DESCRIPTION OF THE ENVIRONMENT

3 DESCRIPTION OF THE ENVIRONMENT

Information for this section has been compiled from field observations and ground truthing to verify the accuracy of information sourced from reports including:

1. EIA for Step-in-Dyke RDA#1 (CD&A – 2005),
2. EIA for 2.8 Million Metric Tonne Per Year Efficiency Upgrade at JAMALCO – (CD&A -2004),
3. Biosurvey of Jamalco's Special Mining Lease Area in Southern Manchester – (BEG's LTD. – 2000),
4. Floral and Faunal Survey of Jamalco Special Mining Lease Areas and Environs of the Refinery and Port Facilities (BEG's LTD. - 2005), and
5. Report on Webbers Gully Floodplain Mapping for Alcoa Train Line – Rio Minho River – (2005).

3.1 LAND USE AND GEOLOGY

3.1.1 LAND USE

Jamalco's current RDAs are sited on lands formally occupied by sugarcane cultivation which were divested by Monymusk Sugar Factory.

The Bowens community which previously occupied lands located on the western side of RDA 1 and 2 was relocated to what is now called New Bowens. The relocation was to facilitate expansion of Jamalco's residue disposal storage capacity.

RDA 5 will be constructed on approximately 100Ha of lands owned by Jamalco and lies adjacent to the other RDAs (East and South perimeters will be bounded by the existing RDA 2 and RDA 4 embankments).

Two residential communities are located within one half mile of the RDA's, New Bowens to the Northeast and Cornpiece to the Southeast.

3.1.1.1 HISTORICAL

3.1.1.1.1 CLARENDON

3.1.1.1.1.1 Topography

The topography of Clarendon is characterised by the diverse nature of the coastal fringe and offshore islands and cays. The national and marine park and protected area of the Brazilletto Mountains, Portland Ridge, Peake Bay, Portland Bight and the plains in the Southern areas with elevations from 0-150 meters, the Mocho Mountains at elevations of 150-300 meters, extending to the limestone uplands in the north around main ridges, and the Bull Head Mountain.

3.1.1.1.1.2 Area and Land Cover

Clarendon contains an area of 1142.8 km^2.

Land cover in Clarendon is characterised by a scattering of villages and major urban centres, vast areas of sugar cane, wetlands, dry forests, scrub, industrial estates, aquaculture, mixed cultivation including bananas, citrus, subsistence crops by small farmers which includes yams, peas, sweet potatoes, etc.; the decline of the sugar industry has left large areas abandoned and taken over by scrub vegetation. Uncultivated areas due to salinity include much of the coastal side of the plains. Tidal flats are largely inaccessible. There are also the dry forests of the Brazilletto Mountains and the Portland Ridge, where Taino petroglyphs and some Taino burial caves are to be found.

3.1.1.1.1.3 Industrial Development Plan

Light industrial land use is confined to the rural/urban settlements and linear occupancy along district, sub-arterial and arterial roads. Heavy and special industrial plants include bauxite processing plant at Halse Hall (Jamalco), sugarcane processing at Moneymusk and New Yarmouth.

Transportation and access routes including all classes of roads and railway lines link all urban centres and also penetrate agricultural areas, national parks and conservation areas.

TABLE 3-1: URBAN SETTLEMENT DEVELOPMENT

CLARENDON – HEIRARCY OF GROWTH CENTRES		
District Centres	**Sub-Regional Centres**	**Regional Centres**
James Hill	Lionel Town	May Pen
Kellits		
Hayes		
Chapelton		
Kemps Hill		
Osbourne Store		
Mocho		
Rock River		
Chapelton		
Frankfield		
Alston		

3.1.1.1.1.4 Parish Council/Land Use Zoning

The parish of Clarendon is covered by Development Orders and subsequently falls under the aegis of the Town and Country Planning Act. Thus any form of development requires an application to the relevant Local Planning Authority (Parish Council) for permission to carry out building, engineering and mining operations or change in the use of land or buildings.

There are no specific demarcated zones for land use, but there are general statements of intended uses, supporting requirements and standards. This project does not present a change in land use for the site specified.

3.1.1.1.1.5 Aesthetics

There are several areas of outstanding natural beauty, visual and recreational amenity, and therapy. There are also areas which are felt to be aesthetically appealing and spiritually inspiring. The view from the Brazilletto Mountains over the protected Peake Bay and West Harbour wetlands and the sea is outstanding. The Milk River Bath is world renown for its therapeutic quality, and the Canoe Valley-Portland Bight wetlands supports considerable marine life and is itself outstandingly beautiful.

A wide variety of micro climates exits in the parish, ranging from cool climatic conditions in northern Clarendon near the Manchester border, to high temperatures on the Clarendon plains (location of proposed RDA) and dry limestone forests in the Portland Bight and Brazilletto Mountains.

It is not assumed that the proposed RDA will contribute negatively to aesthetics of the area since the location is behind the existing RDAs and away from the natural lines of sight of the majority of residential communities in the area.

3.2 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 3-1: Geology Map of Southern Clarendon). 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 above sea level (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 Savannah.

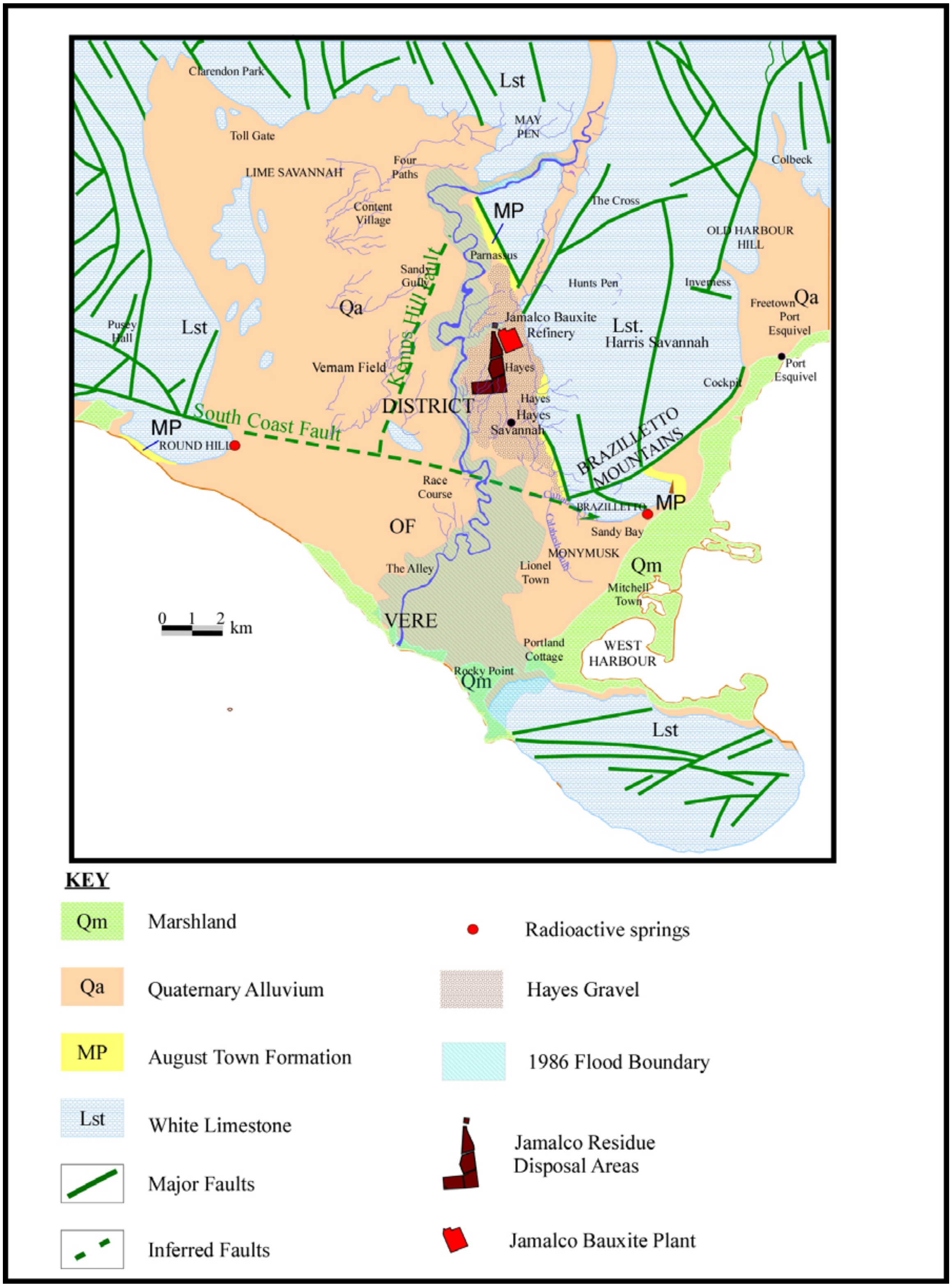


FIGURE 3-1: GEOLOGY MAP OF SOUTHERN CLARENDON

South of Hayes the alluvial fan flattens out to form what have been called the Vere Plains (Figure 3-1). 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.

3.2.1 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 3-1). 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 (Plate 3-1). Clay is rare and the gravels are well-drained. 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.

PLATE 3-1: HAYES GRAVEL AT SITE OF PROPOSED RESIDUE DISPOSAL AREA

3.2.2 THE LIMESTONE BEDROCK

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

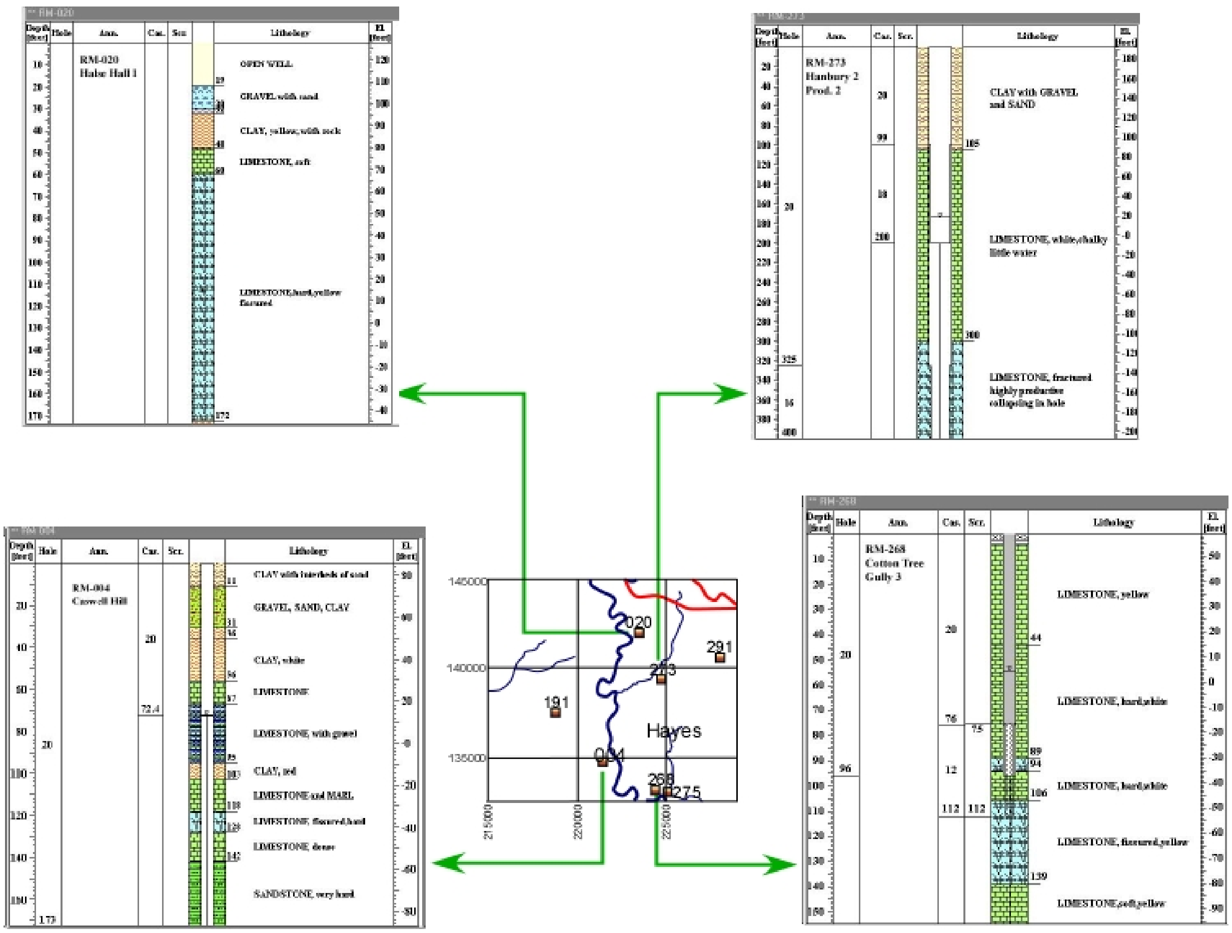


FIGURE 3-2: WELL LOGS THROUGH THE HAYES GRAVELS (SOURCE: HTTP://WWW.GEOCITIES.COM/KKARANJAC/)

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.

3.2.3 GEOTECHNICAL CHARACTERISTICS

3.2.3.1 THE ALLUVIAL FAN COMPLEX

Table 3-2: **Properties of Various Soil Groups (adapted from Conrad Douglas & Associates EIA on the construction of Residue Disposal Area 4)** below shows the characteristics of materials that should be expected in the Hayes Gravels.

TABLE 3-2: PROPERTIES OF VARIOUS SOIL GROUPS (ADAPTED FROM CONRAD DOUGLAS & ASSOCIATES EIA ON THE CONSTRUCTION OF RESIDUE DISPOSAL AREA 4)

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
Silty sands, poorly graded sand-clay mixtures	S.M.	Semi-pervious to pervious	Good	Low	Fair

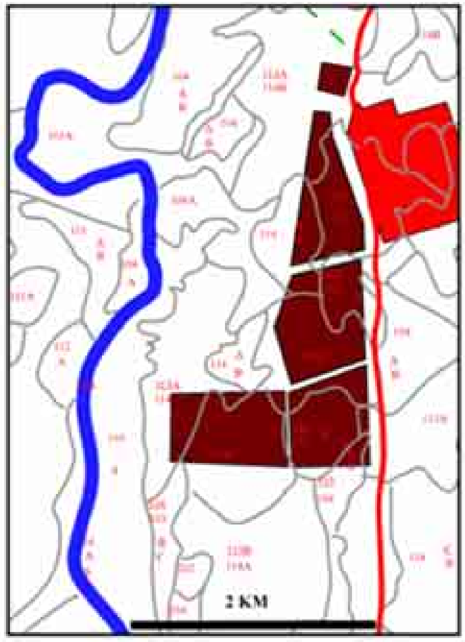
In summary the gravels tend to be pervious to very pervious with good to excellent shear strength, of negligible compressibility and good to excellent workability as a construction material. Alluvial materials sourced from other places in the Rio Minho fan should also be well suited for construction after washing and grading.

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 absence of caverns or fissures at shallow depth should be ascertained.

3.2.3.2 SOILS

The soils of the Hayes region are intimately associated with the alluvial deposits of the Rio Minho Fan Complex. Figure 3-3 indicates the distribution of the different soils of the area. In Figure 3-3: SOILS MAP OF HAYES, CLARENDON the classification follows that used by the Ministry of Agriculture, the symbol group representing the soil type and steepness of slopes.



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%)

FIGURE 3-3: SOILS MAP OF HAYES, CLARENDON

3.2.4 MINERAL RESOURCES

The only mineral resources of note are the limestone forming the Harris Savannah 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 Minho. 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.

3.3 HYDROGEOLOGY AND HYDROLOGY

3.3.1 HYDROGEOLOGY

3.3.1.1 HYDROSTRATIGRAPHY

The Clarendon Alumina Works consisting of the bauxite/alumina plant and the Residue Disposal Areas (RDAs) owned by Jamalco is located within the parish of Clarendon on the south central coast of the island (Figure 3-4: Basin Location). 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 3-5).

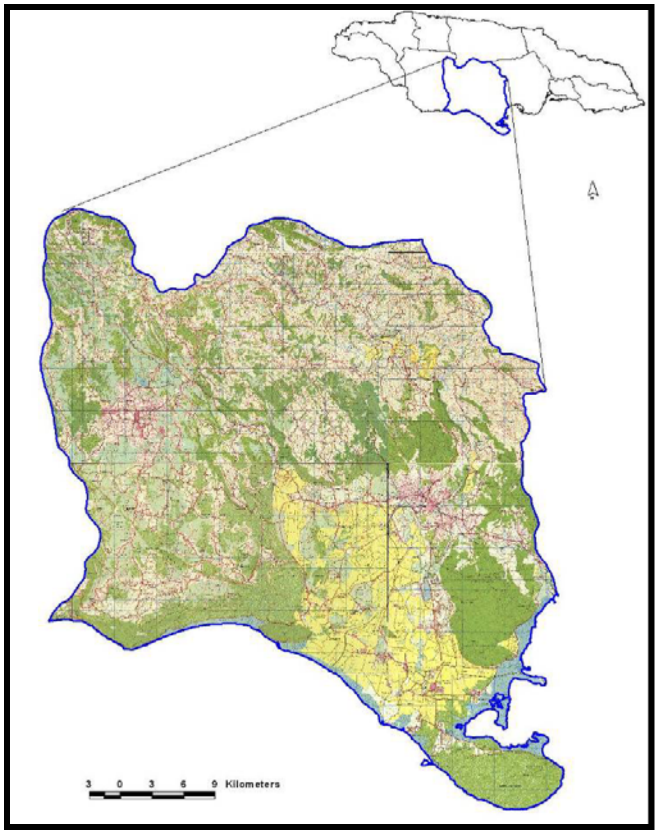


FIGURE 3-4: BASIN LOCATION

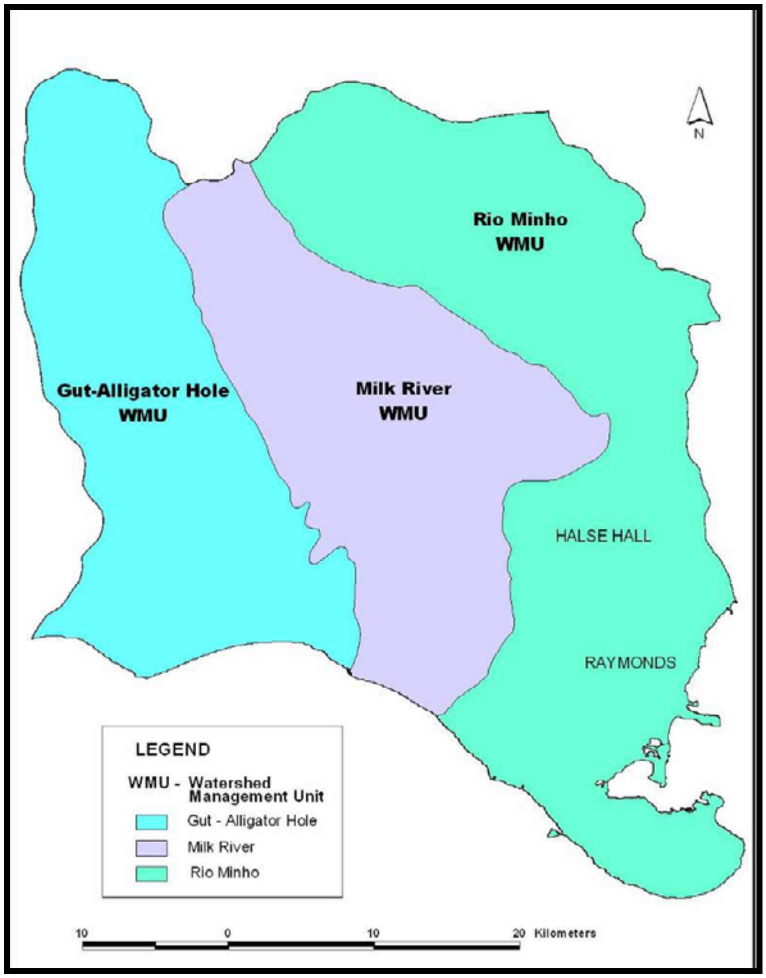


FIGURE 3-5: Basin Watershed Management Units

The Rio Minho Hydrologic Basin extends over an area of 1,705 km2 (Figure 3-4). The Basin is subdivided into 3 sub-basins and 3 hydrostratigraphic units (Figure 3-6). Table 3-3 below summarizes the area for each catchment.

Figure 3-6: Hydrostratigraphy Map of Project Areas

TABLE 3-3: 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

3.3.1.2 HYDROGEOLOGIC CHARACTERISTICS

The REFINERY is located within the Clarendon Plains subdivision (Rio Minho Watershed Management Unit) atop the limestone aquifer (Figure 3-7). 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 3-8).

FIGURE 3-7: Location of REFINERY

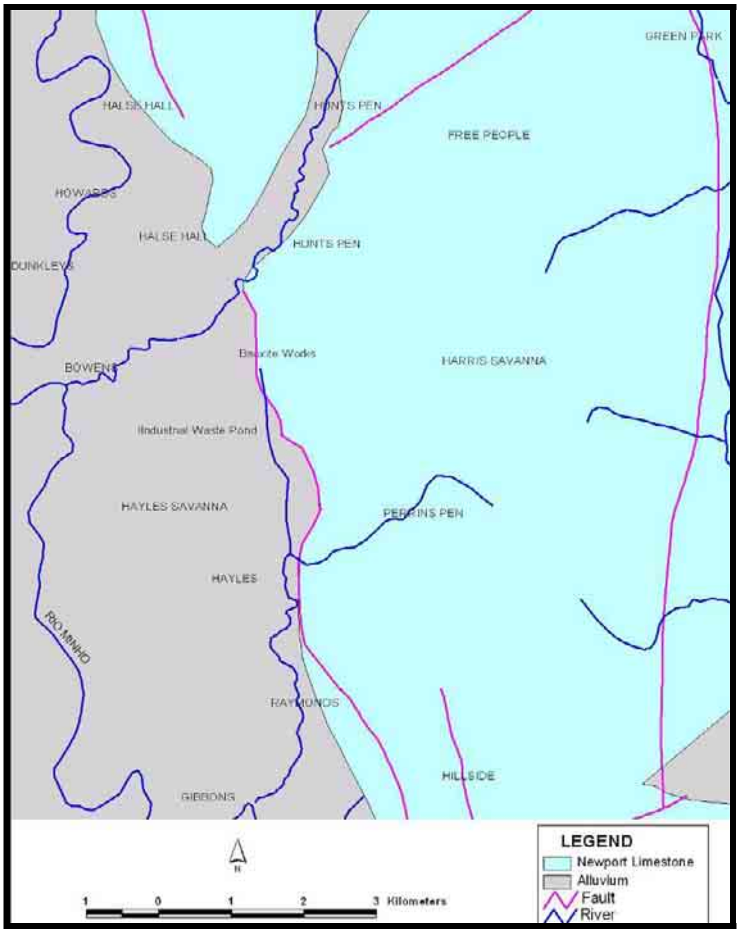


FIGURE 3-8: Geology of Area

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 refinery 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 REFINERY 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 REFINERY 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 REFINERY 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 REFINERY 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).

3.3.1.3 STRUCTURE

The area around the REFINERY 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 3-8).

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 3-9 and Figure 3-10

FIGURE 3-9: CROSS-SECTION – EAST-WEST DIRECTION ACROSS THE HALSE HALL AREA

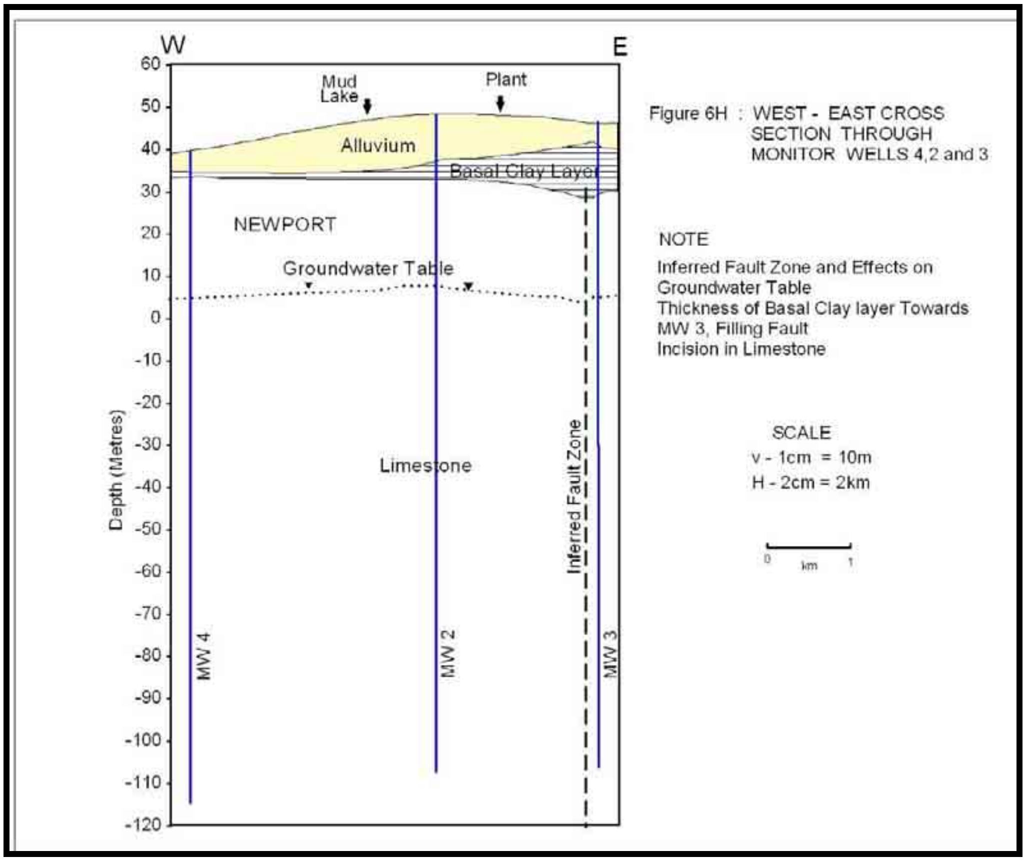
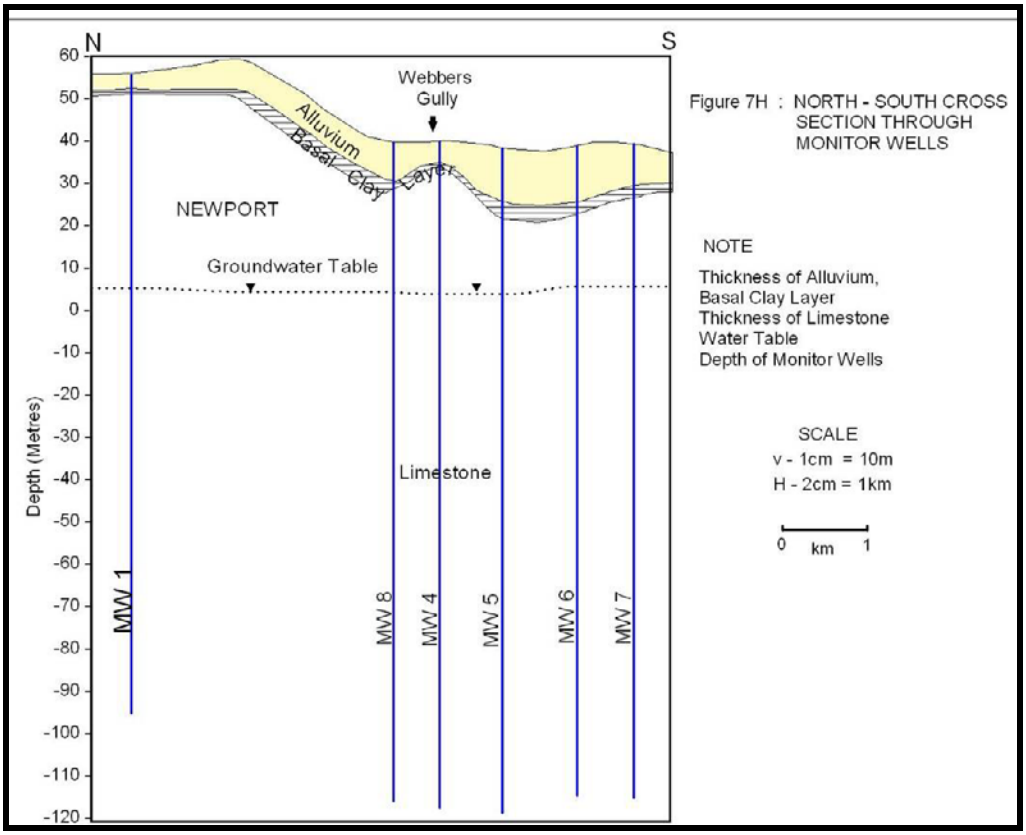


FIGURE 3-10: CROSS-SECTION – NORTH-SOUTH DIRECTION ACROSS THE HALSE HALL AREA



3.3.1.4 TOPOGRAPHY AND DRAINAGE

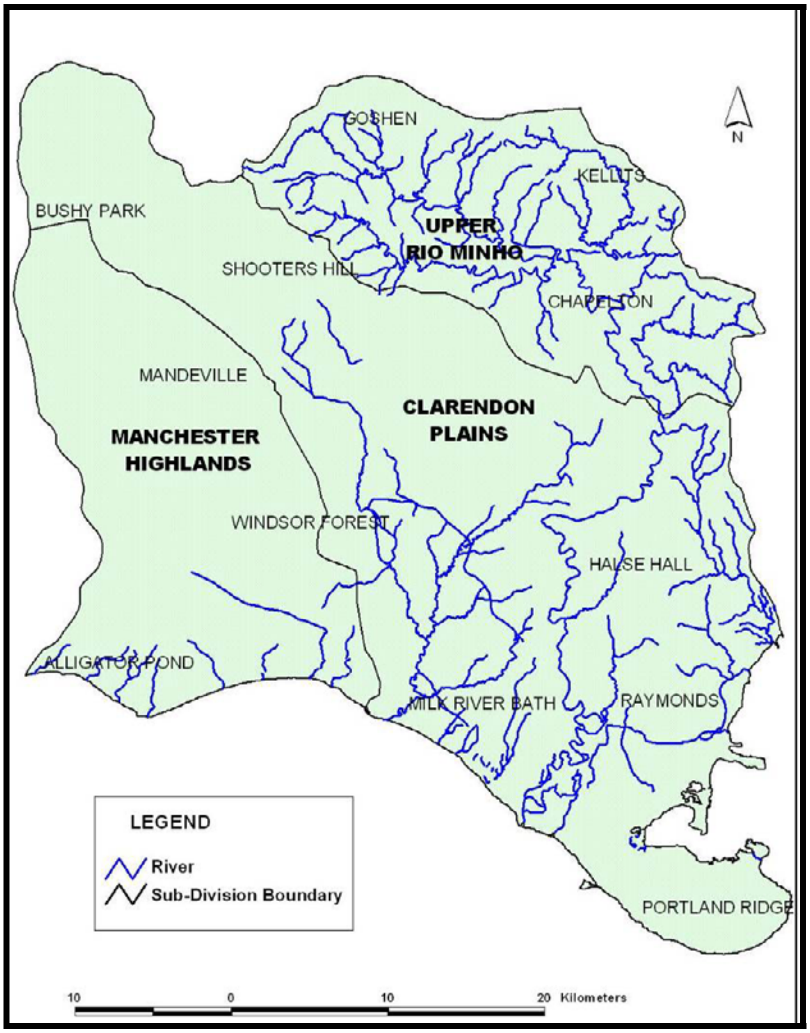
Topographically the area is of low relief with gentle rolling hills on the Harris Savannah. The Brazilletto Mountains form the high ground rising to 250 metres above mean sea level to the east of the bauxite/alumina plant. The Rio Minho flows in a north-south direction west of the RDAs and is the major 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 RDA 1 (Mud Lake) and the Clear Lake. The Webbers Gully flows between the northern dike of the RDA 1 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.

3.3.2 HYDROLOGY

3.3.2.1 SURFACE WATER HYDROLOGY

The hydrologic sub-division of the Rio Minho basin is shown as Figure 3-11.

FIGURE 3-11: 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 Webbers Gully has a sub-basin that covers an area of approximately 17.8km^2.

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), totalling 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.

3.3.2.2 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 3.3.1.1 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 3-12.

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).

3.3.3 WATER RESOURCES

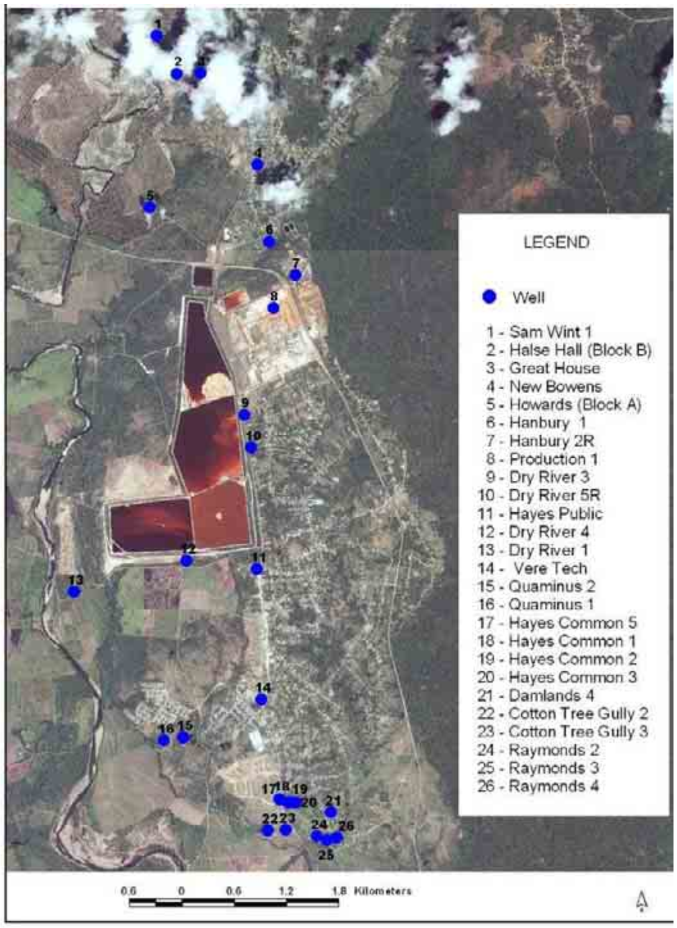
3.3.3.1 WELL LOCATIONS AND YIELDS

There are no hydraulic structures on the Rio Minho River in the vicinity of the proposed site for the development of additional RDAs.

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.

There are 26 production wells tapping the limestone aquifer, 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 REFINERY. A list of these wells, the owners, their use and licensed/historical yield is given in Table 3-4 below. The locations of these wells are shown in Figure 3-12.

FIGURE 3-12: Location of Production Wells



The greater numbers of the wells is located south of the REFINERY, 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 m^3/d; that for the Ministry of Education (Vere Technical well) totals 1,690 m^3/d and the historical abstraction for the Sugar Company of Jamaica (SCoJ) totals 131,112 m^3/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 REFINERY is 226,762 m^3/day.

TABLE 3-4: List of Production Wells East of the Rio Minho and within the Vicinity of the REFINERY

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
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

Name of Well	Name of Owner	Water Use	Yield (m^3/day)
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 REFINERY. 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 3-13.

FIGURE 3-13: Location of the Monitor Wells

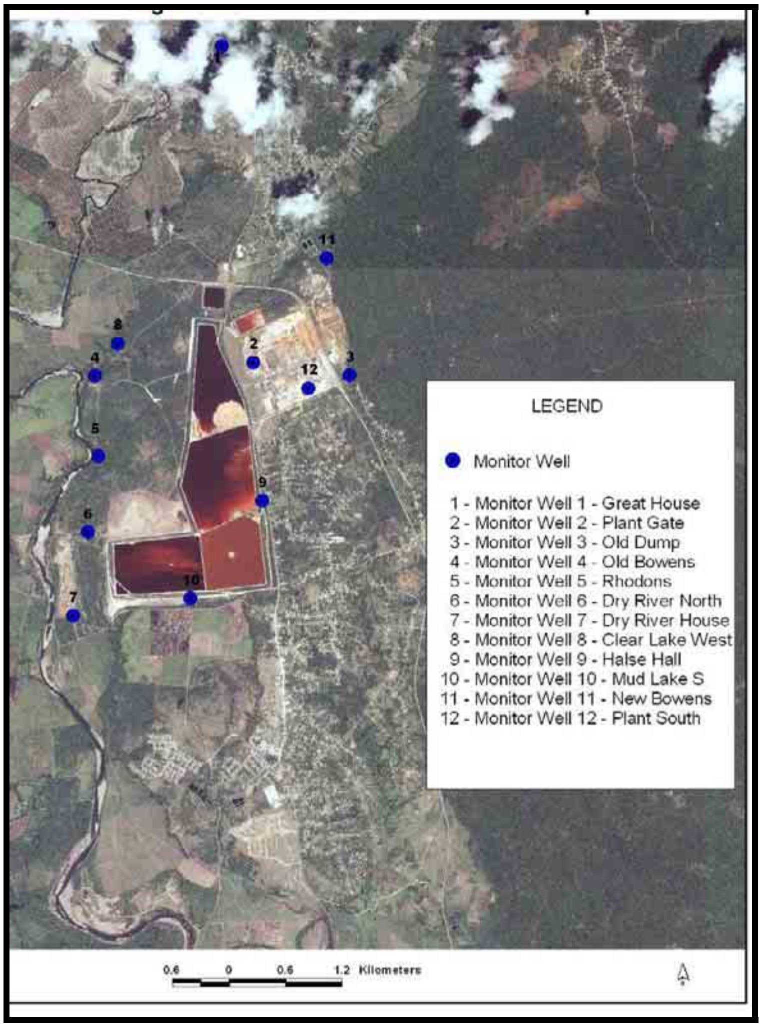


TABLE 3-5: Construction Details of Monitor wells-Jamalco-REFINERY (MS-MEDIUM SAND FS-FINE SAND)

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	5	+0.3	146.3	146.6	MS	-1.5	141.7	140.2	141.7	1.5 0 to 1.5
				Screen	5	146.3	149.3	3.0	FS	141.7	143.2	1.5		
				Bank	5	149.3	152.4	3.1	MS	143.2	152.4	9.2		
2	Plant Gate	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	141.7	140.2	141.7	1.5 0 to 1.5
				Screen	5	149.3	152.4	3.1	FS	140.2	143.2	3.0		
				Bank	5	152.4	155.4	3.0	MS	143.2	155.4	12.2		
3	Old Dump	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	144.8	143.3	144.8	1.5 0 to 1.5
				Screen	5	149.3	152.4	3.1	FS	144.8	146.3	1.5		
				Bank	5	152.4	155.4	3.0	MS	146.3	155.4	9.1		
4	Old Bowens	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	144.8	143.3	144.8	1.5 0 to 1.5
				Screen	5	149.3	152.4	3.1	FS	144.8	146.3	1.5		
				Bank	5	152.4	155.4	3.0	MS	146.3	155.4	9.1		
5	Rhodons	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	144.8	143.3	144.8	1.5 0 to 1.5
				Screen	5	149.3	152.4	3.1	FS	144.8	146.3	1.5		
				Bank	5	152.4	155.4	3.0	MS	146.3	155.4	9.1		
6	Dry River North	10.16	152.4	Blank	5	+0.3	146.3	146.6	MS	-1.5	143.3	141.8	143.3	1.5 0 to 1.5
				Screen	5	146.3	149.3	3.0	FS	143.3	144.8	1.5		
				Bank	5	149.3	152.4	3.1	MS	144.8	152.4	7.6		
7	Dry River House	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	143.3	143.3	143.3	1.5 0 to 1.5
				Screen	5	149.3	152.4	3.1	FS	143.3	148.8	1.5		
				Bank	5	152.4	155.4	3.0	MS	144.8	155.4	10.6		
8	Clear Lake West	10.16	155.4	Blank	5	+0.3	149.3	149.6	MS	-1.5	143.3	141.8	143.3	1.5 0 to 1.5
				Screen	5	149.3	152.4	3.1	FS	143.3	146.3	3.0		
				Bank	5	152.4	155.4	3.0	MS	146.3	155.4	9.1		
9	Halse Hall	10.16	155.4	Blank	5	+0.6	128.0	128.6	MS	-1.5	127.5	126.0	126.5	1.5 0 to 1.5
				Screen	5	128.0	131.0	3.0	FS	127.5	134.0	6.9		
				Bank	5	131.0	134.0	3.0	MS	134.0	155.4	21.0		

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)**		
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

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 3-10

Details on the construction of the monitor wells are given in Table 3-5 above.

3.3.3.2 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 REFINERY 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 REFINERY 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.

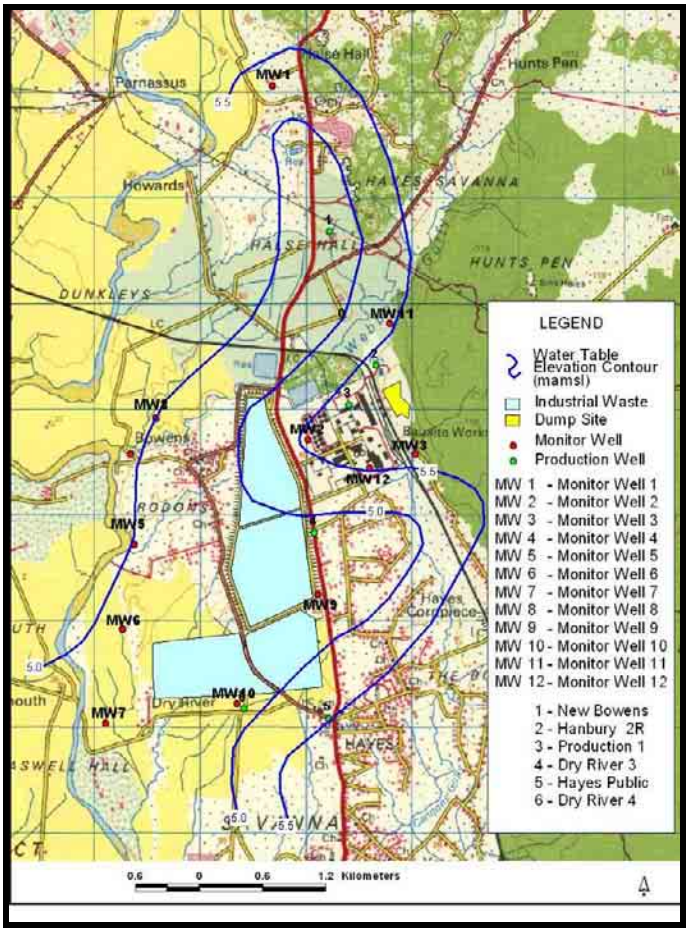
The water table elevation upon completion of the monitor wells and that on April 1, 2004 is compared in Table 10 below.

Table 3-6: 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 3-14. 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 REFINERY.

FIGURE 3-14: Water Table Elevation Map



3.3.3.2.1 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 3-4 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 REFINERY was 226,762 m^3/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 REFINERY 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.

3.3.3.2.2 RESERVOIR VOLUME

The effective ness 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 REFINERY 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 REFINERY 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 REFINERY. 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.

3.3.4 WATER QUALITY

3.3.4.1 AMBIENT WATER QUALITY

The groundwater resources of the Clarendon Plains and the area around the REFINERY 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 3-7 below.

TABLE 3-7: 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

Constituents	Units	Concentrations
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

3.3.4.2 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 REFINERY 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.

3.3.4.3 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 REFINERY 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.

3.3.4.3.1 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 REFINERY 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 REFINERY 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 REFINERY 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 REFINERY are all located along the South Coastal Fault Zone, which is open to the sea at both its eastern and western ends.

3.3.4.3.2 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 REFINERY 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.

3.3.4.4 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:

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

1 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.

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

3 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.

4 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.

3.3.4.4.1 WATER QUALITY MONITORING

Jamalco has conducted water quality monitoring around the REFINERY 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 REFINERY. 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 3-8 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 3-9. 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 3-10 below.

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

TABLE 3-8: 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 3-9: 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 3-10: LIST OF FACILITIES, SOURCES, SAMPLE SITES AND PARAMETERS ANALYZED

Facility/Location	Source/Supply	Sample Site	Parameters
Clarendon Alumina Works [REFINERY]	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: Technical Chlordane: Methoxychlor. **Organics:** 1,1-Dichloroethane: Chloroform: Benzene: 1,2-Dichloroethane: 2,4,6-Trichlorophenol: Pentachlorophenol: Hexachloroethane: Benzo(a)Pyrene.
	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	
	Breadnut Valley Well after Treatment	Drinking Fountain in Plant Office	
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	

3.3.4.4.2 ANALYTICAL RESULTS

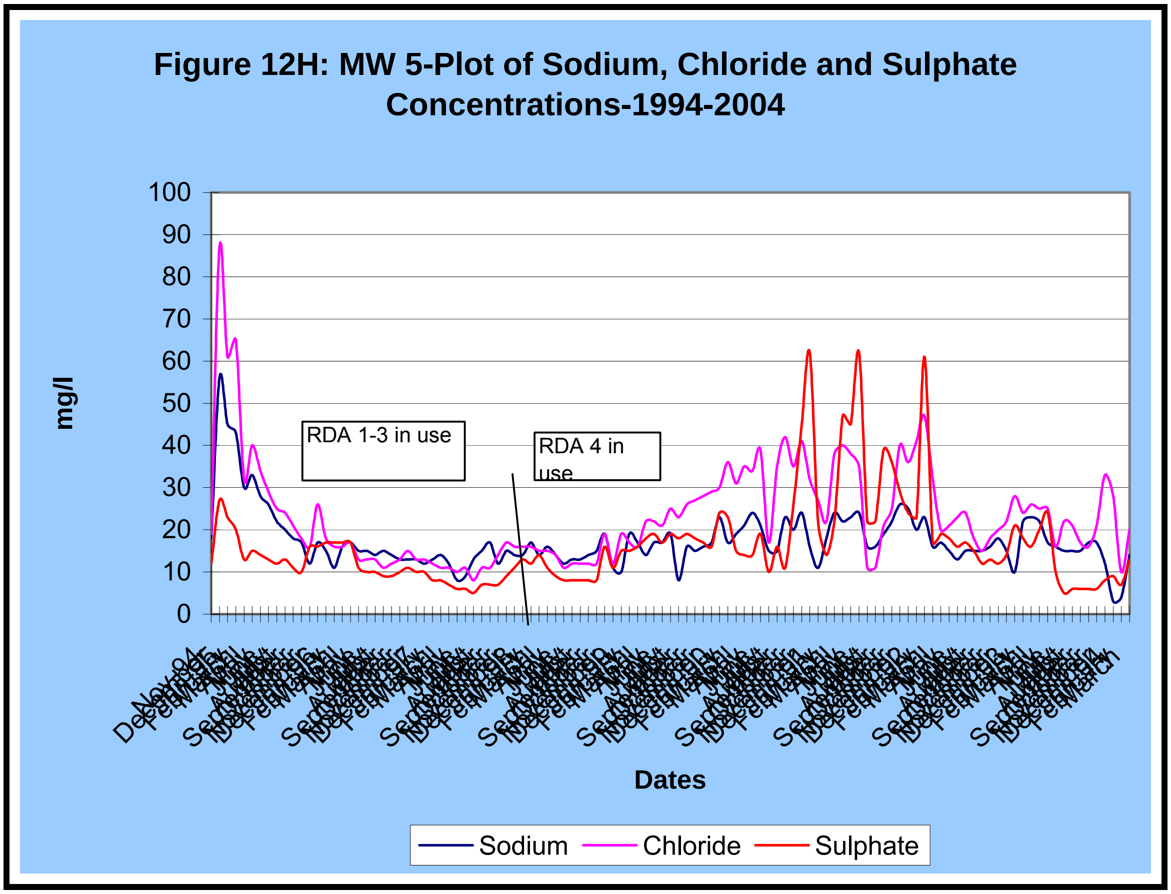
a) Borehole Profile

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 and Analysis

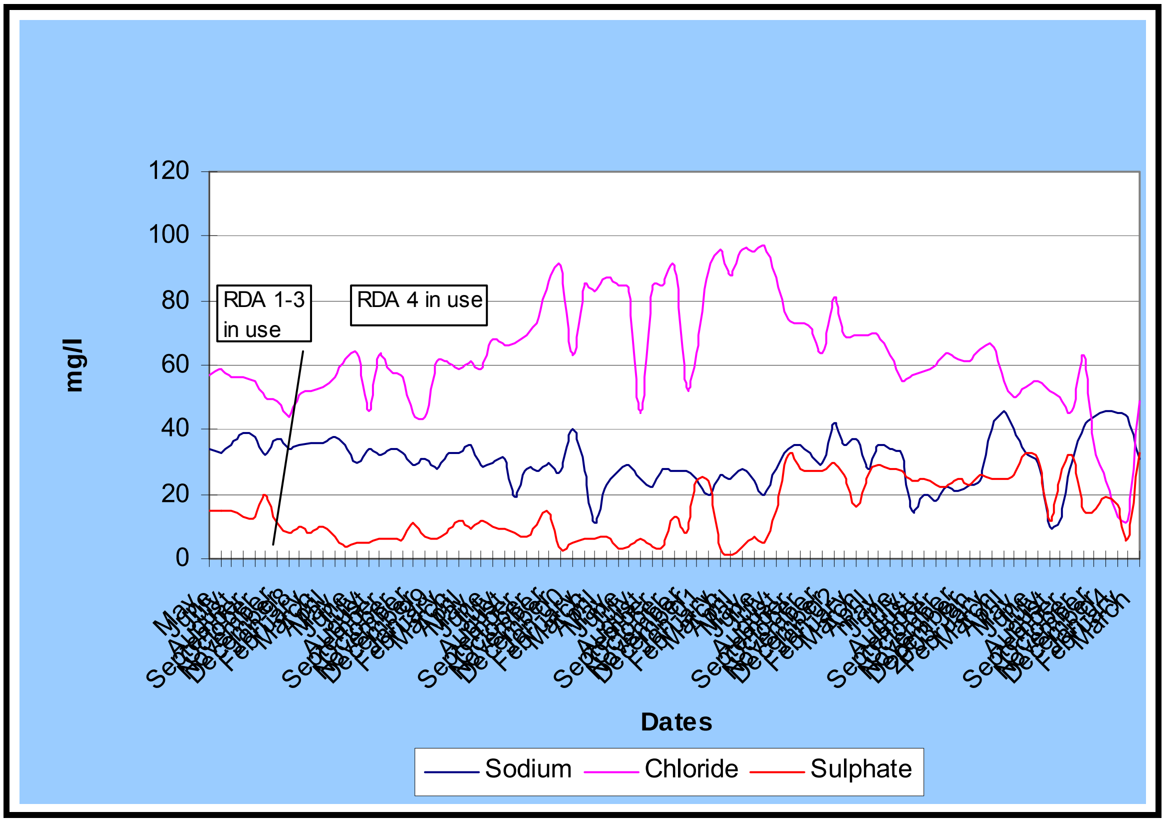
The results for the monthly sampling and analysis programme are shown plotted for four of the monitoring points-3 monitor wells and 1 production well. The points are MW 5 to the west of the RDAs; MW 9 to the east of the RDAs; MW 10 to the south of the RDAs and Hayes Public well located to the south of 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 3-15 to Figure 3-19.

FIGURE 3-15: MW 5-Plot of Sodium, Chloride and Sulphate Concentrations-1994-2004



At MW 5, to the west of the RDAs, the data plot Figure 3-15 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.

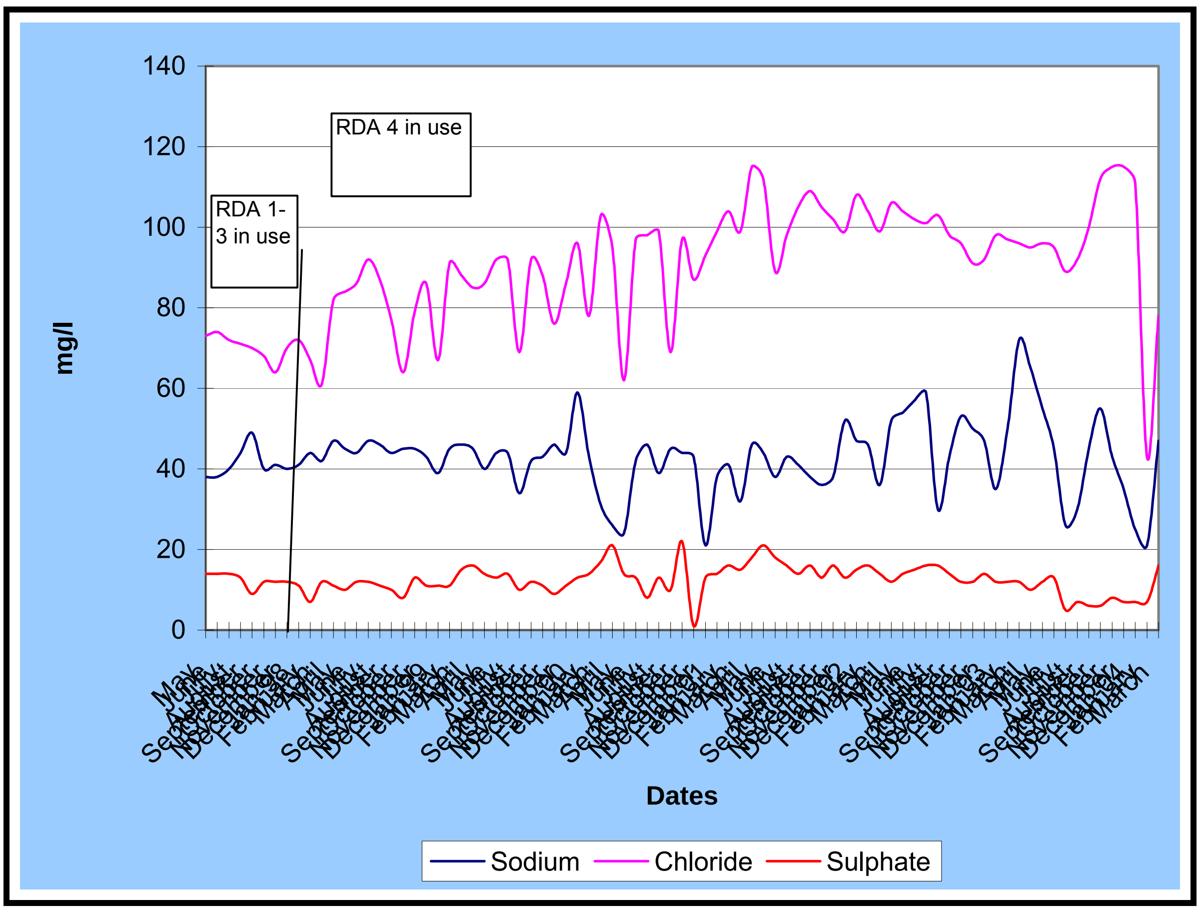
FIGURE 3-16: MW 9-Plot of Sodium, Chloride and Sulphate Concentrations-1994-2004



At MW 9, to the east of the RDAs, the plot Figure 3-16 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.

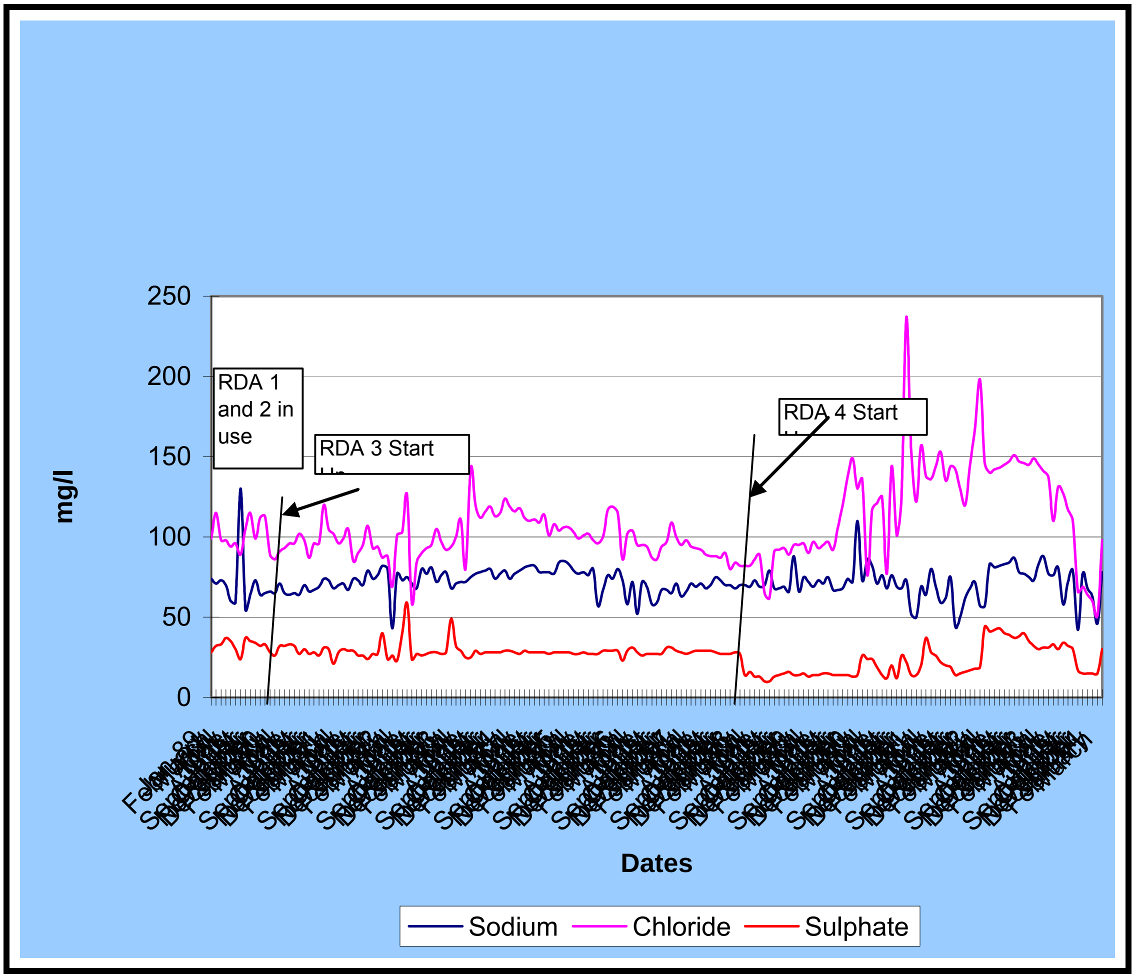
FIGURE 3-17: MW10-Plot of Sodium, Chloride and Sulphate Concentrations-1994-2004



At MW 10, to the south of the RDAs, the plot (Figure 3-17) 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 3-18: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 3-18 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 3-11.

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 3-11: Analytical Results of Heavy Metals for Hayes Public Well (NWC) – April 2004

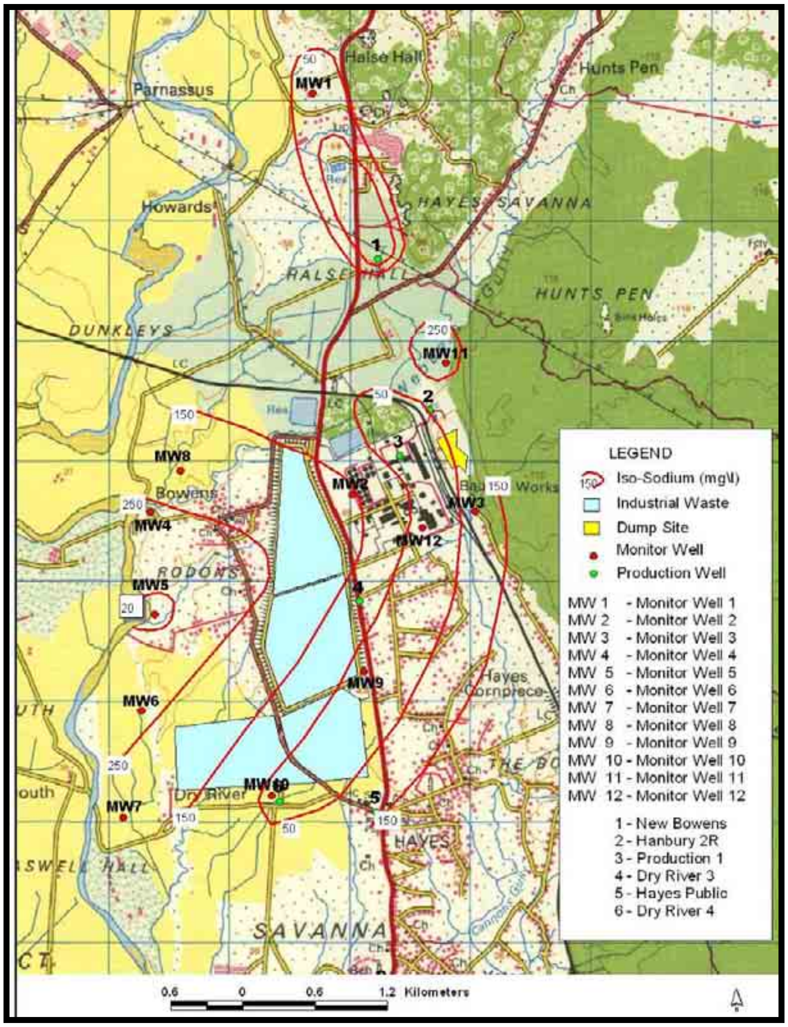
Parameter	Concentration (mg/l)	Lab Reporting Limit (LRL) (mg/l)	WHO Guideline Limit for Drinking Water (mg/l)	Remarks
Aluminium	0.22	0.10	0.20	Exceeds Guideline-No toxicological Effect.
Antimony	<0.50	0.50	0.002	
Arsenic	<0.50	0.50	0.05	
Barium	0.055	0.010	None	
Beryllium	<0.0050	0.0050	None	
Cadmium	<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	

Parameter	Concentration (mg/l)	Lab Reporting Limit (LRL) (mg/l)	WHO Guideline Limit for Drinking Water (mg/l)	Remarks
Lead	<0.10	0.10	0.05	
Manganese	<0.010	0.010	0.1	
Mercury	<0.00020	0.00020	0.001	
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 Figure 3-11 and Table 3-13 The sodium concentration reported for monitor well 1 and shown in Figure 3-11 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 REFINERY. 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 3-19. 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 3-19: 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 3-10 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 3-14 to Table 3-17. 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.

<u>TABLE 3-12: Summary of Analytical Results and Field Data – April 2004</u>

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**

TABLE 3-13: 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 3-14: 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 3-15: 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 3-16: 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 3-17: 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**

3.4 AIR QUALITY AND WEATHER

3.4.1 AIR QUALITY

3.4.1.1 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 refinery which is the major source for atmospheric emissions is approximately 165 feet above mean sea level (amsl) and is surrounded by a mix of undeveloped and residential land uses. The terrain elevations rise up to over 400 feet amsl at approximately 2000 feet to the east of the refinery. The RDAs are not significant sources of air emissions.

3.4.1.1.1 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.

3.4.1.1.2 AIR EMISSIONS

The primary emissions that are released from the REFINERY refinery include particulates, NO_x, SO_2, CO, neglible quantities of VOCs and trace levels of metal.

3.4.1.1.2.1 Particulates

Emissions of particulates are released from the calciners, boilers and medical waste incinerator. In addition, particulates are intermittently released as a result of mining activities, windblown dust associated with bulk material handling, transportation and stocking of raw material (bauxite), intermediate product (hydrate) and the alumina product itself.

Particulate emissions have also been 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.

These include but not limited to the use of hooded conveyors, sprinkler systems, cyclones, bag houses and ESPs.

The location has implemented a number of fugitive emission control measures inclusive of the following:

- Controlling fugitive particulate emissions from storage piles through enclosures, covers or stabilization, minimizing the slope of the upwind face of piles where practicable. Confining as much pile activity as possible to the down wind side of piles.
- Limiting the size of loads to minimize loss of material to wind and spillage.
- Planting special wind breaks at critical points.
- Prompt removal of soil and other dust -forming debris from paved roads and scraping and compaction of unpaved roads to stabilize the road surface as often

as necessary to minimize re-entrainment of fugitive particulate matter from the road surface.

- Vegetating areas with grass.
- To the extent practicable restricting vehicular travel to established paved roads.
- Watering of unpaved roads and other unpaved open spaces as often as necessary to minimize re-entrainment of fugitive particulate matter from these surfaces. Drip irrigation is also practiced at the refinery.
- Maintaining good house keeping practices to minimize the accumulation of materials, which could become fugitive.

The major source of fugitive dust at Jamalco is from open areas (uncovered with grass or unpaved).

3.4.1.1.2.2 NOx Emissions

NOx emissions are not anticipated to be an issue during the implementation of the RDA project.

3.4.1.1.2.3 SO_2 and CO Emissions

Sulphur dioxide and carbon monoxide emissions are not anticipated to be an issue during the implementation of the RDA project.

3.4.1.1.2.4 Trace Metals

Trace Metals such as mercury are not anticipated to be an issue during the implementation of the RDA project.

3.4.1.1.2.5 Ambient Air Quality Monitoring

Jamalco operates two ambient air-monitoring stations located in the New Bowens and Corn Piece communities. These stations are capable of monitoring SO_2, NOx, COx and Ozone.

Data derived from these stations have consistently shown levels well below the Jamaican Ambient Air Quality standards.

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.

Jamalco also maintains a stringent 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.

3.5 WEATHER

3.5.1 REGIONAL SETTING/SPHERE OF INFLUENCE

Jamalco's refinery which is proposed for upgrade is 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 plant has been in its 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

3.5.2 RDA REGIONAL 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.

3.5.3 RAINFALL

Rainfall totals for the southern Clarendon region are low when compared to that of the northern Manchester regions. 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 3-18: ANNUAL RAINFALL - INCHES. JAMALCO REFINERY

YEAR	Month												YEAR'S TOTAL	MONTHLY AVERAGE
	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.		
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 at the refinery for a period 1999 -2003, indicates that the maximum temperatures range from 34.5 deg. Celsius to 31 deg. Celsius and that the low temperatures range from 24 deg. Celsius 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 3-19: 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

3.6 WILDLIFE AND VEGETATION

3.6.1 INTRODUCTION

The proposed construction of the RDA will occupy an estimated 100 hectares of land adjacent to RDA 4. The previous four lakes cover an estimated area of 210 hectares (519 acres). The areas in proximity to the walls of the RDAs and the lands behind them that extend to the river, support a vegetation type typical of a scrubland/ thorn savannah. In most areas, the physiognomy of the plant communities are very similar. Whilst in others the structure of the vegetation has been modified by specific events or activities such as old excavations, grazing, tree felling for charcoal burning or post making, and even flood events. The area, although in proximity to the Rio Minho, appears to be dry. This is evident with the existing plant community that demonstrates xerophytic adaptations such as thick land shiny cuticles, small leaves or succulent parts.

The map and table below shows sample locations and coordinates at Hayes.

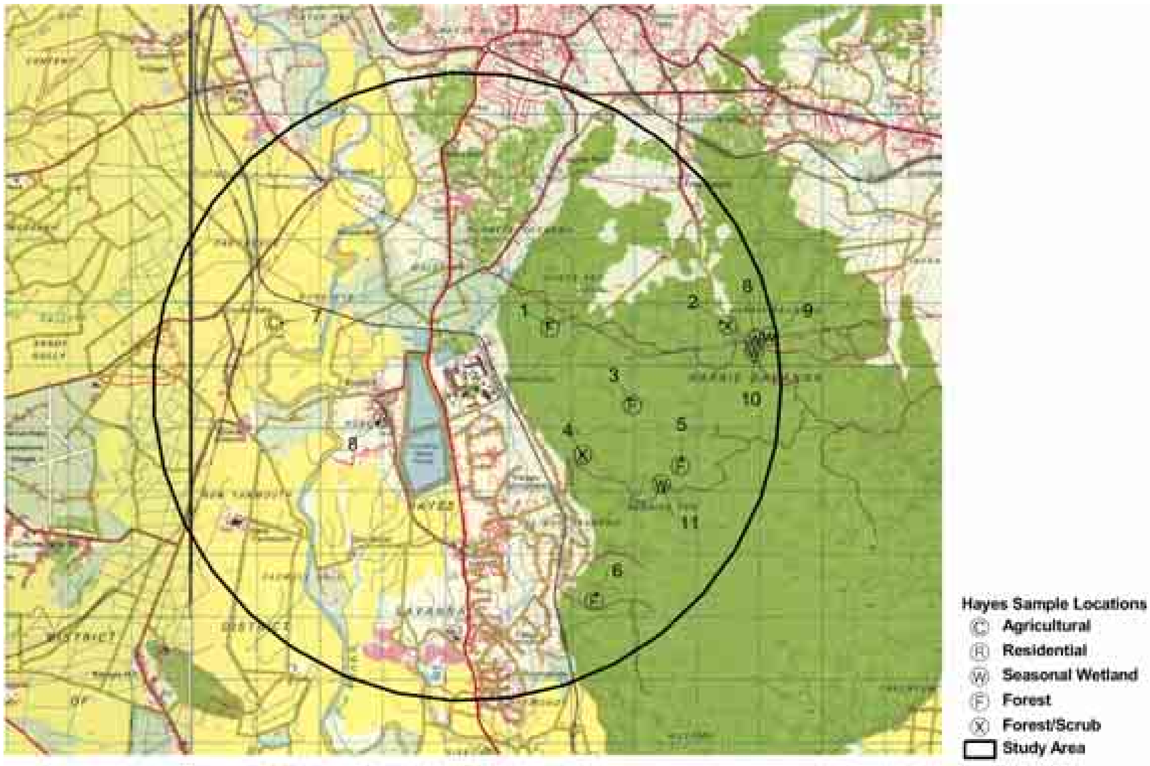


FIGURE 3-20: : MAP SHOWING SAMPLE LOCATIONS AT HAYES, CLARENDON

TABLE 3-20: COORDINATES OF SAMPLE SITES AT HAYES, CLARENDON (COORDINATES CORRESPOND TO 1:50,000 METRIC MAP)

ID HAYES	TYPE	X	Y
1	Woodland	225,665	139,600
2	Woodland/Scrub	228,497	139,634
3	Woodland	226,978	138,356
4	Woodland/Scrub	226,193	137,584
5	Woodland	227,740	137,401
6	Woodland	226,373	135,248
7	Agricultural	221,270	139,679
8	Seasonal Wetland	228,934	139,417
8	Residential	223,016	138,160
9	Seasonal Wetland	229,160	139,452
10	Seasonal Wetland	228,916	139,208
11	Seasonal Wetland	227,432	137,113

3.6.2 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, faecal deposits, burrows among others.

3.6.3 ECOLOGICAL CONTEXT

3.6.4 NATIONAL BIOLOGICAL DIVERSITY – INTERNATIONAL AND NATIONAL LEVELS

Jamaica is 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 3-21-Flora diversity[i]

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 3-22- Fauna diversity[i]

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 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 IV

3.6.5 FINDINGS

3.6.5.1 SAMPLE LOCATIONS

The following locations were selected as representative of the different ecosystem identified during the reconnaissance. The selected sample sites are indicated on the accompanying maps.

3.6.5.1.1 HAYES FACTORY PERIMETER

The circular perimeter of 5 km radius around the Hayes factory is subdivided into a western agricultural and eastern woodland area, the latter forming a part of Harris Savanna. Residential areas mainly stretch along the main road that runs southwards from Curatoe Hill trough Hayes and towards Lionel Town. To the east of the road, the bed of Rio Minho meanders southward.

Growing on top of flat though often rugged limestone, the woodland consists of a mosaic of secondary scrub dominated by exotic plants and degraded dry limestone forest of varying quality. Secondary scrubs are most common in the most northern section of the area and along drive roads. The least disturbed dry forest is found away from drive roads and footpaths. Shallow depressions filled with alluvial deposits intersect the limestone. These soil-rich areas are mostly clear-cut and covered with grassy plants. Prone to flooding, they contain a series of seasonal wetlands that support a unique flora.

The agricultural and residential areas are located on the Clarendon alluvial plain. They have lost their natural vegetation in the distant past and are dominated by exotic plants. The major crop species is sugar cane.

Location 1 and 2 - Strongly disturbed limestone forest with only few tall trees, mainly Red Birch. Dense and rather scrubby, but with many native species typical of mature forest.

Locations 2 and 4 - Mixture of strongly disturbed limestone forest dominated by native species and secondary scrub dominated by exotics.

Locations 3 and 5 - Located within a section of least disturbed forest. A variety of tree species grow to considerable height. Some patches close to undisturbed forest.

Location 7 - Agricultural area dominated by sugar cane and pastures.

Location 8 - Residential area dominated by exotic fruit trees and ornamental species.

3.6.5.2 DESCRIPTION OF VEGETATION TYPES

The vegetation was generally what is expected in highly disturbed areas.

The ecology of this 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. An 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 4-3-23: Thorn Scrub below.

TABLE 4-3-23: 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)

Family Name	Scientific Name	Common Name	Status/Rank	Habit
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-bit/Fingrigo	Same	Shrub (6m)
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) (Figure x)
- 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.

PLATE 3-2: TYPICAL STANDS OF WILD POPONAX FOUND ON AND AROUND RDAS

Summary

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

3.6.5.3 FAUNAL STUDIES

3.6.5.3.1 4.6.6.3 GENERAL FAUNAL DESCRIPTION

The primary focus of the faunal studies was on the avifauna in the area and for the other species noted such as insects, reptiles and amphibians. Analysis of avifauna species was conducted in relation to habitat types as outlined above in the vegetation analysis.

The vegetation types identified in the study area have the potential to support a number of bird species, providing habitats particularly for columbids, and passerines. The vegetation types have also been known to support a large number of migrant warblers in the winter season.

Generally, bird counts conducted over the study period did not confirm a large number of bird species and only one migrant was identified in the total of fifteen (15) species identified.

TABLE 3-24: Coastal and Thorn Scrub

FAMILY NAMES	SCIENTIFIC NAMES	COMMON NAMES	STATUS/ RANK	FEEDING HABIT
Apodidae	*Tachornis phoeicobia*	Antillean Palm Swift	R1	Insectivore
Apodidae	*Streptoprocne zonaris*	White-Collard swift	R1	Insectivore
Ardeidae	*Bubulcus ibis*	Cattle Egret	R1	Omnivore
Cathartidae	*Cathartes aura*	Turkey Buzzard	R1	Scavenger
Charadriidae	*Charadrius vociferous*	Killdeer	R1	Omnivore
Columbidae	*Columbina passerine*	Ground Dove	R1	Frugivore
Columbidae	*Zenaida aurita*	Mourning Dove	R1	Frugivore
Cucilidae	*Crotophaga ani*	Smooth-billed Ani	R1	Omnivore
Emberizinae	*Tiaras olivacea*	Yellow-faced Grassquit	R1	Frugivore
Falconidae	*Falco sparverius*	American Kestrel	R1	Carnivore
Mimidae	*Mimus polyglottos*	Northern Mockingbird	R1	Omnivore
Scolopacidae	*Actitis macularia*	Spotted sandpiper	W1	Omnivore
Sturnidae	*Sturnus vulgaris*	European Starling	I1	Frugivore
Trochilidae	*Mellisuga minima*	Vervain	R1	Nectarivore
Tyrannidae	*Tyrannous dominicensis*	Gray Kingbird	S1	Insectivore

Families -13
Species - 15
Endemics -none

3.6.5.4 OTHER FAUNA

Insects were fairly well represented, with butterflies and bees being the most obvious of the group. Lepidoptera (butterflies etc.) were represented with at least 5 different species noted. More importantly is the ecological functions of these insects where they act as pollinators. Other insect's species included ants, beetles, stinkbugs, wasps and honeybees.

3.6.5.4.1 AMPHIBIANS AND REPTILES

Reptiles and amphibian were not noted during surveys however literature reviews indicated the likely occurrence of certain species in the study area. Please refer to the list below, which a list of potential amphibians and reptiles in study area.

Serpentes

- ✓ *Arrhyton funereum* - endemic
- ✓ *A. callillaemum* - endemic
- ✓ *Typhlops jamaicensis* - endemic

SPHAERODACTYLUS

- ✓ *Sphaerodactylus argus* – not endemic

Celestus

- ✓ *Celetes duquesneyi* - endemic
- ✓ *C. d crusculus* - two subspecies – endemic
- ✓ *C. barbouri*

Anolis

- ✓ *Anolis valencienni* - endemic
- ✓ *A. sagrei*

***A OPALINUS* - ENDEMIC MAYBE EXTINCT**

- ✓ *A. lineatopus* - endemic

***A. GRAHAMI* - ENDEMIC INTRODUCED TO OTHER ISLANDS**

- ✓ *A. garman i*- endemic introduced to other islands

Sauria

- ✓ *Ameiva dorsalis*

Testudines

- ✓ *Trachemys terrapen*

Amphibia

- ✓ **Anura**
  - o *Osteopilus brunneus -* endemic
  - o *Hyla wilderi* **-** endemic
  - o *Hyla marianae* **-** endemic
  - o *Bufo marinus* **-** introduced
- ✓ *Eleutherodactylus planirostris planirostris*
- ✓ *E. pantoni pantone*
- ✓ *E.junori* **-** endemic
- ✓ *E.jamaicensis* **-** endemic
- ✓ *E.grabhami* **-** endemic
- ✓ *E gossei gossei* - endemic
- ✓ *E. gossei oligaulax* - endemic
- ✓ *E. cundalli* - endemic
- ✓ *E. cavernicola* - endemic
- ✓ *E. calyptahyla crucialis* **-** endemic

At least four species of *Arrhyton sp* of which three are endemic. The snakes feed on other reptiles and amphibians such as *Anolis spp, Eleutherodactylus* adults and eggs as well as *Sphaerodactylus spp*. Of the *Sphaerodactylus spp* one, not endemic, has a range extending to the study area.

In addition, at least six *Anolis spp* are suspected to occupy the area. Of these six species at least five are endemics with one species thought to be extinct. Our largest reptile *C.acutus* has also been reported in the Portland Bight area.

Of the amphibians at least 15 species are thought to have the potential to occur in the study area and of these fifteen, twelve are endemic. Furthermore, nine of those species are *Eleutherodactylus spp.*

3.6.5.4.2 BUTTERFLIES

As with amphibians and reptiles, this group was not surveyed and unfortunately literature did not yield concrete data on species distribution. Information from the Begs report 2000, which focused on faunal studies in Southern Manchester, indicated the likely occurrence of certain species. The report identified seven families accounting for 41 species. Of which nine are endemic species or subspecies.

3.7 ARCHAEOLOGICAL AND HISTORICAL RESOURCES

3.7.1 SUMMARY [ii]

The parish of Clarendon was named in honour of the celebrated Lord Chancellor of England & Wales. The parish of Vere, now merged in it, was named after Vere, daughter of Sir Edward Herbert, Attorney General to Charles I, and first wife of Sir Thomas Lynch, who, with her two sons, died on her passage from England to Jamaica in 1683.

Carlisle Bay, the scene of the principal military engagement with a foreign foe which has taken place in Jamaica during the British occupation, is on the south-west coast of the old parish of Vere.

3.7.2 BUILDINGS AND MONUMENTS OF ARCHITECTURAL AND HISTORIC INTEREST

There are various buildings and monuments of architectural and historic interest in the parish of Clarendon. Some of these are listed below.

- Halse Hall Great House
- Churches, Cemeteries, Tombs'
- St. Peter's Church, Alley
- Clock Tower
- May Pen Clock Tower

3.7.3 NATURAL SITE

- Milk River Spa

3.7.4 PROTECTED NATURAL HERITAGE SITES

3.7.4.1.1 NATURAL SITE

- Mason River Botanical Station

3.7.4.1.2 Other Heritage Sites[iii]

3.7.4.1.2.1 Arawaks

In Clarendon, they lived in Portland Ridge (the part of the parish that juts out into the sea) as well as in the Braziletto Mountains and on Round Hill. There was also a village on the banks of the Rio Minho near Parnassus Estate and the others were on the banks of the Milk River.

3.7.4.1.2.2 Halse Hall Great House

Halse Hall Great House, believed to be built on the site of a house that stood on the Site of Buena Vista, was acquired by Thomas Halse in 1655 who came to Jamaica with Venables. Henry de la Beche, one of its many owners was the founder of the Geological Survey of Great Britain. He made detailed Geological notes of the places he visited in Jamaica. In 1969 the estate was acquired by ALCOA, the house renovated by them. It is now the property of the National Trust.

3.7.4.1.2.3 St. Peter's Church Alley

St. Peter's Church Alley, is the 3rd oldest Anglican Church in Jamaica. Built in 1671, it became the Parish church for Vere in 1673 it was extensively damaged by the 1692 earthquake and had to be almost totally rebuilt in 1975

3.7.4.1.2.4 Morgan's Valley and Estate

Sir Henry Morgan, a privateer, buccaneer and former Governor of Jamaica, owned Morgan's Valley and Estate. He lived there while he was Governor of Jamaica.

3.7.4.1.2.5 May Pen Clock Tower:

May Pen Square is over 80 years old. It was constructed in honor of Dr. Samuel Glaister Bell, a renowned doctor of the parish who lost his life while crossing the Rio Minho after visiting a patient. The May Pen Clock Tower is made of stone. It is approximately twenty-four (24) feet in height, eight feet (8) in width, and eight feet in length. The exact date of its erection has not been ascertained, but it appears to have been constructed after World War II.

3.7.4.1.2.6 St Gabriel's Anglican Church

Once called Lime Savannah Chapel, was the "daughter" Church of St. Paul's in Chapelton. When the Church of the White Cross fell into disuse, St. Gabriel's took its place.

3.7.4.1.2.7 St. Paul's Church- Chapleton

When the present parish of Clarendon was divided into the parishes of Clarendon and Vere, the Cross church was then the parish church of Clarendon. St. Paul's was built as a chapel of Ease to the Cross Church, and was the first place of worship erected in Upper Clarendon. It was originally known as "the Chapel". It took the name from the church, being called "Chapel Town," and in the course of time shortened to its present form, Chapleton.

3.8 NOISE LEVELS AND VIBRATION

3.8.1 BASELINE NOISE LEVELS

Noise levels are measured on a reasonably regular basis at the existing RDAs. Recently, these measurements have been taken in support of the Step-in-dyke being constructed in RDA 1. Recent data from the RDAs taken during active operation of heavy equipment (track excavators, loaders, bulldozers and trucks) follows.

The audiometric survey was conducted using a Metrosonic audio dosimeter. The survey points were triangulated around RDA 1 (See Plate 3-3 below), along the RDA #1 perimeter wall. The audiometer was operated continuously throughout the duration of the survey, with instantaneous readings for the Sound Pressure Levels (SPL) being recorded at one minute intervals, or at a moment of significant activity,1 over a period of fifteen (15) minutes each.

Table 3-25, Table 3-26, and Table 3-27 show the instantaneous measurements for the SPL levels which were recorded from the audiometer at the three survey points indicated in Plate 3-3 below.

[1] Significant activity is to be defined as, any activity which affects the audiometer's SPL measurement such that it deviates from the instantaneous 'background' effecting activity.

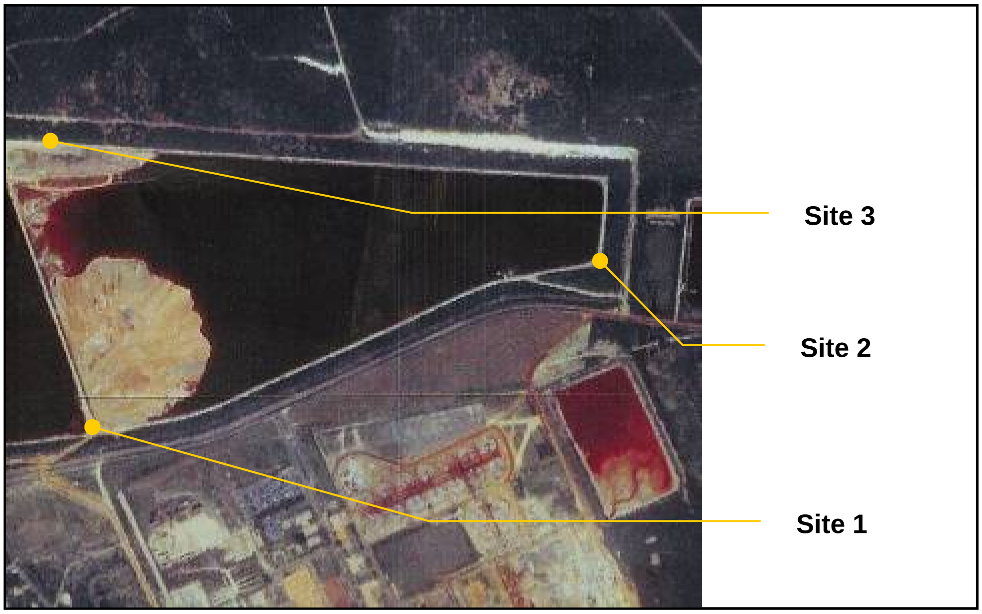


PLATE 3-3: AUDIOMETRIC SURVEY SITES AROUND RDA # 1[2]

3.8.1.1 SOUND PRESSURE LEVEL (SPL) ANALYSIS

3.8.1.1.1 SITE 1

The average SPL value at site 1 was calculated as 62.6 db. There were only two occasions when the 70.0db limit was exceeded; however, only on one of the two exceedances was due to the operation of heavy the equipment, whereas the other was due to inherent background activity such as wind. It should be noted that the occasion which generated the highest SPL value was the instantaneous and continual inherent background activity, which is beyond the control of Jamalco.

[2] Please note that the aerial picture does not represent the RDA's present state. It is only to be used as a guide to indicate the audio metric survey points

TABLE 3-25: SITE 1 SPL VALUES

Time/ mins	SPL/ db	Effecting Activty
0	61.6	Background (2)
0-1	70.7	Caterpiller Grader
1	62.6	Background (2)
2	73.2	Background (2)
3	66.2	Truck Traveling along Highway
4	59.1	Background (2)
4-5	66.7	Truck Carrying Reject Material
5	63.4	Background (2)
6	61.5	Background (2)
7	59.2	Background (2)
8	59.3	Background (2)
9	62.9	Background (2)
10	61.1	Background (2)
11	66.4	Passing Truck
12	61.6	Background (2)
13	53.6	Lull in Wind
14	60.0	Background (2)
15	58.2	Background (2)
Average	**62.6**	

Table Notes

- Time ranges displayed as x-y are to be perceived as any time measurement between x and y
- The "Effecting Activity" labeled as "Background (1)" is defined as perpetuating noise from continuous wind movement across the microphone.
- Information in blue font represent "Significant Activity" and information in red font represent exceedances above the 70db limit

3.8.1.1.2 SITE 2

In the absence of significant construction activity, the contributing agent to the variation of the SPL values would be the random activity which occurs in the background. The terrain at Site 2 is such that there is a thick growth of epiphytes along the outer area of the dyke's perimeter wall. This growth was observed to act as buffer to the prevailing winds, resulting in the diminished effects of the prevailing wind on the SPL levels measured by the audiometer at Site 2. The effect of the diminished wind activity at Site 2 is reflected in the average SPL values observed at Site 2 and Site 3. (See Table 3-26 and Table 3-27 below)

TABLE 3-26: SPL VALUES FOR SITE 2

Time/ mins	SPL/ db	Effecting Activity
0	66.9	Background (2)
1	73.2	Passing Trucks on Highway
1-2	53.2	Lull in Wind
2	60.1	Background (2)
3	54.4	Lull in Wind
4	53.8	Lull in Wind
4-5	65	Horn of Bauxite Rail
5	65.7	Background (2)
6	65.4	Background (2)
7	56.5	Background (2)
8	63.5	Background (2)
9	54.6	Background (2)
10	60.0	Passing Vehicle on Highway
11	55.6	Background (2)
12	57.6	Background (2)
13	60.4	Background (2)
14	67.0	Background (2)
15	57.1	Background (2)
Average	**60.6**	

Table Notes

- Time ranges displayed as x-y are to be perceived as any time measurement between x and y
- The "Effecting Activity" labeled as "Background (2)" is defined as perpetuating noise from continuous wind movement across the microphone.
- Information in blue font represent "Significant Activity" and information in red font represent exceedances above the 70db limit

3.8.1.1.3 SITE 3

The terrain at Site 3 is an open flat area with no buffer or vegetation alongside the perimeter of the original RDA #1 wall. Therefore, the wind passes over the land unhindered.

A comparison between SPLs for Site 1, Site 2, and Site 3 reveal that Site 3 consistently has higher SPLs either Site 1 or Site 2. This is due to the accessibility and/or the vulnerability to the area to the prevailing wind for the reason described above. It should be noted that the influence of the wind activity is especially evident in the average SPL value recorded at Site 3, which is only 1 db below the defined standard of 70db.

Therefore, one may conclude that the SPL levels at the site are greatly influenced by the naturally occurring wind activity, and may elevate SPL values above the 70db limit. The likely occurrence of such events is beyond the control of Jamalco.

TABLE 3-27: SPL VALUES FOR SITE 3

Time/ mins	SPL/ db	Effecting Activty
0	73.4	Background (2)
1	69.3	Background (2)
2	57.9	Background (2)
3	71.1	Background (2)
4	66.6	Background (2)
5	64.4	Background (2)
6	70.2	Background (2)
7	61.5	Background (2)
8	79.7	Background (2)
9	75.6	Background (2)
10	69.7	Background (2)
11	66.4	Background (2)
12	61.0	Background (2)
13	66.4	Background (2)
14	74.1	Background (2)
15	77.0	Background (2)
Average	**69.0**	

Table Notes

- Time ranges displayed as x-y are to be perceived as any time measurement between x and y
- The "Effecting Activity" labeled as "Background (2)" is defined as perpetuating noise from continuous wind movement across the microphone.
- Information in blue font represent "Significant Activity" and information in red font represent exceedances above the 70db limit\

were determined by identifying communities that might be impacted during the various phases of this project. The communities' were identified through field surveys and aerial photographs.

The selected areas were monitored using a digital audiometer (Quest Electronics Model 2700, Impulse Sound Level meter) with a wind screen. The instrument was calibrated using a supplied calibrator prior to being used.

A total of x locations were identified and monitored to determine baseline noise levels. The selected sites monitored are:

Location 1:

Location 2:

Location 3:

Location 4:

3.8.2 AUDIOMETRIC SURVEY

Survey results…… TO FOLLOW

3.8.3 VIBRATION ANALYSIS

The proposed impact of vibration associated with the proposed earthworks are not expected to carry into the bordering communities of Hayes and Hayes Cornpiece. Any vibration associated with the potential blasting exercises will be monitored along with the usage of the explosives to effectively minimise the possibility of adverse effects.

3.9 NATURAL HAZARD VULNERABILITY

3.9.1 NATURAL HAZARD VULNERABILITY

3.9.1.1 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 3-21. 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 part, Vere Plains, it is not. It is suggested that this may be a function of continuing movements along the South Coast Fault.

With respect to the plant and RDA area (Figure 7), 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.

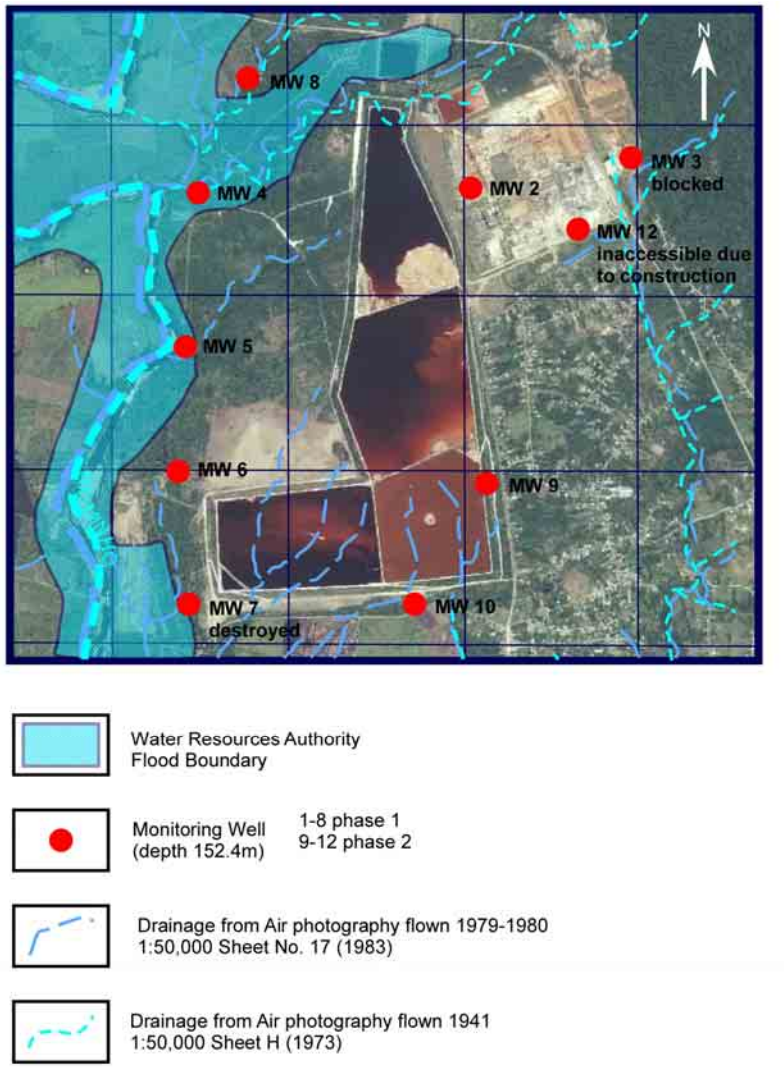


FIGURE 3-21: 1986 FLOOD BOUNDARY AND MONITORING WELLS AT THE REFINERY.

Using data from the Trout Hall rainfall station in the Upper Rio Minho Basin an analysis of the maximum 24hr rainfall depths for the 10, 25, 50, and 100yr return period floods was undertaken by the Water Resources of Jamaica (WRA) (Table 3-28). Data from the Trout Hall rainfall station was used because it is generally located in the Upper Rio Minho Watershed and it best represents the rainfall distribution over the watershed.

TABLE 3-28: 24HR RAINFALL BASED ON DATA FROM THE TROUT HALL RAINFALL STATION[3]

Storm Duration	1950 – 1986 Data (Trout Hall) (mm)			
	10yr	25yr	50yr	100yr
1min	17.9	21.7	28.5	30.4
15min	37.3	45.1	59.3	63.2
1hr	71.8	86.8	114.0	121.5
2hr	97.6	119.4	162.5	177.8
3hr	107.2	131.5	180.5	198.8
6hr	123.4	151.9	211.0	234.2
12hr	143.0	176.6	247.8	277.7
24hr	**175.0**	**217.0**	**308.0**	**347.0**

The profiles for the 10 – 100yr floods used by WRA were developed using the Steady flow analysis and one-dimensional flow methodology. Input data utilised information such as cross-sections of river channels. There are eight hydraulic structures on the Webbers Gully that could affect flow, none on the Rio Minho in the vicinity of the proposed development. Eight (8) parallel and identical circular culverts, each with a diameter of 3.96m serve as conveyance capacity at two locations on the Webbers Gully, located at the Alcoa train line and at the main road from Hayes to May Pen. The starting water surface elevations for the simulation of flood levels for Webbers Gully are presented in Table 3-29.

TABLE 3-29: STARTING WATER SURFACE ELEVATIONS AT THE WEBBERS GULLY/RIO MINHO RIVER JUNCTION[4]

Return Period (yr)	Peak Flow (m3/s)	Water Surface Elevation (m) a.m.s.l.
	Webbers Gully	Rio Minho River
10	86	33.35
25	111	34.66
50	129	35.51
100	145	36.17

Using a Hydrologic Engineering Center River Analysis Systems (HEC-RAS) modelling software developed by the US Corps of Engineers and the following scenarios, revealed:

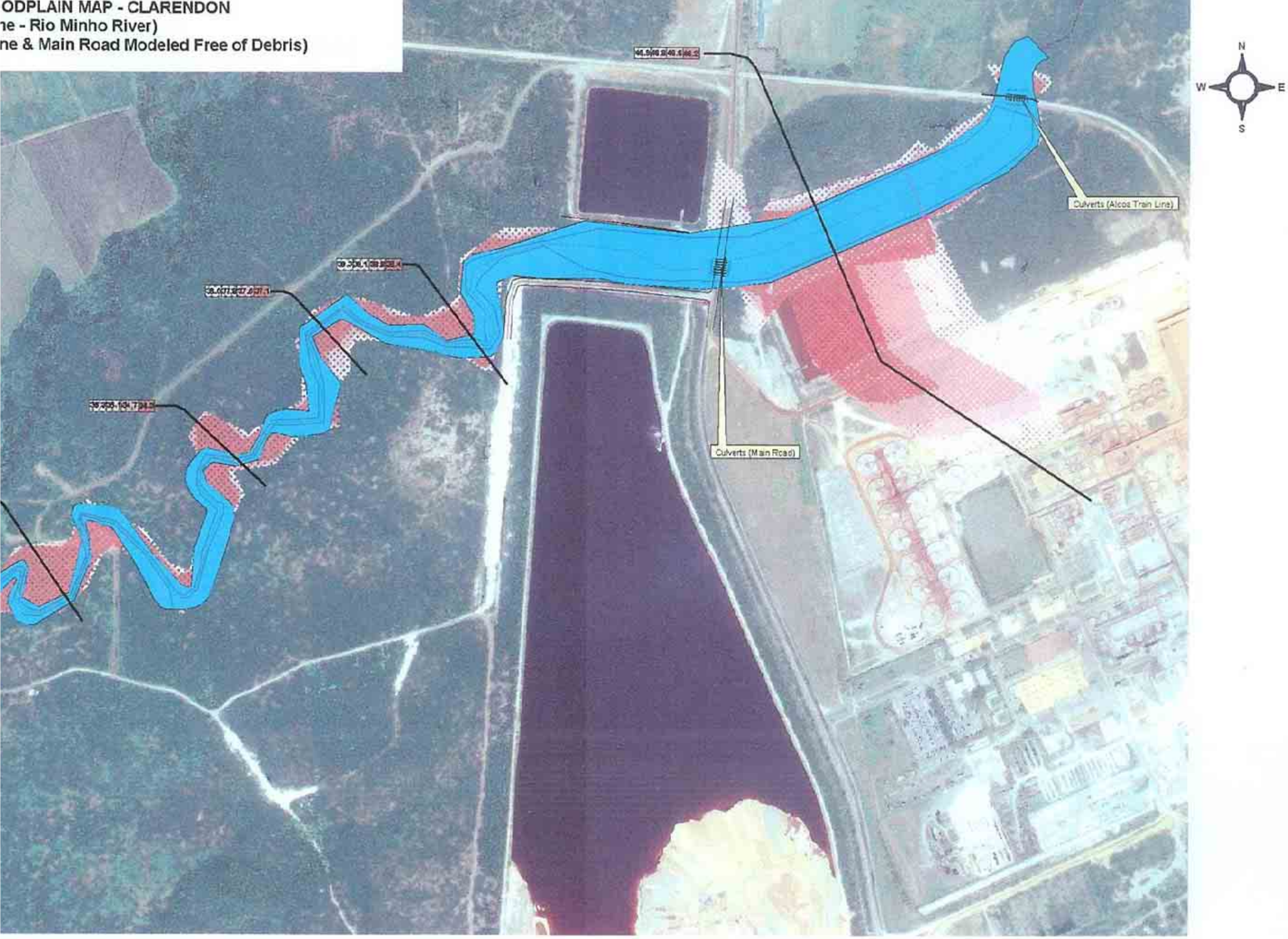
[3] Part of Rio Minho River/Webbers Gully Floodplain Mapping Project, Prepared by Water Resources Authority, June 2005
[4] Part of Rio Minho River/Webbers Gully Floodplain Mapping Project, Prepared by Water Resources Authority, June 2005

1. Scenario 1: the culverts are free of debris and any other obstruction that may restrict flow,
2. Scenario 2: the capacity of the culverts was approximately 50% blocked by debris, and
3. Scenario 3: the capacity of the culverts was nearly 100% blocked by debris

Flood plain Maps (Figure 1-1, Figure 3-23, and Figure 3-24) show the outcome of the above scenarios.

The Alley Bridge, which is approximately 2km downstream of the proposed site, had no effect on flood levels even with the bridge opening completely blocked. The WRA found that there was no significant inundation on either side of the Webbers Gully by any flood events modelled. There was general overtopping of the left bank of the Webbers Gully in all three scenarios by the flood events along the reach extending from the train line to the main road. However, there was only significant overtopping of the right bank if the culverts are blocked. Flood duration for the 50 and 100yr events along the Webbers Gully are expected to last for approximately 3 to 4 hours when culverts are clear.

ODPLAIN MAP - CLARENDON
ne - Rio Minho River)
ne & Main Road Modeled Free of Debris)



TH T-YEAR FLOODS
aximum 24hr Rainfall (mm)
217
269
308
347

Datum: JAD2001
Coordinate System: WGS 1984
Projection: Lambert Conformal Conic
Central Meridian: -77
Lattitude of Origin: 18
Standard Parallel 1: 18
Standart Parallel 2: 18
False Easting: 750000
False Northing: 650000

Scale 1:3,500

Topographic Base Map: IKONOS Satellite Image (2001)

LOCATION MAP

WEBBERS GULLY FLOODPLAIN MAPPING PROJECT

Prepared by: L. Barrett — Engineer/Hydrologist

Assisted by: H. Thomas — Dir. Resource Management
A. Haiduk — Water Resources Engineer
E. Douglas — Senior Assistant Hydrologist
H. Roper — Assistant Hydrologist

CLIENT: ALCOA MINERALS JAMAICA, INC. (JAMALCO) KIER/CCC

PART OF WEBBERS GULLY AND RIO MINHO RIVER FLOODPLAIN MAPPING

Water Resources Authority
Hope Gardens
P.O. Box 91
Kingston 7
Jamaica

Date: June 2005

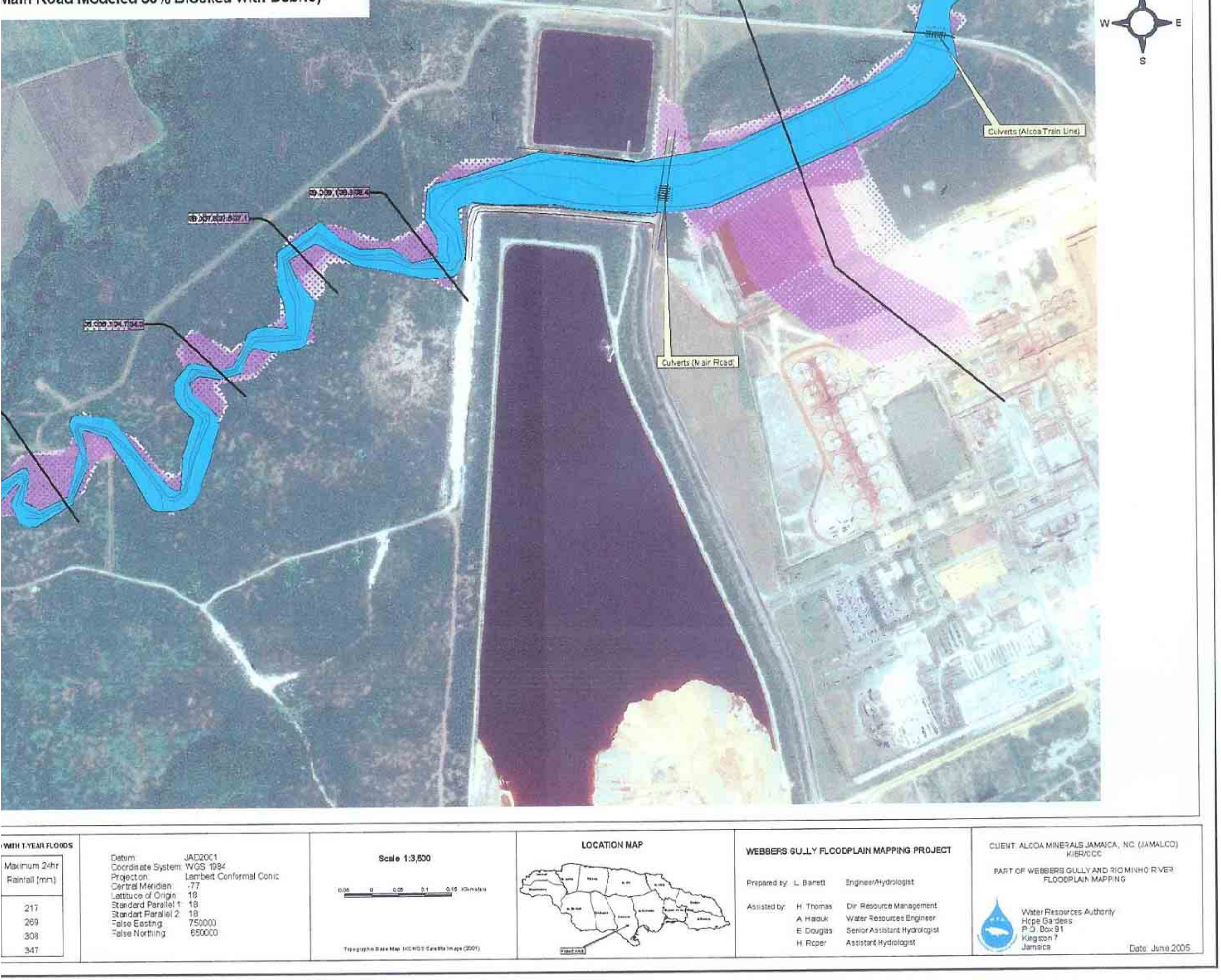


FIGURE 3-23: OUTCOME OF SCENARIO 2

AR FLOODS

n 24hr

(mm)

Datum: JAD2001
Coordinate System: WGS 1984
Projection: Lambert Conformal Conic
Central Meridian: -77
Lattitude of Origin: 18
Standard Parallel 1: 18
Standart Parallel 2: 18
False Easting: 750000
False Northing: 650000

Scale 1:3,600

Topographic Base Map: IKONOS Satellite Image (2001)

LOCATION MAP

WEBBERS GULLY FLOODPLAIN MAPPING PROJECT

Prepared by: L. Barrett — Engineer/Hydrologist

Assisted by:
H. Thomas — Dir. Resource Management
A. Haduk — Water Resources Engineer
E. Douglas — Senior Assistant Hydrologist
H. Roper — Assistant Hydrologist

CLIENT: ALCOA MINERALS JAMAICA, INC. (JAMALCO) KIER/CCC

PART OF WEBBERS GULLY AND RIO MINHO RIVER FLOODPLAIN MAPPING

Water Resources Authority
Hope Gardens
P.O. Box 91
Kingston 7
Jamaica

Date: June 2005

3.9.1.2 LANDSLIDES

There appear 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 3-25) 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.

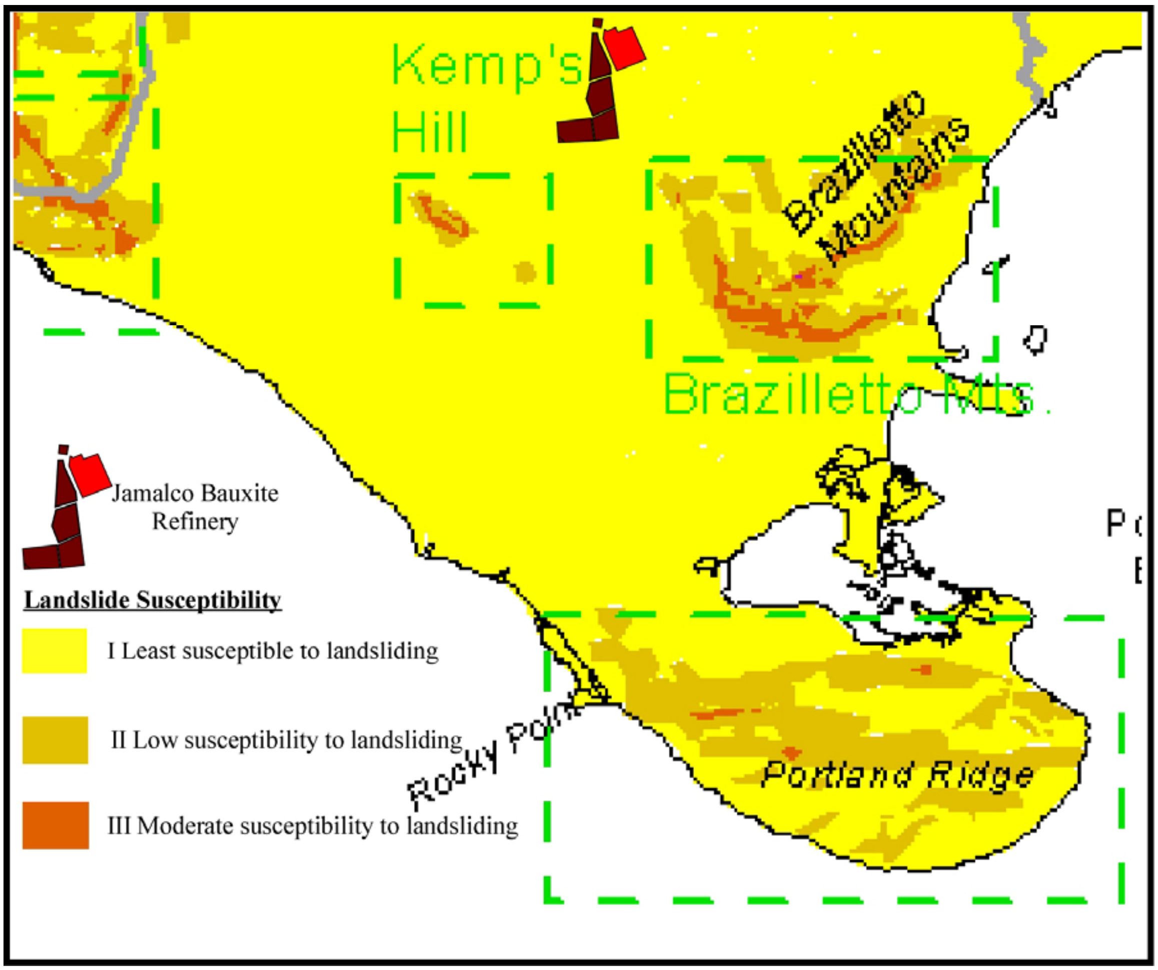


FIGURE 3-25: LANDSLIDE SUSCEPTIBILITY MAP OF SOUTHERN CLARENDON (SOURCE: SOUTH COAST DEVELOPMENT PROJECT.)

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 appear to be successful where the grass has caught. On the east-facing slopes the grass cover is well-developed (Figure 3-26), but on other slopes the cover is still incomplete.

FIGURE 3-26: GRASS COVERING SLOPE OF DYKE OF RESIDUE DISPOSAL AREA.

3.9.1.3 TECTONICS AND FAULTING

3.9.1.3.1 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 3-27). 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.

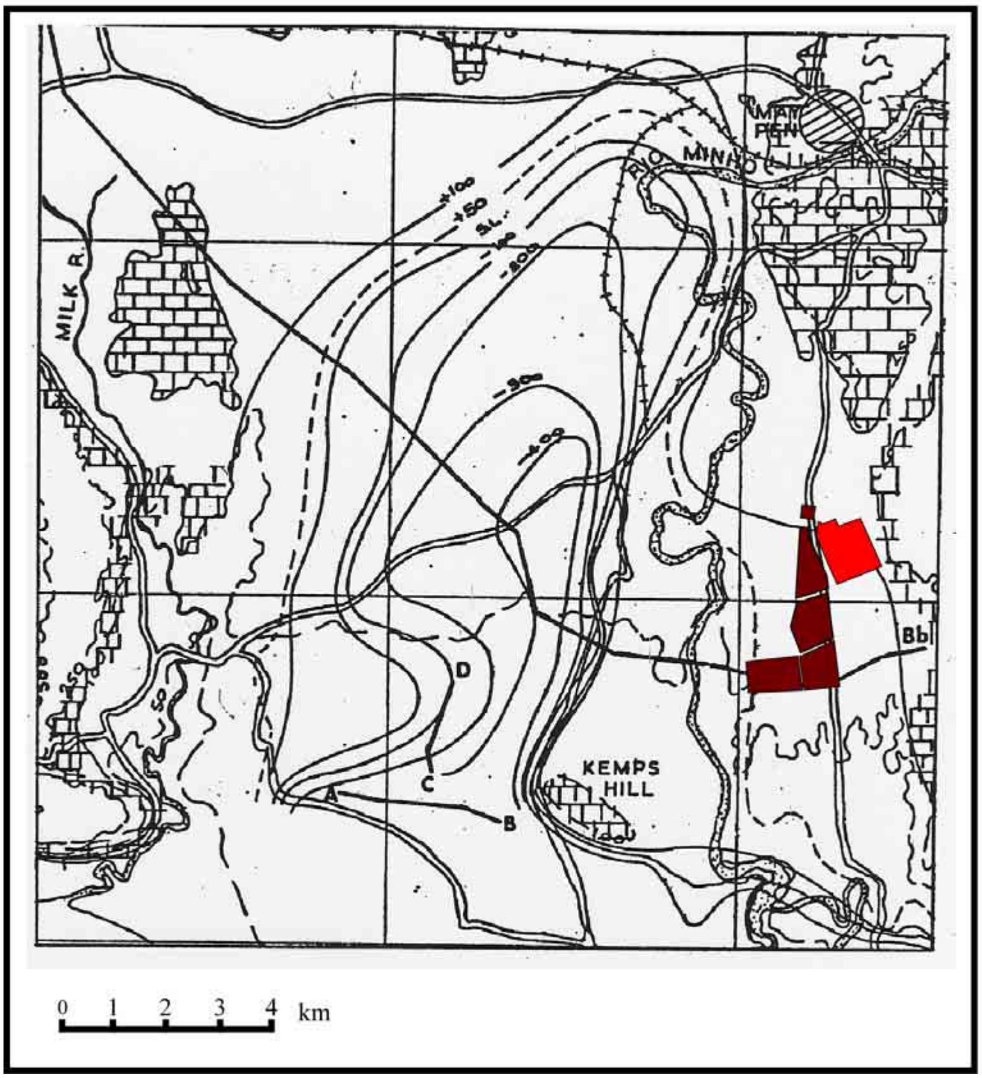


FIGURE 3-27: CONTOUR MAP SHOWING LIMESTONE ELEVATIONS UNDER PLAIN (ELEVATIONS IN FEET ABOVE SEA LEVEL). (SOURCE: CHARLESWORTH, 1980).

3.9.1.3.2 LOCATION OF FAULTS

The distribution of faults on Figure 2 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 age relationship with the alluvial plain are uncertain. However, the variability in depth to bedrock (Figure 3-27) 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 3-27; 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. 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).

3.9.1.4 *SEISMIC ACTIVITY*

3.9.1.4.1 LOCAL

Figure 3-28 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.

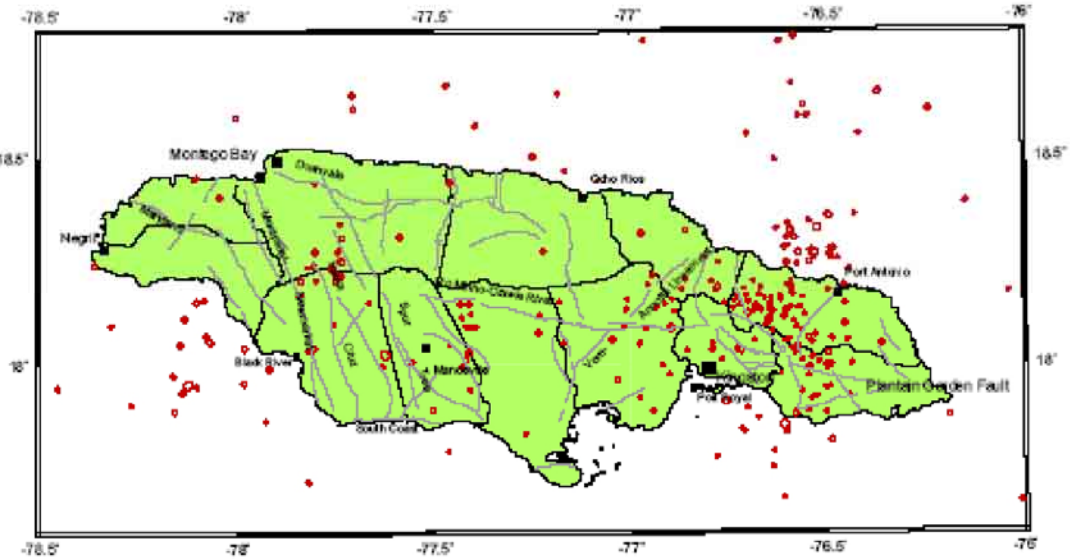


FIGURE 3-28: EPICENTRES OF EARTHQUAKES OCCURRING BETWEEN 1998 AND 2001 LOCATED IN AND AROUND JAMAICA. (SOURCE: THE EARTHQUAKE UNIT).

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 (Appendix D) 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 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.

3.9.1.5 CONCLUSIONS

- The type of limestone does not directly affect the nature of the bauxite deposits. Other factors, such as height above water table, elevation and position on fault blocks may also play a part in ultimate quality of the bauxite.
- There appear to be no impediments from a geological standpoint, to mining bauxite in the proposed area of northern Manchester Parish.
- The mining operation is not likely to encounter problems any different from those experienced in the present mining areas.
- A more complete appraisal will require detailed geological and orebody mapping to determine slopes of mined out orebody faces, extent of brecciated zones in the limestone, etc.