ENVIRONMENTAL IMPACT ASSESSMENT
STEP-IN-DYKE CONSTRUCTION
RDA #1 – JAMALCO
CLARENDON

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November 2004

ENVIRONMENTAL IMPACT ASSESSMENT

STEP-IN-DYKE CONSTRUCTION

RDA # 1- JAMALCO,

CLARENDON

JAMALCO,
A PLANT WITHIN A PARK

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EXECUTIVE SUMMARY

Executive Summary

An Environmental Impact Assessment (EIA) was conducted on the proposed construction of a Step-In-Dyke and the implementation of “Dry Stacking” technology at Residue Disposal Area Number One (RDA #1) located at the Jamalco facility in Halse Hall, Clarendon.

In 1970 Alcoa commissioned, a 500,000 ton per year alumina refinery in Halse Hall, Clarendon, with one of its most outstanding features being a sealed tailings impoundment pond (residue disposal area) which became the standard and hallmark for red mud management and disposal in Jamaica.

Since being commissioned in 1972, RDA #1 has not experienced any negative environmental impacts, structural failures or any unusual incidents that would detract from its integrity. The Jamalco facility, along with its RDA’s have been meticulously operated and maintained in keeping with the exacting requirements and standards of Alcoa and the legislations and regulations of the Government of Jamaica.

It is proposed to install a step-in dyke and the necessary pipe work at RDA#1 to allow for the implementation of a slope stacking operation which will increase the volume of residue that can be safely stored in a smaller area than presently being used. A step-in dyke is basically a smaller dyked area located within a larger dyke. Construction of this step-in dyke would enable Jamalco to create additional volume for 6 months storage of residue based on a production level of 1.32 Million tonnes of Standard Grade Alumina and also to utilize critical storage space prior to the start up of the recently permitted expansion activities.

The Step-in-dyke and residue slope have been designed to provide as-built factors of safety of about 1.3 for end of construction conditions, using available residue properties and assumed properties for the bauxite reject, the Conceptual Design was developed considering the formation of a "Dry Stack" with 3% slopes, and the residue achieving

60% solids upon draining and drying. These values are considered achievable considering the use of the existing paste thickener (a vessel used for liquid/solid separation), Jamalco's climate, and the rotation of this disposal area with other available areas for residue deposition.

The step-in-dyke and residue slope will be designed in such a manner that they are not too close to the perimeter dykes in order to ensure that the stability of the perimeter dykes are not reduced.

Aspects of the surrounding environment, monitoring and management plans were studied, analysed and assessed. These included:

- Geotechnical/Soil Analysis
- Air Quality and Weather
- Water Resources
- Wildlife and Vegetation
- Natural Hazards and Vulnerability
- Socio-Economic Analysis/Community Consultations
- Policy, Legislation and Relevant Regulations
- Identification and Analysis of Alternatives
- Determination of Potential Environmental Impacts
- Impact Mitigation Actions
- Monitoring and Environmental Management Plans

Alternatives to the proposed project were evaluated and the proposed project was the preferred alternative.

Potential impacts resulting from the implementation of the proposed project were evaluated and analysed. Potential negative impacts were identified in the form of:

- Fugitive Dust
- Air Quality
- Noise
- Pollution of Surface and Groundwater

Potential positive impacts were identified to a limited extent in the creation of jobs from the project and the continued operation of the refinery due to additional residue storage space.

Suitable, cost effective mitigation actions were identified for all potentially negative impacts identified.

In keeping with its Environmental Health and Safety policies as well as the legislation and regulations of the Government of Jamaica, Jamalco has an extensive Environmental Monitoring and Management Programme which is carried out on all aspects of its operations.

Conclusion

The proposed construction of a step-in dyke within the existing RDA #1 at the Jamalco facility is a progressive and environmentally sound project that should be seriously considered for implementation.

The project encompasses elements of responsible environmental management that is in the forefront of Alcoa's principles and guidelines. The project if approved and implemented will:

- Utilize existing residue disposal area footprints to generate approximately 750,000 m^3 of additional residue disposal area.
- Improve on the sealed impoundment technology by incorporating the dry stacking technology that will increase the solid percentage of the residue to approximately 60%.
- Not present any new potentially negative environmental impacts to the environment or humans.

- Increase land and water conservation at the facility.
- Introduce a proven and relevant technology that will further enhance Jamalco's highly effective and environmentally friendly residue disposal programme

All potential negative impacts identified can be easily and cost effectively mitigated using proven technologies, most of which are already in use at the existing RDAs.

Recommendations

The potential benefits of this project to Jamalco, the environment and Jamaica as a whole are quite evident. The low level of potential impacts to the environment and humans makes it a viable project which we recommend should be permitted for implementation.

PROJECT DESCRIPTION

1 Project Description

1.1 Background

1.1.1 Jamalco

Jamalco is a 50/50 joint venture Alumina refining company owned by the Government of Jamaica and Alcoa Minerals of Jamaica LLC. In 1970 Alcoa commissioned, a 500,000 ton per year alumina refinery in Halse Hall, Clarendon, with one of its most outstanding features being a sealed tailings impoundment pond (residue disposal area) which became the standard and hallmark for red mud management and disposal in Jamaica.

While Jamalco pioneered the use of sealed tailing impoundment the parent company Alcoa has over time devoted significant resources to Research and Development in the area of red mud management which have been implemented and recommended for Jamalco.

Between the last quarter of 2004 and 2007 the facility will be upgraded to produce 2.8 million tonnes of alumina annually. The mining, refining and port operations will be modified in order to facilitate this upgrade. The mining and residue handling operations will also be upgraded to meet the refineries increase demand for bauxite and residue disposal storage space respectively. The entire Jamalco operation currently employs approximately 600 persons and is managed by Alcoa Minerals of Jamaica for the joint venture.

Jamalco is a zero discharge facility since all the water collected from the plant site or the residue system is impounded within the disposal area for re-use in the plant. The facility generates 1.1 tonnes of red mud residue for every ton of alumina produced. Presently there are four active residue areas covering 214 hectares.

1.1.2 RDA #1

The proposed development site, RDA #1, was commissioned in 1972 and was constructed to meet Jamalco's internal standards as well as international standards for sealed impoundments. RDA #1 comprises 45 hectares with dimensions of approximately 1,332 ft in width, 1,652 ft in length, with an existing perimeter dyke elevation of 195 ft. The area has not received red mud residue since approximately 1980, but has been used primarily as a cooling pond and for storage of bauxite rejects (oversized materials primarily limestone) and as a surge pond for rainfall runoff. Figure 1-1: Regional Map – Project Location above shows the location of the project area.

Figure 1-1: Regional Map – Project Location

RDA #1 was constructed as a, clay lined impoundment (See Figure 1-2: RDA #1 Step-in-Dyke General Layout) with compacted clay impervious seal on both the bottom and the existing main embankment which makes up the perimeter dyke wall. On the base of RDA #1, the compacted clay impervious seal is approximately 1.5 ft thick and measures approximately 13 ft thick on the embankment sides (See Figure 1-3: RDA #1 Cross-Section).

Since being commissioned in 1972, RDA #1 has not experienced any negative environmental impacts, structural failures or any unusual incidents that would detract from its integrity. The Jamalco facility, along with its RDA's have been meticulously operated and maintained in keeping with the exacting requirements and standards of Alcoa. RDAs # 3 and 4 have been recently upgraded, with dyke walls elevated by an additional 20ft to allow for increased capacity. The RDA's are located atop dry alluvium soil with an estimated 30-40 ft of clay before limestone and the associated limestone aquifer are encountered. The limestone aquifer is the principal source of groundwater in the Clarendon area.

Figure 1-2: RDA #1 Step-in-Dyke General Layout

Figure 1-3: RDA #1 Cross-Sections

1.2 The Proposal

It is proposed to install a step-in dyke and the necessary pipe work at RDA#1 to allow for the implementation of a slope stacking operation which will increase the volume of residue that can be safely stored in a smaller area than presently being used. A step-in dyke is basically a smaller dyked area located within a larger dyke. Construction of this step-in dyke would enable Jamalco to create additional volume for 6 months storage of residue based on a production level of 1.32 Million tonnes of Standard Grade Alumina and also to utilize critical storage space prior to the start up of the recently permitted expansion activities.

Jamalco proposes to install an earthen step-in dyke at its Residue Disposal Area (RDA) #1 with a total area of 19.23 hectares. A 19.95 hectare portion of RDA #1 will continue to operate as a cooling and surge water pond (See Figure 1-4 below). It is proposed that the step in dyke will be constructed by displacing existing stacked residue with reject fill material (primarily limestone) which is presently located in the southern section of RDA #1 (see Figure 1-5 below). A 0.28 hectare section of the southeast corner of RDA #1 will be reserved for continued use as reject material storage (Summarized in Table 1-1 below)

Figure 1-4: Cooling Pond Section of RDA #1

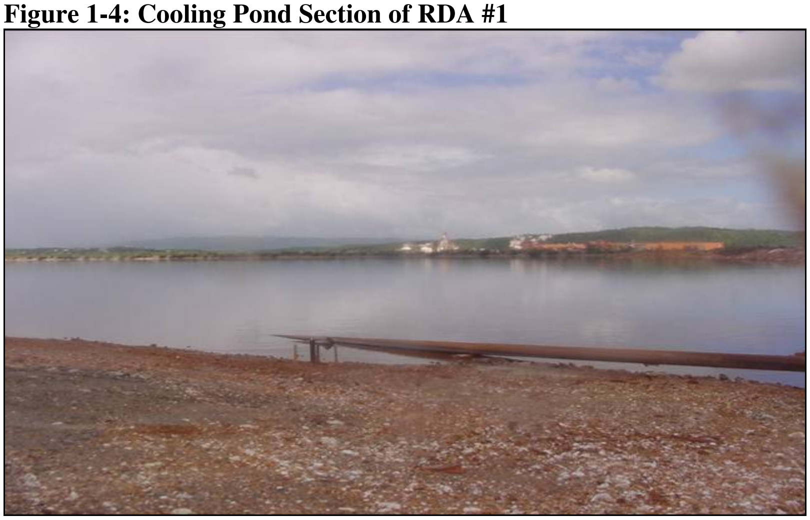


Table 1-1: Site Specification Summary

Total Area of RDA #1	45 Ha
Proposed stacked area	19.23 Ha (2070467 sq. ft.)
Area to remain cooling pond	19.95 Ha
Area for drainage channels, etc	2.9 Ha
Proposed reject material storage area	0.28 Ha (30141.27 sq. ft.)

Figure 1-5: Bauxite Rejects and Caustic Contaminated Materials in RDA # 1

Construction of the step-in dyke is basically an earth movement project where heavy equipment will be utilized to manipulate the existing bauxite rejects into machine compacted dyke walls. The barrage and dyke fill will be machine compacted with a minimum of six (6) passes of a D6 tractor in lifts of 12 inch maximums.

1.2.1 Design Concept

This step-in dyke concept was developed considering the following conditions:

1. The factor of safety of the existing Perimeter dykes, considering slope stability, was not to be reduced below Alcoa's requirements because of additional loading caused by the "step-in-dyke" and the "dry stack" residue deposits.

2. Obtain 6 months of storage of thickened residue, dried to 60% Solids (weight basis).

3. The proposed concept could be designed to provide a facility that would comply with Alcoa Standards for the Storage of Bauxite Residue.

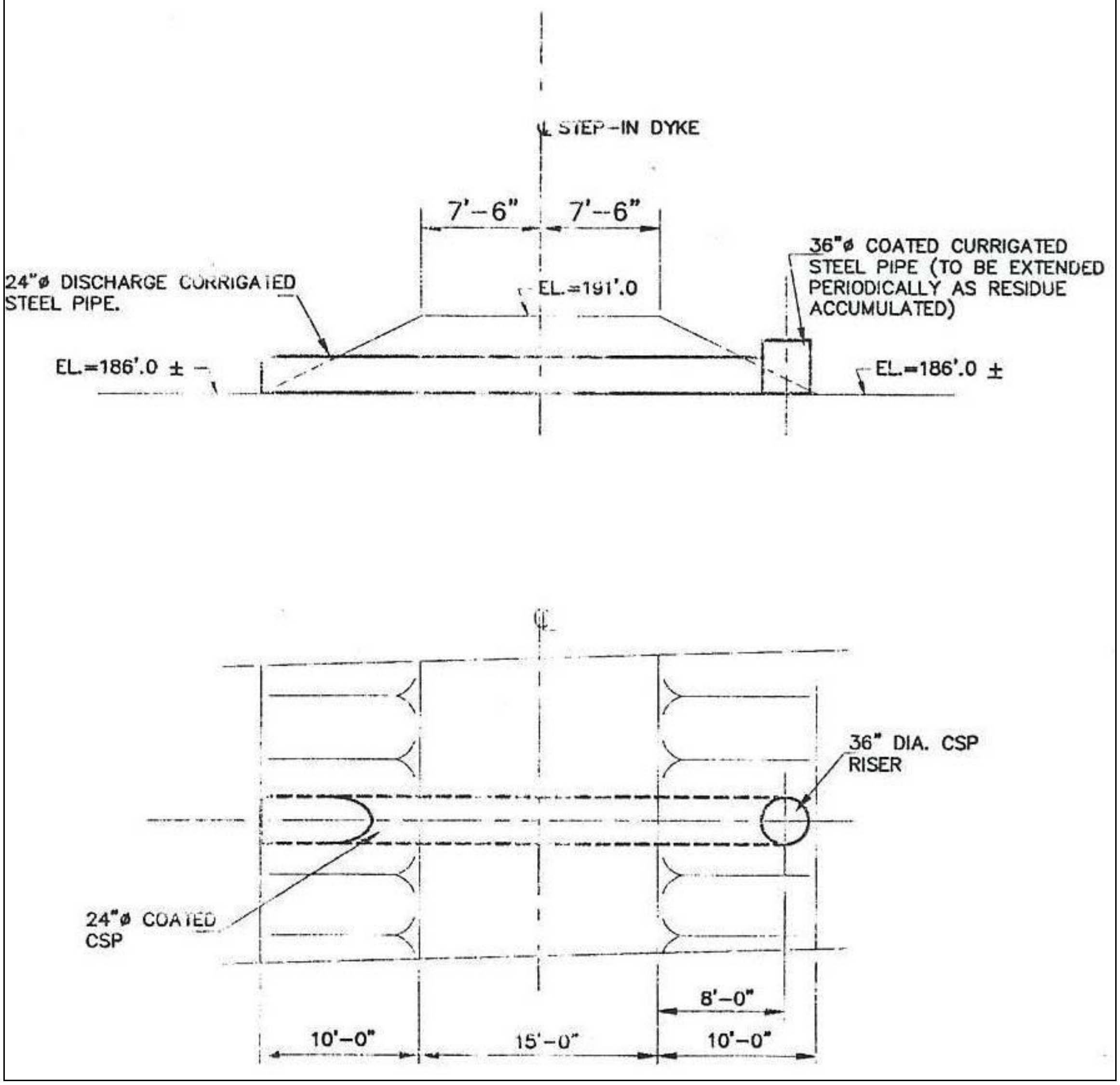
4. Storm runoff from the "dry stack" to be managed consistent with Alcoa standards.

5. The surface area of the cooling pond would be as large as possible.

The Step-in-dyke and residue slope have been designed to provide as-built factors of safety of about 1.3 for end of construction conditions, using available residue properties and assumed properties for the bauxite reject, the Conceptual Design was developed considering the formation of a "Dry Stack" with 3% slopes, and the residue achieving 60% solids upon draining and drying. These values are considered achievable considering the use of the existing paste thickener (a vessel used for liquid / solid separation), Jamalco's climate, and the rotation of this disposal area with other available areas for residue deposition.

A total of 19 catch basins are proposed for the perimeter of the step-in dyke for collection and discharge of liquids from within the step-in dyke to the proposed main drainage channel located on the outside. This drainage channel will drain the decant and stormwater to the cooling pond. The catch basins comprise 36 inch diameter coated corrugated steel pipe risers connected to 24 inch diameter corrugated steel discharge pipe (as depicted in Figure 1-6: CATCHMENT BASIN DETAIL). The 36 inch diameter risers will be extended periodically as residue accumulates in the area.

Figure 1-6: CATCHMENT BASIN DETAIL



In RDA #1, the bottom elevation (top of impervious seal) is at 132 ft, with existing mud levels at approximately 182 ft (mud depth approx. 50 ft). The existing perimeter dyke crests at an elevation of 195 ft and the proposed step-in dyke is designed for a maximum elevation of 191 ft (keeping in mind that the centreline of the step-in dyke is located approx. 105 ft from the centreline of the perimeter dyke – See Figure 1-3). With existing mud levels at 182 ft, it is anticipated that there will be heaving of material when the bauxite rejects are placed. This heaved material will be excavated and used to form the drainage channel that will surround the step-in dyke. Horizontal wick drains (See Figure 1-7: Drainage Layout) will be located at an elevation of 186 ft covered by approximately

Figure 1-7: Drainage Layout

2 ft of sand, to remove moisture from the stacked residue and channel it to the drainage channel and ultimately the cooling pond. The step-in dyke will be constructed from compacted reject fill and capped with a 12 inch thick layer of coarse marl. The potential for dyke erosion will be minimised through constructing to design specifications, active monitoring of the structures and proper maintenance of the drainage system.

The maximum load possible in the internal dyke will not exceed the designed capability of the external dyke wall. This is inclusive of 50 year rainfall events and seismic activity causing horizontal acceleration equal to a 1:500 year seismic activity. In the unlikely event that the step-in dyke is breached, the materials contained within will flow by gravity towards the cooling pond contained within RDA #1 and would still not pose a threat to the environment or humans.

Presently, mud is pumped to the RDA's via a 20 inch diameter discharge pipe from the existing paste thickener – located towards the south western end of RDA#1 (See Figure 1-8). The proposed project will tie into this line just outside the thickener area and continue to the step-in dyke where it transitions into a 16 inch diameter corrugated steel pipe (See Figure 1-9: Preliminary Piping Layout). It is proposed that there will be two (2) mud drop locations which will be served by the 16 inch pipe. These locations are basically in the centre of the step-in dyke and represent the high point from which the area slopes at 3% in all directions.

Figure 1-8: Bauxite Rejects in Foreground with Paste Thickener in Background

Figure 1-9: Preliminary Piping Layout

There will be rotation of residue between the step-in dyke in RDA #1 and the other RDA's to insure that residue placed in the area will have the proper conditions and sufficient time to attain 60% solids. The project is expected to create more than 750,000 cubic metres of storage space. This method of stacking is highly recommended within the bauxite and alumina industry, based on its safety and environmental track record and will provide valuable data, which will assist in the implementation and operation of the technology on a larger scale in the proposed RDA #5.

The activities proposed for RDA#1 encompass all three phases of the development:

- pre-construction
- construction, and
- operational phase

i. Pre-Construction

Preconstruction activities for this proposed project will involve the following activities:

- Apply for and receive all relevant permits and licenses
- Mobilization of equipment for earth works

ii. Construction Phase

Construction Activities will include:

- Sorting of stockpiled bauxite reject
- Movement of materials using heavy equipment
- Shaping and compaction of the materials to form the step-in dyke walls and drainage channel
- Proper location and placement of all components of the design (piping, wick drains, catch basins, etc.)

- Active monitoring for design, environmental and worker safety concerns

iii. Operational Phase

During the operational phase, the following will take place:

- Residue slurry from the plant will be thickened in the paste thickener at the RDA, and pumped to the two (2) mud drop locations in the middle of the step-in dyke
- Liquids will be drawn off the slurry via the wick drains, catch basins and by evaporation
- Liquids collected through the drains and basins will be channelled to the cooling pond for storage and for reuse in the plant
- The stacked residue will dry to a consistency of approximately 60% solids
- The dykes, both step-in and perimeter will be inspected and maintained in keeping with Alcoa's standards and all government rules and regulations

1.2.1.1 Slope Stability Analyses

1.2.1.1.1 METHOD OF ANALYSES

Using the Geotechnical parameters assigned to the residue and soil layers, slope stability analyses were performed to determine the factors of safety of the Step-in-Dyke, Thickened Tailings Slope, and the Perimeter dyke. The factors of safety determined by slope stability analyses are the ratios of the sum of resisting forces on a soil mass (forces that resist displacement) to the sum of the driving forces (forces tending to cause displacement of the soil mass).

In slope stability analyses, trial failure surfaces are defined and the resisting and driving forces are calculated for the soil mass within the trial failure surfaces. These calculations include the geometry of the soil / residue layers and slope surface, geometry of the trial failure surfaces, the shear strengths of the soil and residue layers, unit weights of the layers, the geometry of the water table and forces on the trial failure surface due to hydrostatic pressures. The factor of safety is calculated for numerous trial failure surfaces in order to find the trial failure surface with lowest factor of safety. The trial failure surface with the lowest factor of safety defines the soil and residue mass that has the greatest tendency to undergo failure or displacement.

The slope stability analyses were performed with the aid of a computer program that is designed to model the dyke, slope, soil layers, Geotechnical parameters, ground water surface, hydrostatic pressures, and to make the calculations for numerous trial failure surfaces. Using this computer program, a grid routine was first used to calculate the minimum factor of safety for trial failure surfaces over a large field. After the grid routine was completed, an incremental step search routine was used to find the failure surface with the lowest factor of safety. A normal slope stability calculation would consider over 300 trial failure surfaces and define the geometry (coordinates of the arc center and radius) of the trial failure surface by a dimension of about 2 feet.

The Modified Bishop Method was used to evaluate the slope stability of the proposed dykes. From experience, the Modified Bishop Method has provided more realistic evaluations of residue slopes than the Modified Janbu Method. Slope stability analyses of existing slopes of residue by the Modified Janbu Method indicated minimum factors of safety of about 0.8, where the Modified Bishop Method provided factors of safety near 1.0, a more realistic value for a marginally stable slope.

1.2.1.1.2 Step–In Dyke and Thickened Residue Slope

Slope stability analyses were performed on different designs of the Step-in-dyke and thickened residue slope to determine a configuration that would provide adequate factors of safety to preclude slope stability failures. Stability analyses were performed on Step-in-dyke configurations using short-term strength parameters to simulate end of construction loading conditions. Since the in-situ and thickened residues are fine-grained materials with very low permeability, end of construction considered pore pressure increases proportional to the additional loading by the thickened residue deposits. Based upon these analyses, the Step-in-dyke with crest at Elevation 191 Feet, situated on a foundation fill 64 feet wide, should provide a stable configuration that will fulfill Alcoa's Standards.

The results of the stability analyses for end of construction conditions for the crest of the dyke at Elevation 190 Feet shows the minimum factor of safety was determined to be 1.39 for a trial failure surface with the arc center located over the foundation fill with a radius of 46 Feet. This type of failure surface is typical for dykes constructed on thick deposits of materials with low strength values.

The Step-in-dyke and foundation fill configuration was also evaluated for long term and seismic loading conditions. The arc centers of the trial failure surfaces for these analyses were similar to the end of construction condition with the exceptions that the radii and factors of safety differed. For the long term, static analyses, the radius of the arc was 49 Feet and the factor of safety was determined to be 2.01. For the seismic loading conditions, the radius of the arc of the trial failure surface was 50.3 Feet and the minimum factor of safety was determined to be 1.93. These values fulfill Alcoa's Standards for long term and seismic loading conditions.

Based upon an evaluation of the factors of safety for the crests of the Step-in-dyke constructed at Elevation 190 Feet (F.S. = 1.39) and Elevation 194 Feet (F.S. = 1.01), a Step-in-dyke with crest constructed to Elevation 191 Feet would provide a short term factor of safety of about 1.30, the requirement as stated in Alcoa's Standards. The factors of safety of the Step-in-dyke with crest at Elevation 191 Feet, considering long term and seismic loading conditions, will also fulfill Alcoa's Standards.

In summary, the stability analyses of the Step-in-dyke are summarized as follows:

Table 1-2: Summary of Stability Analysis on Step in Dyke

Condition	Arc Center	Radius	Safety Factor	Alcoa Standard
End of Construction	Over Berm, El. 200 Ft.	46 Ft.	1.39	1.3
Long Term, Static	Over Berm, El. 200 Ft.	49 Ft	2.01	1.5
Long Term w/ Seismic	Over Berm, El. 200 Ft	50.3 Ft	1.93	1.0

1.2.1.1.3 PERIMETER DYKE AND STEP-IN-DYKE

Important to the planning for the thickened residue disposal facility on RDA#1 is the effect that additional residue might have on the slope stability of the perimeter dykes that contain the impounded residue. The additional residue disposal facilities (step in dykes, residue slope) will be designed in such a manner that they are not too close to the perimeter dykes in order to ensure that the stability of the perimeter dykes are not reduced. The minimum set back distance from the perimeter dyke to the step-in-dyke should accommodate the drainage channels to convey storm runoff to the Cooling Pond. To accommodate the drainage channels along the East and West perimeter dykes require a drainage channel with a 60 Feet wide base, with the elevations established at the required elevations. To accommodate the drainage channels, the minimum centerline to centerline set back distance from the perimeter dyke to the Step-in-dyke was determined to be 105 Feet. Slope stability analyses were performed on the combination perimeter dyke and step-in-dyke with a set back distance of 100 Feet, slightly more conservative than the required set back for the drainage channel.

Since the perimeter dyke has been in place for more than 36 years, stability analyses were performed using long term strength parameters for the soils in the perimeter dyke and short term strength parameters for the thickened residue deposits. Based upon this analysis, the minimum factor of safety for the perimeter dyke was determined to be 1.49 for a trial failure surface encompassing only the perimeter dyke. This Factor of Safety essentially fulfills Alcoa’s Standard for the stability of the containment dykes of bauxite residue storage facilities at 1.5. Larger trial failure surfaces that would include the step-in-dyke resulted in factors of safety on the order of 2.0, well above Alcoa’s minimum requirement. Essentially, this analysis indicates that the set back distance of 100 Feet is sufficient so as not to cause a reduction of the slope stability of the perimeter dykes.

A slope stability analysis was performed on the combined perimeter dyke and step-in-dyke configuration considering the additional loading associated with an earthquake. A “pseudo-static” slope stability analysis was performed on this dyke configuration with the additional loading associated with a horizontal acceleration of 0.105 gravity (G). Studies have shown that that a horizontal acceleration of 0.105 G would be associated with a seismic event with a return period of about 500 years at the Clarendon Works. For this analysis, the long term strength parameters were used for the perimeter dyke, and the total strength parameters were used for the residue materials. This analysis indicated that the minimum factor of safety was found to be 1.34 and the trial failure surface encompasses only the perimeter dyke. A much larger trial failure surface, that includes the step-in-dyke, was computed to have a minimum factor of safety of 2.12. These factors of safety, considering a design seismic event, are greater than the minimum of 1.0 as stated in Alcoa's Standards. Therefore, this configuration of perimeter dyke and step-in-dyke fulfils Alcoa's requirements for slope stability.

AREA SUMMARY:

Total Area of Residue Lake No. 1 (El. 195 +/-)	45 Ha.
Cooling Lake Area (W.S. @ El. 188.0 Ft.)	19.95 Ha.
Area of proposed reject fill area	0.3 Ha.
Area of Proposed TTD Facility	19.23 Ha.
Area for Drainage Channels, Etc.	2.9 Ha.
Overall Dimensions:	Width ~ 1332 Ft
	Length ~ 1652 Ft.
Step-in-dyke:	Crest Elev. 191 Ft.
	Width 15 Ft.
	Slopes: 2 H. to 1 V.
Foundation for Step-in-dyke	Surface Elev. 186 +/- Ft
	Width 32 Ft. Left & Right of C/L
Residue Surface (3 % Slope)	Elev. 190 Ft. @ Step-in-dyke
	Elev. 209 Ft. @ Center of Stack
Residue Storage Capacity	750,000 cubic meters

1.2.1.2 Environmental Management

The consideration of a step-in dyke serves to do more than just afford Jamalco the opportunity to store residue materials for an additional six (6) months; it also represents a concerted effort by the company to include real environmental management strategies in its operations. This includes:

Land Conservation – Jamalco has RDA's covering 214 hectares of land. While it is agreed that at least one additional RDA must be constructed within the lifespan of the refinery, it is of great environmental benefit to identify areas within the existing framework where additional capacity is located and maximize the use of existing footprints in lieu of building new areas.

Recycle/Reuse – to further reduce its dependence on well water and further depletion of resources, Jamalco incorporates a closed-loop system as a feature of its operations. This involves the collection and storage of all process water and stormwater generated on the site and making them available for reuse in daily plant operations.

DESCRIPTION OF THE ENVIRONMENT

2 Description of the Environment[i]

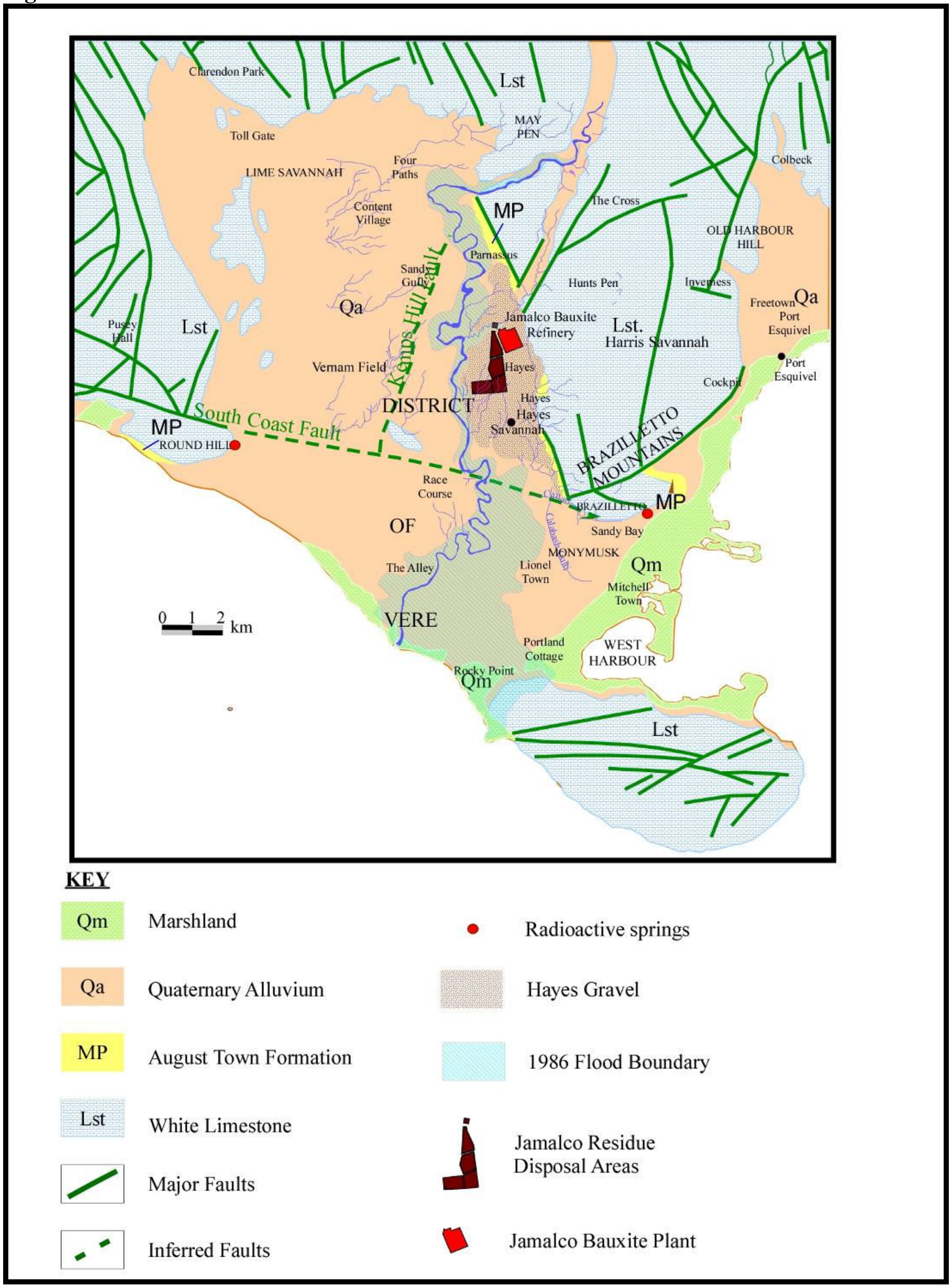
2.1 Geotechnical Analysis and Soil

2.1.1 Modification of Residue Disposal Area No. 1

2.1.1.1 Geology

The area under consideration is in the district of Halse Hall, in southern Clarendon. It can be located on the 1:50,000 topographic Sheet 17 (metric edition) at co-ordinates 245385 (Figure 2-1). Geomorphologically, the area lies on the gently sloping alluvial fan of the Rio Minho. The apex of the fan, at May Pen, lies at an altitude of about 70 m asl, although the present river bed is incised into the fan, being at about 50 m asl at May Pen. From May Pen the river flows over a straight line distance of about 20 km to the sea. In the vicinity of Hayes, at the confluence with Webbers Gully, the river bed lies at an altitude of 38 m asl, while the plant and RDAs at Hayes, east of the river, lie on an old, dissected terrace remnant at elevations of 45 to 50 m asl with flat to gently undulating topography. The terrace remnant forms a high spot between Webbers Gully, which borders the site on the north and northwest before entering the Rio Minho, and Cannons Gully which extends along the eastern side of the site, draining to the south at Bog and separating the site from the limestone plateau of Harris Savanna.

Figure 2-1: GEOLOGY MAP OF SOUTHERN CLARENDON



South of Hayes the alluvial fan flattens out to form what have been called the Vere Plains (Figure 2-1). Elevations over this area are low and the water table is relatively high, so that settlements such as Lionel Town and Alley are frequently flooded.

The rocks of the area consist of two main units. The various unconsolidated alluvial sediments, part of the Rio Minho fan complex, rest on limestone bedrock with a highly irregular surface.

2.1.1.1.1 The Alluvial Fan Complex

The alluvial fan contains a wide range of more or less unconsolidated siliciclastic sediments. The top of the original fan, which has been extensively dissected, is preserved only in the neighbourhood of Halse Hall and Hayes (Figure 2-1). The sediments underlying the plant and RDAs make up this remnant and have been called the Hayes Gravels. The gravels range in particle size from pebbles and cobbles to silt and range in thickness from zero to 5-6 m in the north to 14-15 m in the south of the plant area (Figure 2-2). Within the rest of the eastern part of the fan the sediments are very variable, although generally finer grained than the Hayes gravels, and with alluvial clay lenses.

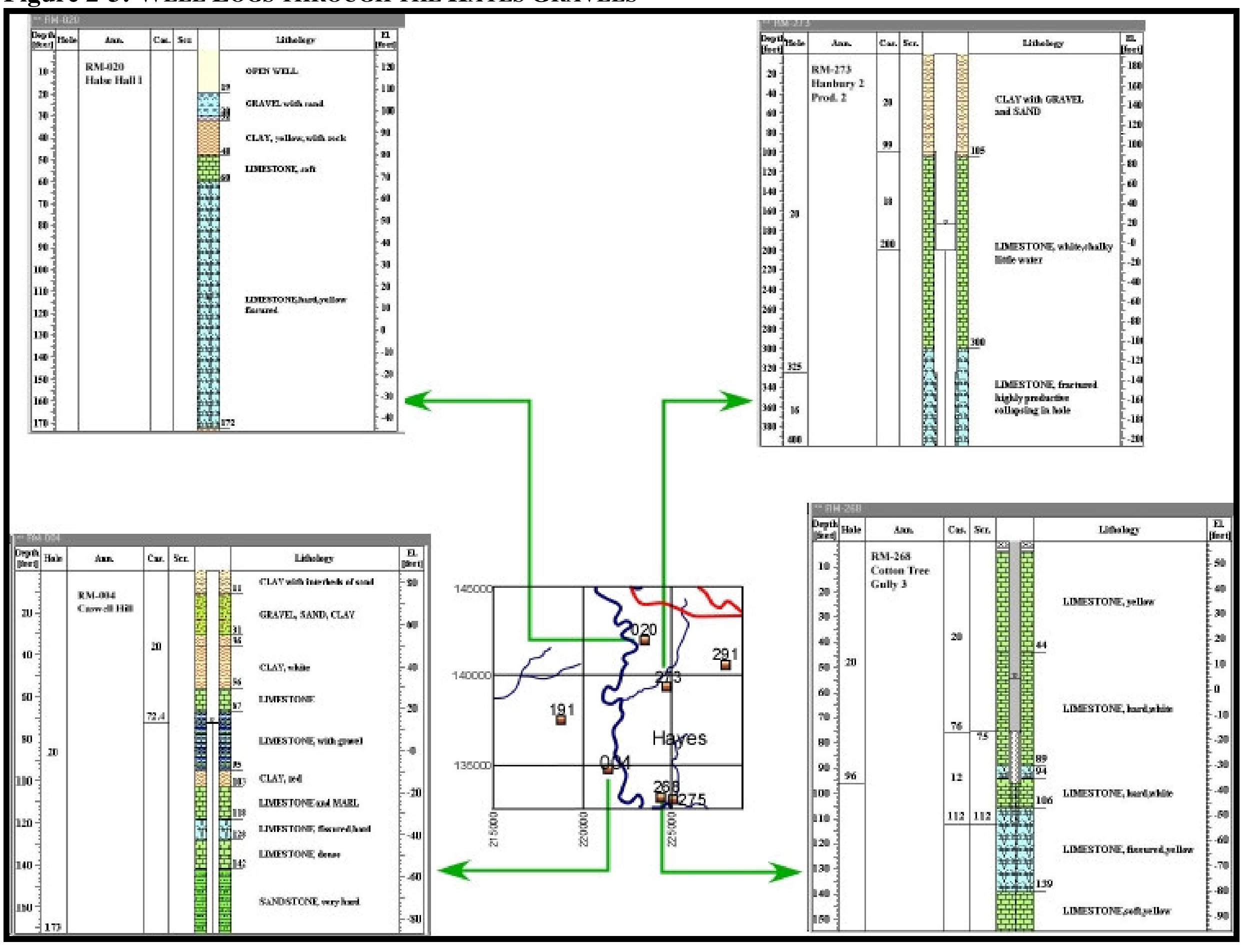
Figure 2-2: Hayes Gravel at Site of Proposed Residue Disposal Pond[1]

[1] *(Source:* http://www.geocities.com/kkaranjac/)

2.1.1.1.2 The Limestone Bedrock

The sediments of the Hayes Gravels are separated from the limestone bedrock by an irregularly developed layer of clay (Figure 2-3), at least in part being a weathered palaeosol developed on the limestone surface.

Figure 2-3: WELL LOGS THROUGH THE HAYES GRAVELS



The limestone has been divided by the Mines and Geology Division into the lower, relatively pure Newport Limestone (Mn on Geological Sheet 16) and the upper, less pure August Town Formation (MP). The Newport limestone consists of moderately well-bedded, compact limestones, containing frequent rubbly layers, while the August Town Formation consists of impure limestones with irregularly interbedded marly and clayey layers. These rocks are exposed along the eastern side of the alluvial fan, less than a kilometre east of the plant site.

2.1.1.2 Geotechnical Characteristics

2.1.1.2.1 The Alluvial Fan Complex

Table 2-1 below, adapted from an earlier report (Conrad Douglas & Associates) indicates the characteristics of materials that should be expected in the Hayes Gravels. In summary the gravels should be pervious to very pervious with good to excellent shear strength, of negligible compressibility and good to excellent workability as a construction material, as utilized in the construction of the RDA dykes (Figure 2-4) Alluvial materials sourced from other places in the Rio Minho fan should also be well suited for construction after washing and grading.

TABLE 2-1: PROPERTIES OF VARIOUS SOIL GROUPS (ADAPTED FROM CONRAD DOUGLAS & ASSOCIATES EIA)

Typical Names of Soil Groups	Group Symbols	Important Properties			
		Permeability when Compacted	Shearing Strength when Compacted and Saturated	Compressibility when Compacted and Saturated	Workability as a Construction Material
Well-graded gravels, gravel sand mixtures, little or no fines.	G.W.	Pervious	Excellent	Negligible	Excellent
Poorly graded gravels, sand mixtures, little or no fines.	G.P.	Very pervious	Good	Negligible	Good
Silty Gravels, poorly graded gravel-sand-silt mixtures.	G.M.	Semi-pervious to impervious	Good	Negligible	
Clayey gravels, poorly graded gravel-sand-clay mixtures.	G.L.	Impervious	Good to fair	Very low	Good
Well-graded sands, gravelly sands, little or no fines.	S.W.	Pervious	Excellent	Negligible	Excellent
Poorly graded sands, gravelly sands, little or no fines	S.P.	Pervious	Good	Very Low	Fair

Typical Names of Soil Groups	Group Symbols	Important Properties: Permeability when Compacted	Shearing Strength when Compacted and Saturated	Compressibility when Compacted and Saturated	Workability as a Construction Material
Silty sands, poorly graded sand-clay mixtures	S.M.	Semi-pervious to pervious	Good	Low	Fair

Figure 2-4: PHOTO OF AN RDA DYKE

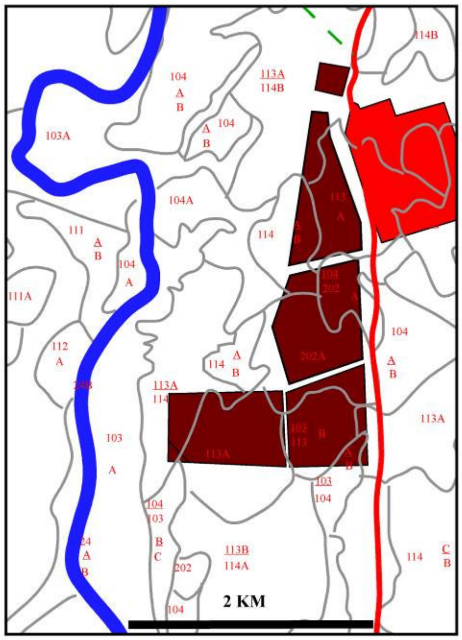
The limestone bedrock of the area may be thickly stratified and massive, but contains frequent zones of less competent, rubbly and marly limestone. There may be a case-hardened layer up to several metres thick, over the softer limestone, where it has been indurated from weathering. The rubbly zones are frequently the result of brecciation associated with faults. Solution features consist of joints widened by solution and there may be cave development. Most large features in the limestones of southern Clarendon and St. Catherine consist of vertical shafts with widening laterally into extensive cave complexes in some areas, such as Portland Ridge (Fincham, 1997).

In summary the bearing capacity of the limestone bedrock is good, although for large structures the presence or otherwise of caverns or fissures at shallow depth should be ascertained.

2.1.1.3 Soils

The soils of the Hayes region are intimately associated with the alluvial deposits of the Rio Minho Fan Complex. Figure 2-5 indicates the distribution of the different soils of the area. In Figure 2-5 the classification follows that used by the Ministry of Agriculture, the symbol group representing the soil type and steepness of slopes.

Figure 2-5: SOILS MAP OF HAYES, CLARENDON



SOIL TYPES

24	Agualta Sandy Loam
103	Agualta Loam
104	Agualta Clay
111	New Yarmouth Loam
112	New Yarmouth Clay Loam
113	Halse Hall Clay
114	Halse Hall Clay (Red Phase)
202	Rhymsbury Clay

SLOPE CATEGORIES

A	0 - 2 Degrees (0% - 5%)
B	2 - 5 Degrees (5% - 11%)
C	5 - 10 Degrees (11% - 22%)

2.1.1.4 Mineral Resources

The only mineral resources of note are the limestone forming the Harris Savanna plateau, which has been used as a source of marl and crushed stone from the disused quarry near Halse Hall, and the sand and gravel extraction industry in the bed and flood plain of the Rio Grande. The Hayes Gravels contain small pebbles and occasional larger cobbles of the semiprecious stone jasper (Porter et al. 1982; Porter, 1990). Rarely fragments of silicified wood may be collected.

2.2 Air Quality and Weather

2.2.1 Air Quality

2.2.1.1 Air Quality Management Program

Jamalco has developed and maintained an Air Emissions Management Program to ensure compliance with the Natural Resources Conservation Authority (NRCA) ambient air quality standards, pending air quality regulations, Alcoa Air Emissions standards as well as to conform with ISO 14001 requirements and the company's EHS policy.

The Clarendon Alumina Works (CAW) facility which is the major source for atmospheric emissions is approximately 165 feet above mean sea level (msl) and is surrounded by a mix of undeveloped and residential land uses. The terrain elevations rise up to over 400 feet above msl at approximately 2000 feet to the east of the refinery.

2.2.1.1.1 Meteorological Features

The facility operates an on-site meteorological tower, which is located at the center of the refinery. Hourly surface observations are monitored which includes:

- Wind speed
- Wind direction
- Air temperature
- Barometric Pressure
- Ground temperature
- Precipitation and,
- Standard deviation of the Wind direction.

Analysis of data derived from the onsite tower indicates that predominantly there is a strong occurrence of light winds from the northeast, which is typical for areas within this tropical latitude. See wind rose, which shows a joint frequency distribution based on the wind speed and direction for each hour of the year.

2.2.1.1.2 Air Emissions

The primary emission that may be released from the Residue Disposal Areas is Particulates.

2.2.1.1.2.1 Particulates

Particulate emissions may be associated with the Residue Disposal Area (RDAs) should the surface of these lakes become dry.

Proven particulate control and dust suppression strategies have been employed at Jamalco facilities, which have significantly minimized particulate and fugitive dust emissions. In the case of the RDA's, an irrigation regime consisting of sprinkling or other method of water transfer will be implemented and utilized to mitigate fugitive dust should it be formed, particularly with the prospect of reducing residue to 60% solids.

The major source of fugitive dust at Jamalco is from open areas (uncovered with grass or unpaved) particularly those that have vehicular traffic and these areas also have dust control programs in place.

2.2.1.1.2.2 Ambient Air Quality Monitoring

Jamalco maintains a stringent Total Suspended Particulate (TSP) monitoring program. There are seven (7) permanent TSP monitoring stations; these are located in communities around the refinery, at the RDAs, Breadnut Valley and at the Rocky Point Port facility.

Monthly monitoring reports are submitted to the regulatory agencies through the Jamaica Bauxite Institute (JBI), which have responsibility to conduct environmental monitoring of the Bauxite & Alumina Industry.

Calibration checks are conducted on the monitors on a scheduled basis and are done within applicable test methods and manufacturers specifications.

2.3 Weather

2.3.1 Regional Setting/Sphere of Influence

2.3.1.1 Refinery Area

Jamalco's refinery and RDA's are located in Halse Hall, Clarendon between the New Bowens settlement to the north, Cornpiece to the south, the Braziletto Mountains to the east and its red mud lakes to the west. The operations have been in their present location since 1972 and is the largest industrial facility in the general area.

Major settlements in the area of the plant include:

- Cornpiece
- Kemps Hill
- Savannah
- Hayes Newtown
- New Bowens
- Race Course
- Hayes
- Rocky Point
- Raymonds
- Lionel Town
- Halse Hall
- Alley

2.3.1.2 Local Climate

South Clarendon has a dry climate. With poor surface drainage and extremely permeable soils, the area is heavily dependent on catchment of rainfall and often suffers from drought.

2.3.2 Rainfall

Rainfall totals for the southern Clarendon region are low. Over the period 1983 – 2003 the area averaged 988.1 mm (38.9 inches) of rainfall with a monthly average of 83.1 mm (3.27 inches). The area experiences its wettest period during the months of May-June (90 – 163 mm) and August-November (89 – 154 mm).

This generally low rainfall is responsible for the aggressive and well maintained irrigation regime employed at the Jamalco refinery to manage the real potential for fugitive dust emissions.

Table 2-2: ANNUAL RAINFALL - INCHES. JAMALCO REFINERY

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR'S TOTAL	MONTHLY AVERAGE
1983	0.44	6.68	0.40		2.54	6.48	0.06	6.36	1.42	5.29	2.01	0.16	31.84	2.89
1984	0.52	2.17	5.39	0.58	5.37	3.62	2.13	1.76	5.88	3.86	1.75	0.07	33.10	2.76
1985	0.14	-	-	-	-	-	-	2.45	1.86	8.62	7.74	1.12	21.93	1.83
1986	1.95	0.78	1.05	3.53	-	22.56	1.36	0.52	3.36	8.87	2.01	0.78	46.77	3.90
1987	1.86	0.28	0.16	6.90	6.48	1.31	1.70	3.04	1.46	17.38	5.52	3.10	49.19	4.10
1988	0.10	0.63	1.63	2.20	5.62	1.59	1.65	8.70	8.81	1.24	6.53	1.81	40.51	3.38
1989	2.99	1.60	3.01	0.74	4.64	1.40	0.21	1.61	7.15	0.98	1.22	0.36	25.91	2.16
1990	2.04	0.79	1.78	2.51	1.43	2.11	2.26	0.60	1.33	6.59	7.68	1.80	30.92	2.58
1991	0.39	0.26	1.58	1.46	7.52	0.37	1.66	1.67	2.36	2.24	3.37	0.37	23.25	1.94
1992	0.21	2.22	0.38	1.61	9.11	2.95	0.47	2.14	4.36	2.82	1.24	0.22	27.73	2.31
1993	3.60	3.54	4.62	7.89	27.45	0.75	1.82	0.75	4.76	0.68	3.59	7.27	66.72	5.56
1994	1.74	0.07	2.62	3.29	4.10	0.00	1.70	4.10	3.22	0.58	13.85	0.70	35.97	3.00
1995	2.75	0.80	2.31	5.09	6.19	3.05	1.13	13.08	8.32	17.70	0.87	1.83	63.12	5.26
1996	1.40	0.17	0.90	0.94	0.60	0.92	2.17	4.40	6.12	6.83	7.22	0.03	31.70	2.64
1997	1.03	0.89	1.26	1.36	0.85	7.88	0.33	0.64	5.70	6.47	3.14	2.15	31.70	2.64
1998	0.74	1.54	8.55	2.53	0.67	1.14	4.96	4.15	11.36	5.71	2.21	4.66	48.22	4.02
1999	0.87	3.10	6.93	0.93	2.43	3.67	2.96	1.75	13.63	11.73	8.87	1.99	58.86	4.91
2000	0.77	1.75	1.65	3.47	1.28	0.85	2.47	2.00	9.28	3.80	1.05	6.19	34.56	2.88
2001	1.75	0.35	0.49	1.48	6.14	0.09	1.73	0.55	2.31	5.30	8.55	5.78	34.52	2.88
2002	3.27	1.81	2.39	3.80	20.05	6.68	0.34	0.47	22.48	6.04	0.94	1.60	69.87	5.82
2003	1.31	0.91	1.97	3.00	14.72	3.46	1.08	12.64	2.28	3.30	1.46	1.11	47.24	3.94
2004	1.07	0.16	0.24	0.16	1.07								2.70	0.54

Review of temperature data collected at the Jamalco refinery meteorological station for a period 1999-2003, indicates that the maximum temperatures range from 34.5 deg. Celcius to 31 deg. Celcius and that the low temperatures range from 24 deg. Celcius to 18.9 degrees. The intense and prolonged heat of this typically xerophytic environment combined with the low rainfall results in a dry and sometimes dusty environment, if no controls are in place.

Jamalco has a sprinkling and irrigation regime for exposed areas of the plant, which includes landscaping and irrigation of open spaces.

Table 2-3: TEMPERATURE - JAMALCO REFINERY

MONTHS	1999		2000		2001		2002		2003	
	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.
JANUARY	31.6	21.1	31.1	19.7	31.0	23.0	31.5	20.5	31.5	21.0
FEBRUARY	31.1	19.9	31.5	18.9	31.7	23.0	32.2	20.0	32.0	21.1
MARCH	31.5	20.8	31.8	19.1	31.4	20.2	32.7	19.9	32.3	21.4
APRIL	31.8	21.4	32.1	20.9	32.2	21.1	32.9	20.7	32.9	22.1
MAY	32.6	23.0	32.2	22.3	32.6	21.8	31.8	21.6	32.4	22.1
JUNE	32.6	23.6	32.6	22.7	33.3	22.7	32.2	22.3	32.1	22.9
JULY	33.4	23.5	33.8	22.7	33.5	23.5	32.9	23.0	33.4	23.1
AUGUST	33.8	24.0	33.7	23.2	33.8	23.5	34.4	23.3	34.0	23.0
SEPTEMBER	33.3	23.0	33.4	23.0	34.5	23.0	33.3	22.8	34.0	22.8
OCTOBER	31.9	21.7	33.9	22.5	33.3	22.4	33.4	22.7	34.0	229.0
NOVEMBER	32.2	21.8	33.5	21.9	31.2	21.2	33.3	23.1	32.8	22.6
DECEMBER	31.4	20.5	31.3	22.6	32.2	20.4	32.5	21.7	32.1	21.1

2.4 Water Resources

2.4.1 Hydrogeology

2.4.1.1 Hydrostratigraphy

The Clarendon Alumina Works (CAW) consisting of the bauxite/alumina plant and the Residue Disposal Areas (RDAs) are located within the parish of Clarendon on the south central coast of the island (Figure 2-6). The parishes of Clarendon and Manchester together form the Rio Minho Hydrologic Basin that consists of the Rio Minho, the Milk River and the Gut-Alligator Hole Watershed Management Units (Figure 2-7)

Figure 2-6: BASIN LOCATION

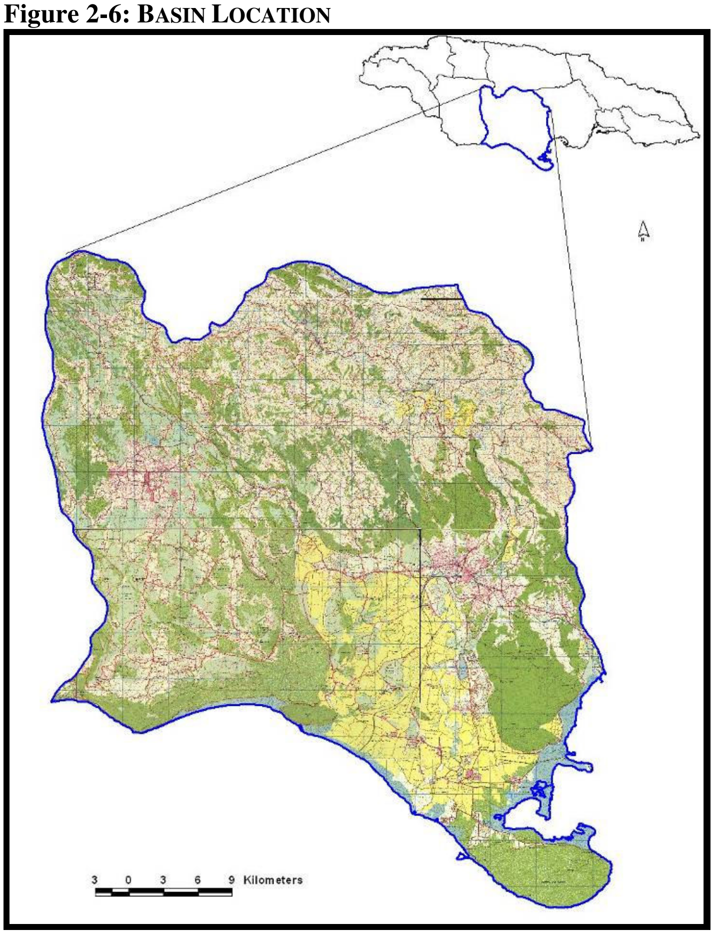
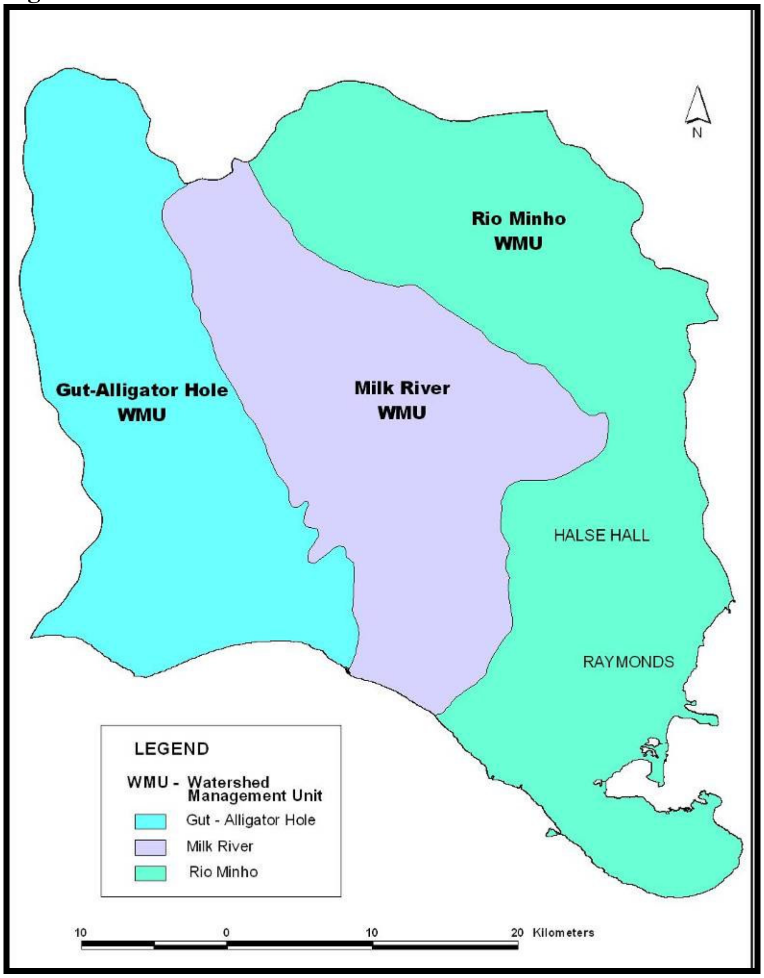


Figure 2-7: BASIN WATERSHED MANAGEMENT UNITS



The Rio Minho Hydrologic Basin extends over an area of 1,705 km^2 (Map 1). The Basin is subdivided into 3 sub-basins and 3 hydrostratigraphic units (Figure 2-8). Table 2-4 below summarizes the area for each catchment.

Figure 2-8: HYDROSTRATIGRAPHY MAP OF PROJECT AREAS

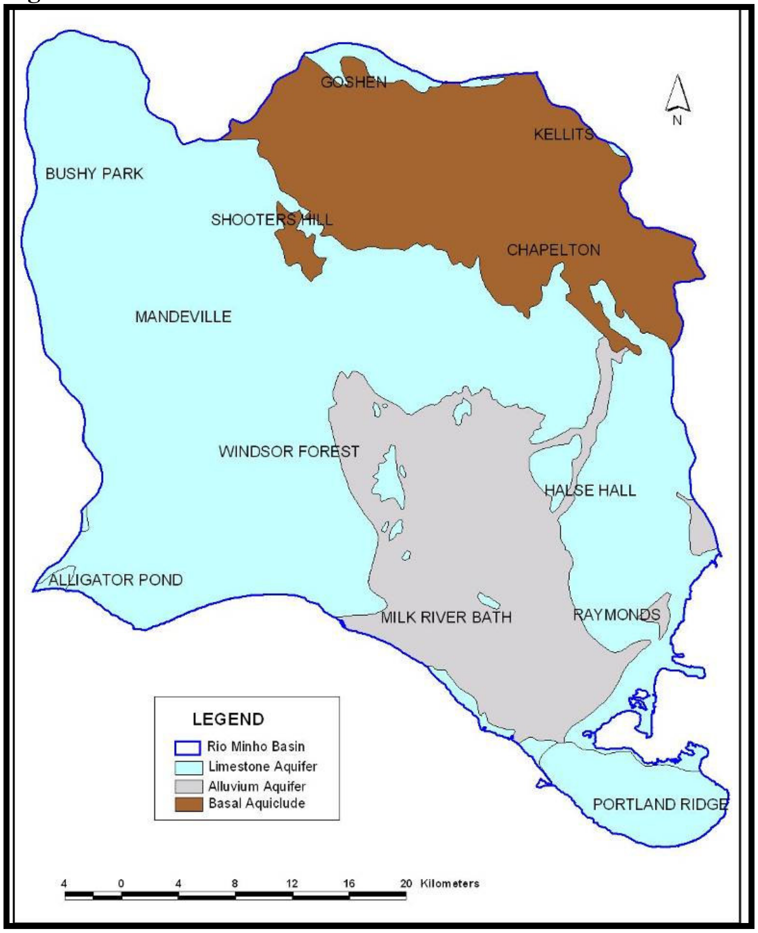


Table 2-4: Areas OF THE HYDROSTRATIGRAPHY UNITS OF THE SUB-DIVISIONS OF THE RIO MINHO HYDROLOGIC BASIN

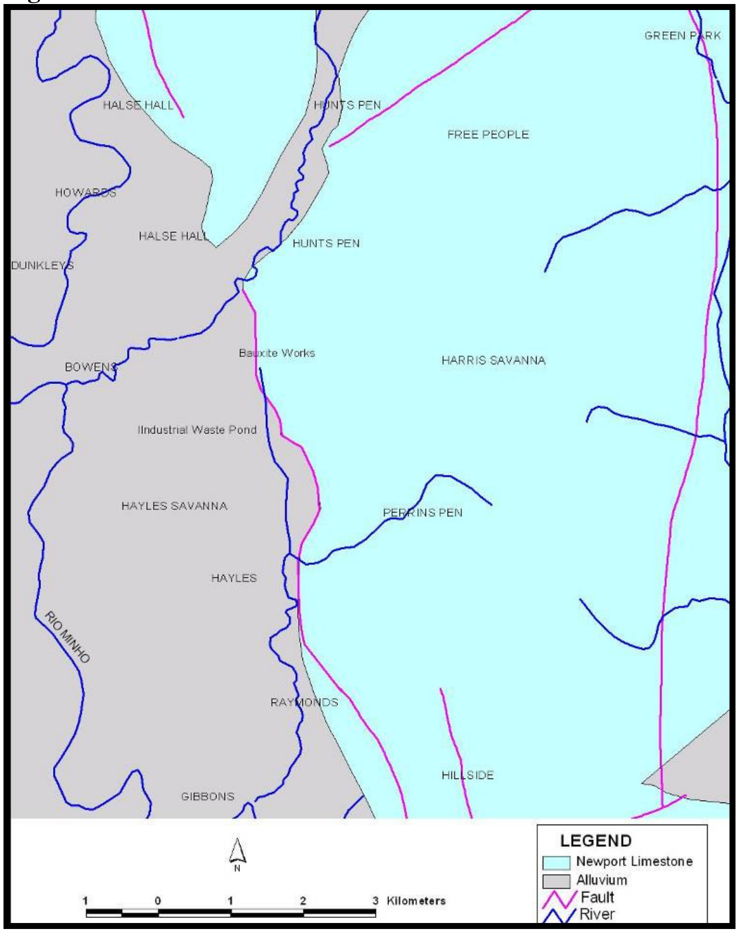
Sub-basins	Hydrostratigraphic Units (km^2)			Total	Percent
	Basement Aquiclude	Limestone Aquifer	Alluvium Aquifer (Aquiclude)		
Upper Rio Cobre	362	31	NIL	393	23
Clarendon Plains	6	528	415	949	56
Manchester Highlands	NIL	358	(5)	363	21
Total	368	917	420	1,705	----
Percent	22	54	24	----	100

2.4.1.2 Hydrogeologic Characteristics

The CAW is located within the Clarendon Plains subdivision (Rio Minho Watershed Management Unit) atop the limestone aquifer (Figure 2-9) The limestone formation is a member of the White Limestone Group of Tertiary Age (7-28 million years). The alluvium of Pleistocene Age (2 million years) has been deposited atop the limestone (Figure 2-10).

Figure 2-9: LOCATION OF CAW

Figure 2-10: GEOLOGY OF AREA



The White Limestone acts as a single hydrogeological unit. The main member the Newport Formation covers most of the Rio Minho basin to a considerable depth. It outcrops in the hills of the Brazilletto Mountains and underlie the alluvium of the plains, where it is the principal source of groundwater. The exact thickness of the limestone is not known but the UNDP/FAO water resources project estimated that in the southern area of the basin the thickness exceeds 1,200 metres as proven by an exploratory oil well drilled at Portland Point.

The primary limestone formation under the CAW is the Newport Limestone Formation. This formation extends throughout the Rio Minho Basin and is the major aquifer that provides water to the wells that support irrigation, domestic and industrial water in the parish. The Newport is essentially a micrite and in its lowest horizon is characterized by an abundance of corals. The majority of the monitor wells drilled by Jamalco penetrated the middle to lower horizons of the Newport Limestone as marked by the abundance of fossils such as gastropods, corals and bivalves.

The limestone aquifer is very permeable and of high transmissivity. The Dry River 5R well yielded 8722 m^3/day with a drawdown in the water table of 0.27 metre. The specific capacity, an indication of the wells performance, was 32,304 m^3/day per metre of drawdown. The transmissivity of the limestone was calculated from the pumping test information as 15,200 m^2/d (15,200 m^3/day/m).

The high permeability is demonstrated by the loss of circulation (drill water) during the drilling, the drop of the drill string as cavities were encountered and the high yield/low drawdown of the monitor wells when tested using a compressor as a pumping unit. The wells drilled in the vicinity of the CAW encountered the water bearing horizons at 13 to 16 metres below sea level. The saturated thickness of the limestone in the area is estimated to be in excess of 150 metres as proven by the Vernamfield well drilled into the same central depression atop which the CAW is located. At the final drill depth of the monitor wells there was evidence of high secondary permeability and the saturated thickness was in excess of 110 metres.

The alluvium atop the limestone consists mostly of sands, gravels and clays. The alluvium also fills the fault-incised channels in the underlying limestone. One such channel approximates the course of the Rio Minho. The alluvium thickens southwards from Bowens. The coarser sediments are concentrated within the buried channel and along the course of the Rio Minho. Monitor Well 5 located on the banks of the Rio Minho west of the RDA proved a thickness of 17 metres of coarse sand and gravel with clay between 15 to 17 metres. Examination of the lithologic logs from the monitor wells drilled around the CAW indicates a basal layer of clay separating the alluvium from the underlying limestone. The Alcoa No. 1 borehole located at E4655 N3618 encountered 10 metres of white sticky clay atop the limestone. The alluvium in the vicinity of the CAW is dry and no water was encountered during the drilling of the monitor wells. The alluvium is unsaturated and functions as an aquiclude (Geomatrix Jamaica Ltd. 1995).

2.4.1.3 Structure

The area around the CAW is a large limestone depression criss-crossed by several faults The lateral and vertical movements along these faults are responsible for the variation in lithology encountered during the drilling of the monitor and production wells i.e. lower, middle or upper Newport Limestone Formation. Faults that cross the area and trend northeast to southwest and northwest to southeast truncate at the boundary of the alluvium. The faults are buried beneath the alluvium but if extrapolated would meet north of the Webbers Gully at New Bowens settlement. One fault trending northwest to southeast passes east of the bauxite/alumina plant and has incised a deep channel within the limestone. The thickened alluvium encountered in Hanbury No 2R well and Monitor Well 3 mark this fault zone. This fault reappears at Raymonds to the south of Hayes Township where it abuts onto the South Coastal Fault (Figure 2-10).

The UNDP/FAO Water Resources Assessment of the Rio Minho-Milk River Basin, Annex II-Water Resources Appraisal divides the basin into 3 units and treats each unit as being separate. The boundary between Units B and C was said to be a groundwater divide at the western edge of the Brazilletto Mountains until it intersects the South Coastal Fault, which for all purposes is the southern boundary of the limestone aquifer. While there is no evidence for the groundwater divide the fault that is located east of the plant could be the eastern boundary of Unit B.

Cross sections drawn in a north-south and east-west direction across the Halse Hall area show the following:

- The erosional (wavy) surface of the limestone
- The variation in thickness of the alluvium
- The basal clay layer at the limestone/alluvium boundary; and
- The water table in the limestone aquifer.

The cross sections are shown as Figure 2-11 and Figure 2-12

Figure 2-11: Cross-section – East-West Direction across the Halse Hall Area

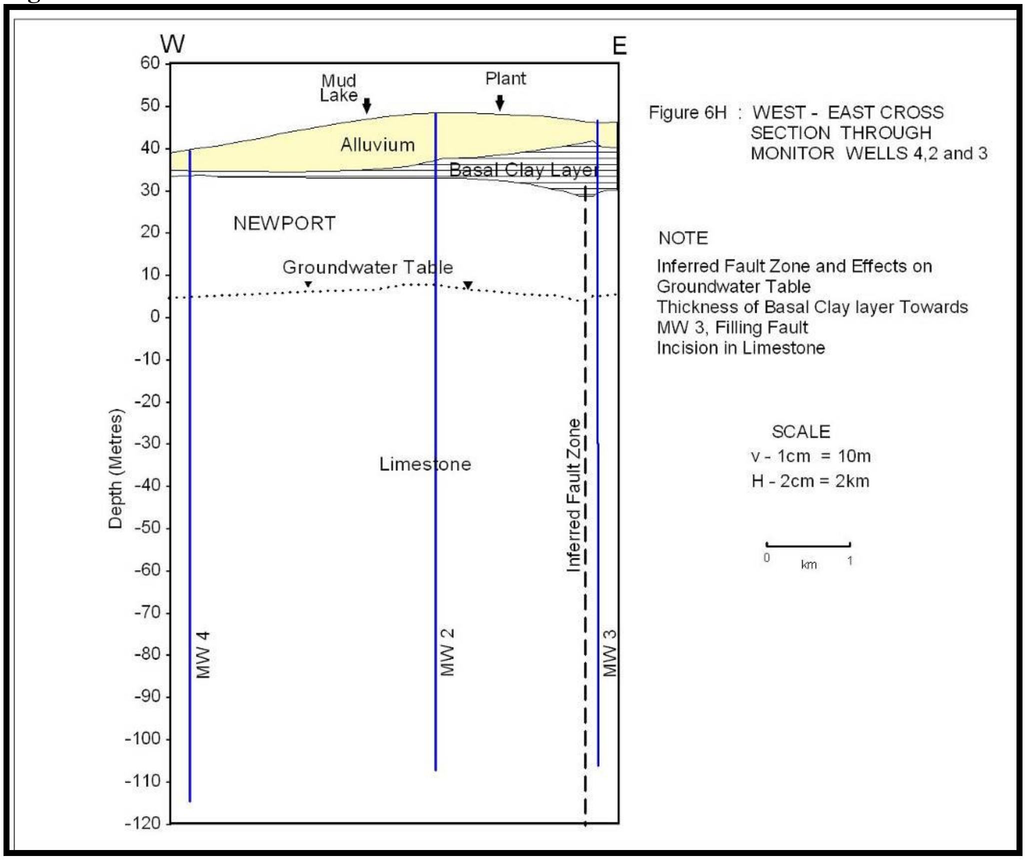
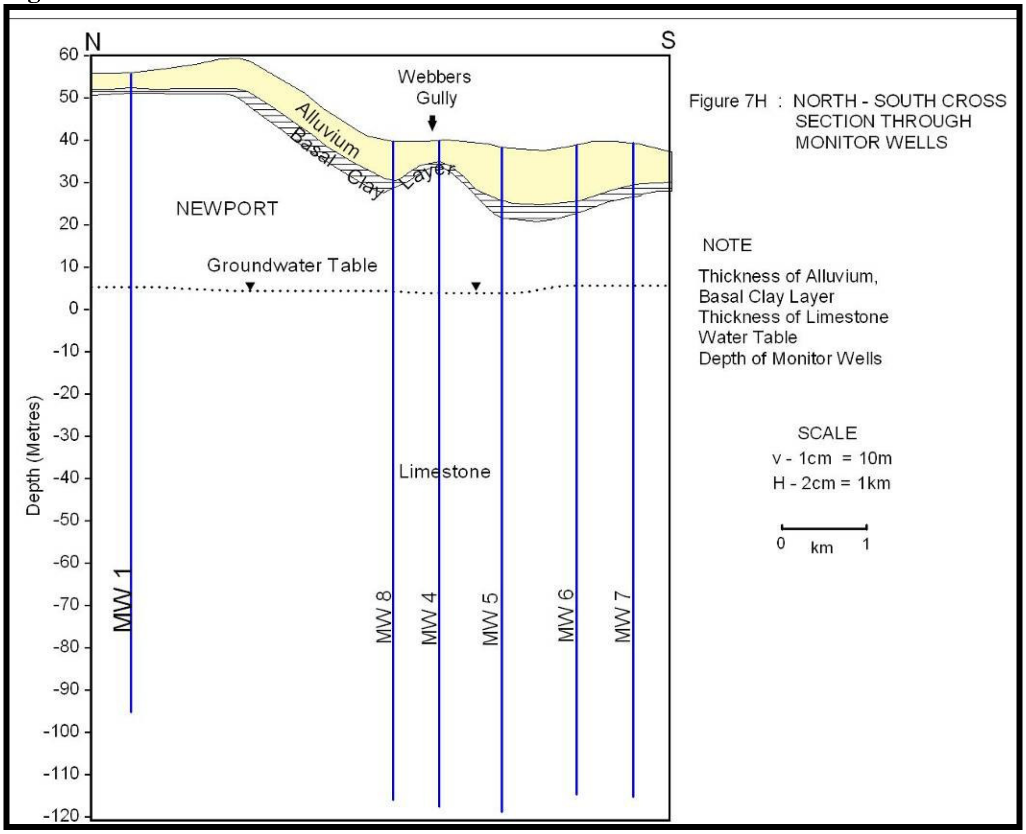


Figure 2-12: Cross-section – North-South Direction across the Halse Hall Area



2.4.1.4 Topography And Drainage

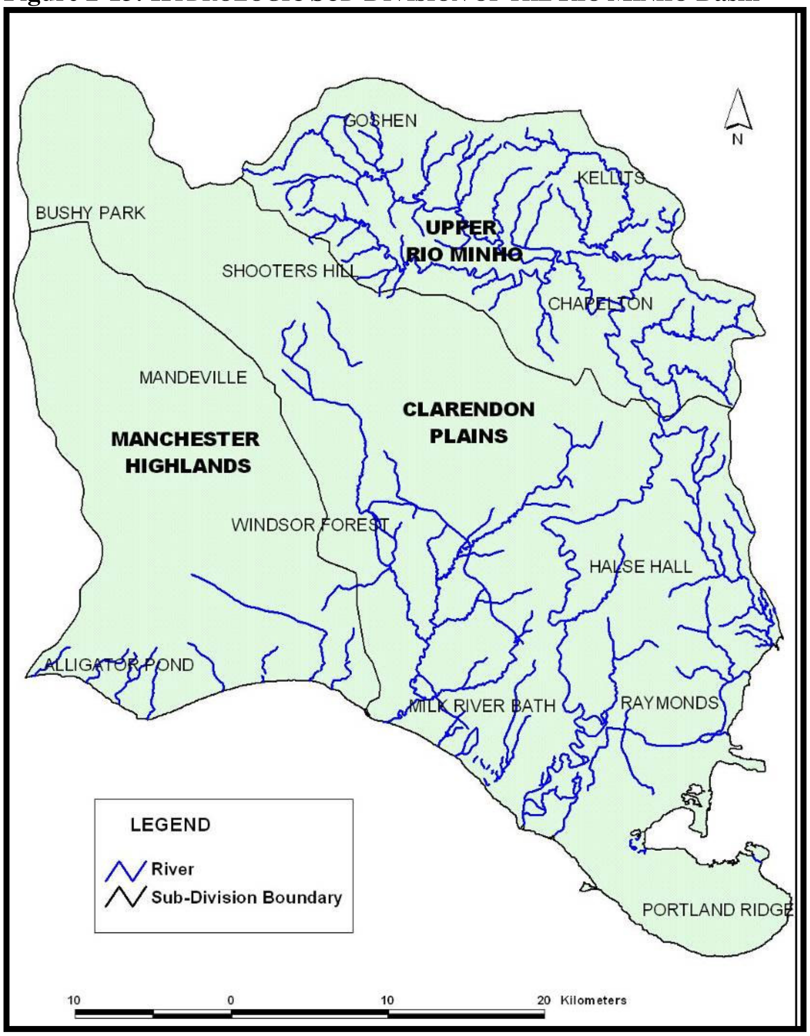
Topographically the area is of low relief with gentle rolling hills on the Harris Savanna. The Brazilletto Mountains form the high ground rising to 250 metres above mean sea level to the east of the bauxite/alumina plant. The Rio Minho flows in a north-south direction west of the RDAs and is the major surface water drainage system. The Webbers Gully, a tributary of the Rio Minho, drains the area north of the Plant. The Webbers Gully is seasonal and carries storm water from the northeast section of the basin into the Rio Minho. During high rainfall events when the Rio Minho is in spate its stage is higher than that of the Webbers Gully with the result that the gully cannot enter the river and will overtop its banks with resultant flooding. The Webbers Gully was straightened to facilitate the construction of the No. 1 RDA (mud lake) and the Clear Lake. The Webbers Gully flows between the northern dike of the No. 1 RDA and the southern edge of the Clear Lake. Monitor well 8 is located just south of the Webbers Gully before it joins the Rio Minho.

2.4.2 Hydrology

2.4.2.1 Surface Water Hydrology

The hydrologic sub-divisions of the Rio Minho basin is shown as Figure 2-13.

Figure 2-13: HYDROLOGIC SUB-DIVISION OF THE RIO MINHO Basin



The Rio Minho and the Webbers Gully are the main constituents of the surface water hydrologic system in the Halse Hall area.

The Rio Minho, located west of the RDAs, flows in a north-south direction. The Webbers Gully, a tributary of the Rio Minho, drains the area between New Bowens and the plant site. The alluvium filled Webbers Gully joins the Rio Minho Valley through Palmers Cross at the Barrel Hole sink west of Chateau, May Pen. It joins the Rio Minho at Old Bowens flowing north of Monitor well 8.

The Rio Minho and the Webbers Gully are seasonal in flow. The Rio Minho is seasonal between May Pen and Alley. The river loses its flow-an average of 20 million cubic metres per year (MCM/yr)-just north of May Pen to the limestone aquifer. At Alley the river becomes perennial and is sustained by wet season surface water throughflow from the Upper Rio Minho sub-basin (111 MCM/yr) and perennial inflow of irrigation return water (22 MCM/yr), totaling 133 MCM/yr average discharge to the sea. There is no significant contribution to the Rio Minho throughout its passage across the Clarendon Plains sub-basin to the sea.

Ponding of water occurs along the course of both surface water systems. The ponding indicates the effectiveness of the basal clay layer in preventing vertical movement of water through the alluvium to the limestone aquifer. However along the Webbers Gully in the vicinity of the clear lake there are outcroppings of limestone. Surface flow as well as any contaminant can enter the limestone aquifer through these surface exposures of limestone.

2.4.2.2 Ground Water Hydrology

Ground water is water that is stored within the saturated section of the limestone formation. The natural level of the water i.e. the water table, marks the upper section of this zone of saturation. Rainfall is the sole source of recharge to the ground water system but artificial, intentional or unintentional, inflows can also contribute and may affect ground water type and quality. The impact will depend on several factors and may include.

- Hydrostratigraphy
- Permeability
- Water levels
- Flow direction

As stated above in section 2.4.1.1 the two main hydrostratigraphic units within the project area are the limestone aquifer and the alluvium aquifer/aquiclude. The alluvium is unsaturated and does not function as an aquifer. It can for all purposes be classified as an aquiclude.

A hydrostratigraphic unit is a geologic formation (or series of formations), which demonstrates a distinct hydrologic character. An aquifer is a geologic formation or group of formations that readily and perennially yields water to a spring or well. An aquiclude is the opposite of an aquifer.

The alluvium overlies and confines the limestone aquifer within the project area. The full penetration of the alluvium during the well drilling operations proved its lack of water. The limestone aquifer was partially penetrated to a thickness of 135 metres out of a reported thickness of 1350 metres-10% only. Yet this was the deepest drilling to have been done in the area. The confinement of the aquifer was evident in the drilling of the monitor wells where artesian rises in the water level of up to 14 metres were noted (Geomatrix 1995).

Ground water is ponded within the karstic Clarendon Plains limestone aquifer by clayey alluviums on the downfaulted southern block of the South Coastal Fault. Along its southeastern boundary alluviums and underlying coastal aquicludes act as a barrier to direct outflow to the sea. Note the change (increase) in the elevation of the water table just behind the fault as shown in Figure 2-14.

The alluvium south of the South Coastal Fault is an aquifer and is tapped by the Sugar Company of Jamaica using tube wells to provide irrigation and domestic water to its operations at Monymusk. The thickness of the alluvium in this area was determined in 1978 using a gravity survey (Bouguer Anomaly) to be a maximum of 650 metres (Wadge, Brooks and Royall 1983).

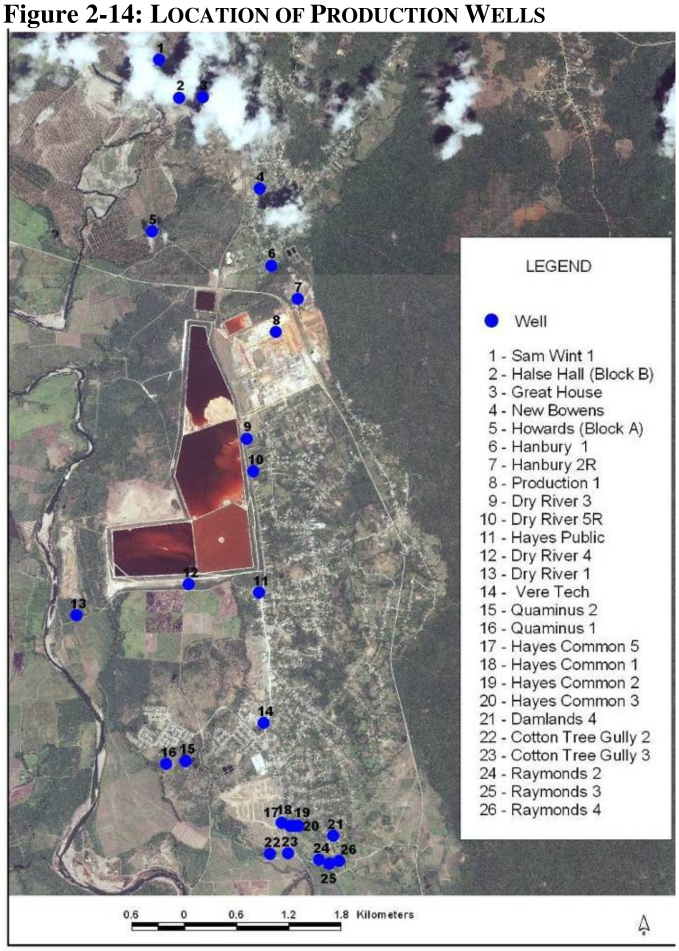
2.4.3 Water Resources

2.4.3.1 Well Locations And Yields

The seasonal character of the main rivers in the Basin combined with the high agricultural demand account for the heavy reliance on ground water. Wells tapping the limestone aquifer produce water for agricultural, domestic and industrial uses. At present over 80% of the water supplied in the basin is from ground water.

Located east of the Rio Minho River within the Clarendon Plains sub-division and to the north (from Halse Hall Great House) and south (to Raymonds) of the CAW are 26 production wells tapping the limestone aquifer. A list of these wells, the owners, their use and licensed/historical yield is given in Table 2-5 below. The locations of these wells are shown in Figure 2-14.

Figure 2-14: LOCATION OF PRODUCTION WELLS



The greater numbers of the wells are located south of the CAW, and are all owned by SCOJ, are all used for irrigation and are centered on the Hayes Common/Raymonds area. The location of these wells is along the South Coastal fault that is open to the sea at the western and eastern ends. The high permeability associated with the fault and the ponding of groundwater behind the fault influenced the locations. The wells located along the fault are high producers.

Of these 26 wells the Sugar Company owns 14 that are used for irrigation purposes; the National Water Commission owns 2 for Public Water Supply; the Ministry of Education owns 1 for agricultural uses and Jamalco owns 9 for private domestic, agricultural and industrial uses. The wells owned by Jamalco and used for agricultural purposes are leased to a farming entity.

The total licensed abstraction for the wells owned by Jamalco total 83,830 cubic metres per day (m3/d); that for the National Water Commission totals 10,130 m3/d; that for the Ministry of Education (Vere Technical well) totals 1,690 m3/d and the historical abstraction for the Sugar Company of Jamaica (SCOJ) totals 131,112 m3/d. One well, Quaminus 2, is shared between the NWC and the SCOJ. The NWC purchases water from this well to meet the demands of the Hayes New Town.

The total licensed or historical entitlement of abstraction from the area around the CAW is 226,762 m^3/day.

Table 2-5: LIST OF PRODUCTION WELLS EAST OF THE RIO MINHO AND WITHIN THE VICINITY OF THE CAW

Name of Well	**Name of Owner**	**Water Use**	**Yield (m^3/day)**
Great House	Jamalco	Private Domestic	250
Sam Wint	Jamalco	Agriculture	7,560
Halse Hall (Block B)	Jamalco	Agriculture	11,160
Howrads (Block A)	Jamalco	Agriculture	10,880
Dry River 3	Jamalco	Industrial	9,815
Dry River 5R	Jamalco	Industrial	9,815
Hanbury 1	Jamalco	Industrial	8,184
Hanbury 2R	Jamalco	Industrial	10,902

Table 2-5: LIST OF PRODUCTION WELLS EAST OF THE RIO MINHO AND WITHIN THE VICINITY OF THE CAW - continued

Name of Well	Name of Owner	Water Use	Yield (m^3/day)
Production 1	Jamalco	Industrial	15,264
New Bowens	National water Commission	Public Supply	3,272
Hayes Public	National water Commission	Public Supply	6,858
Vere Technical	Ministry of Education	Agricultural/Domestic	1,690
Hayes Common 1	Sugar Company of Jamaica	Irrigation	11,088
Hayes Common 2	Sugar Company of Jamaica	Irrigation	13,944
Hayes Common 3	Sugar Company of Jamaica	Irrigation	10,224
Hayes Common 5	Sugar Company of Jamaica	Irrigation	11,088
Quaminus 1	Sugar Company of Jamaica	Irrigation	15,936
Quaminus 2*	Sugar Company of Jamaica	Irrigation	8,184
Cotton Tree Gully 2	Sugar Company of Jamaica	Irrigation	9,168
Cotton Tree Gully 3	Sugar Company of Jamaica	Irrigation	9,096
Damlands 4	Sugar Company of Jamaica	Irrigation	2,760
Raymonds 2	Sugar Company of Jamaica	Irrigation	6,072
Raymonds 3	Sugar Company of Jamaica	Irrigation	9,168
Raymonds 4	Sugar Company of Jamaica	Irrigation	10,200
Dry River 1	Sugar Company of Jamaica	Irrigation	9,168
Dry River 4	Sugar Company of Jamaica	Irrigation	5,016

*- well shared between SCOJ and NWC.

In addition to the 26 production wells there are two disused production wells, Dry River 2 and Dry River 6, as well as twelve (12) monitor wells located around the CAW. Of the 12 monitor wells one has been destroyed (Monitor Well 7) and one has become inaccessible due to expansion of the plant.

The 12 monitor wells were drilled in 2 phases. Phase 1 saw 8 wells being completed in 1994 with a further 4 wells in phase 2 being completed in 1997. The locations of the monitor wells are shown as Figure 2-15.

Figure 2-15: LOCATION OF THE MONITOR WELLS

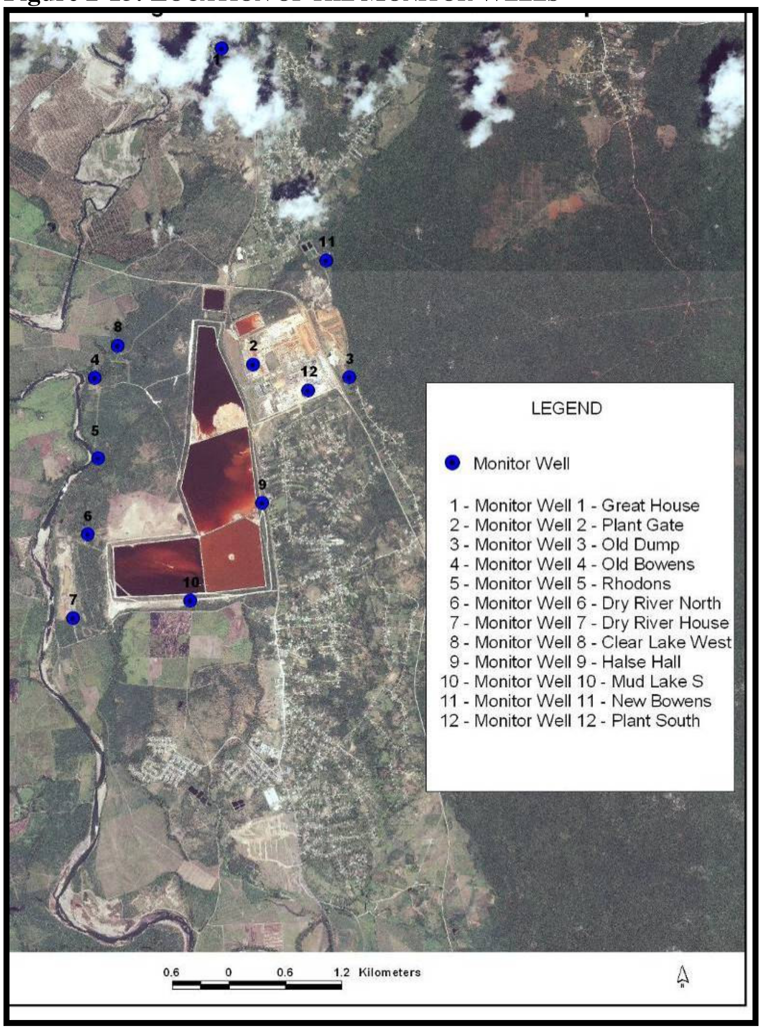


Table 2-6: CONSTRUCTION DETAILS OF MONITOR WELLS-JAMALCO-CAW

Monitor Well		Drill Hole		Casing/Screen					Filter Pack				Seal	Cement Grout
No.	Name	Dia. (cm)	Depth (m)	Type	Dia. (cm)	From (m)	To (m)	Length (m)	Type	From (m)	To (m)	Thickness (m)		
1	Great House	10.16	152.4	Blank Screen Bank	5 5 5	+0.3 146.3 149.3	146.3 149.3 152.4	146.6 3.0 3.1	MS FS MS	-1.5 141.7 143.2	141.7 143.2 152.4	140.2 1.5 9.2	141.7	1.5 0 to 1.5
2	Plant Gate	10.16	155.4	Blank Screen Bank	5 5 5	+0.3 149.3 152.4	149.3 152.4 155.4	149.6 3.1 3.0	MS FS MS	-1.5 140.2 143.2	141.7 143.2 155.4	140.2 3.0 12.2	141.7	1.5 0 to 1.5
3	Old Dump	10.16	155.4	Blank Screen Bank	5 5 5	+0.3 149.3 152.4	149.3 152.4 155.4	149.6 3.1 3.0	MS FS MS	-1.5 144.8 146.3	144.8 146.3 155.4	143.3 1.5 9.1	144.8	1.5 0 to 1.5
4	Old Bowens	10.16	155.4	Blank Screen Bank	5 5 5	+0.3 149.3 152.4	149.3 152.4 155.4	149.6 3.1 3.0	MS FS MS	-1.5 144.8 146.3	144.8 146.3 155.4	143.3 1.5 9.1	144.8	1.5 0 to 1.5
5	Rhodons	10.16	155.4	Blank Screen Bank	5 5 5	+0.3 149.3 152.4	149.3 152.4 155.4	149.6 3.1 3.0	MS FS MS	-1.5 144.8 146.3	144.8 146.3 155.4	143.3 1.5 9.1	144.8	1.5 0 to 1.5
6	Dry River North	10.16	152.4	Blank Screen Bank	5 5 5	+0.3 146.3 149.3	146.3 149.3 152.4	146.6 3.0 3.1	MS FS MS	-1.5 143.3 144.8	143.3 144.8 152.4	141.8 1.5 7.6	143.3	1.5 0 to 1.5
7	Dry River House	10.16	155.4	Blank Screen Bank	5 5 5	+0.3 149.3 152.4	149.3 152.4 155.4	149.6 3.1 3.0	MS FS MS	-1.5 143.3 144.8	143.3 148.8 155.4	143.3 1.5 10.6	143.3	1.5 0 to 1.5
8	Clear Lake West	10.16	155.4	Blank Screen Bank	5 5 5	+0.3 149.3 152.4	149.3 152.4 155.4	149.6 3.1 3.0	MS FS MS	-1.5 143.3 146.3	143.3 146.3 155.4	141.8 3.0 9.1	143.3	1.5 0 to 1.5
9	Halse Hall	10.16	155.4	Blank Screen Bank	5 5 5	+0.6 128.0 131.0	128.0 131.0 134.0	128.6 3.0 3.0	MS FS MS	-1.5 127.5 134.0	127.5 134.0 155.4	126.0 6.9 21.0	126.5	1.5 0 to 1.5
10	Mud Lake South	10.16	155.4	Blank Screen Bank	5 5 5	+0.8 146.3 149.3	146.3 149.3 152.3	147.1 3.0 3.0	MS FS MS	-1.5 140.0 152.4	140.0 152.4 155.4	138.5 12.4 3.0	140.0	1.5 0 to 1.5
11	New Bowens	10.16	155.4	Blank Screen Bank	5 5 5	+0.8 149.4 152.4	149.4 152.4 155.4	150.2 3.0 3.0	MS FS MS	-1.5 122.0 154.0	122.0 154.0 155.4	120.5 32.0 1.4	121.5	1.5 0 to 1.5
12	Plant Site South	10.16	152.4	Blank Screen Bank	5 5 5	+0.4 137.2 140.2	137.2 140.2 143.2	137.6 3.0 3.0	MS FS MS	-1.5 91.5 143.2	91.5 143.2 155.4	90.0 51.7 12.2	90	1.5 0 to 1.5

MS-Medium Sand FS-Fine Sand

Each well was drilled to a depth of 155.4 metres and completed with 5 cm diameter PVC casing and screen. The annular space of each well was packed with gravel and coarse sand. The screened area, which was close to the bottom of the well, was packed off using bentonite as a seal. Development was carried out using a compressor as the pumping unit. Water samples were collected every 30 metres to develop a water quality profile with depth. The locations of the monitor wells are shown on Figure 2-12

Details on the construction of the monitor wells are given in Table 2-6 above.

2.4.3.2 Groundwater Levels

Groundwater level (elevation of water table above sea level) is monitored monthly by Jamalco staff at each of the 10 accessible monitor wells. The groundwater table fluctuates seasonally with recharge and abstraction/discharge. When recharge exceeds abstraction/recharge the storage increases and the water table rises. When abstraction/discharge exceeds recharge water is taken from storage and the water table elevation will decline. In the dry season the water table elevation in the area around the CAW varies from 2.40 to 4.10 metres above sea level with the highest level being recorded at Monitor Well 1 to the north.

The year 2003 was one of high water table elevations as the recharge from the extreme rainfall events in May/June and September of 2002 increased storage within the limestone aquifer. Water table elevations around the CAW remained higher than 6 metres above sea level for all of 2003. In fact at two wells, monitor wells 1 and 12, the water table elevation was higher than 7 metres above sea level. This has gradually declined and in April of 2004 the water table elevations varied from a high of 5.34 (in the north of the area) to a low of 4.51 (west of the RDAs) metres above sea level. There has not been a decline in the groundwater table since the measurements began in 1998.

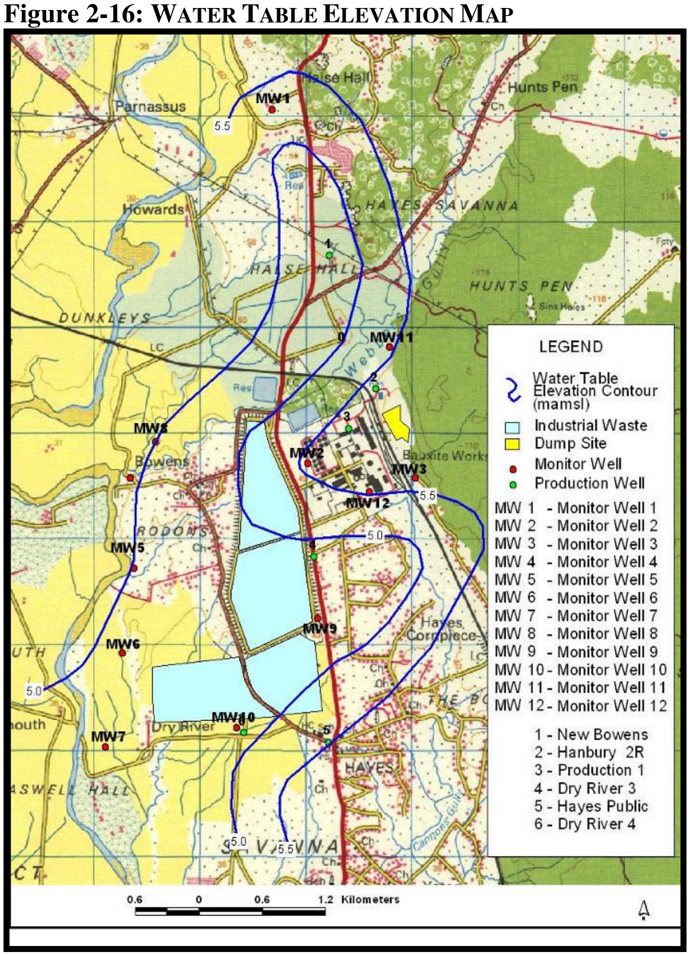
The water table elevation upon completion of the monitor wells and that on April 1, 2004 is compared in Table 2-7 below.

Table 2-7: Comparison of Water Table Elevations for the Monitor Wells

Name of Well	Water Table Elevation (M asl)		Remarks
	Upon Completion	April 2004	
Monitor Well 1	3.35	5.20	MW 1-8 completed
Monitor Well 2	4.63	5.63	In 1994
Monitor Well 3	4.23	5.23	
Monitor Well 4	4.37	4.95	
Monitor Well 5	3.85	4.97	
Monitor Well 6	3.79	4.51	
Monitor Well 8	3.84	4.97	
Monitor Well 9	3.91	4.80	MW 9-12 completed
Monitor Well 10	3.87	4.81	In 1997
Monitor Well 11	3.79	5.34	
Monitor Well 12	3.87	7.38*	*June 2004

The water table elevation map for April 2004 is shown as Figure 2-16. The groundwater table elevation shows a high of just over 6 metres above sea level. The direction of flow is from the high to the low elevation and is from north to south through the CAW.

Figure 2-16: WATER TABLE ELEVATION MAP



2.4.3.3 Discharge

Knowledge of the discharge to the sea via the limestone south of the South Coastal Fault is not known. There is no evidence to show that there is a discharge along this reach to the sea. The actual discharge into the sea may be some distance offshore where the White Limestone is exposed to the seabed. It is possible that outflow may be restricted to those periods of high water table and marine discharge in normal conditions may be small.

The principal discharge from the aquifer is by abstraction from pumped wells. In Table 2-5 a list of the pumped wells is given with the licensed or historical abstraction rates.

The total committed water for abstraction from the area around the CAW was 226,762 m3/day (10.30 x 108 imperial gallons per day). There has never been a period when all the wells have been abstracting at their maximum and the 226,762 m3/day was being abstracted. This area of the limestone aquifer has the greatest abstraction in the basin and is concentrated in particular to the area south of the CAW that includes the Hayes Common-Raymonds area. Many of the wells suffer from saltwater contamination either from penetration of the fresh water-seawater interface along the South Coastal Fault, the movement of saltwater (influenced by the pumping) along the fault that is open to the sea at both the western and eastern ends or the recirculation of return saline irrigation water.

2.4.3.4 Reservoir Volume

The effectiveness of an aquifer to supply water on a reliable basis is determined by the volume of the reservoir rock capable of holding the water. The effective volume of the reservoir is that amount of water that the rock will yield.

The thickness of the permeable section of the aquifer in the northern area of the basin is not known. However this is determined by the depth to the impermeable basement rocks (Yellow Limestone or Volcanic rocks) and the aquifer is thin where these rocks are near to the surface. In the area around the CAW the impermeable sediments are covered by the great thickness of the White Limestone (Newport Formation) and they do not affect the depth to which water can penetrate. The depth of solution in the limestone is limited by the lowest base level in effect during the history of solution development. The degree of karstification has a direct bearing on the capacity of the limestone to store and transport water. In the area beneath the CAW the level of karstification and high permeability in the limestone was found to be over 100 metres deep and has been proven to be over 150 metres deep within the central depression.

The reservoir volume is assumed to be equivalent to the saturated thickness of the reservoir. Assuming a saturated thickness of at least 100 metres and an area of the aquifer bounded by the South Coastal Fault to the south, by the Rio Minho to the west, by the fault between the plant and the Brazilletto Mountains to the east and by an imaginary east-west line drawn north of the Great House and Sam Wint wells with an approximate area of 34.5 square kilometres, the volume of the reservoir would be 345 million cubic metres of water (a value of 10% is used for the calculation of the reservoir volume).

The groundwater table elevations are relatively flat in the central area of the basin and around the CAW. They are controlled by several factors, which will include the storativity and the transmissivity of the aquifer. The dry season water table elevation varies from 2.5 metres above sea level to a high of 5 metres above sea level, which gives an average water table elevation of approximately 3.75 metres above sea level within the study area. The total water that could be abstracted is 12.94 MCM.

2.4.4 Water Quality

2.4.4.1 Ambient Water Quality

The groundwater resources of the Clarendon Plains and the area around the CAW are associated with the limestone aquifer, which occurs throughout the area and fills the central depression. Except where contaminated by industrial and municipal effluents or seawater, the quality of the groundwater is adequate for all standard uses. Physical, chemical and bacteriological quality is generally as follows:

- pH 7.2
- Conductivity 450 to 700 uS
- TDS 250 to 450 mg/l
- Coliform 5 MPN/100 ml.

Total Dissolved Solids (TDS) tends to be slightly high for use in industrial boilers without softening, but the bacteriological quality requires minimum treatment for use as a municipal/ public or private water supply. However where contamination has occurred the quality would vary depending on the nature of the contaminant.

The typical background quality of the groundwater in the limestone aquifer is shown in Table 2-8 below.

Table 2-8: TYPICAL BACKGROUND QUALITY OF GROUNDWATER IN THE LIMESTONE AQUIFER-CLARENDON.

Constituents	Units	Concentrations
pH		7.2
Turbidity	NTU	<1.0
Colour	HU	<5
Specific Conductivity	uS	550
Calcium	mg/l	<75
Magnesium	mg/l	10
Sodium	mg/l	12
Potassium	mg/l	1.0
Iron	mg/l	0.01
Chloride	mg/l	10
Sulphate	mg/l	8
Nitrate	mg/l	4
Carbonate	mg/l	0.0
Bicarbonate	mg/l	260
Total Hardness	mg/l	270
Total Alkalinity	mg/l	260
Total Dissolved Solids	mg/l	350
Bacteriological	MPN/100 ml	<5
Na:Cl ratio		<1.5

2.4.4.2 Groundwater Chemical Types

All groundwater can be classified into types according to the dominance of various anions and cations in the water. The major types are:

1. Calcium/Magnesium bicarbonate
2. Sodium bicarbonate
3. Calcium chloride
4. Sodium chloride

Natural groundwater, which is uncontaminated, has as the dominant cation, calcium or magnesium, dependent on the source rock through and over which the water flows. The dominant anion is bicarbonate and together with the dominant cation, the chemical water type becomes calcium or magnesium bicarbonate water. The changes from the naturally occurring calcium bicarbonate type water to the sodium chloride type water is an indication of contamination of the groundwater and the replacement of the calcium by sodium and the bicarbonate by chloride.

Around the CAW the major groundwater chemical type is the calcium bicarbonate type with sodium chloride type to the south around Hayes Common-Raymonds and at depth within the limestone aquifer.

2.4.4.3 Sources Of Groundwater Contamination

The assessment of any change in groundwater quality and type must include an evaluation of the possible sources of contamination and the impact each can have on water quality.

Around the CAW there are three main possible sources of contamination of groundwater. These are:

1 The intrusion of saltwater (saline intrusion) into the karstic aquifer as a result of the **over pumping** resulting in high chloride and sodium concentrations.

2 **Industrialization**, specifically the bauxite/alumina operations at Halse Hall consisting of the plant and the RDAs.

3 **Municipal** impacts from the improper disposal of liquid and solid wastes.

2.4.4.3.1 Saltwater Intrusion

The limestone formation responds as a Ghyben-Herzberg aquifer. The Ghyben-Herzberg Principle specifies that the occurrence of saline groundwater in a coastal aquifer, similar to that of the Rio Minho Hydrologic basin within which the CAW is located, is dependent on the head of fresh water above sea level. A ratio if 1:40 i.e. one metre of fresh groundwater above sea level to 40 metres of fresh groundwater below sea level before entering the freshwater/saline water interface. This has been proven by Botbol in the adjoining Rio Cobre Hydrologic basin a karstic limestone area. Around the CAW with water levels 6 metres above sea level there should be 240 metres of freshwater below sea level before the fresh/salt water interface is encountered.

Within the area of the CAW the potential for saline intrusion by way of upconing from the Ghyben–Herzberg Zone is provided by the below sea level pumping depressions associated with the well fields around the Hayes Common-Raymonds area. The saline water can also be brought to the upper level of the aquifer by way of the faults, which act as preferred paths of flow due to the increased permeability along the fault zones. In addition the wells south of the CAW are all located along the South Coastal Fault Zone, which is open to the sea at both its eastern and western ends.

2.4.4.3.2 Industrialization-Bauxite/Alumina Operations

The bauxite/alumina industry produces an alkaline waste known commonly as “red mud”. This bauxite residue is a thick fluid suspension with water content between 65 – 75% depending on the technology and method of management used, high concentrations of sodium and hydroxide ions; iron oxides and organic substances which originate from the bauxite and which on decomposition and reaction with caustic soda, impart an unpleasant smell to the water. The pollutants present in the bauxite residue are in sufficient quantities to make the groundwater unfit for domestic and agricultural uses, in the event the bauxite residue is not effectively contained within the storage areas. Effective containment is achieved through the use of sealants such as clay.

The CAW was constructed in the early 1970’s. The plant is located on the Clarendon Plains, an important agricultural region where over 90% of the irrigation water and 100% of the public water supply is derived from groundwater using wells tapping the limestone aquifer. The bauxite residue is a potential agent for degrading this water quality with potentially significant social and economic consequences.

The bauxite residue is disposed of into Residue Disposal Areas (RDA). RDA 1 was commissioned into use on March 6, 1972. RDA 2 and RDA 3 were constructed in 1980 and 1990 respectively. RDA 4 was constructed in 2000 and the dike was raised by an additional 20 feet in 2004. The RDAs have all been sealed with clay in the base and the sides. Supernatant (caustic enriched) liquor and plant runoff are collected and stored in RDAs (clear and storm lakes) from where it is recycled into the plant. Total volume of mud in storage exceeds 15 million tonnes.

2.4.4.4 Contamination Criteria

The monitoring programmes established by Jamalco in conjunction with the Government of Jamaica regulating agencies are intended to detect above average concentrations of the chemical constituents that can contaminate the groundwater. The inclusion of the aesthetic indices such as colour, taste and odour also assist in the determination of the level of contamination of groundwater.

Five indices are specifically used to detect contamination from the bauxite/alumina operations. These are:

1 Sodium to chloride concentration ratio exceeding the maximum ratio encountered in uncontaminated groundwater in Jamaica of 1.5 (White and Rose 1975).

2 High sodium content. This alone is not a precise indicator as sodium chloride waters are found in the limestone aquifer as a result of saline intrusion. However in this form of contamination high sodium concentrations are associated with high chloride concentrations. This is not the case in the event of a caustic contamination.

3 Sodium to calcium concentration ratio in excess of the ratios generally encountered in uncontaminated groundwater of 1.0

4 High pH values in excess of 8.5 units, the limit set by the USEPA and the WHO for drinking water and the maximum encountered in groundwater in Jamaica.

5 The presence of suspended solids, red discoloration, poor smell and unpleasant taste.

In addition high conductivity, TDS and alkalinity concentrations aree used to determine the source of the contamination.

2.4.4.4.1 Water Quality Monitoring

Jamalco has conducted water quality monitoring around the CAW since 1989. The programmes have been intensified over the years to generate information on the impact of the bauxite/alumina operations on the groundwater quality of the limestone aquifer. Initially the programme consisted of monthly sampling and analysis of existing production wells within and around the CAW. The drilling of the monitoring wells has led to the expansion of the monitoring programmes and the level of the analysis done. The monitoring and analysis has led to an increased database on which to base the evaluation of the impacts of the bauxite/alumina operations on groundwater quality. To date the following have been completed and for which data is available:

1 Analysis on a monthly basis of production wells between January 1998 to the present for the parameters- pH, conductivity, chloride, sulphate, sodium, magnesium carbonate, calcium carbonate, and hardness. The sodium:chloride ratio was calculated from the results. The sampling points included-Production wells 1 and 2, Hayes Common wells 1,2 and 3, Dry River 2 and 5 wells, Hayes Public well, Quaminus 2 well, Halse Hall well (Greenvale), Woodside well, Breadnut Valley well, Rocky Point (Morelands) well, Rocky Point drinking water (trucked water) and Webbers Gully.

2 The completion of the first 8 monitor wells in 1994 led to the expansion of the programme and provided monitor points that were not affected by pumping and tapped groundwater deep within the aquifer.

3 The completion of the next 4 monitor wells in 1997 further expanded the programme.

4 During the drilling of the monitor wells water samples were collected every 30 metres depth below the water table to ensure that a water quality profile of the monitor well could be developed. Each monitor well yielded 4 sets of samples. The parameters analyzed are shown in Table 2-9 below.

5 Since 1998 Jamalco has contracted a consultant to carry out quarterly sampling and analysis of all the wells as an independent assessment of the impacts of the bauxite/alumina operations on water quality. The samples are analyzed by a USEPA and NELAP certified laboratory in the USA. The sample points and the parameters analyzed are shown in Table 2-10. Jamalco at the same time continues its independent sampling and analysis of the same monitor points.

6 In 2000 Jamalco instituted a twice-yearly sampling of all the sources of water to its facilities to assess the quality of water being used for domestic purposes. The sampling points and the parameters analyzed are shown in Table 2-11 below.

The data collected has been analyzed and to date no significant contamination of groundwater has been detected.

Table 2-9: PARAMETERS ANALYZED FOR EACH WATER SAMPLE, MW1 TO 12.

Group of Parameters	Constituents
Metals	Aluminium: Arsenic: Barium: Cadmium: Calcium: Chromium: Iron: Lead: Magnesium: Manganese: Mercury: Selenium: Silver: Sodium.
Inorganics	Cyanide (Total): Chloride: Carbonates: Bicarbonates: Nitrate: Sulphate: Hexavalent Chromium.
Physical/chemical	Turbidity: pH: Specific Conductance
Organics	Phenol: Polychlorinated Biphenyls (PCB): Naphthalene
VOAs (Volatile Organic Aromatic Compounds)	Acetone: Benzene: toluene: Carbon Tetrachloride: Vinyl Chloride: Chloroform: Chlorobenzene: 1,1-Dichloroethane: Methyl Ethyl Ketone (2-Butane)
TPH (Total Petroleum Hydrocarbons)	Hydrocarbons-Petroleum

Table 2-10: LIST OF WELLS AND PARAMETERS-MONTHLY SAMPLING PROGRAMME JAMALCO

Sampling Point	Well Depth (m)	Use of Water	Parameters
Monitor Well 1	155.4	Monitoring	Lab:- Sodium
Monitor Well 2	155.4	Monitoring	Calcium,
Monitor Well 3	155.4	Monitoring	Magnesium
Monitor Well 4	155.4	Monitoring	Chloride
Monitor Well 5	155.4	Monitoring	Sulphate
Monitor Well 6	155.4	Monitoring	Nitrate
Monitor Well 8	155.4	Monitoring	TDS
Monitor Well 9	135.0	Monitoring	Alkalinity
Monitor Well 10	152.4	Monitoring	
Monitor Well 11	155.4	Monitoring	Field:- pH
New Bowens	70.1	Public Supply	Temp.
Dry River 3	76.2	Industrial	Cond.
Dry River 4	55.8	Irrigation	
Hayes Public	67.0	Public Supply	Water Levels
Production 1	86.3	Industrial	Na:Cl ratio
Production 2	122.0	Industrial	calculated

Duplicate samples are collected and a comparison made of the analytical results between the Jamalco Laboratory and the USEPA Laboratory in the USA that analyses the samples. The comparison indicates that on the whole the results compare favourably. However at times the difference in the chloride concentration has been very large. This probably due to the fact that the samples are analyzed beyond the maximum holding time and the samples were not preserved in the field.

Table 2-11: LIST OF FACILITIES, SOURCES, SAMPLE SITES AND PARAMETERS ANALYZED

Facility/Location	Source/Supply	Sample Site	Parameters
Clarendon Alumina Works [CAW]	Production Well 1	At Well Head	**Metals:** Aluminium; Arsenic: Cadmium: Calcium: Copper: Iron: Lead: Magnesium; Manganese: Mercury: Selenium: Sodium: Zinc **Non-metals:** Chloride; Cyanide: Fluoride; Nitrate: Sulphate: TDS: pH; Temp.: **Bacteria:** Coliform -T and F **Pesticides:** gamma-BHC: Aldrin: Dieldrin: 4,4'-DDT:
	Production Well 2	At Well Head	
	Dry River Well 3	At Well Head	
	Groundwater from PW 1/PW 2 after Treatment	Drinking Fountain in Building 1	
Halse Hall Great House	Great House Well	At Well Head	
	Great House Well after Treatment	At Great House Kitchen Tap	
Breadnut Valley	Breadnut Valley Well	At Well Head	

Facility/Location	Source/Supply	Sample Site	Parameters
	Breadnut Valley Well after Treatment	Drinking Fountain in Plant Office	Technical Chlordane: Methoxychlor. **Organics:** 1,1-Dichloroethane: Chloroform: Benzene: 1,2-Dichloroethane: 2,4,6-Trichlorophenol: Pentachlorophenol: Hexachloroethane: Benzo(a)Pyrene.
Woodside Lands Office	NWC Supply from Kraal Well 1	Drinking Fountain in Main Office	
Rocky Point Port	Trucked Water	Domestic Tank Tap	
Waterloo Road Office	NWC Supply from Hermitage Dam	Tap in Office Kitchen/Pantry	

2.4.4.4.2 Analytical Results

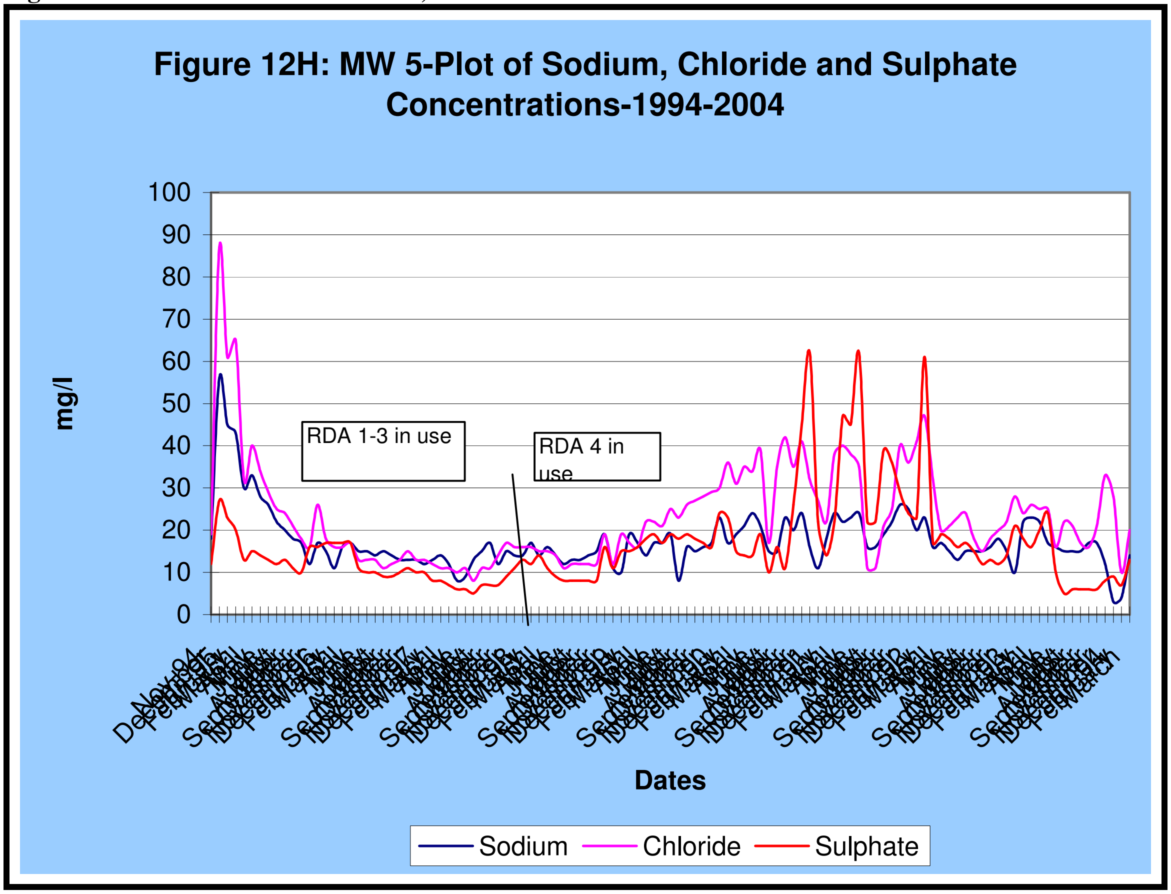
a) Borehole Profile

The samples collected from each borehole at 30 metre intervals during drilling indicate that no contamination resulting from the bauxite/alumina operations was detected in any of the wells. In several wells the sodium concentration was higher than normal but so was the chloride concentration. The Na:Cl ratios were at all times less than 1. It is noteworthy that neither Arsenic, Cadmium, Mercury, Selenium nor Silver was detected at any depth within any of the wells. Phenol was the only organic compound detected at one level in 5 of the wells and all at very low concentrations. No Volatile Aromatic Compound was detected at any concentration that exceeded the guideline values. No TPH was detected that would be a cause for concern.

b) Monthly Sampling any Analysis

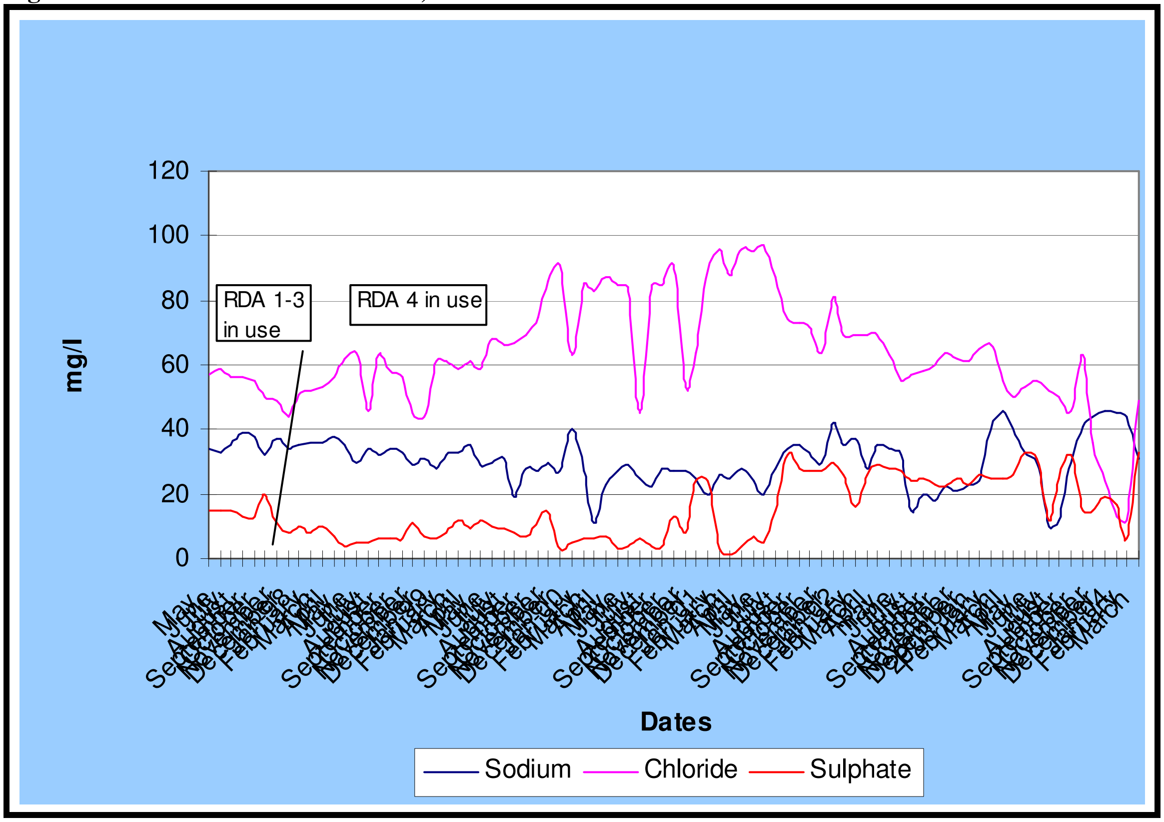
The results for the monthly sampling and analysis programme are shown plotted for four of the monitoring points-3 monitor wells and 1 production well. The points are MW 5 to the west of the RDAs; MW 9 to the east of the RDAs; MW 10 to the south of the RDAs and Hayes Public well located to the south of the RDAs and between MW 9 and MW 10. The Hayes Public well was selected, as this well is the source of the water supply for the Hayes community and has been the discussion of many community meetings as to its quality and suitability for domestic uses. The plots of the sodium, chloride and sulphate concentrations are shown as figures Figure 2-17 to Figure 2-21.

Figure 2-17: MW 5-PLOT OF SODIUM, CHLORIDE AND SULPHATE CONCENTRATIONS-1994-2004



At MW 5, to the west of the RDAs, the data plot Figure 2-17 shows no significant increase in the sodium concentration over time. There is a close correlation between the chloride and sodium concentrations. In all cases the Na:Cl ratio would be less than 1. The assessment took into consideration the impact of each RDA as it was commissioned into service. As can be seen there was an increase in the chloride and sodium concentration after RDA was brought on stream. However, this is not due to leakage from the RDA but to the below average recharge coupled with increased pumping.

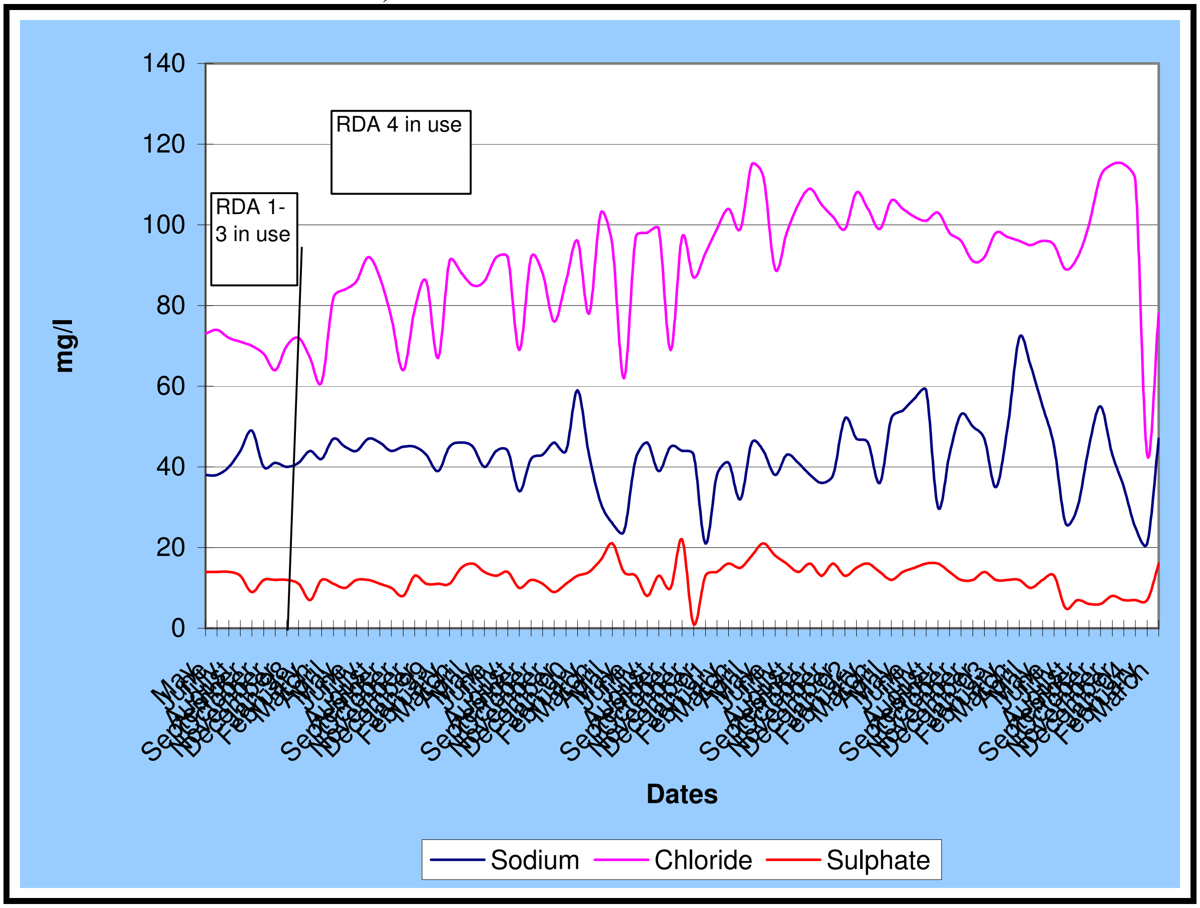
Figure 2-18: MW 9-PLOT OF SODIUM, CHLORIDE AND SULPHATE CONCENTRATIONS-1994-2004



At MW 9, to the east of the RDAs, the plot Figure 2-18 while showing a varying concentration for sodium does not show a trend toward an increasing concentration. The chloride shows an increasing upward trend in concentration up to June 2001 where after there is a decline in the concentration. This increased chloride concentration is probably due to the less than average rainfall/recharge between 1999 to 2000 and the increased pumping to meet water demand. Here also the high chloride concentration compared to the lower sodium concentration would ensure that the Na:Cl ratio is less than 1.

The commissioning of RDA 4 did not lead to any increase in sodium concentration. The increase in chloride concentration is not attributable to the RDA but to recharge and pumping conditions and would most probably represent increased salinity of the groundwater during that period. An increase in the sulphate concentration after June 2001 was noted. This led to the concentration moving from less than 20 mg/l to between 20 to 30 mg/l. The reason for this is not known but the concentration is still far below the WHO guideline value of 400 mg/l.

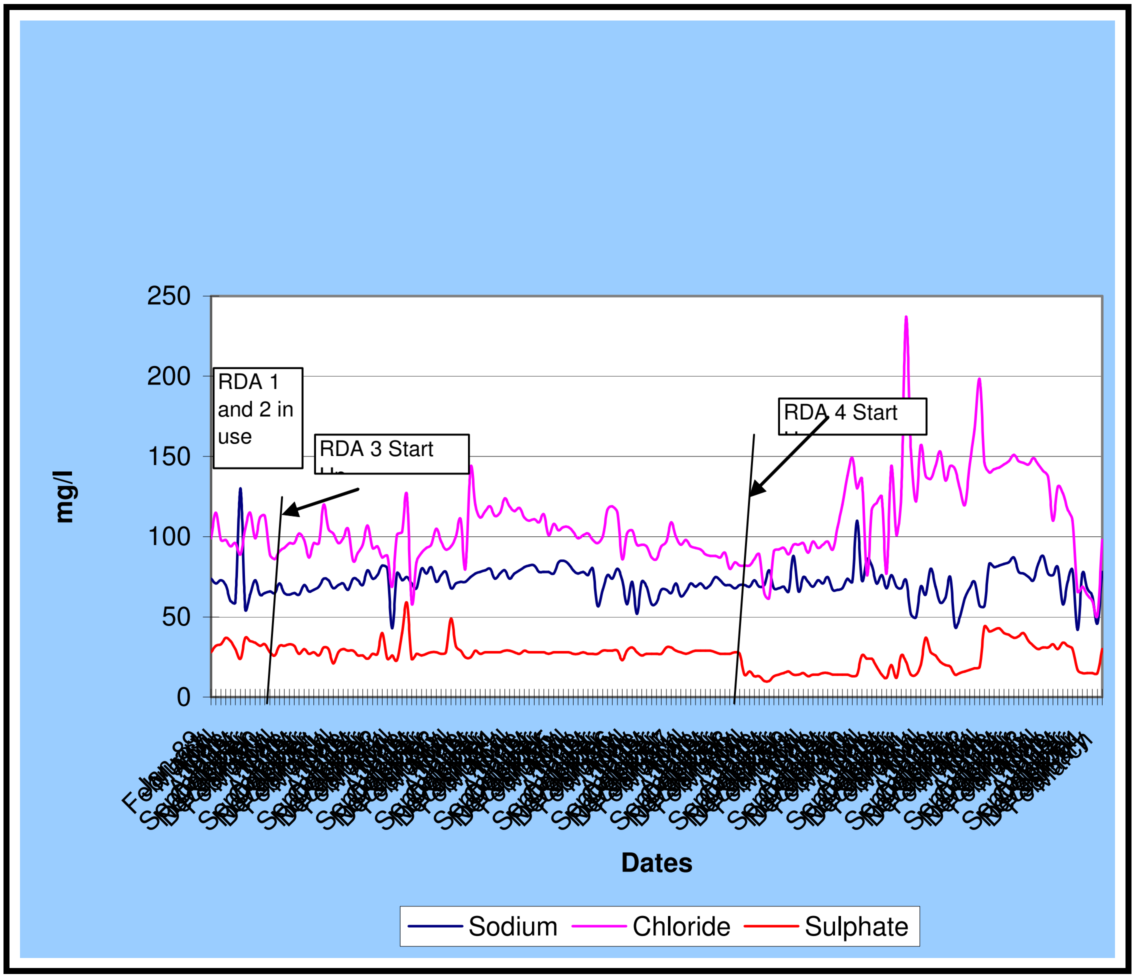
Figure 2-19: MW10-PLOT OF SODIUM, CHLORIDE AND SULPHATE CONCENTRATIONS-1994-2004



At MW 10, to the south of the RDAs, the plot (Figure 2-19) there is a trend to an increase in chloride concentration. This well is located close to the Dry River 4 irrigation well that has reported chloride concentrations of up to 150 mg/l. There has not been a trend towards an increase in the sodium and sulphate concentrations.

The use of RDA 4 after 1998 has not resulted in an increase in the sodium concentration. As is the pattern with the other wells an increase in the chloride concentration was noted. However this is more related to salinity changes within the aquifer. There was no overall change in the sulphate concentration.

Figure 2-20:HAYES PUBLIC WELL PLOT OF SODIUM, CHLORIDE AND SULPHATE CONCENTRATIONS 1989-2004



At the Hayes Public well, also south of the RDAs, the plot Figure 2-20 shows a very constant concentration of sodium and chloride up to the year 2000. The chloride concentration has shown an increase since 2000 that again may be due to the below average recharge and increased pumping. The start up of RDA 3 and RDA 4 as shown on the graph did not in any way affect the concentrations of sodium and sulphate. This well is the most southern of the monitor points and is the closest to the South Coastal Fault and the wells at Hayes Common that show high chloride concentrations exceeding 350 mg/l at times. The Na:Cl ratio here would also be less than 1.

The controversy of the possible contamination of the Hayes Public well has led to many meetings between Jamalco and the Hayes community. The monthly sampling does not show any caustic contamination at the Hayes well. Further investigation was recommended and on April 1, 2004 a sample was collected and analyzed for heavy metals. The results are presented below in Table 2-12.

As can be seen only one parameter exceeds the World Health Organization (WHO) guideline value for drinking water. That parameter is Aluminium and the concentration was reported at 0.22 mg/l while the guideline value is 0.20 mg/l. Aluminium has no toxicological effect on the human body. The concentration of Copper was reported at 0.011 mg/l with a guideline value of 1.0 mg/l. Barium was reported at 0.055 mg/l. There is no guideline value for Barium. All the other thirteen parameters had concentrations less than the Laboratory Reporting Limit (LRL).

The conclusion reached is that the water quality at the Hayes Public well meets the drinking water guidelines and is suitable for use as a domestic water supply. The bauxite/alumina operations have not impacted on the water quality in the limestone aquifer to affect that being abstracted at the Hayes Public well.

Table 2-12: ANALYTICAL RESULTS OF HEAVY METALS FOR HAYES PUBLIC WELL (NWC) – APRIL 2004

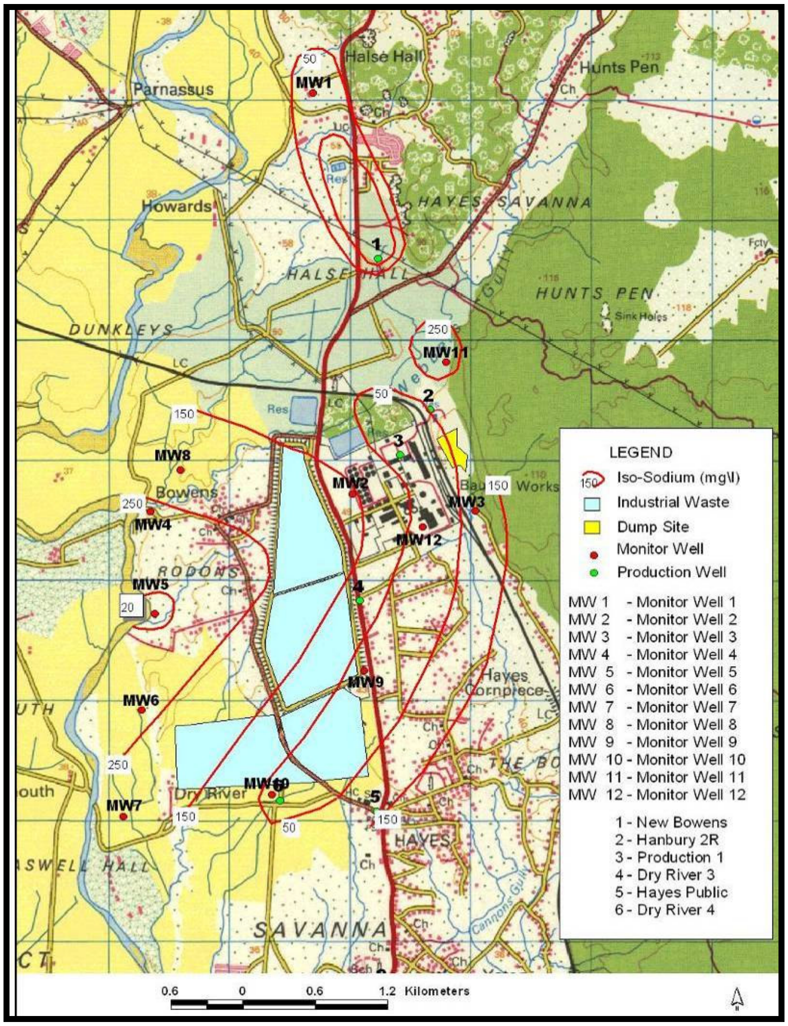
Parameter	Concentration (mg/l)	Lab Reporting Limit (LRL) (mg/l)	WHO Guideline Limit for Drinking Water (mg/l)	Remarks
Aluminium	0.22	0.10	0.20	Exceeds Guideline-No toxicological Effect.
Antimony	<0.50	0.50	0.002	
Arsenic	<0.50	0.50	0.05	
Barium	0.055	0.010	None	
Beryllium	<0.0050	0.0050	None	
Cadmium	<0.010	0.010	0.005	
Chromium	<0.020	0.020	0.05	
Copper	0.011	0.010	1.0	
Iron	<0.10	0.10	0.3	
Lead	<0.10	0.10	0.05	
Manganese	<0.010	0.010	0.1	
Mercury	<0.00020	0.00020	0.001	

Parameter	**Concentration (mg/l)**	**Lab Reporting Limit (LRL) (mg/l)**	**WHO Guideline Limit for Drinking Water (mg/l)**	**Remarks**
Nickel	<0.020	0.020	None	
Selenium	<0.50	0.50	0.01	
Thallium	<0.50	0.50	0.006	
Zinc	<0.020	0.020	5.0	

The analytical results for the quarterly sampling done in April 2004 are included as Table 2-13 and Table 2-14 The sodium concentration reported for monitor well 1 and shown in Table 2-13 incorrect and is not in keeping with previous historical results reported. This high sodium concentration and the lower chloride concentration yields a Na:Cl ratio of 2.73 which would indicate caustic contamination. However this well is located north and upgradient of the CAW. It is outside the zone of contamination from the bauxite/alumina works and saline intrusion. The duplicate sample analyzed by Jamalco reported a sodium concentration of 8 mg/l and chloride concentration of 12 mg/l with the Na:Cl ratio at 0.67 which is more in keeping with the historical results reported since 1994.

The iso-sodium plot for April 2004 is shown as Figure 2-21. Sodium concentration varies from 50 mg/l to over 250 mg/l west of the RDAs. The contours of the highest sodium concentrations (250 mg/l) match those areas where saline intrusion is met at depth in the wells-MW 6 and 8.

Figure 2-21: ISO-SODIUM PLOT - APRIL 2004



c) Facilities Sampling

The sampling of sources of water being supplied to Jamalco's facilities across Clarendon and the Kingston Office is executed twice per year-once in the dry season and once in the wet season. The objective of the sampling programme is to determine the quality of water supplied for use within the facility and to determine the impact of the bauxite/alumina operations on water quality. As shown in Table 2-11 the facilities are supplied with water from both Jamalco's own wells and from the National Water Commission's public supply. The analysis is for specific parameters and covers metals, non-metals, pesticides, PCBs and volatile organics. The results for January 2004, the last sample period, are presented as Table 2-15 to Table 2-18. The results indicate that the bauxite/alumina operations, the disused solid waste dump at Mineral

Heights and the sewage disposal methods in the May Pan area have not impacted on the water quality in the limestone aquifer.

Table 2-13: SUMMARY OF ANALYTICAL RESULTS AND FIELD DATA – APRIL 2004

PARAMETER	MONITORING WELL RESULTS (mg/l)											WHO DW Guideline (mg/l)	US EPA DW Standard (mg/l)	Typical Limestone Aquifer *WQ (mg/l)
	MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-8	MW-9	MW-10	MW-11	MW-12			
LAB RESULTS														
CALCIUM	72	74	NO	78	66	110	80	63	60	170	N	75		75
MAGNESIUM	33	41		53	12	44	46	37	37	22	O	150		10
SODIUM	71	180	S	250	17	280	170	31	47	290		200	200	12
CHLORIDE	26	350	A	430	20	470	360	49	78	410	S	250	250	10
NA/CL RATIO	2.73	0.51	M	0.58	0.85	0.60	0.47	0.63	0.60	0.71	A	-	-	<1.5
ALKALINITY	260	250	P	250	210	310	260	280	270	510	M	-	-	260
**NITRATE	0.24	0.13	L	<0.050	0.073	1.00	0.17	0.069	0.12	0.18	P	10 (as N)	10 (as N)	4
SULFATE	19	23	E	60	13	58	38	33	16	63	L	400	250	8
TDS	340	850	HOLE	1100	290	1300	880	390	430	1300	E	-	500	350
Field Data														
TEMP. (*C)	29.2	29.8	Blocked	33.1	31.7	30.6	31.0	28.9	28.8	25.1		-	-	
pH	7.46	7.71	At 144'	7.51	7.53	7.29	7.48	7.52	7.53	7.44		6.5-8.5	6.5-8.5	7.2
COND. (uS)	569	1430		1930	500	2050	1460	681	742	2150		-	-	550
DTW (m)	51.46	43.71	42.43	35.54	32.93	32.26	34.95	38.10	33.38	47.91				
DOW (m)	152.4	155.4	155.4	155.4	155.4	152.4	155.4	135.00	152.4	155.4	143.2			
TOW ELEV. (m)	56.66	49.34	47.66	40.49	37.90	36.77	39.92	42.90	38.19	53.25	50.24			
WATER(m)(amsl)	5.20	5.63	5.23	4.95	4.97	4.51	4.97	4.80	4.81	5.34				
ODOUR/OTHER										**Very Turbid**				

***Shaded Values = exceedances *WQ – Water Quality. NS – Not Sampled. **Nitrate – As N includes Nitrite if present. ND – Not Detected NP – Well Not Pumping**

Table 2-14: SUMMARY OF ANALYTICAL RESULTS AND FIELD DATA – APRIL 2004

PARAMETER	MONITORING WELL RESULTS (mg/l)											WHO DW Guidelines (mg/l)	US EPA DW Standards (mg/l)	Typical Limestone Aquifer WQ(mg/l)
	PW-1	PW-2	HP	NB	DR-3	DR-4								
LAB RESULTS														
CALCIUM	88	88	98	77	P	100						75		75
MAGNESIUM	14	16	20	11	U	23						150		10
SODIUM	42	43	78	22	M	87						200	200	12
CHLORIDE	52	70	98	31	P	140						250	250	10
NA/CL RATIO	0.81	0.61	0.80	0.71		0.62						-	-	<1.5
ALKALINITY	270	260	310	240	O	330						-	-	260
**NITRATE	2.2	2.1	1.5	1.9	U	1.3						10 (as N)	10 (as N)	4
SULFATE	15	15	30	5.4	T	34						400	250	8
TDS	410	380	560	320		610						-	500	350
Field Data														
TEMP. (*C)	24.6	25.4	26.1	24.5		25.8						-	-	
pH	7.74	7.71	7.44	7.63		7.53						6.5-8.5	6.5-8.5	7.2
COND. (uS)	659	700	900	481		969						-	-	550
DTW (m)	ND	ND	ND	ND	ND	ND								
DOW (m)	86.3	122	67.0	70.1	76.2	55.8								
TOW ELEV. (m)														
WATER(m)(amsl)														

***Shaded Values = exceedances *WQ – Water Quality. NS – Not Sampled. **Nitrate – As N includes Nitrite if present. ND – Not Detected NP – Well Not Pumping.**

Table 2-15: ANALYTICAL RESULTS-METALS-JANUARY 2004

PARAMETERS	MONITORING POINTS RESULTS (mg/l)											LRL* (mg/l)	WHO DW Stds (mg/l)	US EPA DW Stds. (mg/l)
	Production Well 1	Production Well 2	Buildg 1 Ftn.	Plant Stores Ftn	Great House Well	Great House Tap	WS Tap	BV-Well	BV-Tap	RP Tap	WR Tap			
METALS														
Aluminium	0.24	0.23	0.22	0.23	0.21	No	0.20	0.26	0.24	0.20	0.29	0.1	0.2	None
Arsenic	<0.005	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	0.005	0.05	0.03
Cadmium	<0.0005	<0.0005	0.00072	<0.0005	<0.0005	Data	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0005	0.005	0.005
Calcium	91	91	90	89	85		80	97	97	78	43	0.5	75	None
Copper	<0.002	0.0041	0.57	0.0064	<0.002	Sample	0.0097	0.0094	0.16	0.0066	<0.002	0.005	1.0	1.3
Iron	0.047	0.014	0.063	0.014	0.010		0.034	0.18	0.020	0.036	0.012	0.1	0.3	0.3
Lead	<0.005	<0.005	<0.005	<0.005	<0.005	Bottle	<0.005	<0.005	<0.005	<0.005	<0.005	0.002	0.05	0
Magnesium	15	15	15	15	12		9.3	1.4	1.4	15	10	0.1	150	None
Manganese	< 0.005	<0.005	<0.005	0.018	<0.005	Broke	<0.005	<0.005	<0.005	<0.005	0.008	0.005	0.1	0.05
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002		<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	0.001	0.002
Selenium	0.006	<0.005	<0.005	<0.005	<0.005	Spilt	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	0.01	0.05
Sodium	48	48	48	48	21		7.2	5.8	5.6	48	10	0.5	200	200
Zinc	0.099	<0.020	0.13	2.2	<0.020	Sample	2.1	0.038	0.026	<0.020	<0.020	0.02	5.0	5.0

NOTES
Production Well 1-At well head ***LRL-Laboratory Reporting**
Limit
Production Well 2-At well head
Plant Stores-At Drinking Water Fountain
Buildg 1 Ftn - Building 1 Drinking Water Fountain.
Great House Well - At Well Head.
Great House Tap – Kitchen Tap.
WS Tap - Woodside Drinking Water Fountain (NWC Supply).
BV Well – Breadnut Valley Well – At Well Head.
BV Tap – Breadnut Valley Drinking Water Fountain.
RP Tap – Rocky Point Port Drinking Water Tank-At Tap (Trucked Water).

Table 2-16: ANALYTICAL RESULTS-NON-METALS AND BACTERIOLOGICAL-JANUARY 2004

PARAMETERS	MONITORING POINTS RESULTS (mg/l)											LRL* (mg/l)	WHO DW Stds. (mg/l)	US EPA DW Stds. (mg/l)
	Production well 1	Production well 2	Buildg 1 Ftn	Plant **Stores** Ftn	Great House Well	Great House Tap	WS Tap	BV-Well	BV-Tap	RP Tap	WR Tap			
NON-METALS														
Chloride	56	58	58	57	27	27	10	13	12	61	10	1	250	250
Cyanide	0.0033	<0.001	<0.001	<0.001	0.0014	<0.001	0.0012	0.0011	0.0026	0.003	0.0048	0.001	0.1	0.1
Fluoride	0.16	0.13	0.13	<0.10	<0.10	0.14	0.14	<0.10	<0.10	0.12	0.10	0.1	1.5	4
Nitrate*	2.4	2.6	2.7	2.2	2.4	2.4	1.7	1.5	1.5	2.4	0.23	0.05	10	10
Sulphate	22	23	21	22	6.9	6.5	3.5	2.4	2.5	23	39	2	400	250
Total Dissolved Solids (TDS)	430	430	420	430	310	320	270	270	260	390	210	10	1000	500
PH	7.44	7.57	7.77	7.42	7.58	7.78	7.44	7.44	7.45	7.77	8.01	NA	6.5-8.5	6.5-8.5
Temperature	24	24.5	10.5	13.4	25.3	26.1	29.3	30.1	18.8	28.6	25.4	NA	None	None
BACTERIOLOGICAL (MPN/100ml)														
Total Coli form	< 3	< 3	<3	<3	< 3	<3	<3	<3	< 3	<3	< 3	NA	0	0
Faecal Coliform	< 3	< 3	< 3	<3	< 3	<3	<3	< 3	< 3	< 3	< 3	NA	0	0

NOTES
Production Well 1-At well head.
Production Well 2-At well head .
Plant Stores-At Drinking Water Fountain
Buildg 1 Ftn - Building 1 Drinking Water Fountain.
Great House Well - At Well Head.
Great House Tap –Kitchen Tap.
WS Tap - Woodside Drinking Water Fountain (NWC Supply).
BV Well – Breadnut Valley Well – At Well Head.
BV Tap – Breadnut Valley Drinking Water Fountain.
RP Tap – Rocky Point Port Drinking Water Tank-At Tap (Trucked Water).
WR Tap – Waterloo Road Office Kitchen Tap (NWC Supply).

***LRL-Laboratory Reporting Limit**

***Nitrate-Nitrogen**

Table 2-17: ANALYTICAL RESULTS-PESTICIDES/PCBS-JANUARY 2004

PARAMETERS	MONITORING POINTS RESULTS (ppb)											LRL* (ppb)	WHO DW Stds (ppb)	US EPA DW Stds. (ppb)
	Production well 1	Production well 2	Buildg 1 Ftn	Plant Stores Ftn	Great House Well	Great House Tap	WS Tap	BV-Well	BV-Tap	RP Tap	WR Tap			
PESTICIDES/ PCBs														
gamma-BHC [Lindane]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	3	0.2
Aldrin	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	0.03	NF
Dieldrin	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.03	NF
4, 4'-DDT	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.3	1	NF
Technical Chlordane	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	0.3	2
Methoxychlor	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	30	40

*LRL-Laboratory Reporting Limit NF-None Found

Table 2-18: ANALYTICAL RESULTS-ORGANICS-JANUARY 2004

PARAMETERS	MONITORING POINTS RESULTS (ppb)											LRL* (ppb)	WHO DW Stds. (ppb)	US EPA DW Stds. (ppb)
	Production well 1	Production well 2	Buildg 1 Ftn	Plant Stores Ftn	Great House Well	Great House Tap	WS Tap	BV-Well	BV-Tap	RP Tap	WR Tap			
ORGANICS														
1, 1-Dichloroethane*	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	NF	5
Chloroform*	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	30	100
Benzene*	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	NF	5
1, 2-Dichloroethane*	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	10	NF
2,4,6-Trichlorophenol+	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10	10	NF
Pentachlorophenol+	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	50	10	30
Hexachloroethane+	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10	NF	NF
Benzo(a)Pyrene+	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10	0.01	NF

***Volatile Organic Compounds---+Base Neutral/Acid Compounds:**

NR-Not Reported ***LRL-Laboratory Reporting Limit** **NF-None Found**

2.4.5 Expansion of Plant-Impact on Water Resources

2.4.5.1 Introduction

Among the aims of the recently permitted efficiency upgrade of the Jamalco bauxite/alumina facility is to increase the production of alumina. The proposal is for production to be increased from the existing 1.25 million tonnes per year to 2.8 million tonnes per year. Along with this increase in production the following will also increase:

1) Production of bauxite residue which at the current industry rate is on a 1.2:1 ratio with the production of alumina.

2) The proposed modification to RDA#1 and the construction of RDA # 5 to store the increased bauxite residue

3) Wastewater generation including sewage

4) Water use to meet the increased production and the domestic demands from an expanded staff

There is a potentially increased risk to the groundwater resources of the Rio Minho Hydrologic basin with the efficiency upgrade of the plant and the increased production of bauxite residue, liquid and solid wastes, runoff and withdrawal of groundwater. However, for the purposes of this EIA, only considerations directly and indirectly related the increased production of bauxite residue will be identified and assessed.

2.4.5.2 Risks

2.4.5.2.1 Risk from Increased Bauxite Residue Production.

The RDA area to be used for the storage of the bauxite residue is bounded on the west by the Rio Minho, to the east by the dikes of RDA 1 and 2, to the south by the dike of RDA 4 and to the north by the fence between the Old Bowens Road and the recently installed mud thickener. The area is located on a terrace of alluvium deposited by the Rio Minho. The monitoring wells to the west of the proposed RDA site are MW 4, 5 and 6. The lithologic logs for each of these boreholes indicate a thinning of the alluvium to the north. At MW 4, the most northern of the 3 monitor, wells the alluvium is 6.1 metes thick while at MW 5 and 6 to the south the alluvium is 15.2 metres thick in each borehole. In all 3 boreholes the alluvium consisted of intercalated sand, silt and clay.

The present site preparation has however indicated that there is a limestone high in the northwestern corner and the limestone is exposed at the surface. The highs and lows of the limestone (wavy erosional surface) are shown in the cross sections Figure 2-11 and Figure 2-12

The area was classified by the Water Resources Authority as having a high pollution vulnerability because of the karstified nature of the limestone aquifer and the low attenuation capacity of the overlying alluvium. The appearance of the limestone at the surface may significantly increase the risk of contamination of the aquifer. The area therefore needs to be completely sealed, and this is the traditional practice of RDA construction at Jamalco.

The proposed method of disposal is a thickened mud with stacking and drying. Effluent to the clear lake will have to be collected to ensure that this fraction of the effluent that could contaminate the groundwater is removed from the drying areas thus reducing the risk to water resources.

The water quality monitoring programme and the analysis of the data generated has shown that the existing RDAs have not had any significant impact on the quality of water within the aquifer (Section 2.4.4). The sealing and drainage systems utilized in the construction of these RDAs have been such that no significant leakage has occurred to contaminate groundwater.

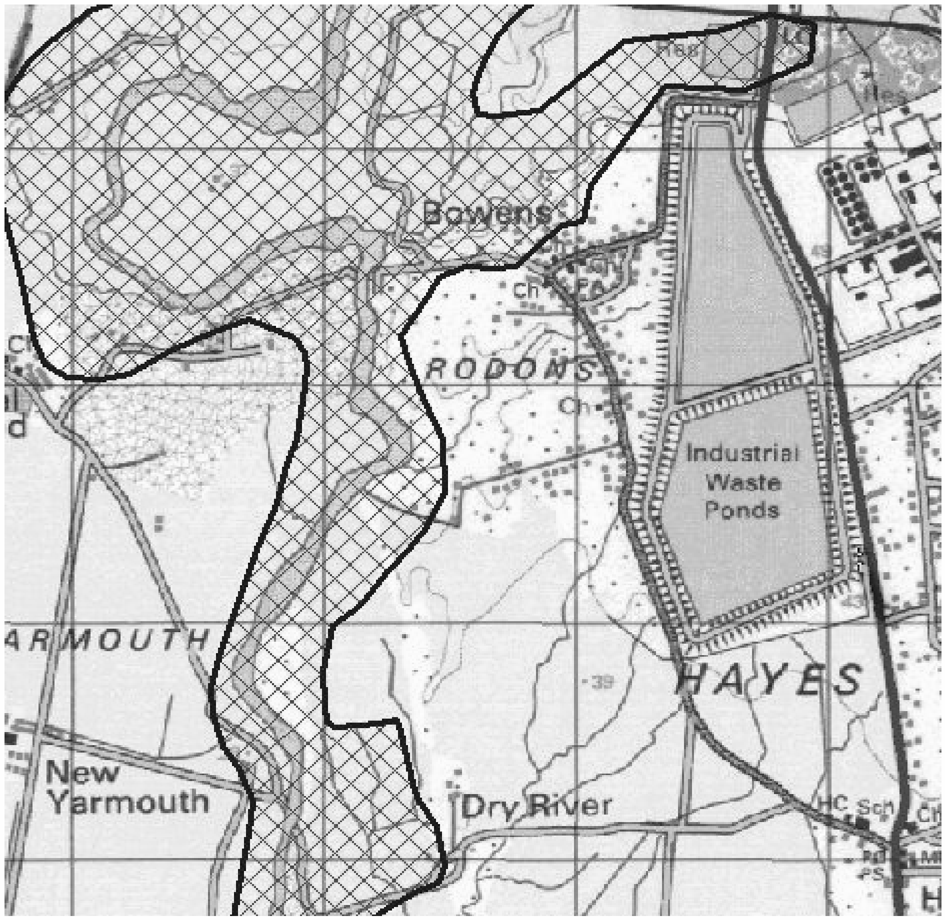
2.4.6 Flood Risk

The Rio Minho over geologic time deposited the alluvium atop the limestone formation. As the river meandered across the plains there was erosion and deposition of alluvial material to shape the present landforms. At Halse Hall the CAW and the RDAs are located on one of two terraces formed by the river. The first terrace is the highest and the present and proposed RDAs are located atop these terraces. The second terrace is the lower of the two and was recently mined by Jamalco for material to raise the dike on

RDA 4. This terrace is normally flooded when the Rio Minho is in spate. However there is a need to assess the flood boundaries for different rainfall events; to determine within which boundary the RDAs are and will be located and to determine if the present and future RDAs are at risk from flooding and a total washout. The flood plain mapping and modeling that is required to enable such a determination is beyond the scope of this assessment.

In 1986 the rainfall event that led to the wide scale flooding of Southern Clarendon was reportedly a 100-year event. The mapped flood boundaries for the area around the CAW are shown on Figure 32 below. The mapping was done after the event and once the flooding had receded hence there may be some inaccuracy in the boundaries.

Figure 32: Flood Boundaries around the CAW for the 1986 Flood Events



As can be seen, the flood boundaries for the Webbers Gully extends across the clear lake and up into New Bowens. The Rio Minho flood boundaries follow the contour of the terraces. It is not known if the flood level was above the second terrace. RDAs 3 and 4 were not yet constructed at the time of flooding. No damage was reported to RDAs 1&2.

The impact of climate and weather variability could yield a higher flood event where the flood boundaries for a lesser or similar rainfall event could be higher and would cause damage to the RDAs.

Flooding of the RDAs would have a significant and possible catastrophic impact on the water quality within the basin. The surface water system would be the first to become contaminated followed by the groundwater system as the contaminated surface water recharges the aquifers-limestone and alluvium. The plant would have to cease operations, as the loss of the RDAs would mean that there would be no bauxite residue storage area.

The mapping of the flood boundaries would allow for the design of structures to prevent the floodwaters from reaching the RDAs. One possible structure could consist of embankments of river material protected by gabions to prevent erosion of the embankments as was done in Webbers Gully after the straightening of the gully. Non-structural methods to prevent flooding could also be implemented. These could include the regular cleaning of the river to remove material deposited and so maintain the gradient and freeboard of the river.

It should be noted that the location of the monitor wells, particularly MW 5 and 6, were selected to prevent flooding and compromise of the monitoring system as well as loss of the monitoring point.

It is therefore recommended that Jamalco employ the services of a Hydrologist with experience in modeling and use of the HEC-RAS software to determine the flood levels for various events. The mitigation effect of different structural and non-structural methods to reduce the impact of the flooding could also be modeled to determine the most optimal solution.

2.4.7 Early Warning/Monitoring System

The ability to determine at a very early stage any impact that the bauxite/alumina operations has on the groundwater around the CAW will be necessary and critical to reducing the risk to groundwater quality. While the existing monitor wells were located, designed and constructed to allow for this determination, over time it has been noted that improvements can be made. However at the time of the location of the monitor wells there was not as much information on the hydrogeology of the area as there is now. The drilling, monitoring and interpretation of the analytical data has led to a greater understanding of the hydrogeology and the water resources around the CAW. The loss of two monitor wells however, has left gaps within the system that need to be closed.

The monitor wells as designed, in the absence of any data at that time, monitors water quality from one zone only and that zone is deep within the aquifer. The screens were placed at depths based on the theory that the denser caustic effluent would sink to the base of the water column or the aquifer bottom. However because of the depth of the monitor wells, a few enter the mixing zone above the freshwater/seawater interface and there is no detection of high sodium concentration without the corresponding high chloride concentration; no detection of pH above 8.5 units and no detection of high alkalinity.

An assessment of the system to date would show that it has performed well and has provided new information to enable a more informed understanding of the water resources of the area. However improvements to the system can and should be made.

It is recommended that the following be implemented to upgrade the monitoring system and analytical systems to ensure that impacts of bauxite/alumina operations on water quality can be easily and quickly detected to allow mitigative action to be taken.

1 Replace monitor wells 7 and 12 to close two gaps.

2 Based on the expansion of the CAW locate and construct new monitor wells to enable improved coverage around the CAW.

3 Install multi-level piezometers to enable determination of zone contributing contaminant, if any, to the well

4 Dedicated sampling pumps to be installed in each well to prevent cross contamination

5 Analyze for heavy metals (suite of 16) for each well at least once per year. Analyses to be done overseas at USEPA and NELAP certified laboratory.

6 Jamalco to improve sampling procedures and upgrade laboratory to ensure QA/QC of analyses

7 Priority to be given in laboratory to analyses of samples to ensure completion within the maximum holding time.

2.4.8 Conclusions

1) Water quality degradation-resulting from possible leakage from the expanded Refuse Disposal Areas (RDAs) and increased withdrawal of groundwater from the limestone aquifer to meet the increased demand for water. The former could lead to contamination by caustic effluent while the latter could lead to increased salinization of groundwater as a result of over pumping and the movement inland of seawater.

2) Dewatering of the aquifer and the sustainability of aquifer yield

3) Damage to the RDAs caused by flooding of the areas from the Rio Minho River as a result of significant rainfall events in the upper watershed.

The risk to water quality from caustic effluent can be eliminated if the construction of the RDAs is executed in accordance with engineering standards, as have the previous RDAs (1-4). As shown through the information generated by the monitoring programmes executed by Jamalco and by the consultant on behalf of Jamalco have shown no significant change in water quality with time and previously expanded operations. The concentrations of certain parameters indicate the expanse of the seawater intrusion within the limestone aquifer due to over development for agriculture in the pre-1961 period when there was no management of water resources in the basin.

The assessment of water resources also indicates that meeting the increased demand may not result in an increase in withdrawal from the aquifer. Improved water use efficiency and the bringing into the industrial process wells formerly used for agricultural purposes, can assist in meeting the water demand. If there is to be increased withdrawal there is sufficient resources to meet the demand. The main concern would be the location of the wells to minimize interference effects and reduce drawdown while maintaining water quality.

The risk to the RDAs from the floodwaters of the Rio Minho after a significant rainfall event is high and a most critical risk. The flood boundaries for the Rio Minho in the vicinity of the CAW should be derived and where necessary structures put in place to prevent erosion of the RDAs and contamination of water resources. Protection for the anti-flooding structures should also be placed where necessary.

The ability of the monitoring network to detect at an early stage the impacts on water resources from the expansion of the CAW will be very critical. The areal coverage of the network (covering all the gaps); the effectiveness of the network (is it providing the data and information to assess the impacts if any); the frequency of monitoring and the parameters monitored need to be assessed and action implemented to deal with any shortcomings. Recommendations for improvement are set out in section 2.4.7 above.

2.5 Wildlife and Vegetation

2.5.1 Methodology

The ecological assessment was conducted primarily through qualitative methods supported by literature research. The literature review was based on a series of relatively current studies which employed the use of quantitative methods for several areas in the sphere of influence of the project sites. Methods employed included the following:

- Aerial photography and land use classification mapping to identify plant species distribution and classification.
- Ground- truthing to confirm land use classification and vegetation type and distribution
- Plant collection and plant identification through the aid of a recognized taxonomist and herbarium
- Literature research of information related to the geographical influence of the proposed project to generate species inventories.
- Animal identification through field guides, photography, vocalization, tracks, fecal deposits, burrows among others.

2.5.2 Ecological Context

The vegetation types noted in the study area range from wet limestone forests to coastal vegetation, featuring extensive areas of mangroves and dry xerophytic vegetation.

This gradation of vegetation types is influenced by elevation, temperature, degree of rainfall and soil types. The coastal areas are exposed to harsher conditions due to water unavailability in saline areas, where plants require special adaptations to manage physiological drought to more inland areas where cooler temperatures and frequent rainfall have influenced the evolution of hydrophillic species.

2.5.2.1 National Biological Diversity – International And National Levels

A diversity in habitats has clearly led to Jamaica being rated fifth highest in endemic plants of any island, worldwide. Based on information through the National Strategy and Action Plan on Biological Diversity in Jamaica- 2003, of the 3,304 known vascular species to occur in the country at least 28% are endemic.

Table 2-19-FLORA DIVERSITY[2]

Terrestrial flora	# of indigenous species	# of endemic species	% endemicity
Bromeliads	60	22	36.7
Orchids	230	60	26
Ferns	579	67	11.5
Cacti	20	10	50
Palms	10	7	70
Grasses	~200	1	0.5

Faunal species similarly have high levels of endemicity with land birds showing 45% and amphibians and reptiles showing a 100% and 76%, respectively

Table 2-20- FAUNA DIVERSITY[2]

Terrestrial fauna	# of indigenous species	# of endemic species	% endemicity
Land snails	514	505	98.2
Grapsid crabs	9	9	100
Jumping spiders	26	20	76.9
Fireflies	48	45	93.8
Butterflies	133	20	15
Ants	59	6	10.3
Amphibians	22	22	100
Reptiles	43	33	76.7
Shore & Seabirds	39	1	2.6
Land birds	67	30	44.8
Bats	21	2	9.5
Other mammals	2	2	100

In order to protect this diversity, the Government, through the Forestry Department, has entered into an arrangement with Jamalco, guided by a 'no-net-loss' policy where the two

[2]Source: National Strategy and Action Plan on Biological Diversity in Jamaica - 2003

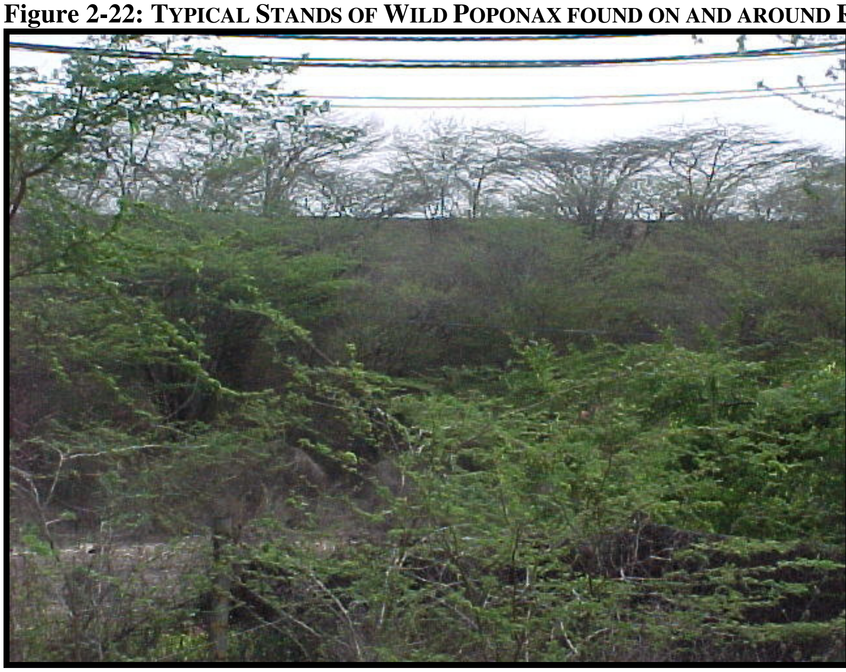
organizations will work to compensate for the loss of forest cover due to mining operations. This will see the establishment of new forests on selected reclaimed bauxite mined out areas as well as the protection and preservation of existing forests. The full text of the MOU is presented in Appendix II: REFORESTATION PLAN IN JAMAICA – MEMORANDUM OF UNDERSTANDING BETWEEN MINISTRY OF AGRICULTURE- FORESTRY DEPARTMENT AND ALCOA.

2.5.2.2 Residue Disposal Area

A new Residue Disposal Area (RDA), adjoining the existing RDA 4 is proposed for construction in the future. Prior to the construction of RDA#5 it is proposed by Jamalco that RDA#1 be modified to accommodate a dry stacking technology and facilitate an additional six (6) months of residue storage.

This EIA is primarily focused on the modifications to RDA#1 and no disturbance or negative impacts are envisioned for any floral or faunal species due to this project.

Figure 2-22: TYPICAL STANDS OF WILD POPONAX FOUND ON AND AROUND RDA



The general ecology of the site and the areas along the railway leading to the alumina plant reflects plant species exposed to dry and hot conditions which may be generally described as Thorny scrub. Many of the water conservation measures employed by species in the coastal areas, described below, were noted here. The dominant species was Wild poponax (*Acacia tortusa*) which had an even distribution. Specimens were found to be of an average height of 3 m (9ft). The plants were highly branched with deep canopies, accounting for an estimated 60% of the plants height. However, the plants did not form a continuous canopy. A herb or sub-canopy was not represented in the scrub area. However, Seymour grass (*Andropogon pertusus*) was quite common. The species list is presented in Table 2-21 below.

Table 2-21: Thorn Scrub

Family Name	Scientific Name	Common Name	Status/Rank	Habit
Amaranthaceae	*Achyranthes indicia*	Devil's horse whip	Widespread	Annual herb
amaranthaceae	*Gomphrena decumbens*	None	Common	Herb
Anacardiaceae	*Mangifera indicia*	Mango	Cultivated/Naturalized	Tree (5-10m)
Anacardiaceae	*Anacardium occidantale*	Cashew	Cultivated	Tree (4-8m)
Asclepiadaceae	*Calotropis procera*	Dumb cotton	Widespread	Shrub/Tree (4-6m)
Boraginaceae	*Ehertia tinifolia*	Bastard cherry	Fairly common	Tree (6-15m)
Cactaceae	*Harrisia gracilis*	Torchwood dildo	Common	Shrubby cactus (2-6m)
Caesalpiniaceae	*Haemotoxylum campechianum*	Logwood	Common/Naturalized	Tree (10m)
Commelinaceae	*Commelina diffusa*	Water grass	Widespread	Weed
Compositae	*Eupatorium spp*	None		Usually a Shrub
Euphobiaceae	*Jatropha gossypiifolia*	Belly-ache Bush/Cassada Marble	Common	Shrub (60-120cm)
Fabaceae	*Crotalaria retusa*	Rattle weed	Common	Shrubby herb (1m)
Malvaceae	*Sida acuta*	Broom weed	Common	Under shrub
Mimosaceae	*Leucaena leucocephala*	Lead Tree	Widespread	Shrub/Tree (3-6m)
Mimosaceae	*Mimosa pudica*	Shame-a-Lady/Shame weed	Widespread	Weed (30-100cm)
Mimosaceae	*Samanea saman*	Guan go	Common/Naturalized	Tree (16m)
Mimosaceae	*Acacia tortusa*	Wild poponax	Common	Shrub/Tree (3-5m)
Nyctaginaceae	*Pisonia aculeate*	Cockspur/Wait-a-	Same	Shrub (6m)

Family Name	Scientific Name	Common Name	Status/Rank	Habit
		bit/Fingrigo		
Orcidaceae	*Broughtonia sanguine a*	Orchid	Common	Epiphyte
Poaceae	*Andropogon pertusus*	Seymour grass	Widespread	Grass, stoloniferious
Poaceae	*Axon opus compressus*	Carpet grass	Widespread	Grass, stoloiferous
Sapindaceae	*Blighia sapida*	Ackee	Same	Tree (8-15m)
	None	Callaloo	Cultivated	Shrub

The Rio Minho River runs through a section of the study area. Vegetation flanking the river showed a marked difference to that found on the plains. The height, diversity and density of the plant species were much greater and the proximity to water resources is undoubtedly a contributing factor. Aquatic and hydrophilic plants represented the only variation from xerophytic vegetation and naturally their distribution was limited to the waterbodies and waterways traversing the Thorn Scrub. Tree species found in close proximity to the river included Guango, Ackee and Mango. Other noticeable plants found close to the water edge included reeds (*Typha domingensis*) and water grass (*Commelina diffusa*).

General trends observed in the vegetation found in proximity to the RDA were as follows:

- Vegetation height of Wild Poponax increased with distance from the access road with an average height of 2.6m (8.5ft)
- Areas of bare ground were mainly as a result of pathways

Sugarcane fields to the south of the RDA could come within the sphere of influence during the construction phase of the RDA.

2.5.3 Summary

Sixteen plant families were recorded accounting for twenty-four species. One endemic species was noted, *B.sanguinea*, a common orchid.

2.6 Natural Hazard Vulnerability

2.6.1 Natural Hazard Vulnerability

2.6.1.1 Flooding

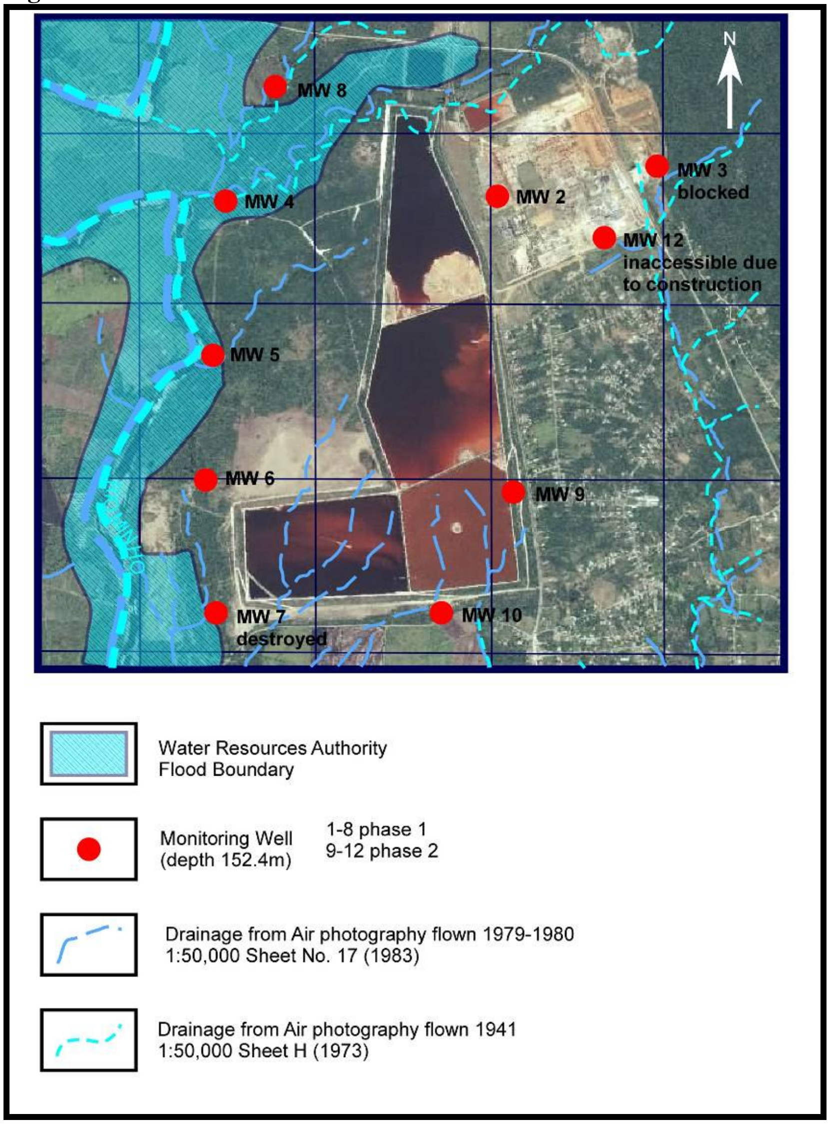
Specific records of flooding in the Rio Minho floodplain date back to 1886, reported in the Tri-Weekly Gleaner, June 19, 1886 (Rowe, 2004, in preparation), when heavy rains in June of that year led to what was believed to be the worst flooding on record for that river. The river was 40 ft (12.2 m) deep at the May Pen bridge, some 4 ft higher than the previous record, and did immense damage to roads and property. Affected localities included Halse Hall and Parnassus and Caswell Hill.

The worst flood event of the 20th century occurred in 1986, when rainfall within the Rio Minho catchment caused the river to overflow its banks to cover wide areas of the Rio Minho Alluvial Fan. The approximate extent of this flood event is inserted on Figure 2-1. According to the Water Resources Authority, this event had an estimated return period of 100 years.

The most notable feature of the flood water extent is that north of Kemps Hill the flooding was confined to a relatively narrow floodplain, whereas south of Kemps Hill the flood waters spread out over a wide area. This is a reflection of the fact that the river is incised into the upper part of the fan, while in the southern, Vere Plains part, it is not. It is suggested that this may be a function of continuing movements along the South Coast Fault.

With respect to the refinery and RDA area (Figure 2-23), the risk from flooding is low, due to the fact that these are constructed on the high terrace of the well-drained, relatively thin Hayes Gravels. During the June 1986 flood event the only part of the plant that was flooded was the low-lying storm lake at the northern end of the RDAs.

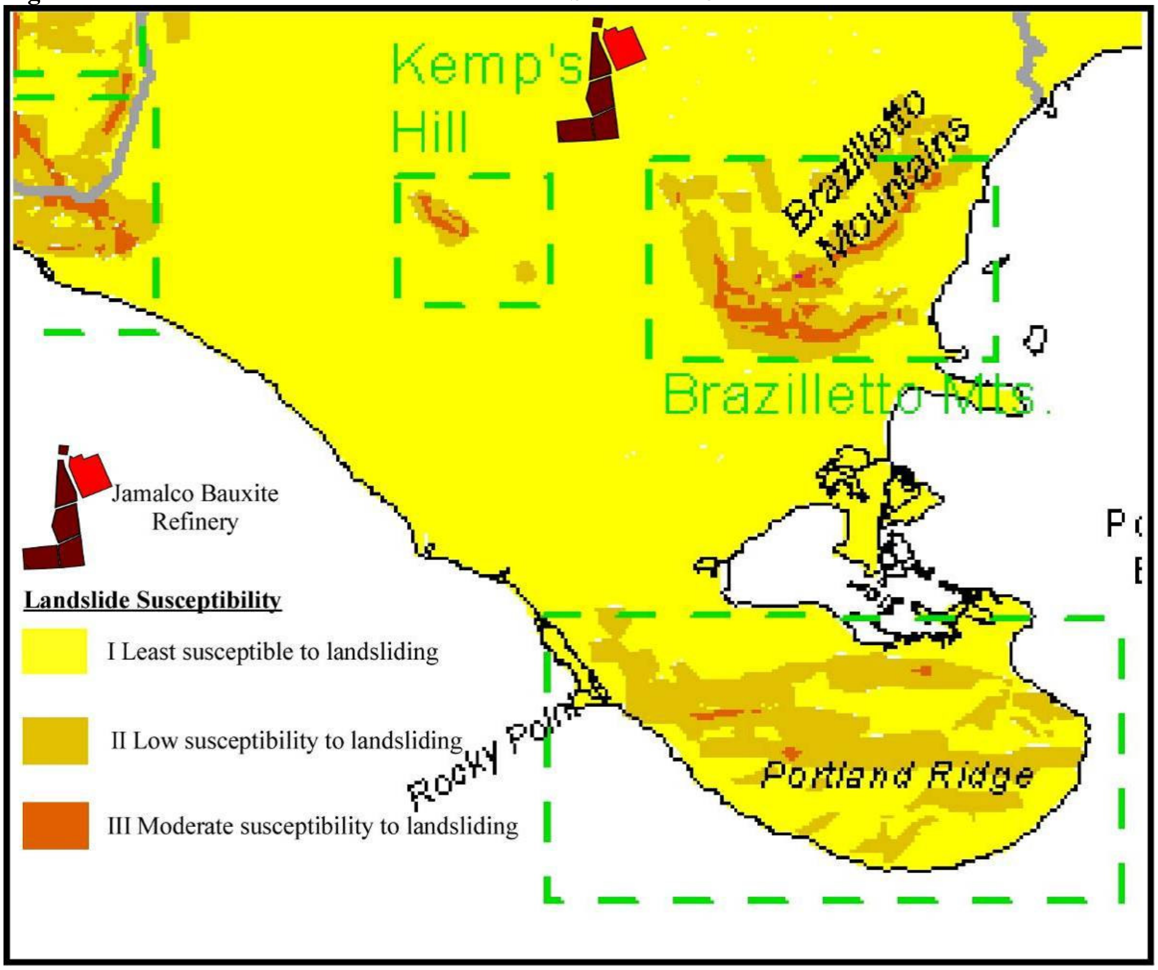
Figure 2-23: 1986 FLOOD BOUNDARY AND MONITORING WELLS AT CLARENDON ALUMINA WORKS



2.6.1.2 Landslides

There appears to be no historical records of landslides in the district. While no detailed assessment of the landslide susceptibility has been carried out in southern Clarendon to date, the landslide susceptibility map of southern Clarendon (Figure 2-24) indicates low susceptibility levels at Hayes. This can be attributed to the flat lying nature of the topography, the presence of fairly easily drained alluvial soils, and the relative dry climate.

Figure 2-24: LANDSLIDE SUSCEPTIBILITY MAP OF [3]SOUTHERN CLARENDON



The design and construction of the dykes impounding the present RDAs appear to be sound, with no reports of slumping or collapse. The slopes of the dykes are subject to erosion from rainfall, taking the form of vertical runnels. The attempts to control or reduce this erosion through the planting of grass, appears to be successful where the grass has caught. On the east-facing slopes the grass cover is well-developed (Figure 2-25). On other slopes the cover is still incomplete.

[3] *(Source: South Coast Development Project.)*

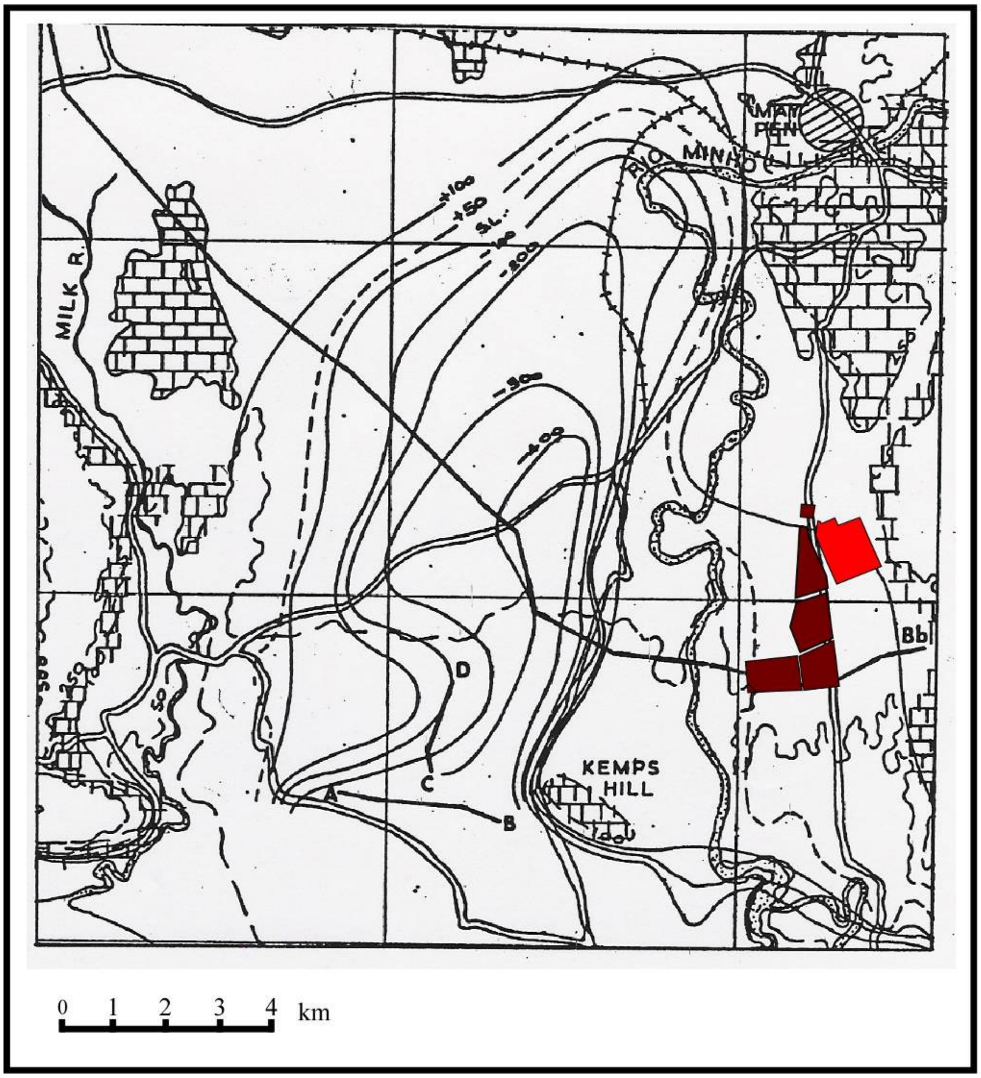
Figure 2-25: GRASS COVERING SLOPE OF DYKE OF RESIDUE DISPOSAL AREA.

2.6.1.3 Tectonics And Faulting

2.6.1.3.1 Tectonic History

The tectonic history of the Clarendon Plains includes block faulting in the surrounding limestone uplands, producing the half graben in the limestone bedrock underlying the plains (Figure 2-26). This fault activity probably continued during the earlier stages of the formation of the alluvial fan complex. It is likely that the southern Clarendon Plains are experiencing gradual subsidence in recent times.

Figure 2-26: Contour Map showing Limestone Elevations under Plain (Elevations in Feet above Sea Level).[4]



2.6.1.3.2 Location of Faults

The distribution of faults on Figure 2-1 is derived from Geological Sheet #16, May Pen (1974), the earlier 1:250 000 scale geological map of Jamaica (1958) and Charlesworth (1980). The Rio Minho alluvial plain appears largely unaffected by faulting, but as these are superficial deposits it is unlikely that any faults can be identified by surface mapping. Two sets of faults have been mapped within the limestone. One set has a general ENE-WSW trend, while the other set trends roughly N-S. The effects of this faulting and the

[4] *(Source: Charlesworth, 1980).*

age relationship with the alluvial plain are uncertain. However, the variability in depth to bedrock (Figure 2-26) suggests the presence of N-S trending faults in the bedrock which have controlled the thickness of alluvial sediments (e.g. the Kemps Hill fault, Figure 2-1; Charlesworth, 1980). These faults may even extend up into the lower part of the alluvial cover, although there is no direct evidence for this. The ENE-WSW trending set is truncated by the alluvium, indicating that the faulting pre-dates the deposition of at least the more recent alluvial material. These faults probably are also continuous beneath the alluvial cover.

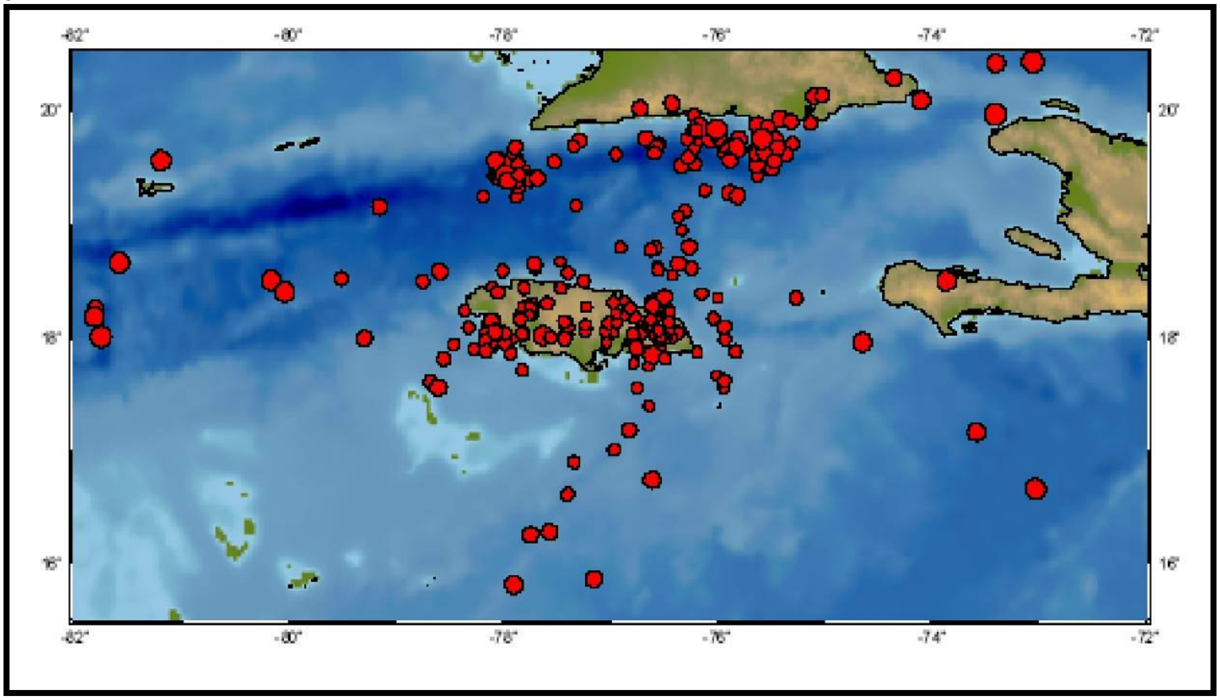
The southern part of the alluvial plain, south of Kemps Hill, contains thicker alluvial deposits and this difference in thickness appears to be controlled by the E-W trending South Coast Fault, a well defined feature which extends from Great Pedro Bay in St. Elizabeth a distance of approximately 60 km, through the Brazilletto Mountains in southern Clarendon and beyond (Figure 2-1). That this fault is still active is strongly suggested by the existence of the radioactive mineral springs that occur at Salt River and Milk River (Zans et al., 1963).

2.6.1.4 Seismic Activity

2.6.1.4.1 Regional

Jamaica lies in the seismically active northern plate boundary zone of the Caribbean Plate (Draper et al., 1994 and Figure 2-27). High magnitude earthquakes originating from as far away as the south coast of Cuba may be felt in Jamaica. For example the Cabo Cruz earthquake of magnitude 6.9 which occurred in May 1992 was felt with intensity 4 in Kingston, Jamaica. The 1993 earthquake of magnitude 5.4 which originated in Jamaica was felt in Cuba with intensities of 3-4. No damage was reported in either case from the distant country (pers. comm. M. Grandison).

Figure 2-27: EPICENTRES OF EARTHQUAKES OCCURRING BETWEEN 1998 AND 2001 IN THE VICINITY OF JAMAICA[5]

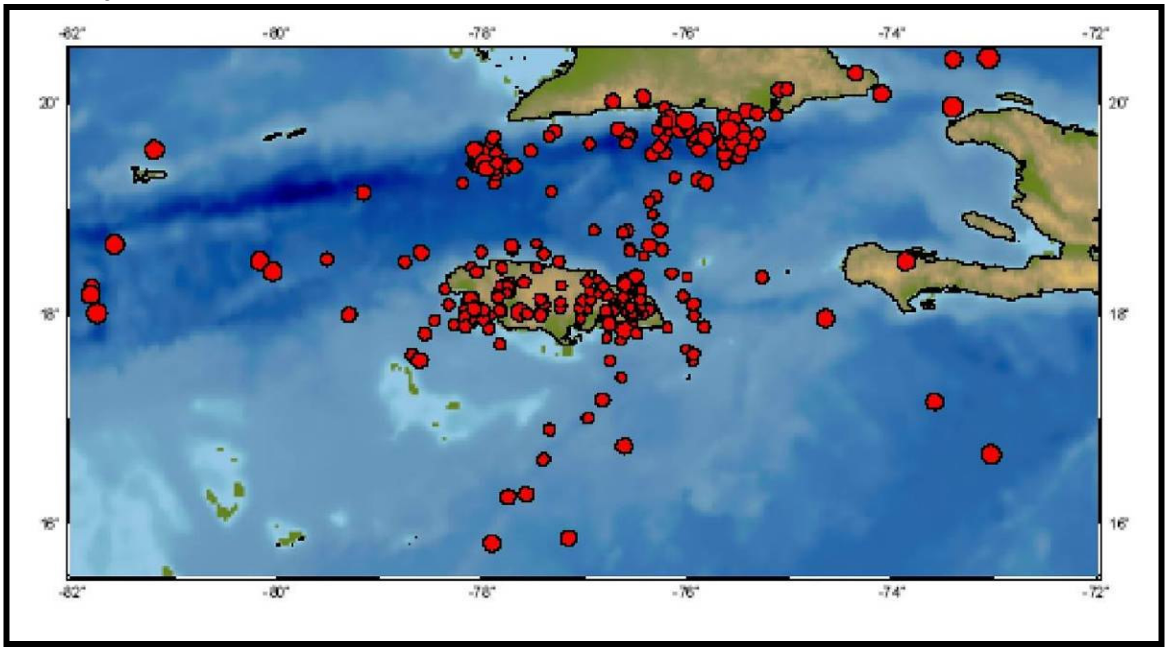


2.6.1.4.2 Local

Figure 2-28 is a map of Jamaica showing the epicentres for earthquakes that occurred in the period 1998-2001. No local earthquakes of these magnitudes occurred in the vicinity of Hayes, although there is one located on the trace of the buried South Coast Fault.

[5] *(Source: The Earthquake Unit).*

Figure 2-28: EPICENTRES OF EARTHQUAKES OCCURRING BETWEEN 1998 AND 2001 LOCATED IN AND AROUND JAMAICA[6]



An investigation of the historical records carried out for an earlier EIA for the Hayes plant and RDAs (Conrad Douglas and Assoc.) of seismic activity in this area has shown that the adverse effects of earthquakes have been experienced there:

"The well-documented 1692 Port Royal earthquake had disastrous effects in the Lower Vere Plains, with modified Mercalli intensities of MM(X) being experienced in Alley and Salt River, both of which lie at about a 10 km radius from the study area.

The following quote from a newspaper clipping written by the local Rector illustrates: "all brick and stone building were thrown down and water spewed out of the chasms opened in the ground by the earthquake so that even dry gullies ran water". The St. Peter's Anglican Church in Alley built in 1671 was destroyed beyond repair. However, the Halse Hall Great House, where alluvial thicknesses are comparatively low, survived the 1692 earthquake, as well as subsequent ones."

The Great House (now the property of JAMALCO) is situated about 6 km to the north of the JAMALCO alumina plant, and perhaps, more significantly, lies on the well-drained

[6] *Source: The Earthquake Unit).*

Hayes gravels, well above the water table.

"Subsequent damaging earthquakes are, most notably, those of 1907 and 1957. The 1907 earthquake appears to have caused some damage in the Vere Plains. Intensities of MM(VII) were reported in Alley with incidence of damage to chimneys and buildings (Tomblin & Robson, 1977). The 1957 earthquake had intensities of MM(IV) to MM(V) in the Lower Vere Plains (Robinson *et al.*,_1959). In each 50-year period, starting with 1991 and counting backward for four 50-year cycles, at least one damaging earthquake, of MM(VI) or higher, has occurred in the area. Shepherd (1971) reported that Lower Vere had a frequency of 5-9 damaging earthquakes per century on average.

Compared to the rest of Jamaica, the study area is not in a very active zone. However, the Vere Plain is largely built up of alluvial clays, sand and gravel, and in the presence of ground water, this material will be susceptible to liquefaction in an earthquake of high enough intensity. Thus, the height of the water table will be an important factor in determining the area's earthquake risk.

2.6.1.5 Conclusion

- The geotechnical characteristics of both the limestone bedrock and the overlying Hayes gravel are suitable for continued expansion of plant facilities and additional RDAs.
- The risk of flooding is minor, except for the area immediately north of the present RDAs.
- The plant and RDA areas are unlikely to experience landslides.
- The present design of the dykes impounding the RDAs appears to result in stable structures. The planting of grass on the dyke slopes to combat erosion is successful where the vegetation has caught, notably on east-facing slopes.

Seismic activity is low in the immediate vicinity of the plant, but more distant, high magnitude events are likely on a multidecadal scale. These should not pose a problem through liquefaction.

SOCIO-ECONOMIC ANALYSIS/COMMUNITY CONSULTATIONS

3 Socio-Economic Analysis/Community Consultations[ii]

3.1 Summary

3.1.1 Introduction

This report presents the findings of a survey conducted among residents within the radius of influence of the project, in Southern Clarendon between May and June 2004. While this survey was not conducted to solicit views and opinions solely for the modification of RDA#1, it was designed to address the wider issue of the Efficiency Upgrade/Expansion of the entire operations which included the Residue Disposal Areas.

Additionally, meetings have been held with community council groups, a major public meeting has been held and other community consultations have taken place in recent times to address various issues related to Jamalco's operations, including the Residue Disposal Areas. Also, a review of the concerns and opinions of the residents from the earlier EIA study for the construction of RDA# 4 completed by Conrad Douglas & Associates Limited (1996) was conducted to revisit the issues at that time.

3.1.2 Socio-Economic Survey

The objective of the survey was to determine the level of knowledge of the population of the existing and proposed operations, to ascertain their views on the perceived or known impacts of the operations as well as to solicit their perceived solutions to existing problems.

3.1.2.1 Methodology

The survey was based on a 5 per cent sample of households from the enumeration districts in the study area (as defined by the Statistical Institute of Jamaica) for the 2001 Population Census. The households for administration of the questionnaire were selected at random by the interviewer, within the enumeration districts. The respondent in all instances was the household head.

The information collected through the questionnaire included the following:

1. Personal Characteristics
    - Age and Gender
    - Number of Years Lived in the Community
2. Opinions on the community
    - Factors most preferred
    - Factors least preferred
    - Benefits of large scale development to the community
3. Awareness and Opinions on Existing Bauxite Operations
    - Perceived negative impacts
    - Perceived positive impacts

   Knowledge of and Views on Upgrade Plans as they relate to:
    - Economic Value of the Community
    - Pollution
    - The Local Environment generally
    - The Individual
    - Job Opportunities
4. Water Availability
    - Source of drinking water
    - Perception of water quality
5. Miscellaneous
    - Awareness of community activities by Jamalco
    - Working experience in bauxite industry
    - Receipt of compensation for pollution problems

In most instances the questions allowed for multiple responses. The responses were coded and the data captured. The findings as they relate to the two main areas of the parishes indicated are summarized below. The details of the specific findings related to the communities are presented elsewhere in this report.

3.1.2.2 The Survey Population

- Issues related to "quality of life and people" were viewed as the best things about the communities; the reasons people liked their communities. An equal percentage of the respondents, 44.4%, stated that what they liked most about their communities was the "friendly people" and the quietness of the communities. The availability of farmland was the next highest ranked, selected by 15% of respondents.

- The factors, which were reported by most Clarendon respondents as the reason for not liking their community, were unemployment and poor roads. Unemployment was given as the reason by 41.4 per cent of respondents and poor roads by 33.3 per cent.

- More than 7 out of 10 (71.7 per cent) of Clarendon respondents viewed "large scale development as beneficial to the community. Job opportunities and the potential for development of skills were seen as the primary reasons for this view.

- Respondents who did not agree with the statement saw large-scale development as impacting negatively on the environment.

- No direct connection was made between negative impacts and the RDA's, however, opinions related to water quality were mentioned on several occasions.

3.1.2.3 Awareness and Opinions on Existing Bauxite Operations

- The majority of respondents (99. per cent) in the vicinity of the RDAs are aware of the existence of bauxite or alumina processing plant operations in the area

- Of these (84.8 per cent) said they personally experience negative impacts

- Dust, soot or gaseous emissions, odour and damage to property are the three factors identified by most of the respondents as the negative impacts. Forty six per cent identified dust etc., while odour and property damage were both identified by 25 per cent and 23 per cent respectively.

- Eight out of ten (83.8 per cent) of the respondents agreed that the bauxite facility has had negative impacts on the people in the community. The reason given by the majority of the respondents is that “the area smells like caustic soda more often than not”. Just about a half of the residents (51.5%) gave this response. Almost one fifth of the respondents noted an increase in the frequency of illness (19%), while 14% of the residents chose “the area has widespread corrosion” and “plants are harder to grow” as reasons.

- Seventy –eight (78.8%) respondents agreed that the bauxite facility has had positive impacts on the people in the community. ”Job opportunities” and ironically “environmental conditions” were the reasons given by the majority of the respondents: 51.5 per cent and 16.2 per cent respectively.

3.1.2.4 Knowledge and Views on Upgrade Plans

- Nine out of ten (90.9 per cent) of the Clarendon respondents were aware of the upgrade plans.

- 79 persons felt that the proposed upgrade would affect them personally while 15 respondents felt that it would not affect them. Approximately 4 per cent were not sure while the remaining 1 per cent did not respond.

- While 47.5 per cent of respondents were of the view that the upgrade would have a positive impact on economic value of the community a higher 64.7 per cent saw the effect on job opportunities as positive. Less than 15% of respondents were of the view that there would be no change in relation to job opportunities (13 per cent) or on the economic value (9 per cent) of the community.

- Approximately 39 per cent of respondents were of the view that the proposed upgrade will impact negatively on pollution, 53.5 per cent saw a positive impact while 1 per cent saw no change. 3 per cent said they did not know what the impact on pollution would be.

- The responses to the question on the main impact overall of the proposed upgrade suggested positive as well as negative factors. The increased circulation of dust in the area emerged as the main impact seen by the respondents. More than half (53.5% per cent) of responses identified this as the main impact. 29.3 per cent) of the respondents indicated ‘more jobs’ as the main impact. More air pollution and noise (19 per cent) and more occurrences of diseases that affect breathing (6 per cent) were the next highest nominated.

- As reasons for the particular answers given, 32.3 per cent stated that ‘the present bauxite and mining and processing facilities have caused this already so it can only get worse’. Only 7 respondents felt that more jobs would be available.

3.1.2.5 Availability of Water

- (48.5 per cent) of respondents had water piped indoor available to them, while 47.5 per cent had water piped outdoor. The public standpipe was the source for 8.1 person. 3 people are unaccounted for. .

- The National Water Commission was the original supplier for all the respondents.

- More than half of the respondents are of the view that the water is not safe to drink (51.5 per cent) while only 29.3% feel that the water is safe. The proportion that does not know or are not sure is 12 per cent.

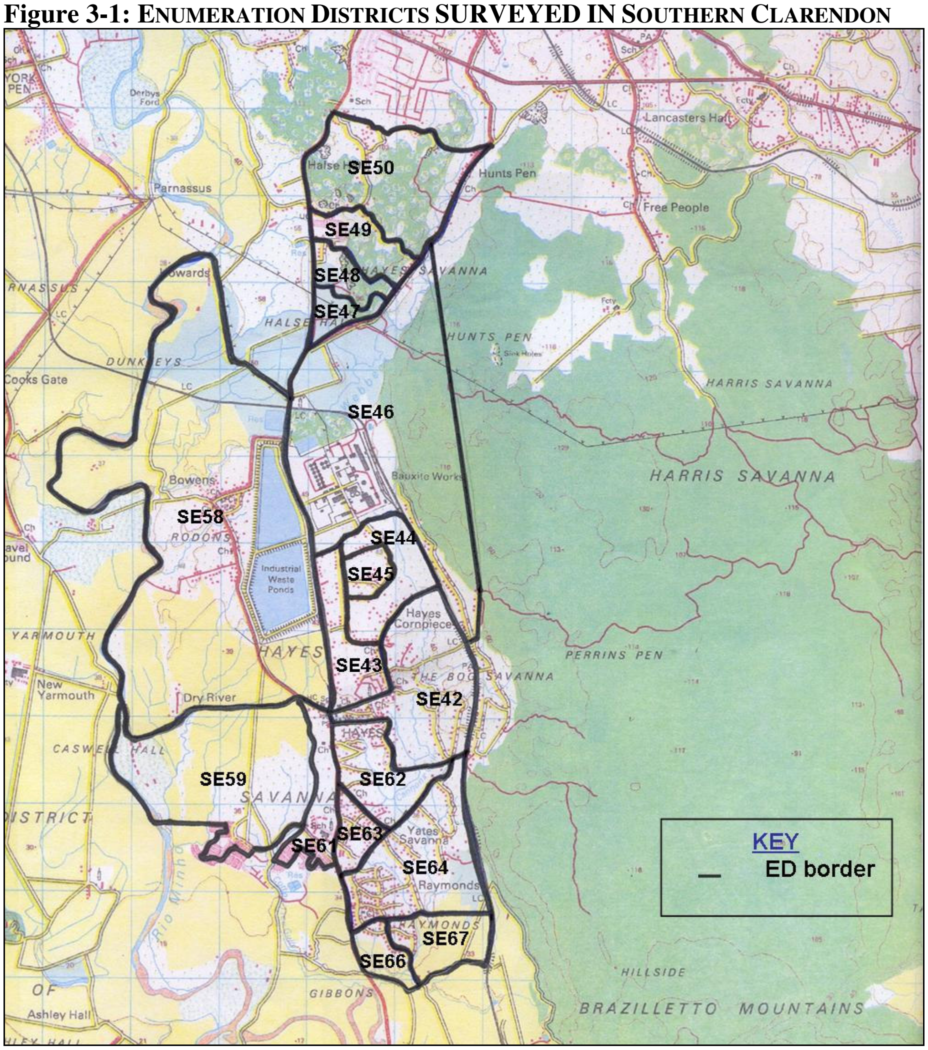
- The main reason given for belief that the water was not safe by 94 per cent of the respondents who stated this view was that the water was affected by bauxite mining and other sources. Sixty nine per cent of the respondents, who felt that the water was safe to drink, felt this way because the National Water Commission tested the water frequently or that the water looked and or smelt clean.

3.2 Southern Clarendon

3.2.1 The Communities

While the selection of the areas for interviewing were based on the enumeration districts as defined by STATIN, the communities as presented in this report were defined in the field by the interviewer and the respondent. Accordingly it is possible for a number of communities to cross Ed boundaries. The list of communities identified appears in Figure 3-1 below.

Figure 3-1: ENUMERATION DISTRICTS SURVEYED IN SOUTHERN CLARENDON



3.2.2 Demographic and Social Profile

The total population identified for this area in the 2001 census was 24,100. Females were predominant, comprising 50.5 per cent of the total. The women were slightly older than the men with an average age of 27.5 years compared to 27 years for men. In relation to educational attainment approximately 65 per cent of the population 15 years and older had attained a secondary level education, while 7 per cent had attained tertiary level.

There were 5,567 housing units in the area, 90 per cent of which were of the separate-detached type. The main material used in the construction of the housing units was concrete. Average household size was 3.5. While approximately 55 per cent of units were owned, 42.4 per cent were occupied under lease and rent free arrangements.

Eighty-two per cent of the approximately 6100 households had access to piped water. Of this, 9 per cent was receiving the water from a private source. Less tan a half (48 per cent) of households had access to water closets as toilet facilities.

3.2.3 Finding of the Study for the Communities

Due to the small size of the community samples, the analysis will be presented on the basis of the absolute numbers and not on percentages.

3.2.3.1Mineral Heights

3.2.3.1.1 The Survey Population

A total of 17 respondents were covered in the survey, 10 men and 7 women ranging between 20 and 59 years old. The majority of persons (10) have lived in the community between 11-20 years. Two persons have been residents for more than 20 years.

3.2.3.1.2 Main Findings

3.2.3.1.2.1 Opinions on the Community

- Twelve persons reported that they liked the community because of the friendly people and because it was quiet and 4 persons liked it because of the clean environment.

- Crime and Violence (5) Unemployment (4) and poor roads (3) were the main reasons given for not liking the community.

- Fifteen of the 17 residents interviewed viewed "large scale development as beneficial to the community". Job opportunities and the potential for development of skills were seen as the primary reasons for this view

3.2.3.1.2.2 Awareness and Opinions on Existing Bauxite Operations

- Sixteen (16) persons said that they were aware of the existence of bauxite or alumina processing plant operations in the area and 12 of them said that they had not experienced any negative impacts from the operations.

- The 4 who reported that the operations had impacted negatively on them identified dust, soot and gaseous emissions and odour as the factors affecting them.

- Four persons agreed that the bauxite facility has had negative impacts on the people in the community. The reasons given were that, the area smells like caustic soda more often than not (2); the area has widespread corrosion (1); and you get sick more often (1).

- All 17 respondents agreed that the bauxite facility has had positive impacts on the people in the community because of the job opportunities (16); educational and social benefits (2); and improved community relations (1).

3.2.3.1.2.3 Knowledge and Views on Upgrade Plans

- Fifteen of the 17 persons were aware of the upgrade plans, 10 thought the impact on the economic value of the community would be positive and 14 saw the impact on job opportunities as positive.

- With regard to the impact on pollution, 9 persons saw it as negative, 5 as positive, 1 saw no change and 2 did not know.

- While 11 persons felt the upgrade will *not* affect them personally, 3 felt it would and 3 were not sure. One person did not respond.

- The responses to the question on the main impact overall of the proposed upgrade suggested positive as well as negative factors. The prospects of job opportunities emerged as the main impact seen by 10 of the respondents. More dust circulating in the area (5); loss of income (2); more air pollution and noise (1); less air pollution and noise (1); and more diseases affecting breathing (1); were the other reasons given.

- As reasons for the particular answers given, 11 stated that more jobs would be available. Presumably in relation to the circulation of dust and the existence of more pollution and noise, 3 respondents felt that the present bauxite and mining and processing facilities have caused this already so it can only get worse and this is something common to all bauxite operations (1). One respondent was of the opinion that the upgrade will add new equipment that will be cleaner to operate.

3.2.3.1.2.4 Availability of Water

- All 17 respondents had water piped indoor available to them with The National Water Commission as the original supplier

- Fourteen (14) persons were of the view that the water is safe to drink because it is tested frequently by the NWC (13) and it looks and smells clean (1).

3.2.3.1.2.5 Awareness and Solutions

- Only 4 of the 17 respondents stated that they had ever voiced an opinion on the pollution problem.

- Eight (8) persons said that they were satisfied with efforts to deal with the health problems in the community.

- No one had ever received compensation from Jamalco

- Four (4) persons reported that they or members of their household had worked in the bauxite industry.

- Six (6) of the 17 respondents indicated an awareness of programs or activities initiated by JAMALCO.

- While 7 persons said they did not know or were unsure of what should be done about the pollution problem, 5 responses suggested that the bauxite emissions should be controlled/ reduced and the air filtered, while 2 responses recommended a plant upgrade.

- In relation to the health problems, the responses were as follows; provide free/partially funded healthcare (2); build/expand clinic (1); and compensation for residents/discomfort allowance (1); upgrade plant (2).

- Eleven (11) persons did not know or did not respond.

3.2.3.2 Bowens

3.2.3.2.1 THE SURVEY POPULATION

A total of 16 respondents were covered in the survey, 7 men and 9 women. Fourteen persons were between the ages of 20 and 59 years and 2 men were 60 years and over. The majority of persons (11) have lived in the community for more than 10 years, with 5, more than 20 years.

3.2.3.2.2 MAIN FINDINGS

3.2.3.2.2.1 Opinions on the Community

- Eight persons reported that they liked the community because it is quiet, 4 because of the friendly people and 3 because of the availability of farmland.

- Unemployment (6), poor roads (4) and the dirty environment (2) were the main reasons given for not liking the community.

- Ten of the 16 residents interviewed saw “large scale development as beneficial to the community”. Job opportunities (8) were seen as the primary reason for this view.

3.2.3.2.2.2 Awareness and Opinions on Existing Bauxite Operations

- All 16 persons said that they were aware of the existence of bauxite or alumina processing plant operations in the area and 14 of them said that they had experienced negative impacts from the operations.

- Odour (6), dust, soot and gaseous emissions (6) and damage to property (5) were the main factors identified.

- All but two persons agreed that the bauxite facility has had negative impacts on the people in the community. The reasons given were that, the area smells like caustic soda more often than not (8); you get sick more often (3); and plants are harder to grow (2).

- Twelve of the 16 respondents agreed that the bauxite facility has had positive impacts on the people in the community because of the job opportunities (7) and the environmental conditions (4).

3.2.3.2.2.3 Knowledge and Views on Upgrade Plans

- Fifteen of the 16 persons were aware of the upgrade plans, 5 thought there would be no change in the economic value of the community impact on the economic value of the community, while there were as many responses (4) for a positive impact as for a negative impact. In relation to job opportunities, while 7 persons saw a positive effect, 5 persons saw no change, 2 saw a negative effect and 2 did not know.

- With regard to the impact on pollution, 10 persons saw it as positive, 5 as negative, and 1 did not know.

- While 14 persons felt the upgrade will affect them personally, 2 felt it would not.

- The responses to the question on the main impact overall of the proposed upgrade suggested negative factors. More dust circulating in the area (8) and more air pollution and noise (6) were the main reasons given.

- As reasons for the particular answers given there were 13 responses stating that the present bauxite and mining and processing facilities have caused this already so it can only get worse.

3.2.3.2.2.4 Availability of Water

- Fourteen respondents had water piped indoor available to them and 2 had outdoor pipe. The National Water Commission was the original supplier

- Only 1 person was of the view that the water is safe to drink. Nine said it was not safe and 5 were not sure. Seven persons gave the reason for doubting the safety as ‘bauxite mining affects the water’.

3.2.3.2.2.5 Awareness and Solutions

- Thirteen of the 16 persons said they had voiced their opinion on the health and pollution problems in the community

- Thirteen (13) persons said that they were not satisfied with efforts to deal with the health problems in the community.

- Six of the 16 respondents had received compensation in the past.

- Three (3) persons reported that they or members of their household had worked in the bauxite industry.

- Six (6) of the 16 respondents indicated an awareness of programs or activities initiated by JAMALCO.

- Regarding advice on solutions to the pollution problem, 5 persons suggested a relocation of the plant and 4 recommended control and reduction of bauxite emissions.

- In relation to the health problems, the responses were as follows; provide free/partially funded healthcare (5); build/expand clinic (2); and compensation for residents/discomfort allowance (4).

3.2.3.3 Raymonds

3.2.3.3.1 THE SURVEY POPULATION

A total of 17 respondents were covered in the survey, 8 men and 9 women. All except one man ranged in age between 20 and 59 years old. The majority of persons (9) have lived in the community between 11-20 years and 7 persons have been residents for more than 20 years.

3.2.3.3.2 MAIN FINDINGS

3.2.3.3.2.1 Opinions on the Community

- Twelve persons reported that they liked the community because of the friendly people and because it was quiet and 4 persons liked it because of the availability of farmland.

- Poor roads (6); unemployment (5); crime and violence (3); the dirty environment (2); and unfriendly people (1); were the main reasons given for not liking the community.

- Ten of the 17 residents interviewed saw "large scale development as beneficial to the community". Job opportunities (8) were the primary reason for this view. One person indicated the opportunity for skills development and one person although seeing the benefits of large-scale development, thought that it would affect environmental quality, negatively.

3.2.3.3.2.2 Awareness and Opinions on Existing Bauxite Operations

- All 17 persons said that they were aware of the existence of bauxite or alumina processing plant operations in the area and all of them said that they had experienced negative impacts from the operations.

- Dust, soot and gaseous emissions (10); damage to property (5); and odour (2) were the main factors identified.

- All 17 also agreed that the bauxite operations have had negative impacts on the people in the community. The reasons given were that, the area smells like caustic soda more often than not (12); the area has widespread corrosion (1); you get sick more often (3); and plants are harder to grow (1).

- While 11 respondents agreed that the bauxite facility has had positive impacts on the people in the community, 6 said it did not. Job opportunities (8) and environmental conditions (3) were cited as the reasons.

3.2.3.3.2.3 **Knowledge and Views on Upgrade Plans**

- Fifteen of the 17 persons were aware of the upgrade plans. Ten persons thought the impact on the economic value of the community would be positive and 14 saw the impact on job opportunities as positive.

- With regard to the impact on pollution, 12 persons saw it as positive, 5 as negative.

- Most persons (16) felt the upgrade will affect them personally.

- The responses to the question on the main impact overall of the proposed upgrade suggested positive as well as negative factors. Most responses (8) related to 'more dust circulating in the area' while 7 responses indicated t job opportunities as the main impact. Loss of income (1) more air pollution and noise (6) were the other reasons given.

- As reasons for the particular answers given 10 stated that the present bauxite and mining and processing facilities have caused this already so it can only get worse. There were 7 responses stating that more jobs would be available.

3.2.3.3.2.4 Availability of Water

- The majority of respondents (14) received water from outdoor pipes. Only 2 had indoor pipes and 1 used a public standpipe. The National Water Commission was identified as the original supplier.

- Fourteen (14) persons were of the view that the water *was not* safe and 3 were not sure. The reason given by the 14 persons was that bauxite mining affects drinking water.

3.2.3.3.2.5 Awareness and Solutions

- All but one person indicated that they had voiced their opinion regarding health and pollution problems.

- Sixteen (16) of the 17 persons said that they were not satisfied with efforts to deal with the health problems in the community.

- Ten (10) persons had received compensation in the past.

- Four (4) persons reported that they or members of their household had worked in the bauxite industry.

- Only 3 of the 17 respondents indicated an awareness of programs or activities initiated by JAMALCO.

- Thirteen (13) persons suggested an upgrade of the bauxite plant as a solution to the pollution problem. Two (2) responses suggested that the bauxite emissions should be controlled/reduced and the air filtered.

- In relation to the health problems, the main responses were as follows; provide free/partially-funded healthcare (6); relocate JAMALCO farther away (5); and compensation for residents/discomfort allowance (2).

3.2.3.4 Savanna

3.2.3.4.1 THE SURVEY POPULATION

A total of 15 respondents were covered in the survey, 8 men and 7 women. Twelve persons were between the ages of 20 and 59 years and 3 men were 60 years and over. The majority of persons (9) have lived in the community for more than 20 years. Six persons have been resident between 11 and twenty years.

3.2.3.4.2 MAIN FINDINGS

3.2.3.4.2.1 Opinions on the Community

- Six persons reported that they liked the community because it is quiet, 4 because of the friendly people and 3 because of the availability of farmland.
- Unemployment (9) and poor roads (5) were the main reasons given for not liking the community.
- Ten of the 15 residents interviewed saw "large scale development as beneficial to the community". Job opportunities (7) were seen as the primary reason for this view.

3.2.3.4.2.2 Awareness and Opinions on Existing Bauxite Operations

- All 15 persons said that they were aware of the existence of bauxite or alumina processing plant operations in the area and all of them said that they had experienced negative impacts from the operations.
- Odour (5); dust, soot and gaseous emissions (5) and damage to property (5) were the factors identified.
- Fourteen persons agreed that the bauxite facility has had negative impacts on the people in the community. The reasons given were that, the area smells like caustic soda more often than not (7); and you get sick more often (3) ; the area has widespread corrosion (2) and plants are harder to grow.

- Thirteen of the fifteen respondents agreed that the bauxite facility has had positive impacts on the people in the community because of the job opportunities (5); environmental conditions (5); improved community relations (2) and educational and social benefits (1).

3.2.3.4.2.3 Knowledge and Views on Upgrade Plans

- Fourteen of the 15 persons were aware of the upgrade plans but not all thought the impact on the economic value of the community would be positive. While 6 persons thought the impact would be positive, 5 expressed the view that it would be negative, 1 thought there would be no change and 2 did not know. Ten of the respondents felt however that the impact on job opportunities would be positive.

- With regard to the impact on pollution, 10 persons saw it as positive and 5 as negative.

- Most persons (14) felt the upgrade will affect them personally.

- The responses to the question on the main impact overall of the proposed upgrade suggested more negative than positive factors. More dust circulating in the area (8) and more diseases affecting breathing (5) were the main reasons given. There were 4 responses for more job opportunities.

- As reasons for the particular answers given 12 respondents felt that the present bauxite and mining and processing facilities have caused this already so it can only get worse and this is something common to all bauxite operations (2).

3.2.3.4.2.4 Availability of Water

- Most persons (11) used outdoor pipes, and 4 had water piped indoors. The National Water Commission was the original supplier

- The respondents were equally divided on the question of the water safety; six persons were of the view that the water is safe to drink, 5 felt it was not safe and 4 were not sure. The water is tested frequently by the NWC (5) and it looks and smells clean (1); while bauxite mining affects the drinking water (4) were the responses regarding reasons for the opinions.

3.2.3.4.2.5 Awareness and Solutions

- Ten of the 15 persons said that they had voiced their opinion about the pollution and health problems in the past.
- All 15 respondents said that they were not satisfied with efforts to deal with the health problems in the community.
- Fourteen persons had received compensation in the past.
- Five (5) persons reported that they or members of their household had worked in the bauxite industry.
- Only 4 of the 15 respondents indicated an awareness of programs or activities initiated by JAMALCO.
- Suggestions regarding the solutions to the problem of pollution were as follows: relocate the plant (6); upgrade the plant and control/reduce bauxite air emissions.
- In relation to the health problems, the main responses was provide free/partially-funded healthcare (6).

3.2.3.5 Hayes Cornpiece

3.2.3.5.1 THE SURVEY POPULATION

A total of 30 respondents were covered in the survey, 15 men and 15 women. The majority of persons (25) were between the ages of 20 and 49 years and 23 persons have lived in the community for more than 20 years.

3.2.3.5.2 MAIN FINDINGS

3.2.3.5.2.1 Opinions on the Community

- Friendly people (11), quiet (5) and availability of farmland (4) were given as the main reasons for liking the community.

- Poor roads (14); unemployment (14); and the dirty environment (6) were the main reasons given for not liking the community.

- Twenty four of the 30 residents interviewed saw "large scale development as beneficial to the community". Job opportunities (20) were seen as the primary reason for this view.

3.2.3.5.2.2 Awareness and Opinions on Existing Bauxite Operations

- All 30 persons said that they were aware of the existence of bauxite or alumina processing plant operations in the area and all of them said that they had experienced negative impacts from the operations.

- Dust, soot and gaseous emissions (25); noise (12) and odour (9) and damage to property (8) were the main factors identified.

- All persons agreed that the bauxite facility has had negative impacts on the people in the community. The reasons given were that, the area smells like caustic soda more often than not (22); too much noise (9); you get sick more often (9); plants are harder to grow (9) and area has widespread corrosion (6);

- The majority of respondents (21) agreed that the bauxite facility has had positive impacts on the people in the community mainly because of the job opportunities (15); educational and social benefits (5).

3.2.3.5.2.3 Knowledge and Views on Upgrade Plans

- The majority of respondents (27) were aware of the upgrade plans. Seventeen (17) thought there would be positive effects on the economic value of the community. In relation to job opportunities, while 20 persons saw a positive effect, while 5 persons saw no change.

- With regard to the impact on pollution, 15 persons saw it as negative while 12 persons saw it as positive.

- Twenty eight (28) persons felt the upgrade will affect them personally, 2 felt it would not.

- The responses to the question on the main impact overall of the proposed upgrade suggested negative factors. More dust circulating in the area (19) and more air pollution and noise (6) were the main negative reasons given while 8 responses indicated more jobs.

- As reasons for the particular answers given there were 23 responses stating that the present bauxite and mining and processing facilities have caused this already so it can only get worse.

3.2.3.5.2.4 Availability of Water

- The majority of respondents (20) had outdoor piped water available to them, 7 had indoor pipe with The National Water Commission being the original supplier

- Only 8 persons were of the view that the water is safe to drink. Nineteen said it was not safe because bauxite mining affects the water.

3.2.3.5.2.5 Awareness and Solutions

- Twenty three of the 30 persons said they had voiced their opinion on the health and pollution problems in the community

- All 30 persons said that they were not satisfied with efforts to deal with the health problems in the community.

- Twenty two (22) of the 30 respondents had received compensation in the past.

- Twenty one (21) persons reported that they or members of their household had worked in the bauxite industry.

- Twenty respondents indicated an awareness of programs or activities initiated by JAMALCO.

- Regarding advice on solutions to the pollution problem, 14 persons suggested a relocation of the residents and 6 recommended the relocation of the plant.

- In relation to the health problems, the responses were as follows; provide free/partially funded healthcare (14) and compensation for residents/discomfort allowance (5).

3.2.3.6 Hayes Newtown

3.2.3.6.1 THE SURVEY POPULATION

A total of 4 respondents were covered in the survey, 1 man and 3 women all between the ages of 20 and 59 years. All 4 had lived in the community for between 11 and 20 years.

3.2.3.6.2 MAIN FINDINGS

3.2.3.6.2.1 Opinions on the Community

- No one reason stood out as the main one for liking the community as each person had a different response; friendly people, availability of farmland, quiet and no crime and violence.

- Unemployment (3), poor roads (1) and more development needed (2) were given as reasons for not liking the community.

- The 4 respondents were divided equally on the issue of the benefits of large-scale development as 2 said it was beneficial while said it was not. The potential for skills development and the negative effect on the environment were given as the reasons for the respective answers.

3.2.3.6.2.2 Awareness and Opinions on Existing Bauxite Operations

- All 4 persons said that they were aware of the existence of bauxite or alumina processing plant operations in the area and all of them said that they had experienced negative impacts from the operations.

- Odour (3) was the main factor identified.

- All agreed that the bauxite facility has had negative impacts on the people in the community, because the area had widespread corrosion.

- The 4 persons also agreed that the bauxite facility has had positive impacts on the people in the community and interestingly identified environmental conditions as the reason.

3.2.3.6.2.3 Knowledge and Views on Upgrade Plans

- All 4 persons were aware of the upgrade plans and were not very positive about the impact on the economic value of the community. Two thought this would be negative and 2 thought there would be no change. In relation to job opportunities 3 persons thought there would be no change.

- All 4 persons did however see a positive effect on pollution.

- The 4 persons felt the upgrade will affect them personally as more dust would be circulating in the area. This was because this was common to all bauxite operations.

3.2.3.6.2.4 Availability of Water

- All 4 respondents had water piped indoor available to them .The National Water Commission was the original supplier

- No one was of the view that the water is safe to drink because bauxite mining affects drinking water.

3.2.3.6.2.5 Awareness and Solutions

- All 4 persons said they had voiced their opinion on the health and pollution problems in the community and all said that they were not satisfied with efforts to deal with the health problems in the community.

- Two of the 4 respondents had received compensation in the past.

- Two (2) persons reported that they or members of their household had worked in the bauxite industry.

- Two of the 4 respondents indicated an awareness of programs or activities initiated by JAMALCO.

- Regarding advice on solutions to the pollution problem, 1 person suggested an upgrade of the plant and 1 recommended control and reduction of bauxite emissions.

- In relation to the health problems there were 3 responses recommending a relocation of people and 2 suggesting community meetings.

POLICY, LEGISLATION, REGULATIONS & STANDARDS

4 Policy, Legislation and Regulations

4.1 POLICY, LEGAL & ADMINISTRATIVE FRAMEWORK

This section provides a background on Alcoa's (Jamalco) Environmental Policy and International & National Policies, Legislation and Regulations applicable to the proposed modification of Jamalco's Residue Disposal Area number 1 (RDA #1)

4.1.1 ALCOA'S RELEVANT POLICIES, PRINCIPLES AND GUIDELINES

4.1.1.1 Alcoa's Environmental Policy

The Jamalco facility, under the management of Alcoa, strives to meet or exceed all environmental policies and regulations locally and within its corporate structure. As such, the facility is operated under strict guidance and guidelines to insure compliance at all levels of operation. The following information is derived from the existing Jamalco Environmental Policy Document.

It is Alcoa's policy to operate world-wide in a manner which protects the environment and the health of our employees and of the citizens of the communities where we have an impact.

- ✓ We will comply with all applicable environmental laws, regulations and permits, and will employ more restrictive internal standards where necessary to conform with the above policy.
- ✓ We will anticipate environmental issues and take appropriate actions which may precede laws or regulations.
- ✓ We will work with government and others at all levels to develop responsible and effective environmental laws, regulations and standards.

- ✓ All Alcoans are expected to understand, promote and assist in the implementation of this policy.

4.1.1.2 Alcoa's Environmental Principles

In support of Alcoa's Environmental Policy, the following principles have been developed to provide additional direction on specific issues. The implementation plan, which follows, provides details on how the Policy and Principles will be carried out.

- ✓ *We will support Sustainable Development*
- ✓ Alcoa will incorporate sustainable development into our operations by integrating environmental considerations into all relevant business decisions. We will achieve cleaner production through programs of waste minimization and pollution prevention with specific and measurable reduction targets.
- ✓ *We will practice responsible use of natural resources*
- ✓ Alcoa will utilize the best available information to plan and execute all projects that involve extraction of raw materials, or which may restrict the use of natural resources or impact ecosystems.
- ✓ *We will utilize techniques accepted as best practices on a worldwide basis for resource extraction, resource use, waste management, and rehabilitation of ecosystems disturbed by our activities.*
- ✓ *We will use energy wisely*
- ✓ Alcoa will strive to maximize efficient energy use, conserving non-renewable resources.
- ✓ *We will practice sound environmental management*
- ✓ Alcoa will integrate environmental management fully with business and operating management to ensure that long-term and short-term environmental issues are considered together with market and economic aspects when decisions are made

about new and existing facilities, processes, products, services, acquisitions and divestitures.

- ✓ *We will provide training and information*
- ✓ Alcoa will sponsor training in the environmental area. We will also provide employees, suppliers, customers and neighbors with information needed to understand and help us achieve the goals of our environmental policy.
- ✓ *We will audit our operations and report findings*
- ✓ Alcoa will audit each of its operations on a regular basis to identify strengths and weaknesses of the location's environmental management process and to identify actions that need to be taken to prevent environmental problems or correct environmental deficiencies. Appropriate management, including the Alcoa Board of Directors, will be informed of the audit findings.
- ✓ *We will sponsor activities to improve the science of environmental protection.*
- ✓ Alcoa will sponsor and conduct research and development (including application of emerging technologies) to improve our ability to predict, assess, measure, reduce, and manage environmental impacts of our operations. We are committed to continuous improvement in all aspects of our environmental performance.
- ✓ *We will develop and adhere to high standards.*
- ✓ Alcoa will develop and implement worldwide environmental standards and best practices with emphasis on areas that are unique to our business.
- ✓ *We will report on our activities*
- ✓ Alcoa will communicate promptly and openly with individuals and communities regarding the environmental aspects and impacts of our operations, as well as with concerned parties who request such information. Alcoa will also provide an annual Environmental Health and Safety report that describes our programs, plans

and performance. The report will be made available to shareholders and the public.

Implementation of these policies, principles and guidelines within Alcoa, begins with the CEO who is ultimately responsible for assuring conformance with Alcoa's Environmental Policy Worldwide. The technical guidance and support will be provided by the environmental staff and other support groups.

At Jamalco, local implementation of these policies, principles and guidelines is the responsibility of the location manager, business unit managers, staff support groups, operating managers, sponsoring managers, environmental affairs staff, government affairs staff, Alcoa personnel and other staff groups.

4.2 Local Policies, Legislation and Regulations

4.2.1 Policy, Legislation, Regulations & Standards

The following represents descriptions of applicable legislative requirements with which activities of this proposed modification must comply:

- Agenda 21
- Natural Resources Conservation Authority (NRCA) Act, 1991
- Watershed Protection Act, 1963
- Bauxite and Alumina Encouragement Act, 1950
- Town & Country Planning Act, 1987
- Water Resources Act/Underground Water Control Act, 1959
- Public Health Act, 1985
- Disaster Preparedness & Emergency Management Act, 1993
- National Solid Waste Management Authority Act, 2001
- Occupational Safety & Health Act, 2003 (DRAFT)
- Clarendon Parish Provisional Development Order, 1982

4.2.1.1 Agenda 21

In June 1992, Jamaica participated in the United Nations Conference for Environment and Development (UNCED). One of the main outputs of the conference was a plan of global action, titled Agenda 21, which is a “comprehensive blueprint for the global actions to affect the transition to sustainable development” (Maurice Strong). Jamaica is a signatory to this convention. Twenty seven (27) environmental principles were outlined in the Agenda 21 document. Those relevant to this project, which Jamaica is obligated to follow are outlined below:

The proposed project is governed by national policies and regulations but the country also subscribes to international environmental policies. Jamaica is signatory to one such convention which came out of the conference on the Environment and Development, held at Rio de Janeiro in June 1992.

The United Nations hosted the EARTH SUMMIT '92 and from this conference twenty - seven (27) environmental principles were outlined. Not all of these principles are applicable to the project but those deemed relevant and appropriate are outlined below.

Principle 1: Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature.

Principle 2: States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own environment and developmental policies, and the responsibilities to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond the limits of national jurisdictions.

Principle 3: The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations.

Principle 6: The special situation and needs of developing countries, particularly the least developed and those most environmentally vulnerable, shall be given special priority. International actions in the field of environment and development should also address the interests and needs of all countries.

Principle 10: Environmental issues are best handled with the participation of all concerned citizens, at the relevant level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in the decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.

Principle 17: Environmental impact assessments, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to the decision of a competent national authority.

4.2.1.2 Natural Resources Conservation Authority Act, 1991

The Act is the overriding legislation governing environmental management in the country. It also designates National Parks, Marine Parks, Protected Areas and regulates the control of pollution as well as the way land is used in protected areas.

This Act requires among other things, that all new projects or expansion of existing projects which fall within a prescribed description or category must be subjected to an Environmental Impact Assessment (EIA).

The regulations require that eight (8) copies of the EIA Study Report must be submitted to the Authority for review. There is a preliminary review period of ten days to determine whether additional information is needed. After the initial review the process can take up to ninety days for approval. If on review and evaluation of the EIA the required criteria are met, a permit is granted.

Specifically, the relevant section(s) under the Act which addresses the proposed mining activities are:

s.10: (1) Subject to the provisions of this section, the Authority may by notice in writing require an applicant for a permit of the person responsible for undertaking in a prescribed area, any enterprise, construction or development of a prescribed description or category-

(a) to furnish the Authority such documents or information as the Authority thinks fit; or

(b) where it is of the opinion that activities of such enterprise, construction or development are having or are likely to have an adverse effect on the environment, to submit to the Authority in respect of the enterprise, construction or development, an EIA containing such information as may be prescribed,

and the applicant or, as the case may be, the person responsible shall comply with the requirement.

s.12: Licenses for the discharge of effluents etc.

s.17: Information on pollution control facility

s.18: Enforcement of Controls – threat to public health or natural resources

s.32-33: Ministerial Orders to protect the environment

s.38: Regulations

4.2.1.3 Wildlife Protection Act, 1945

This act involves the declaration of game sanctuaries and reserves, game wardens, control of fishing in rivers, protection of specified rare or endemic species. The Act also provides for the protection of animals and makes it an offence to harm or kill a species which is protected. It stipulates that, having in one's possession "whole or any part of a protected animal living or dead is illegal."

This Act has to be considered for the proposed project, ecological assessments will determine if rare or endangered species will be impacted.

4.2.1.4 Watershed Protection Act, 1963

This Act governs the activities operating within the island's watersheds, as well as, protects these areas. The watersheds which are designated under this Act include Rio Minho, Cane River and Rio Nuevo watersheds areas.

Determinations will be made to identify any potential impacts that this project may have on the various watershed areas and will propose mitigative actions where impacts are identified.

4.2.1.5 Bauxite And Alumina Encouragement Act, 1950

This Act authorizes a company to produce bauxite and alumina. It also identifies the power of the Minister on behalf of the Government, to approve the expansion of the alumina industry in Jamaica. In addition, the Act identifies exemption of customs duty for articles/materials used in the production of bauxite, as well as, specific circumstances for payments of General Consumption Tax and conditions for exemption from excise and customs duty. Special provisions are also made for exemptions from Income Tax.

4.2.1.6 Town & Country Planning Act, 1987

This Act governs the development and use of land. Under this law the Town Planning Department is the agency responsible for the review of any plans involving industrial development. The law allows for specific conditions to be stipulated and imposed on any approved plans. This planning decision is based upon several factors, these include;

- the location of the development
- the nature of the industrial process to be carried out
- the land use and zoning
- the effect of the proposal on amenities, traffic, etc.

This Act is applicable to the proposed modification of RDA #1.

4.2.1.7 Water Resources Act; The Underground Water Control Act, 1959

The Underground Water Control Act of 1959 is the legal instrument and is enforced by the Water Resources Authority (WRA). The Water Resources Act is expected to provide for the management, protection, controlled allocation and use of water resources of Jamaica. Thus the water quality control for both surface and ground water are regulated by this Act.

If the proposed facility intends to utilize any existing ground water, permission would be needed, in the form of an issued license for this activity. Under this Act exploratory activities such as the boring/drilling of wells for the purpose of searching for underground water without the written consent would be a violation.

In addition, any activity which negatively influences the quality of existing water, whether ground or surface, would be relevant to this Act.

The proposed project will impact on:

- Ground water resources as it proposes, to increase ground water extraction rates.

4.2.1.8 The Public Health Act (1974)

This Act controls and monitors pollution from point sources. Any breaches of this Act would be sent through the Central Health Committee which takes action through the Ministry of Health, Environmental Control Division (E.C.D.). The ECD has no direct legislative jurisdiction, but works through the Public Heath Act to monitor and control pollution from point sources. Action against any breaches of this Act would be administered by the Central Health Committee. The functions of the department include:

- The monitoring of waste water quality, including regular water quality analysis, using water standards published by NEPA;
- Monitoring of occupational health as it relates to industrial hygiene of potentially hazardous working environments;
- Monitoring of air pollutants through its laboratory facilities.

In addition, there are various sections of this legislative instrument which governs and protects the health of the public. Relevant sections under the Public Health Act of 1985, are Sections 7.- (1) *A Local Board may from time to time, and shall if directed by the Minister to do so, make regulations relating to (o) nuisances* and 14.- (1) *The Minister may make regulations generally for carrying out the provisions and purposes of this Act, and in particular, subject to section 7, but without prejudice to the generality of the foregoing, may make regulations in relation to (d) air, soil and water pollution.*

Aspects of the project related to odour have been considered since odour is a part of the Air Emissions regulations to be promulgated in 2004.

4.2.1.9 Disaster Preparedness And Emergency Management Act, 1993

The principal objectives of the Act is to advance disaster preparedness and emergency management measures in Jamaica by facilitating and coordinating the development and implementation of integrated disaster management systems. Jamalco has established procedures and guidance documents in place in terms of disaster preparedness and emergency management.

4.2.1.10 National Solid Waste Management Authority Act, 2001

The National Solid Waste Management Authority (NSWMA) under this Act has the responsibility to manage and regulate the solid waste sector. It includes requirements for licences for operators and owners of solid waste disposal facilities (in addition to permit requirements of NEPA).

4.2.1.11 Occupational Safety & Health Act, 2003 (Draft)

This Act oversees the prevention of injury and illness resulting from conditions at the workplace, the protection of the safety and health of workers and the promotion of safe and healthy workplaces.

Sampling of sections from the Draft Act that are relevant to this project, include:

4. (1) This Act applies to all branches of economic activity and to all owners, employers and workers in all such branches.

5. (1) The owner of every industrial establishment or mine which carries on business on or after the appointed day shall, subject to subsection (8), apply to the Director in the prescribed form to be registered under this Act.

18. (1) Provides a description of the duties of employers, outlining the need for quality work areas and work environments, procedures and guidelines that will result in safe and healthy workplaces.

19. (1) discusses the duties of employers at construction sites in terms of employee safety and health during work activities.

25. (1) an employer shall make or cause to be made and shall maintain an inventory of all hazardous chemicals and hazardous physical agents that are present in the workplace.

26. (1) this section provides guidelines and procedures for employers to follow in terms of identification of hazardous chemicals. This includes labeling and identification protocols.

30. (1) Basically, this section of the Act requires an employer to provide training of its employees with a potential for exposure to hazardous chemicals or physical agents.

It is expected that this Draft Act will be Gazetted in the near future. As such, it is important that Jamalco have an understanding and appreciation for its contents.

4.2.1.12 Clarendon Parish Provisional Development Order, 1982

This document provides the development plan for the Parish of Clarendon. It clarifies the role and responsibility of the local planning authority and provides guidance on how development of the parish should proceed. All activities in this proposed modification Jamalco’s RDA #1 that requires local planning authority approval will be properly identified and the appropriate permits and licenses will be secured.

Special note: The Jamaica Bauxite Institute (JBI) is the regulatory agency monitoring the bauxite industry, and as such their policies will extend to any development on bauxite owned lands.

4.2.2 Summary of the Legislation and Responsible Agencies

Table 4-1: NATIONAL LEGISLATION AND RESPONSIBLE AGENCIES

LEGISLATION	INSTITUTION RESPONSIBLE
NRCA Act, 1991	Natural Resources Conservation Authority
Wildlife Protection Act, 1945	Natural Resources Conservation Authority
Watershed Protection Act, 1963	Natural Resources Conservation Authority
Bauxite & Alumina Encouragement Act, 1950	Ministry of Agriculture & Mining Jamaica Bauxite Institute Mines and Geology Division
Town & Country Planning Act, 1987	Town Planning Department
The Water Resources Act/UWC Act, 1959	Water Resources Authority
Public Health Act, 1985	Ministry of Health/Environmental Control Division
Disaster Preparation & Emergency Management Act, 1993	Office of Disaster Preparedness and Emergency Management
National Solid Waste Management Authority Act, 2001	National Solid Waste Management Authority
Clarendon Parish Provisional Development Order, 1982	Town Planning Department

IDENTIFICATION AND ANALYSIS OF ALTERNATIVES

5 Identification and Analysis of Alternatives

5.1 Analysis of Alternatives

5.1.1 Residue Disposal Alternatives

5.1.1.1 Use Alternative Technology For Residue Disposal

This can be done and will be done as dry-stacking technology has been proposed as part of this project. Dry-stacking technology will significantly increase the life span of the new residue disposal area since it requires a smaller storage area and offers greater residue storage per unit area.

5.1.1.2 Continued Use of Sealed Impoundments

Sealed impoundments have been used successfully by Jamalco for over 40 years. Engineered impoundments consisting of compacted clay or synthetic liners can be used. The only limiting factor has traditionally been the hydrostatic head which in the case of RDAs 3 & 4 has been significantly improved through the use of under drain technology, which will be applied to this case. Groundwater assessments and analyses to date have not associated groundwater problems with impacts of the sealed impoundments. A combination of thickened tailings disposal "dry stacking" in a sealed impoundment may be the ideal alternative. This is the proposed method for residue disposal in RDA #1 & 5. Some of the advantages of thickened tailings disposal are as follows:

- Increased caustic soda recovery
- Faster consolidation of the solid phase resulting in faster attainment of workable load bearing capacity
- Reduced unit land area

5.1.1.3 Disposal At Sea Using Pipelines Or Barges

Impractical, Jamaica relies on the quality and beauty of its coastal resources to risk the potential damage that this alternative would entail. The potential for environmental and socio-economic damage is significant and should not be risked.

5.1.1.4 Unsealed Red Mud Lakes

This practice has been used in Jamaica in the past; however, it would represent a step back for Jamalco as their existing technology, sealed impoundments, far supersedes the use of unsealed lakes and is therefore impractical. The deposition of red mud in unsealed lakes can lead to significant environmental problems, primarily with groundwater and surface water resources through seepage. Jamalco has never utilized this mode of residue disposal as it designs its plants to be zero discharge operations.

5.1.1.5 Disposal In Surface Waterways (Rivers And Streams)

The Jamalco refinery is located just to the east of the Rio Minho River Basin and there is a possibility that this surface waterway could be used as a disposal point for red mud. This is not a good alternative, as the dependence on the river for irrigation and in some cases domestic water use coupled with the potentially devastating environmental impact makes it impractical.

5.1.1.6 Shoreline Land Reclamation

This involves creation of an impoundment dyke adjoining the shore, but with its footprints in the marine environment. Bauxite residue is stored in the shoreward area behind the dike. This is unacceptable since it results in significant loss of marine resources

5.1.1.7 No Action

The Jamalco operations in Halse Hall is anticipating a production rate of 2.8 million metric tones per year by 2006 with the recently approved upgrade and will continue to produce 1.1 tonnes of residue for each tonne of alumina manufactured. It is estimated that the existing configuration of residue disposal areas may have less than two (2) years of capacity for residue disposal. With the implementation of dry stacking technology and the re-assessment of existing available capacity such as in RDA#1 the facility can create an additional 750,000 m^3 of storage space based on current production rates and allow the facility sufficient time to permit and construct the proposed RDA #5, which is part of the upcoming facility upgrade. Doing nothing would take away this capacity and most likely result in the facility fast-tracking the construction of new RDA's in the area or seeking other means of disposal which may not be as environmentally sound as dry stacking in a sealed impoundment.

DETERMINATION OF ENVIRONMENTAL IMPACTS

6 Determination of Environmental Impacts

6.1 Fugitive Emissions

Potential fugitive dust problems may occur during the following conditions, especially when it is windy:

- Vehicular traffic on the RDA's
- During earth movement during construction
- Excessive drying of residue

6.1.1 Vehicular Traffic

On occasion, vehicular traffic such as personnel vehicles, trucks and other heavy equipment move in and out of the general area of the RDA's. During these times, there exists a potential for fugitive dust to be produced and transported by wind into surrounding areas.

6.1.2 Construction Activities

During construction activities, the potential exists for fugitive emissions from earth movement and clearing, vehicular traffic on dirt roads or spillage of soils during transport.

6.1.3 Excessive Drying of Residue

With the implementation of dry stacking, the potential does exist that residue reaching 60% solids or better may be produced. Under the right conditions of dryness and wind intensity, the fine grained residue may become entrained and disperse. The other residue lakes are kept moist or wet for the most part and usually are not seen as contributing to fugitive dust formation.

6.2 Air Quality

The fact that caustic soda is a component of the waste stream makes it possible that potentially nuisance odours may emanate from the residue area. The nature of the dry stacking technology may however, result in a decrease of this potential impact due to the low water content in the residue. There is no mitigation for this potential impact.

6.3 Noise

Jamalco has always operated within the local standards and regulations for industrial noise levels. In areas of the operation that have a potential to exceed these levels, signs are posted and safety equipment provided. The greatest potential for noise level increases at the RDA's will be during construction activities when heavy equipment will be operating in the RDA#1. The reasonably remote location of RDA#1 in terms of proximity to residences should make this potential impact negligible during this project.

An audiometric survey was recently conducted at the plant boundaries to establish a baseline for the area and to assess the potential for noise impacts on the adjoining communities, which found that no negative noise impacts (above accepted levels) are experienced by the surrounding communities under normal operation. Accidents and equipment failures may result in noise impacts which would be unavoidable.

6.4 Loss of Biodiversity

The loss of biodiversity will not be a potential impact for this project due to the location of RDA#1 and the fact that all disruptive work will be taking place within the existing structure. No mitigative actions will be necessary.

6.5 Pollution of Surface and Ground Water

Due to the proximity of the RDA's to Webbers Gully and the Rio Minho River (all part of the Rio Minho Watershed Management Area), it is important that the potential for impacting these areas is reviewed.

Since the existing RDA#1 was constructed with a compacted clay liner on both the floor and dyke walls of the structure, and since there has been no evidence of failure during the past 32 years of operation, it is not anticipated that the planned works will change this situation. In the unlikely event that the step-in dyke was to fail, the perimeter dyke of RDA#1 will easily contain the residue and the space utilized as the cooling pond will be more than sufficient to hold the residue. Adequate freeboard and contingencies have been designed into the project to insure that the stacked residue will not flow over the crest of the perimeter dyke and that the lake will maintain its potential to contain the anticipated storm surge of a 100 year flood event.

It is not anticipated that any pollution of surface or ground water will result from the implementation of this project. The company will continue to enforce its rigorous ground water management program.

6.6 Waste Management

No new waste management impacts are anticipated at the Residue Disposal Area. The area will not be required to take any new waste streams and existing waste streams will continue to be managed appropriately as is the norm. No mitigation will be necessary.

6.7 Labour

6.7.1 Construction

The proposed works to construct the step-in dyke will result in the employment of workers. Employment however, is not a major feature of the project as most of the work will be done by heavy equipment and associated operators without the need for many skilled trades or labourers. Nonetheless, the project will represent a beneficial social and economic impact for the community. No mitigation will be necessary.

6.8 Aesthetics

Aesthetics will not be impacted by the implementation of this project. The proposed works will not be visible from outside of the existing RDA's. The existing foliage on the external dykes blends with the natural environment and will eliminate any visual intrusion which may result from the project. No further mitigation will be necessary.

6.9 Change in Drainage and Storm Water Management

The only anticipated changes to drainage and stormwater management will be inside of RDA#1. The designs explain how the changes will work and how assurances of capacity and functionality will be maintained. There will be no changes in drainage and stormwater management outside of the RDA's, therefore resulting in no change to existing drainage and stormwater systems in place external to RDA#1. No mitigative actions will be necessary.

6.10 Flooding Potential

Flooding potential in RDA#1 is addressed in the designs, where the reconfigured cooling pond will have sufficient freeboard and capacity at all times to handle any surges that would be associated with a 100 year flood event. It is not anticipated that flood waters would flow above the crest of the perimeter dyke at 195 ft elevation. No mitigation will be necessary.

6.11 Impact of leachate

Leachate from the dry stacking process will be drawn off by wick drains and catch basins and directed into the adjacent cooling pond where it will be stored and reused at the refinery. RDA#1 has been used primarily as a cooling pond since approximately 1980 and has not had any negative impacts on the environment. It is not anticipated that leachate from the dry stacking process will result in a negative impact on the environment. Jamalco will continue to enforce its ground water monitoring program through the network of wells which are strategically located around the RDAs. No further mitigation will be necessary for this potential impact.

6.12 Avoidable/Irreversible Impacts

No irreversible impacts have been identified for this project. All identified impacts are avoidable or mitigable.

MITIGATION ACTIONS

7 Mitigation Actions

7.1 Fugitive Emissions

Potential negative fugitive emission impacts have been identified for this project. Sources of these impacts are:

7.1.1 Vehicular Traffic

Negative impacts may be realized during vehicular traffic in and around the RDA's. The dry climatic condition of South Clarendon, coupled with the prevailing winds may cause fugitive emissions to form. As a mitigative measure, the roadways are kept moist through irrigation. Methods of irrigation will include tanker trucks and sprinkler systems. This is an ongoing aspect of the Jamalco operations and will attract no additional cost for implementation.

7.1.2 Construction Activities

During construction activities the potential exists for fugitive emissions to be formed. Any fugitive emissions that are formed will be managed through proper planning of construction activities and the use of irrigation techniques. This is not expected to be a major issue with this project due to the moisture content of the materials to be used to construct the step-in dyke.

7.1.3 Excessive Drying of Residue

At times, sections of the dry stacked residue may become dry enough to allow for dispersion in the wind. Operations will be continuously monitored and any indication of excessive drying will be addressed through irrigation and sprinkling systems at the RDA's. This will be designed into the project and will incorporate existing sprinkler systems. The sprinkler system should represent a minimal cost to Jamalco as irrigation and sprinkling systems are located at the RDA's presently.

7.2 Air Quality

Proper servicing and maintenance of heavy duty diesel equipment should alleviate most impacts; these types of equipment naturally emit some degree of partially combusted fuel into the atmosphere, which is a minor impact.

Jamalco conducts air quality testing at all of its major sources on a regular basis. Additionally, there are air quality monitors set up around the RDAs, in surrounding communities and other receptor points to measure the presence of impacts and in some cases to quantify the impact if it exists.

- Jamalco has developed and maintains an Air Emissions Management Program to ensure compliance with local and Alcoa's internal ambient air quality standards.

MONITORING PLAN

8 Monitoring Plan

In keeping with its Environmental Health and Safety policies as well as the legislation and regulations of the Government of Jamaica, Jamalco has an extensive Environmental Monitoring Programme which is carried out on all aspects of its operations.

In respect of Section 17 of the NRCA Act of 1991 the company is required to and submits the results of its Monitoring Programme to NEPA on a quarterly basis.

Among the parameters reported to NEPA are:

- raw materials used
- water quality
- effluent quality
- hazardous materials used
- water consumption
- fuel specifications
- materials and chemicals consumption. This category includes:
    - ♦ solvents
    - ♦ flocculants
    - ♦ oils and lubricants
    - ♦ acids
    - ♦ refrigerants

Jamalco also provides monthly monitoring and reporting to the Jamaica Bauxite Institute (JBI). In addition to the above named, ongoing monitoring activities, Jamalco will implement a monitoring programme during this project, which will cover the pre-construction, construction and operations phases.

These will be based on the potential impacts identified in the impact identification and impact mitigation actions documented in those sections of this report.

The objective is to insure that all potential impacts and the appropriate mitigation actions are taken.

Monitoring will be done at regular intervals as follows:

1. At start-up of construction all activities will be monitored every week for the first two months.
2. Monitoring will take place every two weeks from month two to month six.
3. Monitoring will be on a monthly basis for three months during commissioning and start-up.

Monitoring reports will be prepared and submitted to NEPA for each monitoring interval for 1 to 3 above. As part of their standard operating procedures, Jamalco monitors its residue areas on a quarterly basis. A sample Dyke Inspection Checklist is presented below as Figure 8-1.

Figure 8-1: Sample Dyke Inspection Check List

Jamalco

QUARTERLY INSPECTION 2004
BAUXITE RESIDUE DISPOSAL AREA DIKES

PERIOD:
AREA:
SOLID ELEV:
LIQUID ELEV:
RDA STATUS (In/Out Service):

DATE OF INSPECTION:
TOTAL PRECIP. FOR QTR:
TOTAL NO. OF RAINDAYS:
TOTAL EVAP. FOR QTR: **mm**
CURRENT WEATHER CONDITION:

ITEM	EAST OR COMMON DIKE	WEST DIKE	NORTH DIKE	SOUTH DIKE
Dike Alignment (mm)				
Dike Settlement (mm)				
Crest Condition (**Good**/**Fair**/**Bad**)				
External Sloughing (**None**/**Some**/**Extensive**)				
Internal Sloughing (**None**/**Some**/**Extensive**)				
External Erosion (**None**/**Some**/**Extensive**)				
Internal Erosion (**None**/**Some**/**Extensive**)				
Seepage &/Or Wet Spots (**None**/**Some**/**Extensive**)				
Condition Of Vegetation (**Healthy**/**Struggling**/**Discolored**)				
Pipeline Condition (**Good**/**Fair**/**Bad**)				
Peizometer Level Readings				
Avg. Conductivity Readings From Peizometers				

Remarks:

Report Done By: **Date:**

8.1 Construction Monitoring Programme

The following is an outline of a typical construction monitoring program that can be modified as necessary to meet the needs of NEPA. A detailed version will be submitted to NEPA after the granting of the permit and prior to the commencement of the proposed development. The monitoring program will include the following at a minimum:

- Introduction – explaining the nature of the project and outlining the need for a monitoring program and the relevant specific provisions of the permit license granted.
- The various activities and parameters being monitored.
- The methodology to be employed and the frequency of monitoring.
- The sites being monitored, stating any outer boundary where no impact from the development is expected if stated by NEPA or other local Agencies.
- A summary of data collected. Tables and graphs will be used where appropriate.
- Discussion of results with respect to the project in progress, highlighting any parameter(s), which exceeds the standard (s) and mitigation implemented.
- Frequency of reporting to NEPA.
- Recommendations

Appendices of data and photographs

8.2 Environmental Management

Jamalco is an ISO 14001 and ISO 9000 certified facility. Jamalco's ISO 14001 certification was issued by Det Norske Veritas (DNV) in November of 2002 and remains valid until November 2005. The associated Environmental Management System (EMS) is accredited by ANSI RAB.

The EMS covers Jamalco's operations and includes activities associated with the railway transportation system, the bauxite alumina refinery, plant waste storage and disposal sites and the port at Rocky Point.

In keeping with the mandates of its ISO 9000 quality certification, Jamalco abides by their Quality Policy, which states:

Jamalco is committed to being "The Alumina Supplier of Choice"

- "Jamalco will relentlessly pursue continual improvement in everything we do to:
- Consistently provide product that meets customer and other applicable requirements for quality
- Enhance customer satisfaction by consistently meeting and exceeding their expectations
- Be cost effective and remains competitive in the global market
- Operate in a safe and environmentally responsible manner"
- Excellence Through Quality

Jamalco has a highly qualified technical, administrative and support staff within its Environmental Management Department, many trained to the tertiary level. All employees within the Department report to the Manager, Environmental, Health &

Safety, a senior manager in the company who in turn reports directly to the Managing Director.

All aspects of Jamalco's operations have an environmental management, health and safety component. Environmental Standard Operating Procedures, guidelines and instruction have been developed by Jamalco to govern operations in all areas. As a result, all technical and support staff have a responsibility to insure that they operate in a safe and responsible manner regardless of the task being undertaken.

Many aspects of environmental management at the facilities are monitored through the use of checklists, periodic reporting and internal audits. These provide timely indications as to the effectiveness of the procedures and provide indications as to the need for changes where applicable. The monitoring and checks also inform process operations and controls.

8.2.1 Training

Jamalco has a commitment to the improvement and advancement of all its employees. A major component of this commitment is the provision and facilitation of training for employees at all levels.

Specific to environmental management, Jamalco provides training in the following areas, which are designed to keep relevant employees and contractors informed and ensures competence in performing their duties. The training program achieves the following:

- Conformance with Jamalco's EH&S policy
- Identifies significant actual and potential impacts of their work
- Defines associated benefits of improved personal performance
- Identifies the roles and responsibilities in achieving conformance with the EMS
- Relays proper environmental operating procedures for managing environmental related aspects of their duties

- Reinforces Jamalco's policy that only properly trained and experienced individuals are allowed to work unsupervised

APPENDICES

APPENDIX I

APPENDIX I : SURVEY INSTRUMENT

Socio-Economic Survey for the Expansion of JAMALCO's Plant Operations, Port Facilities, and Mining Operations

Community Name ______________________________ Community Code | | | | | |

SECTION 1
PERSONAL CHARACTERISTICS

1) Gender
   1. Male
   2. Female

2) Age Range
   1. Under 20
   2. 20 – 39
   3. 40 – 49
   4. 50 – 59
   5. 60 – over
   6. Not Stated/No Response

3) How many years have you been living in the community?
   1. 0 – 5 Years
   2. 6 – 10 Years
   3. 11 – 20 Years
   4. more than 20 Years
   5. Not Stated/No Response

SECTION 2
OPINIONS ON THE COMMUNITY

4) What do you like most about the community? ***ASK & WAIT FOR RESPONSE***
   1. Friendly people
   2. Clean environment:
   3. Availability of farmland
   4. Quiet
   5. No crime & violence
   6. Other, (specify)______________________________
   7. Not Stated/No Response

5) What don't you like about the community? ***ASK & WAIT FOR RESPONSE***
    1. Poor roads
    2. Lack of Utilities
    3. Crime & violence
    4. Unemployment
    5. Dirty environment
    6. Other, (specify)______________________________
    7. Not Stated/No Response
6) "Large scale development is beneficial to this community " (e.g. construction activities, plant upgrades, mining operations, housing) Do you agree?
    1. Yes
    2. No
    3. Not Stated/No Response (Go to Q 8)

7) Why do you think so?
    1. Job opportunities
    2. It will reduce the peacefulness of the area
    3. Offers skills development
    4. Improves utilities
    5. It will affect environmental quality in a negative way
    6. Other (specify)
    7. Not Stated/No Response

SECTION 3
AWARENESS & OPINIONS ON EXISTING BAUXITE FACILITIES

8) Are you aware that there is bauxite mining or alumina processing plant operations in your area?
    1. Yes
    2. No (Go to Q 14)
    3. Not Stated/No Response

9) Are you experiencing any negative impacts from the bauxite operation or facility mentioned above?
    1. Yes
    2. No (Go to Q 11)
    3. Not Stated/No Response

10) If **YES ASK**: What is this negative impact?
    1. Odour
    2. Traffic
    3. Dust, soot or gaseous emission
    4. Noise
    5. Damage to your property

6. Not Stated/No Response
7. Other, (specify)______________________

11) Would you say that the bauxite mining or processing facility has had negative impacts on the people in this community?
    1. Yes
    2. No (Go to Q 13)
    3. Not Stated/No Response

12) If **<u>YES, ASK</u>** - WHY WOULD YOU SAY THAT?
    1. The area has widespread corrosion
    2. The area smells like caustic soda more often than not
    3. You get sick more often
    4. Plants are harder to grow
    5. Too much noise
    6. Other (specify)
    7. Not Stated/No Response

13) Would you say that the existing bauxite mining and alumina processing facility have had a positive impact on this community?
    1. Yes
    2. No

14) What positive impacts do you think the bauxite mining and alumina processing facility has had on the community?

1. Improved community relations
2. Job opportunities
3. Educational and social benefits
4. Amenities – roads, lights, water supply
5. Environmental conditions
6. None of the above
7. Other (specify)______________________________
8. Not Stated/No Response

SECTION 4
KNOWLEDGE AND VIEWS ON UPGRADE PLANS

15) Are you aware that JAMALCO proposes to upgrade their existing bauxite mining operations and processing plant facilities in the near future?
    1. Yes
    2. No
    3. Not Stated/No Response

16) What effect do you think the proposed upgrade of JAMALCO's bauxite mining operations and processing plant facilities in or near your area will have on the

following:

Economic value of the community

1. Positive
2. Negative
3. No Change
4. Don't Know
5. Not Stated/No Response

Job Opportunities

1. Positive
2. Negative
3. No Change
4. Don't Know
5. Not Stated/No Response

Pollution

1. Positive
2. Negative
3. No Change
4. Don't Know
5. Not Stated/No Response

17) Do you think the proposed upgrade will affect you personally?

1. Yes
2. No
3. Don't Know/Not Sure
4. Not Stated/No Response

18) What do you think are the main impacts that the upgrade would have on the local environment?

1. More jobs
2. Loss of income
3. More dust circulating in the area
4. Less air pollution and noise
5. More air pollution and noise
6. Contamination of Water supplies
7. Better community relations
8. Improved water supply and other amenities
9. More occurrences of diseases that affect breathing
10. More crime in the community
11. Increased population
12. Don't know/Not Sure
13. Other (specify)
14. Not Stated/No Response

19) Why do you think so?

1. The present mining and processing facilities have caused this already. So it can only get worse.
2. The upgrade will add new equipment that will be cleaner to operate
3. More jobs will be available
4. This is something common to all bauxite operations
5. The upgrade will cause more people to pass through the community. So it gives more opportunity for crime
6. This is something that someone told me
7. Don't Know/Not Sure
8. Other (specify)
9. Not Stated/No Response

SECTION 5
AVAILABILITY OF WATER

20) What is your main source of drinking water?

1. Indoor tap/pipe
2. Outdoor private tap/pipe
3. Public standpipe
4. Spring, pond, river
5. Rainwater (tank or drum)
6. Trucked water (NWC)
7. Other (specify)
8. Not Stated/No Response

21) If you have piped running water in or around your household, who supplied it originally?

1. National Water Commission
2. JAMALCO
3. Other (specify)
4. Don't Know
5. Not Stated/No Response

22) "In this community, I think that we have access to safe water to drink" Do you agree?

1. Yes
2. No
3. Don't Know/Not Sure
4. Not Stated/No Response

23)Why do you think so?

1. bauxite mining or processing operations affect the drinking water
2. Sources (not bauxite mining or alumina processing related)

affect the drinking water quality
3. The water is tested frequently by the N.W.C.
4. The water looks and/or smells clean
5. Other, please specify
6. Not Stated/No Response

24) Have you or anyone in your household, received compensation for any pollution problems?

1. Yes
2. No
3. Don't Know
4. Not Stated/No Response

25) Have you or any member of your household ever worked for a bauxite company or in the bauxite industry?

1. Yes
2. No
3. Don't Know/Unsure
4. Not Stated/No Response

26) Are you aware of any programs or activities initiated by Jamalco in your community?

1. Yes
2. No
3. Don't Know/Unsure
4. Not Stated/No Response

THANK YOU
END OF INTERVIEW

Name of Interviewer:
Date of Interview:

APPENDIX II

Appendix II: REFORESTATION PLAN IN JAMAICA – MEMORANDUM OF UNDERSTANDING BETWEEN MINISTRY OF AGRICULTURE- FORESTRY DEPARTMENT AND ALCOA

CLARENDON, JAMAICA -- Alcoa and Jamaica's Forestry Department have signed an agreement to work together to rehabilitate reclaimed mined-out lands through reforestation on the island. The five-year accord includes developing a public education program, planting of suitable trees, and a research program aimed at enhancing the development and reforestation of the lands.

JAMALCO and the Forestry Department in the Ministry of Agriculture (GOJ)have signed a memorandum of Understanding (MOU), to establish a framework for collaboration for the successful rehabilitation of reclaimed mined-out lands through reforestation of these areas.

This five year accord, signed recently by Jerome Maxwell, JAMALCO'S Managing Director and Marilyn Headley, Conservator of Forests, at the Halse Hall Great House in Clarendon, will see the Forestry Department and JAMALCO partnering to effect this restoration of adequate plant cover.

Guided by the 'no-net-loss' policy, the two organizations will work to compensate for the loss of forest cover due to mining operations. This move will see the establishment of new forests on selected reclaimed bauxite mined out areas as well as the protection and preservation of existing forests.

Under the MOU, the Forestry Department will utilize its skills for the establishment and management of forests, along with a forest research program aimed at enhancing the development and reforestation of the lands.

According to Miss Headley, this is in keeping with the Forestry Department's mandate outlined in the Forest Act of 1996 and which includes privately owned properties such as the JAMALCO lands.

At the signing, Mr. Maxwell, described the MOU as "timely and reflective of JAMALCO's environment protection policies and Alcoa's worldwide 'One Million Trees' project."

Specific areas of cooperation agreed on in the MOU include the development of a public education program for farmers and students to improve understanding of the contribution of forests to local and national well-being and economic development. Provisions have also been made for other areas of collaboration to be explored.

The agreement also specifically mandates the planting of suitable ornamental and lumber tree species such as cedar, ficus, acacia, wild tamarind, blue mahoe, mahogany, bitter wood, bitter damson, and spanish elm along with fruit trees such as mango, orange, avocado, breadfruit and ackee.

Appendix IV - Forest Reserves of Jamaica

Forest Reserves of Jamaica

· conservation of naturally existing forests

· as a source of forest products

· for the conservation of soil and water resources

· to provide parks and other recreational facilities for public use

· as a habitat for the protection and conservation of endemic flora and fauna

· the forest reserve areas shown in the Gazette are estimates, based on descriptive, not surveyed, boundaries

A programme of surveying forest reserve boundaries is underway and survey data are being digitised which will produce more accurate maps. In the years since the Forestry Department was established in 1937, the government has set aside a significant portion of its land for forest reserves. They now amount to over 111,000 hectares or over 10 percent of the country's total area. These protected areas provide us with a be cared for so that their benefits can be enjoyed by future generations. The 1996 Forest Act provides for the creation and protection of forest reserves for the following purposes:

Most of the country's forest reserves are located in areas of rugged terrain such as the John Crow Mountains, Blue Mountains and Cockpit Country as well as the dry, hilly uplands in the south, west and north-west portions of the country. Despite their remoteness, serious encroachment has taken place. The 1998 analysis of forest cover and land use in Jamaica, carried out by the Forestry Department, shows that more than 20 percent of land within forest reserves has been impacted by human activity such as conversion to agricultural and/or residental use, mostly without Forestry Department permission.

Under the Forest Act, the Minister may declare to be forest reserves any Crown land, or private land if the owner requests such a declaration.

Further, the Minister may order or declare any land not in a forest reserve to be a forest management area, including private land if he is satisfied that the use of the land should be controlled for the protection of the national interest. Crown lands may be declared a protected area if required for a number of purposes specified in the Forest Act, including flood and landslide .Further, the Minister may order or declare any land not in a forest reserve to be a forest management area, including private land if he is

satisfied that the use of the land should be controlled for the protection of the national interest.

Crown lands may be declared a protected area if required for a number of purposes specified in the Forest Act, including flood and landslide

protection, soil preservation, erosion, maintenance of water supply and protection of amenities, flora and fauna. On protected areas cultivation, grazing, burning and clearing of vegetation is prohibited or strictly regulated.

The forest reserve areas listed in the following table are garnered from The Jamaican Gazette. The records show that the area of forest reserves and Crown lands managed by the Forestry Department is 109,514 hectares, of which 98,962 hectares are forest reserves and 10,552

hectares are Crown lands. These figures from the Gazette show a variation from those compiled by the Forestry Department in its recent assessment of forest cover and land use. The reasons for the difference are:

· the forest reserve areas compiled by the Forestry Department during its assessment were digitised from 1:250 000 maps and not from

actual surveyed forest reserve boundaries.

Parish Remarks

Forest Reserves of Jamaica by Parish

Forest Reserve/

Crown Land Name

Area (ha) Reference in the

Manchester Denham Farm 20.00 27-09-1956 486 Part of Devon Land Settlement

Gourie 141.65 Crown

Hudson's Bottom 226.63 Crown

John Anderson 121.40 Crown

New Forest 160.78 01-12-1950 432 Part of New Forest Land Settlement

Oxford 133.55 Crown

Ramble 48.18 01-12-1950 435

St. Jago A 163.90 09-10-1969 654 Plan A, Vol 1030 Fol 433

St. Jago B 66.00 09-10-1969 654 Plan B, Vol 1030 Fol 433

Virginia 13.03 01-12-1950 434 Part of Virginia Land Settlement

Total Manchester 472 623

Clarendon Bull Head 220.06 01-12-1950 417

Kellets-Camperdown 1497.79 01-12-1950 417

Kellits Stream A 8.30 01-12-1950 425 Block A (Miller's Spring)

Kellits Stream B 1.62 01-12-1950 425 Block B (Mosquito River)

Peace River 116.70 25-06-1959 423

Peak Bay A 302.72 01-12-1950 433 Block A

Peak Bay B 152.57 01-12-1950 433 Block B

Peak Bay C 60.70 01-12-1950 433 Block C

Peckham 70.89 01-12-1950 426 Prev. 06-09-1945 (part of Peckham Land Sett.)

Pennants A 169.19 01-12-1950 437 Block A (part of Pennants Land Sett.)

Pennants B 59.40 01-12-1950 438 Block B (part of Pennants Land Sett.)

Pennants (Douces) A 26.42 01-12-1950 438 Block A (part of Pennants Land Sett.)

Pennants (Douces) B 3.07 01-12-1950 438 Block B (part of Pennants Land Sett.)

Pennants (Douces) C 2.55 01-12-1950 438 Block C (part of Pennants Land Sett.)

Portland Ridge 5612.30 Crown Vol 403 Fol 40

Teak Pen A 532.99 01-12-1950 439 Block A (part of Teak Pen Land Sett.)

Teak Pen B 149.74 01-12-1950 440 Block B (part of Teak Pen Land Sett.)

Total Clarendon 3375 5612

St. Catherine Dawson Mountain 1 55.04 Crown Lot 101, Mount Dawson Land Settlement

Dawson Mountain 2 75.86 Crown Lot 104, Mount Dawson Land Settlement

Harkers Hall 6.82 01-12-1950 425 Prev. 06-09-1945 (Harkers Hall Land Sett.)

Healthshire Hills 4856.40 01-12-1950 422

Treadways 26.39 01-12-1950 422 Part of Treadways Land Settlement

Troja 18.86 21-07-1955 362 Lot 41, Troja Land Settlement

Twickenham Park 2.06 Crown

Little Goat Island 6.00 30-06-1960 278 2.4 km south of the mainland

Great Goat Island 188.00 30-06-1960 278 2.0 km south of the mainland

Total St. Catherine 5102 133

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