ENVIRONMENTAL ASSESSMENT

Jamaica North South Highway – Caymanas to Linstead Realignment

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Submitted to:	NATIONAL ROAD OPERATING & CONSTRUCTING COMPANY LTD

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1.0 INTRODUCTION

1.1 BACKRGOUND

This report entails the results derived from an inland vegetation, geology, hydrology and drainage and archaeological surveys for part of the first leg of the North South Highway Caymanas to Linstead. The section assessed is the proposed realigned section starting in the vicinity of the Caymanas intersection.

This leg was approved for construction and an Environmental Permit issued Permit number 2012-14017-EP00084. Subsequently, to this alignment, China Harbour Engineering Company (CHEC) sought to change the initial sections (0+000 km to 4+200 km), which will result in the alignment changing from starting just north of the Ferry Police station to in the vicinity of the Caymanas intersection. This proposed realigned section runs adjacent to the recently constructed Caymanas Country Club Estates (CCCE) housing development and end east of the existing Caymanas Estate intersection with Mandela Highway (Figure 1).

It is because of these changes that this report became necessary in support of amending the existing Environmental Permit.

1.2 JUSTIFICATION

In negotiating the project the Approved alignment was used in this process. However, only the alignment corridor belt was determined; no detailed geological survey was conducted. The progression of the works has given rise to major challenges which has led to a realignment of this section of the Highway. The following reasons advanced seek to justify rational for the proposed realignment:

- The Approved alignment is a much longer route that would have required the acquisition of larger parcels of lands which would have led to a fragmentation of the lands zoned for the Caymanas Economic Zone.
- Geological conditions along the Approved alignment are unsuitable with soft foundations that can lead to differential

settlements occurring during the operation period resulting in poor driving conditions.

- The area where the Approved alignment merges with the Mandela Highway is occupied by a police station, school and residential developments which would necessitate major demolition and relocations. In addition, the NWC pipelines would be impacted and this could prove complicated to divert or relocate the pipelines.
- The proposed realignment will not have an impact on vehicles heading south from Kingston heading to Portmore.
- The proposed realignment will lead to a reduction in the amount of lands sequestered from the New Era Development.

The general layout of the road segment is illustrated in Figure 2 to Figure 6.

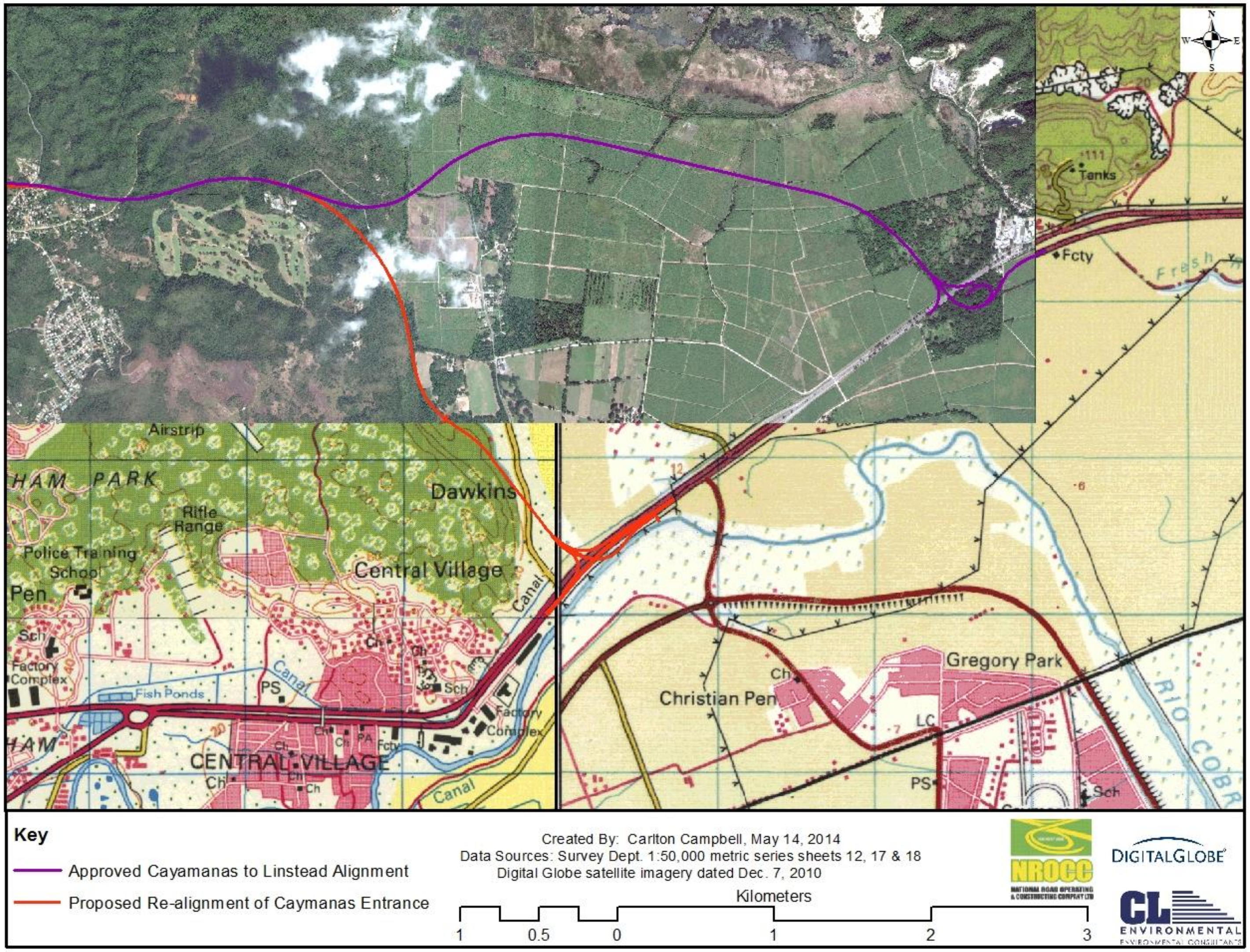

Figure 1 *Map showing a section of the approved North South Highway Caymanas to Linstead Link and the proposed realigned section*

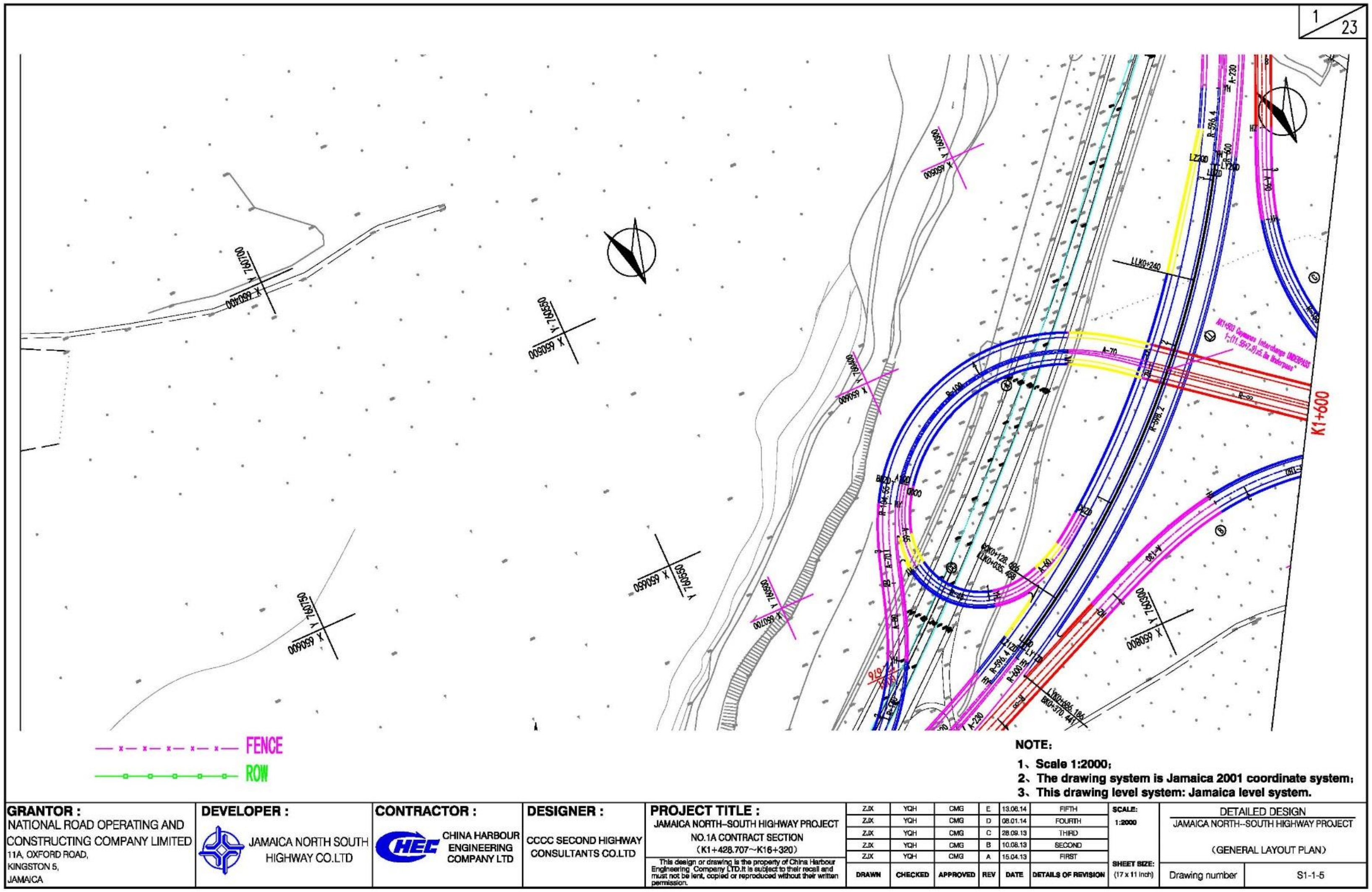

Figure 2 General road layout section 1

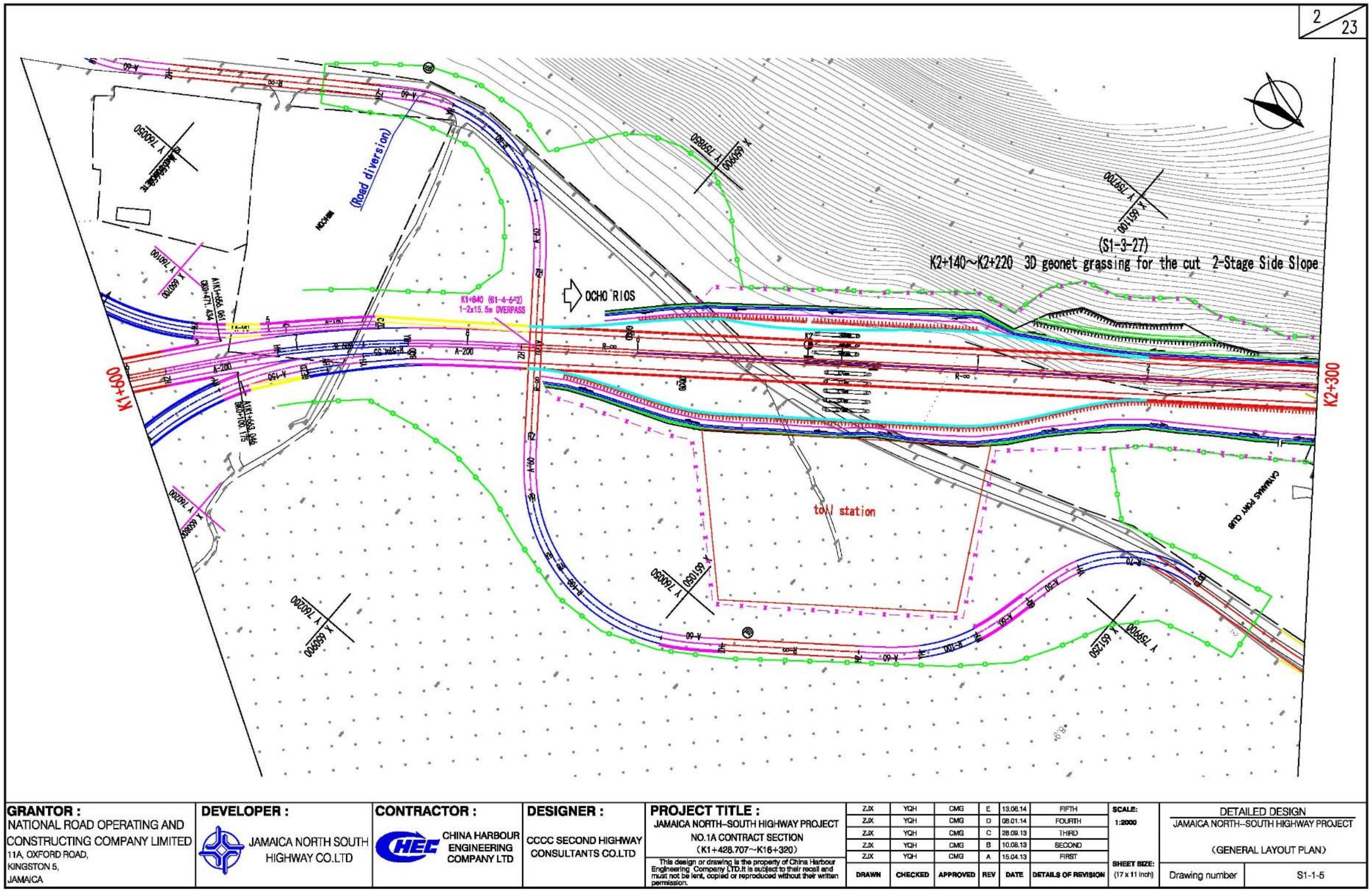

Figure 3 General road layout section 2

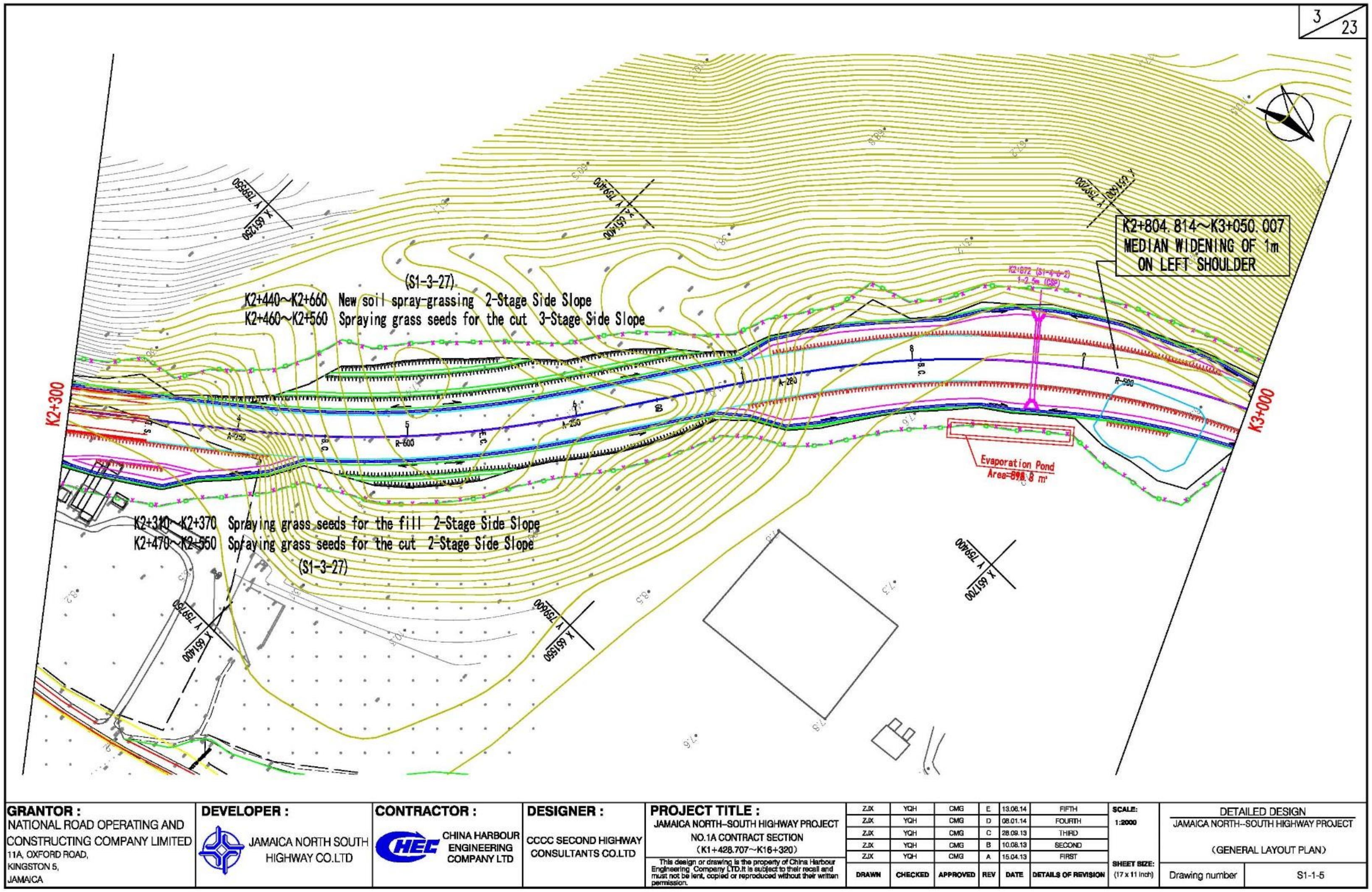

Figure 4 General road layout section 3

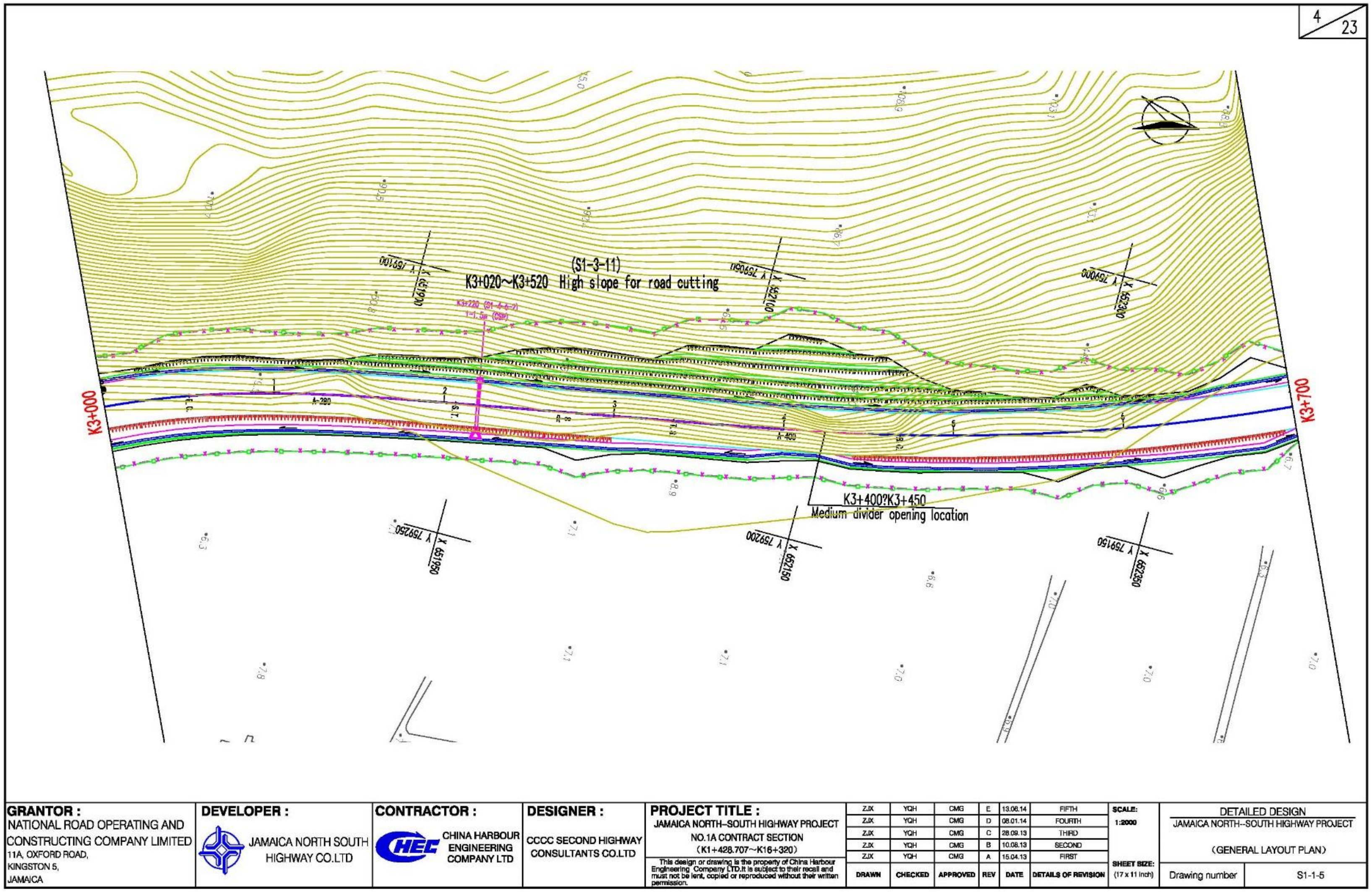

Figure 5 General road layout section 4

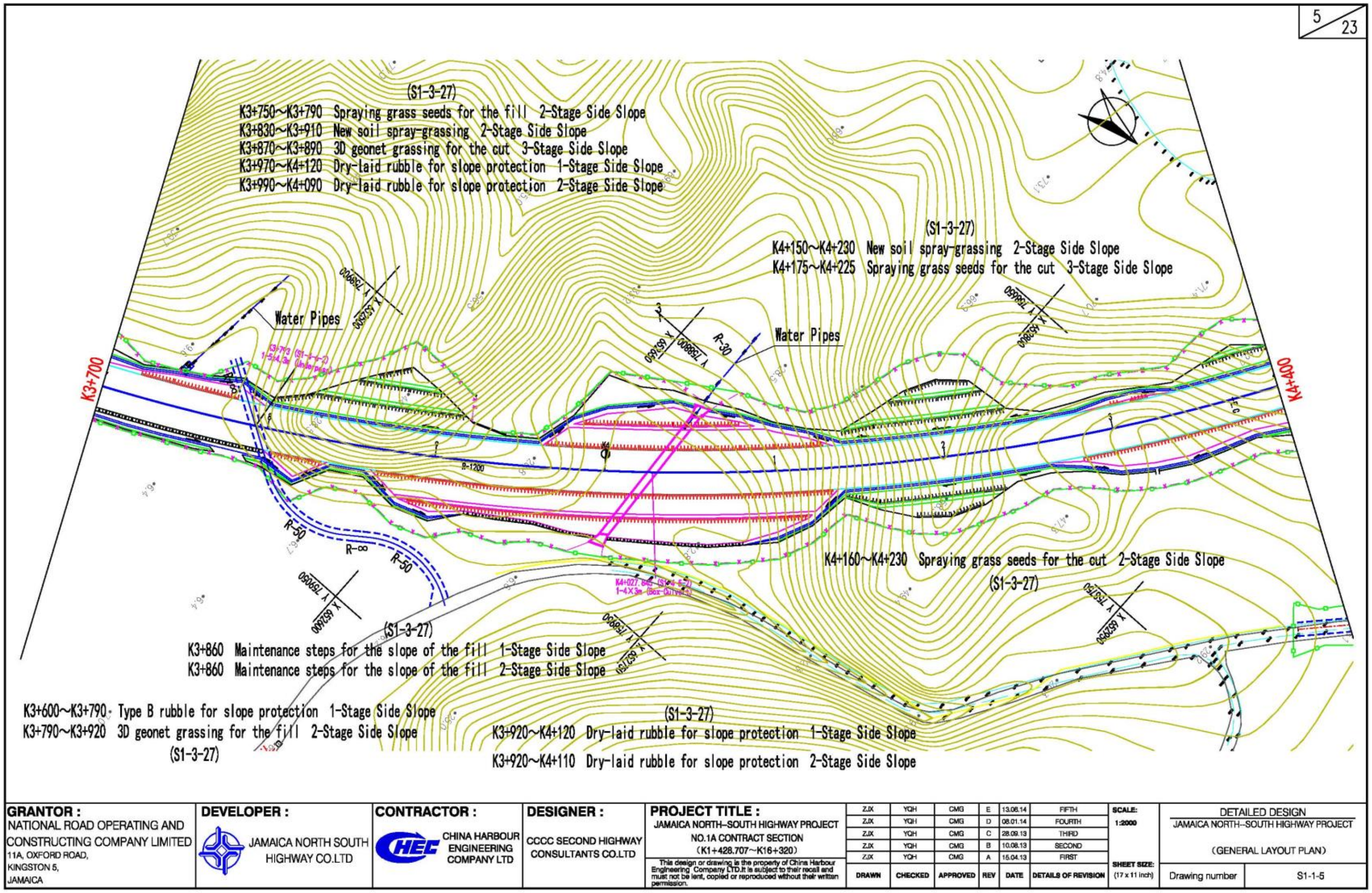

Figure 6 General road layout section 5

2.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

2.1 PHYSICAL

2.1.1 Baseline Morphology and Drainage

The new section of the alignment extends between the Mandela Highway Interchange at Dawkins and the 4250 match-line (near the entrance of the Caymanas Golf Club). The Highway will come down the Caymanas fault escarpment which borders the Caymanas plains to the West. The escarpment forms an asymmetrical N-S oriented ridgeline with an overall height of 150 meter. To the West the ridge is defined by gentle slopes ranging from 5 to 26%. The escarpment east of the ridgeline consists of near vertical slopes in excess of 50%. The road crosses the escarpment through a topographic low which correspond with the intersection of a secondary fault with the Caymanas Fault system that formed the escarpment. Near the start of this section of the Highway the topography has an elevation of 75 meters coming down to an elevation of 10 m at the Mandela Highway Interchange.

The ridgeline that defines the escarpment forms a watershed divide which separates the Fresh River watershed from the Rio Cobre watershed. Although the Rio Cobre runs due south of the Mandela Highway near the proposed intersection, this section of the proposed Highway in its current configuration does not contribute to the Rio Cobre watershed. Surface drainage between the ridgeline and the escarpment is mainly defined by sheet flow. Drainage channels are very short, in the order of a few hundred meters and are poorly defined. The longest channels occur in the section near the Caymanas golf course where the Highway crosses the ridgeline. The drainage in the area east of the watershed divide flows in a general easterly and north-easterly direction towards the Fresh River in the Ferry area. This applies also the irrigation canal of the National Irrigation Commission which runs parallel to North of the Mandela Highway and intersects the proposed Highway in this area. Although the slopes east of the divide are very steep, a significant amount of the surface runoff is obviously converted to groundwater flow through the high primary and secondary permeability of the limestone deposits. The coarse sand and gravels in the plains at the foot of escarpment are also very permeable and absorb similarly much of the surface runoff and prevent the development of distinct drainage channels at the foot of the escarpment.

Figure 7 shows the location of all wells in close proximity to the proposed Highway alignment. All wells are located outside the footprint of the Highway including the Ellis Golf Course well owned by UDC which is located just outside the Highway embankment.

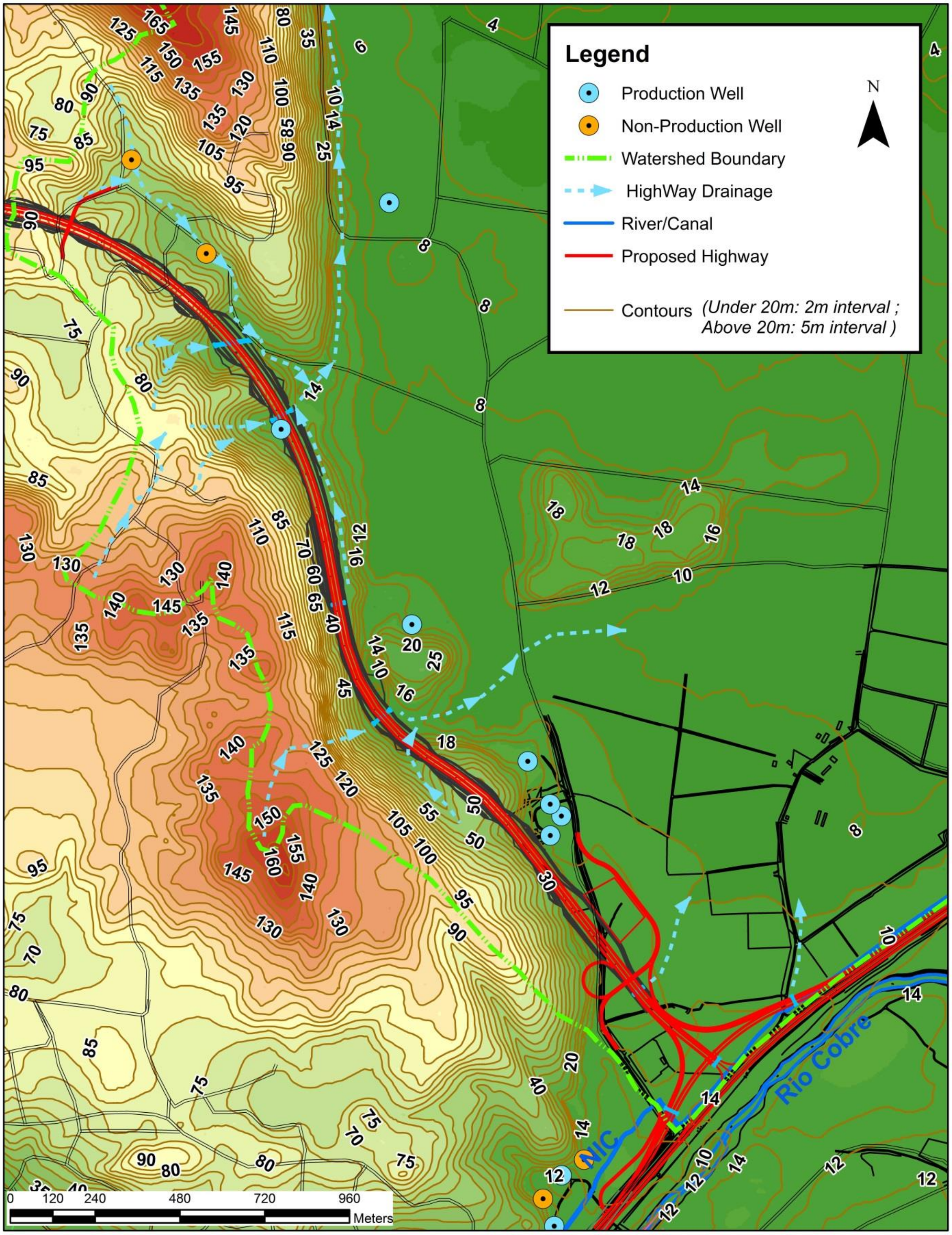

Figure 7 Topography and Drainage of the New Alignment

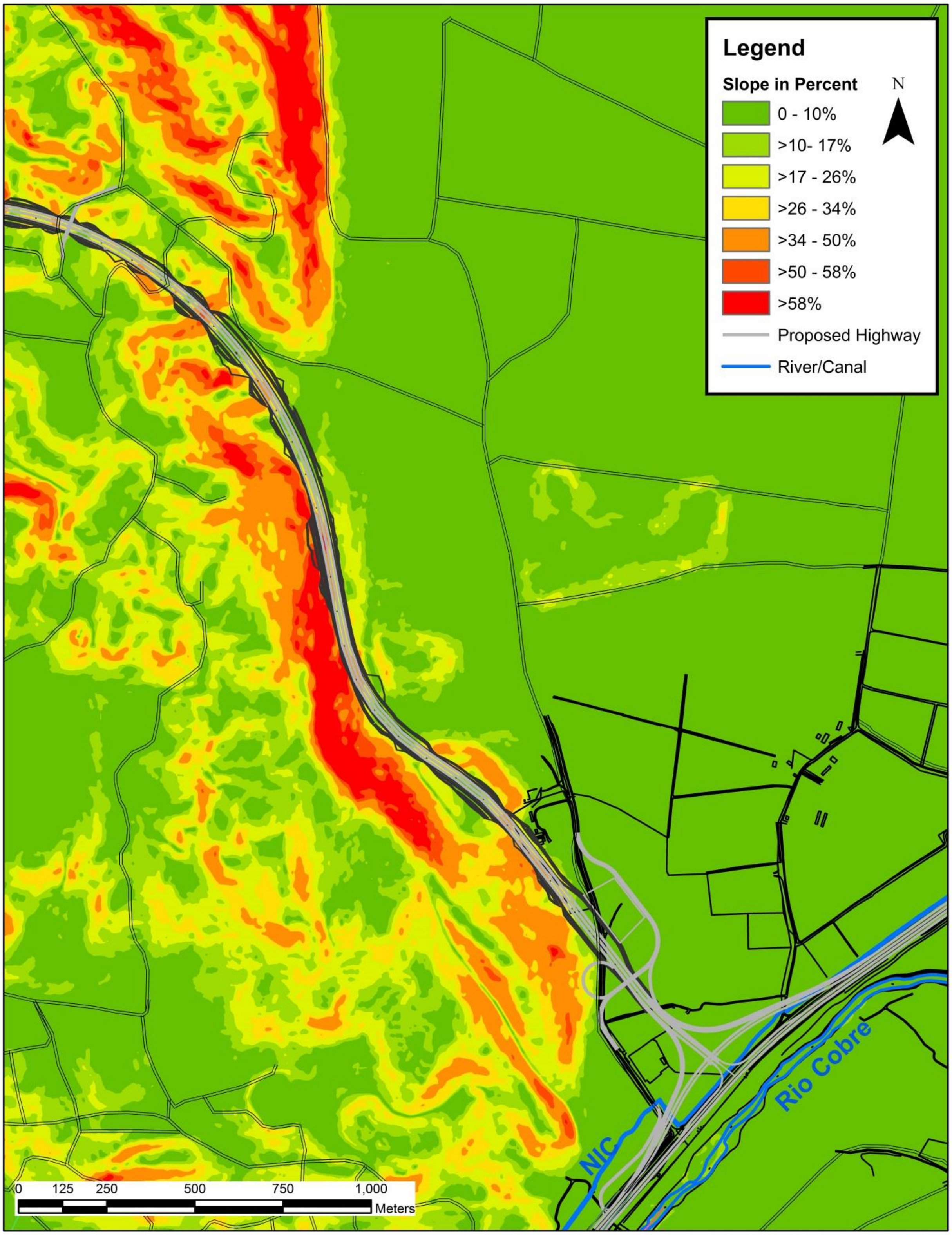

Figure 8 Slope Map of the New Alignment

The escarpment does not show signs of significant instability (Figure 8). The scree deposits at the foot of the escarpment are small and almost non-existing and consist mainly of boulder of approximately 1m diameter. The escarpment shows many vertical limestone exposures which are in situ and appear to be mostly stable. It is however recommended that the escarpment is surveyed in detail to identify and remove potential loose rock formations or boulders. The White limestone deposits of the Waldestone formation have a relative low potential for the development of large cavities and sinkholes but a potential nevertheless. After the excavation of the embankment of the highway special attention should be given to identify any potential cavities still hidden below the surface as these hidden cavities can be widened by increase infiltration of surface runoff.

2.1.2 Geology

Clarendon Block. The main bedrock in the area is the White Limestone Group, which along the alignment consists mainly of the Newport Formation. In this area, the Newport is a soft marly (wackestone) shallow-water limestone that is recrystallized in places with massive beds, and may contain corals. These fossils can preferentially dissolve leaving fossil molds or cavities in the rock, creating a vuggy appearance. This limestone is also subject to surface pitting and dissolution.

The 1:250,000 Geological Map of Jamaica indicates that the northern sections of the alignment (past match line consist of the Walderston Formation which is lithologically similar to the Newport, but stratigraphically older (underlying) (Figure 9). The Walderston Formation may also have a coarser grain size (packstone) than the Newport, which gives it a higher primary porosity (Plate 2). The White Limestone is underlain at depth by the Yellow Limestone. Both formations are considered limestone aquifers, with well-developed secondary porosity along joints, bedding planes, and fractures, which may have developed into underground cavities connected to surface sinkholes.

Plate 1 Caymanas Fault Escarpment

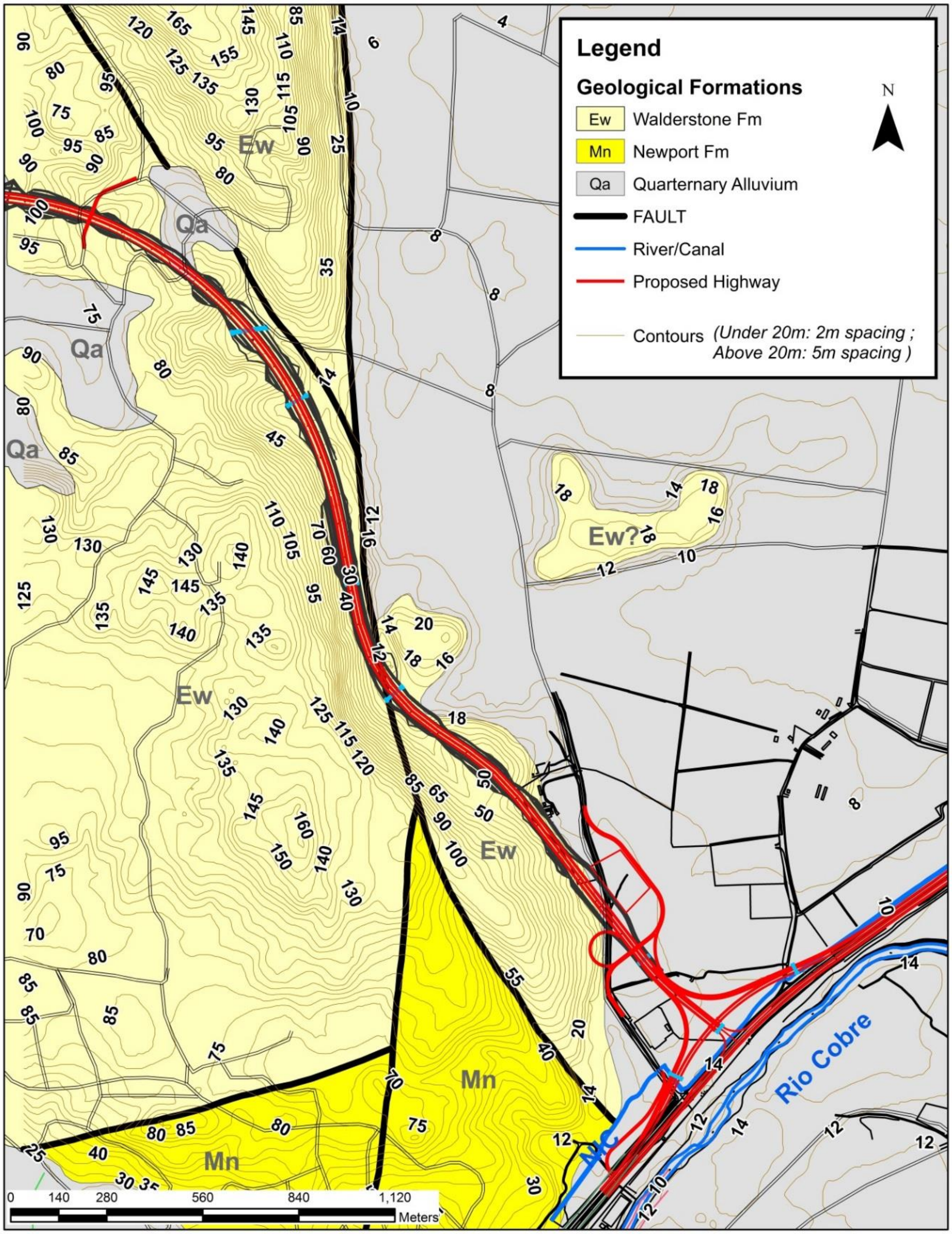

Figure 9 *Geology of the New Alignment*

Source: Adapted from published Mines and Geology Division Maps.

Plate 2 Typical Limestone (Walderston) Outcrop

Much of the new alignment traverses a fault zone, which marks the contact between the limestone block and the alluvial plain. The main fault along the alignment route trends to the north-north east. Movement along the fault is likely to have altered the original marly limestone lithology to breccias within the zone of movement with a talus apron forming along the foot of the fault scarp (Plate 3). This may result in higher levels of secondary porosity as well as instability. However, the high level of purity in this limestone often results in rapid re-cementation of scree and infilling of voids by more crystalline calcium carbonate (Plate 4).

Both diffuse and conduit flows of groundwater are likely to occur within the White Limestone.

Plate 3 Limestone Outcrop in the Fault Escarpment

Plate 4 Outcrop with re-cemented laterite and scree

Based on information available at the Earthquake Unit website for the period 1997-2007, the area to the north of the site has experienced a number of recent earthquakes as shown by the epicenter clustering. Epicenters occurring tens of kilometres outside away from the site will have the potential to impact the site depending on the intensity of the earthquake (release of energy) (Figure 10).

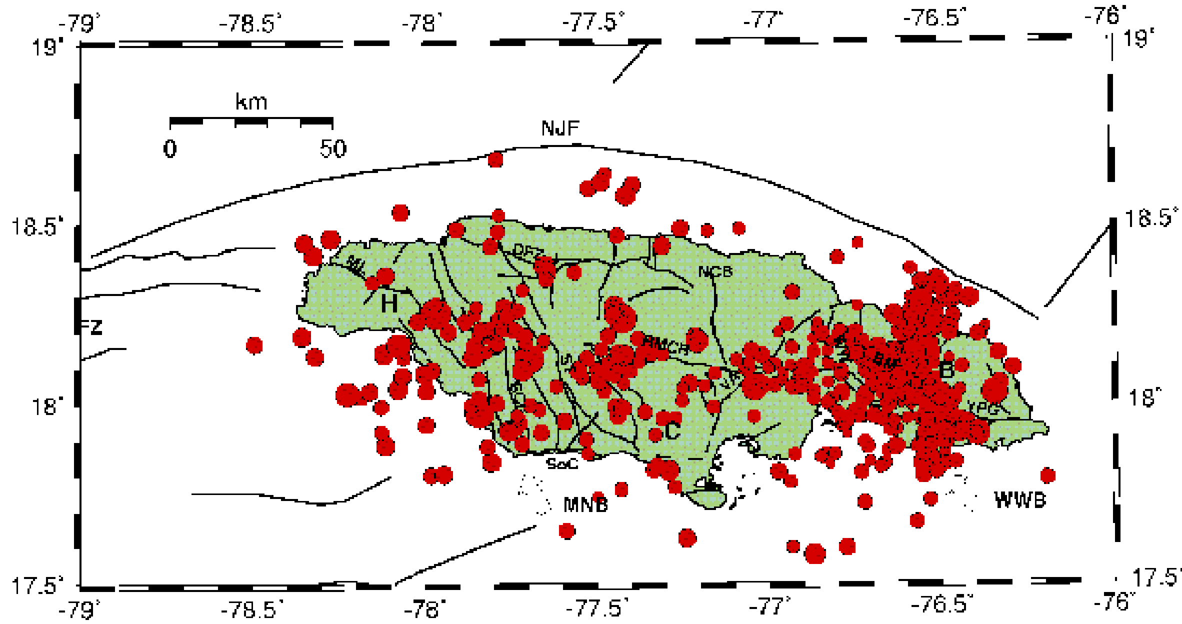

Figure 10 Seismicity in Jamaica 1997-2007

Source: http://www.mona.uwi.edu/earthquake/jaequake.php

2.1.3 Soils

The Caymanas Alluvial Series (Sandy and Clay Loams) is a relatively thick (>1 m), fertile soil developed on Recent alluvium associated with the Rio Cobre floodplain (Plate 5). It is characterized by very gentle slopes (0 to 2 degrees). Internal drainage depends on the presence of clay lenses. Sandier areas can be expected to have very good infiltration capacity and high permeability. The top soil tends to be dark grey brown, becoming paler and coarser with depth.

Plate 5 Coarse Alluvium with fluvial bed-forms

The Bonnygate Stony Loam and the St Ann Clay Loam are upland soils developed on the White Limestone. These soils are found on slopes at elevations above 15 m above mean sea level (amsl). In general the Bonnygate Stony Loam (dominant on the hillside traversed by the new alignment) is a very shallow soil (2 cm to 30 cm) with low fertility. Internal drainage may be very rapid particularly where secondary porosity (e.g. joints, faults, cracks etc.) occurs. The thin topsoil is a clayey brown to red soil becoming stonier with depth. The St Ann's Clay Loam may be encountered in areas closer to the top of the hill where slopes may be gentler (plateau), nearer to the golf course for example. This reddish soil is generally deeper and more acidic with a lower fertility than other upland soils.

2.1.4 Hydrology Assessment

There are a few very small communities that depend on water sources close to the proposed alignment to provide domestic water; it is therefore necessary that any changes to the hydrological nature of the surroundings be minimal to ensure the sustainability of these water schemes.

The re-alignment of the highway does not completely alleviate the problem of the intersection with Fresh River. The Fresh River catchment will still be traversed by the proposed highway, interfering with the peak runoff flows associated with it. These flows will eventually need to flow and be discharged. It is recommended that the culverts in this region are adequately sized to handle the 1:100yr peak flows.

2.1.4.1 Water Sources and Recharge Areas

Water resources include sinkholes and wells. Sinkholes are natural holes in the ground caused by the erosion of water, usually occurring in regions of limestone formation, which facilitates in the recharging of aquifers through which surface runoff. Throughout the length of the proposed alignment, the topography includes various depressions in which sinkholes occur. A safety buffer of 50m was established within reason around the Caymanas alignment of Highway 2000. With the re-alignment of the southern-most leg of the highway, three (3) sinkholes (previously located directly under the highway alignment reservation in the EIA) were avoided.

Figure 11 indicates several wells, both pumping and non-pumping, within close proximity of the proposed H2K Caymanas alignment. This map should be used as a guide to avoid the covering and/or destruction of these wells. With the re-alignment of the highway, two (2) wells previously determined to be affected by the construction of the proposed North-South alignment were avoided. These wells are owned and operated by both private and government entities. The re-alignment will not cover these wells and furthermore will avoid leading to their destruction and/or contamination.

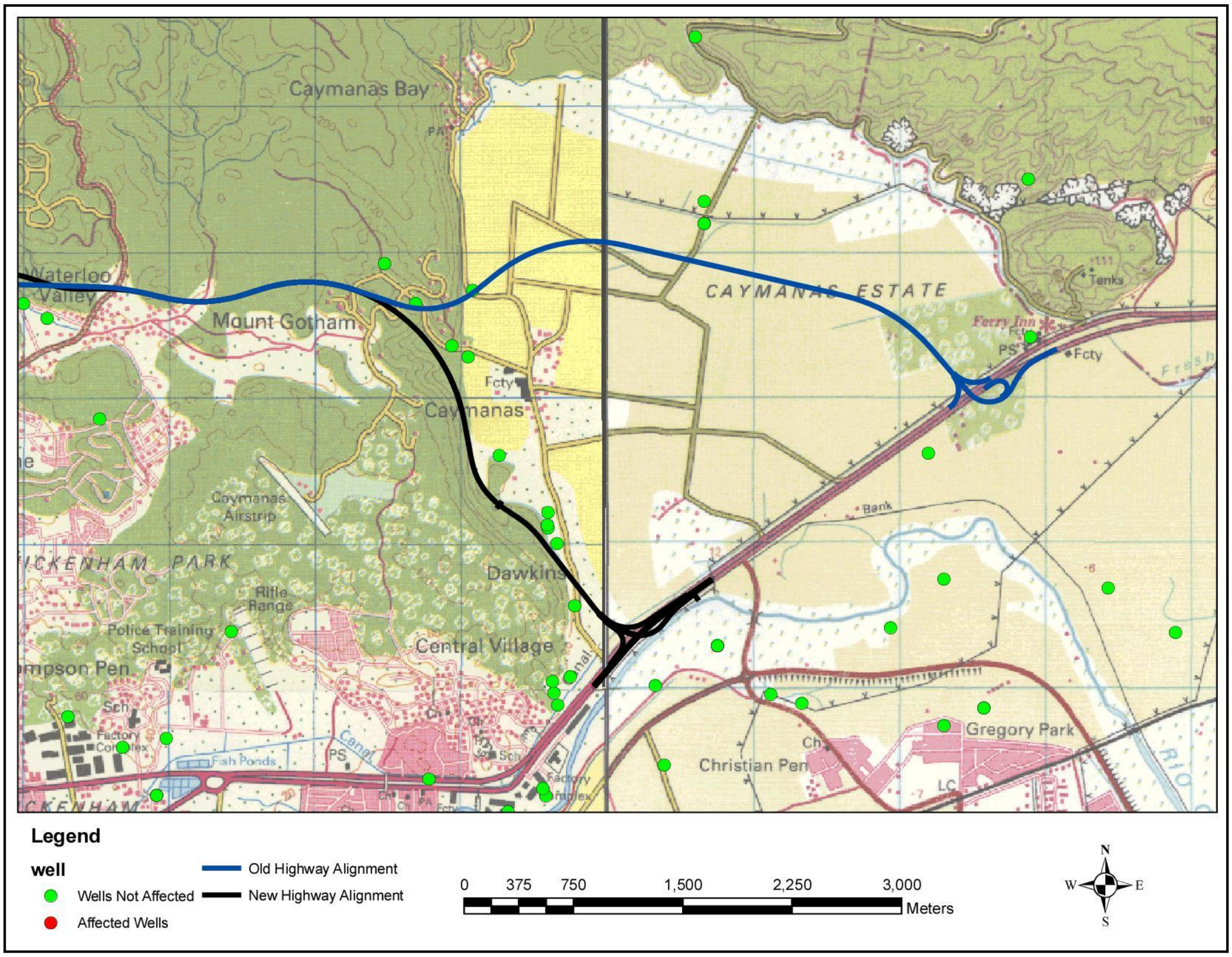

Figure 11 *Alignment superimposed on wells map of Jamaica*

2.1.4.2 Delineated Catchments

Topographic maps of Jamaica were assembled over a DEM to determine the extents of the watersheds that will be impacted by the implementation of the proposed alignment. The process of defining the catchments in the GIS (ArcHydro) involved:

- Smoothing the DEM of sinks
- Defining Flow accumulations in streams
- Defining catchments after specifying minimum catchment areas for each stream

Affected Water Streams

Based on the sub-catchments and streams identified, the proposed re-alignment will cross two (2) major river basins (Table 1 and Figure 12). The H2K Caymanas alignment ends at Central Village, where Fresh River traverses the existing road. The alignment does not cross the river itself but does impact the overall catchment area of this water source. The impacted catchment area of the Fresh River measures 0.46 km^2 (0.73%). The crossing of the highway will negatively affect surface runoff in this area and can be mitigated through the construction of culverts.

Table 1 Summary of rivers and associated catchment area that cross the proposed alignment

Nr	RIVER	Crosses Alignment	Catchment Area (km^2)
1	Rio Cobre	0.53 km NW of Content	461.4
2	Fresh River	0.70 km East of Mount Gotham	63.07

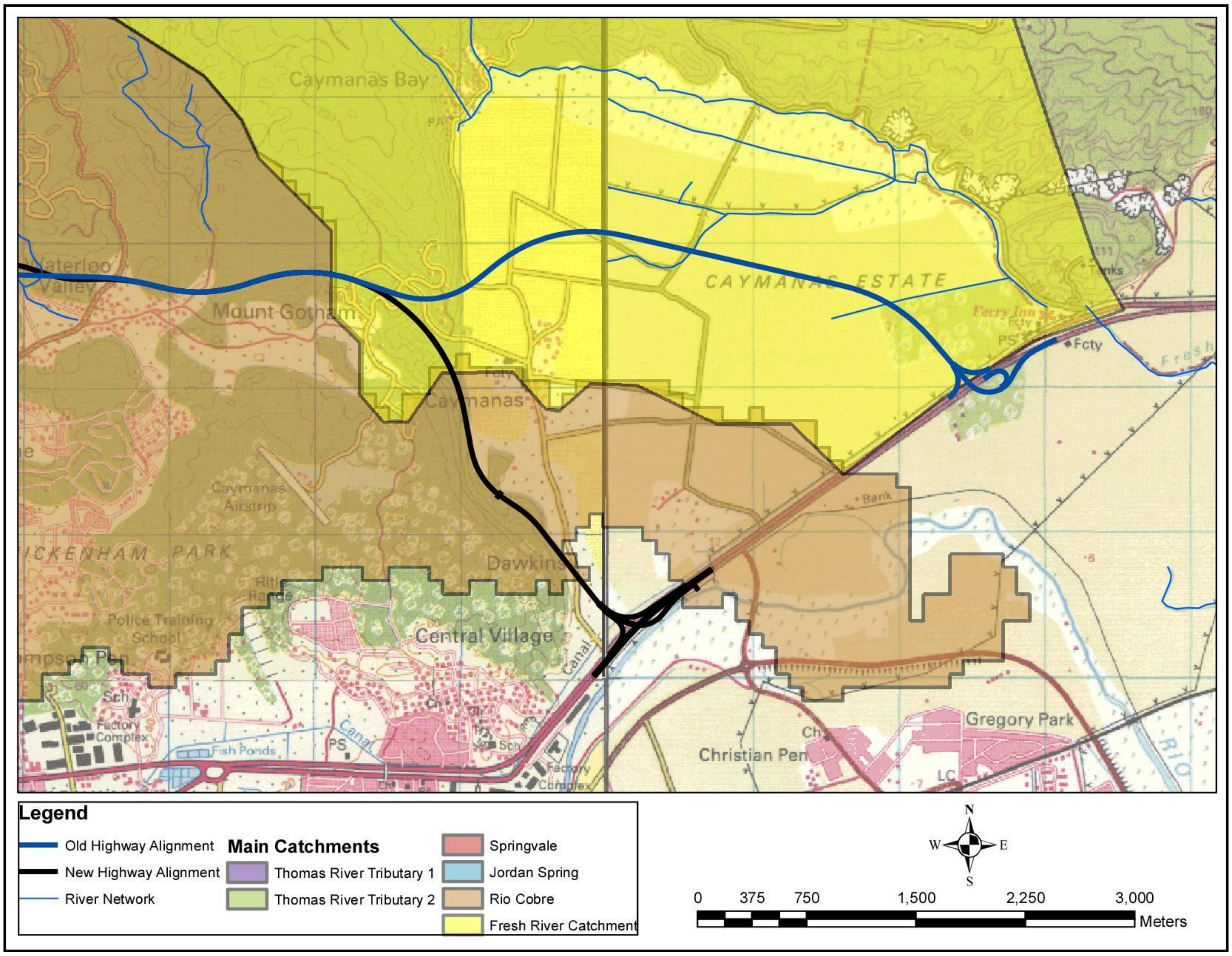

Figure 12 *Showing the major rivers which cross the proposed H2K alignment*

Rio Cobre

The Rio Cobre originates north of the alignment and flows south-east. It collects flows from the rivers aforementioned in the Bog Walk area and eventually discharges these flows into the sea. Having the largest area, the catchment associated with the Rio Cobre measures 46,140 hectares. A dam is located downstream of the proposed alignment (Plate 6).

Plate 6 *Rio Cobre Dam situated downstream of the proposed alignment crossing*

Fresh River

The Fresh River commences from the foothills of Caymanas Bay and continues to the harbour of Hunts Bay. This river presently traverses Mandela Highway where it eventually discharges into Hunts Bay. The proposed H2K Caymanas alignment ends before it crosses the river but is located within the Fresh River catchment (Figure 13). This indicates that appropriate evaluation of the hydrological nature should be conducted and necessary culvert be put in place to facilitate the free flow of runoff into the Fresh River.

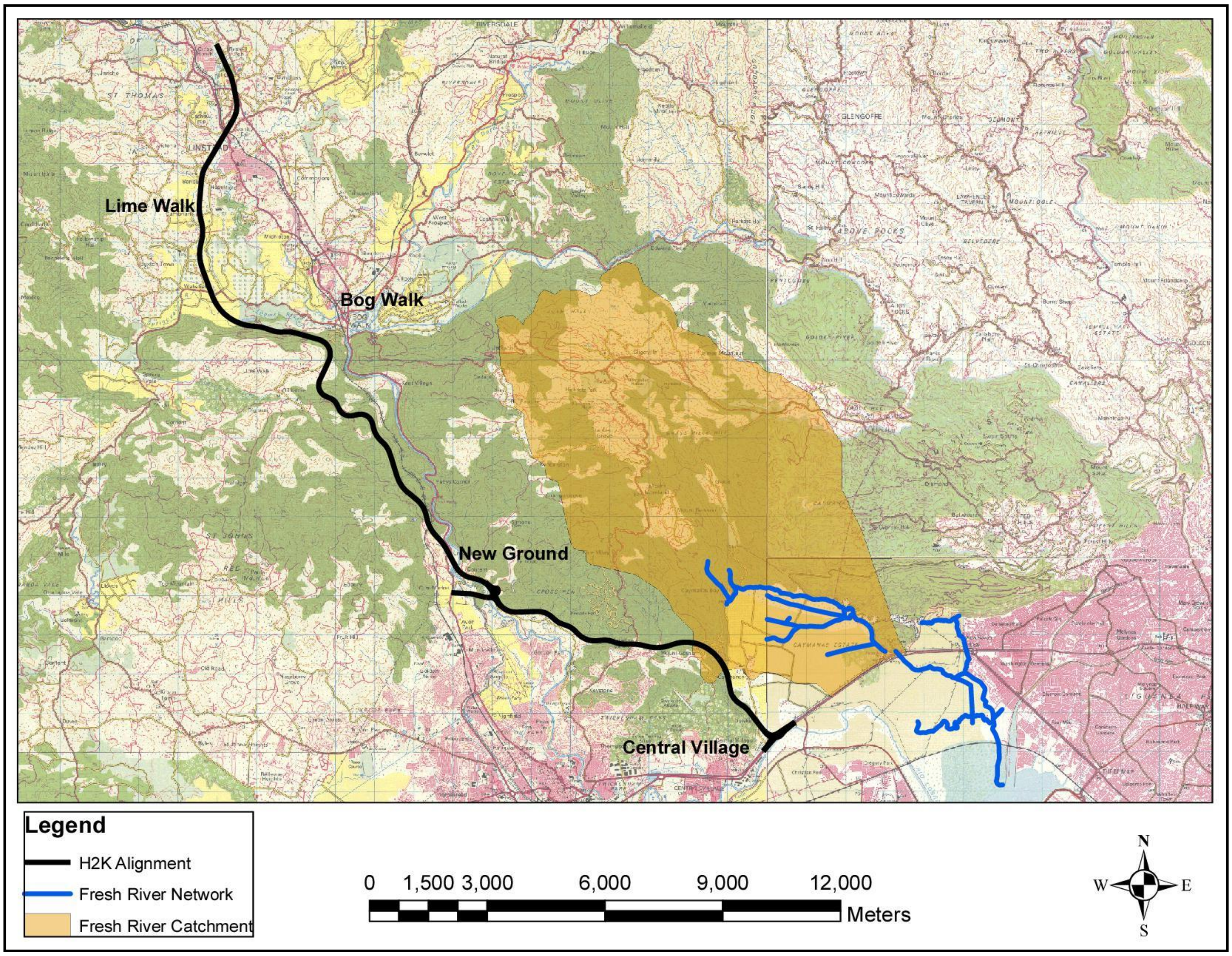

Figure 13 Showing the H2K alignment superimposed on the Fresh River catchment

2.1.5 Hydrological Modelling

The methodology used for the analysis is as follows:

1. Data collection to include:
    a. Collection of soils information;
    b. Collection of land use maps;
    c. The topography of the catchments;
    d. Anecdotal data collection;
2. Delineating catchments and confirmation of streams/rivers;
3. Calculating runoffs using the US Soil Conservation Service (SCS) method.

2.1.5.1 Description of SCS Model

SCS method is an empirical model for rainfall runoffs which is based on the potential for the soil to absorb a certain amount of moisture. On the basis of field observations, this potential storage S (millimetres or inches) was related to a 'curve number' CN which is a characteristic of the soil type, land use and the initial degree of saturation known as the antecedent moisture condition. Hydrological modelling of the watersheds encompassed three main elements:

- Precipitation;
- Rainfall abstraction model (Curve number method);
- Runoff model (Dimensionless unit hydrograph).

Precipitation

The maximum 24-hour rainfall for the 100 year return period at the rainfall gauges, within the vicinity of the watersheds, was used for the determination of the precipitation to be applied to the model. The rainfall depths across the catchments were determined by creating a rainfall depths contour map over catchments, by using the rainfall gauges in and around the catchments. A weighted rainfall depth was then determined for each watershed. The values are shown in Table 2 for the present and future scenarios.

Table 2 Weighted rainfall depth determined for each watershed

Watershed	***Weighted Rainfall Depths (mm/24 hr)***	
	Rio Cobre	**Fresh River**
Current rainfall	336	292
Recommended design rainfall based on Climate Change[1]	354	307

[1] "Extreme precipitation for Jamaica: 1895 to 2100", International Conference on Flood Resilience: Experiences in Asia and Europe, Christopher Burgess; Michael Taylor; Tannecia Stephenson; Arpita Mandal

Rainfall Abstraction Model

The SCS curve number method was used to determine the rainfall excess P_e using the following equation:

$$P_e = \frac{(P^2 - I_a^2)}{P - I_a} + S$$

Where, P = precipitation

Ia = Initial abstraction

S = Potential retention which is a measure of the retention capacity of the soil.

The Maximum Potential retention, S, and the watershed characteristics are related through the Curve number CN.

$$S = \frac{25400 - (254 \times CN)}{CN}$$

Curve Numbers have been tabulated by the NRCS on the basis of soils group, soil cover or land use, and antecedent moisture conditions (initial degree of saturation).

Soils

The catchments were superimposed on the ministry of Agriculture's soils map of Jamaica to identify the soils distribution within each catchment (Figure 14). It was found that all the catchments had high proportions of Clay loam and Stony loam. The soil types are distributed across the catchments as follows:

The catchment associated with Rio Cobre has over thirty percent (30%) clay loam material with high proportions of sandy loam;

The Fresh River catchment is mainly comprised of stony loam with areas of peat loam, silty clay and clay loam.

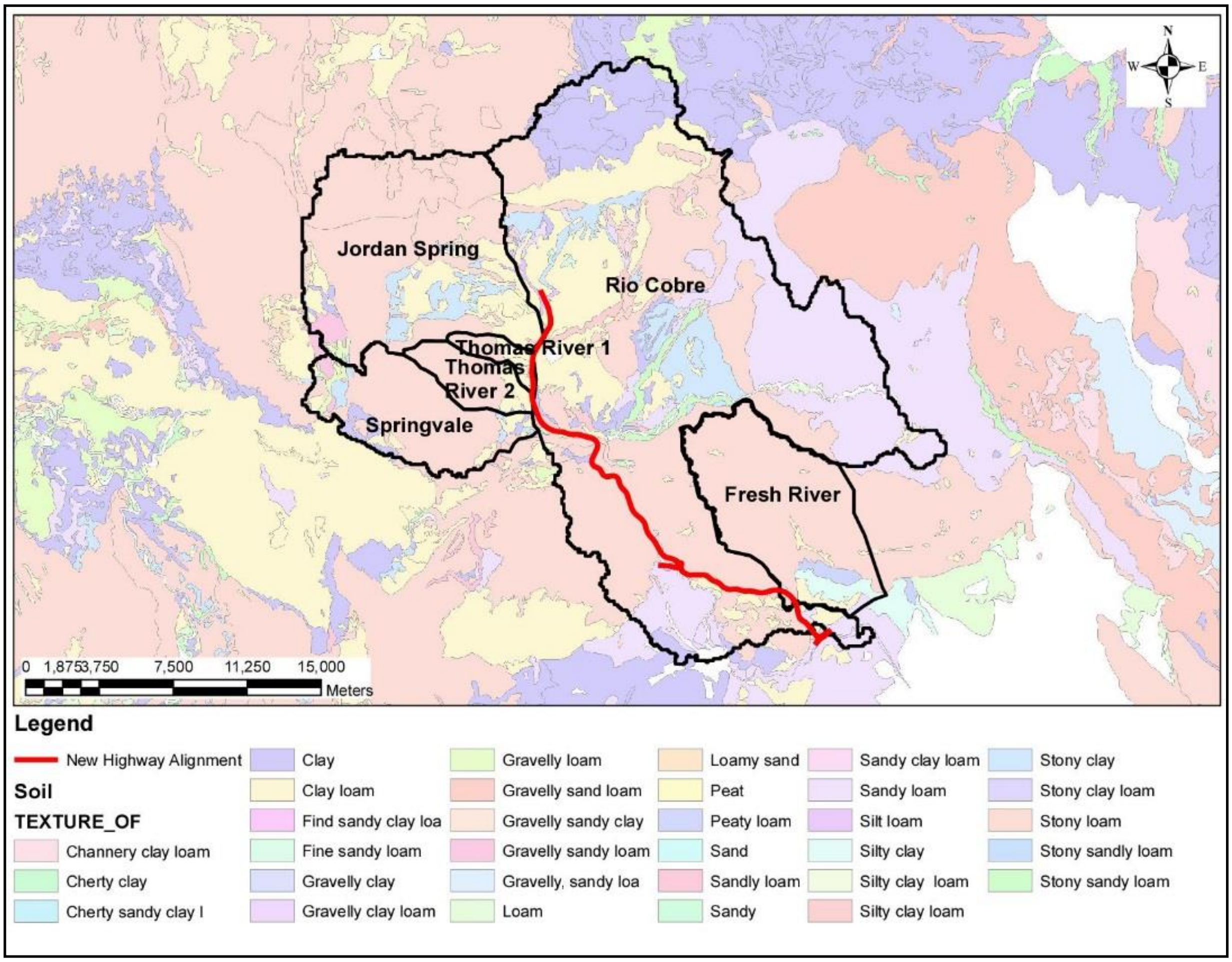

Figure 14 Catchment areas superimposed on soils map of Jamaica

Land Use

The Land use for each catchment was determined from inspection of the Forestry Department land use map seen in Figure 15, as well as satellite imagery of the catchments. The following was noted:

1. The catchment associated with the Rio Cobre was determined to have significantly high concentrations of forests, fields and crops (over 80%). Concentrations of urban space were identified along the western and southern reaches of this catchment;
2. The Fresh River catchment comprises of mainly forests and fields with small areas of plantation (crops). Concentrations

of urban space were identified along the south-eastern reaches of this catchment.

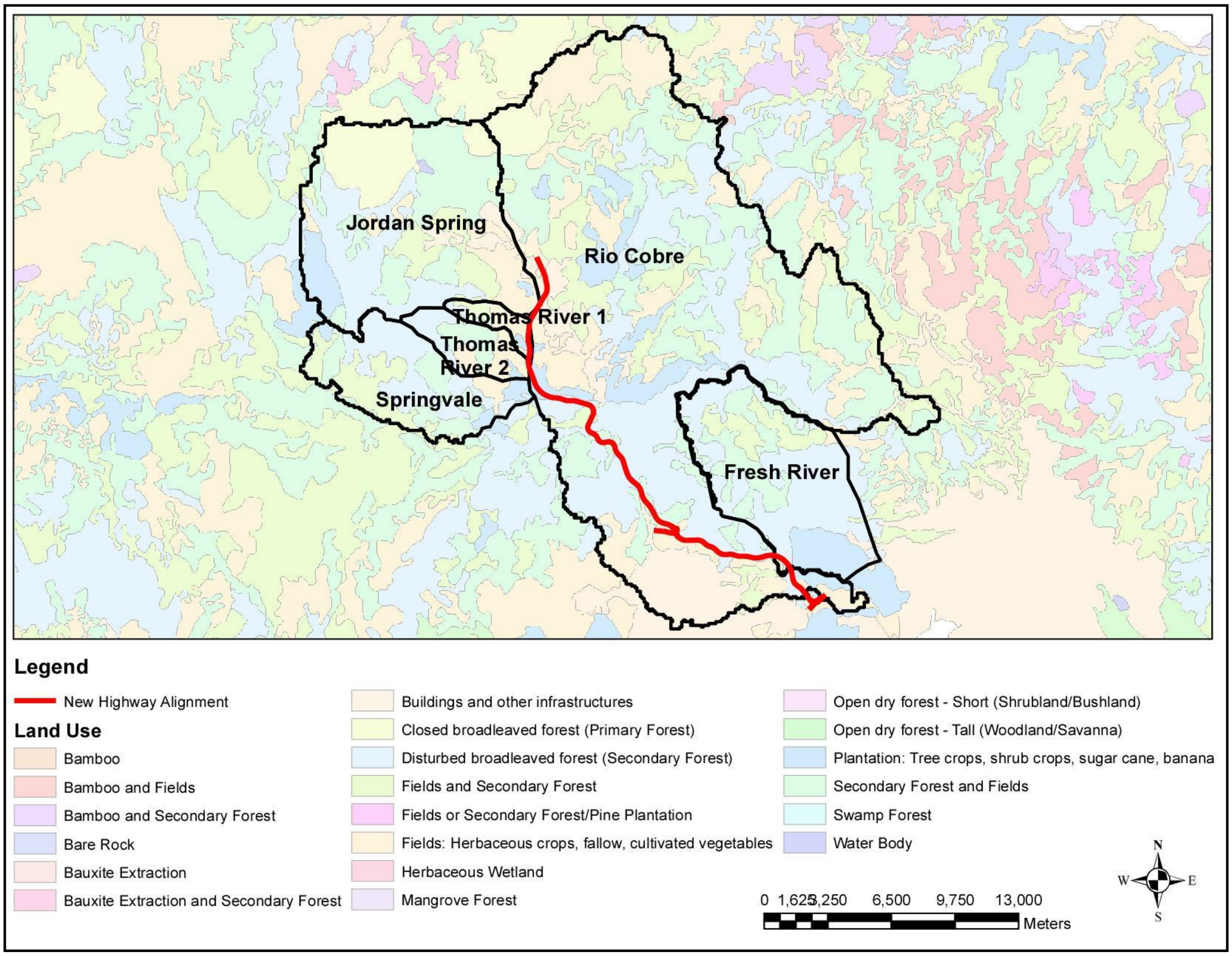

Figure 15 Land Use map of Jamaica with superimposed catchments and highway alignment

Curve Numbers (CN)

The curve numbers used in the SCS method were selected for normal antecedent moisture conditions (AMC II) as outlined in the 'Storm Design Manual' put together by Niagara county board shown in Table 3. The curve numbers for existing conditions were selected for the catchments were as follows:

Rio Cobre - 40 (based on the soil texture being a mixture of sandy and clay loams with high proportions of fields and forests);

Fresh River - 38 (based on the soil texture being a mixture of stony loam and clay with high proportions of fields and forests).

Table 3 Showing curve numbers corresponding to appropriate soil type and land usage

Description of Land Use	**Hydrologic Soil Group**			
	A	**B**	**C**	**D**
Paved parking lots, roofs, driveways	98	98	98	98
Streets and Roads:				
Paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
Cultivated (Agricultural Crop) Land*:				
Without conservation treatment (no terraces)	72	81	88	91
With conservation treatment (terraces, contours)	62	71	78	81
Pasture or Range Land:				
Poor (<50% ground cover or heavily grazed)	68	79	86	89
Good (50-75% ground cover; not heavily grazed)	39	61	74	80
Meadow (grass, no grazing, mowed for hay)	30	58	71	78
Brush (good, >75% ground cover)	30	48	65	73
Woods and Forests:				
Poor (small trees/brush destroyed by over-grazing or burning)	45	66	77	83
Fair (grazing but not burned; some brush)	36	60	73	79
Good (no grazing; brush covers ground)	30	55	70	77
Open Spaces (lawns, parks, golf courses, cemeteries, etc.):				
Fair (grass covers 50-75% of area)	49	69	79	84
Good (grass covers >75% of area)	39	61	74	80
Commercial and Business Districts (85% impervious)	89	92	94	95
Industrial Districts (72% impervious)	81	88	91	93
Residential Areas:				
1/8 Acre lots, about 65% impervious	77	85	90	92
1/4 Acre lots, about 38% impervious	61	75	83	87
1/2 Acre lots, about 25% impervious	54	70	80	85
1 Acre lots, about 20% impervious	51	68	79	84

The curve numbers were then modified for two additional conditions, they were for the present condition plus the development of the highway and for the future condition plus the development of the highway. Resulting curve numbers used in generating runoff are outlined in Table 4. The development of the highway will impact the curve number and runoff by no more than 0.2% in any one catchment or river. However, there were significant increases for the future development condition as it was estimated that the rural catchments will see more residential developments whereas the industrial and urbanized areas will become more intense.

Table 4 Curve Numbers used in SCS model

Curve Number (CN):	Watershed	
	Rio Cobre	**Fresh River**
Existing Conditions	40	38
Existing Conditions with H2K	40	38
Future Developed Areas	44	42

2.1.5.2 Runoff

The peak runoffs were calculated using the type III rainfall distribution. Type III rainfall distribution was selected because it best describes the storm/rainfall events which are observed throughout Jamaica based on historical event (storm/rainfall) trends; Rainfall/storm event will commence at a lower (calm) state after which a significant peak will be observed. The primary inputs into the model are as follows:

- Drainage area size (A) in square miles (square kilometres);
- Time of concentration (Tc) in hours;
- Weighted runoff curve number (RCN);
- Rainfall distribution (Figure 16);
- Total design rainfall (P) in inches (millimetres).

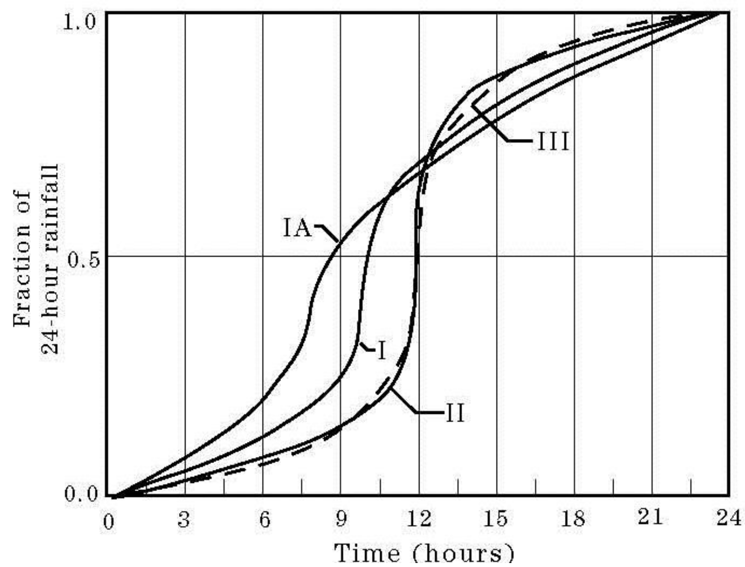

Figure 16 SCS 24-hour Rainfall Distributions

The runoff generated for each catchment where the catchments cross the re-alignment varies from 339.3 to 3,954.6 cubic metres per second for the existing condition. In regards to the future flows, Rio Cobre catchment generates an estimated 4829.3 cubic metres per second and Fresh River catchment generates 565.4 cubic metres per second. See Table 5 for a summary of the runoffs generated for each catchment and respective scenario.

Table 5 Runoff generated for the different catchments impacted by the H2K Caymanas alignment

Hydrology	Units	Location	
		Rio Cobre	Fresh River
Catchment area	HA	46140	6329
Return period	Years	100	100
Tc	min	87	165
Peak runoff			
Existing Condition	m^3/sec	3954.6	339.3
Existing Condition plus highway	m^3/sec	3999.2	343.9
Future Flows (fully developed catchment with highway)	m^3/sec	4829.3	565.4

2.1.6 Hydraulics Assessment

The proposed Drainage Design Criteria is the AASHTO Highway Drainage Guidelines.

2.1.6.1 Review of Implemented Guidelines

The proposed drainage was designed in accordance with the AASHTO Highway Drainage Guidelines, 4th Edition. Major structures (> 5.0 m in span) along the Toll Road was designed to convey a 1:100 year storm with a 1.0 m freeboard between the edge of shoulder elevation and the water level, whereas, minor structures convey a 1:10 year storm without surcharging and to convey a 1:100 year storm with a 0.6 m freeboard between the edge of shoulder elevation and the water level.

Storm sewers were designed to convey a 1:2 year storm without surcharging and to convey a 1:100 year storm through the major system with a maximum of 300 mm of flooding.

Minimum culvert sizes were determined to be 900 mm in diameter. All culverts and drainage works shall be designed for the applied loads and an assumed minimum 75-year service life. Appropriate erosion control measures must be incorporated in the design.

Concrete head walls are required for all culverts with any opening dimension greater than 1.5 m. Concrete head walls or end sections are required for all culverts with any opening dimension smaller than 1.5 m. All designs were assessed for compliance with the AASHTO Highway Drainage Guidelines.

2.1.6.2 Culvert Design Assessment

It is essential that the size and location of the culvert openings will allow surface water to cross the proposed highway alignment and to ensure that the road grade is at an elevation that water collection in depressions/sinks will not rise to the road grade. The sizing and placement of the proposed culverts are dependent on topographical and hydrological nature of the surroundings. The parameters required to calculate the peak discharge of culverts are:

- Drainage area
- 24 hour rainfall

- Type of distribution(hyetograph)
- Curve number

After calculating the peak runoff of all proposed culverts, we can sizing the proposed culverts according to their peak runoff for the 1:100 year storms.

2.1.6.3 China Harbour Engineering Company (CHEC) Design Criteria

Minor structures (span < 5m) are to be designed so as to convey a 1:10 year storm without surcharging and to convey a 1:100 year storm with a 0.6 m freeboard between the edge of shoulder elevation and the water level.

Each culvert was assessed based on this criteria and determined if the sizes and quantities are adequate to convey the flows generated by the respective storm events.

Chainage K1+800

The proposed drainage plan for the crossing at chainage 1+800 along the H2K highway involves implementing a corrugated steel pipe (CSP) of diameter 2m and an invert slope of 0.15%. This design was based on estimated 1:10yr and 1:100yr flows of 4.40 m^3/s and 9.98 m^3/s respectively. An assessment of the proposed culvert hydraulics was conducted using a culvert analysis program developed by the United States Department of Transportation. The design criteria proposed by China Harbour Engineering Company (CHEC) were input into the software and the culvert capacity determined.

Based on the proposed configuration of one (1) 2m culvert barrel and the estimated peak flows based on the catchment, it was determined that the proposed configuration is adequate to conduct the 1:10 year flows across the road without surcharging (see Figure 17).

However, it was determined that the proposed configuration is inadequate in conducting the 1:100 year flows across the road with a maximum freeboard of 0.6m (see Figure 19). The result of the modelling revealed that two (2) culvert pipes with diameters of 2m or greater is required to conduct the 100yr peak flows across the highway under these conditions (see Figure 21). These simulated conditions revealed that the water surface will rise approximately 0.1m above the road surface. It was concluded that the invert slope of 0.15% was the limiting factor in that the headwater at the culvert will rise above the road and cause overtopping. Table 6 below summarizes the flows associated with the required culverts at crossing K1+800 based on the modelling conducted by CEAC Solutions.

Table 6 Summary of culvert flows at crossing K1+800

Return Period	Number of Culverts	Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Outlet Velocity (m/s)
1:10	1	4.4	4.4	11.64	1.43	0.637	1-S2n	0.817	1.005	0.831	3.562
1:100	1	9.98	9.71	12.76	2.551	2.251	5-S2n	1.329	1.51	1.341	4.342
1:100	2	9.98	9.98	11.76	1.548	0.768	1-S2n	0.878	1.072	0.889	3.695

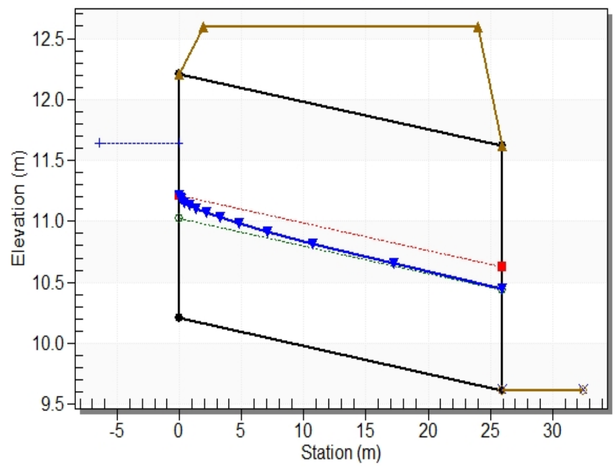

Figure 17 Water surface profile for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

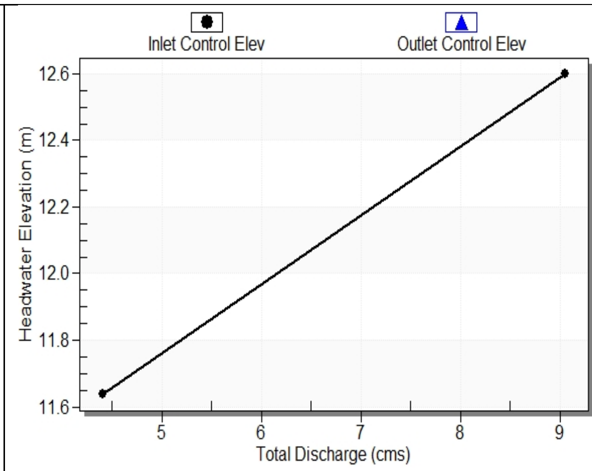

Figure 18 Performance curve for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

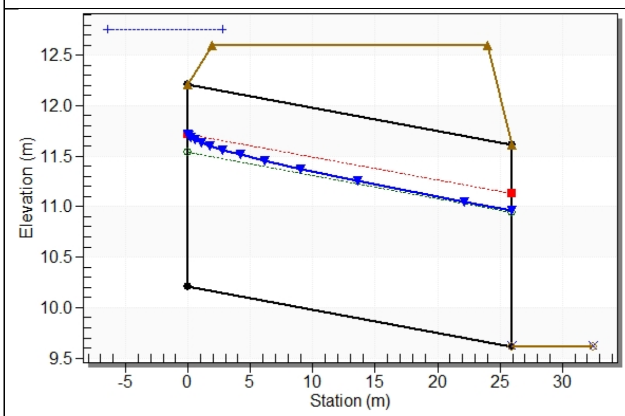

Figure 19 Water surface profile for culvert during 1:100yr rainfall event using one (1) 2m culvert pipe.

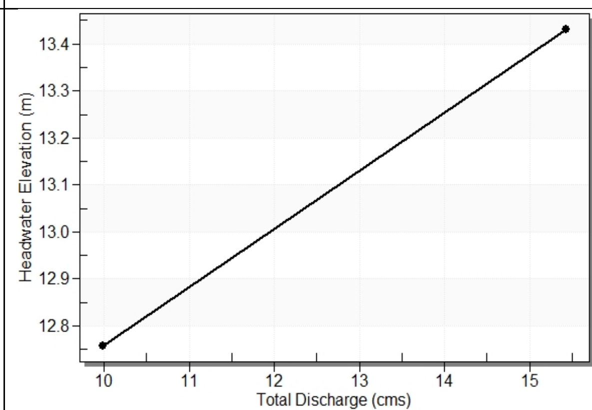

Figure 20 Performance curve for culvert during 1:100yr rainfall event using one (1) 2m culvert pipe.

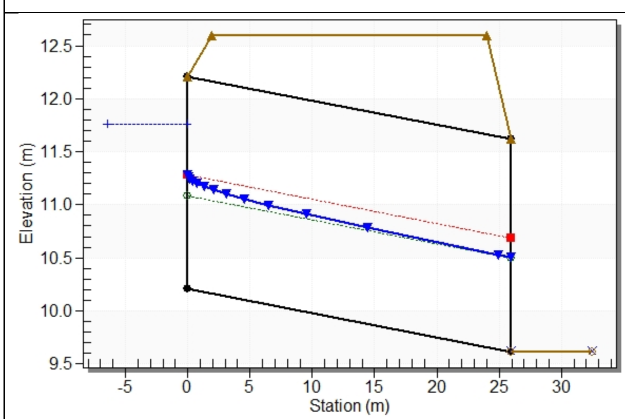

Figure 21 Water surface profile for culvert during 1:100yr rainfall event using two (2) 2m culvert pipes.

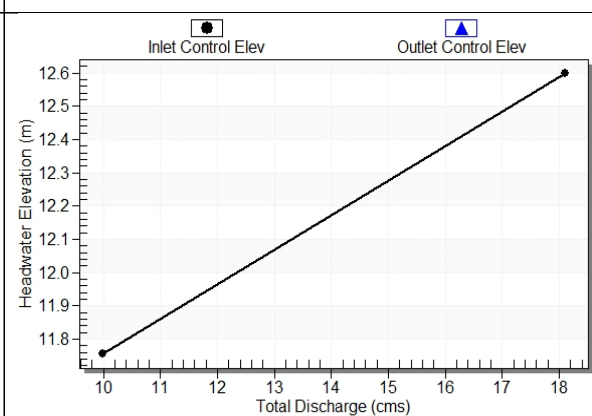

Figure 22 Performance curve for culvert during 1:100yr rainfall event using two (2) 2m culvert pipes.

Chainage K2+872

The proposed drainage plan for the crossing at chainage 2+872 along the H2K highway involves implementing a corrugated steel pipe (CSP) of diameter 2.5m and an invert slope of 0.15%. This design was based on estimated 1:10yr and 1:100yr flows of 5.79 m^3/s and 18.43 m^3/s respectively. An assessment of the proposed culvert hydraulics was conducted using a culvert analysis program developed by the United States Department of Transportation. The design criteria proposed by China Harbour Engineering Company (CHEC) were input into the software and the culvert capacity determined.

Based on the proposed configuration of one (1) 2.5m culvert barrel and the estimated peak flows based on the catchment, it was determined that the proposed configuration is adequate to conduct the 1:10 year flows across the road without surcharging (see Figure 23).

It was also determined that the proposed configuration is sufficient in conducting the 1:100 year flows across the road with a maximum freeboard of 0.6m (see Figure 25). It was concluded that the invert slope of 0.50% was the limiting factor in the height of the headwater at the culvert. Table 7 below summarizes the flows associated with the required culverts at crossing K1+800 based on the modelling conducted by CEAC Solutions.

Table 7 Summary of culvert flows at crossing K2+872

Return Period	Number of Culverts	Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Outlet Velocity (m/s)
1:10	1	5.79	5.79	7.62	1.521	0.728	1-S2n	1.074	1.082	1.074	2.871
1:100	1	18.43	18.43	9.62	3.474	3.525	7-M2c	2.500	1.965	1.965	4.453

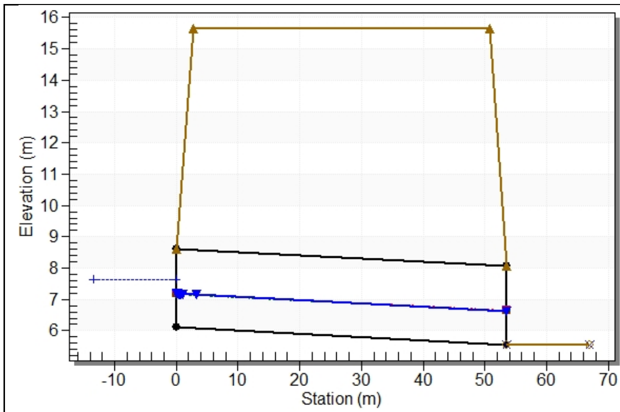

Figure 23 Water surface profile for culvert during 1:10yr rainfall event using one (1) 2.5m culvert pipe.

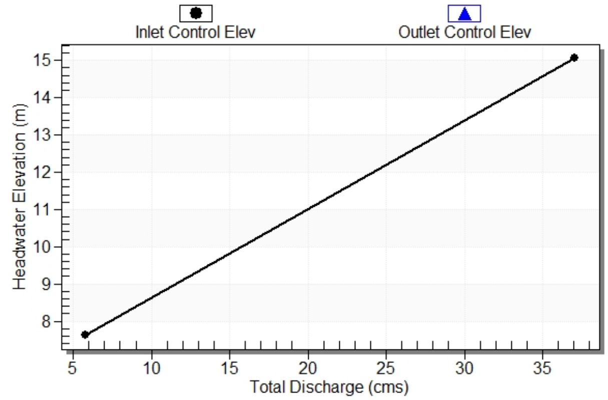

Figure 24 Performance curve for culvert during 1:10yr rainfall event using one (1) 2.5m culvert pipe.

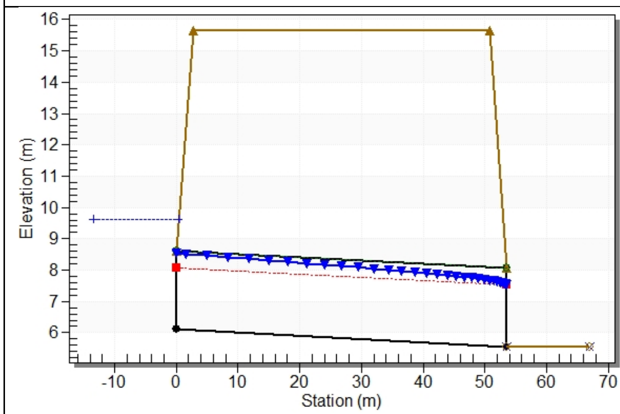

Figure 25 Water surface profile for culvert during 1:100yr rainfall event using one (1) 2.5m culvert pipe.

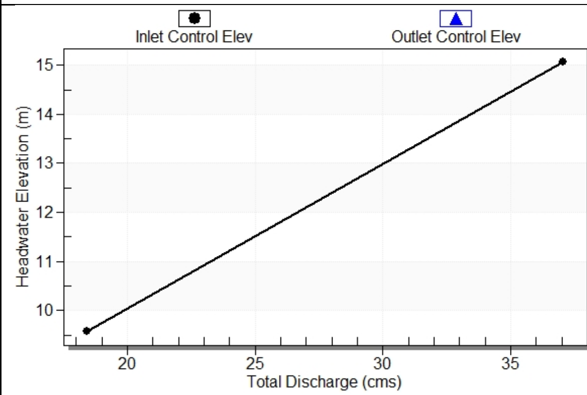

Figure 26 Performance curve for culvert during 1:100yr rainfall event using one (1) 2.5m culvert pipe.

Chainage K3+780

The proposed drainage plan for the crossing at chainage 3+780 along the H2K highway involves implementing a corrugated steel pipe (CSP) of diameter 2m and an invert slope of 0.15%. This design was based on estimated 1:10yr and 1:100yr flows of 2.46 m^3/s and 6.82 m^3/s respectively. An assessment of the proposed culvert hydraulics was conducted using a culvert analysis program developed by the United States Department of Transportation. The design criteria proposed by China Harbour Engineering Company (CHEC) were input into the software and the culvert capacity determined.

Based on the proposed configuration of one (1) 2m culvert barrel and the estimated peak flows based on the catchment, it was determined that the proposed configuration is adequate to conduct the 1:10 year flows across the road without surcharging (see Figure 27).

It was also determined that the proposed configuration is sufficient in conducting the 1:100 year flows across the road with a maximum freeboard of 0.6m (see Figure 29). It was concluded that the invert slope of 0.50% was the limiting factor in the height of the headwater at the culvert. Table 8 below summarizes the flows associated with the required culverts at crossing K1+800 based on the modelling conducted by CEAC Solutions.

Table 8 Summary of culvert flows at crossing K3+780 using a 2.5m culvert pipe

Return Period	Number of Culverts	Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Outlet Velocity (m/s)
1:10	1	2.46	2.46	8.00	1.005	0.00	1-S2n	0.566	0.741	0.586	3.358
1:100	1	6.82	6.82	8.89	1.905	0.914	1-S2n	0.985	1.262	1.002	4.331

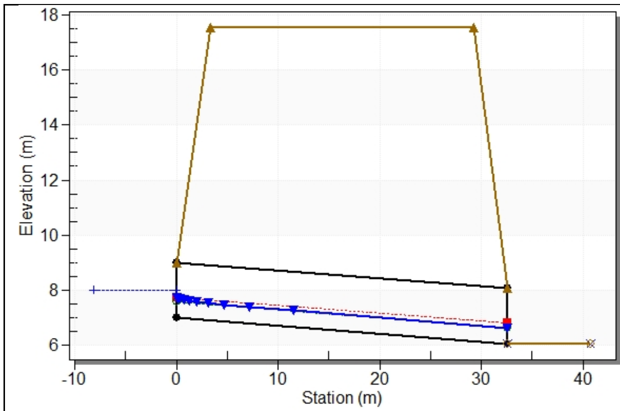

Figure 27 Water surface profile for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

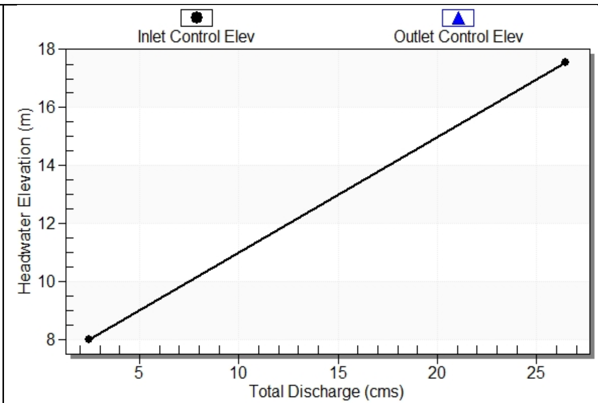

Figure 28 Performance curve for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

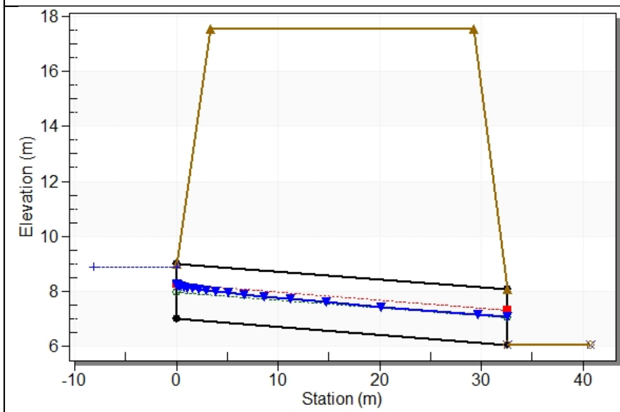

Figure 29 Water surface profile for culvert during 1:100yr rainfall event using one (1) 2m culvert pipe.

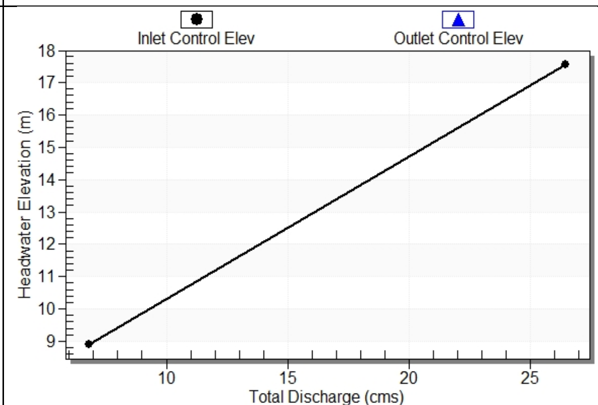

Figure 30 Performance curve for culvert during 1:100yr rainfall event using one (1) 2m culvert pipe.

Chainage K4+030

The proposed drainage plan for the crossing at chainage 4+030 along the H2K highway involves implementing a concrete box culvert 4m x 3m with an invert slope of 3%. This design was based on estimated 1:10yr and 1:100yr flows of 3.87 m^3/s and 10.88 m^3/s respectively.

An assessment of the proposed culvert hydraulics was conducted using a culvert analysis program developed by the United States Department of Transportation. The design criteria proposed by China Harbour Engineering Company (CHEC) were input into the software and the culvert capacity determined.

Based on the proposed configuration of the concrete box culvert and the estimated peak flows based on the catchment, it was determined that the proposed configuration is adequate to conduct the flows across the road. The result of the modelling revealed that the concrete culvert with dimensions 4m x 3m is sufficient to conduct the both the 10 year and 100yr peak flows across the highway. Table 9below summarizes the flows associated with the required concrete box culvert at crossing K4+030 based on the modelling conducted by CEAC Solutions.

Table 9 Summary of culvert flows at crossing K4+030 using a 4m x 3m box culvert

Return Period	Number of Culverts	Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Outlet Velocity (m/s)
1:10	1	3.87	3.87	10.89	0.682	0.00	1-S2n	0.173	0.457	0.243	3.986
1:100	1	10.88	10.88	11.57	1.359	0.380	1-S2n	0.382	0.910	0.546	4.979

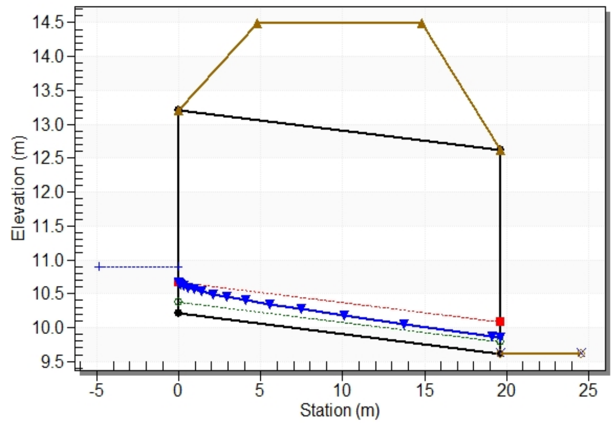

Figure 31 Water surface profile for culvert during 1:10yr rainfall event using one (1) 4m x 3m box culvert.

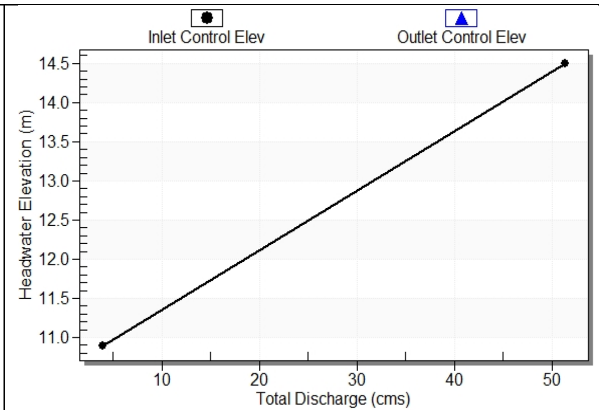

Figure 32 Performance curve for culvert during 1:10yr rainfall event using one (1) 4m x 3m box culvert.

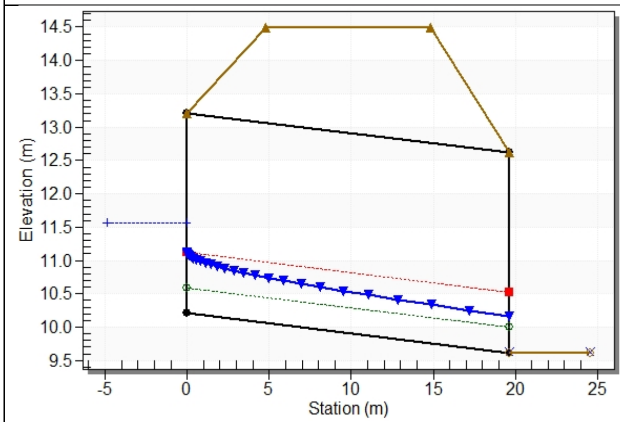

Figure 33 Water surface profile for culvert during 1:100yr rainfall event using one (1) 4m x 3m box culvert.

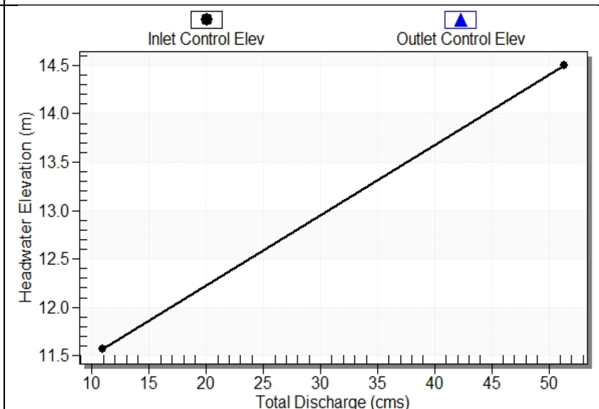

Figure 34 Performance curve for culvert during 1:100yr rainfall event using one (1) 4m x 3m box culvert.

Chainage K4+849.4

The proposed drainage plan for the crossing at chainage 4+849.4 along the H2K highway involves implementing a corrugated steel pipe (CSP) of diameter 2m and an invert slope of 3%. This design was based on estimated 1:10yr and 1:100yr flows of 5.41 m^3/s and 12.16 m^3/s respectively. An assessment of the proposed culvert hydraulics was conducted using a culvert analysis program developed by the United States Department of Transportation. The design criteria proposed by China Harbour Engineering Company (CHEC) were input into the software and the culvert capacity determined.

Based on the proposed configuration of one (1) 2m culvert barrel and the estimated peak flows based on the catchment, it was determined that the proposed configuration is adequate to conduct the 1:10 year flows across the road without surcharging (see Figure 35).

It was also determined that the proposed configuration is sufficient in conducting the 1:100 year flows across the road with a maximum freeboard of 0.6m (see Figure 37). It was concluded that the invert slope of 3% was the limiting factor in the height of the headwater at the culvert. Table 10 below summarizes the flows associated with the required culverts at crossing K1+800 based on the modelling conducted by CEAC Solutions.

Table 10 Summary of culvert flows at crossing K4+849.4 using a 2.5m culvert pipe

Return Period	Number of Culverts	Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Outlet Velocity (m/s)
1:10	1	5.41	5.41	64.15	1.621	0.00	1-S2n	0.836	1.118	0.836	4.346
1:100	1	12.16	12.16	65.75	3.217	2.273	5-S2n	1.386	1.676	1.389	5.228

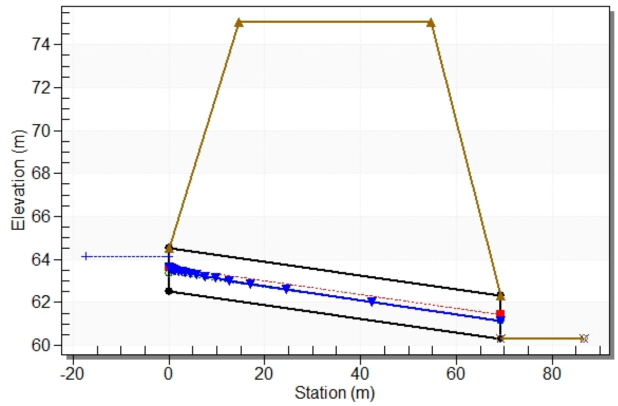

Figure 35 Water surface profile for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

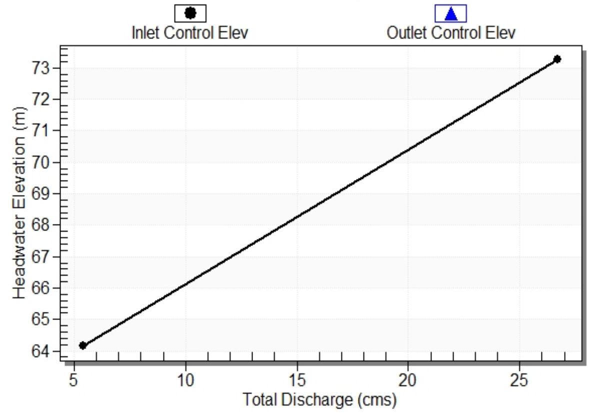

Figure 36 Performance curve for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

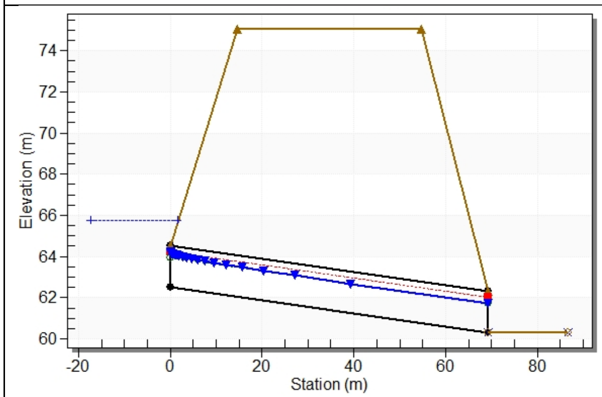

Figure 37 Water surface profile for culvert during 1:100yr rainfall event using one (1) 2m culvert pipe.

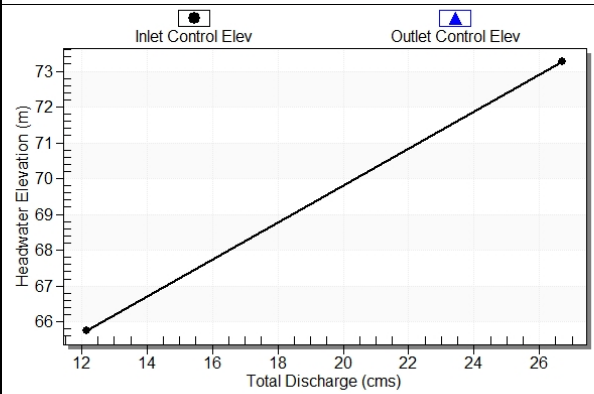

Figure 38 Performance curve for culvert during 1:100yr rainfall event using one (1) 2m culvert pipe.

2.1.6.4 National Works Agency (NWA) Design Criteria

The national standards stipulate that major drainage system are to be designed so as to convey a 1:25 year storm without exceeding a minimum freeboard of 25% of the design flow depth[2]. Each culvert was assessed based on this criteria and determined if the sizes and quantities are adequate to convey the flows generated by the respective storm events.

[2] NWA, Roads, Infrastructure, Drainage and Traffic Management, Development and Investment Manual Vol. 3 – Section 1

Chainage K1+800

The proposed drainage plan for the crossing at chainage 1+800 along the H2K highway involves implementing a corrugated steel pipe (CSP) of diameter 2m and an invert slope of 0.15%. This design was based on estimated 1:25yr flow of 5.72 m^3/s respectively. An assessment of the proposed culvert hydraulics was conducted using a culvert analysis program developed by the United States Department of Transportation. The design criteria proposed by China Harbour Engineering Company (CHEC) were input into the software and the culvert capacity determined.

Based on the proposed configuration of one (1) 2m culvert barrel and the estimated peak flows based on the catchment, it was determined that the proposed configuration is adequate to conduct the 1:25 year flows across the road with the allowable freeboard (see Figure 39). Table 11 below summarizes the flows associated with the required culverts at crossing K1+800 based on the modelling conducted by CEAC Solutions.

Table 11 Summary of culvert flows at crossing K1+800

Return Period	Number of Culverts	Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Outlet Velocity (m/s)
1:25	1	5.72	5.72	11.90	1.691	0.938	1-S2n	0.950	1.152	0.964	3.815

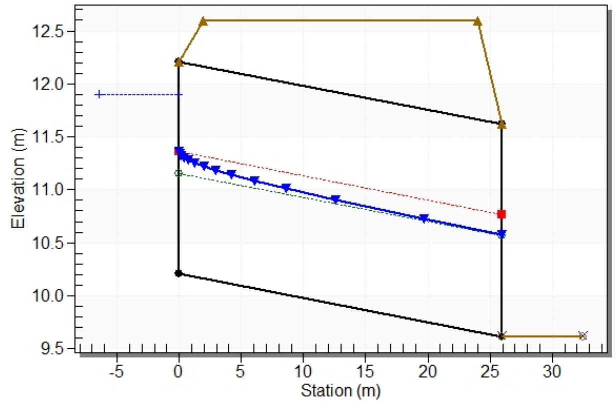

Figure 39 Water surface profile for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

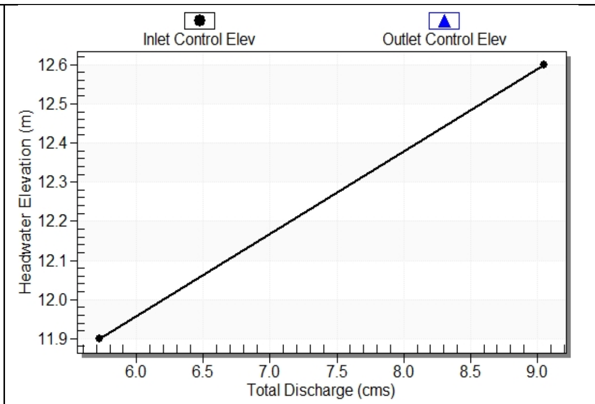

Figure 40 Performance curve for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

Chainage K2+872

The proposed drainage plan for the crossing at chainage 2+872 along the H2K highway involves implementing a corrugated steel pipe (CSP) of diameter 2.5m and an invert slope of 0.50%. This design was based on estimated 1:25yr flow of 7.53 m^3/s respectively. An assessment of the proposed culvert hydraulics was conducted using a culvert analysis program developed by the United States Department of Transportation. The design criteria proposed by China Harbour Engineering Company (CHEC) were input into the software and the culvert capacity determined.

Based on the proposed configuration of one (1) 2.5m culvert barrel and the estimated peak flows based on the catchment, it was determined that the proposed configuration is adequate to conduct the 1:25 year flows across the road with the allowable freeboard (see Figure 41). Table 12 below summarizes the flows associated with the required culverts at crossing K2+872 based on the modelling conducted by CEAC Solutions.

Table 12 Summary of culvert flows at crossing K2+872

Return Period	Number of Culverts	Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Outlet Velocity (m/s)
1:25	1	7.53	7.53	8.07	1.781	1.970	2-M2c`	1.250	1.242	1.242	3.092

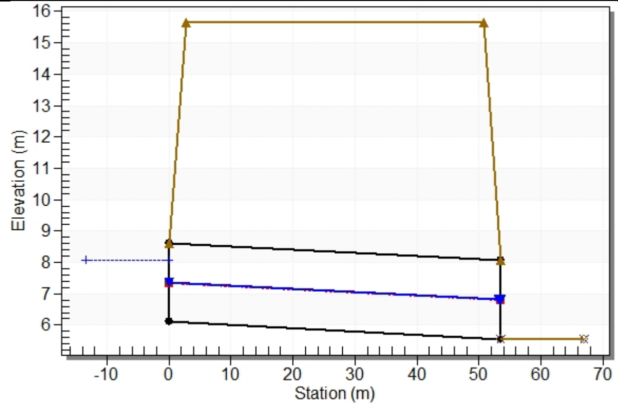

Figure 41 Water surface profile for culvert during 1:10yr rainfall event using one (1) 2.5m culvert pipe.

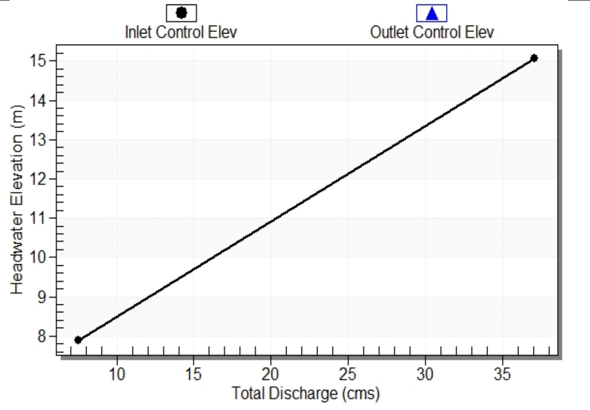

Figure 42 Performance curve for culvert during 1:10yr rainfall event using one (1) 2.5m culvert pipe.

Chainage K3+780

The proposed drainage plan for the crossing at chainage 3+780 along the H2K highway involves implementing a corrugated steel pipe (CSP) of diameter 2.5m and an invert slope of 0.50%. This design was based on estimated 1:25yr flow of 3.20 m^3/s respectively. An assessment of the proposed culvert hydraulics was conducted using a culvert analysis program developed by the United States Department of Transportation. The design criteria proposed by China Harbour Engineering Company (CHEC) were input into the software and the culvert capacity determined.

Based on the proposed configuration of one (1) 2m culvert barrel and the estimated peak flows based on the catchment, it was determined that the proposed configuration is adequate to conduct the 1:25 year flows across the road with the allowable freeboard (see Figure 43). Table 13 below summarizes the flows associated with the required culverts at crossing K3+780 based on the modelling conducted by CEAC Solutions.

Table 13 Summary of culvert flows at crossing K3+780 using a 2.5m culvert pipe

Return Period	Number of Culverts	Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Outlet Velocity (m/s)
1:25	1	3.20	3.20	8.16	1.173	0.047	1-S2n	0.647	0.849	0.657	3.551

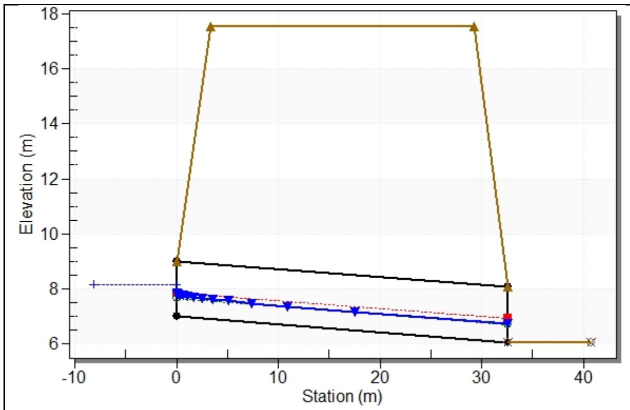

Figure 43 Water surface profile for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

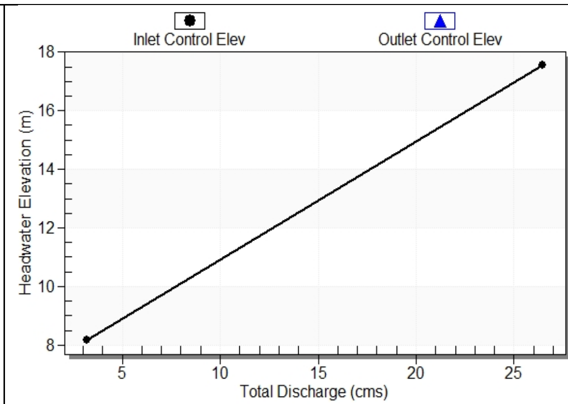

Figure 44 Performance curve for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

Chainage K4+030

The proposed drainage plan for the crossing at chainage 4+030 along the H2K highway involves implementing a 4m x 3m box culvert and an invert slope of 3%. This design was based on estimated 1:25yr flow of 5.80 m^3/s respectively. An assessment of the proposed culvert hydraulics was conducted using a culvert analysis program developed by the United States Department of Transportation. The design criteria proposed by China Harbour Engineering Company (CHEC) were input into the software and the culvert capacity determined.

Based on the proposed configuration of one (1) 4m x 3m box culvert and the estimated peak flows based on the catchment, it was determined that the proposed configuration is adequate to conduct the 1:25 year flows across the road with the allowable freeboard (see Figure 45). Table 14 below summarizes the flows associated with the required culverts at crossing K4+030 based on the modelling conducted by CEAC Solutions.

Table 14 Summary of culvert flows at crossing K4+030 using a 4m x 3m box culvert

Return Period	Number of Culverts	Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Outlet Velocity (m/s)
1:25	1	5.80	5.80	11.02	0.813	0.00	1-S2n	0.225	0.544	0.298	4.225

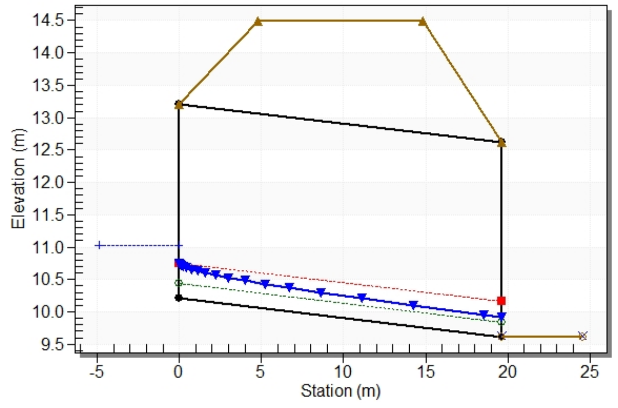

Figure 45 Water surface profile for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

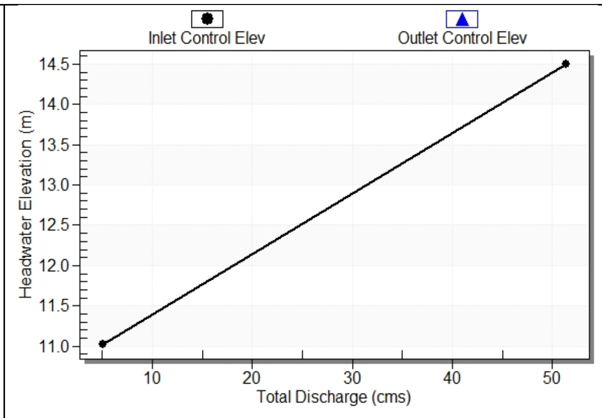

Figure 46 Performance curve for culvert during 1:10yr rainfall event using one (1) 2m culvert pipe.

Chainage K4+849.4

The proposed drainage plan for the crossing at chainage 4+030 along the H2K highway involves implementing a 4m x 3m box culvert and an invert slope of 3%. This design was based on estimated 1:25yr flow of 5.80 m^3/s respectively. An assessment of the proposed culvert hydraulics was conducted using a culvert analysis program developed by the United States Department of Transportation. The design criteria proposed by China Harbour Engineering Company (CHEC) were input into the software and the culvert capacity determined.

Based on the proposed configuration of one (1) 4m x 3m box culvert and the estimated peak flows based on the catchment, it was determined that the proposed configuration is adequate to conduct the 1:25 year flows across the road with the allowable freeboard (see Figure 47). Table 15 below summarizes the flows associated with the required culverts at crossing K4+030 based on the modelling conducted by CEAC Solutions.

Table 15 Summary of culvert flows at crossing K4+849.4 using a 2.5m culvert pipe

Return Period	Number of Culverts	Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Outlet Velocity (m/s)
1:25	1	7.57	7.57	64.59	2.056	0.147	5-S2n	1.014	1.332	1.022	4.685

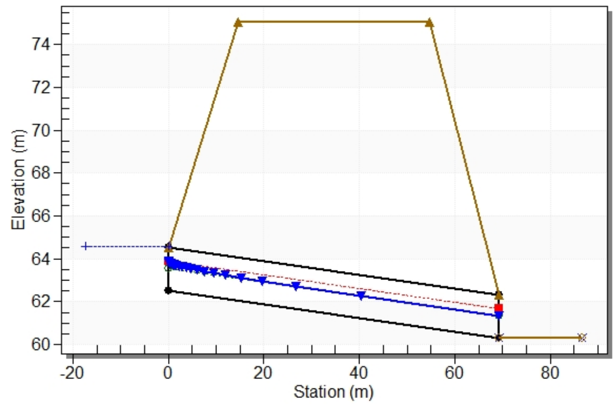

Figure 47 Water surface profile for culvert during 1:10yr rainfall event using one (1) 4m x 3m box culvert.

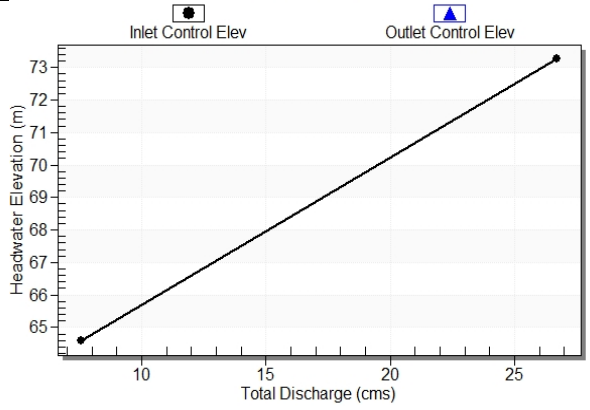

Figure 48 Performance curve for culvert during 1:10yr rainfall event using one (1) 4m x 3m box culvert.

2.1.6.5 Summary

The proposed drainage openings were designed to convey the 1:10 year runoff without surcharging and the 1:100 year runoff with a maximum of 0.6 freeboard below the edge of the shoulder. This approach must ensure that the aquifer recharge areas (sinkholes) remain intact during construction and operation phases of the highway. An important design challenge is to protect the drainage crossing against scour and blockage due to fast moving water. It is recommended that features be included to reduce the energy of the stream flows upstream of drainage crossing. Discharge from drainage crossings will be into pre exiting watercourses.

Of the five (5) culvert crossings examined, it is recommended that the design for the culvert at chainage K1+800 be revised using the guidelines which CHEC have used themselves as a basis. The headwater elevations associated with this culverts will cause flooding on the highway itself (0.1m water depth above road surface) during the 1:100 year rainfall event. Using the national standards developed by NWA, all culvert were adequate given the minimum freeboard constraint. It must be noted that although majority of the culvert designs may have passed with under both the CHEC and NWA guidelines, the possible issue of localized flooding in the vicinity of the crossing was not appropriately addressed. The guidelines by which CHEC has designed their drainage safeguards the highway but does not provide any mitigation against local flooding within the surroundings; this needs to be addressed. It is recommended that the headwater elevations be reduced as much as possible so as to alleviate any possible adverse effects of the localized flooding.

2.1.7 Ambient Particulates (PM 2.5 and PM 10)

Coarse particles are airborne pollutants that fall between 2.5 and 10 micrometres in diameter. Fine particle are airborne pollutants that fall below 2.5 micrometres in diameter. Sources of coarse particles include crushing or grinding operations, and dust stirred up by vehicles traveling on roads. Sources of fine particles include all types of combustion, including motor vehicles, power plants, residential wood burning, forest fires, agricultural burning, and some industrial processes.

PM2.5 and PM10 particulate sampling was conducted for 24 hours each, using Airmetrics Minivol Tactical Air Samplers. Sampling was conducted at two (2) locations at the southern perimeter wall of Caymanas Country Club Phases I Block A (P1) and at the western perimeter wall of Phase 2 Block C (P2).

The locations are illustrated in Figure 49 and the coordinates listed in Table 16.

Table 16 Particulate sampling locations coordinates in JAD2001

STATION	JAD 2001	
	NORTHING (m)	EASTING (m)
P1	652596.0545	759280.5684
P2	652381.1131	759099.8995

For the PM2.5 sampling event, the level at Station P2 had particulate values non- compliant with the 24-hour US EPA standard of 35 µg/m3 (Table 17).

Table 17 PM 2.5 results compared with US EPA standard

STATION	AVERAGE RESULT (µg/m3)	US EPA 24-HR STD. (µg/m3)
P1	24.02	**35**
P2	**55.83**	**35**

The PM 10 sampling exercise was conducted from 7:00pm on Thursday November 27th, 2014 until 7:00pm on Friday November 28th, 2014, and the PM2.5 sampling exercise was conducted from 10.30 am Saturday November 29th, 2014 until 10.30 am Saturday November 29th, 2014.

Figure 49 Locations of particulate sampling

For the PM10 sampling event both locations had particulate values compliant with the 24-hour US EPA standard of 150µg/m³ (Table 18).

Table 18 PM10 results compared with US EPA standard

STATION	RESULT (µg/m³)	US EPA STD. (µg/m³)
P1	22.77	**150**
P2	33.19	**150**

At the time of the survey, some residents complained that there was a dust nuisance due to the construction of the highway.

2.1.8 Noise

2.1.8.1 Method

A data logging noise survey exercise was conducted to establish baseline conditions at the boundaries of the first row of houses from the west perimeter wall of Caymanas Country Club Phase 2 Block C. The data logging exercise was conducted for 39 hours and 37 minutes between 6:51pm Thursday 27th November, to 10:28 am Saturday 29th, November 2014. The reading was taken at one (1) location (Station N1 - western perimeter wall of Phase 2 Block C) listed below in Table 19 and depicted in Figure 50.

Table 19 Noise Station numbers and locations in JAD2001

STATION	LOCATION	JAD 2001	
		Northing (m)	Easting (m)
N1	West Perimeter Wall	652381.1131	759099.8995

Noise level readings were taken by using Quest Technologies SoundPro DL Type 1 hand held sound level meters with real time frequency analyser setup in outdoor monitoring kit. The octave band analysis was conducted concurrently with the noise level measurements. Measurements were taken in the third octave which provided thirty three (33) octave bands from 12.5 Hz to 20 kHz (low, medium and high frequency bands).

The noise meters were calibrated pre and post noise assessment by using a Quest QC - 10 sound calibrator (Appendix 1). The meter was programmed using the Quest suite Professional II (QSP II) software to collect third octave, average sound level (Leq) over the period, Lmin (The lowest level measured during the assessment) and Lmax (The highest level measured during the assessment) every ten (10) seconds.

Figure 50 Location of the noise monitoring

Average noise levels over the period were calculated within the QSP II software using the formula:

$$\textbf{Average dBA} = 20 \log 1/N \sum_{j=1}^{N} 10^{(Lj/20)}$$

Where N = number of measurements
L_j = the jth sound level
j = 1, 2, 3 .... N

A windscreen (sponge) was placed over the microphone to prevent measurement errors due to noise caused by wind blowing across the microphone. The noise monitoring outdoor kit and the particulate pump are shown in Plate 7.

Plate 7 Photo showing noise meter at Station N1 (foreground) and particulates pump in the background (P1)

2.1.8.2 Results

This section outlines the results of the seventy two (72) hour noise monitoring exercise.

Station N1- Western Perimeter Wall

During the 39 hours and 37 minutes period, noise levels at this station ranged from a low (Lmin) of 29.9 dBA to a high (Lmax) of 83.1 dBA. Average noise level for this period was 47.1 L_{Aeq}. The fluctuation in noise levels over the 39 hours and 37 minutes period is depicted in Figure 51.

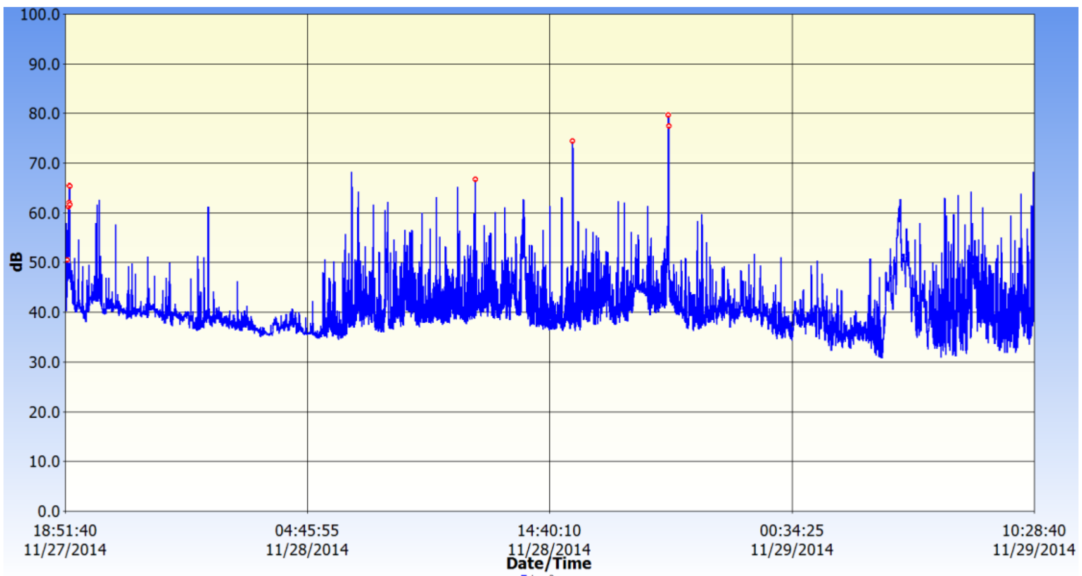

Figure 51 Noise fluctuation (Leq) over 72 hours at Station 1

Octave Band Analysis at Station 1

The noise at this station during the 39 hours and 37 minutes period was in the low frequency band centred around the geometric mean frequency of 63 Hz (octave frequency range is 2807 - 3534 Hz) (Figure 52).

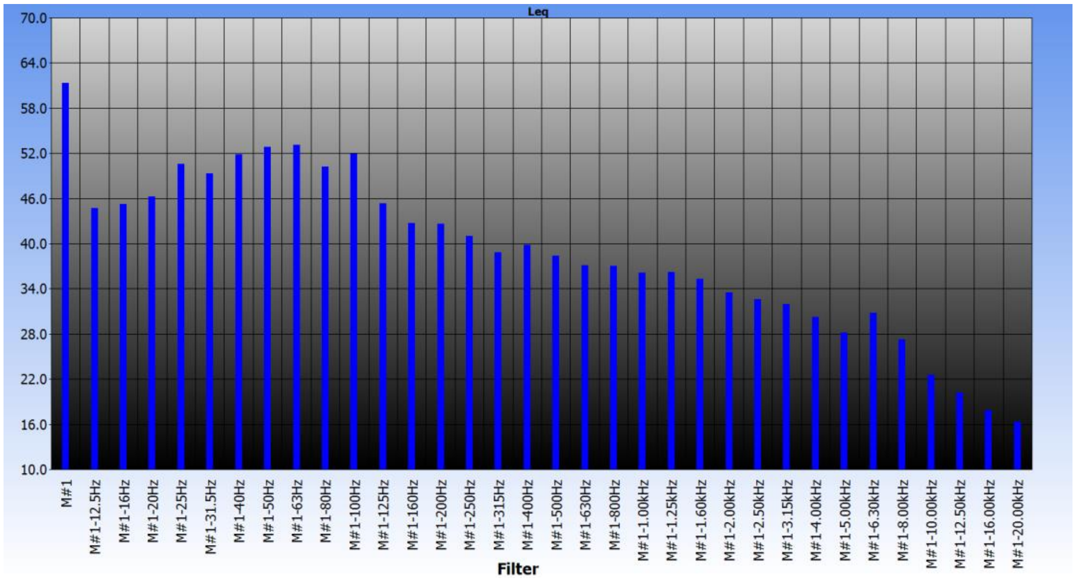

Figure 52 Octave band spectrum of noise at Station 1

L10 and L90 – Station 1

The two most common L_n values used are L_{10} and L_{90} and these are sometimes called the 'annoyance level' and 'background level' respectively. L_{10} is almost the only statistical value used for the descriptor of the higher levels, but L_{90}, is widely used to describe the ambient or background level. L10-L90 is often used to give a quantitative measure as to the spread or "how choppy" the sound was.

L10 is the noise level exceeded for 10% of the time of the measurement duration. This is often used to give an indication of the upper limit of fluctuating noise, such as that from road traffic. L90 is the noise level exceeded for 90% of the time of the measurement duration. The difference between L10 and L90 gives an indication of the noise climate. When the difference is < 5 dBA then it is considered that there are no significant fluctuations in the noise climate, moderate fluctuations 5-15 dBA and large fluctuations >15 dBA.

Figure 53 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows moderate fluctuations (L10 – L90) ≈61.0% of the time, no significant fluctuations (L10 – L90) ≈31.7% of the time and large fluctuations

(L10 – L90) ≈7.3% of the time, in the noise climate at this station. The overall L10 and L90 at this station for the time assessed were 46.9 dBA and 36.0 dBA respectively.

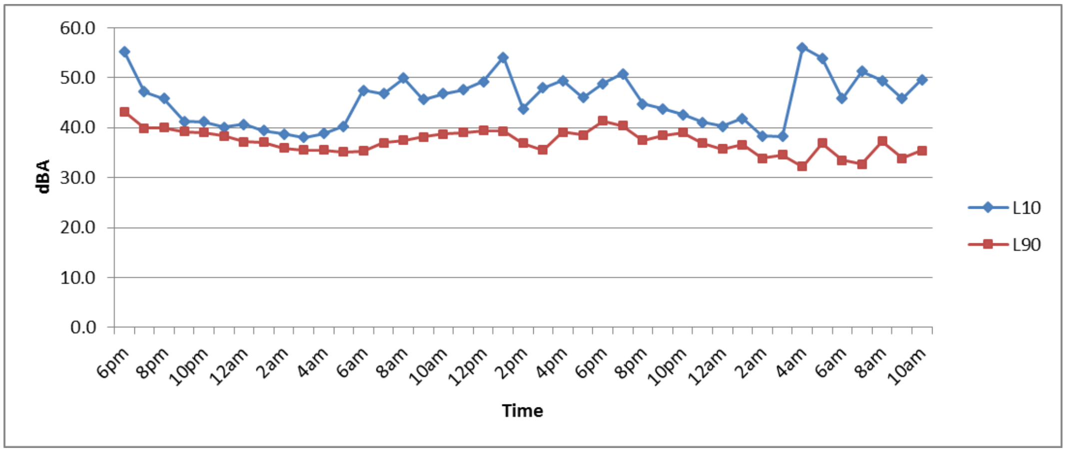

Figure 53 L10 and L90 for Station 1

2.1.8.3 Comparisons with the National Environment and Planning Agency and the Federal Highway Administration

National Environment and Planning Agency (NEPA)

Comparisons were done with the measured day time and night time noise levels with the NEPA standards. The ambient noise levels complied with the standards (Table 20).

Table 20 Comparison of noise measured with NEPA Day and Night time standards

LOCATION	ZONE	AVERAGE DAYTIME – 7am -10pm (L_{Aeq})	NEPA DAY TIME STD. (dBA)	AVERAGE NIGHT TIME – 7am -10pm	NEPA NIGHT TIME STD. (dBA)
N1	Residential	49.0	55.0	44.0	50.0

Federal Highway Administration (FHWA)

Noise standards issued by the Federal Highway Administration (FHWA) for use by state and Federal highway agencies in the planning and design of highways are depicted below in Table 21.

Table 21 FHWA noise standards for use by state and Federal highway agencies for planning and design of highways

Land Use Category	Design Noise Level-L10	Description of Land Use Category
A	**60dBA** (Exterior)	Tracts of lands in which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose. Such areas could include amphitheatres, particular parks or portions of parks, or open spaces which are dedicated or recognized by appropriate local officials for activities requiring special qualities of serenity and quiet.
B	**70dBA** (Exterior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, picnic areas, recreation areas, playgrounds, active sports areas, and parks.
C	**75dBA** (Exterior)	Developed lands, properties or activities not included in categories A and B above.
D	-	For requirements on undeveloped lands see paragraphs 5a(5) and (6), this PPM.
E	**55dBA** (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums.

Based on the land use categories listed above, Category B is the most apt to describe the land use within the study area of the noise assessment.

Comparisons with the FHWA standard (Category B) has indicated that for the measured period (39 hours and 37 minutes), the L10 noise levels at the station was in compliance with the FHWA standard (Figure 54).

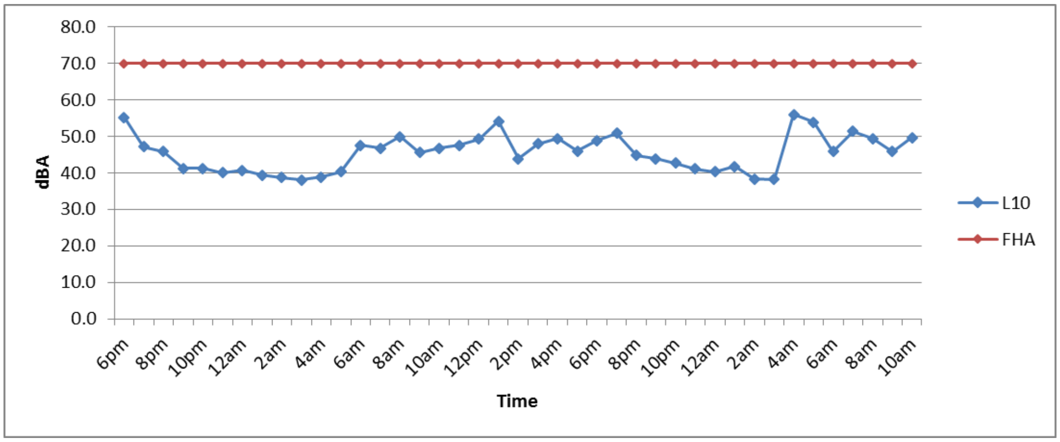

Figure 54 Comparison of L10 at Station 1 with FHWA standard

2.1.8.4 Community Noise Level Descriptors

Day - Night Average Sound Levels (L_{dn})

L_{dn} or DNL is a 24-hour equivalent continuous level in dBA where 10 dB is added to night-time noise levels from the hours of 10:00 p.m. to 7:00 a.m. before being averaged. It accounts for the moment to moment fluctuations in A weighted noise levels over a 24-hour period due to all noise sources. The L_{dn} represents the averaging of the Leq (1) over the 24-hour period with the penalty added.

The US Environmental Protection Agency (EPA) has established a noise guideline (L_{dn} < 55 dBA) for the prevention of outdoor activity interference and annoyance. This is relevant to outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.

The Ldn was 53.0 dBA therefore compliant with the US EPA guideline.

Community Noise Equivalent Levels (CNEL)

CNEL is equivalent to the European Standard of Day Evening Night Levels (L_{den}). It is a 24-hour equivalent continuous level in dBA where 5 dBA is added to evening noise levels from 7:00 p.m. to 10:00

p.m. and 10 dBA is added to night-time noise levels from 10:00 p.m. to 7:00 a.m.

The CNEL levels can give an indication of the likelihood of community complaints about a noise source (Figure 55).

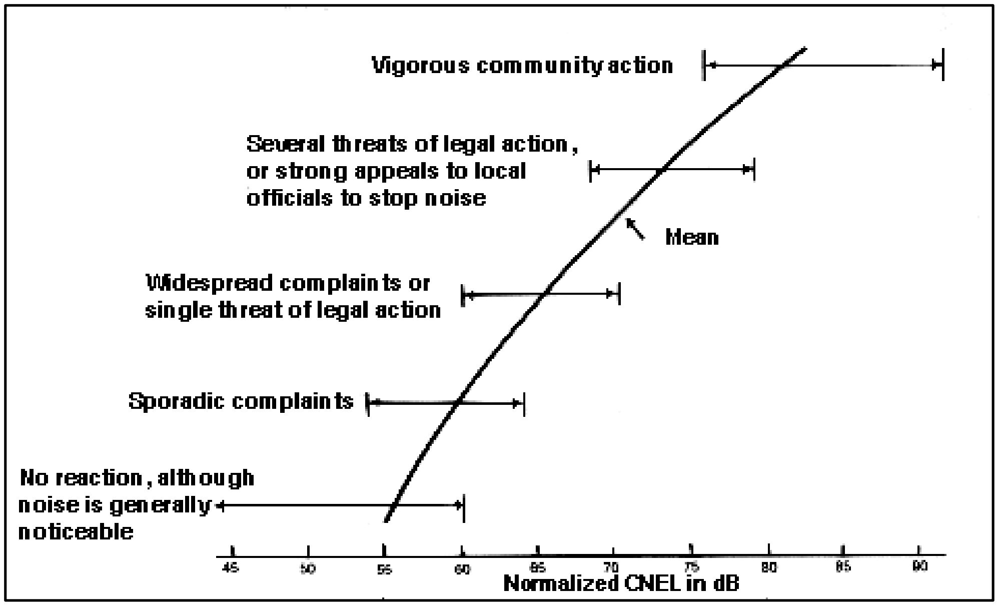

Figure 55 Anticipated community reaction versus normalized CNEL (dB)

Source: Adapted from US Environmental Protection Agency (1971)

The calculated CNEL level at the station was compared with the guideline level that it is expected to have sporadic complaints from the community. The level of 53.5 dBA was in compliance with the guideline (Figure 55).

2.1.9 Vibration

No vibration measurements were taken, however, there were no complains at the time of the survey from residents in Caymanas Estates.

2.2 BIOLOGICAL

2.2.1 Vegetation

The areas focused on in this survey were limited to the Caymanas Estate community; more precisely, that section of the development beginning in the vicinity of the Caymanas Golf and Country Club (CGCC) (in the highland areas) and ending just north-east of the Island Cement Company's facility at Mandela Highway (in the lowlands). The level of anthropogenic disturbance varied along the swath of the planned rights-of way, ranging from an active construction zone; a residential development; recreational facilities; and small industrial complexes.

Based on the variability in topography the study site was divided into three zones. The first proceeded 0.76 km down-slope Mount Gotham, roughly south-east from the CGCC to the CCCE housing development (Figure 56). This was an active construction zone where the rights-of-way were already cleared and an approximate 100 m swath of exposed limestone (both pulverised and unprocessed) was observed. The vegetation within was limited to a smattering of relict and regenerating tree species as well as secondary pioneer herbs and shrubs.

Figure 56 Zone 1, as approximated by the dashed, yellow boundary. Note the cleared area within the red-boundary lines which represent the 100 m wide rights-of-way.

The second zone ran south by south-east along the planned rights-of way at the foot of the Mount Gotham range (Figure 57). The flora present was disturbed; however, it appeared to be the least disturbed of the three zones. The vegetation appeared to consist of elements from both the montane dry limestone forest and agricultural lands that the rights-of way straddles. This zone was approximately 1.55 km in length.

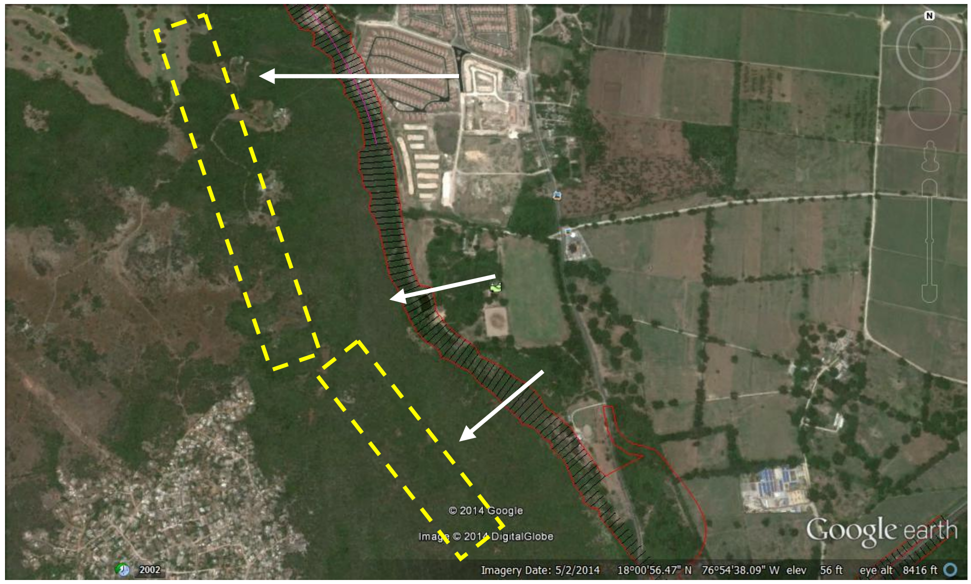

Figure 57 Zone 2, as approximated by the dashed, yellow boundary.

The third and final zone traversed roughly 0.74 km south-east over fallow agricultural lands (Figure 58). This segment located in the lowland areas showed the highest anthropogenic disturbance with parcels dedicated to housing developments, equestrian and cement processing facilities. Some sections appeared to have been recently cleared or at least maintained as such; particularly so on lands adjacent to the West Indies Home Contractors and Island Cement Company facilities.

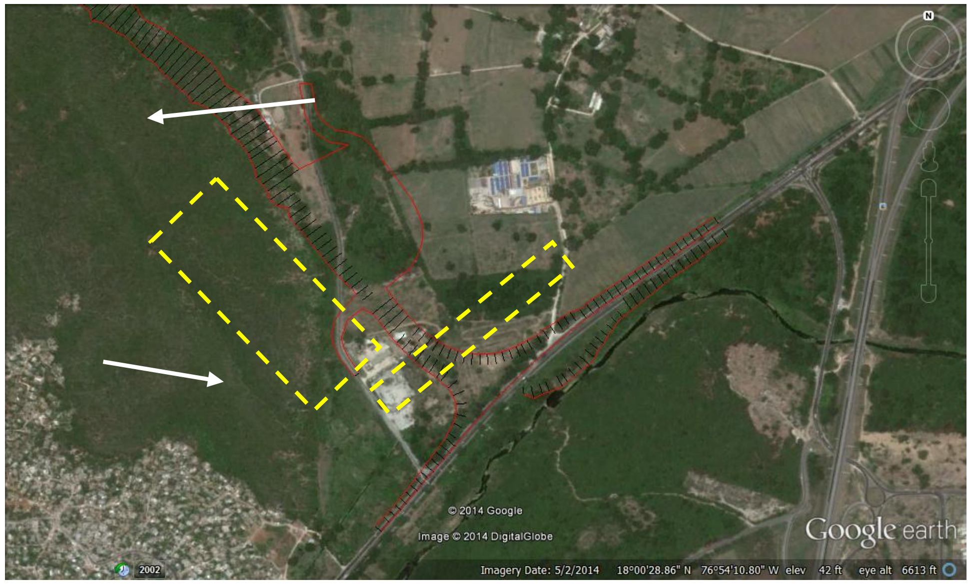

Figure 58 Zone 3, as approximated by the dashed, yellow boundary

2.2.2 Methodology

Owing to the variability in disturbance at the study site, it was determined that the area could have been effectively surveyed using a series of walk-though floral inventories. During these walk-throughs, species composition and abundance were noted; the latter being ranked according to a DAFOR[‡] scale. These sorties were concentrated within the three described zones.

Walk-throughs for Zone 1 included areas adjacent to the already cleared rights-of-way. This was done in order to characterise the vegetation that may have existed in the path of the planned development.

Virtually all plant species encountered during the field surveys were identified *in-situ* or samples collected and taken to the University of the West Indies Herbarium for later identification.

[‡] DAFOR occurrence rank: a subjective scale of species occurrence within an area of study. The acronym refers to, **D**ominant, **A**bundant, **F**requent, **O**ccasional, **R**are (Barbour et al. 1987).

2.2.3 Results and Observations

In this study 82 plant species were encountered of which six were endemic. With the exception of the cleared rights-of-way, the flora located on Mount Goshen was indicative of a disturbed dry limestone forest that showed increasing levels of disturbance towards the lower elevations. The majority of the species (Appendix 2) were from these highland areas and were characteristically different in growth form and stature to the flora in lowland areas.

Highland vegetation tended to be comprised of thin-boled phanerophytes (5-15 cm DBH), 3-5 m in height, with root systems capable of penetrating the limestone substrate. The ground layer was typically exposed; however, in several sections *Bromelia* and *Agave* spp. were quite common (Figure 59). Epiphytic constituents were somewhat limited.

Figure 59 Patch of Agave sp. located in Zone 1. Note thin-boled trees in background

The lowland vegetation was constituted mainly by herbaceous and shrubby constituents. Leguminous phanerophytes were conspicuous with several large members hosting *Tillandsia* and *Hyolocereus* epiphytes (Figure 60).

2.2.3.1 Zone 1

Owing to the level of construction activity within this area (Figure 61), the resulting plant community was sparse and restricted to areas not cleared during land preparation (Figure 62). Using this relict border community, one may estimate that the original flora was comprised mainly of tree species such as *Bauhinia divaricata* (Bull Hoof), *Bursera simaruba* (Red Birch), *Haematoxylum campechianum* (Logwood), *Leucaena leucocephala* (Lead Tree) and *Spathodea campanulata* (African Tulip Tree). Several seedlings of *Acacia tortuosa* (Wild Poponax) were also present here, most likely proliferating as a result of the disturbance.

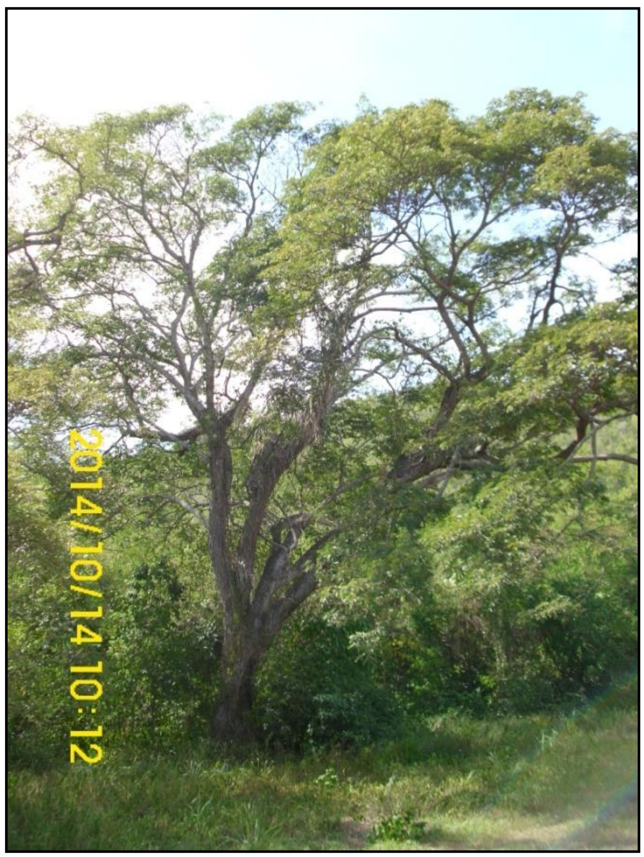

Figure 60 Samanea saman bearing epiphytes.

Shrubs were less common, nonetheless species such as *Agave sobolifera* (May Pole), *Ateramnus lucidus* (Crab Wood) and *Bunchosia media* were common. Shrubby herbs tended to be scattered across the disturbed limestone substrate; namely, *Abutilon* *abutiloides* and *Urena lobata* (Ballard Bush). The grass, *Panicum maximum* was commonly restricted to the fringes.

Figure 61 Active construction zone in Zone 1 of study area.

Figure 62 View of relict vegetation community in Zone 1

Endemic species were infrequent. Shrubs, such as *Cordia bullatta* and *Xylosoma* sp. were rare; occurring only in a few open areas. Endemic epiphytes such as *Hylocereus triangularis* (God Okra) (Figure 64), *Ipomoea lineolata*, and *I. ternata* were more frequent but absent from clearings. The endemic palm *Sabal jamaicensis* (Bull Thatch) was a conspicuous constituent (Figure 63). Overall, 53 plant species were encountered here.

Figure 63 The palm Sabal jamaicensis in background

Figure 64 The endemic, epiphytic, cactus Hyolocereus triangularis

2.2.3.2 Zone 2

This zone straddled the basal contours of Mount Goshen and the alluvium of the lowlands behind the CCCE housing development (Figure 65), Kingston Polo Club and the Caymanas Pony Club. Fifty eight species were encountered along this segment.

Blighia sapida (Ackee), *Delonix regia* (Poinciana) and *Samanea saman* (Guango) were often large, conspicuous tree constituents of the alluvium. The latter two species often bore epiphytes such as *Tillandsia* sp., *Hohenbergia* sp. and the ende*mic H. triangularis*. The endemic palm, *Roystonea altissima* (Mountain Cabbage) was also present (Figure 66). Along the basal slopes; however, the common tree species were *Bauhinia divaricata*, *Bursera simaruba*, *Catalpa longissima* (French Oak), *Leucaena leucocephala* and *Melicoccus bijugatus* (Guinep).

Figure 65 View at rear of Caymanas Country Club Estates housing development

Ateramnus lucidus, *Bunchosia media* and *Bromelia penguin* (Ping-Wing) were common shrubs on limestone, while *Ricinus communis* (Castor Oil Plant) plants were quite frequent in the lowlands. *Stenotaphrum secundatum* (Crab Grass) and *Panicum maximum* (Guinea Grass) were the dominant herbs on the alluvium in this region.

Figure 66 Endemic palm Roystonea altissima

The current rights-of-way should take the highway development nearby/through a pond system that (according to local reports) was fed by subsurface runoff and rainwater (Figure 67). The dominant plant species in this community was *Pistia stratiotes* (Water Lettuce). Bordering the pond were primarily sedges (*Cyperus* spp.).

Figure 67 Pond behind Kingston Polo Club

2.2.3.3 Zone 3

This area could be characterised as being in a state of constant anthropogenic disturbance (Figure 68 and Figure 69). As such species richness was low with only 27 species encountered. The dominant growth forms were herbs and shrubs, namely *Cynodon dactylon* and *Abutilon abutiloides* respectively. Nonetheless the tree species *Cordia alba* (Duppy Cherry), *Leucaena leucocephala* and *Samanea saman* were virtually ubiquitous. The arboreal grass *Bambusa vulgaris* (Bamboo) was an unexpected constituent lining man-made drainage canals.

Figure 68 Open land in vicinity of proposed toll booth

Figure 69 Maintained area in vicinity of proposed interchange

The vegetation communities present within the study area exhibited various levels of anthropogenic influence and as such would be affected by a development such as this in various ways. The overall assessment of the study site is that the vegetation in each locale sampled was disturbed but areas along and adjacent to Mount Goshen (Zones 1 and 2) had the highest endemism and as such care should be taken in carrying out the development in these areas.

However, for the lowland areas (Zone 3) it should be noted that although anthropogenic influence was higher and as a result species richness was relatively lower than in the other zones, endemism was common. Trees like the commonly occurring Guango (*Samanea saman*), imported during the island's early colonial history to provide fodder for livestock (Asprey & Robbins 1953), were well established in Zone 3. Several *S. saman* trees possessed approximate DBH values of over 50 cm; accounted for most of the tree cover; and produced sturdy branches hosting several epiphytes and hemi-epiphytes including the ecologically important *Hohenbergia* sp. and *Hylocereus triangularis* (God Okra).

The impacts and possible mitigations for the lowland and highland areas are outlined in 3.0. As with any development the options of not to-build and the use of alternative routes should always be considered.

2.3 LAND USE

2.3.1 Previous

The area has a long history of sugar production from cane dating back to the 18th century. The remains of these plantation works are still to be found in ruins on the estate. Coconuts and bananas were cultivated in the 20th century diversifying sugar cane production.

2.3.2 Present

The area is used for agricultural (sugar cane cultivation), residential Caymanas Country Club Estates and Caymanas Bay), recreational (Caymanas Golf and Country Club, Kingston Polo Club, jockey riding school and pony club) telecommunications (Lime and Digicel towers and fibre optics) and for water resources (wells). There are areas that informal dumping occurs and there are commercial/manufacturing for example the cement batching plant.

2.4 HERITAGE

The Caymanas Estate has a long history of sugar production dating back to the 18th century. There were three estates Ellis, Treadways (later Dawkins) and Taylor each possessing an animal mill for producing sugar. The three estates were amalgamated during the late 19th century under the ownership of CrumEwing and became the largest producer of sugar in the island.

Various ethnic groups including the Taino have used the area as evidenced by the artefacts found. The property has seen various land uses over the past namely, sugar cane cultivation, banana and coconut production.

The Archaeology Division of the Jamaica National Heritage Trust has no objection to the proposed development pending that the recommendation of having a Watching Brief carried out at the time of clearing so that the recovery of artefacts can take place above is taken into consideration and implemented.

For more information consult the Archaeological Impact Assessment for the Jamaica North-South Highway Project - Section 1A Caymanas Interchange (Jamaica National Heritage Trust 2014).

2.4.1 Methodology

A multi-faceted approach was used including documentary research and archaeological field surveys in the conduct of the Archaeological Assessment. These included a desk-based assessment, field walk survey and the recording and analysis of artefacts.

The desk-based assessment involved a thorough review of all the available written and graphic information relating to the area in order to identify the likely character, extent and relative quality of the actual or potential archaeological and architectural resources. It included relevant historical documents, journals and books, aerial photographs and/or satellite imagery, maps and other contemporary data found in the nation's repositories such as the Island Record

Office, National Archives, National Library of Jamaica, University of Technology (UTECH), University of the West Indies (UWI) and private collections. Web sites were also consulted.

Historical documentation including, maps, plans, estate accounts, correspondence, titles, deeds, just to list a few. The published and unpublished results of any previous archaeological work on the site or in its vicinity and satellite images and aerial photographs.

Field walk survey using a Transect Linear Field Walk survey was the archaeological technique employed to identify areas of pre-historical and / or historical activities and features.

All archaeological features, including artefacts, were recorded by means of sketches, digital photographs, GPS, survey, and field notes. Where artefact assemblages were identified, samples were collected and recorded for analysis. The preliminary analysis of artefacts was done to establish manufacture location and cultural association. Additionally, individuals familiar with the site were interviewed, the information noted and added to the data base on sites.

2.4.2 Findings

2.4.2.1 Desk Based Assessment

Prehistoric Sites

A number of prehistoric sites were found within the Caymanas vicinity namely White Marl, Caymanas Bay and Ferry Hill. The White Marl site is believed to be the largest Taino site in the island covering approximately 33 acres. The site was noted in 1897 and was excavated in the 1950s and 1960s.Several Taino skeletal remains were recovered, numerous whole vessels, shell tools, stone axes and other implements. A burial cave was found 500 yards northeast of the White Marl Museum also with numerous Taíno skeletal remains and five complete pots.

The Caymanas Estate property has a rich history in sugar cultivation dating as far back as the 18th Century. In 1739 the Caymanas Estates produced 210 hogsheads of sugar. George Ellis' Caymanas producing 40, Robert Treadway (deceased) owner of Caymanas Pitney producing 140 and George Hanbury Taylor Caymanas producing 30.

Tredway Caymanas was eventually owned by Colonel Henry Dawkins and subsequently known as Dawkins.

Historical Background

The Caymanas Estate property has a rich history in sugar cultivation dating as far back as the 18th Century. In 1739 the Caymanas Estates produced 210 hogsheads of sugar. George Ellis' Caymanas producing 40 hogsheads of sugar, Robert Tredway (deceased) owner of Caymanas Pitney producing 140 hogsheads of sugar and George Hanbury Taylor Caymanas producing 30 hogsheads of sugar. Tredway Caymanas was eventually owned by Colonel Henry Dawkins and subsequently known as Dawkins. All three estates relied on animal mills for processing sugar.

The three estates had their Slave Villages (Figure 70 and Figure 71).

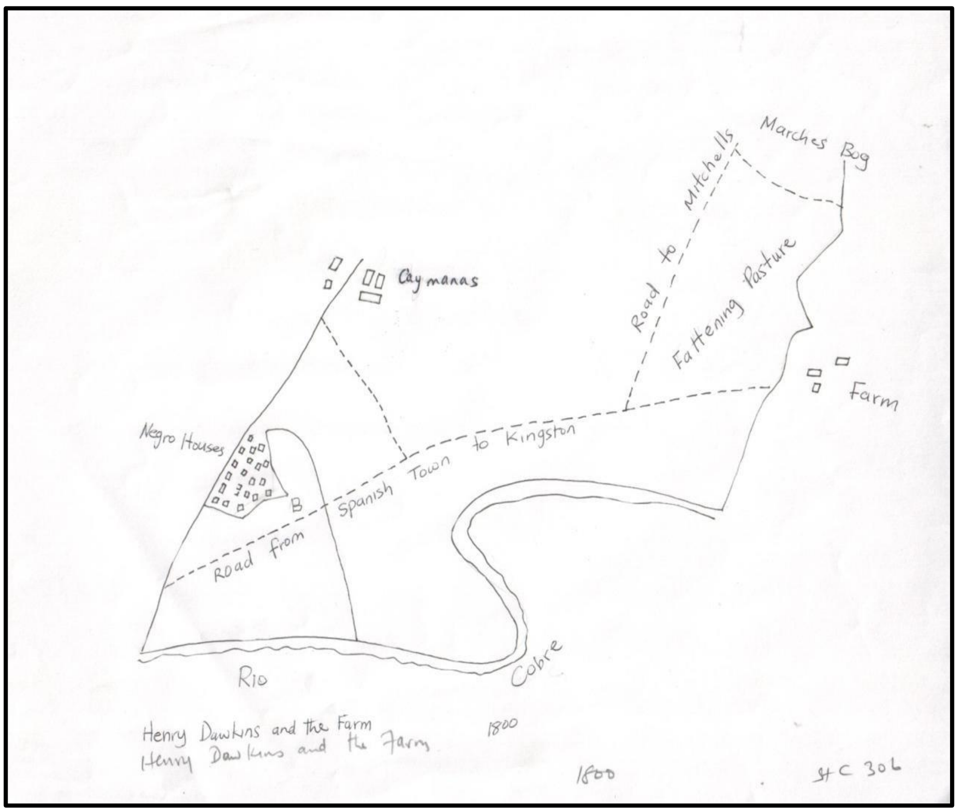

Figure 70 Map showing the Slave Village on Dawkins Estate labelled as Negro Houses

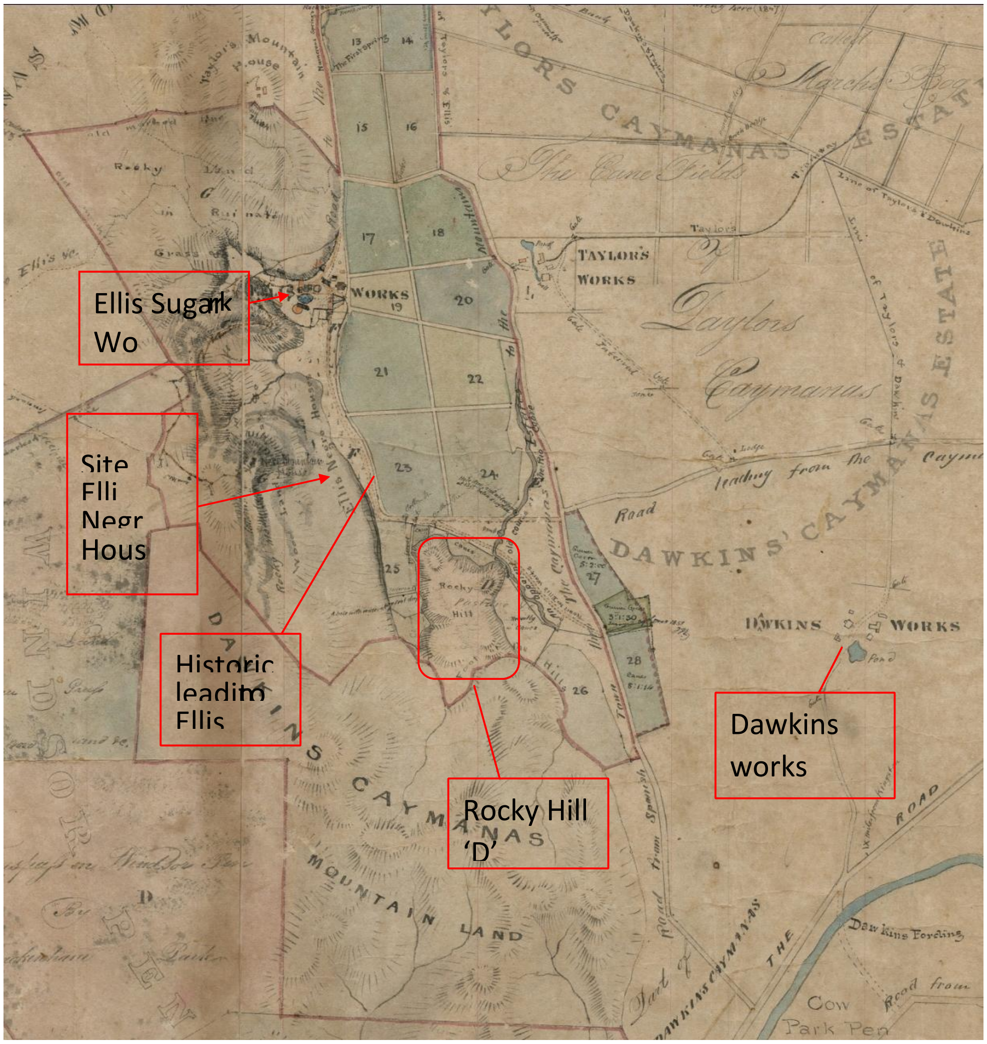

Figure 71 Map depicting Ellis works, Ellis Slave Village, Historic road, Rocky Hill 'D' and Dawkins works

2.4.2.2 Site Assessment

The field survey was concentrated mainly on the Ellis estate, west of the Caymanas Country Club Housing Development. This section of the highway will run just to the west of the Old Ellis Works (Figure 71) now demolished and encompasses the historic road to Ellis works and the Slave Village (Figure 71).

It also traverses land to the south of the property road leading from Ellis/Taylor to the Caymanas Golf Course. It follows the alignment of the historic property road that ran to Ellis works in the vicinity of the present water pumping station. Our desktop assessment and survey identified a section of this area to be the Ellis Slave Village (Figure 71).

An assemblage of artefacts was found along the roadway (Plate 8 and Plate 9) and in the vicinity of the Slave Village.

Plate 8 Assemblage of artefacts in the roadway in the vicinity of the Slave Village

Some Spanish rubble along with pieces of Taino sherds and pieces of ceramic sherds were found in the vicinity of Grid reference 18Q 0297252, 1993816 in the area just to the west of the Old Ellis Works.

Plate 9 The team surveys the area that starts this leg of the highway

At grid reference point 18Q02 97261, 1993 705 another assemblage of artefacts was discovered. This was in the vicinity of the pump house and the assemblage contained Taino pottery sherds. The area was evaluated to ascertain the archaeology of the site. This area was cleared of vegetation and a grid system 3x5 metre square was established over the area. Six one metre square units were randomly selected and excavated. The units were excavated by 10cm interval which defined a level. Each unit was excavated to approximately 20 cm or two levels below the surface. The first 10 cm or Level 1 comprised of a dark grey sandy loam soil that contained numerous pieces of Taino pottery, European ceramics, and metal objects from the historical period. These pre-historical and historical artefacts were juxtaposed with contemporary material. This is a clear indication that the area has been disturbed; most likely the soil being tilled for farming purposes. The presence of banana plants bears testimony to this activity. The presence of charcoal kiln in proximity to the site may have contributed to the dark colour of the soil and also the disruption of the soil.

Of note is a beautiful amber coloured stone that was fashioned in the form of a bead probably for a necklace by the Taino. This is an indication that the Taino occupying the area was engaged not only in intricate production of stone tools as was the case in White Marl but also in craft production.

At grid reference point 18Q0297298, 1993632in the Slave Village area a number of artefacts were recovered (Plate 10).

Plate 10 Showing assemblage of artefacts in situ in the Ellis Slave Village

Plate 11 Showing wine bottle sherds in situ in the Ellis Slave Village

The JNHT have identified points of interest along the proposed realigned Jamaica North South Highway between metering 0+000 to 4+200 (Figure 72).

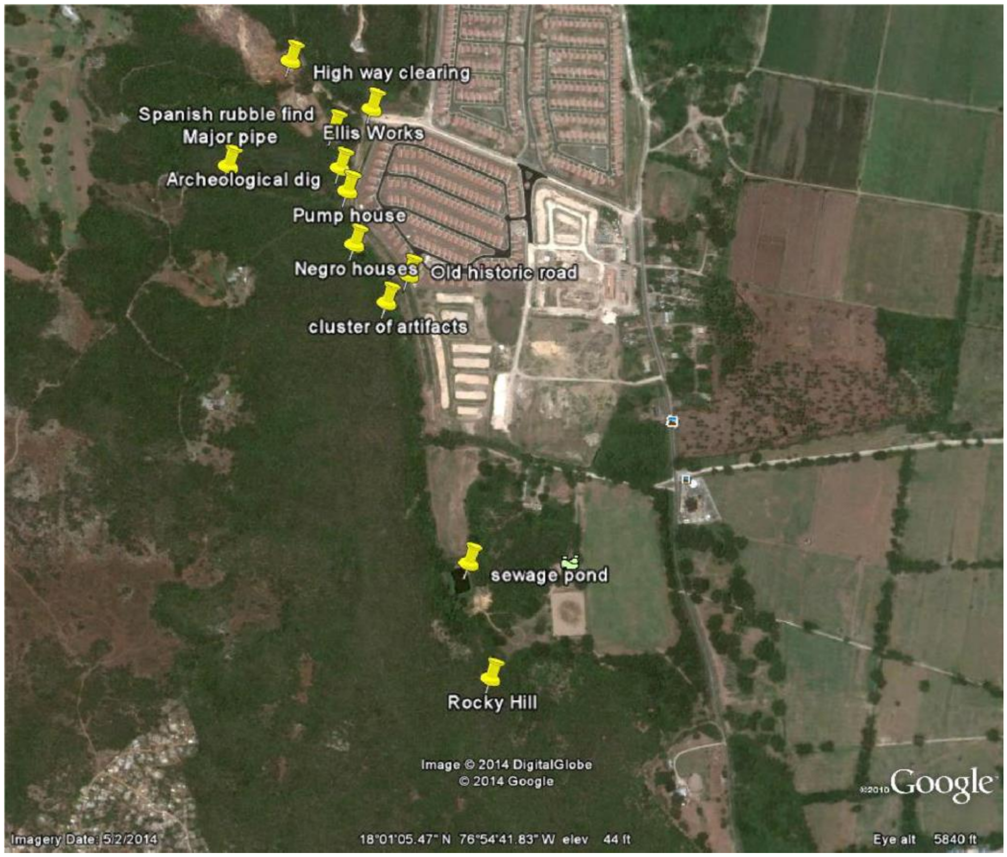

Figure 72 Satellite image showing points of interest

2.4.2.3 Find

The inventory exercise revealed the presence of three main material types, namely, clay, glass and metal. The material types were further subdivided into ware groups. The total number of pieces collected from this site was twenty-six pieces. These pieces can be divided into three periods; prehistoric, historic and modern.

Most of the artefacts recovered were sherds. The dates of the artefacts found ranged from 650 AD to the 20thCentury.

3.0 IDENTIFICATION AND ASSESSMENT OF POTENTIAL IMPACTS AND MITIGATION

3.1 PHYSICAL

3.1.1 Geology

Typically with road construction there will be a number of physical impacts arising from the change in topography from natural (baseline) terrain to a flattened compacted road surface running along the proposed alignment. These include:

1. A change to the elevations along the physical footprint of the alignment including the right of way. This is mainly due to grading, benching and filling to stabilize the road. The engineering design of the road optimizes the stability of the slope (mainly by run shortening or terracing of the slope) as a result of these earth works, so that the main indirect impact of this is expected to be related to the visual effect from a natural environment to a highway.

2. Potential effects on habitat fragmentation as a result of the physical presence of the road and terrain change are expected to be off-set by the fact that the alignment is traversing a natural boundary between the limestone hillside and the alluvial plain.

3. Slope modification and compaction along the road alignment as well as design drainage engineering at the crossings will modify the natural drainage system by reducing infiltration along the physical footprint of the paved surface and by increasing sheet flows on the surface. No surface expressions of sinkholes have been noted along the new alignment. The engineered drainage specifically provides for transmission of stormwater down slope of the roads and tie-in to pre-existing drainage networks. Due to the fact that the bedrock along the alignment tends to be rubbly, care will have to be taken to

maintain the diameter of the culverts so that they do not become blocked by colluvial debris over time.

3.1.2 Drainage and Hydrology

In the higher reaches of the new alignment (on the limestone plateau approaching the golf course, from about match line 3500) there is some potential for there to be subterranean karstic cavities or depressions. Underground drainage on the plateau is generally well-developed, although the development of the polje (upland karstic floodplain or interior valley) at the Caymanas Golf Course indicates that there is also the potential for the underground sinks to be become blocked. How the golf course has impacted the hydrology of the natural polje system and surrounding areas lies outside the scope of this assessment, but it is likely that engineered drainage has taken mitigated any potential adverse effects.

Potential impacts associated with the re-alignment and implementation of the highway may include:

- Recharge paths for surface run-off may be traversed by the alignment, decreasing the volume of run-off reaching the sinkholes;
- Surface run-off will become contamination due to oil spills. This problem may be more prone in areas where fuel stations are located;
- Operational risk of flooding as a result of smaller than required culverts. As concluded, some of the proposed culvert will need to be revised in order to ensure no localized flooding occurs at these particular crossings;
- Risk of increased flooding along the roadway during construction;
- Risk of indirect siltation of existing drains/gullies during construction and or heavy rainfall periods.

Actions can be taken to effectively reduce or prevent potential impacts identified. They are as follows:

- Consider the use of use detention ponds or retarding basins which aid in the reduction of the peak flows in the drains crossing the highway;

- A drainage and vegetated buffer area should be installed around and within the sinkhole drainage area to improve runoff water quality by filtration and adsorption of contaminants before direct discharge to sinkholes;
- Culverts and proper drainage should be implemented wherever the alignment crosses the surface run-off paths for the sinkholes to ensure the recharge area is not disturbed;
- Sedimentation basins or check dams should be taken into consideration upstream of culverts (with regular maintenance cleaning) to prevent siltation of the channel.

3.2 NATURAL HAZARDS

Increased risk from earthquakes. While the potential for earthquakes to occur will not change as a result of the project, the increase in vulnerability (based on investment, development of the road as a lifeline connecting communities as well as increased human use of the area) will result in an increase in the overall risk along the route. The alignment between the Mandela Interchange and Mount Gotham overlies a fault zone. If there is no further seismic activity along this fault in the foreseeable future, the fact that the limestone here is prone highly brecciated could potentially cause landslides in the future in areas where there might be increase slope loading as a result of poor drainage and heavy rainfall. This is off-set by the fact that there will be engineered storm water drainage to mitigate this, and by the fact that this limestone brecciate is likely to re-cement and be quite stable. If there is further seismic activity, ground shaking can potentially result in disruption of the surface. In the lower elevation areas, where the alignment overlays alluvium, there is a potential for liquefaction during ground acceleration, particularly in areas where the soil is sandy and saturated.

3.3 PARTICULATES

3.3.1 Construction

Site preparation has the potential to have a two-folded direct negative impact on air quality of the surrounding residential area. The first impact is air pollution generated from the construction equipment and transportation. The second is from fugitive dust from the proposed construction areas and raw materials stored on site. Fugitive dust has the potential to affect the health of construction workers, the resident population and the surrounding vegetation.

Mitigation

1. Areas should be dampened every 4-6 hours or within reason to prevent a dust nuisance and on hotter days, this frequency should be increased.
2. Cover or wet construction materials such as marl to prevent a dust nuisance.
3. Where unavoidable, construction workers working in dusty areas should be provided and fitted with N95 respirators.

3.3.2 Operation

With the anticipated increase in vehicular traffic it is expected that the level of particulate, NOx and SO2 will increase. Sources of particulate include dust from brakes, tyre wear and from off the vehicular body. However, the impact is expected to be minor.

Mitigation

1. Keep the surface and soft shoulders clean of fugitive dust particles.

3.4 NOISE

3.4.1 Construction

Site clearance for the proposed cemetery necessitates the use of heavy equipment to carry out the job. These equipment include bulldozers, backhoes, excavators etc. These possess the potential to have a direct negative impact on the noise climate. Noise directly attributable to site clearance activity should not result in noise levels in the residential areas to exceed 55dBA during day time (7am – 10 pm) and 50dBA during night time (10 pm – 7 am). Where the baseline levels are above the stated levels then it should not result in an increase of the baseline levels by more than 3dBA.

Construction noise can result in short-term impacts of varying duration and magnitude. The construction noise levels are a function of the scale of the project, the phase of the construction, the condition of the equipment and its operating cycles, the number of pieces of construction equipment operating concurrently. To gain a general insight into potential construction noise impacts that may result from the project, the typical noise levels associated with various types of construction equipment are identified in Table 22.

Table 22 Typical construction equipment noise levels

Type of Equipment	Typical Sound Level at 50 ft. (dBA Leq.)
Dump Truck	88
Portable Air Compressor	81
Concrete Mixer (Truck)	85
Jackhammer	88
Scraper	88
Bulldozer	87
Paver	89
Generator	76
Piledriver	101
Rock Drill	98
Pump	76
Pneumatic Tools	85
Backhoe	85

Adapted from - Route 101A Widening and Improvements, City of Nashua Hillsborough County, New Hampshire; McFarland-Johnson, Inc. May 30, 2007

Recommended Mitigation:

i. Use equipment that has low noise emissions as stated by the manufacturers.
ii. Use equipment that is properly fitted with noise reduction devices such as mufflers.
iii. Use temporary noise shields, noise blankets and noise walls to interrupt the line of sight to receptors.
iv. Operate noise-generating equipment during regular working hours (e.g. 7 am – 7 pm) to reduce the potential of creating a noise nuisance during the night.

Construction workers operating equipment that generates noise should be equipped with noise protection. A guide is workers operating equipment generating noise of ≥ 80 dBA (decibels) continuously for 8 hours or more should use ear muffs. Workers experiencing prolonged noise levels 70 - 80 dBA should wear earplugs.

3.4.2 Operation

The noise impact from the proposed highway was predicted using SoundPlan Model 7.3. The traffic data used were those used for the original EIA. The noise levels at 8 locations to be generated by vehicles using the realigned highway were investigated. The results were compared with the NEPA standard, Ldn and CNEL guidelines and reported in Table 23, Table 24 and Table 25 respectively. When the predicted noise levels were compared with the NEPA day and night time standards, only Stations N2 and N3 were compliant with both standards and Station N7 during the day.

Table 23 Predicted traffic noise levels compared to NEPA day and night time standards

LOCATION	PREDICTED DAY TIME LEVEL (dBA)	NEPA DAY TIME STANDARD (dBA)	PREDICTED NIGHT TIME LEVEL (dBA)	NEPA NIGHT TIME STANDARD (dBA)
N1	**60.9**	55	**59.4**	50
N2	47.7	55	46.2	50
N3	49.2	55	47.7	50
N4	**56.0**	55	**54.6**	50
N5	**52.8**	55	**51.4**	50
N6	**67.5**	65	**66.1**	60
N7	54.7	55	**53.3**	50
N8	**60.3**	55	**58.8**	50

NB: Numbers in red and bold exceed the NEPA standards

Only Stations N2, and N3 were compliant with the USEPA guideline.

Table 24 Predicted L_{dn} levels compared to USEPA guidelines

LOCATION	PREDICTED L_{dn} (dBA)	USEPA L_{dn} Guideline (dBA)
N1	**66.4**	<55
N2	53.2	<55
N3	54.7	<55
N4	**61.6**	<55
N5	**58.4**	<55
N6	**73.1**	<55
N7	**60.3**	<55
N8	**65.8**	<55

The US Department of Housing and Urban Development (HUD) has established guidelines (Standard 24 CFR 51 B) for evaluating noise impacts on residential projects seeking financial support under various grant programs (44 FR 135:40860-40866, January 23, 1979). Sites are generally considered acceptable for residential use if they are exposed to outdoor Ldn values of 65 dB or less, "normally unacceptable" if they are exposed to outdoor Ldn values of 65-75 dB and unacceptable if they are exposed to outdoor Ldn values above 75 dB. When, the Ldn levels are compared with this guideline, Stations N1, N6 and N8 were non-compliant hence unacceptable for residential use (Table 25).

Table 25 Predicted L_{dn} levels

LOCATION	PREDICTED L_{dn} (dBA)
N1	**66.4**
N2	53.2
N3	54.7
N4	61.6
N5	58.4
N6	**73.1**
N7	60.3
N8	**65.8**

Mitigation:

1. Ensure that a properly designed noise wall/barrier is erected in areas of residential development to ensure that the noise levels emitted from the vehicles that use the realigned section comply with the NEPA standards and community noise descriptors at the residential areas.

3.5 VIBRATION

3.5.1 Construction

Construction activities often generate vibration complaints. This may be as a result of interfering with persons normal routines/activities. This can become more acute if the community has no understanding of the extent and duration of the construction. This can lead to misunderstandings if the contractor is considered to be insensitive by the communities although he may believe he is in compliance with the required conditions/ordinances.

Construction activities can result in various degrees of ground vibration. This is dependent on the type of equipment used and the methodologies employed.

Various governmental agencies have criteria regarding architectural and structural damage, as well as annoyance and acceptability of vibration. In general, most of the criteria specify that for a PPV less than approximately 3.048 mms^{-1} (0.12 inches per second), the potential for architectural damage due to vibration is unlikely. A PPV of approximately 3.048 mms^{-1} (0.12 inches per second) to 12.7 mms^{-1} (0.50 inches per second) there is potential for architectural damage due to vibration, and for a PPV greater than approximately mms^{-1} (0.50 inches per second) the potential for architectural damage due to vibration is very likely.

Human beings are known to be very sensitive to vibration, the threshold of perception being typically in the PPV range of 0.14 mms^{-1} to 0.3 mms^{-1} (British Standard BS 5228-2:2009). An indication of the effects of ground vibration on humans is detailed by the standard and detailed in Table 26.

Table 26 Guidance on the effects of vibration

VIBRATION LEVEL	EFFECT
0.14 mms^{-1}	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3 mms^{-1}	Vibration might be just perceptible in residential environments.
1.0 mms^{-1}	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents.
10 mms^{-1}	Vibration is likely to be intolerable for any more than a brief exposure to this level.

Source: (British Standard BS 5228-2:2009)

The effects of construction vibration (both on humans and buildings) is summarized in Table 27.

Table 27 Effects of Construction Vibration

PEAK PARTICLE VELOCITY (mm/sec)	EFFECTS ON HUMANS	EFFECTS ON BUILDINGS
< 0.127	Imperceptible	No effect on buildings
0.127 – 0.381	Barely perceptible	No effect on buildings
0.508 – 1.27	Level at which continuous vibrations begin to annoy in buildings	No effect on buildings
2.54 – 12.7	Vibrations considered unacceptable for people exposed to continuous or long-term vibration	Minimal potential for damage to weak or sensitive structures
12.7 – 25.4	Vibrations considered bothersome by most people, however tolerable if short-term in length	Threshold at which there is a risk of architectural damage to buildings with plastered ceilings and walls. Some risk to ancient monuments and ruins.
25.4 – 50.8	Vibrations considered unpleasant by most people	U.S. Bureau of Mines data indicates that blasting vibration in this range will not harm most buildings. Most construction vibration limits are in this range.
>76.2	Vibration is unpleasant	Potential for architectural damage and possible minor structural damage

Vibrations from various types of construction equipment under a wide range of construction activities have been measured by the Federal Transit Administration (FTA) in the United States. The data in Table 28 provides a reasonable estimate for a wide range of soil conditions. Additional data on other equipment are represented in Table 29 were obtained from measurements on several projects including the Central Artery/Tunnel Project in Boston and from several published sources including the FTA Manual and Dowding's Textbook.

Table 28 Vibration source levels for construction equipment (from measured data)

Table 12-2. Vibration Source Levels for Construction Equipment (From measured data.[7,8,9,10])			
Equipment		**PPV at 25 ft (in/sec)**	**Approximate L_v† at 25 ft**
Pile Driver (impact)	upper range	1.518	112
	typical	0.644	104
Pile Driver (sonic)	upper range	0.734	105
	typical	0.170	93
Clam shovel drop (slurry wall)		0.202	94
Hydromill (slurry wall)	in soil	0.008	66
	in rock	0.017	75
Vibratory Roller		0.210	94
Hoe Ram		0.089	87
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	86
Jackhammer		0.035	79
Small bulldozer		0.003	58
† RMS velocity in decibels (VdB) re 1 micro-inch/second			

Source: FTA (2006)

To predict the vibration at a receptor from the operation of the equipment listed in Table 28, the following equation is used:

$$PPV_{equip} = PPV_{ref} \times (25/D)^{1.5}$$

where: PPV (equip) is the peak particle velocity in in/sec of the equipment adjusted for distance

PPV (ref) is the reference vibration level in in/sec at 25 feet from Table 12-2

D is the distance from the equipment to the receiver.

Table 29 Equipment Vibration Emission Levels

Equipment Description	Vibration Type Steady or transient	Ref PPV at 100 ft.
Auger Drill Rig	Steady	0.011125
Backhoe	Steady	0.011
Bar Bender	Steady	N/A
Boring Jack Power Unit	Steady	N/A
Chain Saw	Steady	N/A
Compactor	Steady	0.03
Compressor	Steady	N/A
Concrete Mixer	Steady	0.01
Concrete Pump	Steady	0.01
Concrete Saw	Steady	N/A
Crane	Steady	0.001
Dozer	Steady	0.011
Dump Truck	Steady	0.01
Excavator	Steady	0.011
Flat Bed Truck	Steady	0.01
Front End Loader	Steady	0.011
Generator	Steady	N/A
Gradall	Steady	0.011
Grader	Steady	0.011
Horizontal Boring Hydraulic Jack	Steady	0.003
Hydra Break Ram	Transient	0.05
Impact Pile Driver	Transient	0.2
Insitu Soil Sampling Rig	Steady	0.011125
Jackhammer	Steady	0.003
Mounted Hammer hoe ram	Transient	0.18975
Paver	Steady	0.01
Pickup Truck	Steady	0.01
Pneumatic Tools	Steady	N/A
Scraper	Steady	0.000375
Slurry Trenching Machine	Steady	0.002125
Soil Mix Drill Rig	Steady	0.011125
Tractor	Steady	0.01
Tunnel Boring Machine (rock)	Steady	0.0058
Tunnel Boring Machine (soil)	Steady	0.003
Vibratory Pile Driver	Steady	0.14
Vibratory Roller (large)	Steady	0.059
Vibratory Roller (small)	Steady	0.022
Welder	Steady	N/A
Concrete Batch Plant	Steady	N/A
Pumps	Steady	N/A
Blasting	Transient	0.75
Clam Shovel	Transient	0.02525
Rock Drill	Steady	0.011125
3-ton truck at 35 mph	Steady	0.0002

Source: ATS Consulting (2013)

To predict the vibration at a receptor from the operation of the equipment listed in Table 29, the following equation is used:

$$PPV_{equipment} = PPV_{ref} (100/D_{rec})^n$$

Where:

PPV_{ref} = reference PPV at 100 ft.
D_{rec} = distance from equipment to the receiver in ft.
n = 1.1 (the value related to the attenuation rate through ground)

The closest receptor to the highway construction at Caymanas Estates Phase 1 is approximately 709.46 feet (216.24 m) and at Phase II 58.71 feet (17.89 m).

The vibration impact was predicted on the closest receptors with the use of twelve (12) pieces of construction equipment (Table 30).

Table 30 Predicted vibration levels at the closest receptors in Caymanas Estates in PPV in/sec and PPV mm/sec in brackets

EQUIPMENT	PHASE 1 RECEPTOR VIBRATION	PHASE II RECEPTOR VIBRATION
Pile Driver (Impact)	0.010 (0.25)	0.422 (10.72)
Blasting	0.087 (2.21)	1.347 (34.21)
Vibratory Roller	0.0014 (0.04)	0.058 (1.47)
Large Bulldozer	0.00059 (0.015)	0.025 (0.64)
Small Bulldozer	0.0000198 (0.0005)	0.00083 (0.021)
Loaded Truck	0.0005 (0.0127)	0.021 (0.533)
Jack Hammer	0.00023 (0.0058)	0.0097 (0.246)
Back Hoe	0.0013 (0.033)	0.02 (0.508)
Dump Truck	0.0012 (0.0305)	0.018 (0.457)
Frontend Loader	0.0013 (0.033)	0.02 (0.508)
Grader	0.0013 (0.033)	0.02 (0.508)
Paver	0.0012 (0.0305)	0.018 (0.457)

Comparing these level with the British Standard from a human standpoint, only blasting would most likely cause a complaint in Phase I (closest receptor) and most other equipment use would result in no vibration being perceived except with pile driving on which might just be perceptible. At Phase II (closest receptor), with the exception of a small bulldozer and the jack hammer (borderline), vibration from all other equipment would be perceptible. In fact, the levels of which will start to result in complaints.

From a building standpoint, only the blasting might have an impact on buildings. At that level (PPV 2.21 mm/sec), it would have minimal potential for damage to weak or sensitive structures. The development at Caymanas Phase I is relatively new and is expected to be well engineered hence no potential damage is foreseen. For Phase II, pile driving and blasting are the only activities which have the potential to cause damage to buildings. With a PPV of 10.72 mm/sec, pile driving has minimal potential for damage to weak or sensitive structures, however, blasting (PPV of 34.21 mm/sec) will not harm most buildings as most construction vibration limits are in this range.

Mitigation

1. Design considerations and project layout:
    - Route heavily-loaded trucks away from residential streets, if possible. Select streets with fewest homes if no alternatives are available.
    - Operate earth-moving equipment on the construction lot as far away from vibration-sensitive sites as possible.
2. Sequence of operations:
    - Phase demolition, earth-moving and ground-impacting operations so as not to occur in the same time period. Unlike noise, the total vibration level produced could be significantly less when each vibration source operates separately.
    - Avoid nighttime activities. People are more aware of vibration in their homes during the nighttime hours.
3. Alternative construction methods:
    - Avoid impact pile-driving where possible in vibration-sensitive areas. Drilled piles or the use of a sonic or vibratory pile driver causes lower vibration levels where the geological conditions permit their use.

- Select demolition methods not involving impact, where possible.
- Avoid vibratory rollers near sensitive areas.

4. Do pre blast surveys to document structure conditions in the Caymanas Estates.
5. Ensure blasting is conducted by a licenced blaster.
6. Have regular meetings or devise a communication strategy to inform the residents of construction activities.

3.5.2 Operation

Occasionally, transportation agencies receive complaints from residents living near roads about annoying or even structurally-damaging traffic-induced vibration.

Traffic-induced vibration is either ground-borne vibration and air-borne vibration or a combination of both. Site specific factors influence vibration levels. These include the characteristics of the highway traffic flow, unevenness of pavement surface, transmission path between the source and the receiver, and building parameters. In extreme circumstances, traffic-induced ground-borne vibration may be perceptible to residents living near roads. However, it is very unlikely to result in damage to residential buildings. Air-borne vibration may increase sound levels inside residences due to the resonance of light building components. The vibration of these components can also contribute to the feeling of vibration inside a room (Hajek J, Chris T. Blaney and David K. Hein 2006).

Ground-borne vibration is caused by the dynamic impact forces of tyres on the pavement surface that can propagate and excite footings and foundation walls below ground. Vibration of footings and foundation walls can induce vibration in other building components below or above ground.

Air-borne vibration is caused by low frequency sound that can excite building components above ground.

There are three basic types of dynamic tyre forces acting on the pavement surface simultaneously (Figure 73). These are:

1. ***Impact forces of the individual parts of the tyre tread***. The impact frequency of these forces on the pavement, at highway speeds, is typically in the range of 800 to 1500 Hz, depending on the pavement macrotexture and on the tyre tread pattern. Although the forces associated with the individual parts of the tyre tread are significant producers of pavement-tyre noise, their contribution to the ground-borne vibration is negligible.
2. ***Impact forces linked to the unsuspended mass of the vehicle***. The unsuspended vehicle mass is the mass below the vehicle suspension system, mainly axles, wheels, and tyres. At highway speeds, a specific part of the tyre comes into contact with the pavement surface about 10 to 15 times per second. This frequency is related to the frequency of the tyre bounce (also called axle hop).
3. ***Impact forces linked to the fundamental frequency of trucks***. At highway speeds, a typical 5-axle tractor semi-trailer has the fundamental frequency of the suspended mass of about 1 or 2 Hz. Thus, the suspended mass (the part of the truck supported by the suspension system) heaves up and down about 1 or 2 times per second as the truck moves at highway speeds. When the truck heaves down, its static weight on the pavement increases due to the dynamic motion component.

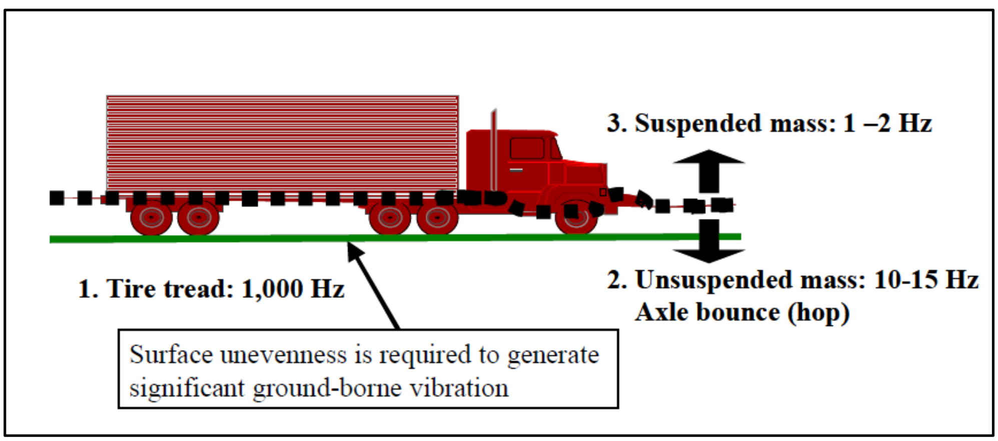

Figure 73 Source of vibration caused by a truck

The three types of tyre impact forces interact and produce ground-borne vibration with the dominant frequency, at highway speeds, between 10 and 15 Hz.

Air-borne vibration is caused by low frequency sound, produced by engines and exhaust systems of large diesel trucks, which can excite building components above ground. The fundamental frequency of truck exhaust systems (engine combustion and firing) is typically 50 to 200 Hz, and this frequency may correspond to the fundamental frequency of light building components.

There is a correlation between the way people perceive highway noise and highway traffic induced vibration. With the increase of sound level, the number of people who complain about high noise level increases and so does the number of people who complain about vibration. Sound and vibration caused by the same source also interact. For example, sound may result in vibration of a window pane and the pane may rattle. Or, in an extreme case, ground-borne vibration can vibrate room surfaces, such as a floor, and produce ground-borne noise in the form of rumbling sound.

There is a potential for vibration nuisance from vehicular traffic traversing the highway on proximity to the Caymanas Phase Estates II, particularly from the heavy duty vehicles.

Mitigation:

1. Ground-borne vibration induced by highway traffic can be effectively controlled by the maintenance of smooth roadway surfaces.
2. The solution for air-borne vibration is increasing the sound transmission loss of exterior walls, doors and windows, tightening of loose elements of a building or a room, and making the interior of rooms more sound absorbing.
3. Erect signs reminding drivers of the heavy duty vehicles not to use their jake brakes unnecessarily.

3.6 BIOLOGICAL

3.6.1 Vegetation

3.6.1.1 Perceived Impacts to the Highland Areas (Zones 1 & 2)

Habitat fragmentation and the loss of endemic species are the two main ecological threats posed by the planned roadway development, especially on the highland areas during construction and operational phases. Other potential impacts include increased surface runoff of rainwater and sediment; the encouragement of urban sprawl and increased human intrusion into previously untouched areas.

3.6.1.2 Perceived Impacts to the Lowland Areas (Zone 3)

The vegetation located in the lowland areas exhibited signs of noticeable human modification (with several agricultural and residential developments) and as such, the natural ecological habitat was already degraded in these locations. Therefore, the vegetation here should be the least affected by the highway development.

However, care should be noted regarding the *S. saman* trees (mentioned above) and *Roystonea altissima* palm based on their ecological role and endemism respectively. In fact, trees over 18 cm DBH should be carefully assessed before their removal.

It should also be noted that the vegetation along the west-bound side of the Mandela Highway borders a water-way and a cemetery and it may be advised to limit expansion works to the east-bound leg.

3.6.1.3 Habitat Fragmentation

Habitat fragmentation is the process whereby a large, continuous area of habitat is both reduced in area and divided into two or more fragments by roads, fields, towns and many other human constructs (Primack, 2006). These fragments are often isolated from each other by a highly modified or degraded landscape and their edges experience an altered set of microclimate conditions called "edge-effect". Edge effect refers to the variation in the observed microenvironment at the fragment edge. Differences in microclimate factors such as light, temperature, wind and humidity may each significantly impact species composition and vigour within the fragment.

Fragmentation normally occurs during circumstances of severe habitat loss where (for example) large areas of natural vegetation may be cleared for agricultural or residential developments. However, it may also occur when the area of disturbance is reduced to a minor degree: such as roadway developments similar to this project. Comparatively, the clearance needed for a roadway is much less than that needed for agriculture; nonetheless, the thoroughfare may induce the following habitat destructive issues:

- Roadways may act as physical barriers to the passive movement of spores and seeds across a landscape.
- Highways may also restrict the movement of animal species that often act as pollen and seed vectors for many plants
- Roadways help to divide once continuous populations into smaller, more isolated, contiguous populations due to restrictions on the movement of spores and seeds. This may precipitate further population decline due to inbreeding depression, genetic drift and other issues common to small population size.
- Fragments may also experience the increased incidence of fire due primarily to the increased penetration of wind, reduced humidity, higher temperatures and the accumulation of drying wood from dying or dead trees expected at fragment-edges (Primack, 2006). Commuters along highways may also dispose of flammable debris along the corridor, further contributing to this risk.
- Fragmentation may also lead to increased vulnerability of the fragment to invasion by exotic and native pest species as well as diseases.

Mitigation:

1. Limit rights-of-passage to areas already showing noticeable signs of habitat degradation. For example areas with open fields, pastureland, low endemism and areas of agricultural or isolated residential development.
2. Incorporate at regular intervals engineering solutions that would help minimise habitat fragmentation such as tunnels and/or bridges especially at higher elevations. These structures would help reduce population isolation by providing links between potentially fragmented habitats (Primack, 2006; Smith & Smith, 2006). They would also minimise the impact of vegetation removal. Comparatively, highway developments that do not incorporate these features may result in higher incidences of population isolation; complete vegetation removal within the swath of the rights-of-way; as well as further habitat degradation from engineered land modifications, designed to suitably grade the highway.
3. It is understood, however, that fencing may be a necessary feature of this development so as to limit the disposal of solid waste into the plant communities as well as restrict the encroachment of humans and livestock.

3.6.1.4 Accidental or intentional removal of important plant species

Over 56 plant species were encountered, including *Agave* and Bromeliad species, during the field excursion: six were endemic. Therefore, the area could be considered species rich with an indigenous component – important to the local environment and the natural history of the country.

Mitigation:

1. The removal of the endemic species should be avoided.
2. If removal is necessary, a nursery should be established for the maintenance and propagation of these and other naturally occurring plants. These plants may later be reintroduced into the forest or used for landscaping and other aesthetic purposes.

3. The development should be fenced to impede human and livestock access to the adjacent vegetation through which the highway runs.
4. Relocation of the highway, alternate to Location L, should be considered.

3.6.1.5 Human Encroachment, Urban Sprawl and Control of Invasive Species

The study site, although disturbed, is species rich and possesses a relatively high tree density. Therefore, minimising the impact on the flora during the construction phase of the development is important. This impact may continue also into the operation phase of the project. Furthermore, as in any land modification project, the clearing of natural vegetation allows the intrusion of invasive plant and animal species into the development site.

Mitigation:

1. A proper plan should be developed concerning transportation routes and storage for equipment and material.
2. The proposed post construction or operation road network should be kept simple as well as be used throughout the preparation and construction phases of the project.
3. A buffer area should be established and maintained between the project area and the surrounding limestone forest.
4. Fencing of exposed points to human and ruminant entry should reduce their intrusion.
5. Proper planning regarding access points to the construction site should be established.
6. Further planning will be required for the establishment of development zones within nearby lands, villages and towns. This should direct controlled or prohibited development of nearby areas.

3.6.1.6 Increased soil/substrate erosion

The potential for land slippage is greatly increased as a result of vegetation removal. A plant's roots act as a mesh within the substrate increasing its cohesiveness and improving drainage. Areas where bare ground is exposed tend to erode faster than areas inhabited by plants as they help percolate rainwater into the substrate below and into underground aquifers. The substrate of the elevated areas was comprised mainly of limestone rock, which readily succumbs to weathering over time by rainfall and flowing water. Therefore, there could also be a resulting shift in the level of the water table as a result of plant removal.

Mitigation:

1. If possible, trees with trunks of DBH 20cm and greater should be left intact.
2. Remove trees only as would be necessary. Hence a proper procedure should be developed as to site preparation prior to project initiation.

3.6.1.7 Storage and transportation of raw materials

Plant growth and health can be significantly affected by dust, grime and toxic emissions. Leaching from storage areas can disturb the pH balance in the soil and result in plant loss. Owing to the fact that the main substrate type (especially in elevated areas) was porous limestone rock, any chemical/material spills may quickly reach the underlying water table.

Mitigation:

1. A central area should be designated for the storage of raw materials. This area should be lined in order to prevent the leakage of paints and chemicals into the sediment.
2. In terms of transporting equipment, the paths of the planned roadways should be used, rather than creating temporary pathways just for equipment access.

3.6.1.8 Increased human and invasive species access

As in any development, the clearing of natural vegetation allows the intrusion of invasive plant and animal species into the development site.

Mitigation:

1. A buffer area should be established and maintained between the project area and the surrounding limestone forest. Fencing will most likely be necessary.
2. Fencing of exposed points to human and ruminant entry should reduce their intrusion.
3. Proper planning regarding access points to the construction site should be established.

Further policy planning will be required for the establishment of development zones within nearby lands, villages and towns. This should direct controlled or prohibited development of nearby areas.

3.7 PROXIMITY OF THE HIGHWAY TO THE HOUSING DEVELOPMENT

3.7.1 Construction

The proposed highway realignment will result in a section of Caymanas Country Club – Phase II Block C being impacted and approximately 3 lots will be impacted and approximately 100 metres of the western perimeter wall will be demolished and rebuilt to accommodate the realigned highway. The demolishing of the perimeter wall has the potential to create a security risk for the residents in Phase II.

Mitigation:

1. Identify the home owners whose home will be demolished from early and begin dialogue.
2. Arrange for the replacement of these homes, preferably located in the Caymanas Country Club once the owners agree.

3. Construct the new perimeter wall before demolishing the existing section that will be removed.
4. Ensure that security will not be breached, and if that will occur provide alternative security arrangements.
5. Have regular meetings with the community to inform them of the progress of the construction.

3.7.2 Operation

In addition, to the potential noise and vibration impacts detailed previously, the construction of the highway has the potential to have a visual impact.

Mitigation

1. The replacement perimeter wall should be finished to a similar condition or better than the existing wall.
2. Ensure that the area is landscaped.

3.8 HERITAGE

The rich artefact assemblage observed along the old access road is an indication that the archaeology of the area merits some attention. The potential for these to be lost during the construction of the proposed realigned section of the North South Highway.

Mitigation:

We recommend that a Watching Brief be carried out at the time of clearing so that salvaging of artefacts can take place.

3.9 TRAFFIC

3.9.1 Construction

During the construction of the realigned highway there will be disruptions in the normal traffic flow due to construction activities and realignment of the existing Caymanas Bay roadway. This will cause inconvenience to the travelling public which may include longer travel time. Additionally, there will be an increase in vehicular traffic in the area especially those of heavy duty vehicles which may increase the potential for vehicular accidents.

Mitigation:

1. Inform the public of the pending traffic changes at least one month prior. This could be in the form of a public meeting. Additionally, both the print and electronic media should be used.
2. Ensure that the disruptions and waiting times are kept to a minimum.
3. Ensure that adequate signage and flagmen are used along the route.
4. Develop a traffic management plan beforehand.
5. Ensure that the heavy duty vehicles obey the traffic code.
6. Do not park or operate the construction vehicles in a manner that will restrict or disrupt the flow of traffic along the existing roadways.

3.9.2 Operation

The operation of the highway is not expected to have a negative impact on the existing traffic flows within the Caymanas Bay area or along the Mandela Highway (Appendix 3).

4.0 REFERENCES

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5.0 APPENDICES

Appendix 1 Noise calibration certificate

3M Oconomowoc
Personal Safety Division

3M Detection Solutions
1060 Corporate Center Drive
Oconomowoc, WI 53066-4828
www.3M.com/detection
262 567 9157 800 245 0779
262 567 4047 Fax

Page 1 of 2

3M

Certificate of Calibration

Certificate No: 5507895QIG030085

Submitted By: C.L. ENVIRONMENTAL CO

22 FORT GEORGE HEIGHTS, OLD STONY HILL RD, KINGSTON 9, JAMAICA

Serial Number: QIG030085
Customer ID:
Model: QC-10 CALIBRATOR

Date Received: 9/11/2014
Date Issued: 9/17/2014
Valid Until: 9/17/2015

Test Conditions:
Temperature: 18°C to 29°C
Humidity: 20% to 80%
Barometric Pressure: 890 mbar to 1050 mbar

Model Conditions:
As Found: IN TOLERANCE
As Left: IN TOLERANCE

SubAssemblies:
Description: **Serial Number:**

Calibration Procedure: 56V981

Reference Standard(s):

I.D. Number	Device	Last Calibration Date	Calibration Due
ET0000556	B&K ENSEMBLE	12/15/2013	12/15/2014
T00230	FLUKE 45 MULTIMETER	2/14/2014	2/14/2016

Measurement Uncertainty:
+/- 1.1% ACOUSTIC (0.1DB) +/- 1.4% VAC +/- 0.012% HZ
Estimated at 95% Confidence Level (k=2)

Calibrated By: James Neuman 9/17/2014
JAMES NEUMAN **Service Technician**

Reviewed/Approved By: 9/17/2014
Technical Manager/Deputy

This report certifies that all calibration equipment used in the test is traceable to NIST or other NMI, and applies only to the unit identified under equipment above. This report must not be reproduced except in its entirety without the written approval of 3M Detection Solutions.

098-393 Rev. B

An ISO 9001 Registered Company
ISO 17025 Accredited Calibration Laboratory
ACCREDITED

3M Oconomowoc
Personal Safety Division

3M Detection Solutions
1060 Corporate Center Drive
Oconomowoc, WI 53066-4828
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262 567 9157 800 245 0779
262 567 4047 Fax

3M

Certificate of Calibration

Certificate No: 5507895QIG030085

(A) indicates out of tolerance condition

Test Type	Nominal	Tolerance-	Tolerance+	As Found	As Left	Unit
AC OUT/1kHz	1.000	0.950	1.050	1.000	1.000	VAC
Calibration	114.0	113.7	114.3	113.8	114.0	dB
Frequency	1000	980	1020	1001	1001	Hz

* indicates non accredited

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Calibration Laboratory

Appendix 2 Vegetation Species Encountered in the Three Survey Zones

Species	Common name	DAFOR (Zone 1)	DAFOR (Zone 2)	DAFOR (Zone 3)	Growth form
Achyranthes indica	Devil's Horse-whip			F	Herbs
Amaranthus crassipes			R		
Croton lobatus		R			
Cynodon dactylon	Bermuda Grass		O	A	
Cyperus sp.			R-O	O	
Musa sapientum	Banana		R		
Panicum maximum	Guinea Grass	F	A	F	
Petiveria alliacea	Guinea Hen Weed	O			
Pistia stratiotes	Water Lettuuce		R		
Sansevieria trifasciata	Tiger Cat	O			
Stachytarpheta jamaicensis	Vervine			O	
Stenotaphrum secundatum	Crab Grass		F		
Antigonon leptopus	Coralita		O	O	Scramblers / Twiners / Climbers / Ephiphytes
Cleome viscosa	Wild Caia	O	A	F	
Clitoria ternatea	Blue Pea			R	
Hohenbergia sp.			R	R	
*Hylocereus triangularis**	God Okra, Prickle Withe	O-F	O	O	
*Ipomoea lineolata**		O			
Ipomoea sp.			R	O	
*Ipomoea ternata**		O			
Passiflora maliformis	Sweet Cup			R-O	
Paullinia jamaicensis	Supple Jack	R			
Phaseolus sp.		R			
Tillandsia sp.		R	O		
Trichostigma octandrum	Basket Withe	R			

Species	Common name	DAFOR (Zone 1)	DAFOR (Zone 2)	DAFOR (Zone 3)	Growth form
Urechites lutea	Nightshade, Nightsage	O-F	O	O	
Abutilon abutiloides		F		F-A	Shrubby Herbs
Mimosa pudica	Shame-o-lady			O	
Urena lobata	Ballard Bush	F	O		
Acalypha wilkesiana	Copper Leaf		R		Shrubs
Agave sobolifera	May Pole	F	O		
Allamanda cathartica	Yellow Allamanda	O			
Amyris plumieri	Candlewood	O	A		
Ateramnus lucidus	Crab Wood	F-A	F		
Bromelia penguin	Pingwing	O-F	F		
Bunchosia media		F	F		
Calotropis procera	French Cotton			R-O	
Coccoloba krugii		R	R		
Croton linearis	Rosemary	R-O	R-O		
Croton lucidus	Basket Hoop	F			
Euphorbia nudiflora		O	R		
Pisonia aculeata	Cockspur	O	O	F	
Pithecellobium unguis-cati	Privet	R	R	O	
Ricinus communis	Castor Oil Plant, Oil Nut	O	F	O	
Schaefferia frutescens		R			
Sida acuta	Broomweed	O	R	O	
Solanum erianthum	Wild Susumber	R			
*Xylosma sp.**		R			
Acacia maracantha	Park Nut	O	R	R	Trees

Species	Common name	DAFOR (Zone 1)	DAFOR (Zone 2)	DAFOR (Zone 3)	Growth form
Acacia tortuosa	Wild Poponax	F	O-F	O-F	
Adenanthera pavonina	Red Bead Tree		R		
Albizia lebbeck	Woman's Tongue Tree			O	
Annona reticulata	Custard Apple		R		
Artocarpus altilis	Breadfruit			R	
Astrocasia tremula			R		
Bambusa vulgaris	Bamboo	O	R	F	
Bauhinia divaricata	Bull Hoof	F	O-F		
Blighia sapida	Ackee	O	F		
Bumelia sp.		R			
Bursera simaruba	Red Birch	F	F		
Canella winterana	Wild Cinnamon		O		
Capparis flexuosa	Bottle-Cod Root		O		
Cassia emarginata	Senna Tree	O	O	O	
Catalpa longissima	French Oak		O-F	F	
Ceiba pentandra	Silk Cotton Tree	R	O		
Comocladia pinnatifolia	Maiden Plum		R		
Cordia alba	Duppy Cherry	R	O	A	
*Cordia bullatta**		R			
Cordia sebestena	Scarlet Cordia	R			
Croton eluteria	Cascarilla Bark		O		
Delonix regia	Poinciana	R	F		
Guazuma ulmifolia	Bastard Cedar		O	F	
Haematoxylum campechianum	Logwood	F-A	O		
Leucaena leucocephala	Lead Tree	F	F	F-A	

Species	Common name	DAFOR (Zone 1)	DAFOR (Zone 2)	DAFOR (Zone 3)	Growth form
Malpighia glabra	Wild Cherry		O		
Mangifera indica	Mango		R		
Melicoccus bijugatus	Guinep		O-F		
Nectandra sp.		R	R		
Piscidia piscipula	Dogwood	R-O	O		
*Roystonea altissima**	Mountain Cabbage		R		
*Sabal jamaicensis**	Bull Thatch	O			
Samanea saman	Guango	O	F	F-A	
Spathodea campanulata	African Tulip Tree	F	O		
Tabebuia sp.		R			
Terminalia catappa	West Indian Almond		R-O		

**Endemic (Adams 1972 and Parker 2003)*

Appendix 3 Caymanas Interchange Traffic Assessment Report

Jamaica North South Highway Project

Caymanas Interchange
Traffic Assessment Report

Prepared for

China Communications Construction Co. LTD

Prepared by

Wang, Zhongren, Ph.D., P.E., T.E.

10008 Albacore Way

Elk Grove, CA 95757, USA

March 31, 2014

(Redone on Nov. 5, 2014)

Table of Contents

Chapter 3b THE TRUMPET CAYMANAS INTERCHANGE

3b.1 Lane Configurations

As shown in Figure 3-1, the intersection between the Jamaica North-South Highway (JNSH) and Mandela Highway is designed as a trumpet interchange. The Mandela Highway has two lanes in each direction; the JNSH also has two lanes in each direction. All ramps are single-lane ramps, except the two ramps to-and-from downtown Kinston to JNSH, which have two lanes. At the interchange, the design speeds for JNSH and all the ramps are 60, and 40 kph, respectively. The design speed for the Mandela Highway is 96 kph.

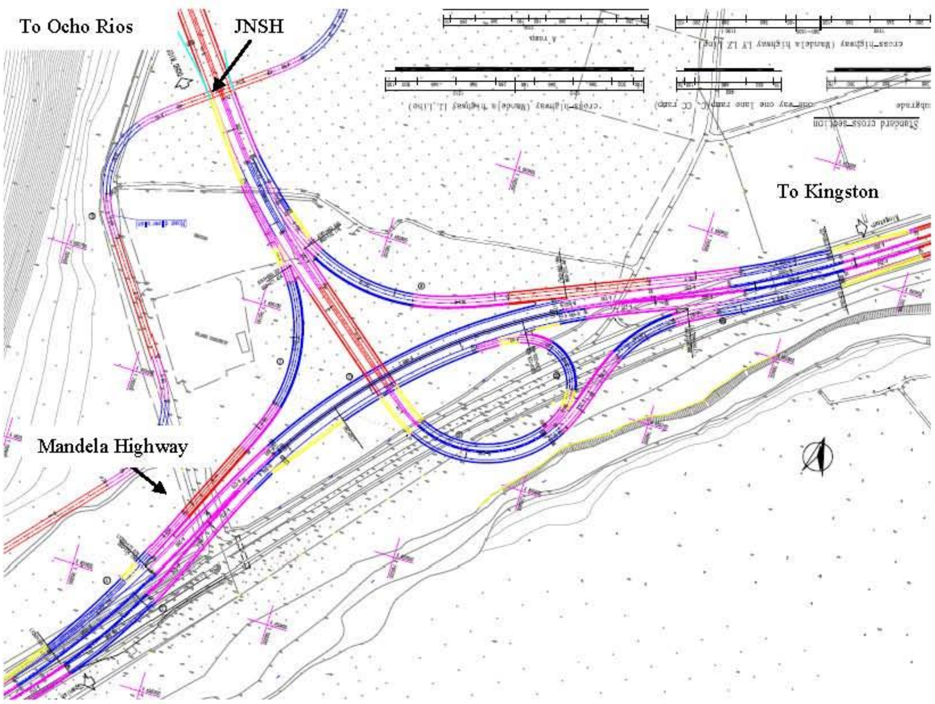
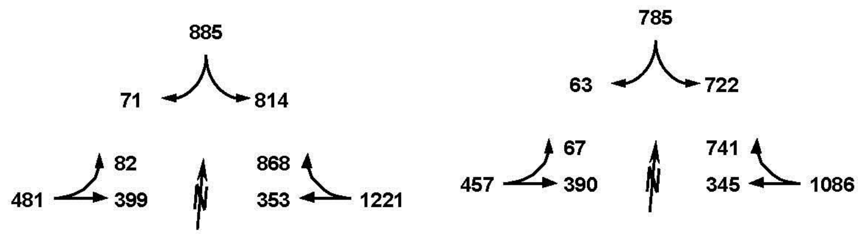


Figure 3b-1. The Trumpet Interchange with Mandela Highway.

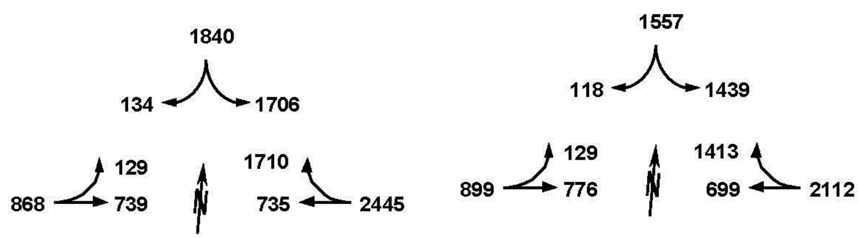
3b.2 Traffic Demand

The existing and 20-year forecast traffic demand by movement for the full cloverleaf interchange is shown in Figures 3b-2 and 3b-3, respectively. Both the morning and evening peak hour traffic volumes are shown. As it can be seen from Figures 3b-2 and 3b-3, the demand in the morning peak hour is generally higher than that in the evening peak hour. The traffic analyses are therefore performed based on the morning peak hour demand instead of the evening one.



AM peak turning movement (existing 2013) PM peak turning movement (existing 2013)

Figure 3b-2. The Existing Traffic Volumes at the Interchange with Mandela Highway.



AM peak turning movement (forecast 2033) PM peak turning movement (forecast 2033)

Figure 3b-3. The Forecasted Traffic Volumes at the Interchange with Mandela Highway.

3b.3 Merging Analysis

Observation of the demand situations across the trumpet interchange indicates that merging operations exists in three places. These areas include one along JNSH (EBLT vs. WBRT), and two along the Mandela Highway (SBLT vs. EBTH and SBRT vs. WBTH).

The design year 2033 morning peak hour demand was used in merging analyses. The merging flows are identified for each merging operation as shown in Figure 3b-4, and tabulated in Table 3b-2. For example, for the NB direction along JNSH, EBLT traffic merges into the WBRT traffic. The EBLT flow is 129 vph; while the WBRT is 1710 vph, The merging analyses were performed using the HCS software based on the 2010 HCM merging analysis methodology [1]. The analysis results are also tabulated in Table 3b-2. The detailed software outputs can be found in Appendix I through III.

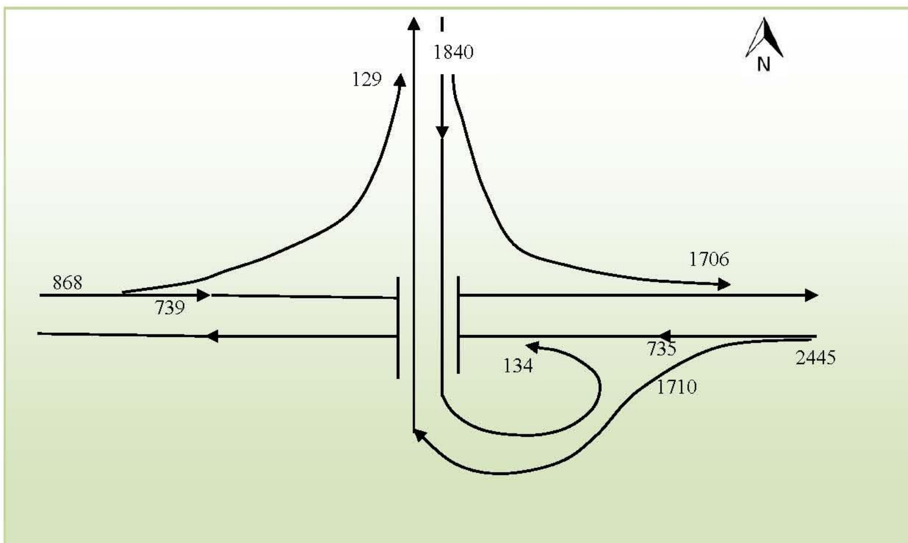


Figure 3b-4. Demand Mapping onto the Trumpet Interchange (AM forecast 2033)

Based on the analysis, the worst merging operations occur when the SBLT traffic merges into EBTH traffic along Mandela Highway. At this time, the level of service is at LOS=B. Therefore, the proposed facility design is justified in terms of merging operations.

Table 3b-2 Merging Analysis

Direction / Flow	Along JNSH	Along Mandela Highway	
	NB	EB	WB
	EBLT vs. WBRT	SBLT vs. EBTH	SBRT vs. WBTH
EBLT Flow, vph	129	----	----
EBTH Flow, vph	----	739	----
WBRT Flow, vph	1710	----	----
WBTH Flow, vph	----	----	735
SBLT Flow, vph	----	1706	----
SBRT Flow, vph	----	----	134
# of Freeway Lanes	2	2	2
# of Merging Lanes	1	2	1
Density, pc/km/ln	18.1	16.2	9.7
LOS	B	B	A

3b.4 Summary and Recommendations

In this report, the merging analysis for the trumpet interchange was performed using the design year traffic demand. It was found that the worst level of service is LOS=B, which is acceptable. Therefore, the proposed facility design is justified. No further improvement is recommended.

REFERENCES

[1] Highway Capacity Manual. Transportation Research Board, National Research Council, Washington, D.C., USA, 2010.

HCS 2010: Freeway Merge and Diverge Segments Release 6.41

Phone: Fax:
E-mail:

____Merge Analysis____

Analyst:	Zhongren Wang
Agency/Co.:	Consultant
Date performed:	10/30/2014
Analysis time period:	AM
Freeway/Dir of Travel:	NB
Junction:	EBLT vs.WBRT
Jurisdiction:	JNSH
Analysis Year:	2033

Description: Trumpet Caymanas Interchange (JNSH vs. Mandela Highway)

____Freeway Data____

Type of analysis	Merge	
Number of lanes in freeway	2	
Free-flow speed on freeway	55.0	mph
Volume on freeway	1710	vph

____On Ramp Data____

Side of freeway	Right	
Number of lanes in ramp	1	
Free-flow speed on ramp	35.0	mph
Volume on ramp	129	vph
Length of first accel/decel lane	500	ft
Length of second accel/decel lane		ft

____Adjacent Ramp Data (if one exists)____

Does adjacent ramp exist?	No	
Volume on adjacent Ramp		vph
Position of adjacent Ramp		
Type of adjacent Ramp		
Distance to adjacent Ramp		ft

____Conversion to pc/h Under Base Conditions____

Junction Components	Freeway		Ramp		Adjacent Ramp	
Volume, V (vph)	1710		129			vph
Peak-hour factor, PHF	0.94		0.94			
Peak 15-min volume, v15	455		34			v
Trucks and buses	7		7			%
Recreational vehicles	0		0			%
Terrain type:	Level		Level			
Grade		%		%	%	
Length		mi		mi	mi	
Trucks and buses PCE, ET	1.5		1.5			
Recreational vehicle PCE, ER	1.2		1.2			

```
Heavy vehicle adjustment, fHV          0.966       0.966
Driver population factor, fP           1.00        1.00
Flow rate, vp                          1883        142                    pcph

_________________________Estimation of V12 Merge Areas_________________________

                  L  =            (Equation 13-6 or 13-7)
                   EQ
                  P  =    1.000   Using Equation  0
                   FM
                  v  = v  (P  ) =  1883   pc/h
                   12   F   FM

_______________________________Capacity Checks_________________________________

                           Actual        Maximum         LOS F?
     v                     2025          4500            No
      FO
     v  or v               0    pc/h     (Equation 13-14 or 13-17)
      3     av34
Is   v  or v      > 2700 pc/h?           No
      3     av34
Is   v  or v      > 1.5 v  /2            No
      3     av34        12
If yes, v    = 1883                   (Equation 13-15, 13-16, 13-18, or 13-19)
         12A

________________________Flow Entering Merge Influence Area______________________
                      Actual        Max Desirable        Violation?
     v                2025          4600                 No
      R12
_________________Level of Service Determination (if not F)_____________________

Density, D = 5.475 + 0.00734 v  + 0.0078 v   - 0.00627 L   =   18.1    pc/mi/ln
          R                    R          12            A
Level of service for ramp-freeway junction areas of influence  B

_____________________________Speed Estimation__________________________________

Intermediate speed variable,                 M  = 0.316
                                              S
Space mean speed in ramp influence area,     S  = 50.9    mph
                                              R
Space mean speed in outer lanes,             S  =  N/A    mph
                                              0
Space mean speed for all vehicles,           S  = 50.9    mph
_______________________________________________________________________________
```

HCS 2010: Freeway Merge and Diverge Segments Release 6.41

Phone: Fax:
E-mail:

_____Merge Analysis_____

Analyst:	Zhongren Wang
Agency/Co.:	Consultant
Date performed:	10/30/2014
Analysis time period:	AM
Freeway/Dir of Travel:	NB
Junction:	SBLT vs.EBTH
Jurisdiction:	JNSH
Analysis Year:	2033

Description: Trumpet Caymanas Interchange (JNSH vs. Mandela Highway)

_____Freeway Data_____

Type of analysis	Merge	
Number of lanes in freeway	2	
Free-flow speed on freeway	55.0	mph
Volume on freeway	739	vph

_____On Ramp Data_____

Side of freeway	Right	
Number of lanes in ramp	2	
Free-flow speed on ramp	35.0	mph
Volume on ramp	1706	vph
Length of first accel/decel lane	500	ft
Length of second accel/decel lane	500	ft

_____Adjacent Ramp Data (if one exists)_____

Does adjacent ramp exist?	No	
Volume on adjacent Ramp		vph
Position of adjacent Ramp		
Type of adjacent Ramp		
Distance to adjacent Ramp		ft

_____Conversion to pc/h Under Base Conditions_____

Junction Components	Freeway		Ramp		Adjacent Ramp	
Volume, V (vph)	739		1706			vph
Peak-hour factor, PHF	0.94		0.94			
Peak 15-min volume, v15	197		454			v
Trucks and buses	7		7			%
Recreational vehicles	0		0			%
Terrain type:	Level		Level			
Grade		%		%		%
Length		mi		mi		mi
Trucks and buses PCE, ET	1.5		1.5			
Recreational vehicle PCE, ER	1.2		1.2			

```
Heavy vehicle adjustment, fHV          0.966       0.966
Driver population factor, fP           1.00        1.00
Flow rate, vp                          814         1878                  pcph

_________________________Estimation of V12 Merge Areas_________________________

                  L   =           (Equation 13-6 or 13-7)
                   EQ
                  P   =    1.000   Using Equation  0
                   FM
                  v   = v  (P  ) =  814    pc/h
                   12   F   FM

_______________________________Capacity Checks_________________________________

                           Actual        Maximum         LOS F?
     v                     2692          4500            No
      FO
     v  or v               0    pc/h     (Equation 13-14 or 13-17)
      3     av34
Is   v  or v      > 2700 pc/h?           No
      3     av34
Is   v  or v      > 1.5 v  /2            No
      3     av34         12
If yes, v    = 814                    (Equation 13-15, 13-16, 13-18, or 13-19)
         12A

________________________Flow Entering Merge Influence Area_____________________
                      Actual        Max Desirable         Violation?
     v                2692          4600                  No
      R12
_________________Level of Service Determination (if not F)_____________________

Density, D = 5.475 + 0.00734 v  + 0.0078 v   - 0.00627 L   =   16.2    pc/mi/ln
         R                    R           12            A
Level of service for ramp-freeway junction areas of influence  B

_____________________________Speed Estimation__________________________________

Intermediate speed variable,                 M  = 0.274
                                              S
Space mean speed in ramp influence area,     S  = 51.4    mph
                                              R
Space mean speed in outer lanes,             S  =  N/A    mph
                                              0
Space mean speed for all vehicles,           S  = 51.4    mph
_______________________________________________________________________________
```

HCS 2010: Freeway Merge and Diverge Segments Release 6.41

Phone: Fax:
E-mail:

____Merge Analysis____

Analyst:	Zhongren Wang
Agency/Co.:	Consultant
Date performed:	10/30/2014
Analysis time period:	AM
Freeway/Dir of Travel:	NB
Junction:	SBRT vs.WBTH
Jurisdiction:	JNSH
Analysis Year:	2033

Description: Trumpet Caymanas Interchange (JNSH vs. Mandela Highway)

____Freeway Data____

Type of analysis	Merge	
Number of lanes in freeway	2	
Free-flow speed on freeway	55.0	mph
Volume on freeway	735	vph

____On Ramp Data____

Side of freeway	Right	
Number of lanes in ramp	1	
Free-flow speed on ramp	35.0	mph
Volume on ramp	134	vph
Length of first accel/decel lane	500	ft
Length of second accel/decel lane		ft

____Adjacent Ramp Data (if one exists)____

Does adjacent ramp exist?	No	
Volume on adjacent Ramp		vph
Position of adjacent Ramp		
Type of adjacent Ramp		
Distance to adjacent Ramp		ft

____Conversion to pc/h Under Base Conditions____

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	735	134		vph
Peak-hour factor, PHF	0.94	0.94		
Peak 15-min volume, v15	195	36		v
Trucks and buses	7	7		%
Recreational vehicles	0	0		%
Terrain type:	Level	Level		
Grade	%	%	%	
Length	mi	mi	mi	
Trucks and buses PCE, ET	1.5	1.5		
Recreational vehicle PCE, ER	1.2	1.2		

```
Heavy vehicle adjustment, fHV          0.966       0.966
Driver population factor, fP           1.00        1.00
Flow rate, vp                          809         148                    pcph

_________________________Estimation of V12 Merge Areas_________________________

                  L  =            (Equation 13-6 or 13-7)
                   EQ
                  P  =    1.000   Using Equation  0
                   FM
                  v  = v  (P  ) =  809    pc/h
                   12   F   FM

_______________________________Capacity Checks_________________________________

                           Actual        Maximum         LOS F?
     v                     957           4500            No
      FO
     v  or v               0    pc/h     (Equation 13-14 or 13-17)
      3     av34
Is   v  or v      > 2700 pc/h?           No
      3     av34
Is   v  or v      > 1.5 v  /2            No
      3     av34        12
If yes, v    = 809                    (Equation 13-15, 13-16, 13-18, or 13-19)
         12A

________________________Flow Entering Merge Influence Area______________________
                      Actual        Max Desirable         Violation?
     v                957           4600                  No
      R12
_________________Level of Service Determination (if not F)_____________________

Density, D = 5.475 + 0.00734 v  + 0.0078 v   - 0.00627 L   =   9.7     pc/mi/ln
         R                    R           12            A
Level of service for ramp-freeway junction areas of influence  A

_____________________________Speed Estimation__________________________________

Intermediate speed variable,                M  = 0.296
                                             S
Space mean speed in ramp influence area,    S  = 51.1    mph
                                             R
Space mean speed in outer lanes,            S  =  N/A    mph
                                             0
Space mean speed for all vehicles,          S  = 51.1    mph
_______________________________________________________________________________
```