20th April 2018 Letter Ref: 152/MoW/082

Ministry of Works,
Project Executing Unit, George Price Highway Rehabilitation Project
#4 Lily Street, Orchid Garden Area
City of Belmopan, Cayo District
Belize C.A.

For the attention of Mr Derick Calles

Dear Mr Calles:

Consulting Service for the Supervision of Works for the George Price Highway Rehabilitation Project Design Review Report Addendum – Lot 3 BoQ Review

In accordance with the ***TOR Section IV Scope of Services*** and further to the Design Review Report submitted under cover of letter Ref.#044 on 9th March please find attached an addendum (Section 7.3) to that report covering Section III (Lot 3) review of bill of quantities

Should you have any queries or comments please do not hesitate to contact the undersigned.

Yours sincerely,

Andrew Clough

Team Leader / Senior Resident Engineer

cc PEU / Chia Engineering / IMC Project Manager / IMC Director

Attachment :- Design Review Addendum Section 7.3 Lot 3 BoQ Review

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7.3 Section III (Lot 3) Review of Quantities

To provide a comparison of costs the Lot 2 rates were applied to the Lot 3 quantities to give an overall indication of the areas where discrepancies exist in the Bill of Quantities. The summary below for Lot 3 BoQ shows an estimated BZ$25 million in the estimated Contract amount based upon the rates from Lot 2. The remeasure total is BZ$26 million giving a shortfall of BZ$1 million.

SECTION III (LOT 3) MEASUREMENT REVIEW					
Item No	**Item Description**		**Estimated Contract Amount Bz$**	**Remeasured Amount Bz$**	**Difference Amount Bz$**
1	BILL No 1: General Items and Preliminaries		**1,957,320.00**	**1,957,320.00**	**0.00**
2	BILL No 2: Demolition and Site Clearance		**12,500.00**	**43,750.00**	**31,250.00**
3	BILL No 3: Earthworks and Roadworks		**11,469,050.00**	**12,428,359.18**	**959,309.18**
4	BILL No 4: Drainage		**7,437,347.50**	**7,443,197.50**	**5,850.00**
5	BILL No 5: Garbutt Creek Flood Relief Culvert C314		**1,189,235.00**	**1,189,235.00**	**0.00**
6	BILL No 6: Scour Protection - B04: Red Creek Bridge		**125,250.00**	**125,250.00**	**0.00**
7	BILL No 7: Little Barton Creek Culvert C306a		**1,185,115.00**	**1,185,115.00**	**0.00**
8	BILL No 8: W03 & W04 Retaining Walls		**621,980.00**	**621,980.00**	**0.00**
	Sub-Total Grand Summary		**23,997,797.50**	**24,994,206.68**	**996,409.18**
	Contingencies to be expended if ordered or if required by the Engineer	5%	**1,199,889.88**	**1,249,710.33**	**49,820.46**
	Total (Bz$)		**25,197,687.38**	**26,243,917.01**	**1,046,229.64**

Whilst there were some undermeasure in the Bill No.2 *Demolition and Site Clearance* and Bill No.4 *Drainage* the significant increase is in the Bill No.3 *Earthworks and Roadworks*. Within the Bill No.3 the main undermeasure were found in the topsoil excavation, subbase, base and bus-stops. Items with no measure which may result in a claim for addition payment were rock excavation and roadbed preparation where there were no relevant bill items.

The Item 3.1.01 *Topsoil* was measured for 0.5m either side of the road which does not reflect the true measure of removal which should be from toe of slope or even back of drain to the edge of existing road. A more realistic measure will increase volume from 3,000m^3 to 41,000m^3. The items 3.302 to 3.305 subbase and base course measurements did not include any provision for side roads, accesses, verge and the length of the road was incorrectly measured. The bulk of the increase in cost will come from these items which are estimated to be undermeasured by BZ$700,000. The bus-stop item was incorrectly measured at 8 instead of 10 which gives BZ$130,000 undermeasure. The roadbed or subgrade preparation outside of the existing road was not included so an estimated amount of BZ$170,000 was included based upon the rate for the preparation of the existing road surface. Although there are no significant realignments for this section there are some lowering of the road alignments which may encounter rock and has not been covered in the BoQ. However as there is some overestimation in the cut quantities this should be able to cover small areas of rock.

At this stage it is estimated that there will be a BZ$1 million shortfall.

IDB Project LO-3344/OC-BL: GEORGE PRICE HIGHWAY REHABILITAION PROJECT
Government of Belize – Ministry of Works – PEU

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Consulting Service for the Supervision of Works for the George Price Highway Rehabilitation Project

Design Review Report
February 2018

Submitted by
IMC Worldwide Limited, UK

Quality Management

Design Review Report

Version No.	Status	Comments/revisions from previous draft	Prepared by/date:	Reviewed by/date:	Authorized by:
1	Draft		Andrew Clough 8 March 2018	David Jones 8 March 2018	Abdullah Miah 9 March 2018
			AJC	*DJ*	*AM*

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Consulting Service for the Supervision of Works for the George Price Highway Rehabilitation Project

Table of Contents **Page**

Consulting Service for the Supervision of Works for the George Price Highway Rehabilitation Project

Design Review Report - February 2018

EXECUTIVE SUMMARY

The full Design Review operation did not commence until 8th January 2018. At this stage the Contractors for Lots 1 and Lot 2 had commenced mobilization which put some urgency on the review works. Both Contracts designs have a significant number of omissions and design queries that are itemized in the Design Review Recommendation Table (Section 8). The itemized list covers all aspects of the design and has at times significant bearing on the functionality, safety, buildability, budgetary constraints of the Contracts. As the Design Consultant is not reachable the queries or design philosophies used cannot be answered and much of the review has been a forensic examination of the design in an attempt to understand the concepts used.

Priority was placed on the Roaring Creek Bridge where some initial issues had already been picked up by the Project Execution Unit (PEU) and Ministry of Works (MoW). The preliminary reviews concluded that some major design queries existed and these were discussed with MoW in a meeting held on 13th January 2018. A way forward was agreed whereby the Contractor will carry out any amendments to the design under 'Value Engineering' and the MoW will sign off on the revised designs. This is to prevent major delays to the project which has already mobilized. The Lot 2 Design has similar design issues with the vertical and horizontal alignments and a similar approach may be necessary in order to avoid delays in providing the 'Good for Construction' Drawings.

It should be noted that the number of design review issues found was far more than would normally be expected in such a review with more significance on the impact of the design than would ever be expected. Therefore we have found it necessary to mobilise resources at an earlier stage than was anticipated in order to take a pro-active approach to prevent the Contracts becoming delayed.

1. PROJECT DESCRIPTION

The George Price Highway (GPH) is one of four main highways in Belize. The highway was built in the 1930s and was originally known as the Western Highway, renamed as the George Price Highway in 2012. The road connects Belize City – Belmopan - San Ignacio and Santa Elena-Benque Viejo town (near the Guatemalan border). The project includes rehabilitation of GPH road section from mile 47.9 to 67.3 (total length 19.4 miles) and the replacement of Roaring Creek Bridge. The road is a two-lane highway that passes through flat terrain until reaching the Guatemalan Border.

The George Price Highway Rehabilitation Project will substantially improve road connectivity within Belize's main districts through the upgrading of road infrastructure between Belmopan and Santa Elena.

The scope of the rehabilitation work includes horizontal and vertical realignment of the roadway to meet international safety standards, as well as the upgrading of drainage and construction of runoff channels to improve climate resilience of the road. The project will also address the replacement of major culverts at key locations, clearing of the road reserve, removal of any obstructions, construction of safety barriers, increased road signage and support to the maintenance of the works, once the rehabilitation is completed.

The extent of the project has been divided into three (3) Lots/Sections with one Lot being assigned to the construction of the new Roaring Creek Bridge and the other two Lots/Sections being assigned to the road rehabilitation, as presented in the following section.

The project has been split into three lots as summarised in Table 1.

Table 1. PROJECT SECTIONS (Lots)

Construction Section	Length	Contractor	Contract Amount
Section I Construction of Roaring Creek Bridge	0+000 to 0+485km	M&M Engineering Consultants Limited.	BZ$11,346,823.17
Section II Roaring Creek to Iguana Creek Junction	0+485 to 15+720km	Teichroeb & Sons Limited	BZ$20,540,823.19
Section III Iguana Creek Junction to Santa Elena Town	15+720 to 32+450km	Tender stage	-

Lot 1: Section I Construction of new Roaring Creek Bridge

This lot includes the construction of the new Roaring Creek Bridge alongside the existing bridge that is an old structure - reportedly built in the 1930's or 1940's.

Lot 2: Section II Roaring Creek to Iguana Creek Junction

This section is 15.335km long, starting on the western bank of Roaring Creek at km0+485 to just before the Iguana Creek Junction. This Road Section shows deterioration in the latter half of the section, with the most common defects include edge cracking and shoulder drop-off. Some large culverts will be replaced and the near vertical drops of the hill in the Z-curves (in Teakettle) will be trimmed to improve the road alignment in this area due to safety concerns. The trimming of the back slope will require considerable cut in this area.

Lot 3: Section III Iguana Creek Junction to Santa Elena Town

This section is 16.73km in length, starting just before the Iguana Creek Junction and extending to the Santa Ellen Roundabout. This section also shows deterioration in sections particularly in the villages with edge cracking and lane drop-offs. These defects for the most part include patching, depressions, weathering and ravelling. Drainage will be addressed by replacing of some of the existing culverts to mitigate against flooding.

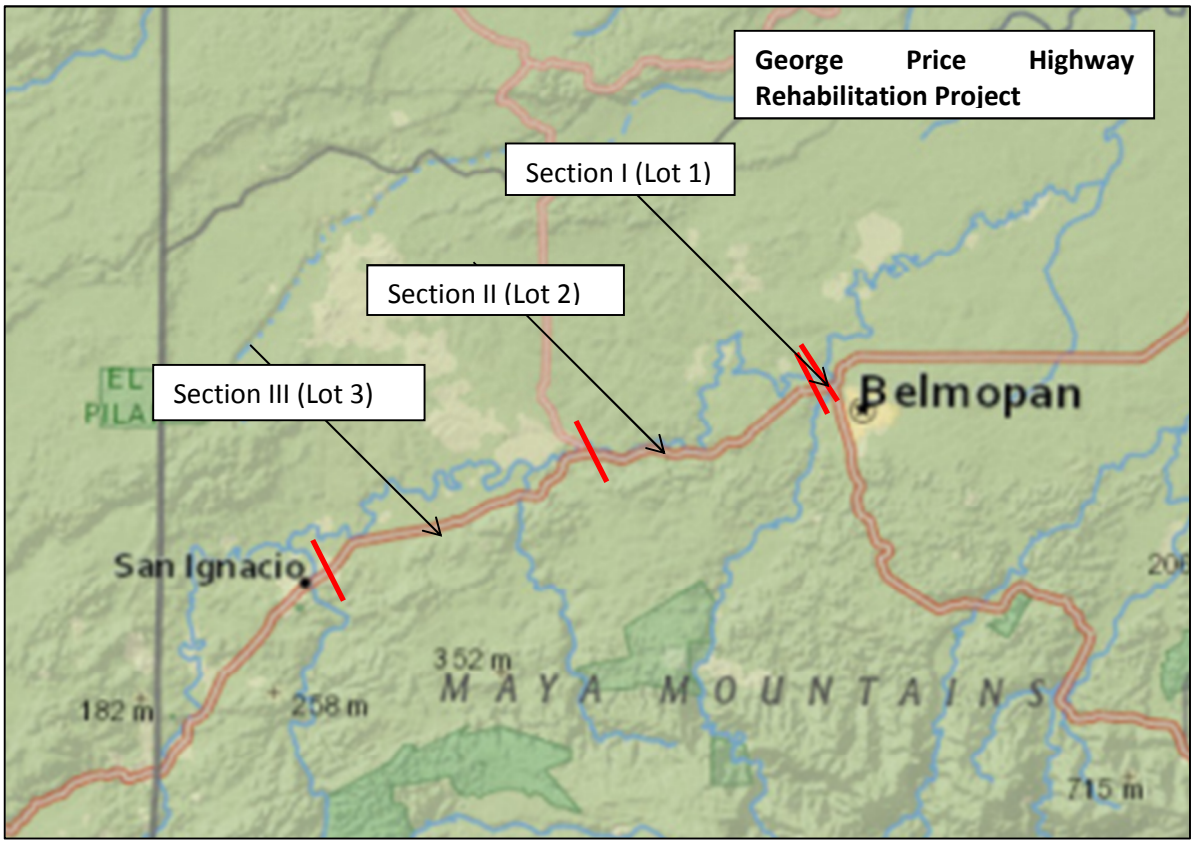

Figure 2:- Map of George Price Rehabilitation Project showing the three main project sections.

Project funding provided by the Inter-American Development Bank and the European Commission (CIF).

2. DESIGN REVIEW OBJECTIVES

2.1 Introduction

The design documents were reviewed and a 'Design Review Recommendation Table' created which is shown in Section 8.0 of the report. This stand-alone section has been submitted to the Client under letter Ref. 037 on 3rd March 2018 with the recommendation that it is referred back to the Design Consultant for their action and / comment.

However as there has been no contact made with the designers the Client will need to comment on each of the recommendations made at this stage so that the 'Good or Construction' drawings can be submitted to the Contractors. Whilst minor changes and omissions can be corrected by the Consultant's team; any major changes will require the Client to sign off on so that design responsibility does not fall on the review Consultant. For example the Lot 1 Bridge Design is already being modified under 'Value Engineering' where the Consultant / Contractor / Client have agreed the items to be redesigned and the Contractor is carrying out the redesign to be signed off by the MoW and checked by the Consultant.

2.2 Contract Documents Reviewed (Task 3.1.1)

The PEU provided a full set of documents for the Project which is listed in the table in Appendix A. The critical documents reviewed were as follow:-

- Feasibility Report prepared by Anthony Thurton 2014
- Environmental and Social Impact Assessments
- Final Design Report
- Survey Control Points
- Geotechnical Reports – Roaring Creek Bridge and Blackman Eddy
- HDM 4 Report
- Hydraulics Report
- Pavement Report
- SECTION 1 Contract Documents (Drawings, BoQ, Specification, Signed Contract)
- SECTION 2 Contract Documents (Drawings, BoQ, Specification, Signed Contract)
- SECTION 3 Bidding Documents (Drawings, BoQ, Specification)

2.3 Review Topographic Survey and Designer's Survey data (Task 3.1.2)

The survey check of the control points and reference points has been carried out alongside the Contractors for Lots 1 and 2. Independent checks will be carried out on Lot 3. There have been no significant issues related to the control points and existing survey of the road. The Contract

ground levels seem to tie in with new survey and land boundaries tie in with those surveyed for the design.

However it is noticeable from the design drawings and the centreline set out on site that there is a significant difference to the cadastral boundary used in the design drawings compared to actual surveyed positions of the fences. The existing survey unfortunately does not pick out clearly all the existing fence lines and CP (concrete post) points along the road which would verify these boundaries. Sections between km3+000 to 5+000 show a significant variance between the existing and the cadastral survey and when the centreline is set out on site the road encroaches onto properties boundaries and the BEL poles within Camolote.

Photo 1. Centreline set out in Camolote Lot 2

The key issue would seem to be that the designer has not checked the Cadastral overlay with existing CP points on the ground and then seems to have used this as the governing factor for the horizontal alignment.

The recommendation is that CP points need to be picked up on site and the horizontal alignment modified in accordance with the actual boundaries verified on site and not a theoretical line.

2.4 Review Site Investigation and Materials Information (Task 3.1.3)

There was no specific soils or materials report prepared at the design stage which showed the local quarries and available material sources for the project. The reports reviewed were the Pavement Design Report and the Geotechnical Reports for the Roaring Creek Bridge and the Blackman Eddy Slip area.

2.4.1 Pavement Design

The Pavement Engineer reviewed the Pavement Report and whilst there were no significant issues with the pavement design regarding structural number and capacity, there were questions raised regarding the constructability and value engineering of the design. If the structure of the existing road is to be utilised the pavement should be an addition to that existing structure which is why the typical cross-section drawings show a 200mm base layer to be placed over the existing pavement. This type situation would require the vertical profile to remain at least 200mm above the existing pavement, otherwise the road section would be in cut and the Contractor would remove the existing base. Once the existing base is removed, the section would require cutting to the full subgrade pavement depth resulting in removal of 525mm below FRL. The design vertical

profiles vary considerably and the areas that could be considered as a base overlay to the existing road are negligible even in Lot 3 where the horizontal alignment tends to follow the existing road.

2.4.2 Geotechnical Investigations

The Geotechnical Investigations Reports carried out at the Roaring Creek Bridge and the Blackman Eddy Slip were inconclusive and required additional reviewing by a geotechnical expert. For this reason the Consultant mobilised a geotechnical engineer to visit the site in early February. Three additional auger boreholes were carried out at the Bridge site to fill in the gaps left from the design report and to verify the rock level.

The inconclusive nature of the Blackman Eddy slip and the fact the slip is clearly still active with steps in the road surface requires that solutions are found to the slip and options given to the PEU for remedying the slips as a way forward in this area. Some preliminary options have been included as a way forward for the slip area.

It should be noted that the 'S' curve area of Section II between Ch9+500 to 10+000 has some significant cut areas which have not been fully surveyed in the design. There was no slope stability analysis found for this cut area in the design report and no boreholes were carried out. The Contractor has been instructed to complete the survey in this area so that the potential of the cut slope following the existing slope and opening up large exposures of rock is avoided. The stability of the slopes will have to be checked as excavation commences as there is no time for detailed analysis. The risk will be that unstable materials may be located in these cut faces and additional slope stability measures will be necessary.

2.5 Geometric Design Review (Task 3.1.4)

The geometric design review report is found in Section 7.0. of this Report which outlines a number of recommendation for the Lot 2 Contract. The horizontal and vertical alignment of the highway when taken in isolation does not have any significant issues except that the project no longer becomes a rehabilitation project but a full reconstruction project. Further detailed designing or value engineering will be necessary.

2.5.1 Horizontal Alignment

The horizontal alignment particularly in Section II would seem to have been designed principally around the cadastral boundary overlay rather than taking into consideration the existing centreline and the existing boundaries surveyed as part of the design. The result is many areas where the road alignment has shifted significantly to the side and the new side drains will actually be cut into the existing road. As recommended in section 2.4 these areas should be rechecked taking into consideration the actual cadastral boundaries which should be checked on site from CP.

2.5.2 Vertical Alignment

The vertical alignment should be conditional on the pavement design and as mentioned in section 2.5 should utilise the existing solid road structure as much as possible and add to that strength

rather than completely obliterating and reconstructing. The vertical alignment should follow the existing at a minimum 200mm above existing level where possible which would allow the base layer to be placed on top of the existing. Where the difference is greater than 200mm this transition or regulating layer would be a subbase material scarified into the existing base. This type of vertical alignment would be ideal in Lot 3 where the horizontal alignment seems to follow the existing centreline. Where the road alignment dictates a cut section then the pavement design reverts to the subgrade option where a pavement of 525m or 675mm depending on location is built up after the cut. These areas should be defined head of the works so that a homogenous road structure is built up.

2.5.3 Side Roads and Urban Areas

The side road junctions are not standardised on the drawings with a specified design radii, construction length, width, sidewalk type etc. and the junctions shown on the plan tend to differ from the typical side road cross-section. It should be noted that the radius measured on the plans is 10m although this is not shown with any dimension. This may not be a practical radius in the urban sections of the road and this will need to be thoroughly reviewed. A typical junction plan should be provided for the rural junctions with shoulders and the urban road where concrete sidewalks are specified. These drawings should be dimensioned and labelled with clear indication where shoulder tapering occurs or raised sidewalks drop down. The Road Safety Audit report identifies the lack of pedestrian facilities for the large Iguana Creek Junction in Lot 3, which will require modification to improve pedestrian safety.

The typical cross-section for the urban areas in the vicinity of bus stops provides for a concrete up-stand sidewalk with covered drain underneath. The drain inverts for the concrete drain do not tie into the earthen side drains either side, which requires either, a significant deepening of the concrete drain or an earth drain to be cut behind the sidewalk. The design in these areas should be completed with greater detailing.

2.5.4 Traffic Management Proposals

There were no traffic management proposals submitted by the Design Consultant so the team will review and comment on the Contractors proposals when submitted to ensure they meet the requirements of the Contract and that they provide safe traffic diversions and maintain the traffic flow at all times. There will be significant issues with traffic management at the sections of cut where the existing road will be lowered up to 2.5m in order to provide a safe route for the existing traffic. Even with single lane traffic working there will be significant drop-offs as the works proceed. Constructability issues did not seem to take a high priority with the Designer at the design stage. Recommendations at this stage would be to see if raising the levels either side of these cut areas would lessen the required cut and reduce not only the risks in construction but also the costs.

2.6 Review of Pavement Design (Task 3.1.5)

The pavement design has been reviewed and the details provided in Section 5.0. Although the pavement design is not practical as the pavement thicknesses vary throughout the project rather than remaining homogenous. The conclusion is that considering the local practice, low traffic volume and adequate drainage provided the pavement design is considered satisfactory.

The practical recommendation would be to standardise the pavement thicknesses provided so that consistency is maintained. There is also a need to clearly define and specify the 'capping' and 'engineered fill' which is not defined separately in the Technical Specification.

The Designers did not provide a specific materials report regarding the potential use of the existing road pavement, cut materials and the available construction materials in the project vicinity.

The pavement details in the road cross-sections do not show the existing road within the pavement cross-sections. These typical cross-sections need to reflect the actual earthworks to be carried out to the Contactor, so sections of full depth cutting and raising of existing pavement can be determined. The horizontal and vertical alignments seem completely independent to the pavement design.

2.7 Review of Structural and Drainage Design (Task 3.1.6)

2.7.1 Structural Report

The full Bridge Design review Report is with Section 4.0. At an early stage significant issues were found in the Structural design of the bridge and it was necessary to deal with these proactively as there has been no feedback from the Design Consultant. Through 'Value Engineering' the modifications to the design are being carried out in a staged process in order to keep the project moving and prevent it coming to a standstill. The full details and status of the value engineering aspect of the works is given in the Section 4.0.

2.7.2 Drainage Design Report

The full hydrologic / hydraulic design analysis is found in Section 3.0 of the report recommends that comprehensive rainfall intensity-duration-frequency analysis be carried out, utilizing data from Belmopan, Central Farm Cayo and Barton Creek. Rainfall durations down to 5 minutes should be considered.

Observed water level and flow data for the recording station on the Belize River at Banana Bank should be analyzed and correlated with historically observed flood levels at Roaring Creek Bridge in order to try and attach a return period to the recent observed event that has formed the basis of design. The specified design return period for Roaring Creek Bridge is 100 years, but at present the return period of the highest historic level used in design is not known.

Incorrect catchment areas were used in the hydrological analysis of the Garbutt Creek and Red Creek bridges. Both hydrological and hydraulic analyses need to be revised. Cross section survey will be required upstream and downstream of the bridge sites.

Culverts C213, C217, C313 and C417 appear to have been oversized. Both hydrological and hydraulic analyses need to be revised. Cross section survey will be required upstream and downstream of the culverts.

In general the roadside drainage provisions are adequate, but there are three reaches in which the roadside drains need to be enlarged.

2.8 Road Safety Assessment (Task 3.1.7)

The preliminary design stage Road Safety Audit (RSA) was submitted as a separate report on 1st March 2018. The purpose of the RSA is to identify any potential road safety problems that may affect any users of the highway and to suggest measures to eliminate or mitigate against those problems.

The Audit team has examined and reported only on the road safety implications of the scheme as presented and has not examined or verified the compliance of the designs to any other criteria.

The audit addresses those physical features in the preliminary design for this project that may adversely affect road user safety when the road is constructed. Audit reports cover exceptions only. Those items in the design that are not considered to present a safety concern, or which are fully agreed with by the auditor, are not listed in this report.

2.9 Review of Environmental and Social Impact assessment report (Task 3.1.8)

The Environmental Impact Assessment (EIA), Social Impact Assessment (SIA) and the Environmental and Social Management Plan (ESMP) prepared at the feasibility stage and included in the works contract have been reviewed together with the Environmental Compliance Plan (ECP) compiled by the DoE.

Our Environmental and Social Specialist has produced a comprehensive checklist that is being monitored on a weekly basis through the Contractor. The Contract does not require the Contractors to specifically have an environmental or social expert on site so the aim is to train the Contractors personnel or at least have one engineer champion that task to build up the capability of the Contractors team. Under the guidance of our specialist the checklist will be reviewed and checked on site each week to ensure that compliances have been met.

2.10 Locate and Plan Utilities Diversions (Task 3.1.9)

All the utility companies have been contacted with assistance of the PEU. Initial meetings were held in December 2017 with BWS and later on the Lot 1 and 2 site with representatives of BWS, BEL, BTL and Cable Companies to determine at an early a stage the location of existing utilities, how they will impact on construction activities and the final proposed relocation of these services. These works are on-going on both Lots 1 and 2 running in conjunction with topographic survey.

The schedule and sequence of diversion of the utility lines is being prepared in conjunction with relevant utility companies. Drawings have been issued to the companies and further utility meetings planned for the near future as part of the Contractors responsibility for protecting all 'known' services and liaising with the companies to carry out the relocation.

The Contract is not clear at all as to the works to be completed in the utility relocation works and the wording of both the Contract and the preamble is confusing because they refer to drawings that show the works to be completed. These drawings were not included in the tender documents and neither the Bill of Quantity (BoQ) details for the build-up to the utility relocation amount. At this stage in the Lot 1 and 2 Contracts it is unclear whether this provisional sum for the works to be carried out for BWSL, BEL and BTL will be sufficient. The drawings of the existing utilities, the proposed new utilities and any temporary diversions required needs to be issued to the Contractor so that a full BoQ can be prepared and the Contractors can schedule this work into their programme.

2.11 Third Party Co-ordination (Task 3.1.10)

As part of project management, we are supporting the Client on the management of utilities diversions and protection works by liaising with the utilities owners / Contractors and PEU as required.

2.12 Review of Contract Document (Task 3.1.11)

The review the contract documents including; Tender Drawings, Plan and Profile Drawings, Standard Detail Drawings, Bill of Quantities, Standard and Particular Specifications has been carried out and the itemised issues with recommendations has been presented in the Design Review Recommendation Table. The Consultant had planned to issue the approved drawings as 'Good for Construction Drawings' but has raised notice that the considerable number of changes being recommended may result in significant changes to the drawings which may cause delays to the drawing issue. The large number of changes to the drawings was not envisaged by the review consultant at tender stage.

The priced Bill of Quantities has been reviewed for Sections I and II and the details presented in Section 7.0 of this report.

2.13 Review of Ancillary Works (Task 3.1.12)

The ancillary works design such as traffic signs, road marking, guardrails, and road furniture to ensure they compliance with standard specifications have been reviewed in conjunction with task 3.1.7 and presented in the separate Safety Audit Report and incorporated where necessary in the Design Review Recommendations Table (Section 7.0) of this report.

3. REVIEW OF HYDROLOGIC / HYDRAULIC DESIGNS

3.1 Previous Investigations

Feasibility level studies for the GPH rehabilitation were completed in September 2014 (Anthony Thurton and Associates Ltd., 2014) and detailed designs were completed in October 2016 (CH2M, Halcrow Group (Trinidad & Tobago) Ltd., 2016). Hydrological and hydraulic studies were carried out as part of the feasibility studies. These hydrological and hydraulic analyses were reviewed as part of the detailed design studies, but very little additional hydrological or hydraulic analyses were carried out as part of the detailed design. Some hydrological analysis was also carried out as part of the environmental and social impact assessment (Belize Environmental Technologies Ltd., 2014).

3.2 The Drainage System

The GPH, between Belmopan and BVDC, runs parallel to the Belize River for most of its length. The road crosses four significant rivers (Roaring Creek, catchment area 293 km^2, Barton Creek, 114 km^2, Garbutts Creek, 51 km^2, Red Creek, 9 km^2, and the Macal River, 1469 km^2)[1]. The bridge over the Macal River is not part of the rehabilitation project. The locations of the bridges that are included in the project are shown in Figure 3.1, along with their catchment areas.

Figure 3.2 indicates the elevation ranges in the bridge catchments (SRTM90 DEM). Catchment areas were delineated using the ArcHYDRO tools in ArcGIS.

Intervening lengths of the GPH between the bridges are provided with cross drainage culverts. A total of 88 cross drainage culverts were identified in the design studies (CH2M, Halcrow Group (Trinidad & Tobago) Ltd., 2016). The locations of culverts are shown in Figure 3.3. Catchment areas are, with a few exceptions, small and difficult to delineate and measure with available topographic data. The SRTM90 DEM is adequate for larger catchments, but on smaller micro-catchments the 90m grid is too coarse. A further issue is that the DEM picks up the top of the canopy and in areas of low relief and mixed land use this can be a problem.

3.3 Locations of Inadequate Drainage

Flooding has occurred in the past at the following bridge crossings:

i) Roaring Creek.
ii) Garbutt Creek.
iii) Red Creek.

In addition, a number of other flood prone areas have been identified along the GPH (Anthony Thurton and Associates Ltd., 2014), (Belize Environmental Technologies Ltd., 2014):

iv) Camalote (Mile 50).
v) Teakettle (Mile 53).

[1] Catchment areas derived from SRTM90 DEM using ArcHYDRO GIS routines.

vi) Blackman Eddy (Mile 58).
vii) Georgeville (Miles 62 & 63).
viii) Central Farm (Mile 64).
ix) San Ignacio (Mile 67).
x) Succotz (Mile 71).
xi) Benque Viejo (Mile 73).

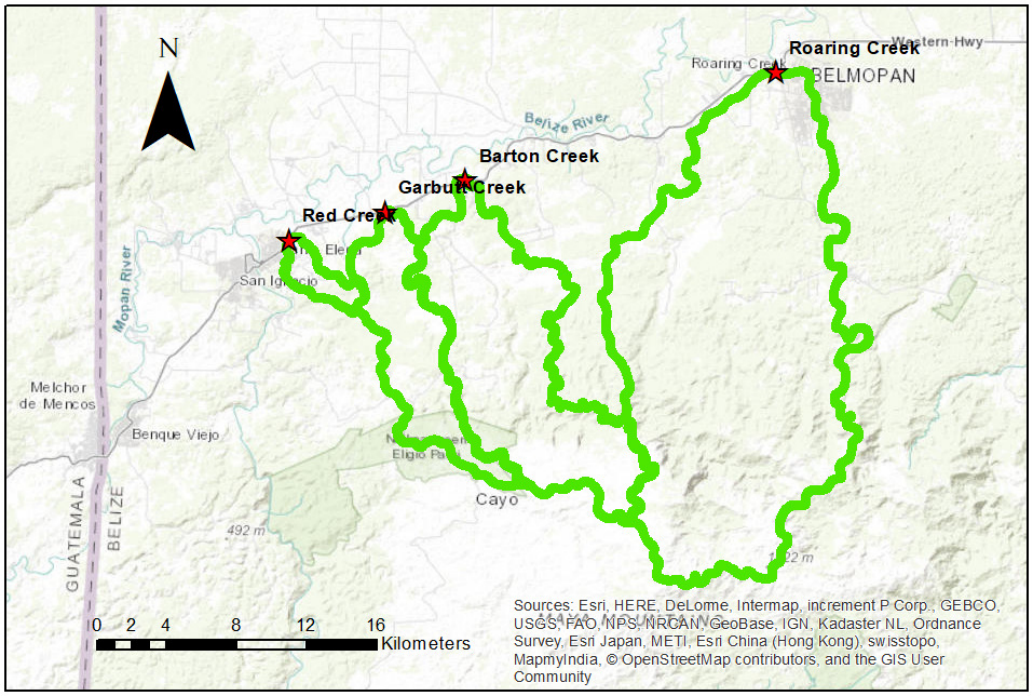

Figure 3.1 Location of bridges and catchment areas

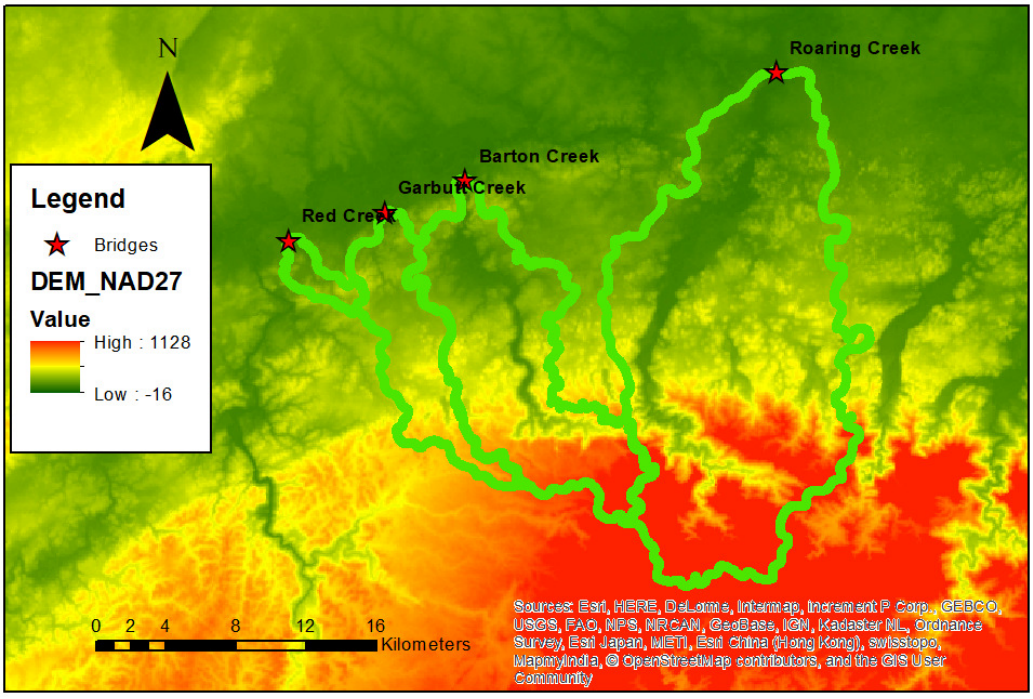

Figure 3.2 Elevation ranges in bridge catchments

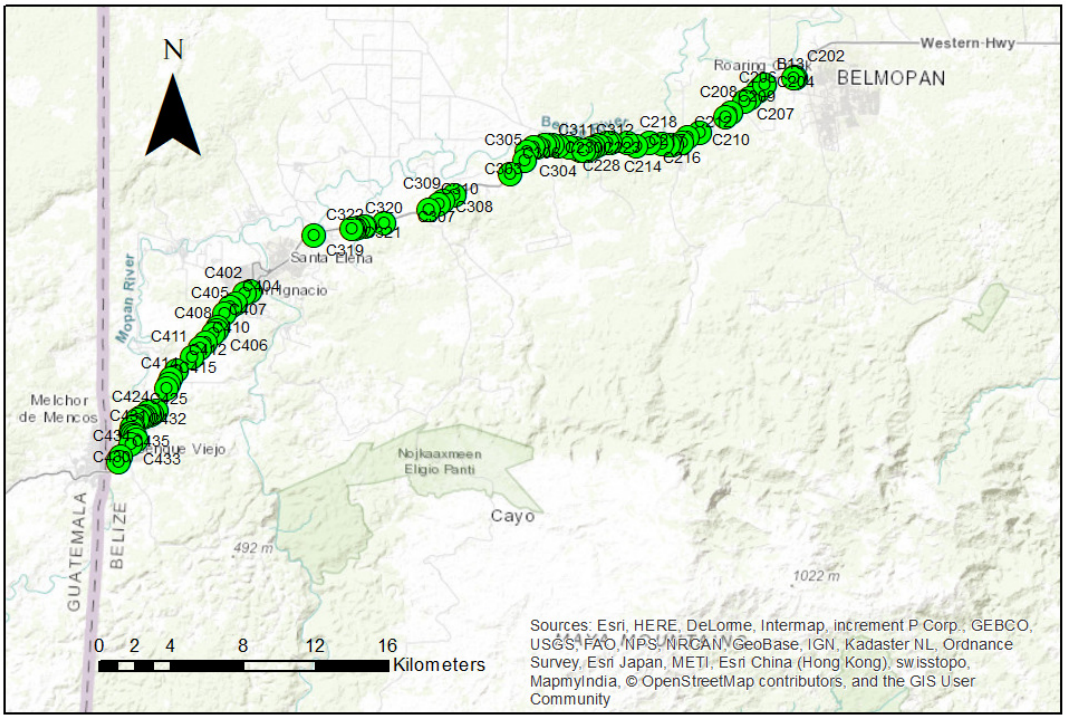

Figure 3.3 Culvert locations on the GPH

3.4 The Hydrometric network

The feasibility and design studies made little use of available hydrometric data, other than rainfall intensity-duration-frequency (IDF) data derived from data for San Ignacio by "Germany GmbH" (not a very satisfactory reference) for the Northern Highway Project in 2013.

The feasibility study (Anthony Thurton and Associates Ltd., 2014) indicated that of 34 operational meteorological stations in Belize, only two record rainfall intensity. However, information included in the ToR for the Philip Godson Highway Project indicated a total of 54 rainfall stations in Belize, of which 8 recorded rainfall intensity. The locations of rain gauges relevant to the GPHP are shown in Figure 3.4.

Rainfall intensity is apparently recorded at Belmopan, Central Farm Cayo and Barton Creek – these stations are particularly relevant to drainage design for the GPHP. There are also daily rain gauges at Banana Bank West, Spanish Lookout, San Ignacio and Cha Creek that would be particularly relevant to culvert design, and upper catchment stations at Bull Run Overseas Ltd., Baldy Beacon1, Cooma Cairn Cayo, and Augustine Cayo that could be particularly relevant for flood frequency assessment on the larger rivers crossing the GPH. There needs to be confirmation with the Belize Meteorological Department of the rainfall data that are available and relevant to the GPHP. IDF data should be developed using all relevant available data, rather than depending upon second hand analysis that is of uncertain origin.

In addition to the rain gauge network, a number of water level recording stations exist on the Belize River. The locations of stations are shown in Figure 3.4. An automatic water level recorder exists at Banana Bank on the Belize River just downstream of the confluence of Roaring Creek, and could be of value in assessing flood risk at the Roaring Creek Bridge. Upstream there are manually read gauges at Iguana Creek, San Ignacio and Benque Viejo. These are apparently read twice daily, and may not therefore record peak flood levels. However, at present the potential impact of backwater from the Belize River on the operation of cross drainage culverts is not known. The available data should be assessed to determine if water surface profiles for the Belize River can be derived that could be used in the drainage analysis. Data has been requested from the Hydrology Unit of the Ministry of Natural Resources.

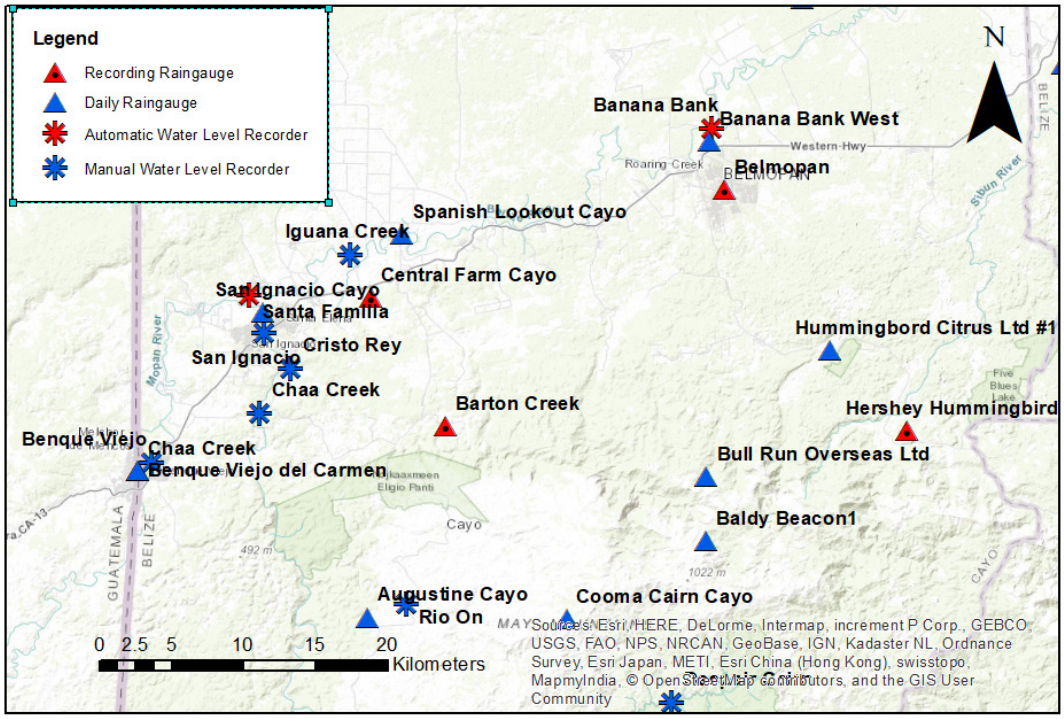

Figure 3.4 Elements of the hydrometric network

3.5 Feasibility Level Studies

In the feasibility studies the rational method was adopted to estimate peak discharges at locations for which analysis was undertaken. In applying the rational method, the Kerby-Kirpich method was used to determine times of concentration which were then used with intensity-duration-frequency (IDF) curves developed in a study attributed to "Germany GBH" for the Northern Highway in 2013. The IDF curves are reportedly for a station at San Ignacio, but data provided in the ToR for the Philip Godson Highway Project indicated that the station at San Ignacio is a daily rain gauge, and that rainfall intensity is observed at Central Farm Cayo (from 1950) and Belmopan (from 1973).

It is unsatisfactory to base design studies on second hand data, the origin of which is poorly referenced. It is recommended that revised IDF curves be prepared using both the Central Farm and Belmopan data. Data for Barton Creek and Hershey Hummingbird should be reviewed also as these would be relevant to the larger catchments.

The rational method is quite appropriate for use with smaller catchment areas.

3.6 Hydrological Analyses Undertaken at Feasibility Level

Hydrological analyses with the rational method are described in the feasibility report for the Red Creek crossing and the Garbutts Creek crossing. Assessment of flooding in the Succotz area was based on flood level analysis for the Mopan River.

The feasibility report (Anthony Thurton and Associates Ltd., 2014) gave the catchment area of the Red Creek crossing as 2.9 km^2. This is considered to be a significant under-estimate. Catchment delineation carried out for this review using the SRTM90 DEM and ArcHYDRO GIS catchment delineation routines gave an area of 8.71 km^2. (

Figure 3.1). The design studies questioned the catchment area used for the Red Creek crossing but did not present an alternative. It will clearly be necessary to re-assess the design discharge for the Red Creek crossing.

The feasibility study gave a catchment area for the Garbutts Creek crossing of 10 km^2. Catchment delineation carried out for this review yielded an area of 50.86 km^2 (

Figure 3.1). The feasibility level hydrological assessments of both the Red Creek and Garbutts Creek crossings is therefore very questionable and revised flood estimates at these sites should be undertaken.

For the flood prone area in Succotz, analysis was made of water level and flow records for the Mopan River. The report did not indicate what station was used, and it is assumed that the station used must have been Benque Viejo, which is a manually read gauge upstream of Succotz (see Figure 3.4). Rating information was used to create a discharge series of annual maximums. The series is not complete, and no fitted frequency distribution was presented. Also, only data up to 2008 were used, and it is not clear whether the annual maximum stage records shown in Table 23 of the feasibility report are indeed annual maximums, or simply the maximum of twice daily recorded stage values. It is assumed that the rating curved presented in Figure 26 of the feasibility report was based on the data given in Table 23. The equation fitted does seem to represent the observations reasonably well, but is not a standard rating relationship, and the discharge data presented in Table 23 most likely resulted from the station rating relationship in the first place. Translation of flood levels at the gauge to flood levels at Succotz was based on observed water levels during TD16 in 2008. The analysis for Succotz should be updated with more recently available water level and discharge data, a revised frequency analysis carried out, and a standard form of rating equation fitted.

In addition to the Red Creek and Garbutts Creek crossings, and Succotz, the feasibility report indicates that flood assessments were made at:

- Camelote (Mile 50)
- Teakettle Village (Mile 53)
- Blackman Eddy (Mile 58)
- Georgeville (miles 62 and 63)
- Benque Viejo (Mile 73)

There is no discussion of any hydrological analysis carried out at these locations, although an indication of remedial works required is given and hydraulic analysis is presented in the hydrological and hydraulic design appendix (Anthony Thurton and Associates Ltd., 2014b). The design studies report indicated that only hydraulic analysis was undertaken at the above locations.

3.7 Hydrological Studies for the Environmental and Social Impact Assessment

Hydrological studies were carried out as part of the Environmental and Social Impact Assessment (Belize Environmental Technologies Ltd., 2014). Rainfall intensity-duration-frequency data were presented in graphical form for the Central Farm station, but this was apparently second hand data and was difficult to interpret. A table of depth-duration-frequency data was also presented for Philip Godson Airport that had apparently been produced by BECA International Consultants Ltd. in 1994. It is not clear to what use the IDF or DDF data were put. Analysis was also presented of flood frequencies in the Mopan River at Benque Viejo. The analysis of annual maximum stage at Benque Viejo indicated a trend of increasing flood levels in the 1980 – 2013 period.

3.8 Hydrological Analyses Undertaken for Design

The Hydrologic / Hydraulic Studies report (CH2M, Halcrow Group (Trinidad & Tobago) Ltd., 2016) questions the catchment areas used for Garbutt Creek and Red Creek bridges in the feasibility report, but does not indicate what the areas should be. It goes on to describe the approach to hydrological analysis in the feasibility report of Rational Method and Kerby-Kirpich, indicating that the approach is reasonable when results are compared with observed conditions of actual flooding. A brief comparison is made of IDF data used in feasibility study with that derived for the station at Consejo, where Halcrow had derived IDF characteristics from 14 years of record. The San Ignacio / Santa Elena IDF curves gave a higher rainfall depth at a 1 hour duration, and on this basis the San Ignacio data were considered to be realistic. It would appear that no independent hydrological analysis was undertaken as part of the design studies.

With regard to climate change impacts, the Hydrologic / Hydraulic Studies report suggested that a current 1:50 year event could be equivalent to a 1:20 year event in the future, with the implication for design being that a 1 hour rainfall could be 20% higher than the 1in 20 year value adopted in the feasibility study.

3.9 Feasibility Level Hydraulic Studies

In their feasibility level studies (Anthony Thurton and Associates Ltd., 2014) the hydraulic performance of a number of cross drainage paths was investigated using Autodesk Civil 3D –

Storm and Sewer Analysis (SSA), as well the HY8 package developed by the US Federal Highway Administration for design and analysis of culvert systems. The HY8 package can consider roadway overtopping.

Anthony Thurton and Associates applied the SSA and HY8 packages in analysis of the Red Creek and Garbutt Creek crossings, as well as a number of culverts. Their application to culverts at Camalote (mile 50), Teakettle (Mile 53), Blackman Eddy (Mile 58) and Georgeville (Mile 62) is presented in the Volume 3 technical feasibility report appendices (Anthony Thurton and Associates Ltd., 2014b).

3.10 Design Hydraulic Studies

Very little additional hydraulic analysis was carried out. Revised analysis was presented only for the Garbutt Creek Bridge. At this location the CH2M Flood Modeller software was used to investigate alternative channel improvement measures.

3.11 Roaring Creek Bridge

The Roaring Creek Bridge is flood prone, and in recent events flood levels have reached the top rail of the bridge. The bridge deck has apparently been submerged twice in the last 10 years. The maximum observed flood height was apparently 8" above the top of the bridge safety rails which are 1.06 m above the bridge deck (Anthony Thurton and Associates Ltd., 2014b). Neither the feasibility or design studies have indicated the date of this maximum observed flood level.

No hydrological analysis of the Roaring Creek was carried out in either the feasibility or the design studies. Reference was, however, made to earlier studies by TYPSA (TYPSA, Ingenieros Consultres y Arquitectos, 2010), in which an estimate was made of the probably maximum flood (PMF) for Roaring Creek. TYPSA estimated the PMF to be 424 m^3/s. Anthony Thurton and Associates did carry out some hydraulic analysis at the bridge site with the SSA and HY- 8 models, using the PMF discharge. No indication was given in the report of the extent of cross sections upstream or downstream of the bridge. Apparently normal depth conditions were assumed for downstream boundary conditions. The SSA model indicated a maximum water level that was 10 m below the bridge deck. The HY-8 model produced a peak water level that was 1.3 m lower than that produced by the SSA model. A peak outlet velocity of 2.16 m/s was produced by the SSA model, and a peak velocity of 5.23 m/s by the HY-8 model. Some further analysis was carried out with the SSA model using a range of fixed downstream boundary conditions. It was found that a downstream boundary level of 30.3 m combined with the PMF resulted in overtopping of the bridge. However, no frequency was attached to this downstream boundary water level.

Anthony Thurton and Associates (Anthony Thurton and Associates Ltd., 2014b) recommended that more detailed investigations be carried out. In the absence of such studies they recommended that the base of the girder of the proposed bridge be set above the level of the highest observed historic flood. They recommended a minimum elevation of 34 m (maximum observed flood elevation is 33.19 m). No attempt has been made to assign a return period to the maximum observed flood level, which could be less than 100 years.

In the design studies (CH2M, Halcrow Group (Trinidad & Tobago) Ltd., 2016), CH2M reviewed the feasibility level studies, and no further analysis was carried out. Clearly backwater influences from the Belize River have a significant influence on flood levels at Roaring Creek Bridge. Flood levels at Roaring Creek Bridge will be the result of the combination of Belize River levels at the confluence with Roaring Creek and flow in Roaring Creek. There will be a range of combinations that could produce similar flood levels. CH2M recommended that 0.5 m freeboard be allowed between the bottom of the bridge girder and the maximum observed flood level.

It is recommended that an analysis be undertaken of water levels in the Belize River at Banana Bank which is about 3.2 km downstream of the Roaring Creek confluence. It is understood that over 40 years of record exist for Banana Bank and it should therefore be possible to determine the frequency of Belize River levels in events that have resulted in bridge submergence in the past. If surface water profiles can be established for the Belize River upstream of Banana Bank, and water levels established at the Roaring Creek confluence with known frequency of occurrence, then hydraulic modeling could be used to establish water levels at the bridge site associated with different Roaring Creek discharges. Were rainfall data for the Roaring Creek catchment adequate, then it could be possible to simulate historic flood events at the Roaring Creek bridge location.

3.12 Barton Creek Bridge

The CH2M hydrologic /hydraulic design studies report states that the environmental and social impact study for the George Price Highway (Belize Environmental Technologies Ltd., 2014) indicated a flooding problem at the Barton Creek Bridge, and that the bridge deck has been overtopped, but this appears to have been an error. The hydrological and hydraulic studies report of the feasibility studies (Anthony Thurton and Associates Ltd., 2014) did not identify any flood problems at the Barton Creek Bridge, nor did the environmental and social impact study. The CH2M hydrologic /hydraulic design studies report, having identified a flooding issue at Barton Creek (p8) makes no further comment on it and no evaluation of Barton Creek is presented in either feasibility or design hydrological and hydraulic studies.

3.13 Garbutt Creek Bridge

The Garbutt Creek Bridge has been overtopped in the past and a flood in 2013 reportedly resulted in damage to the road. The SSA model used feasibility studies indicated that the bridge would overtop in a 20 year event, but the HY-8 model did not. The flood discharge had to be increased by 21% before the HY-8 model indicated overtopping. Remediation measures proposed included channel improvements and raising the level of the bridge deck by 1 m.

The CH2M design studies updated the flood risk assessment, having considered there to be considerable uncertainty associated with the feasibility study design flood estimates. However, no further hydrological analyses were carried out by CH2M. They reported that the cause of the 2013 overtopping had been a blockage to bridge opening caused by the collapse of the old west

side abutment. The CH2M recommendations included removing the old east abutment, providing additional scour protection and improving the downstream channel.

CH2M did carry out additional hydraulic modeling at the Garbutt Bridge site, Their Flood Modeller software was set up to represent Garbutt Creek for 150 m upstream of the bridge site and 130 m downstream of the bridge site. The hydrological analysis carried out for the feasibility studies was not revised and it was found that the bridge did not overtop in a 20 year event, and that considerably higher flows were required to cause overtopping, even with reduced downstream water surface gradients,

Measurement of the catchment area upstream of Garbutt Creek Bridge carried out for this review indicated a catchment area of 50.9 km^2, which is significantly larger than the 10 km^2 adopted in the feasibility study. It is recommended therefore that further hydrological and hydraulic analysis be carried out for the Garbutt Creek Bridge. The larger catchment area is likely to result in greater flood risk. Although flooding in 2013 was attributed to blockage of the bridge opening, it is entirely possible that flooding could have occurred without the blockage as the discharge associated with the flood is unknown.

3.14 Red Creek Bridge

The feasibility level studies reported that overtopping of the Red Creek Bridge has occurred in the past. Hydrological analysis was based on a catchment area of 2.9 km^2, and neither the SSA nor HY-8 hydraulic models indicated bridge overtopping in a 20 year flood event. The 20 year flood discharge was generated from a rainfall intensity of 70 mm/hr. It was found with the HY-8 model that overtopping would only occur with rainfall intensities of 100 mm/hr and above. It would appear that design recommendations were made on the basis of the flood discharge associated with the 100 mm/hr rainfall (a 100 year event).

In their design studies, CH2M recognized that there was considerable uncertainty associated with the feasibility level studies, and carried out further site reconnaissance visits. Their finding was that the bridge had been re-constructed in the mid to late 1990s, and that since then the bridge had not been overtopped. The CH2M hydrologic / hydraulic design studies report indicates that further modeling work was in progress, but we have seen no reports of this.

The catchment area of the Red Creek Bridge estimated for this review is 8.7 km^2, which is significantly larger than that taken by Anthony Thurton & Associates. If the further modeling studies indicated by CH2M cannot be located then it is recommended that further analysis be carried out at this location.

3.15 Benque Viejo Bridge

No analysis of the Beque Viejo Bridge / culvert was presented in the feasibility study (Anthony Thurton and Associates Ltd., 2014b). The design studies report (CH2M, Halcrow Group (Trinidad & Tobago) Ltd., 2016) indicated that options were under review (see p41), but there is no description of analysis undertaken.

3.16 Succotz / Benque Viejo Flood Prone Sites

The approach to hydrological analysis in the Succotz area has been described in section 3.6. The approach makes good use of the available data and the recommendations are considered to be sound.

3.17 Minor Flood Prone Sites

In the feasibility study (Anthony Thurton and Associates Ltd., 2014b), the minor flood prone sites were sections of the highway at which flooding occurred about six to eight time per year, with road overtopping being the result of blocked on under-sized culverts. In the feasibility studies the HY-8 model was used to simulate existing flooding conditions – the discharge was found at which road overtopping would occur. A factor of safety of 1.25 was then added to this discharge, and an appropriate culvert size determined that would convey the discharge with an assumed culvert gradient. The approach was applied to the flood prone sites at Camalote (mile 50), Teakettle Village (Mile 53), Blackman Eddy (Mile 58), and Georgeville (Mile 62).

CH2M (CH2M, Halcrow Group (Trinidad & Tobago) Ltd., 2016) pointed out in their design studies that the approach adopted in the feasibility studies for these flood prone sites probably failed to represent the 20 year return period design flood event. They recommended increased culvert capacity combined with raising of the road surface. There was no evidence in their report of any additional hydrological or hydraulic analyses.

With reference to cross drainage culvert design CH2M stated in their report: "… *the design recommendations are based on site reconnaissance by design team engineers to decide what can be accommodated given the site constraints*." In most cases large pipe culverts were proposed.

The culverts in these areas drain small catchments that are very difficult to delineate, and a fully objective analysis is not possible.

3.18 Roadside Drainage Provision

Roadside drainage was not discussed in either the feasibility or design studies. The design drawings indicate provision of a standard trapezoidal earthen channel section throughout with a base width of 600 mm, side slopes of 1:2 and a depth of 500 mm, resulting in a minimum top width of 2600 mm. Checks have been carried out as part of this review to assess the adequacy of the proposed roadside drains where there is more than 1000 m between cross drainage culverts.

3.19 Assessment of Roadside Drainage Requirements

Generally the road drains from the centre line to either side. There will be a 3.5 m carriageway width, a 1.5 m shoulder, and a 0.5 m verge providing transition to the side drains. The drainage width is thus 5.5 m, plus the width of the proposed side drain of 2.6 m, giving a total drainage width of 8.1 m. Roadside drainage is usually designed on short duration rainfall intensities. Typically 5 minute duration is used. The minimum duration for which data were plotted in the IDF curves used in the feasibility studies was 15 minutes, and there is no basis for extrapolating from this to 5 minute duration. Recourse was made to short duration rainfall intensity data for

Georgetown in Guyana that was recently analyzed for a road project there. Short duration rainfall intensities for Georgetown Guyana are summarized in Table 3.1.

Table 3.1 Short duration rainfall intensities for Georgetown, Guyana

Non-exceedance probability	Return period (years)	5 minute intensity (mm/hr)	10 minute intensity (mm/hr)	15 minute intensity (mm/hr)
0.50	2	164	108	93
0.80	5	221	135	113
0.90	10	260	152	125
0.95	20	296	169	138
0.98	50	344	192	153

At 15 minute duration, the intensities are a little higher than those indicated for San Ignacio in the IDF figure presented in the feasibility and design studies. Using the Georgetown 5 minute intensities may therefore be slightly conservative. It is recommended that short duration data for Belize be analyzed to create properly representative IDF analysis.

For the purposes of this review, 5 minute rainfalls at 10 and 20 year return periods were considered. Assuming that all rainfall in a 5 minute period has to be drained at a uniform rate from a drainable width of 8.1 m, then the required drainage capacities per 100 m length of road at return periods of 5, 10 and 20 years are 0.049 m^3/s, 0.059 m^3/s and 0.067 m^3/s respectively.

Roadside drain discharge capacity, west and east, was calculated on the basis of the average slope between the highest drain bed level between cross drainage culverts and the drain bed level before outfall to a cross drainage channel. Standard charts were prepared for estimation of required roadside drain discharge capacity (Figure) and actual side drain discharge capacity, assuming normal depth of flow of 390 mm (to provide freeboard) (Figure). A Manning's "n" of 0.05 was assumed. Analysis of roadside drains where distances between culverts exceeds 1000 m is summarized in Table 3.2.

Table 3.2 Evaluation of roadside drain capacities between culverts

Culverts	Eastern Reach						Western Reach					
	L (m)	S	Capacity (m^3/s)				L (m)	S	Capacity (m^3/s)			
			Avail.	Reqd. 5y	Reqd. 10y	Reqd. 20y			Avail.	Reqd. 5y	Reqd. 10y	Reqd. 20y
203-204	770	0.026	0.68	0.37	0.45	0.52	907	0.009	0.40	0.45	0.53	0.62
209-210	750	0.022	0.63	0.37	0.45	0.52	920	0.019	0.58	0.45	0.53	0.63
305-306	220	0.025	0.67	0.1	0.13	0.15	790	0.036	>0.7	0.38	0.47	0.53
306-Barton 1	110	0.014	0.50	0.06	0.07	0.08	460	0.008	0.38	0.23	0.28	0.32
306-Barton 2	630	0.035	>0.7	0.32	0.38	0.44	930	0.030	>0.7	0.46	0.56	0.65
Barton - 307	740	0.044	>0.7	0.37	0.44	0.52	740	0.025	0.67	0.37	0.44	0.52
321-322	1370	0.015	0.52	0.68	0.82	0.96	740	0.019	0.58	0.37	0.44	0.52

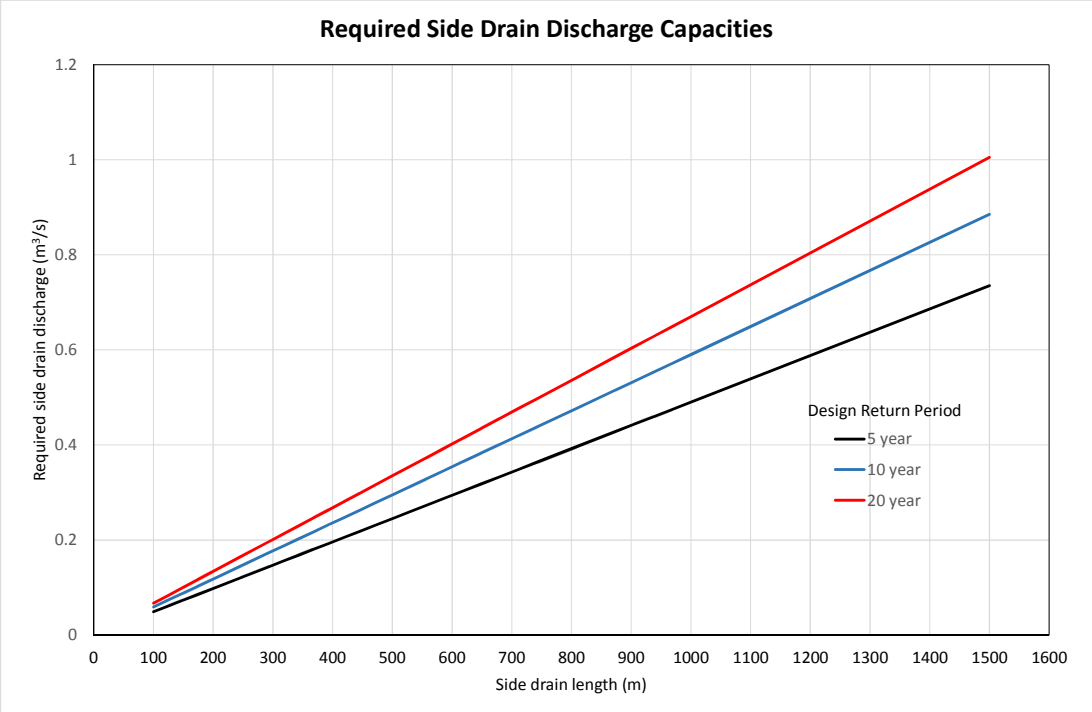

Figure 3.5 Required roadside drain discharge capacity

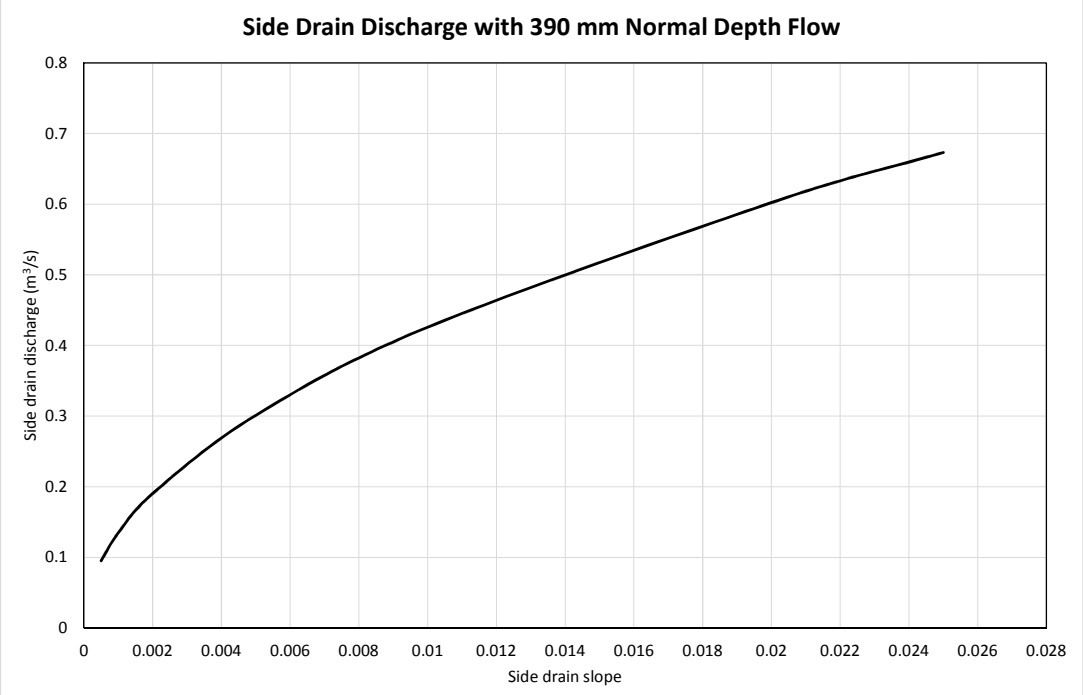

Figure 3.6 Available roadside drain discharge capacity

The analysis undertaken indicates that the roadside drain on the western reach between culverts 203 and 204 is undersized, as is the roadside drain on the western reach between culverts 209 and 210 for a 20 year return period, and the roadside drain on the eastern reach between culverts 321 and 322.

On the western reaches between culverts 203 and 204, and between culverts 209 and 210, the base width of the roadside drains should be increased to transition from 0.6 m at the upstream end to 1.34 m at the outfall section. Deepening and narrowing of the base width would be an alternative. On the eastern reaches between culverts 321 and 322, the base width of the roadside drains should transition from 0.6 m at the upstream end to 2.16 m at the downstream end. Alternatively the channel could be deepened to 0.85 m at the downstream end with base width reduced to zero, resulting in a top width of 3.4 m. The deepening and narrowing of base width could be on a uniform transition from upstream to downstream.

The roadside drains are larger than required in many areas.

3.20 Evaluation of Design Recommendations: Bridges

There has been no hydrological analysis of flood levels at Roaring Creek, and design levels are based on the largest observed historic flood that may or may not be similar to a 100 year event. It may be possible to attach a frequency to recently observed events by analysing Banana Bank water levels and flows in conjunction with catchment rainfall data.

Incorrect catchment areas were used in the assessment of the Garbutt Creek and Red Creek bridges. Hydrological and hydraulic analyses need to be revised for both of these bridges.

3.21 Evaluation of Design Recommendations: Culverts

A site visit by the team leader and Client raised questions over the recommended sizing of replacement culverts C213, C217 and C306a. As part of the current review, no hydrological or hydraulic analysis has been carried out, but culverts cross sectional areas have been plotted against their catchment areas. Catchment areas were estimated from the SRTM90 DEM using ArcHYDRO tools. For large catchments the areas estimated will be reliable, but for micro-catchments they will not be. Figure 3.7 presents the plot of culvert areas against estimated catchment area. It would appear that C213, C217, C417 and C313 may be over-sized. C306a does not appear to be over-sized.

It is recommended that the designs of C213, C217, C313 and C417 be revised. In order to do this channel cross sectional survey will have to be undertaken and ideally revised design storm rainfall data.

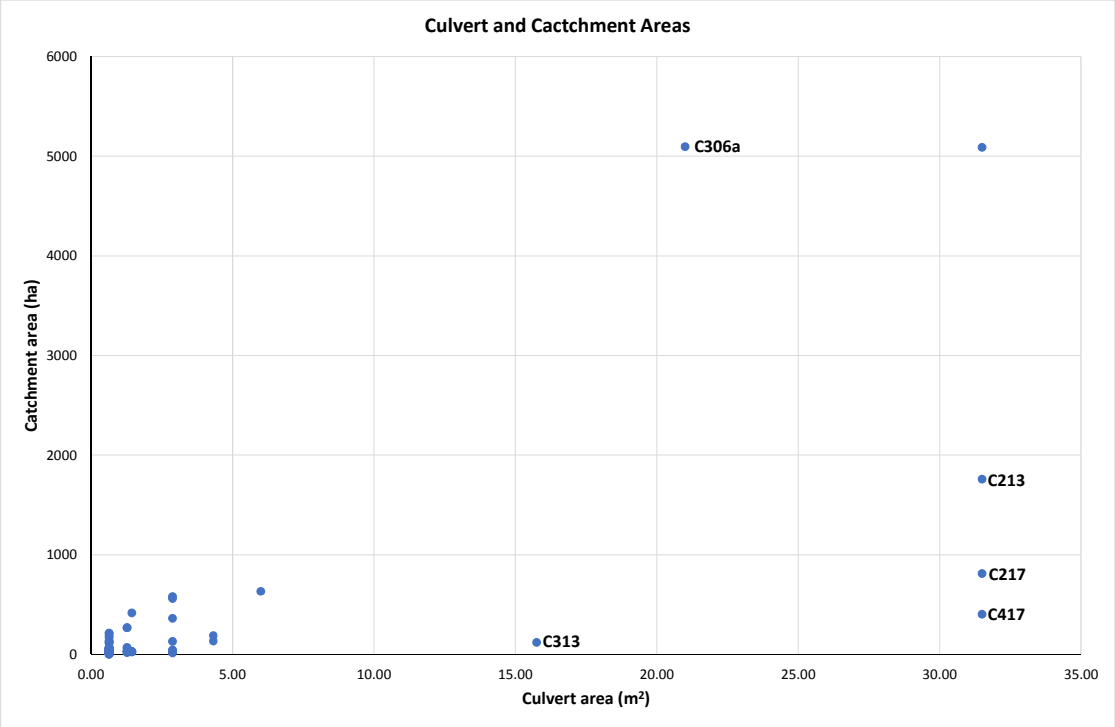

Figure 3.7 Plot of culvert areas against catchment areas

3.22 Conclusions and Recommendations

It is recommended that comprehensive rainfall intensity-duration-frequency analysis be carried out, utilizing data from Belmopan, Central Farm Cayo and Barton Creek. Durations down to 5 minutes should be considered.

Observed water level and flow data for the station on the Belize River at Banana Bank should be analyzed and correlated with historically observed flood levels at Roaring Creek Bridge in order to try and attach a return period to the recent observed event that has formed the basis of design. The specified design return period for Roaring Creek Bridge is 100 years, but at present the return period of the highest historic level used in design is not known.

Incorrect catchment areas were used in the hydrological analysis of the Garbutt Creek and Red Creek bridges. Both hydrological and hydraulic analyses need to be revised. Cross section survey will be required upstream and downstream of the bridge sites.

Culverts C213, C217, C313 and C417 appear to have been oversized. Both hydrological and hydraulic analyses need to be revised. Cross section survey will be required upstream and downstream of the culverts.

In general the roadside drainage provisions are adequate, but there are three reaches in which the roadside drains need to be enlarged.

4. STRUCTURAL REVIEW SECTION I (LOT 1) ROARING CREEK BRIDGE

4.1 Executive Summary

This review was undertaken in 3 parts over 2 visits to Belize by the Senior Bridge Engineer (SBE), Mr David Jones. The initial part was an overview of the design and drawings that took place in early January 2018. At this time several serious concerns came to light that were brought to the attention of the Chief Engineer (CE) of the Ministry of Works (MoW), in a meeting held at the Ministry on 12th January 2018. In this meeting the CE initiated the means by which the design and drawings could be amended as the Designer was no longer contracted by the MoW. The MoW has agreed with the contractor M & M Contracting that it will carry out any redesign works and amendments to the drawings that will be checked by the MoW before being issued for construction. An initial briefing note was produced and passed to MoW listing the concerns raised during the review of the drawings. This is contained in Annex A.

The SBE returned to Belize in early February to continue the review. The second part of the review went into more detail in the drawings and again more serious concerns were raised that required further investigation in the design calculations which became the third part of the review. As part of the investigations M & M were instructed to undertake 3 proving boreholes at the piers. One borehole on the east side of the river to prove the data contained in Borehole 9 shown on the drawings and two boreholes on the west side of the river to determine the rock level as no boreholes had been done previously at this location. The boreholes proved the data shown in the drawings to be accurate.

In order not to slow the progress of the Works the SBE was instructed by the MoW to liaise with M & M on the design changes on the basis that these form 'value engineering' within the Contract. On the completion of the second stage of the review a meeting was held between M & M and SBE to discuss the concerns noted in the design. A briefing paper, attached as Annex B, was produced for the benefit of MoW following this meeting.

The investigation into the design calculations was brought about by the lack of certain standard data that was expected to be seen on the drawings but was not and by what appeared to be massive over-design of certain elements in the bridge. The design calculations were not well presented as there was little annotation on what assumptions the Designer had used in the design and it became apparent that essential design loads may have been omitted from the design as they were not included in the load section where other similar loads were described. In order to determine whether the Designer actually included the 'missing' loads a close examination of the beam design calculation results had to be undertaken. Luckily these loads were found in the results of the design and were found to be at the right magnitude.

In undertaking this investigation into the design calculations it became apparent that the Designer had simplified the design of the pier crossheads and columns which appears to have resulted in

these elements being over-designed. Further work by M & M will be necessary to establish whether these elements can be safely reduced in size.

In summary the design can be described as follows:

There are many parts of the bridge that have been over-designed and can be simply amended to make the cost less than originally tendered.

The drawings contain many details that require amending in order to produce a design for a bridge that can be easily constructed and maintained in the future;

The Designer has failed to include in the drawings essential details that the contractor requires to accurately construct the bridge as intended by the Designer; and

The Designer has failed to check the drawings for their adequacy as details are shown that are obviously incorrect and not what was intended in the design.

During this review liaison with M & M was undertaken to get its view of the proposed amendments and whether it saw any issues in dealing with the design and changes to the drawings. M & M expressed its satisfaction with the proposals and agreed to establish a strategy for completing these changes in a manner that would not impinge on the progress of the Works. M & M can be commended for its attitude and professionalism shown during the review which should lead to a satisfactory conclusion to the design and produce a bridge as intended by the MoW.

4.2 Introduction

IMC Worldwide Ltd. Were contracted to undertake a design review and supervision of the construction of Lot 1 George Price Highway Roaring Creek Bridge in November 2017. Documents were supplied to the SBE at that time but, due to ongoing commitments, he could not attend to this work until after the New Year break and he arrived in Belize on 9th January 2018 for a week. The SBE undertook the initial review of the drawings and met with the client and contractor during this visit.

Following a short interlude when the SBE returned to his prior commitments, a second visit was arranged for him to finalise the design review and other deal with other issues related to the commencement of the bridge works. This visit took place from 4th to 17th February 2018. During this visit the design review was completed and, in agreement with the MoW, liaison meetings were held with the contractor who was to undertake the redesign and amendments to the drawings on a 'value engineering' basis as most of the proposed amendments to the design would result in a saving in the cost of the work.

As the design deficiencies were explained to MoW as the review progressed and options for the solution to these deficiencies presented at the same time the normal procedure for presenting the design review report then awaiting comments from MoW before submitting

recommendations will not be followed in this instance as the recommendations have been made and accepted by MoW as the review was completed.

Design Review Outcome

At the time of writing this report all the design deficiencies listed in Annex B, except the possible changes to the pier crosshead and columns that was identified after the meeting with M & M to discuss the way forward, have been put to M & M for consideration. It is understood at this time that M & M are looking at the proposed changes to the pile and pilecap design as this is the first aspect of the works that is scheduled to commence shortly. Initial comments from M & M are that the pier pilecaps will be incorporated into 1 long pilecap at each pier but the numbers of piles will likely not change. It is also likely that the piles shown below the wing walls at the east abutment will be reduced significantly.

The lifting of the pier pilecaps is known to be acceptable to M & M as this was commented on favourably in the meeting. It is also believed to be acceptable to MoW as it removes the risk to the existing bridge.

With the exception of Item v on the list in Annex B the Items listed from iv to xiv were discussed with M & M in the meeting with no objections being offered therefore it is believed that in the fullness of time these aspects will be dealt with and the design and drawings will be changed.

As the concept of the strut and tie method may not be familiar to M & M's designer and, as this item was not discussed in the meeting, it is unknown how M & M are viewing this change to the design. Further discussions are likely to take place over this issue in the near future when the piling issues have been resolved and the piling commences.

4.3 Value Engineering Discussions

4.3.1 Introduction

The design review of the Roaring Creek Bridge discovered several aspects of the design that stood out as being unusual and, in some cases, caused concern to the reviewer as the detail had potential to have an impact on the long term integrity of the structure. These initial potentially hazardous details were brought to the attention of the Ministry of Works (MoW) in a meeting held on 12th January 2018. More work has been done on this subject since then and further potentially costly items were discovered and added to the list presented to MoW at this meeting. The updated list is added to this briefing note.

The amendments to the details would lead to either a reduction in the cost of the bridge or make it easier to construct therefore it was on this basis that MoW agreed to approach the contractor for it to undertake the design of the amendments for MoW to accept into the final 'for construction' design.

This briefing note outlines the amendments agreed with the contractor in a meeting held on 13th February 2018.

In summary, the design changes shall be to the following structural elements:

- Piling: the reduction in the number of piles;
- Pier pilecaps: combine the individual column pilecaps into one to reduce the reinforcing bar numbers and sizes;
- Piers: reduction in the height of the piers by lifting the pilecaps to a more suitable level;
- Pier crosshead: reduction in the reinforcing bar numbers and sizes;
- Pier crosshead and columns 'frame': reduction in member sizes using the strut and tie method;
- Pier bearings: replace existing poor detail with the 'normal' method of installing bearings and shear keys;
- Abutments and retaining walls: reduction in the reinforcing bar sizes;
- Deck ends at abutments: replace the poor detail of deck overhang with the 'normal' end wall and expansion joint;
- East abutment: removal of 'fin' walls behind the wing walls;
- West abutment: reposition the retaining walls to reduce the impact on the adjacent properties;
- Deck diaphragms: reduction in the reinforcing bar numbers and sizes;
- Beams: removal of the corrosion inducing plates and members at the bearing points;
- Beams: introduce the debonding noted in the design but not inserted on the drawings; and
- Deck slab: sit the permanent formwork slabs directly onto the beams to reduce the deadload of the slab and reinforcing bar numbers and sizes.

4.3.2 The reduction in the number of piles

The piling seems to have been fixed by the designer at 3 No. 450 x 450mm square piles at 1.35m centres in both directions irrespective of the forces being transferred into the foundation. This is obviously an over-design for the wing walls at the east abutment where the earth pressures behind the walls reduce to zero whilst the piles remain as described. The piles will be reduced at these and other locations where it can be shown that the design forces being transferred into the piles do not warrant such a large concentration of piles.

4.3.3 Combining the individual column pilecaps into one

The individual pilecaps have a gap between them of only 450mm thus to save about 4 m3 of concrete the designer is adding the reinforcing bars in the 4 adjoining faces of the pilecaps. By having the pilecaps individually for each column the designer is not fully utilising the effects of the

loads being transferred throughout the total number of piles installed. By combining the pilecaps loads will be transferred from the most heavily loaded column piles to adjacent piles thus making the most efficient use of the piles and potentially reducing the number of piles required.

4.3.4 Lifting the pier pilecaps

It was noted that the west side slope has been detailed cutting into the existing ground by as much as 5m only a short distance from the foundations of the existing bridge west piers. This is unacceptable as there is potential to undermine the existing bridge pier foundation thus endangering the structural integrity of this bridge. By lifting the foundations of the new bridge there is no need to have the side slope as per the original design thus the integrity of the existing bridge is safeguarded. The added benefit of lifting the pilecaps is the reduction in the height of the columns thus creating a saving in concrete and reinforcing bar quantities with the potential to reduce the number of piles at these locations.

It should be noted that during the design review the contractor took additional boreholes on behalf of the reviewer to confirm the level of the anticipated rock horizon at the pier locations. These boreholes confirmed the level of the rock horizon as shown in the original boreholes provided in the bridge drawings. When reviewing the piling at the pier locations it was noted that the anticipated 7m piles would not be utilised as the rock horizon is only 1.5 to 2m below the level of the underside of the pilecap thus, by lifting the pilecaps by 3 to 4m there is no additional cost in extending the piles as the 7m pile as billed will suffice.

4.3.5 Reduction in the reinforcing bar numbers and sizes in the pier crosshead

In the reinforcing drawings for pier/crosshead 'frame' the designer has shown the column reinforcement penetrating 1.5m into the body of the crosshead with the associated circular bars accompanying them. Normally only an effective starter length of 40 times the diameter of the bar needs to penetrate in to an adjacent member concrete for the connection to be fixed. In this case no more than 1m is required thus there is a substantial saving in the quantity of reinforcing bars required. (If the analysis of the pier/crosshead 'frame' shows the bending moments to be significantly reduced as expected the bar diameter and thus this length will be reduced.)

It should be noted that there are several other errors shown on these drawings that, when corrected, will reduce the quantity of reinforcing bars in the crosshead.

4.3.6 Reduction in member sizes using the strut and tie method

In the design the crosshead/columns 'frame' has been input as line members with no allowance for the depth of the crosshead being taken into consideration. For members such as the crosshead, which is deep compared to its width and where the loads are transferred to the concrete as spread loads such as bearings; the crosshead can be considered to form a 'virtual truss' whereby the loads are transferred to the supports by internal struts within the concrete that are tied together by the reinforcing bars thus making a 'virtual truss' within the crosshead. This method can be seen to be more appropriate as the bearings are located relatively close to

the supporting member, the column in this case. (Relatively close in this aspect refers to the distance (d) from the centre of the bearing to the middle of the column being less than the depth (D) of the beam (d < D).)

Utilising the strut and tie method the depth of the beam can be determined as being equal to the maximum distance from the centre of the bearing to the middle of the column so that the strut acts at a maximum of 45o to the vertical. In this case the maximum distance from the centre of the bearing to the middle of the column is 1.58m thus the crosshead can be reduced by 0.42m. The amount of reinforcing bars required in the top of the crosshead can be determined by simple static forces which are believed to give a significant reduction in the amount of reinforcing bar used in this instance.

4.3.7 Replacing the existing bearing fixing detail

The designer has shown the bearings to be set into pockets in the top of the abutments and piers that are created by cutting the top reinforcing bars to enable a plate of cementitious mortar to be placed below the bearing. The normal method of fixing bearings at abutments and piers is to raise the bearing on small plinths above the top of the wall/crosshead so that they can be kept clean, inspected and replaced easily.

The designer also installed the transverse shear keys that hold the deck in place during seismic events at locations that would be damaging to the main beams when such an event occurred. The existing detail will be replaced with the normal shear key into the deck diaphragm thereby protecting the beams.

4.3.8 Reduction in the reinforcing bar numbers and sizes in abutment and retaining walls

The main reinforcing bars that have been placed at the bottom of the walls of these elements to resist the maximum bending moments have been taken to the top of the walls where the bending moment has reduced to zero. By curtailing these large diameter bars where they are no longer required with a smaller bar size that still resists the reducing bending moment will significantly reduce the quantity of reinforcing bar used.

4.3.9 Replacing the deck ends at the abutments

The existing detail shows the ends of the deck being constructed down the back of the abutment wall with an approach slab at road level across the full width of the road. The designer has not taken into consideration the daily movement of the deck when it expands and contracts as the deck is warmed by the sun. This movement would cause the road at the end of the approach slab to be under cyclic loading it is not capable of withstanding thus the road will deteriorate prematurely. By utilising the normal abutment end wall and expansion joints detail this premature deterioration will be avoided.

4.3.10 Removal of 'fin' walls behind the east abutment wing walls

It appears that this is a 'copy and paste' error left on the drawings by the designer as these fin walls have no sensible use and would cause issues on site with the compaction of the earthworks materials behind the wing walls.

4.3.11 Reposition the west abutment retaining walls

It is recognised that there is very little space available for the construction of these walls due to the close proximity of the existing road and the adjacent properties thus repositioning these walls away from the existing road and property boundary fences will make construction easier and avoid potential claims from the property owners.

4.3.12 Reduction in the reinforcing bar numbers and sizes in the deck diaphragms

The details incorporated into the design for the reinforcement of the abutment and pier diaphragms are poor as the designer has failed to recognise the method for constructing these elements. By reducing the size of these reinforcing bars there will be a saving in the quantity of steel used and construction will be made easier for the contractor.

4.3.13 Removal of the corrosion inducing plates in the beams

These elements are not required as the beam concrete alone adequately copes with the stresses imposed on the beam at the bearings. By incorporating these elements into the bottom of the beam the designer has potentially created a path for corrosive compounds to penetrate up to the pre-stressing strands. By removing these plates this path is removed thereby safeguarding the strands from corrosion.

4.3.14 Debonding the pre-stressing strands

Debonding of the pre-stressing strands at the end of the beams prevents the potential for beam end splitting to occur. The end splitting occurs when the forces at the top and bottom of the beam are significantly dissimilar. The debonding of some of the strands reduces the forces at the bottom of the beams thereby equalising the forces in the top and bottom of the beams thus preventing the splitting from occurring.

4.3.15 Sit the permanent formwork slabs directly onto the beams

The existing detail for seating the permanent formers onto the tops of the beams is very unusual and introduces additional unnecessary concrete and reinforcing bars on to the top of the beam that add nothing to the design but add self-weight to the beam. The detail is not well presented as it potentially causes problems with the placement of the concrete when the deck slab is poured. The method for placing these formers directly on to the top of the beam alleviate the problem during the pouring of the slab concrete and keeps the dead loads acting on the beam to a minimum.

Reference for the strut and tie methodology:

https://www.slideshare.net/fawadnajam/ce-7252-lecture-7-strut-and-tie-models

5. GEOMETRIC DESIGN REVIEW

5.1 General Finding

5.1.1 Design Consultant's Final Design Report

The Final Design Report states that the design will conform to AASHTO's Geometric Design Standards for Primary Road of Two Lane Undivided Highway with Paved Shoulders. The report defines the design speeds to be applied as being 100kph generally and 40kph in Urban/Village areas. It defines the following maximum gradients along the road and the maximum cross fall in curves that should be applied as follows:

Normal Road Cross Fall	3%
Shoulder Cross Fall	3%
Maximum Gradient	6%
Maximum Super-elevation	3%

The Final Design Report does not state, for each of the two design speeds, the actual design values applied for the important aspects of the geometric design, namely the following:

- The minimum curve radius for the stated max. super-elevated crossfall of 3%
- The stopping sight distance and decision sight distance used in the design, and therefore the K value for the crest curves.
- Passing sight distance for identification of no-overtaking sections.
- The K value for crest curves able to accommodate the passing sight distance

AASHTO's Geometric Design Standards indicate the following criteria defined in Table 1 to provide a geometric design that delivers safe stopping sight distances and passing sight distances on two lane undivided roads.

Table 1 – Minimum Design Criteria

Design Speed	**Min radius of curvature with 3% super-elevation (m)**	**Stopping Sight Distance SSD**	**Crest rate of vertical curvature, K value**
40	65	50	4
100	525	185	52*
Passing on 2 lane undivided roads		**Passing sight distances PSD**	**K value for passing**
40	To ensure passing sight distance remains within RoW	270	84
100		670	520

* The typical K value used throughout the design is 23. This is not as per the recommendations.

5.1.2 Super Elevation

It is noted that the AASHTO's Geometric Design Standards states that values up to 10% of super-elevation can be used. The standard does however define a limit on the upper value of super-elevation to be applied to curves. It notes that values of greater than 4% should not be used in Urban areas due to constraints of buildings etc. and secondly in areas (within the USA) where snow and ice is anticipated. Neither of these foregoing constraints are applicable to the road sections as it does not pass through formal Urban areas.

The limit of 3% for super-elevation is a severe constraint on the design of a safe horizontal alignment. It is to be recommended that values of up to 6% should be allowable.

5.1.3 Speed Limits along the Road Section

Signing defining the speeds limits on the roads is 55mph and 25mph respectively. To apply the values in Table 1 it assumed that those lengths of the road where the 40kph design speed will apply equates to the limits of the 25mph speed limits. This is as identified by the speed limit signing along the road.

It is noted however that the specification of speed limits on the "Signing and Bus Stop Detail" drawing is inadequate or inconsistent. At some locations different speed limits are signed, for opposing lanes on the same road segment over long sections. Another example is that 25mph speed limits are signed at the start of a road segment but not cancelled at the end. Drivers therefore do not know where the limit ends. Drivers need to be fully aware of the safe speed for a road segment.

5.2 Section I Review Findings

The geometric design of approach road in Lot 1 generally found acceptable.

5.3 Section II Review Findings

5.3.1 General

If the design approach is to generally follow the existing road alignment, there is be little opportunity to improve the overall driving experience, and safety of the route. Some bends, and a number of vertical curves have been adjusted, in the latter case significantly to improve forward visibility. However, in many other locations the forward stopping sight distance is constrained by

The existing alignment also provides very few opportunities where the forward visibility is consistently large enough to allow vehicles to pass (overtake) in safety by having the recommended passing sight distance as AASHTO. Consequently, drivers take risks by overtaking where the forward visibility is inadequate for passing.

5.3.2 Section II Review of Alignment

As noted above all designed horizontal curves should accord with the minima in Table 1 above, using the stated 3% maximum crossfall. A decision on the minima to be applied along the sections is defined by the intended speed limits to be imposed along the road.

The following table summaries the findings along the road. The start and end of the segments was intended to be defined by the speed limits but these proved unreliable compared to the actual situation in the design e.g number of sub-standard geometric features within a supposedly 100kph section requires segments to be amended. The revised segment start and end points are marked '?'.

Table - Review Section 2 segmented by indicated speed limit sections

Road Segment		Design Speed from Speed Limit s	Horizontal Design Providing SSD	Vertical Design And SSD	Horizontal Design providing PSD	Vertical Design Providing PSD
Start	End					
0+485	2+045	40	Complies	2+028, K=23 which is inadequate for SSD for 100kph. Check req'd in ACAD	No as urban area	No as urban area
2+045	3+380	100	Complies	2+595 K=28.75 c.f 52; and L =179m 3+276 K = 46 c.f. 52 & L = 175m Check req'd in ACAD	Yes, basically straight	No. So no passing signs and markings required
3+380	4+710 But move to 4910 as bus stop in between	40	Complies	3+428 & 3+607 sag then hog curve but road is offset from existing on new alignment so two curves should be replaced by gradient to remove the dip. 4+538 Crest curve K = 84 but causes cutting. K value should be reduced as in Urban area to 52 or less to reduce cut (cost saving)	No as urban area	No as urban area
4+710	5+900??	100	Complies to before curve at 5+590. %=590 Curve radius is 500m c.f. 525m. Recommend increase super-elevation above 3% to compensate	5+165 Sag curve with K 41.7 over culvert results in excessive fill. Reduce K value to 26?. Need to ensure adequate cover to culvert to reduce fill costs, currently nearly 2m.(cost saving)	Curve at 5+590 non-compliant as PSD inadequate. Sign as no overtaking zone	No. So no passing signs and markings required
5+900?	6+400?	40? Numerous opposing side entrances and bus stop at 6+130	Complies at 40kph	Complies at 40kph	No as urban area	No as urban area

Road Segment		Design Speed from Speed Limit s	Horizontal Design Providing SSD	Vertical Design And SSD	Horizontal Design providing PSD	Vertical Design Providing PSD
Start	End					
6+400?	7+230?	100	Complies	Complies but sag / crest combination at 6+871 and 7+016 considered poor design due to loss of forward visibility and comfort	No until after 6+700 as PSD outsides of RoW and following curve at 7+350 is sub-standard so does not to allow the full passing sight distance of 670m? Needs confirmation in ACAD	Remove sag/crest combination at 6+871 and 7+016 as can hide a car in the dip, when overtaking
7+230?	10+200	40 as sub standard bend 7+350 and then Bus stops after	Bend at 7+350, radius 200m not satisfactory for 100kph but is compliant for 40. Will need additional signing as high speed downhill approach.	Complies at 40kph Crest at 9+109 Teakettle bends. This crest leads into a series of bends of low radius and follows bends that are sub-standard for 100kph. However the crest curve has a K values of 23 which is significantly in excess of the design requirements for 40kph requiring a lot of cut. The crest needs to be designed for the 90% approach speed as current, rather than for 100Kph This would provide a cost saving.	No, as no OT at Bus stops or between laybys, or at side roads. PSD passes outside of RoW @ 8+300, 8+900, 9+070. So no passing signs and markings required	Yes as urban area
10+200	12+100	100	Bend at 10+600 is 495m radius	Crest curve at 10+396 has K = 119,	PSD not	Passing SD not

Road Segment		Design Speed from Speed Limit s	Horizontal Design Providing SSD	Vertical Design And SSD	Horizontal Design providing PSD	Vertical Design Providing PSD
Start	End					
	Reduce to 11+800 approx		which requires a super elevation of 4.2% for safety, not standard 3%. Increase super elevation. However to maintain the safe SSD land take is required throughout the curve and in advance. If land take is not viable the curve radius should be reduced and the super-elevation increased to 6 or 8% Bend at 11+900 is 200m.so at 3 % super elevation significantly below 100kph standard and the SSD passes well outside of the ROW into Belize Cristian Academy land. Even with 8% super elevation the curve is substandard. Reduce speed limit to before curve	resulting in 1+m cut, and does not provide full passing sight distance. Horizontal alignment prevents overtaking at the location K value is excessive c.f. that for SSD only but inadequate for passing. Safer to indicate to drivers that passing is not viable by reducing the K value and also the cut. (cost saving)	provided before 10+900 or after11+900 approx.. So no passing signs and markings required	provided through out due to switchback alignment. So no passing signs and markings required
12+100 now 11+900	12+800	40	Acceptable	Acceptable	Not applicable due to bus stops and constraints	Not applicable due to bus stops and constraints
12+800	14+600	100	The curve at 13+100 is 500m radius and needs the super elevation increased to4.2%. Between 13+250 and14+000 approx. the HA is a series of reverse sub-standard curves	The vertical alignment includes features inappropriate for 100kph speed. At 12+900 is a dip of 2m that could hide a car. The dip should be raised by some 1m to ensure a car can be seen.	Not provided so no passing signs and markings required	Not provided so no passing signs and markings required.

Road Segment		Design Speed from Speed Limit s	Horizontal Design Providing SSD	Vertical Design And SSD	Horizontal Design providing PSD	Vertical Design Providing PSD
Start	**End**					
			unsuitable for a speed of 100kph. The radii also vary from 100m to 250m which increases the hazard for drivers. The SSD moves outside of the RoW on the bends so that land take is required. The final bend in the length is 2000m radius at 14+330 too near the start of the next 40kph section. The alignment should be reconsidered to attempt to reduce the variation in the curve radius, say nearer to 150m. A speed limit needs to be applied to the length with signing and markings to highlight the alignment.	All crest curves have K values below the recommended value of 52. At 13+340 (where there are substandard horizontal curves) a K value of 10.36 is used and a curve length of 113m. This is sub-standard for 100kph by a long way. The crest curve requires cut to even meet this low standard. Over the final part of the segment the alignment is relatively straight but ends with a substandard crest with a K value of 23, prior to the 40kph speed limited section. A speed limit below 100kph over the length is required.		
14+600	end	40 assumed but not signed on the drawing	The segment is a series of bends of 150 or 200m with a 500m bend in between. These are all acceptable radii for 40kph.	The VA is satisfactory for 40 kph	Not applicable due to curve constraints but no passing signs and markings required at 500m bend due to lack of PSD	Not applicable due to curve constraints but no passing signs and markings required at 500m bend due to lack of PSD over crest curve at bend

5.4 Recommendations

5.4.1 GPH Section II

At several locations in the table, changes to the vertical alignment are identified that can reduce costs, but increase costs in other areas. Detailed design or value engineering is required to confirm the situation and the potential savings/costs.

5.4.2 No Passing Sections

The extent of each no passing sections is not clearly defined on the drawings, except in one limited location. The extent of the no passing sections needs to be reviewed and clearly defined on a separate drawing. The exact extent of these section may then need to be confirmed by onsite surveys of visibility after completion of the road pavement.

5.4.3 Signing of speed Limits and Sub-Standard Bends

The signing layout drawing needs to be amended to take account of the constraints identified in the Table regarding the use of sub – standard curve radius on 100kph design speed sections. A combination of extended speed limits, recommended speed limit curve signing, and improved bend delineation is all recommended to address the use of these sub-standard bends. The Speed Limit signing needs to re-visited to adjust the lengths of 25mph sections and correctly define the start and the end of each of these limits.

5.4.4 Guard Railing

It is noted that in some locations guard railing is defined and in other locations it will be required. Due consideration needs to be given the potential obstruction of both forward stopping and junction visibility.

5.4.5 Combined Signing and Road Marking, and guard railing lay out Drawing

A new combined signing and road marking, and guard railing layout drawing is required to provide for the No Passing and as well as the revised Speed Limit locations and Bend Warning signing. And additionally to ensure there is no conflict between these items' positioning.

6. PAVEMENT DESIGN REVIEW

6.1 Introduction

The road pavement design based on the ODA/TRL Overseas Road Note 31 – A Guide to the Structure Design of Bitumen-Surfaced Roads in tropical and Sub-Tropical Countries (ORN 31). The road surface design based on the ODA/TRL Overseas Road Note 3 – A Guide to Surface Dressing in Tropical and Sub-Tropical Countries (ORN 3).

TRL Road Note 31 was first published in 1962 and revised in 1966 and 1977. Last edition of TRL Road Note 29 on pavement design was published in 1970 and TRL Report LR 1132 - The Structural Design of Bituminous Road was published in 1984. The state of the practice is mechanistic empirical design.

This design review based on TRL Road Note 31 and other international design procedures

6.2 Existing Sealed Pavements

- History - The highway was constructed during 1930s and rehabilitated during 1980s, the pavement structure is of a double layer chip seal surfacing over un-bounded granular base and sub base.
- Record
  - Asphalt cracking not noticed.
  - Raveling of asphalt in some places.
  - Potholes not noticed.
  - Edge of carriageway breaking is evident all through the highway.
  - Shoulder erosion not noticed.
  - Rutting is noticed in Section 3.
  - IRI: riding quality is poor.
  - Deflection measured by Benkelman Beam reported in the Design Report.

6.3 Traffic Forecasting

- Axle Load Survey - The Preliminary Design Report assumes a Standard Axle Load of 8.16 tons. In attempt to provide consistency with Axle load limits in neighboring countries (Mexico and Guatemala) the government increased the legal axle load limit from 8.16 to 9 tons and Equivalency Factor was modified accordingly. Portable weigh pads were used for measuring axle loads at each location.
- List of vehicle classification and category. In accordance with ORN 31 Traffic Classes.
- ESAL for design - Projected 20 years ESAL for Section 1 and 2 is 4.540 X 10^6 and for Section 3 is 3.210 X 10^6
- Overall Traffic Analysis conducted in accordance with ORN 31.
- Future traffic growth factor was considered as 2.5%.

6.4 Soil and Materials Investigation

Field investigation included test pits, boreholes and DCP.

Test conducted on Test Pit samples are:

Moisture content (ASTM D2216)

Atterberg Limits (ASTM D4318)

Wet Sieve & Hydrometer (ASTM C136 & D422)

Standard proctor (ASTM D698)

Modified Proctor (ASTM 1557)

CBR (Soaked 4 days) (ASTM 1883)

Test conducted on Borehole samples are:

Moisture content (ASTM D2216)

Atterberg Limits (ASTM D4318)

Wet Sieve & Hydrometer (ASTM C136 & D422)

Unconfined Compression Strength Test

UU Triaxial (ASTM D2850-03a)

Consolidation (ASTM D2435M-11)

Direct Shear (ASTM D3080-04)

Standard proctor (ASTM D698)

Modified Proctor (ASTM 1557)

CBR (Soaked 4 days) (ASTM 1883)

Acid soluble chloride content (ASTM C 1152)

Sulphide content (NORSOK G-001, Clause D.12.10 or ASTM C114-11b Standard Test Methods for Chemical Analysis of Hydraulic Cement)

In the Preliminary Design twenty nine (29) DCPs were conducted along the George Price Highway from Belmopan to the Benque Boarder. A further nineteen (19) DCPs were conducted along the bypass route in San Jose Succotz. An additional 40 DCPs, at a spacing of approx. one mile, were conducted during final design.

6.5 Specification of road materials

- Prime Coat for surface treatment shall be MC70. The Binder shall be MC3000 Asphaltic Cutback.
- Stone Chipping shall be crushed rock or other approved material in two grades for first coat surface dressing (Grade 1) and second coat surface dressing (Grade 2) respectively for double bituminous surface dressing.

Grade 1

Average Least Dimension (ALD) 11.5-14.0 mm

Percentage of Least Dimensions within 2.5 mm of ALD: 65 min
Percentage passing 5 mm sieve: 1 max

Grade 2
Average Least Dimension (ALD) 7.5-10.0 mm
Percentage of Least Dimensions within 2.5 mm of ALD: 70 min
Percentage passing 5 mm sieve: 1 max

Grade 3
Average Least Dimension (ALD) 4.0-5.5 mm
Percentage of Least Dimensions within 2.5 mm of ALD: 70 min
Percentage passing 2.36 mm sieve: 1 max
Chippings shall be washed to remove all fines.

- Road Base

Road base material shall be approved crushed rock or other material approved by the Engineer complying with the following grading:

BS sieve size (mm)	Percentage by weight passing square mesh
37.5	100
20	60 - 80
10	40 - 60
5.00	25 - 40
2.36	15 - 30
0.6	8 - 22
0.075	5 - 12

The fraction passing the 0.075mm sieve shall not exceed two thirds of the fraction passing the 0.425mm sieve.
The material shall conform to the selected grading throughout the Contract.
Plasticity Index shall be 6 max.
Aggregate Crushing Value shall be 30 max.
CBR Value shall be 80 min.
Los Angeles abrasion value shall be 40% max as alternative to Aggregate Crushing Value.
Between 37.5mm and 5mm 70% by weight shall have two or more broken faces.

- Sub Base

Sub-base material shall be crushed rock or similar hard material, or naturally occurring gravel. The materials shall comply with the following grading:

BS sieve size (mm)	Percentage by weight passing square mesh

BS sieve size (mm)	Percentage by weight passing square mesh
37.5	100
20	90 - 100
10	-
5	30 - 60
2.36	-
0.6	35 - 0
0.075	20 - 0

Liquid Limit 35 max

Plasticity Index 10 max

Aggregate Crushing Value shall be 35 max.

CBR shall be 25 min.

As alternative to Aggregate Crushing Value. The Los Angeles abrasion value shall be 45% max.

6.6 Pavement Structure as per the Design Report

Capping layer of 200mm to be provided in locations where CBR values found only 2. These locations are KM 1 to KM 4.5 (3KM), KM 13.5 to KM 15.5 (2KM) and KM 26 to KM 29 (3KM).

Pavement structure on in situ Subgrade

- For Soil Class S2 (CBR 3 to 4) and Traffic Class T4 (1.5 to 3 million standard axle); SD + 200mm Road Base + 225mm Sub Base + 200mm
- For Soil Class S3 (CBR 5 to 7) and traffic Class T4; SD + 200 Road Base + 275 Sub Base
- For Soil Class S2 and Traffic Class T5 (3 to 6 msa); SD + 200 Road Base + 275 Sub Base + 200mm Capping layer.

Pavement structure on embankment and fill

- For Soil Class S6 (CBR 30) and Traffic Class T4; SD + 200 Road Base
- For Soil Class S6 and Traffic Class T5; SD + 225 Road Base

Pavement structure on existing pavement

- For Soil Class S6 and Traffic Class T4; DSD + 125 Road Base
- For Soil Class S6 and Traffic Class T5; DSD + 175 Road Base

Recommended pavement construction

- From KM 0 +000 to KM 1 + 000: SD + 200mm Road Base + 275mm Sub Base
- From KM 1 + 000 to KM 4 +500: SD + 200mm Road Base + 225mm Sub Base + 200mm Capping layer
- From KM 4 + 500 to KM 13 +500: SD + 200mm Road Base + 275mm Sub Base
- From KM 13 + 500 to KM 15 +870: SD + 200mm Road Base + 225mm Sub Base
- From KM 15 + 870 to KM 26 +000: SD + 200mm Road Base + 325mm Sub Base
- From KM 26 + 000 to KM 29 +000: SD + 200mm Road Base + 275mm Sub Base + 200mm Capping layer

- From KM 29 + 000 to KM 32 +489: SD + 200mm Road Base + 325mm Sub Base

6.7 Alternative design procedures

- Otta Seal may be an option which is a particular type of cost-effective and durable bituminous surface was originally developed in early 1960's by Norwegian Road Research Laboratory and in use in East and South Africa and performing well after more than 12 years. The difference is there is no application of Prime Coat and graded aggregate of crushed and natural can be used. In a particular road project in Botswana aggregate of maximum size 19mm, passing 75 micron 14%, Plasticity Index – slightly plastic to 8%, aggregate crushing value 40% and MC 800 to MC 3000 cutback bitumen was used. The road performed very well after 8 years.

- In accordance with South African Flexible Pavement Design Guide TRH 1996, which is also like TRL Road Note 31 a catalogue based design, for traffic volume of 1 to 3 million ESAs and for Subgrade CBR value from 3 to 7, the pavement structure shall be of SD + 150mm Road Base of CBR 80 + 150mm Sub Base of CBR 30 + 200mm Subgrade of CBR 15. Surfacing life period for Bituminous Double Surface treatment is 6 to 12 years.

TRH4 recommend asphalt concrete when designed for traffic volume is 3 to 10 million ESAs.

It is not possible to compare design procedures such as TRL LR 1132 (UK) as it deals with only asphalt concrete.

- Within the Appendices is a comparison with AASHTO Design Guide 1995 (USA) which shows the required SN (Structural Number) is 2.86 considering Soil Class S3 and Traffic Class T4 (Traffic volume of 1.7 million ESA as in the preliminary design and Subgrade modulus of 16500 psi). SN value becomes 2.29 with 200mm Road Base and 275mm Sub Base as recommended in the preliminary design. The pavement structure is not adequate for traffic volume of 1.7 million ESA. Traffic volume is much higher in the final design and the pavement structure recommended in the Final Design will not satisfy the requirements of AASHTO Design Guide 1995.

- State of the practice pavement design procedure is Mechanistic empirical pavement design. Within the Appendices is the pavement analysis using KENPAVE software (USA) based on mechanistic empirical pavement design (Pavement Analysis and Design – Second Edition by Yang H. Huang, 2004) considering 1.7 million ESA as in the preliminary design. The design life will be much less if traffic volume of final design is considered. The analysis shows if surface dressing is maintained properly the design life with 1.7 million ESA is **10 years**.

6.8 Comments

Maintenance of surface dressing will be needed to ensure the required service life. A rational structural design period for this road should be 10 years.

Considering the buildability it is recommended the pavement structure shall be SD + 200mm Road Base + 275mm Sub Base from KM 0+000 to KM 15 + 870 and SD + 200mm Road Base + 325mm Sub Base from KM 15 + 870 to KM 32 + 489.

Specifications for road materials found satisfactory. Borrow pits and quarries are not indicated in the Detail Design Report. Consultant visited the possible sources of aggregates for road and concrete works. Five sources are located, they are as follows:

- Dump site near Ignacio town for Road Base and Sub Base.
- EXCEL Construction Ltd., inside Spanish Lookout for Road Base, Sub Base and aggregates for Surface Dressing.
- National Aggregate Ltd. 21 miles outside Belize City for Road Base and Sub Base.
- Hanes Ltd. Jagar Paw, Mile 37 Western Highway (13 miles from Balmopan) for Road Base, Sub Base and washed aggregates for Surface Dressing.
- EXCEL Construction Ltd. Stockpile in Humming Bird highway (4 to 5 KM from Balmopan) for Road Base, Sub Base and aggregates for Surface Dressing.

6.9 Conclusion

Considering the local practice, low traffic volume and adequate drainage provided the pavement design is considered satisfactory.

7. REVIEW BILL OF QUANTITIES LOT 1 AND LOT 2

The review of the priced Bill of Quantities for Sections I and II revealed in varying degrees the following discrepancies which will need to be resolved:-

- Items that are under measured.
- Excluded Items (Design items shown on drawings but not included in the BoQ)
- Additional Items. (Items that are not in the drawings or BoQ but are recommended to be included after the Design Review).

7.1 Section I (Lot 1) Construction of Roaring Creek Bridge

The summary for BoQ Lot 1 is shown below. The total remeasure figure is about the same with just a BZ$ 36,000 difference between the original and remeasure totals. There were differences within the individual bill items with excluded items in Bills 4, 5, 6, 7 and 9 but these tended to be equalised by some degree of over measure in each of these bills. Within the bridge items there is a potential savings of BZ$449,000 in the new bridge construction but this is offset by under measure in the existing bridge repairs of BZ$402,000.

SECTION I (LOT 1) MEASUREMENT REVIEW					
Item No	**Item Description**		**Contract Amount Amount Bz$**	**Remeasured Amount Bz$**	**Difference**
1	BILL No 1: General Items and		**1,226,020**	1,226,020	0
2	BILL No 2: Demolition and Site Clearance		**26,750**	26,750	0
3	BILL No 3: Earthworks and Roadworks		**1,148,421**	964,609	-183,812
	Additional Items			*100,000*	*100,000*
4	BILL No 4: Drainage		**90,800**	78,220	-12,580
	Excluded Items of Work			*64,800*	*64,800*
5	BILL No 5: Bridge Works		**6,349,082**	5,900,093	-448,989
6	BILL No 6: Retaining Walls		**712,586**	683,731	-28,855
	Excluded Items of Work			*119,514*	*119,514*
7	BILL No 7: Road Lighting		**56,130**	37,525	-18,605
	Excluded Items of Work			*41,008*	*41,008*
8	BILL No 8: Bridge Repairs		**276,209**	678,135	401,926
9	BILL No 9: Scour Protection		**920,520**	744,204	-176,316
	Excluded Items of Work			*178,057*	*178,057*
	Sub-Total Grand Summary		**10,806,518**	10,842,665	36,147
	Contingencies to be expended if ordered or if required by the Engineer	5%	**540,326**	540,326	0
	Total (Bz$)		**11,346,844**	**11,382,991**	**36,147**

Although with the pluses and minuses the overall measure remains the same there are areas that may vary but have not been fully calculated because the redesign works have not been completed. The bridge redesign may well have savings in the abutment piles and the

reinforcement quantities for the pile caps and abutments. However the requirements for shoes to the piles and redesign work necessary on the bridge may well offset some of these savings. In addition the tie-in to the roundabout and sidewalk along this section of work has not been catered for on the drawings or within the BoQ. These items will require concrete pavement up to the roundabout, raised concrete sidewalks both sides of the carriageway and a widened embankment to cater for the sidewalk and crash barriers. At this stage it is believed the savings plus the contingencies will be able to offset the additional works required.

7.2 Section II (Lot 2) Roaring Creek to Iguana Creek Junction

The summary for BoQ Lot 2 is shown below. The remeasure total shows an additional BZ$3 million will be required between the original and remeasured totals.

SECTION II (LOT 2) MEASUREMENT REVIEW					
Item No	**Item Description**		**Contract Amount Amount Bz$**	**Remeasured Amount Bz$**	**Difference**
1	BILL No 1: General Items and Preliminaries		**2,254,110**	2,254,110	0
2	BILL No 2: Demolition and Site Clearance		**12,500**	41,250	28,750
3	BILL No 3: Earthworks and Roadworks		**11,286,495**	14,334,362	3,047,867
4	BILL No 4: Drainage		**4,306,734**	4,306,734	0
5	BILL No 5: Culvert C213		**859,180**	859,180	0
6	BILL No 6: Culvert C217		**843,670**	843,670	0
	Sub-Total Grand Summary		**19,562,689**	22,639,306	3,076,617
	Contingencies to be expended if ordered or if required by the Engineer	5%	**978,134**	978,134	0
	Total (Bz$)		**20,540,823**	**23,617,440**	**3,076,617**

All the roadworks items are under-measured but the main increases are in the rock excavation, subgrade, and pavement layers within the Bill 3 Earthworks and Roadworks. The item 3.1.03 Rock excavation has a quantity of 1,000m^3 yet the 'S' bend section side cut alone will account for over 15,000m^3 of rock excavation. It is also very likely that the road cut will be within rock material based upon the typical limestone landscape where the more resistant outcrops remain as low hills. A conservative estimate is that this figure will increase by BZ$500,000. The item 3.301 describes the preparation of the surface of the existing road but there is no equivalent item for the subgrade preparation off the edge of the road or in side slopes despite being detailed in the Technical specification. The inclusion of subgrade or roadbed preparation could increase costs by BZ$425,000. The Road Base in the Carriageway and shoulder does not include any material for the side roads, junctions and property accesses. The pavement layers also do not extend out to the side drains but are blocked by a topsoil verge. This type of construction will trap water and not

lead to the proper drainage of these critical layers. The increase in the base quantities to the carriageway and shoulder will be in excess of BZ$600,000.

Potential increases have been identified in the crash barriers, concrete sidewalks, capping layers and utility relocation but these items need to fully designed or detailed before they can be fully calculated. The Safety Audit report identified requirements for additional crash barriers at sharp bends and high embankments. The quantity of the sidewalks within the BoQ does not match with the design drawings so there will need to be a review of the pedestrian movements within these urban sections of the road corridor. There is also a question of the capping and engineered fill materials which are shown on the typical pavement design do not seem to be present in the BoQ or other drawings. The biggest item in the utility relocation work will be the BWSL water relocation or upgrade work. To date the full design has yet to be submitted but we have seen a BoQ between the Utility Company and the Contractor for BZ$934,312 which is over BZ$400,000 more than the figure under Item 1.10.02 in the Contract BoQ. The full work details and payment structure needs to be clarified. An area of caution is the cut areas of the project where these pipes trenches may go through rock which could have severe implications on the time and cost for the project.

Potential savings could be possible where the culvert C213 and C217 are reduced from 3 to 2 cell culverts and the concrete surround omitted from the concrete pipe culverts. However the more significant savings will only be possible on this section if the horizontal and vertical alignments are modified to allow the best use of the existing road.

At this stage with the design in question it is estimated that there will be a BZ$3 million shortfall.

8. DESIGN REVIEW RECOMMENDATIONS

The following table details the concerns and recommendations that were identified by the review team for each of the design documents studied. Each concern has been given alert rating (based on the seriousness of the design omission or discrepancy). The recommended action or design modification is listed alongside the item number and we would recommend that specific attention be given to those concerns rated as 'red' high risk.

Supervision of Works for the George Price Highway Rehabilitation Project

Section I, II, and III (Lot 1, 2 and 3)
Construction of Roaring Creek Bridge
Design Review - DESIGN REPORTS
February 2018

Item	Section	Clause / page	Description	Recommendation	Threat Level	MoW Comments Accept / Decline
	FINAL REPORT - November 2016					
1	Appendix B (Section I)	Consultants Response to Client Comments. Item No. 1, 8, 9 45.	Refers to Technical Specification Art. Numbers but these do not relate to Technical specification numbers in the Section VII Technical Specification issued to the Contractors.	Ensure full technical details provided for the works to be carried out. Determine if the Specification has changed?	Amber	
2	Appendix B (Section I)	Consultants Response to Client Comments. Item No. 2a, 2b, 3	Proposed arrangements for construction not submitted to Consultant.	Whilst temporary works are responsibility of Contractor it would be useful to have the drawings to see how the design consultant envisaged constructing the bridge especially in such close proximity to the existing bridge. MoW to submit drawings.	Amber	

3	Appendix B (Section I)	Consultants Response to Client Comments. Item No. 3	It was noted that the existing utilities were to remain on the existing bridge, yet this does not seem to be the case.	The relocation of these utilities will need to be fully designed especially regarding the 14inch water line and electrical cables. It is clear that the Design Consultant has not taken this on board in dealing with the design.	Red	
4	Appendix B (Section I)	Consultants Response to Client Comments. Item No. 5	*Utility Plans to be provided with the next design submission'*	The full utility plans of the existing and future design have not been included in the design despite being referred to in the BoQ. This will need to be designed at an early stage in the construction contracts.	Red	
5	Appendix B (Section I)	Consultants Response to Client Comments. Item No. 8 and 9	Refers to Technical Specification Art.552.16 However this is not the correct reference to clause in Technical Specification	Technical specification to be checked thoroughly for completeness.	Amber	
6	Appendix B (Section I)	Consultants Response to Client Comments. Item No. 35	*Side walk details to be shown on Dwg GPHRP/060/B00/D005-D007.'*	This shows the bridge sidewalk but no mention of the sidewalk from the shoulder of road.	Amber	
7	Appendix B (Section I)	Consultants Response to Client Comments. Item No. 38	Pile Shoes suggested in GDN GPRH -030-T001-V1.1 with confirmation after installation of test piling. However there is no mention found in the documents or provisional item included.	At this stage it should be included as variation if found to be necessary.	Red	

8	Appendix B (Section I)	Consultants Response to Client Comments. Item No. 48	DWG No. GPHRP-050-S1-D101 It was confirmed that there would be requirement for pavement overlay and full reconstruction in some areas up to the existing roundabout and new drawings would be provided. The roundabout is concrete pavement and there are no tie in drawings or concrete pavement quantities in the BoQ for this area.	The tie will have to be properly designed for line and level plus the pavement requirements where we tie into a concrete pavement.	Red	
9	Appendix B (Section I)	Consultants Response to Client Comments. Item No. 48	Drawing GPHRP 050-D101-C was modified to provide an out ramp to the agricultural show ground. The junction would seem quite elaborate just for an out ramp and for the number of vehicle likely to use the ramp. What was the original requirement from the Client for this side road.	Potential to redesign to a simpler option.	Amber	
10	Appendix B (Section II)	Consultants Response to Client Comments. Item No. 50 and No.70	Existing Private Property accesses to be identified and quantified and design Consultant stated that new drawings would be issued. These have not been found.	Typical private access design to be completed and shown on drawings. Schedule to be produced with existing width and design width plus the culverts needed. Typical drawing should be generated showing access radius, construction up to fenceline, type of pavement construction, type of culvert and headwall.	Amber	
11	Appendix B (Section II)	Consultants Response to Client Comments. Item No. 86	Side walk details to be shown on 100% complete drawings. This was not completed.	Detailed and drawings must be updated so that sidewalks and pedestrian movements can be accommodated. Should tie into existing concrete sidewalks at roundabout.	Amber	

12	Appendix B (Section II)	Consultants Response to Client Comments. Item No. 98	*It is imperative that both the specifications and drawings correlate'.* Whilst this was noted and agreed in response it does not seem to have been done. There is distinct little connections between BoQ preamble, BoQ, Specification and drawings.	Clarifications will need to be issued regarding the works to be carried out.	Amber	

Supervision of Works for the George Price Highway Rehabilitation Project

Section I (Lot 1) Construction of Roaring Creek Bridge

Design Review – DRAWINGS

February 2018

Item	DWG No.	Section/Detail	Description	Recommendation	Threat Level	MoW Comments Accept / Decline
GPHRP-060-S1-B01-D001 to D026 Roaring Creek Bridge						
19	D1	General Arrangements	West pier and side slope: the issue is the distance between the north edge of the pier and the ground level at this location and the ground level at the existing bridge 2nd pier which is shown 5m higher than the new ground level at the new pier. The distance between these points is only 6m.	The existing bridge pier to be temporarily supported by sheet piles whilst the new pier and ground slope is constructed. A permanent solution may be using a gabion slope between the piers.	Red	
20	D2	General Arrangements	Drainage outlets to extend 150mm below soffit.	Lower the outlets so that they hang below the beam by about 150mm.	Amber	
21	D5 et al	Pile details	The use of 450 x 450mm square piles in such profusion is unusual. When dealing with such large foundation forces it is appropriate to use larger diameter circular bored cast in place piles with a diameter in the order of 1 - 1.2m.	As the Contract is let for the square piles it may be inappropriate at this stage to instruct such a fundamental change especially as the equipment needed is totally different from that for driven piles.	Amber	

22	D5 et al	Pile details	The size of the piles (at 450 x 450mm) may cause problems during driving due to their unusually large cross-section. The soils that the piles are being driven into include stiff clays and firm silty clays that would impede the penetration of the pile and it is debatable whether the pile could penetrate such layers without damaging the top of the pile.	Contractor confirms pile this size can be driven thru these soils to rock head without damaging the head of the pile.	Amber	
23	D5 et al	Pile details	The use of prestressed piles is also unusual as this adds to the compressive forces in the piles. Driven reinforced concrete piles are just as adequate unless the Designer can show a verifiable reason for using prestressing.	Contractor confirmed Pre-stressed piles used for ease of handling during transport and positioning in place.	Amber	
24	D5 et al	Pile details	No prestressing forces given.	Note	Amber	
25	D6	Bearing recess detail	Recess shown with high strength grout.	Not needed remove and use normal bearing plinth detail.	Amber	
26	D7 et al	Section B-B at Bearing Location	It is unusual to have a bearing recess for elastomeric bearings as these can easily be sat on a raised plinth for ease of placing and to allow for jack placement when replacing later. The instruction in forming these recesses is to cut a rebar which is not acceptable.	Remove this recess and construct bearing plinths in the normal manner.	Amber	
27	D7 & D13	Rebar details	Top of pile embedded into pile cap shows concrete which is not how this is done.	Reduce the depth to 1.0m and remove outline of pile in the pile cap.	Amber	
28	D7 & D13	Rebar details	Large numbers of very heavy rebars used which will make the rebars hard to fix in place. The same results can be made by using smaller bar sizes as narrower spacing.	4 bars shown to be Y25's should be reduced to Y20's or Y16's.	Amber	

29	D7 & D13	Rebar details	Abutment stem rebars are shown sitting on top of bottom rebars in the pile cap which is a bad detail as it relies on the concrete taking the pressures from these bars in bending.	Place these bars below the bottom rebars so that the pressures are spread by the bottom rebars thus removing any threat.	Amber	
30	D7 & D13	Rebar details	The 'U' bar at the top of the abutment stem is placed inside the transverse rebars which is not a good detail as these bars do not lap with the vertical bars as they should.	Move the legs outside to lap the vertical bars.	Amber	
31	D7 & D13	Rebar details	Bar mark 103 is shown as 12000 long in the Schedule. This is incorrect.	Amend to the correct dimension.	Amber	
32	D7 & D13	Rebar details	Pile cap corner detail shows excessive number of Y25 bars.	Reduce the number to a sensible amount.	Amber	
33	D7 & D13	Rebar details	The transverse rebars in the abutment stem are shown going too high so that the top bar will be in fresh air.	Reduce the height to which these bars extend.	Amber	
34	D8 & D10	Pier Elevations	Individual pile caps to each column. This detail would lead to excessive deflections occurring in the deck as a seismic wave passes perpendicular to the line of piers.	Have a single continuous pile cap for all 3 columns.	Red	
35	D8 & D10	Pier Elevations	The use of individual pier columns may not be appropriate for the seismic conditions here as they may be too flimsy to restrain the movement caused by a seismic event. It may be appropriate to change this columns into a 'leaf' pier that will have more ability to withstand the forces involved.	Replace with a single 'leaf' pier.	Red	
36	D8 & D10	Pier Elevations	The gap between the top of the shear keys and the diaphragm is far too small to construct the diaphragm properly. Also there is no means of locating a jack to raise the deck off the bearings to allow them to be replaced.	Replace the existing detail with shear keys between the bearing plinths in the normal manner and with the top located in the deck diaphragm.	Amber	

37	D9 & D11	Elevation of crosshead	The bearing/shear key detail does not satisfactorily create the resistance to the seismic transverse forces expected as the neoprene pad is located against an unreinforced part of the bearing plinth and the girder that itself is unrestrained. Thus there is no reinforced concrete restraint to the transverse forces.	Replace the existing detail with shear keys between the bearing plinths in the normal manner and with the top located in the deck diaphragm.	Amber	
38	D9 & D11	Elevation of crosshead	The transverse rebars are shown to go to the bottom of the section which will have the lower bars in fresh air.	Stop these bars short of the point where the crosshead reduces in length and have a few bars of differing lengths inserted to the bottom of the face.	Amber	
39	D9 & D11	Elevation of crosshead	The vertical bars are shown going from face to face which will have the end bars in fresh air.	Stop these bars short of the point where the crosshead reduces in height and have a few bars of differing lengths inserted to the ends of the face.	Amber	
40	D9 & D11	Elevation of crosshead	The pier columns are shown penetrating the crosshead concrete thus the bottom bars are placed too high in the section. This will not be the case.	Remove the outline of the pier columns and lower the rebars to the correct cover.	Amber	
41	D9 & D11	Elevation of crosshead	End faces of crosshead have no anti-cracking steel.	Introduce rebars at these locations.	Amber	
42	D9 & D11	Sections A-A and E-E	Bar mark 102 is shown all the way thru the crosshead. This is not necessary.	Remove all but the top BM 102 in the crosshead.	Amber	
43	D9 & D11	Sections A-A and E-E	Bar marks 108 and 109 do not effective act as shear reinforcement.	Replace these bars with 2 'U' bars that lap at mid-height.	Amber	
44	D9 & D11	Section B-B & bottom of crosshead	The outer defined longitudinal bars will not pass thru the gap available in the column rebars that penetrate the crosshead.	A special bar needs to be inserted at these locations on the column rebar/bottom rebar interface to lap on to reduced length longitudinal bars.	Amber	
45	D9 &	Section E-E	Column bottom 'L' bar sits on top of bottom	Change the detail to have the leg lapping the	Amber	

	D11		rebars. It should sit below.	bottom bars.		
46	D9 & D11	Section E-E	End faces of pile cap have no anti-cracking steel.	Introduce rebars at these locations.	Amber	
47	D14 to D17	Section A-A	Vertical stem rebars and pile cap 'U' bars shown as Y25's.	Reduce these toe more sensible diameter.	Amber	
48	D14 to D17	Section A-A	Abutment stem bottom 'L' bar sits on top of bottom rebars. It should sit below.	Change the detail to have the leg lapping the bottom bars.	Amber	
49	D14 to D17	Section A-A	Top of pile embedded into pile cap shows concrete which is not how this is done.	Reduce the depth to 1.0m and remove outline of pile in the pile cap.	Amber	
50	D14 to D17	Section A-A	The 'U' bar at the top of the wall is placed inside the transverse rebars which is not a good detail as these bars do not lap with the vertical bars as they should.	Move the legs outside to lap the vertical bars.	Amber	
51	D14 to D17	Section A-A	Pile cap corner detail shows excessive number of Y25 bars.	Reduce the number to a sensible amount.	Amber	
52	D14 to D17	Plan on Pile cap	Excessive number of piles shown.	Omit central line of piles and reduce the number of piles in the outer lines.	Amber	
53	D18 et al	Section B-B Bearing At Pier	The bearing plate and its associated bolts, shear studs and screws are unnecessary and could be corrosion inducers up to the prestressing strands. It is normal to have the beam sitting directly on top of the bearing or with a thin layer of cementitious mortar between them to take out any imperfections and have a uniformly loaded area.	Remove all the detailed plates, bolts etc.	Red	
54	D19	Plan Diaphragm details	No details shown of diaphragm.	Show details	Amber	

55	D20 et al	Elevation	There is no indication of deflection of the prestressing tendons at the ends of the beams. It is normal to deflect some tendons up into the top flange to balance the forces at the ends of the beams so that the prestressing takes some of the shear forces in the web.	Investigate the need for the pre-stressing strands to be deflected upwards at the ends of the beams.	Amber	
56	D20 et al	Elevation	Do the additional 4 No. 12 diameter rebars give sufficient resistance to the splitting forces at the ends of the beam caused by the concentrated prestressing forces in the flanges.	Investigate the capacity of the anti-splitting rebars.	Red	
57	D20 et al	Elevation	No precamber shown for the beams	Calculate the beam deflections and have the precamber set higher than these figures.		
58	D20 et al	Elevation	Details of some bars protruding out of the ends of the beams are not shown.	Show these details.		
59	D20 et al	Beam Detail A	Bars in top flange are not connected so not effective.	Use a special 'U' bar.		
60	D22	Proposed Construction Method	This detail shows an area that bars personnel during deck pours. This approach is unrealistic as in the event of someone losing their balance adjacent to this area they may have to use the area to regain their balance. It may not be appropriate to install a barrier to prevent this as the area will need to be accessed from the side to form the deck edge.	Leave this to the Contractor. He is more experienced in this aspect of the work.	Red	
61	D22	Detail 1	The overhanging edge of the precast panel and the recess adjacent to the polystyrene former create an area for debris to gather that would be hard to clean.	Extend the polystyrene to the end of the panel so that no overhang exists.	Amber	

62	D22	Panel to Panel Transverse Joint	This detail is very poor as it shows that the gap between the "tight joint" can be as much as 3mm. It only takes a small gap (less than 1mm) to allow a lot of water to escape out of the concrete mix during the vibrating of the concrete thus creating honeycombed concrete.	Remove this detail.	Red	
63	D23	Slab casting sequence	This shows deck being cast from west end towards the east with construction joints at arbitrary locations not points of contraflexure.	Allow contractor to decide which end to start from and set the CJ's at the points of contraflexure.	Amber	
64	D24		This dwg shows the deck diaphragm details that will change with the bearing plinths and shear key so omit.		Amber	
65	D25	All Sections	Holes thru beams do not align with main diaphragm rebars thus continuity is lost.	Adjust locations of holes thru beams to align with main diaphragm rebars.	Amber	
66	D24 & D25	All Sections	These sections show Y25's which are not required as the rebars are for anti-cracking.	Reduce bars to a more suitable diameter.	Amber	
67	D25	Sections thru Pier Diaphragm	These 2 details show rebars running transversely between the ends of the beams. This steel is not needed and can be removed.	Remove transverse rebars from between the ends of the beams.	Amber	
68	D26	Typical section of LP pilaster	This detail is incorrect as it does not show the parapet and walkway correctly.	Redraw this detail.	Amber	
69	D26	Plan & Elevation	Both details a 'Pull Box' built into the parapet thereby weakening it further.	Remove this box and ducts to protect the integrity of the parapet.		
GPHRP 060-S1-B00-D001 to D014 General structural Notes and Standard Details						

70	S1/D1, S1/D4, D23	Note 1.26 Note 4.27 Note 10	This note gives instruction on placing concrete in the area above the beam flange in advance of the main slab concrete. This is potentially dangerous as, in the event of a delay in the concrete supply, a cold joint could form in this critical location above the beam.	Remove the note.	Red	
71	S1/D4	Note 4.10 Note 4.31	The wording of this note is "The elapsed time interval between jacking of strands and transfer shall be less than 15 hours." which is non-sensical as this period is defined by the rate of gain of strength in the concrete so that transfer occurs at a defined concrete strength.	Remove the note.	Red	
72	S1/D4	Note 4.31	Joints should be constructed with kicker to avoid cement slurry loss.	Inform the Contractor	Amber	
73	S1/D5	On Bridge Slab (Parapet detail)	Item #1 The main reinforcement in the parapet does not go below the construction joint formed at the top of the deck slab thus the parapet is not sufficiently fixed to the deck to withstand impacts.	Amend the detail to show the parapet rebars going into the deck slab.	Red	
74	S1/D5	On Bridge Slab (Parapet detail)	Item #2 At the narrowing of the parapet (about 300mm above the construction joint) is located a 100mm duct thus removing a large portion of the compressive concrete where it is highly stressed. This will make this location the weakest on the parapet which is likely to fail at this level under impact loads.	Remove the ducts from inside the parapet.	Red	
75	D011/D012	pedestrian/bicycle picket railing	Drawings show details of pedestrian/bicycle steel railing, the final location of this railing is unknown	determine if this railing will be used on the project if, not this should be eliminated from the drawings	Amber	
76	D012 to D014	Stairs Detail	Drawings shown details of new stairs, the final location of this is unknown, since no where	determine if the Stairs will be used on the project if, not this should be eliminated from	Amber	

			else in the drawings are mentioned	the drawings		
GPHRP 070-S1-B01-D001 to D008 Roaring Creek Scour Protection Drawings						
77	from B01/D001 to B01/D006	Roaring Creek Sour Protection Drawings	Final Level of Rip Rap should raised to match with Existing Bridge Pile Caps, also with the new recommendation of raise new bridge Piles caps. Volumes of excavation will be reduced	Modify Final Rip Rap Elevation and embankment slope to meet new final Pier Pile Cap elevation on New Roaring Creek Bridge according to new recommendation	Red	
78	D101 & D102	Drain Profile	The drain profile do not describe is this one is for existing or proposal. However in case that the profile refer to proposal drain levels those may need tube adjusted since there is not constant gradient between 0+440 and 0+510	Levels on drain Profile need to be adjusted	Amber	
79	S1-D001	Typical Road Sections	The Drawings shown 6 Types of typical cross-section along the 485 meters along section 1 none of then mention de location of Side walk or Metallic Guard Rail	Typical cross sections need to be adjusted to actual site conditions	Amber	
80	S1-D001	Typical Road Sections	The Drawings shown 6 Types of typical cross section along the 485 meters along section 1 none of then mention the dimension of the Verge Area	Typical cross sections need to be adjusted to actual site conditions	Amber	
81	S1-D001	Typical Road Sections	The drawings do not show the subbase on all sections and where it is shown it is 275mm rather than 250m.	Typical cross sections need to be corrected.	Amber	
82	S1-D002	Typical sidewalk and cross walk detail	Section "Typical Sidewalk /drain (Type B) location of this type of drain is not identify in any other drawing, so location is unknown	eliminate this typical section since this may not be used any where in the project	Amber	
83	S1-D003	Typical sidewalk plan view	this typical plan view is already included on S1-D002 Drawings	Should be eliminated	Amber	

84	S1-D004	Section 1-1 D003 metallic guardrail	Drawings specify for the metallic guardrail post 115mm Galvanized Steel Pipe @4meter with angle iron as spacer. This solution may not be adequate for bridge approach since this solution may not warranty case of direct impact with a motor vehicle that this want will not go over the 3 meters or more embankment	IT is recommended to change the Circular post (Pipe) for 150mm galvanized I-beam for post solution with 100mm galvanized C-channel	Red	
85	S1-D004	Typical Delineator Detail	Delineator shown only one type of reflective Wrapped red around the post.	this red reflective red wrap needs to be combined with yellow reflective line on the direction of the traffic and White reflective wraps on the opposite traffic directions. However it may be a better solution to eliminate this for the 485m of Lot 1 since most of the bridge Approaches have Metallic Guardrail which should have reflector and where metallic guard rail is not allocated, those areas are designated to be have a speed limit of under 25mph whereby standard delineator are not necessary	Red	
86	S1-D005	Typical Single Column Ground Sign Cross section	Drawings specify 50mmx50mm Squared Tubing and cross 50mmx50mm Brace	BS Standard recommend for Post square tubing or 3 inch galvanized Pipe. In the case of braces, it is not needed if aluminium plate is 3mm tick. May be subject to contractor proposal.	Amber	
87	S1-D006	Sings Plan View	There are only 5 Warning signs allocated on the plan view, this quantity may be insufficient	Recommend to included additional signs on the bridge approach like 4 object market, two on each side of the bridge approach. Additional signs is required for the bridge approach and pedestrian crossing. Additional stop signs on each access road	Red	

				connecting to the G.P Highway.act		
GPHRP -050-S1-D100 to D112 Plan Profile and Setting Out						
88	S1-D101/D102	Plan and Profile view	The chainage of the new access is not labelled on the drawings making it difficult to determine the location and the distance between objects	label all chainages on plan view for the new alignment of the road	Amber	
89	S1-D101	Plan and Profile Side walk East abutment	In drawing S1-D002 seems that the project have the existent of concrete side walk but no where on Plan View this item is level the way the plan view may represent the sidewalk could be interpreted as Road Shoulder	Address this mater, determine if concrete side walk will be use on the project and the final location	Amber	
90	S1-D101	Plan and Profile access to existing bridge	Others drawings and BOQ shown that the existing bridge will be rehabilitated, drawing D102 show that the existing bridge will be only access trough Road #2 on the west side Rhs of the new bridge. No access trough the East RHS side of the new Bridge is allocated	Access trough the East side Rhs by Guanacaste access should be allocated.	Amber	
91	S1-D103	Profile view Guanacaste	Plan View shown the existence of new cross culvert at this location, but the profile view not show the final elevation of the inlet and outlet of so say culvert	determine the invert level of the new culvert and added to the profile view	Amber	
92	S1-D105	Plan and Profile view at S1-J2 Junction	is noticeable the gradient of 12.88% proposed for this junction, this may be to high for vehicles to access the Hwy when from private areas	Further evaluation may be needed in other to determine if this gradient is adequate for the proper access to the Hwy.	Amber	

93	S1-D107	Plan and Profile View at road RD2	vertical alignment propose from 0+005 to 0+025 may not be adequate for propose culvert, making the new culvert be install lower than the level of the existing ground at the inlet and the outlet of the culvert. Culvert with time may be silted and non-functional.	raise the level of the access road from 0+005 to 0+025 at least 500m	Red	
GPHRP -050-S1-W1001 to W1004 Cross-Sections						
94	S1-W1001	0+000 to 0+140 road section (Sidewalk)	Road sections from 0+040to 0+140 shown the existence of concrete sidewalks on but side of the road this is not levelled foot D101 Or D102 Plan View (applicable to west side w1003, w1004)	This Discrepancy most be adjusted	Amber	
95	S1-W1002, 1003, 1004	0+000 to 0+140 road section (Guardrail)	Section of the Road Shown the new metallic guardrail after Sidewalk reading from centre line to edge of road this may not be adequate, in case of accident the life of the pedestrian may be in risk, the location of this guardrail is also taken space area from the pedestrian reducing the walking area. there is also a discrepancy with drawing D006 where the guardrail is located before possible side walk reading from centre to edge of the road	Final location of Guard Rail Most be determine whether go before sidewalk or after, section of the road most be increase, increasing volume of works	Red	
96	All drawings with road section	Road Sections	Road section Drawings lack information such as Cut area, Fill Area and the labelling. This makes this drawing very unfriendly and difficult to use when Volume of material calculation is needed.	Add additional information required for the proper execution of the works and volume calculation is needed	Red	

97	S1-W1002	Concrete Side Walk	The sidewalk shown in the section does not appear to have drainage pipes to allow storm water to flow pass the side walk and into drainage ditch. This will reduce the life of the road pavement since water will pond all along the edge of the road	4" drain pipes under the concrete sidewalk is recommended in order to evacuate the water coming off the road	Red	
98	D102 / W1003 & W1004	Retaining wall	the west abutment to the bridge is designed with the use of retaining wall, after contractor setting out the retaining walls may be set out closer to the centre of the road	evaluate the actual situation regarding the final location of the retaining wall on the west abutment	Red	
GPHRP 060-S1-W02-D001 to 002 Retaining Wall						
99	W01/D001	Profile Retaining wall	The Dimensions label along the wall view do not match with the different in level between top wall level and top of footing level	verification of final retaining wall top level	Amber	
100	W02/D002	Profile Retaining wall	The Dimensions label along the wall view do not match with the different in level between top wall level and top of footing level	verification of final retaining wall top level	Amber	
101	W01/D002	Detail B Keyed Joint	No where in cross section or longitudinal Section of the Retaining wall is appointed where this type of joint should be used?	This type of joint is recommended on all construction joints both without the Backer Rod, filler or Silicone	Amber	
102	C00/D002	Culverts Section 1-1	The Drawings shown that the 900mm Circular Culvert is encased with 1.4m by 1.4m reinforce concrete	This reinforce concrete encasement may not be necessary if the fill cover over the concrete pipe Culvert is more than 1.3m	Amber	
103	C00/D006	Typical Box Channel	Channel Section shown a full concrete channel floor and wall	the channel walls could be replaced with 200mm thick reinforce masonry block, reducing the cost of the drain and saving to the project	Amber	

Supervision of Works for the George Price Highway Rehabilitation Project

Section II (Lot 2) Roaring Creek to Iguana Creek Junction

Design Review – DRAWINGS

February 2018

Item	DWG No.	Section/Detail	Description	Recommendation	Threat Level	MoW Comments Accept / Decline
GPHRP 050-S2-D201 TO D259 PLAN AND PROFILE						
104	050-S2-D201 to D259	Plan and Profile Dwg	Match Line and profile views on the drawings do not match up consistently. Example CH1+790 on page D205 jumps to CH1+830 on D206, the information for this 40m length is missing. Similar inconsistencies are found throughout.	Drawings to be amended when issued for 'Good for Construction'.	Amber	
105	050-S2-D201 to D259	Plan and Profile Dwg	Drawing key is not complete. Are the grey property boundaries surveyed or from existing plans?	Full key to be produced and in particular the boundaries shown and fencing.	Red	
106	050-S2-D201 to D259	Plan and Profile Dwg	Cadastral Boundaries and existing fencelines do not match and would seem to be offset for example in Camolote. However at CH6+000 they seem to match. The grey lines need to be checked and coincide with the existing boundaries otherwise on site there will be a lot of social issues in removing fencelines.	The cadastral boundary and existing boundary need to be checked **urgently**. It would seem that the whole design has been carried out using the theoretical cadastral boundaries and not the boundaries actually on site.	Red	

107	050-S2-D201 to D259	Plan and Profile Dwg	Side Roads - the limit of works shown on the drawings vary for each side road without any guide as to the design philosophy. The notes 1. and 2. are insufficient. It states minimum 6m and 1m shoulders yet on the drawings it is 7m and 1.5m shoulders. The details need to be confirmed to avoid confusion.	The side road and junction details need to be standardised for major junction, side road junction and accesses. The radii and culvert length need to be shown with inlet and outlet structures. The width need to be confirmed change in shoulder width clearly shown.	Red	
108	050-S2-D201 to D259	Plan and Profile Dwg	Existing Road is catered for when the embankment or pavement is constructed above but there is no mention what the Contractor should do when the new road is constructed to the side or in fact where the existing road is beyond the extent of works. The limit of the works is not clearly shown on the plans.	The Contractor should be given new drawing showing the extent of clearing of existing roads or should this be left in residential areas to provide for access or side walks. There needs to be more clarity on the extent of work to be carried out.	Red	
109	050-S2-D201	Plan and Profile Section II - 0+485 TO 0+786	Culvert C203 at CH0+674.42 should be checked to determine whether additional extension is required due to embankment height.	This will require further investigation to determine whether extension required.	Amber	
110	050-S2-D201 to D259	Plan and Profile Dwgs	Access Culverts - the plan drawings should show the accesses for each property particularly in village areas where there maybe considerable number of accesses over a short distance. Has any consideration been given to businesses compared to residential. There should be defined accesses for gas stations, schools and any businesses with large vehicles.	A schedule of accesses should be made and a standard access drawing provided so that residents know exactly what they will be getting.	Red	
111	050-S2-D201 to D259	Plan and Profile Dwg	Road marking are not in compliance with the norm in Belize. The second edge line on the outside of the shoulder is not safe and could	Centreline and edge road marking needs to be reviewed and modified to meet both international and local Belizean standards.	Amber	

			cause confusion.			
112	050-S2-D201 to D259	Plan and Profile Dwgs	Bus Stop Drainage Detail. There should be detail of how this connects to the earthen side drain as the drain below a side walk tends to be much higher than the earth drain inverts. The typical detail of the drain below the sidewalk is 483mm. It should also be noted that the sidewalk finishes right into a drain which is a safety issue at night.	Bus stop details need to be revised to a more practical solution regarding drainage, safety and pedestrian movements.	Amber	
113	GPHRP-050-S2-D201-D207	PLAN & PROFILE SEC 2 -	Road side drains to culvert 204 from culvert 203.	These roadside drains need to be increased in size. Bed width should transition from 0.6 m at upstream end to 1.34 m at outfall to C204.	Amber	
114	050-S2-D201	Plan and Profile Section II - 0+485 TO 0+786	Culvert C201 goes through bus bay either side of road. The culvert length will need to be close to 30m and goes underneath both sidewalk concrete drains which may clash. There may also be safety issues with a headwall drop-off at back of bus bay and restriction due to properties on the RHS.	Consider a more practical and constructable location.	Red	
115	050-S2-D201	Plan and Profile Section II - 0+485 TO 0+786	Side road culvert at 0+580 to 0+600 intersects with C202 existing skewed culvert. There is no indication of works to be carried out on the existing C202 culvert.	This will require further investigation to determine best solution.	Red	
116	050-S2-D201	Plan and Profile Section II - 0+485 TO 0+786	Building structure 0+535RHS is very close to bus bay. If this is a vendor there will be a temptation to use the bus bay as a parking area.	Social issue to be discussed with PEU to find a solution.	Amber	

117	050-S2-D201	Plan and Profile Section II - 0+485 TO 0+786	Side Road CH0+700 RHS clashes with property boundary and does not seem to be within the existing reserve.	Survey to be checked and the drawings either corrected or the design amended.	Red	
118	050-S2-D203	Plan and Profile Section II - 1+048 TO 1+310	Existing Culverts on side roads and accesses between Ch1+100 to 1+200 have not been designated for removal / replacement or abandoning. The drawings should show clearly work to be carried out and refer to bill item to avoid additional costs.	Contractor will need to be instructed which could lead to additional costs.	Red	
119	050-S2-D203 to D204	Plan and Profile Section II - 1+048 TO 1+310	The Deep cut is interfering with existing fences CH1+250 to 1+370RHS and may not be the best solution or most practical solution in this area especially as the project is a rehabilitation not a reconstruction project. The depth of cut may also encounter rock or unsuitable material leading to additional costs.	Section to be investigated to determine whether a modified vertical alignment would be more practical by reducing costs, risks and potential land acquisition issues.	Red	
120	050-S2-D204 to D206	Plan and Profile Section II - 1+310 to 2+096	The horizontal realignment of the road from CH1+440 to 1+900 should be reviewed with respect to the actual property boundaries.	Potential to revise as the boundaries shown may not be correct. This is a rehabilitation project rather than total rebuild and as such prices maybe reduced if design modified to follow the existing alignment more closely.	Red	
121	050-S2-D203 to D204	Plan and Profile Section II - 1+048 TO 1+310	The bus shelter encroaches at CH 1+540LHS over the property boundary.	Check survey on site and set out.	Amber	
122	050-S2-D208 to D209	Plan and Profile Section II - 2+358 to 2+882	The cut excavation along the centreline of the road from CH2+540 to 2+690 may not be the best solution or most practical solution in this area especially as the project is a rehabilitation not a reconstruction project.	Section to be investigated to determine whether a modified vertical alignment would be more practical by reducing costs, risks and potential land acquisition issues. The cut in this area is +1.25m.	**RED**	

			The depth of cut may also encounter rock or unsuitable material leading to additional costs.			
123	GPHRP-050-S2-D208 to D217	Plan and Profile Section II - 2+358 to 4+978	Realignment of road between CH2+500 to 4+900 may not be the most practical and cost effective solution. The alignment off the existing centreline will have the new road half on the existing embankment and half on new embankment formed over the verge and drain. Increased costs and risks of differential settlement should be considered. Centring over the existing embankment provides for a more stable foundation to the centre structure of the embankment. Consideration of the existing utilities that could be buried along this widening should be taken.	Section to be reviewed and checked on site with regards to existing utilities and quantity of fill required.	Red	
124	050-S2-D205	Plan and Profile Section II - 1+572 to 1+824	Structure CH1+690RHS is within the new drain.	There should be note on drawing to confirm that this is to be removed. Has this been accepted by the owner?	Amber	
125	050-S2-D206	Plan and Profile Section II - 1+824 to 2+096	Cut slopes and drain slopes at 1+930RHS and 2+040RHS potentially interfere with fenceline and property boundary.	Sections to be set out and checked on site.	Amber	

126	050-S2-D209	Plan and Profile Section II - 2+620 to 2+882	The side road and junctions on the drawings do not match the survey. Ch 2+690LHS side road shown as Hithergreen Drive has no junction to main road. Ch2+720RHS has an existing parallel side road to the junction at CH2+620 but this parallel feeder road is removed and there is no side road junction at CH2+720RHS. Junction at Ch2+800 for Discovery Drive is no in the correct position as per the survey.	Area to be resurvey and amended on the design.	Red	
127	050-S2-D209	Plan and Profile Section II - 2+620 to 2+882	Culvert C205 has something on the outlet (watermain?). This needs to be determined. Culvert extended by further 7m at same skew as existing culvert. The outlet needs to be determined to ensure it is in correct position.	Check on site and provide key to drawings	Amber	
128	050-S2-D210 - D212	Plan and Profile Section II - 2+882 to 3+668	Property boundaries in grey? Do match up with the green fenceline shown. Realignment off the existing road centreline is now encroaching onto the green fenceline surveyed. Will there be a land acquisition question and are the grey property boundary lines correct.	Property boundaries and the surveyed fencelines need to be confirmed and put on the plans especially where the road moves away from the existing centreline.	Red	
129	050-S2-D212	Plan and Profile Section II - 3+446 to 3+668	Culvert C206 at CH3+430 to be checked to determine whether extension required with high embankment.	To be checked on site after setting out toe of slope.	Amber	
130	050-S2-D212	Plan and Profile Section II - 3+668 to 3+930	Lamp posts shown on the plan will need to be relocated in Camalote. Has this been catered for in the BEL redesign.	This needs to be rechecked.	Amber	

131	050-S2-D212	Plan and Profile Section II - 3+668 to 3+930	Existing side road not shown on plan at Ch3+730RHS.	This needs to be rechecked.	Amber	
132	050-S2-D212	Plan and Profile Section II - 3+668 to 3+930	Culvert C207 at Ch3+800 shows the existing culvert within existing property and outside the limit of construction. The cadastral boundaries shown on the plan need to be shifted.	Cadastral boundaries and road alignment need to be checked.	Red	
133	050-S2-D212	Plan and Profile Section II - 3+668 to 3+930	Culvert C207 at Ch3+800 shows the new culvert of 2No. 1.2x1.2m concrete culverts flowing into a side drain? Outlet to this structure needs to be checked.	Outlet details need to be shown,	Amber	
134	050-S2-D212	Plan and Profile Section II - 3+668 to 3+930	Ch 3+935 structure or square needs to be defined and Contractor instructed.	Drawings clearly to define work to be carried out by Contractor.	Amber	
135	050-S2-D214	Plan and Profile Section II - 3+930 to 4+192	Extent of bus bay sidewalk and drainage not clear between 3+900 to 4+050 either side.	To be corrected.	Amber	
136	050-S2-D214 to D215	Plan and Profile Section II - 3+930 to 4+452	CH 4+100 to 4+600 LHS cross points should be changed to tie in with rest of drawing.	Modify	Amber	
137	050-S2-D215	Plan and Profile Section II - 4+192 to 4+452	Culvert C207a clashes with side road culvert. Will side road culvert be necessary?	Drainage to be checked to determine if side road culvert required.	Amber	
138	050-S2-D215 to D216	Plan and Profile Section II - 4+452 to 4+716	The cut excavation along the centreline of the road from CH4+452 to 4+716 may not be the best solution or most practical solution in this area especially as the project is a rehabilitation not a reconstruction project.	Section to be investigated to determine whether a modified vertical alignment would be more practical by reducing costs, risks and potential land acquisition issues. The cut in this area is +1.0m.	Red	

			The depth of cut may also encounter			
139	050-S2-D215 to D216	Plan and Profile Section II - 4+452 to 4+716	Extent of sidewalk with drains to be determined as the BoQ only has 120m and this stretches from 4+540 to 4+900 on both sides. Connection details to side drains and culverts to be detailed. How do the entrances and accesses cut through.	The side walks and pedestrian routes in the villages needs to be fully designed.	Red	
140	050-S2-D217	Plan and Profile Section II - 4+716 to 4+978	C208 AT 4+760 has insufficient length to cross the bus stop	To be checked and amended either location of culvert, length of culvert or position of bus bay.	Red	
141	GPHRP-050-S2-D218 to D225	PLAN & PROFILE SEC 2 -	Road side drains to culvert 210 from culvert 209.	These roadside drains need to be increased in size. Bed width should transition from 0.6 m at upstream end to 1.34 m at outfall to C204.	Amber	
142	050-S2-D221	Plan and Profile Section II - 5+764 to 6+026	Building structures at Ch5+900 within toe of slope. These should be identified and Contractor instructed accordingly to remove, relocate or work around.	To be checked and verified on site.	Amber	
143	050-S2-D222	Plan and Profile Section II - 6+026 to 6+288	Extent of sidewalk with drains to be determined as the BoQ only has 120m and this stretches from 6+100 to 6+300 on both sides. Connection details to side drains and culverts to be detailed. How do the entrances and accesses cut through.	The side walks and pedestrian routes in the villages needs to be fully designed.	Red	
144	050-S2-D223 to D224	Plan and Profile Section II - 6+288 to 6+812	Ch6+500 to 6+600RHS the cut slope is affecting the property boundary.	Horizontal alignment to be reviewed and possibly modified to avoid affecting the property boundary.	Red	

145	050-S2-D226 to D227	Plan and Profile Section II - 7+598 to 7+866	Extent of sidewalk with drains to be determined as the BoQ only has 120m and this stretches from 7+500 to 7+900 on both sides. Connection details to side drains and culverts to be detailed. How do the entrances and accesses cut through.	The side walks and pedestrian routes in the villages needs to be fully designed.	Red	
146	050-S2-D227	Plan and Profile Section II - 7+598 to 7+866	Existing lamp posts affected by cut slope 7+700 to 7+900 and it is close to property boundaries.	Review cut slope and back slope to drain as on top of hill the drain can be nominal V drain.	Amber	
147	050-S2-D229	Plan and Profile Section II - 7+860 to 8+122	High embankment may have safety issues at culvert C212 and require safety barriers.	To be checked.	Amber	
148	050-S2-D231	Plan and Profile Section II - 8+384 to 8+646	Drains Ch8+450 LHS has the earth drain to be 1m below FRL flowing into concrete drain below sidewalk at 0.5m be FRL. This would require deepening concrete drain and redesign.	Alternative design to be reviewed for these sections of work.	Amber	
149	050-S2-D230 to D234	Plan and Profile Section II - 8+384 to 9+432	The horizontal realignment of the road from CH8+250 to 9+250 should be reviewed for best solution.	This is a rehabilitation project rather than total rebuild and as such prices maybe reduced if design modified to follow the existing alignment more closely.	Amber	
150	050-S2-D230 to D232	Plan and Profile Section II - 8+646 to 8+908	Culvert C213 Ch8+660 is oversized and can be reduced to 2 cells. The skew will also compromise the Cemetery downstream. Why are the channel profiles not put on drawing up and downstream as a guide. Also the existing and replacement details should be put on the plan. There do not seem to be safety barrier details on the drawings?	Design to be changed.	Red	

151	050-S2-D233	Plan and Profile Section II - 8+908 to 9+170	Full extent of cut slope not shown on drawings at 9+100. This is affecting property boundaries and light posts. This is likely to be rock cut and at present only 100m3 in BoQ.	This needs to be checked on site to determine effect of this cutting. Geotechnical expert to check area to determine a more practical cut slope if rock or better material encountered.	Amber	
152	050-S2-D235 to D236	Plan and Profile Section II - 9+432 to 10+218	Rock exposed at side of road particularly at Ch9+570. There is insufficient quantities in BoQ for rock fill.	Review of full BoQ to take account of rock cut.	Red	
153	050-S2-D235 to D236	Plan and Profile Section II - 9+432 to 10+218	S curve realignment - the cross-sections are not complete and many areas show the cut slope chasing the slope which will lead to large unsightly and potentially unstable cut faces. No geotechnical analysis of the slope and potential failure patterns have been carried out. Other options such as additional signage, safety barriers could have been considered instead of such large unchecked cuttings. Note that insufficient provision has been available in the BoQ for rock cut.	The Contractor is already on site. The surveys should be checked to avoid excessively high cut slopes. Geotechnical input as cutting proceeds to determine safe angle of cut slopes and verify benching in place. This will have to be done on site as works already commenced. Slope protection measures will have to be implemented if problematic areas are found within the weathered rock profile.	Red	
154	050-S2-D236	Plan and Profile Section II - 9+432 to 9+956	Side drains on down slope indicate there are turn outs for the drain but no proper indication or measures shown to prevent erosion.	Standard turn out design should be shown and site checks to ensure existing drainage channel is being used. Erosion protection measures should be detailed.	Amber	
155	050-S2-D238	Plan and Profile Section II - 10+218 to 10+480	Cut section is up to 2m deep over a 200m length which seems excessively for a section without any major safety issues.	Area to be rechecked to determine whether reduction in cut and additional fill either side of hill would not be a better solution. Design philosophy of placing subbase and base above the existing road will cut down on costs and provide better foundation for the new road.	Amber	

156	050-S2-D239	Plan and Profile Section II - 10+480 to 10+742	Horizontal alignment is encroaching onto existing fenceline. The curve could follow the existing alignment more to avoid land issues and provide a better foundation for the road.	Horizontal alignment to be reviewed and possibly modified to avoid affecting the property boundary and improve the foundation for the road.	Red	
157	050-S2-D240	Plan and Profile Section II - 10+742 to 11+004	Culvert C217 at 10+750 has a skew but this will need to studied further. The capacity may be reduced	In order to carry out hydraulic analysis for a revised design, cross section survey required upstream and downstream of culvert. Cross sections at 50 m intervals 200 m upstream and 200 m downstream of culvert.	Red	
158	050-S2-D244	Plan and Profile Section II - 11+790 to 12+052	Horizontal alignment is encroaching onto existing fenceline. The curve could follow the existing alignment more to avoid land issues and provide a better foundation for the road.	Horizontal alignment to be reviewed and possibly modified to avoid affecting the property boundary and improve the foundation for the road.	Red	
159	050-S2-D246	Plan and Profile Section II - 12+314 to 12+576	Extent of sidewalk with drains to be determined as the BoQ only has 120m and this stretches over 300m on both sides. Connection details to side drains and culverts to be detailed. How do the entrances and accesses cut through and culverts underneath.	The side walks and pedestrian routes in the villages needs to be fully designed.	Red	
160	050-S2-D249	Plan and Profile Section II - 13+100 to 13+362	Vertical alignment has cut in low point at Ch13+200. In order to reduce cuts on the hills either side could this section be raised slightly.	Vertical alignment to be checked.	Amber	
161	050-S2-D252	Plan and Profile Section II - 13+886 to 14+148	Existing levels profile view look incorrect as road is following existing road.	To be checked.	Amber	
162	050-S2-D255	Plan and Profile Section II - 14+672 to 14+934	Check reason for horizontal alignment away from road especially in relation to the property boundaries.	To be checked.	Amber	

163	050-S2-D257	Plan and Profile Section II - 15+196 to 15+458	Blackman Eddy slip - the road is aligned slightly to the LHS in this slip area. The area to be widened will require special treatment to avoid slippage.	To be further investigated.	Amber	
164	050-S2-D258	Plan and Profile Section II - 15+458 to 15+720	The cut excavation along centreline from Ch15+530 to 15+580 may not be the best solution.	Cut of 1.6m and effect need to be checked. The existing material needs to be checked to determine if this is best solution.	Amber	
165	050-S2-D258	Plan and Profile Section II - 15+458 to 15+720	The End of the Project is 15+720.	This needs to be confirmed and clearly marked.	Red	
166	050-S2-D259	Plan and Profile Section II - 15+720 to 15+870	THIS DRAWING SHOULD NOT BE IN LOT 2	Drawing to be removed to avoid confusion.	Red	
GPHRP 050--S2-W2001 to W2145 ROADWAY CROSS-SECTIONS						
167	050-S2-W2001 TO W2145	SEC 2 - Cross-sections	Sections are lacking information such as cut and fill quantities. This means that the BoQ measurements cannot be checked against the cross-sections.	The sections should show the base, subbase, capping and fill layers clearly with the quantities for each. This information would assist in the understanding and measurement of the project and in the cross-checking of the Contractors measurements.	Amber	
168	050-S2-W2001 TO W2145	SEC 2 - Cross-sections	The 2:1 back slope for the cut slope should be modified in deep cut areas to avoid large cut volumes and excessive quantities.	Stability checks on existing slopes in the area should be carried out to see if steeper slopes an be safely used. E.g. Km9+080LHS.	Amber	

169	050-S2-W2001 TO W2145	SEC 2 - Cross-sections	The most cost effective and stable design philosophy for the pavement layer is to utilise the existing road rather than completely discard it. By having the existing base level as the new subgrade the pavement can be increased from the existing road providing a stronger road structure. By having the levels the same as existing we are effectively removing this solid existing pavement and replacing with new material.	The cross-section and vertical design needs to be rechecked to provide a stronger, less costly and more constructable road rehabilitation design. The present design is reconstruction and not rehabilitation.	Red	
170	050-S2-W2001 TO W2145	SEC 2 - Cross-sections	Horizontal alignment often shifts to one side causing the new road to be constructed over the existing drain. This drain will need to be thoroughly cleaned out cut to avoid any soft area. The embankment will then need to be benched into the existing road to provide a stable widening. This type of construction will often lead to differential settlement.	Cross-sections need to show clearly the excavation depth, roadbed level and the benching into the existing side slope. Where possible the alignment should follow the existing centreline to avoid differential settlement and settlement of the widened sections.	Red	
171	050-S2-W2001 TO W2145	SEC 2 - Cross-sections	Bus stop drainage does not tie into existing drains.	Drainage in urban areas to be rechecked.	Amber	
172	050-S2-W2007 TO W2008	SEC 2 - Cross-sections	Ch1+260 TO 1+360 went from road being somewhat level with the terrain to be cut well below grade.	Similar comments made on the plan and profile drawings where the cut should not be so great.	Red	
173	060-S2-W2081 TO W2082	SEC 2 - Cross-sections	Ch9+540 TO 9+860 the cross-sections cut lines are following the slope and there is not termination of the cut slope. The slope survey needs to be completed or the cut slopes steepened or benching reduced in order that	Levels need to be completed a further 10m horizontally and the slope stability of the cut areas examined. The cross-section in this area includes 3.55m verge and 2.6m drain before the cut slope even starts. A reduction	Red	

			the slope is completed and not left as a question mark. Excessive cutting in this area could expose highly weathered material with slope stability issues.	in either width will reduce the cut considerably. Also a reduction in the 3.5m bench width will also reduce the cut. The design calculations for this cut slope needs to be submitted.		
174	060-S2-W2144 to W2145	SEC 2 - Cross-sections	The project finishes at 15+720	Remove cross-sections beyond 15+720.	**AMBER**	
GPHRP 060-S2-C00-D001 to D016 / C213-D001-4/ C217-D001-3 TYPICAL CULVERT DETAILS /CULVERT 213 AND 217 DETAILS						
175	GPHRP-060-S2-C00-D002 to D005	SEC 2 TYPE 1 CULVERT	The concrete encasement is usually used where the pipe construction is poor, the backfill is a fine to medium sand and founding conditions are soft soils. In this situation the joints would tend to move and if not properly fitted allow the backfill to escape causing settlement in the road. This dos not seem to be the case in the project area. The removal of the encasement would improve constructability, reduce costs, reduce time and reduce traffic diversions in these areas.	The concrete surround could be removed providing that :- 1. the pipes conform to AASHTO M180 and the joints are well sealed; 2. The backfill material is good granular material that can be compacted in confined spaces; 3. The method of joint sealing is proved to be effective if there is movement; 4. The founding conditions are in good material will minimum chance of settlement.	Amber	
176	GPHRP-060-S2-C00-D002 to 005	SEC 2 TYPE 1 CULVERT	Note 7. All chamfers to be 150mm unless stated - should this read 50 or 25mm? The pipes do not show any bell end or jointing mechanism which will used. the cover should have a maximum and minimum cover stated for the design used.	Chamfer details to be clearly dimensioned. Show the true shape of pipes with the bell end and show the joint details even if encased.	Amber	

177	GPHRP-060-S2-C00-D002 to 016	SEC 2 CULVERTS	Rip-rap detail has not been included in the BoQ. Cross-sections show pavement material up to side slope which is not on typical road cross-sections. What provision for hand rails or crash barriers at these locations, because once vegetated the drop-offs become hidden.	Item will have to be included and priced. Areas of use will have to be determined on site and used only where there is obvious erosion issues. Cross-section details to be checked and typical detail changed. Safety barriers and railings to be added to design.	Amber	
178	GPHRP-060-S2-C00-D016	SEC 2 TYPE 1 CULVERT	Reference to Technical Specification 552 12-4 does not exist in Specification.	Specification to be checked to see which sections are missing.	Amber	
179	GPHRP-060-S2-C213-D001 to D003	Culvert C213 Details	This culvert is over sized and need not be skewed.	Reduce from 3 barrels to two barrels, and remove the skew, leaving culvert perpendicular to road.	Red	
180	GPHRP-060-S2-C217-D001 to D003	Culvert C217 Details	This culvert may be over sized.	In order to carry out hydraulic analysis for a revised design, cross section survey required upstream and downstream of culvert. Cross sections at 50 m intervals 200 m upstream and 200 m downstream of culvert.	Red	
181	GPHRP-060-S2-C213 and C217	Culvert C213 and C217	There are no barriers on the headwalls as safety for people who may walk on the side slope. There are no crash barriers at the edge of shoulder on approaches either side to the culverts.	Additional safety measure should be put into the design.	Amber	
GPHRP 080-S2-D001 to D008 TRAFFIC AND DETAILS						

182	GPHRP-080-S2-D002	Typical Road Cross sections	The typical road sections do not make sense and need to be revised. Verge shows it varies but on X-sections it is 0.5m and only varies at the S curve area on LHS where it widens to 3.55m. A simple table or note could clarify this. Verge material is shown same as existing ground and in BoQ is measures as topsoil. This needs to be properly defined. Road pavement table is confusing and will lead to errors in the field, it should be simplified and clearer. The typical cross-sections do not show cut and fill scenario or the existing road.	The typical cross-section should be re drawn to show what is to be done in the cut on the road, cut in natural ground, fill and over the existing road. Pavement layers to be fixed at 200mm base and 275mm subbase. Verge to be constructed of pavement material to avoid moisture in pavement layers becoming trapped.	Red	
183	GPHRP-080-S2-D002	Typical Road Cross sections	Use of terms engineered fill (min 30% CBR) and capping layer are not defined in the specification.	To avoid confusion have subbase replace capping and engineered fill.	Amber	
184	GPHRP-080-S2-C00-D002	Typical Crossing and sidewalk details	Typical cascade detail Type D and pedestrian drain crossing. There are no places on the plan that show where this detail is to be used.	There is little provision for outlets and erosion protection. Site to be checked for any areas requiring such details such as in the S curve area. This detail should be with culverts.	Amber	
185	GPHRP-080-S2-C00-D002	Typical Crossing and sidewalk details	Side walk drain depth at 483mm may not allow for good drainage from earth drains as the earth drains will tend to be at lower invert. Will lifting hooks or holes be provided on the drain covers to allow for cleaning?	Detail to be modified ideally with earth drain behind sidewalk where space allows.	Amber	
186	GPHRP-080-S2-D007	SIGNING AND BUS STOP DETAIL	Typical bus stop details are not what is reflected on the plan drawings where the distance between the stops is much greater. The BoQ breakdown of 120m drain per bus stop area is totally inadequate.	Dimensions to be added and drainage item will need to be amended.	Amber	

187	GPHRP-080-S2-D007	SIGNING AND BUS STOP DETAIL	Warning signs and crash barriers totally inadequate.	Design to be amended taking into consideration the safety audit comments.	Amber	
188	GPHRP-080-S2-D007	SIGNING AND BUS STOP DETAIL	Road marking- the second white line on the outside of the shoulder is not required.	White line between carriageway and shoulder to remain, white line on outside of carriageway to be deleted.	Amber	
GPHRP 090-S2-D200 to D202 UTILITIES						
189	GPHRP-090-S2-D200 to D202	Utilities	There are no existing utilities shown on the drawings or any details for required diversion works. There are no future works shown on the drawings or typical trench details.	The existing utilities need to be shown, diversion areas identified and the new proposed utilities detailed on the drawings with typical details.	Red	

Supervision of Works for the George Price Highway Rehabilitation Project

Section III (Lot 3) Iguana Creek Junction to Santa Elena Town

Design Review Update 003 – DRAWINGS
February 2018

Item	DWG No.	Section/Detail	Description	Recommendation	Threat Level	MoW Comments Accept / Decline
GPHRP 050-S3-D300 TO D364 PLAN AND PROFILE						
189	050-S3-D300	PLAN & PROFILE SEC 3 -	Start of project chainage incorrect	Official change from 15+870 to 15+720. Issue corrected drawings.	Amber	
190	050-S3-D300	PLAN & PROFILE SEC 3 -	Bus bay position and retaining wall	Recheck to see if position can be adjusted to avoid expensive structure.	Amber	
191	050-S3-D300	PLAN & PROFILE SEC 3 -	Junction Iguana Creek is large but does allow for safe pedestrian movement and the embankment encroaches on land boundaries	Recheck to see if improvements can be made to avoid land take and make pedestrian friendly.	Amber	
192	050-S3-D300 to 001	PLAN & PROFILE SEC 3 -	Unclear extent of sidewalks and drainage. Has this quantity been provided in BoQ.	Recheck and modify if required.	Amber	
193	050-S3-D300 to D364	Plan and Profile Dwg	Match Line and profile views on the drawings do not match up consistently.	Drawings to be amended when issued for 'Good for Construction'.	Amber	

194	050-S3-D300 to D364	Plan and Profile Dwg	Vertical alignment - by keeping the levels near to existing the road will be cut down to provide either 200mm base or the 575mm base and subbase. The existing solid road structure is effectively wasted. Example Ch18+700 to 19+800 the FRL and exiting level is the almost the same and the horizontal alignment follows the existing road. Having the FRL average 200mm above existing would just require an addition of base to the structure instead of cutting out the existing material.	Vertical alignment should take account of the existing road structure especially when the horizontal alignment follows the existing road. The project is rehabilitation not reconstruction.	Amber	
195	050-S3-D300 to D364	Plan and Profile Dwg	Drawing key is not complete. Are the grey property boundaries surveyed or from existing plans?	Full key to be produced and in particular the boundaries shown and fencing.	Red	
196	050-S3-D300 to D364	Plan and Profile Dwg	Cadastral Boundaries and existing fencelines do not match and would seem to be offset for example at Spanish lookout Junction. The grey lines need to be checked and coincide with the existing boundaries otherwise on site there will be a lot of social issues in removing fencelines.	The cadastral boundary and existing boundary need to be checked **urgently**. Surveyors to identify cadastral markers on site.	Red	
197	050-S3-D300 to D364	Plan and Profile Dwg	Side Roads - the limit of works shown on the drawings vary for each side road without any guide as to the design philosophy. The notes 1. and 2. are insufficient. It states minimum 6m and 1m shoulders yet on the drawings it is 7m and 1.5m shoulders. The details need to be confirmed to avoid confusion.	The side road and junction details need to be standardised for major junction, side road junction and accesses. The radii and culvert length need to be shown with inlet and outlet structures. The width need to be confirmed change in shoulder width clearly shown.	Red	

198	050-S3-D300 to D364	Plan and Profile Dwg	Existing Road is catered for when the embankment or pavement is constructed above but there is no mention what the Contractor should do when the new road is constructed to the side or in fact where the existing road is beyond the extent of works. The limit of the works is not clearly shown on the plans.	The Contractor should be given new drawing showing the extent of clearing of existing roads or should this be left in residential areas to provide for access or side walks. There needs to be more clarity on the extent of work to be carried out.	Red	
199	050-S3-D300 to D364	Plan and Profile Dwgs	Access Culverts - the plan drawings should show the accesses for each property particularly in village areas where there maybe considerable number of accesses over a short distance. Has any consideration been given to businesses compared to residential. There should be defined accesses for gas stations, schools and any businesses with large vehicles.	A schedule of accesses should be made and a standard access drawing provided so that residents know exactly what they will be getting.	Red	
200	050-S3-D300 to D364	Plan and Profile Dwg	Road marking are not in compliance with the norm in Belize. The second edge line on the outside of the shoulder is not safe and could cause confusion.	Centreline and edge road marking needs to be reviewed and modified to meet both international and local Belizean standards.	Amber	
201	050-S3-D300 to D364	Plan and Profile Dwgs	Bus Stop Drainage Detail. There should be detail of how this connects to the earthen side drain as the drain below a side walk tends to be much higher than the earth drain inverts. The typical detail of the drain below the sidewalk is 483mm. It should also be noted that the sidewalk finishes right into a drain which is a safety issue at night.	Bus stop details need to be revised to a more practical solution regarding drainage, safety and pedestrian movements.	Amber	
202	050-S3-D307	PLAN & PROFILE SEC 3 -	Cut section of 0.8m is affecting property boundaries with cut slope.	Check existing slopes to see if cut slope can be steepened safely or reduce cut.	Amber	

203	050-S3-D308	PLAN & PROFILE SEC 3 -	Cut section of 1.0m could be reduced if fill either side of slope, or at least the 500mm pavement?	Check vertical alignment.	Amber	
204	050-S3-D313	PLAN & PROFILE SEC 3 -	Culvert C306A at CH19+361 is not shown. This should be identified as major structure. Alignment and lack of protection to erosion need attending.	Check slope stability and whether fill on east side would lessen cut.	Amber	
205	-050-S3-D316	PLAN & PROFILE SEC 3 -	Cut section 2.0m at Ch20+000. The material and back slope can be checked for stability to avoid large cut slopes from drain	Culvert should be skewed and the river protection and training works carried out upstream to lessen chance of flooding.	**RED**	
206	-050-S3-D328	PLAN & PROFILE SEC 3 -	Culvert C 308 is over 20m long without explanation as to why so long?	Check on the round plus outlet.	Amber	
207	050-S3-D331	PLAN & PROFILE SEC 3 -	Survey error on the existing levels	To be corrected	Amber	
208	050-S3-D331	PLAN & PROFILE SEC 3 -	Connection details for tying in existing concrete lined drain to culvert C310 and side road culverts	Provide typical connection details.	Amber	
209	050-S3-D336	PLAN & PROFILE SEC 3 -	Culvert C313 at Ch25+256 may be oversized.	In order to carry out hydraulic analysis for a revised design, cross section survey required upstream and downstream of culvert. Cross sections at 50 m intervals 200 m upstream and 200 m downstream of culvert.	Red	
210	-050-S3-C349-D357	PLAN & PROFILE SEC 3 -	Roadside drains to culvert 321 from culvert 322	These roadside drains need to be increased in size. Bed width should transition from 0.6 m at upstream end to 2.16 m at outfall to C321. Deepening and narrowing of base width is an alternative.	Amber	
211	050-S3-D359	PLAN & PROFILE SEC 3 -	The cadastral boundaries and existing boundaries seem to be offset. The design would seem to follow the cadastral boundaries.	Recheck survey and existing cadastral boundaries on site to see if the horizontal alignment shift is necessary.	Red	

212	050-S3-D363	PLAN & PROFILE SEC 3 -	The end of the project is not clear. Design stops at Ch32+400 but survey goes to 32+489.	End chainage should be made clear. Finish project at Ch32+400.	Red	
GPHRP 050-S3-W2999 to W3148 ROADWAY CROSS-SECTIONS						
213	050-S3-W2999-W3148	Road way Cross-Sections	Cut, Fill, and pavement quantities are not shown on cross-section. If calculated the cut quantity would include the side drain but as per BoQ this is a separate item? Lack of clarity.	Cross-sections should have the level to cut to and the depth of pavement to be placed especially when the new road is varying vertically and horizontally with the existing road pavement.	Red	
214	050-S3-W3000	Road way Cross-Sections	Cross-sections do not seem to warrant at retaining wall at this location. Were other options considered.	Review on site.	Amber	
215	050-S3-W2999-W3148	Road way Cross-Sections	The drain back slope should be checked where it follows the slope. Example at Ch17+620.	Check each cut area for stability if the slope is steepened.	Amber	
216	050-S3-W2999-W3148	Road way Cross-Sections	The vertical alignment seems to follow existing or just below. This will cause unnecessary cut and reduce the strength of the existing embankment.	Vertical alignment to be checked for modification.	Red	
217	050-S3-W2999-W3148	Road way Cross-Sections	Side walk drains in fill slope such as drawing W3072 do not seem the most practical method for controlling drainage.	To be reviewed. Alternative such as earth drain at bottom of slope with inlets connecting to it would perhaps be a more cost effective alternative.	Amber	
218	050-S3-W3074	Road way Cross-Sections	Invert and shape of existing concrete drain should be shown.	add in invert details and shape of existing drain.	Amber	
219	050-S3-W3148	Road way Cross-Sections	Last X-section is Ch32+400.	Project should stop Ch32+400. To be confirmed.	Red	
GPHRP 060-S3-C00-D001 to D019 / C306A-D001-3/ TYPICAL CULVERT DETAILS /CULVERT 306A						

220	060-S3-C00-D001	Culvert summary	Culvert 306a Barton Creek does not exist on schedule.	Modify Drawing and refer to the detailed drawings.	Amber	
221	060-S3-C00-D001	Culvert summary	Note 6 refers to Concrete Cylinder strengths whereas all other documents refer to cube strength.	Correct note.	Amber	
222	060-S3-C00-D001 to D019	SEC 3CULVERTS	The concrete encasement is usually used where the pipe construction is poor, the backfill is a fine to medium sand and founding conditions are soft soils. In this situation the joints would tend to move and if not properly fitted allow the backfill to escape causing settlement in the road. This dos not seem to be the case in the project area. The removal of the encasement would improve constructability, reduce costs, reduce time and reduce traffic diversions in these areas.	The concrete surround could be removed providing that :- 1. the pipes conform to AASHTO M180 and the joints are well sealed; 2. The backfill material is good granular material that can be compacted in confined spaces; 3. The method of joint sealing is proved to be effective if there is movement; 4. The founding conditions are in good material will minimum chance of settlement.	Amber	
223	060-S3-C00-D001 to D019	SEC 3CULVERTS	Note 7. All chamfers to be 150mm unless stated - should this read 50 or 25mm? The pipes do not show any bell end or jointing mechanism which will used. the cover should have a maximum and minimum cover stated for the design used.	Chamfer details to be clearly dimensioned. Show the true shape of pipes with the bell end and show the joint details even if encased.	Amber	
224	060-S3-C00-D001 to D019	SEC 2 CULVERTS	Rip-rap detail has not been included in the BoQ. Cross-sections show pavement material up to side slope which is not on typical road cross-sections. What provision for hand rails or crash barriers at these locations, because once vegetated the drop-offs become hidden.	Item will have to be included and priced. Areas of use will have to be determined on site and used only where there is obvious erosion issues. Cross-section details to be checked and typical detail changed. Safety barriers and railings to be added to design.	Amber	

GPHRP 070-S3-B03-D001 to D009 / B04-D001-008 GARBUT CREEK FLOOD RELEIF WORKS / RED CREEK SCOUR PROTECTION						
225	070-S3-B03-D001	Garbutt Creek Bridge	Problem with catchment area used in feasibility report	Hydrological and hydraulic analysis to be revised. In order to carry out hydraulic analysis for a revised design, cross section survey required upstream and downstream of Bridge. Cross sections at 50 m intervals 200 m upstream and 200 m downstream of bridge.	Red	
226	GPHRP-070-S3-B04-D001	Red Creek Bridge	Problem with catchment area used in feasibility report	Hydrological and hydraulic analysis to be revised. In order to carry out hydraulic analysis for a revised design, cross section survey required upstream and downstream of Bridge. Cross sections at 50 m intervals 200 m upstream and 200 m downstream of bridge.	Red	
GPHRP 080-S3-D001 to D015 TRAFFIC AND DETAILS						
227	GPHRP-080-S3-D002	Typical Road Cross sections	The typical road sections do not make sense and need to be revised. Verge shows it varies but on X-sections it is 0.5m. Verge material is shown same as existing ground and in BoQ is measures as topsoil. This needs to be properly defined. Road pavement table is confusing and will lead to errors in the field, it should be simplified and clearer. The typical cross-sections do not show cut and fill scenario or the existing road.	The typical cross-section should be re drawn to show what is to be done in the cut on the road, cut in natural ground, fill and over the existing road. Pavement layers to be fixed at 200mm base and 325mm subbase and the capping can then be 150mm. Verge to be constructed of pavement material to avoid moisture in pavement layers becoming trapped.	Red	
228	GPHRP-080-S3-D002	Typical Road Cross sections	Use of terms engineered fill (min 30% CBR) and capping layer are not defined in the specification.	To avoid confusion have subbase replace capping and engineered fill.	Amber	

229	GPHRP-080-S3-C00-D002	Typical Crossing and sidewalk details	Typical cascade detail Type D and pedestrian drain crossing. There are no places on the plan that show where this detail is to be used.	There is little provision for outlets and erosion protection. Site to be checked for any areas requiring such details such as in the S curve area. This detail should be with culverts.	Amber	
230	GPHRP-080-S3-C00-D002	Typical Crossing and sidewalk details	Side walk drain depth at 483mm may not allow for good drainage from earth drains as the earth drains will tend to be at lower invert. Will lifting hooks or holes be provided on the drain covers to allow for cleaning?	Detail to be modified ideally with earth drain behind sidewalk where space allows.	Amber	
231	GPHRP-080-S3-D004	SIGNING AND BUS STOP DETAIL	Typical bus stop details are not what is reflected on the plan drawings where the distance between the stops is much greater. The BoQ breakdown of 120m drain per bus stop area is totally inadequate.	Dimensions to be added and drainage item will need to be amended.	Amber	
232	GPHRP-080-S3-D004	SIGNING AND BUS STOP DETAIL	Road marking- the second white line on the outside of the shoulder is not required.	White line between carriageway and shoulder to remain, white line on outside of carriageway to be deleted.	Amber	
233	GPHRP-080-S3-D0014	SIGNING AND BUS STOP DETAIL	Signing at roundabout	This is contractually not part of the site.	Amber	
GPHRP 090-S2-D200 to D202 UTILITIES						
234	GPHRP-080-S3-D300 to D301	Utilities	There are no existing utilities shown on the drawings or any details for required diversion works. There are no future works shown on the drawings or typical trench details.	The existing utilities need to be shown, diversion areas identified and the new proposed utilities detailed on the drawings with typical details.	Red	

Supervision of Works for the George Price Highway Rehabilitation Project

Section I (Lot 1) Construction of Roaring Creek Bridge

Design Review - CONTRACT DOCUMENTS
February 2018

Item	Section	Clause / page	Description	Recommendation	Threat Level	MoW Comments Accept / Decline
CONTRACT AGREEMENT / LETTER OF ACCEPTANCE						
234	1	paragraph 3	The agreement, letter of acceptance, instruction to proceed were all dated the 18th December 2017. With the holiday period this effectively put the Contractor back 1 month as he did not really commence Mobilisation until the second week in January 2018.	Future Contracts should delay the notice to proceed with the works until a realistic date.	Amber	
SPECIAL CONDITIONS OF CONTRACT						
235	Section VI SCC	1.1 (r)/ 1.1 (z) / 21.1 /	The start date is December 2019 and completion April 2019 which gives 16 months. An exact date rather than a month to avoid confusion.	Completion date should be changed to 18th June 2019 and start date confirmed as 18th December 2017.	Red	
GENERAL CONDITIONS OF CONTRACT						
236	GCC	51.4	Advance Payment - GCC Clause 51.4 where it states that payments are to be paid back on proportionate amounts from the works	The repayment of the advance will need to be clarified.	Amber	

			completed in payment terms. However the Advance payment Bond from the bidding documents stats that the bond will expire upon certification of 80% of Contract Price.			
237	GCC	52	Performance Security - it should be made clear from the onset whether bonding or insurance companies from outside of Belize will be acceptable to the Contracting Agency to furnish the Performance Security.	Modify as enquired for future Contracts.	Amber	
SPECIFICATIONS						
238	Section VI	General	The Specification numbering does not correspond to the preamble numbering or the BoQ numbering. The description and item labelling is also different which will lead to confusion.	A generic specification linked to BoQ and preamble should be developed that can be used for future projects.	Amber	
239	613	Fill for Roadworks	The fill has a maximum of 10% passing 0.075mm sieve. However the subbase has 0 to 20% can pass and the base 5 to 12%. The Fill specification is tighter than the pavement layer Specification in this regards.	Fill Specification to be modified to the subbase grading envelope for he finer fraction.	Red	
240	615	Benching	This is critical part of the rehabilitation construction as we widen the existing rod embankment. This benching description should be put on the typical cross-sections to make it clear to the Contractor the requirements.	Modify typical road cross-sections and include in the standard cross-sections at 20m interval as this will affect he quantities.	Amber	

241	714	Subgrade Preparation and Acceptance	714(1) describes the subgrade preparation. This is not shown on the drawings, typical cross-section or included in the BoQ.	This will need to be addressed for the Contract. It will be difficult to have a paid item 715 for treatment of existing pavement surfaces when item 714 Subgrade preparation does not have a BoQ item. The Contractors may well claim.	Red	
242	704	Subbase	Drawing refers to engineered fill and capping layer. This is not found in the specification.	Clarify that Capping and Engineered fill to comply with subbase Specification to avoid confusion.	Amber	
PREAMBLE TO BOQ						
243	Section IX	Preamble to Bill of Quantities	The document was not included in the bound Contract documents, included in GCC Clause 2.3 or in the SCC.	In accordance with GCC Clause 15, the Project Manager (PEU) could confirm that the Preamble to BoQ does form part of the Contract should have been added in Clause 2.3 (h) Bill of Quantities.	Red	
244	Section IX	Preamble to Bill of Quantities	The item numbering of the Preamble, the BoQ and the specification should be comparable so that each item can clearly be identified and compared between the documents. For example the establishment of the Engineers Office is numbered and described completely differently in each document. The Preamble describes this as *'Item 19 Erection of Principal Site Offices for Engineer*', the BoQ '*Item 1.3.01 Erection of site offices and provision of office furniture'* and the Specification calls it '*Item 225 Engineer's Office'.*	For all future Contracts there needs to be time spent producing Contract documents that are synchronised between each other. This will avoid confusion and Contractual misunderstandings between the parties.	Red	

245	Section IX	Preamble to Bill of Quantities	Items in the Preamble are listed but are not found within the Specification or the Bill of Quantities. Examples are Item 23 Progress Photographs, Item 23A Communications systems for the Engineer, 47 Regulating Course	This should be corrected for next contracts. The preamble has not been amended to fit the other Contract Documents.		
246	Section IX	Preamble to Bill of Quantities	There are numerous sections which contradict the Specification and BoQ. This will lead to misunderstandings.		Red	
BILL OF QUANTITIES						
	BILL No 1: General and Preliminaries					
247	1.6.01	Testing of Formation	Testing of formation is not referred to in the specification but proof rolling of the layers prior to fill is mentioned in 614(b) and in the preamble but there is no rate in BoQ for proof rolling. The payment items jump from excavation to fill.	The subgrade compaction work and testing should be specified and shown in the BoQ. There should be a specified subgrade compaction level with the use of proof rolling as a double check after compaction results. This will have to be managed in present Contract but should be corrected for future Contracts.	Amber	
248	1.5 / 1.6	Testing of Materials / Testing of Works	There is no clear description in the Specification for the testing of materials or he testing of works. There should be greater clarity between the documents.	The specification is not clear and should be improved for future Contracts. A summary table should be produced or referred to.	Amber	

249	1.10	Provisional Sums Utilities	The BoQ Items refer to Preamble 'Item #18 Services Diversions' which states that the provisional sums includes all costs incurred in effecting the service diversions as shown on the Drawings. However the drawings do not show or give any indication of the diversions intended by the utility companies. It is interesting that the BoQ item did not refer to the Specification Clause 104 where it describes in more detail where diversions are necessary to permit the construction of the works. There could be an argument that the new works are an upgrade rather than a diversion necessary to allow the road or bridge to be completed.	Any delays in the utility works or effect on the Contractors programme is likely to results in a claim. The utility relocation drawings and works need to be completed and issued to the Contractors as soon as possible. This is likely to be a major delay claim issue on Lots 1 and 2.	Red	
	BILL No 3: Earthworks and Roadworks					
250	3.1.01	General excavation topsoil; max depth not exceeding 0.25m.	This is described in Preamble Item 24 as Strip topsoil not exceeding 150mm depth so there is confusion between the two descriptions. It is not clear where this material will be placed in the final road profile.	Depth of topsoil to be clarified and typical section to be amended to show where the topsoil will be placed. Placing topsoil in verge will tend to block the natural drainage of the pavement layers. Drawings to be amended and issued as soon as possible.	Amber	
251	3.1.01 / 3.1.04 / 3.1.06	Topsoil excavation / stockpiling and reuse	The topsoil quantities for excavation 2906m3, stockpile 2500m3 and reuse 800m3 do not match up as this will leave 1700m3 in stockpile. But then there is a filling to embankment of excavated topsoil of 2500m3.	Topsoil may only be required on the embankment areas as landscaping and the verge can be left as pavement material. There would be slight increase in pavement base and subbase.	Amber	
252	3.1.02	General excavation;	Quantities of this item (2325m3) cannot be identified from the drawings as there is no cut shown.	Quantity allocated on the original BOQ to remain in case there is requirement. Full measure to be carried out after levels taken.	Amber	

253	3.1.05	Disposal of excavated material;	Quantities of this item (2731m3) cannot be identified from the drawings but should this not equal 2,325m3 in item 3.102?	Quantity allocated on the original BOQ to remain in case there is requirement. Full measure to be carried out after levels taken.	Amber	
	3.3 Sub-base, Road Base and Surfacing					
254	3.3.03 and 3.3.05	Subbase and Base in Verge	The quantities do not include for materials extending out to the verge to allow the granular pavement layers to drain. Blocking this a topsoil verge would be counterproductive.	Drawings would need to be modified and there would have to be an increase in quantity once the verge width is confirmed in this area. Design is incomplete and needs to be corrected.	Red	
255	3.3.06	Prime coat to Carriageway and Shoulders. Dressing with 6mm chippings.	The preamble Item 48 describes a prime coat and sand blinding but nothing about chippings. The Specification describes sand blinding before the road is trafficked in Clauses 707 and 727 but no mention of 6mm chippings.	BoQ to be corrected and sand application clarified to the Contractor.	Red	
256	3.3.13	Kerbs to Belmopan Roundabout	Insufficient details on plan drawings or on the cross-sections. The sidewalk details are given but no quantity or location on the plan. There is no consideration of the final pedestrian movements in this area.	The roundabout, sidewalk and concrete road way need to be fully designed as there is no indication on the drawings. The quantity of sidewalk of 150m is likely to increase.	Red	
	3.4 Road Signs and Markings					
257	3.4.01 to 3.4.08	Traffic Signs and road marking paint.	Insufficient details on drawings	Design incomplete. Original BOQ quantities to remain and full design to be produced to show locations.	Amber	
258	3.4.10	Reflective road studs; Prismo II tropica	Insufficient details on drawings	Design incomplete. Original BOQ quantities to remain and full design to be produced to show locations.	Amber	
	4.2 New Culvert Construction					

259	4.2.01	8m long 900mm diameter concrete pipes in trenches not exceeding 1.5m depth.	The length of the culverts in the description (8m)do not match with the drawing, the final length in the drawings is actually longer	adjust the length of the culvert to the Actual drawings: 18.65m, 14.4m, 7.53m, 4.73m	Red	
260	BOX CULVERT	Item not included on the BOQ	6.65m long x 1800 x 1800 reinforced concrete box type culvert in trenches not exceeding 1.5m depth. Complete with reinforced concrete head walls. Excavation and backfill with imported natural material (Type 3 culvert at Chainage 0 + 288)	This culvert need to be included on the BOQ	Red	
261	CASCADE DRAIN	Item not included on the BOQ	Cascade drain Type D (details not shown)32.00m drawings SI - DP - D102	need to be included on the BOQ	Red	
262	BOX DRAIN TYPE C	Item not included on the BOQ	Reinforced concrete box drain Type C 160m (Apparently cross section labelled 'Typical Box Channel Detail' Drwg SI/C00/D006 applies)	need to be included on the BOQ	Red	
	Bill No.6 Retaining Walls					
263	FILL TO RW	Item not included on the BOQ	Filling to excavations under retaining wall footing not in BoQ although required.	Item needs to be added to BoQ.	Red	
	Bill No.9 Scour Protection					
264	Deep Excavation Rip-Rap	Item not included on the BOQ	General excavation to formation level of riprap scour protection, material other than topsoil, rock or artificial hard material: up to depth 5m - 10m. Under Bridge. West Side Chainage 0 + 060 - 0 + 065, Chainage 0 + 065 - 0 + 070. East Side	5,810m3 of excavation need to be included	Red	

			Chainage 0 + 050 - 0 + 060			
265	Rip rap Excavation not included in BoQ	Item not included on the BOQ	General excavation to formation level of riprap scour protection, material other than topsoil, rock or artificial hard material: up to depth 2m. Culverts Type 1 Type 3	70 m3 of excavation need to be included in BoQ.	Red	
266	Rip Rap	Item not included on the BOQ	General filling to drain bed, slopes for scour protection, placing of imported riprap rock material in accordance with the drawings. Culverts Type 1, Type 3	70 m3 need to be included	Red	
267	Geotextile	Item not included on the BOQ	Geotextile for Separation below proposed rip rap boulders for scour protection along drain as per the drawings. Culverts Type 1, Type 3	105 m3 of excavation need to be included	Red	

Supervision of Works for the George Price Highway Rehabilitation Project

Section II (Lot 2) Construction of Roaring Creek to Iguana Junction

Design Review - CONTRACT DOCUMENTS

February 2018

Item	Section	Clause / page	Description	Recommendation	Threat Level	MoW Comments Accept / Decline
			SPECIAL CONDITIONS OF CONTRACT			
267	Section VI SCC	1.1 (r)/ 1.1 (z) / 21.1 /	The start date is stated as February 2018 and the Completion date is August 2019 which gives 18 months. However exact dates rather than a month should be used to avoid confusion especially when the acceptance letter is dated 24th January 2018.	The start, completion, and possession of site dates should have a full day/month/ year date.	Amber	
			GENERAL CONDITIONS OF CONTRACT			
268	GCC	51.4	Advance Payment - GCC Clause 51.4 where it states that payments are to be paid back on proportionate amounts from the works completed in payment terms. However the Advance payment Bond from the bidding documents stats that the bond will expire upon certification of 80% of Contract Price.	The repayment of the advance will need to be clarified	Amber	

269	GCC	52	Performance Security - it should be made clear from the onset whether bonding or insurance companies from outside of Belize will be acceptable to the Contracting Agency to furnish the Performance Security.	Modify as enquired for future Contracts.	Amber	
SPECIFICATIONS						
270	Section VI	General	The Specification numbering does not correspond to the preamble numbering or the BoQ numbering. The description and item labelling is also different which will lead to confusion.	A generic specification linked to BoQ and preamble should be developed that can be used for future projects.	Amber	
271	613	Fill for Roadworks	The fill has a maximum of 10% passing 0.075mm sieve. However the subbase has 0 to 20% can pass and the base 5 to 12%. The Fill specification is tighter than the pavement layer Specification in this regards.	Fill Specification to be modified to the subbase grading envelope for he finer fraction.	Red	
272	615	Benching	This is critical part of the rehabilitation construction as we widen the existing rod embankment. This benching description should be put on the typical cross-sections to make it clear to the Contractor the requirements.	Modify typical road cross-sections and include in the standard cross-sections at 20m interval as this will affect he quantities.	Amber	
273	714	Subgrade Preparation and Acceptance	714(1) describes the subgrade preparation. This is not shown on the drawings, typical cross-section or included in the BoQ.	This will need to be addressed for the Contract. It will be difficult to have a paid item 715 for treatment of existing pavement surfaces when item 714 Subgrade preparation does not have a BoQ item. The Contractors may well claim.	Red	
274	704	Subbase	Drawing refers to engineered fill and capping layer. This is not found in the specification.	Clarify that Capping and Engineered fill to comply with subbase Specification to avoid confusion.	Amber	

PREAMBLE TO BOQ						
275	Section IX	Preamble to Bill of Quantities	The document was not included in the bound Contract documents, included in GCC Clause 2.3 or in the SCC.	In accordance with GCC Clause 15, the Project Manager (PEU) could confirm that the Preamble to BoQ does form part of the Contract should have been added in Clause 2.3 (h) Bill of Quantities.	Red	
276	Section IX	Preamble to Bill of Quantities	The item numbering of the Preamble, the BoQ and the specification should be comparable so that each item can clearly be identified and compared between the documents. For example the establishment of the Engineers Office is numbered and described completely differently in each document. The Preamble describes this as *'Item 19 Erection of Principal Site Offices for Engineer*', the BoQ '*Item 1.3.01 Erection of site offices and provision of office furniture'* and the Specification calls it '*Item 225 Engineer's Office'.*	For all future Contracts there needs to be time spent producing Contract documents that are synchronised between each other. This will avoid confusion and Contractual misunderstandings between the parties.	Red	
277	Section IX	Preamble to Bill of Quantities	Items in the Preamble are listed but are not found within the Specification or the Bill of Quantities. Examples are Item 23 Progress Photographs, Item 23A Communications systems for the Engineer, 47 Regulating Course	This should be corrected for next contracts. The preamble has not been amended to fit the other Contract Documents.	Amber	
278	Section IX	Preamble to Bill of Quantities	There are numerous sections which contradict the Specification and BoQ. This will lead to misunderstandings.		Red	
BILL OF QUANTITIES						
	BILL No 1: General and Preliminaries					

279	Item No.	1.3.04	*Mobilisation of crane to site, establishment of pile driving guide and platform to install piles'…..* This seems to have carried over from Lot 1 and there is no reason for it to be in the Lot 2 Contract.	Future contracts should have more relevant item for roads contract such as asphalt plant or quarry. Otherwise this item could be deleted.	Amber	
280	1.6.01	Testing of Formation	Testing of formation is not referred to in the specification but proof rolling of the layers prior to fill is mentioned in 614(b) and in the preamble but there is no rate in BoQ for proof rolling. The payment items jump from excavation to fill.	The subgrade compaction work and testing should be specified and shown in the BoQ. There should be a specified subgrade compaction level with the use of proof rolling as a double check after compaction results. This will have to be managed in present Contract but should be corrected for future Contracts.	Amber	
281	1.5 / 1.6	Testing of Materials / Testing of Works	There is no clear description in the Specification for the testing of materials or he testing of works. There should be greater clarity between the documents.	The specification is not clear and should be improved for future Contracts. A summary table should be produced or referred to.	Amber	
282	1.9.01	Temporary Works for traffic diversions	Item is not clearly referred in specification or Preamble especially when referring to detour across private land or existing road.	Improved description and in particularly the requirements for safety.	Amber	
283		Maintaining Existing Road	There is no item in BoQ for maintenance of existing road.	A monthly payment item is often useful to give incentive for Contractors to maintain the existing road and can be withheld if no works carried out. Ad to future Contracts.	Amber	

284	1.10	Provisional Sums Utilities	The BoQ Items refer to Preamble 'Item #18 Services Diversions' which states that the provisional sums includes all costs incurred in effecting the service diversions as shown on the Drawings. However the drawings do not show or give any indication of the diversions intended by the utility companies. It is interesting that the BoQ item did not refer to the Specification Clause 104 where it describes in more detail where diversions are necessary to permit the construction of the works. There could be an argument that the new works are an upgrade rather than a diversion necessary to allow the road or bridge to be completed.	Any delays in the utility works or effect on the Contractors programme is likely to results in a claim. The utility relocation drawings and works need to be completed and issued to the Contractors as soon as possible. This is likely to be a major delay claim issue on Lots 1 and 2.	Red	
	BILL No 3: Earthworks and Roadworks					
285	3.1.01 / 3.1.04 / 3.1.06	Topsoil excavation / stockpiling and reuse	The topsoil quantities only cater for 0.5m wide strip of verge. This would effectively block the drainage of the pavement layers and unlikely to remain in place . Either the topsoil should be for side lope and drain or removed and replaced with pavement material.	Topsoil should be removed and the pavement layers extend out to the shoulder slope. There will be savings in the topsoil but increase in the pavement layer items.	Red	
286	3.1.03	Excavation Rock	The descriptions are not good for this item but the quantity is clearly not correct at 1000m3.	This quantity will need to be increased by at least 30,000m3 resulting in an additional BZ$ 500,000.	Amber	
	3.3 Sub-base, Road Base and Surfacing					
287		Subgrade	There is no provision for subgrade which could result in +BZ$ 400,000 additional cost to contract.	Drawings to be made clear where subgrade and benching to be carried out. Contract to be reviewed to determine whether this could be an additional cost.	Amber	
288	3.3.03 and 3.3.05	Subbase and Base in Shoulder	The quantities do not include for materials extending out to the verge to allow the granular pavement layers to drain. Blocking this a topsoil verge would be counterproductive.	Drawings would need to be modified and there would have to be an increase in quantity once the verge width is confirmed in this area. Design is incomplete and needs	Red	

				to be corrected.		
289	3.3.02 and 3.3.04	Subbase and Base Carriageway	The quantities do not include for materials for side roads and accesses. This will result in considerable increase in quantities up to BZ$ 900,000.	Side road and accesses schedules need to be produced with a typical drawing so that quantities can be accurately measured and the Contractor properly instructed regarding works to be carried out.	Red	
290		Prime coat to Carriageway and Shoulders. Dressing with 6mm chippings.	The preamble Item 48 describes a prime coat and sand blinding but nothing about chippings. The Specification describes sand blinding before the road is trafficked in Clauses 707 and 727 but no mention of 6mm chippings.	BoQ to be corrected and sand application clarified to the Contractor.	Red	
291	3.3.10 and 11	Surface dressing	Additional quantities for shoulder and side road works could increase quantities up to BZ$300,000.	Side roads and shoulder works to be fully detailed and measured.	Red	

9. APPENDICES

9.1 Contract Document Review List

No.	REPORT	DESCRIPTION	FORMAT
1	**FEASIBILITY STUDY**	A. Thurton (VOL. 1 and Vol 2) Inception Report	pdf and hardcopy
		A. Thurton (VOL. 3) plus Appendices	pdf and hardcopy
		A. Thurton (VOL. 4) plus Appendices	pdf
		A. Thurton (VOL. 5) plus Appendices	pdf and hardcopy
2	**Environmental and Social Impact assessments for Rehabilitation of the GPH between Miles 47.9 to 79.4**	Environmental and Social Baseline Assessment Report	Hardcopy only
		Inception Report	Hardcopy only
		Environmental and Social Management Plan Report	Hardcopy only
		Public Participation Process	Hardcopy only
		Environment and Social Impact assessment Report	Hardcopy only
		Final Report on the Environmental and Social Impact Study	Hardcopy only
		Final Report on the Environmental and Social Impact Study ANNEXES	Hardcopy only
3	**FINAL REPORT with Estimates**	GPHRP Draft Final Report	pdf
		GPHRP Final Report v1	Word / pdf
4	**FINAL REPORT**	GPHRP Draft Final Report v1	Word / pdf
		GPHRP Final Report v3	Word / pdf
5	**BOQ**	Final section 4 Estimate	xl
		Final Section 3 BOQ v1-1	xl
		Final Section 2 Estimate	xl
		Final Section 1 BOQ Estimate v1	xl
		Copy of BOQ v1 section 2	xl
		Copy of BOQ section 4	xl
		Copy of BOQ section 3	xl
6	**CONTROL POINTS**	Controls Description Phase 1	CAD
		Controls Description Phase 1-CM001 to 31	pdf x31
		Controls Description Phase 2	CAD
		Controls Description Phase 2-CM032 to 68	pdf x37
		Controls Description Phase 3	CAD
		Controls Description Phase 3-CM070 to 120	pdf x50
		GPHR Control Stations	xl
7	**GEOTECHNICAL REPORT**	GPHR-030-R001_100% GDR v1.2	Word / pdf
		GPHR-030-T001_100%_Bridge GDN_23092016	pdf /word
		GPHR-030-T002 FINAL	Word /pdf
8	**HDM 4 REPORT**	Belize HDM4	rar
		GPHRP HDM 4 Draft Final Report v1	Word / pdf
9	**HYDRAULICS REPORT**	GPHR-030-R001 v1.1 Hydrology + Hydraulics Draft Final Report	Word / pdf
10	**INCEPTION REPORT**	GPHR Inception Report v3.1	Word / pdf
11	**INTERIM REPORT**	GPHR Interim Report v5	Word / pdf

12	**LANDTAKE**	**Various files pdf and CAD……**	
13	**PAVEMENT REPORT**	GPHR Pavement Design Report	Word / pdf
14	**SECTION 1**	**Section 1 Bidding Documents**	
		GPHRP Final Section 1 Procurement_of_Works	Word / pdf
		Section 1 BOQ	
		Final Section 1 BOQ Quantities v2	pdf / xl
		Final Section 1 Preamble to BOQ v1	Word / pdf
		Section 1 Drawings	CAD pdf
		050 - CROSS SECTIONS	CAD pdf
		050 - PLAN AND PROFILE	CAD pdf
		060 - STRUCTURES	CAD pdf
		060 - B00 - General Structural Notes & Standard Details	CAD pdf
		060 - B01 - Roaring Creek Bridge (Structural)	CAD pdf
		060 - C00 - Standard Culvert Details	CAD pdf
		060 - PB01 - Existing Roaring Creek Bridge (Rehab)	CAD pdf
		060 - W01 - Retaining Wall 01	CAD pdf
		060 - W02 - Retaining Wall 02	CAD pdf
		070 - DRAINAGE	CAD pdf
		080 - TRAFFIC AND DETAILS	CAD pdf
		090 - UTILITIES	CAD pdf
		Section 1 Specifications-GPHRP-010-S1-T001-v1.2 Technical Specifications letter	pdf word
15	**SECTION 2**	**Section 2 Bidding Documents**	
		Section 2 FINAL Procurement of Works Smaller Contracts	pdf word
		Section 2 BOQ	
		Final Section 2 BOQ Quantities v3 FINAL	pdf / xl
		Final Section 2 Preamble to BOQ v2 FINAL	Word / pdf
		Section 2 Drawings	
		Section 2 Drawings - CAD	rar CAD /pdf
		Section 2 Specifications - GPHRP-010-S2-T001-v2.0 Technical Specifications FINAL	word / pdf
		GPHRP-090-S2-D203 LIGHTING POLE BASE DETAIL-LIGHTING POLE BASE DETAIL	pdf
16	**SECTION 3**	**Section 3 BOQ**	
		Final Section 3 BOQ Quantities v2	pdf / xl
		Final Section 3 Preamble to BOQ v1	Word / pdf
		Section 3 Drawings	
		Section 3 Drawings - CAD	rar CAD / pdf
		Section 3 Specifications - GPHRP-010-S3-T001-v2.0 Technical Specifications letter	word / pdf
		Sections 3 Bidding Documents	
		GPHRP Final Section 3 Procurement of Works	word / pdf
17	**SECTION 4**	**Section 4 Bidding Documents**	

		GPHRP Final Section 4 Procurement of Works Smaller	word / pdf
		Section 4 BOQ	
		Final Section 4 BOQ Quantities v4	pdf / xl
		Final Section 4 Preamble to BOQ v2	Word / pdf
		Section 4 Drawings	
		Section 4 Drawings - CAD	rar CAD / pdf
		Section 4 Specifications - GPHRP-010-S4-T001-v2.0 Technical Specifications letter	word / pdf
18	GPHRP-090-S2-D203 LIGHTING POLE BASE DETAIL	Street light pole base drawing	
19	BWS Drawings and BoQ	BWS - George Price Highway Rehabilitation Project - Belmopan Roundabout to Teakettle	pdf /xl

9.2 Pavement Design Calculation

Following is a comparison with AASHTO Design Guide 1995 (USA) which shows the required SN (Structural Number) is 2.86 considering Soil Class S3 and Traffic Class T4 (Traffic volume of 1.7 million ESA as in the preliminary design and Subgrade modulus of 16500 psi). SN value becomes 2.29 with 200mm Road Base and 275mm Sub Base as recommended in the preliminary design. The pavement structure is not adequate for traffic volume of 1.7 million ESA. Traffic volume is much higher in the final design and the pavement structure recommended in the Final Design will not satisfy the requirements of AASHTO Design Guide 1995.

AASHTO FLEXIBLE PAVEMENT DESIGN 1995:-

$$\log_{10}(W_{18}) = Z_R \times S_0 + 9.36 \times \log_{10}(SN_f + 1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40 + \frac{1094}{(SN_f+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

Where:

W18	Predicted Number of 18-kip equivalent axle load application.
ZR	Standard Normal Deviate
delta(PSI)	Difference between the initial design serviceability index P0, and the design terminal serviceability index Pt, and
MR	Resilient Modulus (psi)
SN	a1D1 + a2D2m2 + a3D3m3
SN	is equal to the structural number indicative of the total pavement thickness required :
Where :	
ai	ith layer coefficient
Di	ith layer thickness (inches) and
mi	ith layer drainage coefficient

Input			
CBR =	5	P_o	4.2
Traffic =	10	P_t	2.5

Calculations :			D1≥SN1/a1 SN1=a1*D1 D2=(SN2-SN1*)/a2m2 SN2*=D2*m2*a2 D3=(SNf-(SN1*+SN2*))/a3m3 SN3*=m3*a3*d3

Values	**Input**		
W_{18} =	**1700000**		
M_R =	**16500**	(Section 1.5)	
S_0 =	**0.49**	(Section 2.1.3)	
(delta(PSI) =	**1.7**	(Section 2.2.1)	
Z_R =	**-1.282**	(Table 4.1)	
R =	**0.9**	(Table 2.2)	

a1	0.4		
a2	0.14	m2	1
a3	0.11	m3	1
SN1			
SN2			

	inches	**mm**	SAY
D1=	0	**0**	0
SN1*	0		
D2=	7.87	**200**	200
SN2*	1.0993325		
D3=	10.82	**275**	275
SN3*	1.1876718	**TOTAL(mm)**	**475**

SN_f =	**2.86**	**SN_Requred = 2.86**	**SN_Pavement as designed= 2.29**
Formulae	= $(Z_R*S_0+9.36*\log(SN_f+1)-0.20+(\log(PSI/(4.2-1.5)))/(0.40+(1094/((SN_f+1)^{5.19}))))+2.32*\log(M_R)-8.07-\log(W))$		

Result =	0.001609

Road Base of 250mm and Sub Base of 350mm makes SN of 2.89

State of the practice pavement design procedure is Mechanistic empirical pavement design. Following is the pavement analysis using KENPAVE software (USA) based on mechanistic empirical pavement design (Pavement Analysis and Design – Second Edition by Yang H. Huang, 2004) considering 1.7 million ESA as in the preliminary design. The design life will be much less if traffic volume of final design considered. The analysis shows if surface dressing is maintained properly the design life with 1.7 million ESA is **10 years**.

INPUT FILE NAME -C: \KENPAVE\George Price Highway_1.DAT

NUMBER OF PROBLEMS TO BE SOLVED = 1

TITLE -George Price Highway

MATL = 1 FOR LINEAR ELASTIC LAYERED SYSTEM
NDAMA=2, SO DAMAGE ANALYSIS WITH DETAILED PRINTOUT WILL BE PERFORMED
NUMBER OF PERIODS PER YEAR (NPY) = 1
NUMBER OF LOAD GROUPS (NLG) = 1
TOLERANCE FOR INTEGRATION (DEL) -- = 0.001
NUMBER OF LAYERS (NL) ---------- = 3
NUMBER OF Z COORDINATES (NZ) ------ = 0
LIMIT OF INTEGRATION CYCLES (ICL) - = 80
COMPUTING CODE (NSTD) ---------- = 9
SYSTEM OF UNITS (NUNIT) ----------= 0

Length and displacement in in., stress and modulus in psi
Unit weight in pcf, and temperature in F

THICKNESSES OF LAYERS (TH) ARE: 7.87 10.83
POISSON'S RATIOS OF LAYERS (PR) ARE: 0.35 0.35 0.35
ALL INTERFACES ARE FULLY BONDED

FOR PERIOD NO. 1 LAYER NO. AND MODULUS ARE: 1 1.650E+04 2 1.500E+04
3 7.500E+03

LOAD GROUP NO. 1 HAS 2 CONTACT AREAS
CONTACT RADIUS (CR) ---------- = 3.55
CONTACT PRESSURE (CP) ---------- = 113.79
NO. OF POINTS AT WHICH RESULTS ARE DESIRED (NPT) -- = 10
WHEEL SPACING ALONG X-AXIS (XW) ---------- = 0
WHEEL SPACING ALONG Y-AXIS (YW) ---------- = 12.2

RESPONSE PT. NO. AND (XPT, YPT) ARE: 1 0.000 0.000 2 0.000 0.000
3 0.000 0.000 4 0.000 0.000 5 0.000 0.000 6 0.000 0.000
7 0.000 0.000 8 0.000 0.000 9 0.000 0.000 10 0.000 0.000

NUMBER OF LAYERS FOR BOTTOM TENSION (NLBT) ---- = 1
NUMBER OF LAYERS FOR TOP COMPRESSION (NLTC) --- = 1
LAYER NO. FOR BOTTOM TENSION (LNBT) ARE: 1
LAYER NO. FOR TOP COMPRESSION (LNTC) ARE: 3

LOAD REPETITIONS (TNLR) IN PERIOD 1 FOR EACH LOAD GROUP ARE: 1700000

DAMAGE COEF.'S (FT) FOR BOTTOM TENSION OF LAYER 1 ARE: 0.6628 5 1.8

DAMAGE COEFICIENTS (FT) FOR TOP COMPRESSION OF LAYER 3 ARE: 3.084E-15 7.143

DAMAGE ANALYSIS OF PERIOD NO. 1 LOAD GROUP NO. 1

POINT NO.	VERTICAL COORDINATE	VERTICAL DISP.	VERTICAL STRESS	MAJOR PRINCIPAL STRESS	MINOR PRINCIAL P. STRESS	INTERMEDIATE STRESS (HORIZONTAL P. STRAIN)
		(STRAIN)	(STRAIN)	(STRAIN)		
1	7.87000	0.03437	28.103	28.436	-1.540	1.335
	(STRAIN)		1.701E-03	1.728E-03	-7.248E-04	-7.248E-04
1	18.70010	0.02390	6.760	7.001	-0.441	0.012
	(STRAIN)		9.102E-04	9.535E-04	-3.861E-04	-3.861E-04
2	7.87000	0.03437	28.103	28.436	-1.540	1.335
	(STRAIN)		1.701E-03	1.728E-03	-7.248E-04	-7.248E-04
2	18.70010	0.02390	6.760	7.001	-0.441	0.012
	(STRAIN)		9.102E-04	9.535E-04	-3.861E-04	-3.861E-04
3	7.87000	0.03437	28.103	28.436	-1.540	1.335
	(STRAIN)		1.701E-03	1.728E-03	-7.248E-04	-7.248E-04
3	18.70010	0.02390	6.760	7.001	-0.441	0.012
	(STRAIN)		9.102E-04	9.535E-04	-3.861E-04	-3.861E-04
4	7.87000	0.03437	28.103	28.436	-1.540	1.335
	(STRAIN)		1.701E-03	1.728E-03	-7.248E-04	-7.248E-04
4	18.70010	0.02390	6.760	7.001	-0.441	0.012
	(STRAIN)		9.102E-04	9.535E-04	-3.861E-04	-3.861E-04
5	7.87000	0.03437	28.103	28.436	-1.540	1.335
	(STRAIN)		1.701E-03	1.728E-03	-7.248E-04	-7.248E-04
5	18.70010	0.02390	6.760	7.001	-0.441	0.012
	(STRAIN)		9.102E-04	9.535E-04	-3.861E-04	-3.861E-04
6	7.87000	0.03437	28.103	28.436	-1.540	1.335
	(STRAIN)		1.701E-03	1.728E-03	-7.248E-04	-7.248E-04
6	18.70010	0.02390	6.760	7.001	-0.441	0.012
	(STRAIN)		9.102E-04	9.535E-04	-3.861E-04	-3.861E-04
7	7.87000	0.03437	28.103	28.436	-1.540	1.335
	(STRAIN)		1.701E-03	1.728E-03	-7.248E-04	-7.248E-04
7	18.70010	0.02390	6.760	7.001	-0.441	0.012
	(STRAIN)		9.102E-04	9.535E-04	-3.861E-04	-3.861E-04
8	7.87000	0.03437	28.103	28.436	-1.540	1.335
	(STRAIN)		1.701E-03	1.728E-03	-7.248E-04	-7.248E-04
8	18.70010	0.02390	6.760	7.001	-0.441	0.012
	(STRAIN)		9.102E-04	9.535E-04	-3.861E-04	-3.861E-04
9	7.87000	0.03437	28.103	28.436	-1.540	1.335

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      (STRAIN)          1.701E-03   1.728E-03 -7.248E-04 -7.248E-04
 9    18.70010   0.02390      6.760      7.001     -0.441      0.012
      (STRAIN)          9.102E-04   9.535E-04 -3.861E-04 -3.861E-04

 10    7.87000   0.03437     28.103     28.436     -1.540      1.335
      (STRAIN)          1.701E-03   1.728E-03 -7.248E-04 -7.248E-04
 10   18.70010   0.02390      6.760      7.001     -0.441      0.012
      (STRAIN)          9.102E-04   9.535E-04 -3.861E-04 -3.861E-04

AT BOTTOM OF LAYER 1   TENSILE STRAIN = -7.248E-04
ALLOWABLE LOAD REPETITIONS =   8.486E+07 DAMAGE RATIO =   2.003E-02

AT TOP OF LAYER 3   COMPRESSIVE STRAIN =   9.102E-04
ALLOWABLE LOAD REPETITIONS =   1.622E+07 DAMAGE RATIO =   1.048E-01

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* SUMMARY OF DAMAGE ANALYSIS *
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AT BOTTOM OF LAYER 1     SUM OF DAMAGE RATIO = 2.003E-02
AT TOP OF LAYER 3        SUM OF DAMAGE RATIO = 1.048E-01

MAXIMUM DAMAGE RATO =   1.048E-01   DESIGN LIFE IN YEARS = 9.54
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