even at open-water pipeline disposal operations where the dissolved oxygen decrease should be greatest, near-surface dissolved oxygen levels of 8 to 9 ppm will be depressed during the operation by only 2 to 3 ppm at distances of 20 to 40 m from the discharge point. The degree of oxygen depletion generally increases with depth and increasing concentration of total suspended solids; near-bottom levels may be less than 2 ppm. However, dissolved oxygen levels usually increase with increasing distance from the discharge point, due to dilution and settling of the suspended material (Schubel J.R., et al, 1978; Neal, R.W. et al, 1977).

Unfortunately, there are still many unanswered questions about the chronic and sublethal effects of turbidity on different aquatic organisms. In some cases suspended solids may reduce photosynthesis, interfere with respiration or feeding behavior, etc. (TGI & NRCD, 1981). Other studies show apparently insignificant effects on organisms even after long exposure to high levels of suspended solids. Although there is apparently no significant migration of trace metals and hydrocarbons into soluble phases, these constituents associated with the suspended particulates may have a minor effect on some organisms that may use the particulates as a food source (Burke, S.L., Engler, R.M., 1977; DiSalvo, L.H., 1979). Although research indicates that even minor impact caused by ingestion of fine-grained suspended sediment is highly unlikely, the toxicity of highly contaminated sediment should be evaluated on a case-by-case basis.

It has been demonstrated that elevated suspended solids concentrations are generally confined to the immediate vicinity of the dredge or discharge point and dissipate rapidly at the completion of the operation (Krenkel et al, 1976). If the amount of turbidity generated by a dredging or disposal operation is used as a basis for evaluating its environmental impact, it is essential that the predicted turbidity levels are evaluated in light of background conditions. Average turbidity levels should be considered. For example, in San Francisco Bay, California, suspended solids levels in 1.5 m of water can average 500 mg/l when wind velocities exceed 5m/sec, which occurs 30 percent of the time (Wakeman et al, 1975). On the Thames River, Connecticut, if the suspended solids levels generated by a 12.8-cu m clamshell operation are "...compared to suspended material variations associated with naturally occurring aperiodic storm events, the dredging related impacts appear negligible" (Bohlen, W.F.; Tramontano, 1977).

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## B. Benthic Effects

Whereas the impact associated with water-column turbidity around dredging and disposal operations appears to be for the most part insignificant, the dispersal of fluid mud dredged material appears to have a relatively significant short-term effect on the benthic organisms within open-water disposal areas. Open-water pipeline disposal of fine-grain dredged material slurry may result in a 45 to 70 percent reduction in the average abundance of organisms and a decrease in the community diversity in the area covered by the fluid mud (Diaz, R.D., Boesch, D.F.,1977; Pfitzenmeyer, H.T., 1970). Despite this immediate effect, recovery of the community apparently begins soon after the disposal operation ceases. Assuming that the disposed material is similar to the sediment in the disposal area, total recovery of the disposal area to predisposal conditions has been observed to require 3 to 18 months. The recovery time depends on factors such as the magnitude of the initial effects, the characteristics and seasonal response of the indigenous organisms to natural stresses, etc. Regardless of the environment, the effect on benthic organisms can be minimized if the dredged material is disposed on similar sediment. In other words, mud should be disposed on mud, and not on sand (DiSalvo, L.H., 1979).

In most cases, the environmental effects associated with the dredging of uncontaminated sediment will be insignificant. However, the effect of fluid mud dispersal at open-water pipeline disposal operations appears to be relatively significant, at least for short term periods (i.e., months). Regardless of the type of dredging or disposal operation, there are certain environments (e.g., spawning grounds, breeding areas, oyster and clam reefs, areas with poor circulation, etc.) and organisms (e.g., coral, sea grasses, etc.) that may be extremely sensitive to high levels of turbidity and/or burial by dredged material. It is therefore necessary to evaluate the potential effect of each proposed operation on a site-specific basis considering the character of the dredged material, the type and size of dredge and its mode of operation, the mode of dredged material disposal, the nature of the dredging and disposal environment and its associated seasonal cycles of biological activity, and the degree and extent of the potential short- and long-term effects relative to background conditions. By implementing developed guidelines, improving operational techniques, and selecting appropriate pipeline discharge configurations, any dredging or disposal operation can be oonditioned to minimize its environmental effects. It must be pointed out that all of the above discussion on dredging effects is based on dredging experience in the U.S. and it is possible not all of it will apply to the Old Harbour environment due to different organisms, different biological productivity dynamics and other factors.

## C. Environmental Impact of Dredging at Old Harbour

Seotions VI. A. and B. describe, in general, the types of environmental impacts that could occur in relation to dredge and fill activities in Old Harbour Bay. Section V. A. outlined the existing environmental data for Old Harbour Bay. The dearth of available data concerning the environmental parameters and the nearshore processes in Old Harbour Bay do not allow one to make any definitive statements concerning the impacts of the proposed dredge and fill activities there. The following information and study activities would be required for any definitive environmental assessment:

- Analysis of current and wave movement to calculate the dispersion patterns from dredging and spoil.
- Analysis of bottom sediments to see what constituents would be released during dredging. Sediment sampling would be done with a suitable study grid, offshore soil borings and analysis of samples. Sediment quality also affects spoil disposal and containment and disposal of dredge spoils on beaches.
- Basic water quality monitoring over a period of months to evaluate the impact of sediment dispersal. This information could also be used in any (Bechtel) analyses of power plant effluent impacts.
- Study of ecological indicators, aquatic life, and the importance of particular forms of life such as benthos and the grass beds in the food chain. Benthos, floating and attached plants, coral reefs, and endemic fish should be included in the study as they all could be affected in some way by dredge and fill activities.

## VII. Dredge Spoil Disposal Alternatives

There will be approximately 1.4 million cubic meters of initial dredge spoil of which to dispose at the Old Harbour site. No estimate is available for the maintenance dredging because shoaling rates need to be estimated from field data on water movement.

From discussions with JPS staff at the Old Harbour site, TGI found that there is considerable sand/sediment movement in front of the existing plant site. They dredge approximately 1530 cubic meters per year from an area immediately in front of the water intakes at the plant. TGI also learned that maintenance dredging has increased in frequency at the AlCan Port Esquivel site over the last three years.

After conducting the site visit, TGI identified the following five alternatives:

1. Open water disposal;
2. Placement on and/or storage near the Old Harbour public beach which is badly eroding;
3. Creation of a diked area in the Old Harbour Bay and use the impounded water for commercial shrimp culture;
4. Disposal on the "land spit" to the Southwest of the plant site;
5. Creation of an artificial island that could be used as a wetland wildlife area, with embayment.

These options are reviewed in this section. While costs for each option cannot be determined accurately at this point because of uncertainties in channel location and dredge type and bottom material, the discussion will be comparative between the various possible options.

## A. Open Water Disposal

The disposal of the initial volume of dredged material, some

1.40 million cubic yards, in open water may present some environmental concerns. The primary potential effects of open water disposal can be classified into three major areas:

1. Changes in existing sediment levels which can affect spawning areas, smother benthic organisms, reduce bottom habitat diversity, reduce food supplies;

2. Increase levels of turbidity, decrease levels of light penetration, cause physical flocculation of plankton and algae and decrease availability of food;

3. Oxygen depletion of organisms and possible release of toxic pollutants, if contained in the dredged material.

There is considerable debate and uncertainty over the effect of open water disposal sites. Specific conditions are controlling factors and no generalization can be made from even one type of site to another.

A list of sources on dredging disposal impacts is provided in the bibliography. None of these deals directly with the Jamaican environment and vary considerably as to adverse impact. Many of the same environmental factors considered in the section on dredging impacts could apply to the disposal options; e.g., resuspension of materials, and subsequent dispersion and diffusion of materials could cause at least some temporary effects on aquatic organisms in the vicinity of the disposal.

Whether or not open water disposal will pose any environmental concern will depend largely on where the spoil is disposed, of what it consists and the ocean current system that is present in that area. No information is available on currents; however, TGI recommends that, if open water disposal is adopted, consideration of fishing grounds and associated habitat and spawning areas be made. TGI assumes that the lowest cost option would be in the area of Goat Island.

Impacts on the fishing activities in the area are a primary environmental concern that could arise from open water disposal. However, information from the Marine Fisheries Division indicates that the major fishing grounds lie some distance from the general areas where dredging would occur and from where open water disposal could be accomplished. (Pers. Comm., Captain Jennings, 1983 and Sample Survey of the Fishing Industry, 1981).

The impacts of this disposal option will also depend upon the nature of the material and the fraction of fines present. Plumes from dredged material of the type thought to be present in the dredged area should be relatively small, in the order of 500-800 yards from the center of the disposal site, again depending upon current actions, and water depths.

Previous open water disposal has occurred with maintenance dredging of the ALCAN site at Port Esquivel, under permission of the Harbourmaster. The Harbourmaster has indicated that open water disposal of the proposed Old Harbour project would probably be permitted in the Portland Bight area (Pers. Comm., Captain Prawl, 1983). There have been no reported environmental problems from these disposal actions, but neither could we find any reports or monitoring programs that studied these actions.

The costs of this disposal option will depend upon the method of dredging. For example, hydraulic dredging with pipeline

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discharge to other areas may or may not be too costly depending on the length of the pipeline.

Another factor to be considered in the open water disposal option is the possible movement of sediments by currents in the area. Disposal should be far enough away from the dredged area to prevent sediment movement to the original site. If open water disposal is to be used it seems obvious that the disposal site be located away from the dredged channel area (unless sidecasting is used), away from fishing grounds and sea grass bed areas (neither of which is well defined in terms of location in the area), and in areas where current patterns will not transport the sediments to such critical areas.

## B. Use of Dredge Spoil as Fill Material for the Old Harbour Public Beach

Based on direct observations and discussions with various individuals it was determined that beach erosion at the Old Harbour Public Beach is quite severe. In fact, sand is currently being removed from the proposed new plant site to be used as fill for the adjacent beach areas.

This option will depend upon the nature of the dredge spoil material, and upon the amount and rate of beach nourishment required or possible. It would appear that the maximum initial amount of needed fill, leaving the existing shoreline in place, would be in the order of 76,500 cubic meters, which is a small fraction of the initial dredge volume. If the shoreline were to be extended outward to "straighten" the public beach shoreline, it is possible that up to 382,600 cubic meters might be placed.

However, removal of this additional beach volume by annual erosion could add to the water intake shoaling problems at the existing and new plant site. This will depend upon the source of the present sediment load that is shoaling at the intakes. This would need to be determined. Obviously, the beach material should not end up in the new dredge area. Nor would it be desirable for it to be transported by currents to the Old Harbour fishing village to the East.

The cost of this option would probably be higher than the open water disposal case, depending upon whether the spoil could be hydraulically placed on the beach area, or placed there by mechanical means from barges that would transport the spoil. The environmental aspects of this option may not be serious; however, pollutants may be present from the agricultural runoff. Therefore, TGI recommends that a chemical analysis be made before dredging.

Use of this option for disposal of maintenance dredge spoil is feasible depending upon the rate of erosion of beach volume from the area. Again, if this material is transported by the littoral currents into the coal unloading area or water intakes, it would be self-defeating. This option might be shared with the Beach Control Authority for the benefit of the residents of the area.

**C. Creation of Diked-Pond Areas for Possible Mariculture Operations**

Mariculture is becoming increasingly discussed in Jamaica.

Several proposals for examining this possibility are underway. The Portland Bight area may have potential for marine shrimp culture (Penaeid shrimp). Salinity levels in the Bight may be appropriate for pond culture of such organisms.

Pond construction costs are a major element in commercial shrimp operations. It is possible that ponds could be constructed in the shallower portions of the area using initial and maintenance dredge spoil to build ten diked sides of ponds.

Assuming a water depth of 20 feet and a berm height of eight feet, a 3:1 slope and a berm width of 15 feet, approximately 1700 lineal feet of dike could be built. If 20-acre pond cells were used, approximately 18 ponds could be constructed.

A complete analysis of this option is beyond the scope of this preliminary study. Costs beyond the spoil placement would be shaping of the slopes, possible core material provisions, armoring of the exposed sides, construction of pipe connections between ponds, hatchery facilities, roads for access, etc., etc. These costs by themselves would be over and above the cost of normal spoil disposal. However, if such an option were feasible, revenue from the operation would offset the costs and if feasible economically, would provide income to JPS.

If, for example, 18 ponds were feasible, it is possible that crop yields of 1000 to 2000 lbs of shrimp per acre per year would be possible. Assuming a conservative wholesale price of $2.00 U.S./lb and 1500 lb/acre, a gross revenue of roughly one million dollars U.S. per year might be possible, which could be used to defray dredging costs.

The U.S. Army Corps of Engineers has studied such an option in the U.S. and has claimed that diked ponds from dredge spoil could be economically feasible. Conditions were not quite the same as Jamaica, but we feel this option might be explored further because of the Government's current interest in shrimp farming as shown by the increasing development of shrimp farms in Jamaica (TGI is currently investigating such an operation at other sites). Maintenance dredge spoil could be used for repair or expansion of ponds.

**D. Creation of Artificial Islands**

This option would involve the use of dredge spoil for creation of land forms that might be used for several purposes; e.g., commercial or research activities. Assuming 1.75 million cubic yards of spoil, 30 feet of water, 3:1 side slope and a 38 foot elevation (above MSL), a circular island of approximately 610 feet in diameter could be constructed.

One possible use for this island might be for the storage of coal inventory, particularly if Jamaica were to become a transshipment site for selling coal to other sites in the Caribbean. This option may be initially more expensive than open water disposal, but if productive use of the island might be made, this could offset the additional initial costs.

Another use of such an island might be as a research area to demonstrate the use of dredge spoil in creating habitat areas such as controlled growth of marsh areas, bird nesting areas, etc. This option would not have direct economic benefit, but could have a benefit from increased knowledge regarding the role of artificial environments in development activities.

## E. Expansion of the "Land Spit" to the West of the Present Site

Based on discussions with agency people and with the U.S. Navy, we feel that the land spit to the west of the plant site is not a natural spit, but rather the remnants of a jetty or a causeway that may have been built in 1941, possibly all the way to Goat Island.

This area could be used for spoil disposal with minimum environmental damage. One possible concern might be the movement of deposited spoil to the west and covering existing grass beds known to be in the area. This option is similar to the island option in that it could create new, and possibly useful, land area by the plant. Depending upon the extent of expansion desired, it is possible that all of the initial spoil could be placed there.

TGI has assumed in all of these options that the amount of spoil that might be placed directly at the new plant site for elevation increase is small compared to the total amount to be dredged. It appears, based upon this initial preliminary review that the open water option probably will have the lowest initial cost for the project. However, TGI has identified other placement options that seem to bear further examination. In reality, it is possible that a mix of disposal options would be used; e.g., some beach fill, some open water disposal, some "land spit" disposal, etc.

## VIII. CONCLUSIONS

TGI concludes,albeit on limited available data, that it will not be an economic hardship on the project to dispose of the spoil and that the environmental aspects of the options could be acceptably managed. The engineering technology is available to address these options. The mariculture option needs further consideration in terms of technical and economic feasibility.

Because of the very limited amount of environmental data, it is difficult to strongly recommend a single disposal option at this point in time. We recommend that a combination of options be pursued. Option B (use of dredge spoil for public beach maintenance and possible expansion) could be used as fill, up to some limiting quantity, by the Beach Control Authority and local officials. This will depend upon the amount of new beach desired and the eastward extent of the new beach. The remainder of the initial spoil would then be placed on the land spit (option E). If any remaining spoil is available, it should be deposited in open water, if the current patterns will not cause it to redeposit in areas where fisheries are affected.

If the mariculture option (option C) proves economically feasible, then this option could be used for all the initial and maintenance spoil and income from the project could offset the dredsins costs.

In either case maintenance dredsins spoil could be handled at the initial spoil disposal sites. Use of the maintenance dredse spoil for beach nourishment will, of course, depend upon the acceptability of the dredsed material for beach use. While there is no data available on the nature of mobile sediment in the area, it is suspected that it may be of an acceptable character.

## PERSONAL COMMUNICATION

* = Persons visited by TGI team in Jamaica

*1. Aldrich, Ted, Director, Environmental Control Division, May 16, 1983

*2. Bryce, Roderick, Geological Survey Division, Ministry of Mining and Energy, May 11, 1983

*3. Carroll, Paul, Chief, Water Quality Branch, Natural Resources Conservation Dept., May 11, 1983

*4. Cottrell, Calvin, Director, Beach Control Authority, Natural Resources Conservation Dept., May 20, 1983

5. Davidson, Oliver, Office of Foreign Disaster Assistance, USAID, June, 1983

*6. Ford, Keith, Office of Disaster Preparedness, May 20, 1983

*7. Francis, Noel, Survey Dept., May, 1983

*8. Freckleton, Dr. Winston, Chief, Oceanography Branch, Natural Resources Conservation Dept., May 18, 1983

*9. Gardener, Derrick, Project & Development Engineer, Old Harbour Power Plant, May 13, 1983

*10 Girvan, Roland, Survey Dept., May 12, 1983

*11 Goodbody, Dr. Ivan, Zoology Dept., University of the West Indes, May 20, 1983

*12. Herron, Valerie, Water Quality Laboratory, Natural Resources Conservation Dept., May 18, 1983

*13. Hey, Winston, Petroleum Corporation of Jamaica, May 10, 11, 12, 16 & 20, 1983

*14. Jennings, Captain, Marine Fisheries Division, May 17, 1983

*15. Laidlaw, Alton, Engineering Division, ALCAN, May 13, 1983

*16. Little, Engineering Division, ALCAN, May 13, 1983

*17. Lowe, Dr. Henry, Director, Energy Division, Ministry of Mining and Energy, May 13, 1983

*18. Matelon, Owen, Industrial and Commercial Development, Ltd., May 17, 1983

*19. Munroe, Earl, Station Manager, Old Harbour Power Plant, JPS, May 13, 1983

*20. Munroe, E.L., Director of Production, Jamaica Public Service Company, Ltd., May, 1983

*21 Pearson, Francis, Chief Engineer, ALCAN, May 11, 1983

*22. Prawl, Captain Patrick, Acting Harbourmaster, Jamaica Port Authority, May 10, 1983

*23. Reeson, Peter, Project Manager for Environment and Special Projects, Petroleum Corporation of Jamaica, May 10, 1983

*24. Rose, Donovan K.B., Acting Principal Director, Natural Resources Conservation Dept., May 18-19, 1983

*25. Rose, Gary, Engineer, Petroleum Corporation of Jamaica, May 10, 1983

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