

CONCEPT DESIGN FOR THE REHABILITATION OF GEORGE PRICE HIGHWAY
SEGMENT: BELMOPAN – GUATEMALA BORDER

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Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ATA	Anthony Thurton and Associates, Ltd.
CDB	Caribbean Development Bank
CBR	California Bearing Radio
DCPT	Dynamic Cone Penetration Test
BM	Benchmark
FWD	Falling Weight Deflectometer
GoBL	Government of Belize
GPH	George Price Highway
HMA	Hoot Mix Asphalt
IDB	Inter-American Development Bank
iRAP	International Road Assessment Program
LFRD	Load Factor and Resistance Design
MOWT	Ministry of Works and Transport
MOFED	Ministry of Finance and Economic Development
MNRE	Ministry of Natural Resources and Environment
PIT	Pile Integrity Tester
RICAM	International Network of Mesoamerican Highways
ROW	Right-of-Way
SPT	Standard Penetration Test
SIECA	Secretaria de Integración Económica Centroamericana.

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1. Introduction and Background

The information herein presents the concept design to be applied in the context of rehabilitation for the George Price Highway (GPH) segment, which is limited to the portion from the Junction of the GPH and Hummingbird Highway to the Guatemala Border.

The purpose of the GPH Road Concept Design is to assess the need for improvement in traffic capacity due to the forecasted commercial and residential growth in the area of interest. A primary goal of this project is to identify improvements needed on GPH Road including vehicular, pedestrian, and bicycle facilities; and to produce conceptual design and implementation plans for the future expansion of GPH road. The necessary studies are funded by the Inter-American Development Bank (IDB).

The GPH is one of four main highways in Belize. It originates in Belize City, runs west through Hattieville, Belize Zoo, the capital city of Belmopan (northern outskirts), San Ignacio, San José Succotz (across the river from Xunantunich archaeological site) and ends at the Guatemalan border at Benque Viejo. The highway bisects the country and ties the eastern and western parts of Belize together. As such, the purposes of this initiative, to name a few, are to improve the quality of life for local populations, facilitate the transport of goods produced in the region, promote the development in the tourism sector, generate and encourage economic activity in the region, to reduce travel time, and significantly improve the overall safety of the motorists who utilize this road segment.

The GPH, formerly known as the Western Highway, connects: (i) Belize City, the economic center; (ii) Belmopan, the national capital; (iii) San Ignacio and Santa Elena, the second largest urban area in the country; and (iv) Benque Viejo on the Guatemalan Border. The GPH is a two-lane, 79.4 mile highway originally built in the 1930s and last rehabilitated in the mid-1980s. Since then, the roadway pavement has deteriorated significantly, particularly between Belmopan (mile 47.9) and the Guatemalan Border at Benque Viejo (mile 79.4), due to: (i) insufficient drainage; (ii) the steep increase in truck traffic from the expansion of, primarily, the petroleum sector and, to a lesser extent, the agriculture and tourism sectors; and (iii) limited maintenance. The poor conditions of the pavement structure along with the absence of paved shoulders, unsafe road alignments, lack of pedestrian facilities in urban areas, and limited marking and signing lead to Belize's high incidence of road fatalities.

Flooding greatly restricts traffic flow along the road, increases the rate of pavement deterioration, and makes evident infrastructure vulnerabilities during extreme weather events. This is a significant issue as the highway is a primary evacuation route for coastal areas including Belize City. A particular concern is the Roaring Creek Bridge (mile 48), located near Belmopan, which was submerged at least twice over the course of the last ten years. These types of flooding events allow for water straining its superstructure, possibly undermining its structural integrity. Loss of access to the bridge cuts off a critical evacuation route during severe storm events. It also causes long-term negative impacts by severely damaging commercial trade and tourism activity between Belize sites and Guatemala.

To address these problems the Government of Belize (GoBL) has requested support from the IADB to finance the George Price Highway Rehabilitation Project (the Project) made of two priority elements of intervention: i) the rehabilitation of the GPH between Belmopan and the Guatemalan Border at Benque Viejo (31.5 miles); ii) and the Roaring Creek Bridge. Despite the lack of information available, the IADB's support has begun with funding provided through a Technical Cooperation to perform two preliminary studies: i) the feasibility study both technical, economic¹, and ii) the environmental and social impact assessment.

In general, the Concept Design is expected to address several critical issues as outlined below.

- a. Improvement of the vertical and horizontal alignment of the road system including areas of serious concerns such as the horizontal curve at the existing Roaring Creek Bridge and the "Z" curve.
- b. Improvement of the drainage system considering the effects of climate change with design allowance for a 20 year storm for the road system and 100 year storm for the Roaring Creek Bridge.
- c. Upgrade of the existing road system to new profile standards approved by the Ministry of Works and Transport (MOWT) including 3.5m (11.5 feet) wide lanes, 1.5m surfaced shoulders and a design life of 20 years.
- d. Conduct new designs for major intersections, particularly the Iguana Creek Road and GPH intersections, as well as, the entrance to Benque Viejo.
- e. Improvement of road safety features primarily through villages and other communities.

2. General Project Description

The George Price Highway is one of four main highways in Belize. It originates in Belize City, runs west through Hattieville, Belize Zoo, the capital city of Belmopan (northern outskirts), San Ignacio, San José Succotz (across the river from Xunantunich archaeological site) and ends at the Guatemalan border at Benque Viejo. The highway bisects the country and ties the eastern and western parts of Belize together. The highway was built in the 1930s and was originally known as the Western Highway. It was renamed the George Price Highway in 2012.

Belize's road network consists of 3,281 km of roads, of which 573 km are primary roads or highways, 765 km are secondary roads and 1,943 km are rural roads. In its entirety, the GPH between Belmopan (mile 47.8) and the Guatemalan Border (mile 79.4) is located within the Cayo District. The Cayo District road network consists of 661 km (411 miles) of roads, of

¹ The Anthony Thurton Associated Ltd. is the Consultant that is in charge to conduct the technical and economic feasibility study.

which 102 km (63.7 miles) are arterial (primary) roads or highways, 115 km (71.3 miles) are distributor secondary roads and 276 km (44.2 miles) are feeder or rural roads. Only 15% of the road network is paved². The detailed map for the Cayo road network is shown in the Annex A.

The existing alignment of this road runs along a relatively flat topography with some mountainous areas and includes also a number of major intersections. Overall, no alignment difficulties were observed along the segment with the exception of milepost 53 to 54, and the access to Benque Viejo del Carmen.

The GPH section of the road system under consideration has been divided in three segments, as illustrated in Figure 1. Segment 1 (Figure 2): From the intersection of GPH with Hummingbird Highway to the intersection of the GPH and the Iguana Creek Road. Segment 2 (Figure 3): From the intersection of the GPH and Iguana Creek Road to Red Creek Bridge in Santa Elena on the GPH. Segment 3 (Figure 4): From the intersection of the GPH and Buena Vista Street in San Ignacio to the Belize-Guatemala Border.

The end point of the Segment 2 and the start point of the Segment 3 were adjusted to the contract limits of the San Ignacio – Santa Elena Bypass (SISEB). The detailed map for the SISEB is shown in the Annex B.



Figure 1: General Site Project Location.

² Road classification definitions: (i) Arterial Roads : main highways carrying high traffic volumes, usually paved; (ii) Distributor Roads: secondary roads linking into Arterial Road Network, carry varying traffic volumes and can be paved or unpaved; and, (iii) Feeder Roads: also called Farm or Sugar Roads, carrying low traffic volumes from agricultural areas to join the Distributor or Arterial network, always unpaved.

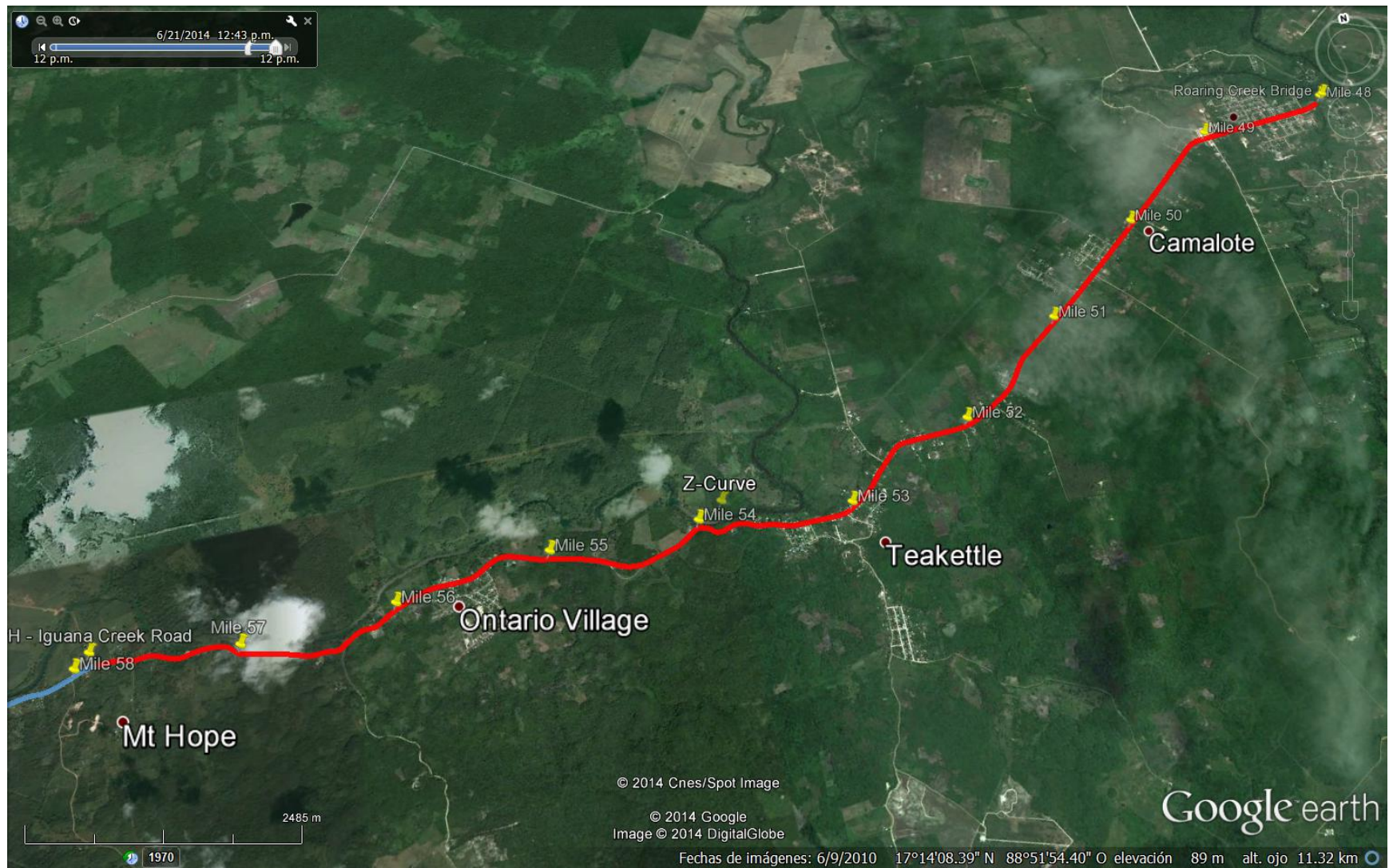


Figure 2: Segment 1- From the intersection of GPH with Hummingbird Highway to the intersection of the GPH and the Iguana Creek Road.

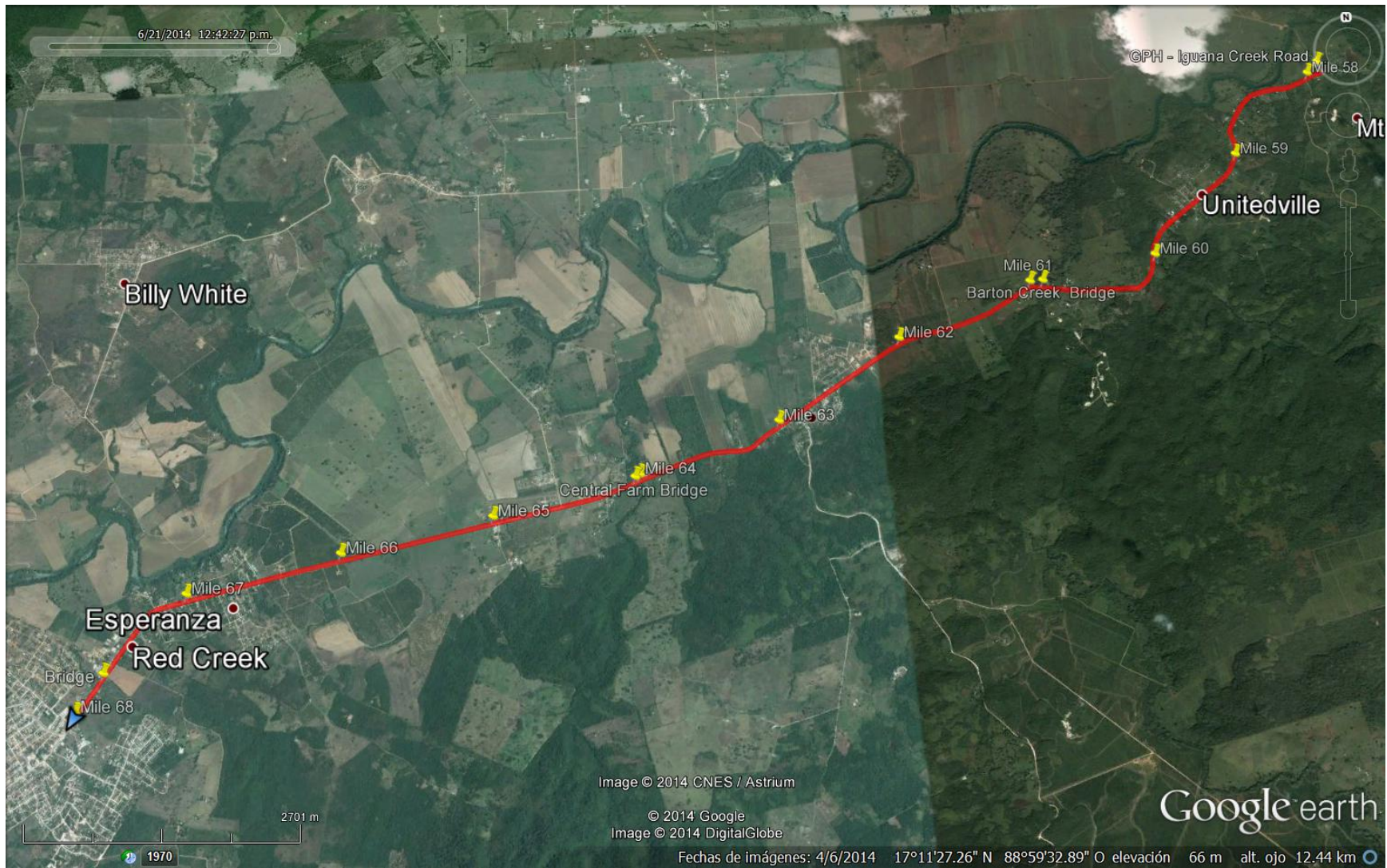


Figure 3: Segment 2 - From the intersection of the GPH and Iguana Creek Road to Red Creek Bridge in Santa Elena on the GPH.

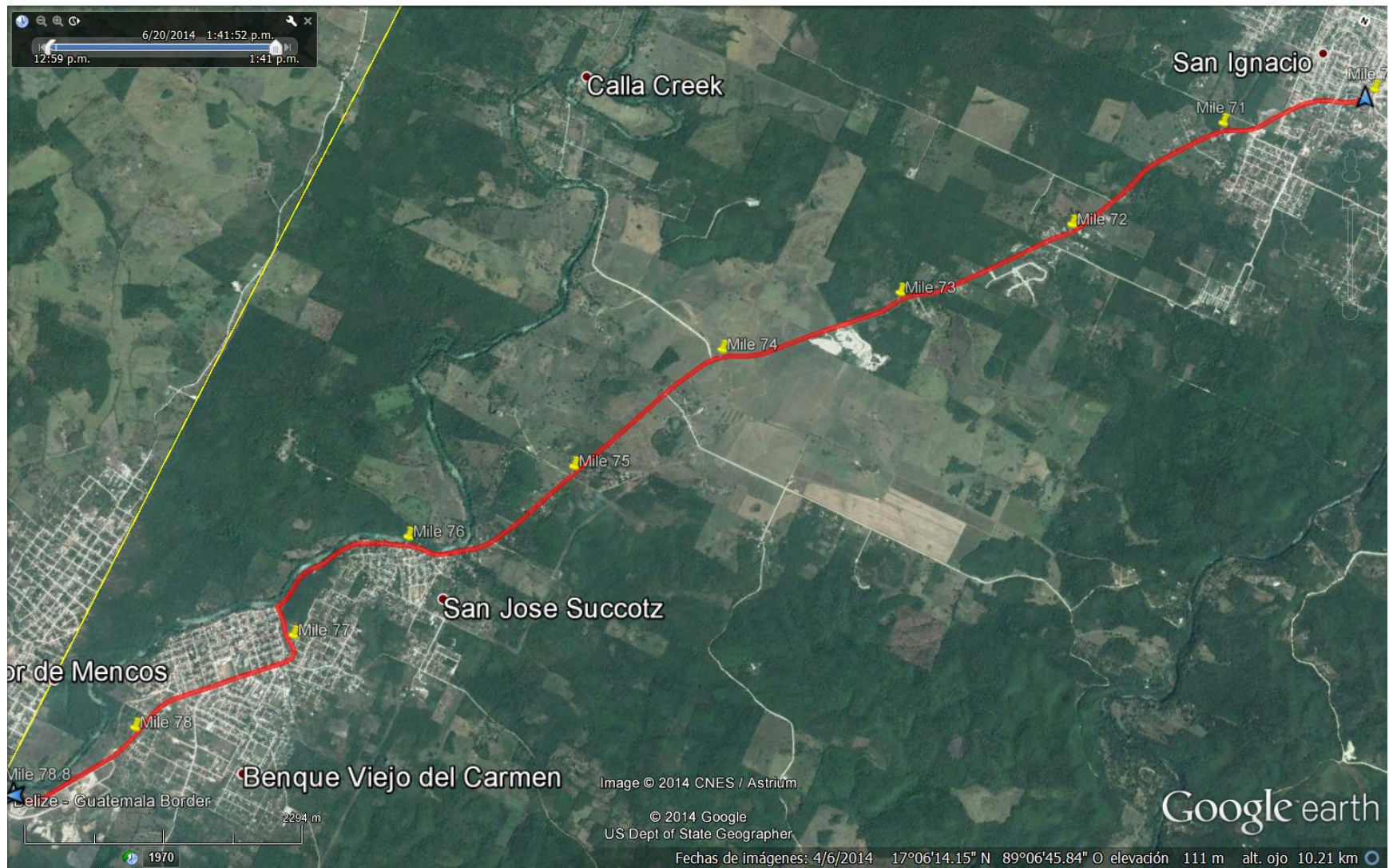


Figure 4: Segment 3 - From the intersection of the GPH and Buena Vista Street in San Ignacio to the Belize-Guatemala Border.

3. Data Collection and Evaluation

During June and July 2014, the Consultant conducted two Technical Missions to Belize with the following objectives: (i) to follow up on the Technical and Economic Feasibility Study and the Environmental and Social Impact Assessment execution; (ii) to collect the necessary information and agree on a delivery timeframe to prepare the Project documents; (iii) to conduct a field visit of the GPH to identify the existing conditions of the road and its functionality during existing and future traffic loads; and, (iv) to contribute to a successful and coordinated development of the studies and loan document preparation.

Furthermore, the Consultant has reviewed documentation relating to the project, which have been supplied by different sources, and together with the information obtained from the project site, is used to determine technical and economic aspects related to the project. Listed in Annex C are the documents reviewed.

Cartographic and topographic information

The MOWT provided digital copies of the topographical maps of the GPH road between the towns of Roaring Creek and the Guatemala Border. The topographic survey was conducted in the year of 2013. Unfortunately these drawings are not tied to the stations (mileages) or BM³ that are made visible in the field. The topography is presented in three segments, and in some cases, the field mileage markers are not properly correlated within the information provided. Important points such as crossings with other roads and the location of special structures are not visible. The review of this information has hindered the development of the Conceptual Design. See Figure 5 below for an example of the aforementioned mileage markers.



Figure 5: Mile 47 is located close to the access road to Belmopan airstrip (elevation 54 meters) and Mile 50 in the Camalote Village.

In the absence of detailed topographical maps supplied to the Consultant for information collection purposes, a topographic map of scale 1:50,000, prepared by Land and Survey

³ A benchmark, abbreviated “BM” is a location whose elevation and horizontal position has been surveyed as accurately as possible.

Department MNRE - Belize, March 2010, has been used as reference only. Therefore, to obtain improved elevation and location readings of the actual geometry of the road, a GPS navigator (Garmin e-Trex GPS 30⁴) has been used during the Consultant's site inspection. Additionally, to achieve a usable road profile, the GPS navigator's altimeter has been set to the elevation shown by the aforementioned reference point, Mile 47 (Figure 5), prior to any recorded readings.

Subsequently, a trial data collection effort has been executed by the Consultant with the objective to correlate the readings of the GPS navigator to the information shown in the reference point, Mile 47 and the three electrical poles that are visible in MOWT topographic survey⁵. By performing this trial test, the Consultant determined that the readings provided by the GPS were in close approximation to the coordinates and elevations provided by reference point, therefore bringing a degree of reliability to continue using the GPS as the main source of topographic data during the analysis of this concept design. The GPS has been also used to get the geographic location of specific points of interest such as: bridges, drain pipes, degraded pavement wearing course, slides, etc. Additionally, geo-referenced photographs and videos have been collected by the Consultant during the site visit which allows importing data directly to the geo-referenced maps such as topographic and satellite images. This procedure improves accuracy during the evaluation of the information collected at the site.

The information gathered during the site visit has been properly processed by using satellite imaging information provided by Google Earth Professional. In this way, a very close approximation to the geometric characteristics of the road's horizontal and vertical alignments has been achieved.

Horizontal Alignment

Assuming that the horizontal alignment is composed by tangents and circular curves, the following table shows the curves sorted by the typical segment road and the length of its radius. Refer to Annex D for the tabulated results.

Segment	Radius	# of curves	Traffic Speed	Alignment Type
Roaring Creek (M48) to Santa Elena (M67)	R < 135 m	5	v < 60 km/h	Winding Road on flat terrain
	135 m ≤ R < 280 m	14	> 60 km/h v ≤ 80 km/h	
	280 m ≤ R < 492 m	24	> 80 km/h v ≤ 100 km/h	
	R ≥ 492 m	26	v > 100 km/h	
San Ignacio (M70) To Frontera Guatemala (M79)	R < 135 m	2	v < 60 km/h	Winding Road on flat terrain
	135 m ≤ R < 280 m	6	> 60 km/h v ≤ 80 km/h	
	280 m ≤ R < 492 m	3	> 80 km/h v ≤ 100 km/h	
	R ≥ 492 m	10	v > 100 km/h	

⁴ WAAS-enable GPS receiver and GLONASS support, 3-axis electronic compass and barometric altimeter.

⁵ The electrical poles are: 5031654, 5031756 and 5031621 TMBs. The first pole is located near to Roaring Creek Bridge.

The table shown above suggests that approximately 73% of the curves along the road possess an adequate curvature radius that allows for traffic speeds between 80-100 km/h, while only approximately 8% possess a curvature radius that does not allow for traffic speeds above 60 km/h. The later type of curves are located between miles posts 53 to 54 (C14, C15, and C16) - known as the Z-curve segment -; curve C28 located in miles posts 56 to 57 (C28); curve C43 between miles posts 58 and 59, and lastly curves C84 and C86 located between miles posts 76 and 77

The elevation profile is generally flat with gentle slopes that range around $\pm 4.5\%$. The segment elevation profiles run along the following elevations: 54 meters at milepost 47.2 (GPH and Hummingbird Highway intersection), 80 meters at milepost 62.1 (GPH and Chiquibul Road intersection), 62 meters at milepost 68.5 (Hawkesworth Bridge in San Ignacio), and 82 meters at miles post 77.9 (Guatemala borderline). Below in Figure 6 is an illustration of the elevation profile of the segment.

The vertical profile along the last segment of the road maintains a slope which is relatively flat. Generally, no significant issues have been found with the horizontal and vertical curves of the existing road.



Figure 6: Profile of the existing road from the intersection of GPH with Hummingbird Highway to the intersection of the GPH and the Iguana Creek Road.

In this segment the vertical profile of the majority of the road is defined by a variety of elevation patterns unique of a flat topography area. This is particularly evident from Mile 48 which is at an approximate elevation of 40 meters, continuing to its highest elevation point of approximately 99 meters at Mile 51.3, and ultimately descending to an approximate elevation of 46 meters at Mile 53.3. The elevation profile slope ranges from around $+3.2\%$ to -1.4% .

In the next segment (Figure 7) the vertical profile of the majority of the road is defined by a variety of elevation patterns unique of a flat topography area. This is particularly evident from Mile 58.5 which is at an approximate elevation of 58 meters, continuing to its highest elevation point of approximately 91 meters at Mile 59, and ultimately descending to an approximate elevation of 57 meters at Mile 61. The elevation profile slope ranges from around $+3.5\%$ to -2.2% .



Figure 7: Profile of the existing road from the intersection of the GPH and the Iguana Creek Road to Red Creek Bridge in Santa Elena.



Figure 8: Profile of the existing road from the intersection of the GPH and Buena Vista Street in San Ignacio to the Belize-Guatemala Border in BVDC

In this segment the vertical profile of the majority of the road is defined by a variety of elevations patterns unique of a flat topography area. This is particularly evident from Mile 70 which is at an approximate elevation of 110 meters, continuing to its highest elevation point of approximately 156 meters at Mile 71.5, and ultimately descending to an approximate elevation of 78 meters at Mile 75.6. The elevation profile slope ranges from around +1.3% to -3.3%.

The Right-of-Way (ROW) was observed to be of approximately 30 meters total. It is important to note that, with a few exceptions, local residents have maintained off ROW limits, this includes intermediate settlements such as Raaring Creek, Camalote, Teakettle Bank, Ontario Village, Blackman Eddy, Unitedville, George Ville, Central Farm, and Esperanza. Unlike the aforementioned intermediate settlements, the segment areas where the access roads to the town of Santa Elena, San Ignacio and Benque Viejo are located, experience a greater degree of ROW encroachment.

It was observed that the existing condition of the pavement in place is considerably deteriorated along the entire segment of study. The deteriorated state of the asphalt structure can be attributable to the lack of asphalt pavement along the shoulders, and select areas that suffered the negative effects of past flooding events that washed away the entire pavement surface (miles posts 50, 53, 59, 71, and 73). It was also observed that the aforementioned areas affected by flooding have been repaired at quality levels that may be sufficient for emergency repairs but not adequate for long term usage.

Populated areas

Per the visual inspection performed along the entire segment of study, it is estimated that approximately 15% of the entire length of the segment along its sides is populated. The following urban-rural agglomerations have been identified in the segment between the start of the project and Santa Elena: Roaring Creek, Camalote, Teakette Bank, Ontario Village, Blackman Eddy, United Ville, George Ville, Central Farm – University, and Esperanza. It is recommended that sidewalks be provided for pedestrians along the both sides of the road. The installation of pedestrian bridges at select locations must be studied. The settlements identified between San Ignacio and the Guatemala borderline is San Jose Succotz and Benque Viejo del Carmen. Currently being studied is a potential re-alignment with the purpose to avoid flooding events around these populated areas.

4. Road Safety

Generally the existing conditions of the segment of study represent a risk not only to local and national motorists but also to the population that settled along the entire length of the segment. The existing conditions of the road and the driving habits of local motorists are the main factors for an increasing accident rate. Current road condition does not ensure the fluidity of the movement of vehicles and in populated areas is also a safety issue for pedestrians and users.

In 2011, the Government of Belize took the decision to undertake the Belize Road Network Evaluation in cooperation with International Road Assessment Program (iRAP) and the Caribbean Development Bank (CDB). The iRAP final report indicates that there were 71 reported fatalities and 790 reported injuries (including serious and minor injuries) in vehicular related accidents in 2009 in Belize. The total number of fatalities agrees with international estimates. However, there is evidence that suggests that the total number of injuries is underreported, mainly because of the poor quality of the reporting systems utilized. The greatest focus in highway safety improvement effort should be on reducing fatalities and serious injuries.

A total number of 13 fatal traffic crashes, for the period of 2011-2012, occurred in the GPH segment between Roaring Creek to Benque Viejo del Carmen. These fatalities took place at: miles 67, 68, 69 & 70 GPH; Junction of GPH and Peter August St., San Ignacio; miles 53 & 54 GPH; Center Road, Spanish Lookout, San Ignacio; miles 72 & 73 GPH, Succotz Village; miles 61&62 GPH, San Ignacio; Central Farm; miles 53 & 54 GPH, Teakettle Village; Young Bank Rd. Camalote Village; Iguana Creek Road, San Ignacio; mile 56 Ontario Village; and Spanish Lookout at San Ignacio.

The total number of traffic related crashes in the Belize road network between 2009 and 2012 is shown the following table⁶.

⁶ Source: Number of Casualties in Traffic Crashes: 2009-2013. The Road Safety Project. MOFED - Belize.

Number of Casualties in Traffic Crashes:2009-2012				
	2009	2010	2011	2012
Total	860	801	874	718
Fatal	78	75	57	69
Injured	782	726	817	649
Pedestrian	139	121	115	104
Fatal	17	13	6	19
Injured	122	108	109	85
Passengers	338	307	368	237
Fatal	24	23	21	12
Injured	314	284	347	225
Cyclist	161	132	126	146
Fatal	14	16	7	22
Injured	127	116	119	124
Drivers	222	241	265	231
Fatal	23	23	23	16
Injured	199	218	242	215

The following safety issues have been observed:

- a. Dangerous curves in the Z curve sector (milepost 59 & 60) and San Jose Succotz and Benque Viejo del Carmen (miles 72 & 73) settlements. It was also reported that accidents of considerable magnitude took place at milepost: 49, 52, 53, 54, 56, 57, 58, 61, 62, 67, 68, 69 and 70.
- b. The various widths of the existing lanes of the road along the segment experience variations that are not sufficient to accommodate the current traffic loads, particularly high tonnage trucks. This restriction causes discomfort to the motorists and instability in their driving. Accidents are likely to occur when motorists are forced to suddenly accelerate and/or break.
- c. Inadequate and non-existing emergency rest areas for vehicles. These emergency rest areas are needed to increase the overall safety of the road and therefore protect pedestrians along the sides of the road. This also allows an adequate area for disabled vehicles and thus maintaining constant flow of traffic at all times.
- d. Lack of traffic protection items such as guiderail and impact attenuators in the populated areas. It is suggested that the project allow for further studies to determine if the installation of guiderail and/or impact attenuators is required to improve roadway safety.

- e. Steep rocky slopes with high risks of failures. The presence of these steep rocky slopes put in danger all road users.
- f. The transitional widths of the roadway to the curves range from insufficient to nonexistent. An adequate transition of the roadway widths is necessary to improve the overall comfort of the users when driving along horizontal curves while maintaining constant speeds. The absence of over widths may cause vehicles to accidentally travel off the route or the occupation of the two vehicle lanes for high tonnage. Road widening will be considered for all curves in function of radius of curvature.
- g. Total absence of signage. It is also a concern that most of the GPH corridor currently has no pavement markings. Delineation treatments, including pavement markings, help drivers track the roadway alignment and keep their vehicles within their assigned lanes; centerline markings also identify where passing maneuvers are, and are not, appropriate on two-lane undivided highways. The Ministry of Works has found that pavement markings in Belize have relatively short service lives because the roads have chip-seal surfaces; passage of vehicle tires over relatively rough chip-seal surfaces may accelerate pavement marking wear. Conventional pavement markings may have service lives as short as one year on chip-seal surfaces. Durable, all-weather pavement makings, using materials such as thermoplastic, cost more than conventional paint markings but may have longer service lives.
- h. Absence of heavy traffic rest stops. These facilities are required to maintain reasonable traffic flow at all times.

5. Design Criteria Adopted⁷

The GPH is part of the Caribbean Tourism Corridor which is part of the International Network of Mesoamerican Highways (RICAM). The RICAM is one of the flagship programs of the Mesoamerica Project⁸ in transport. Involves the rehabilitation, maintenance and construction of 13,132 kilometers of roads located on five corridors.

The Caribbean Tourism Corridor, connects the cities of Cancun, Quintana Roo, Mexico, Belize, Guatemala and the coastal area of Honduras. It includes tourist attractions and cities like Cancun and the Riviera Maya, Belize, Rio Dulce, Bay Amatique Omoa, Tela, La Ceiba and ranges through the port of Trujillo in Honduras. The Caribbean Tourism Corridor has an estimated length of 1,446 kilometers.

⁷ The design criteria were discussed with MOWT on Monday, July 13, 2014. The criteria were verbally agreed.

⁸ Mesoamerican Project is a proposal developed by ten Mesoamerican countries to strengthen regional integration and to promote economic and social development of the participating countries. The objective is to improve progress conditions and human prosperity among population. At the present Mesoamerican Project is composed by: México, Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica, Panamá, Colombia and Dominican Republic.

RICAM roads, as indicated in Article 3 of the Memorandum of Understanding, shall meet the requirements and specifications contained in Annex II of this Memorandum, according to the capabilities of each country. This concept design study will follow the conditions to conform with RICAM, detailed in Annex II. Also used will be the design manuals from SIECA and AASHTO⁹. The new Roaring Creek Bridge will be designed following the AASHTO Guide Specifications for LRFD Seismic Bridge Design, 2nd Edition, 2012.

The design criteria adopted are summarized as follows:

- a. One traffic lane per each traffic direction.
- b. The general design speed will be 100 km/h. The design speed for urban areas will be restricted to 40 km/h.
- c. The minimum horizontal curvature radius for speeds at 100 km/h will be 490 meters. For design speeds of 40 km/h the minimum horizontal curvature radius will be 47 meters, at 4% banking.
- d. Maximum 7% longitudinal road longitudinal slope.
- e. Typical cross section through villages. A traffic lane for traffic direction of 3.50 meters (11', 6"), two shoulders of 1.5 meters (5') and two sidewalks of 1.5 meters (5') Minimum 3.7 meters (12', 2") to lined or unlined "Vee" drain, were applicable.
- f. Typical cross section through highway. A traffic lane for traffic direction of 3.50 meters (11', 6") and two shoulders of 1.5 meters (5'). Minimum 3.7 meters (12', 2") to lined or unlined "Vee" drain, were applicable.
- g. Typical cross section through bridges. A traffic lane for traffic direction of 3.50 meters (11', 6"), two shoulders of 1.5 meters (5') and two sidewalk of 1.5 meters (5'). Standard Rail will be installed along each side of the bridge as a traffic railing¹⁰.
- h. For all typical cross section the "Cross fall" over the roadway 3% slope and 7% slope over the shoulders.
- i. Highway right of way. The construction limits will provide a total clearance of 30 meters (100 feet).
- j. The minor road drainage will be designed to properly capture a one in 20-year storm and the major bridges a one in 100-year storm.
- k. The pavement type selection will be based in the analyses period (20 years) and de design period (4.2 years).

⁹ SIECA - Manual Centroamericano de Normas para el Diseño Geométrico de Carreteras and AASHTO Policy on Geometric Design of Roads and Streets.

¹⁰ Railing Design per AASHTO LRFD Bridge Design Specifications – Chapter 13

The elements of typical cross in mountain are shown in the graph below and the detail of the typical cross sections is shown in Annex E to this report.

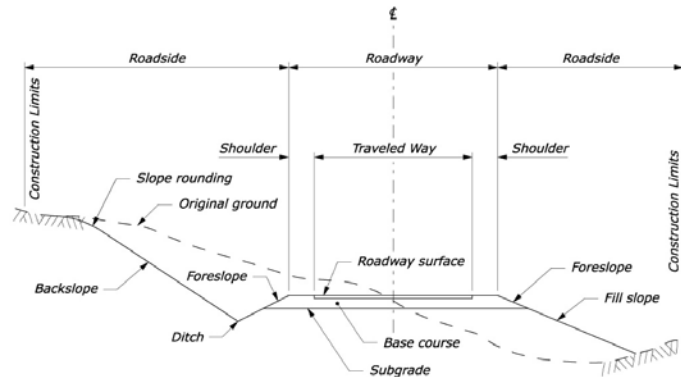


Figure 9: Typical cross section

6. Traffic Projections

The MOWT has conducted several traffic surveys along the project length. Much of these data does not include classification of the vehicles or origin destination details. As such, supplementary surveys were conducted, by ATA Consultant, to collect some of this missing information. The traffic survey was conducted along the George Price Highway starting at the Roaring Creek Bridge near the GPH and HBH junction to the Belize-Guatemala Border near Benque Viejo Del Carmen Town. The survey commenced on July 3, 2014 and ran for seven consecutive days, concluding on July 9, 2014. The survey consisted of two components: a traffic count and categorization and an origin and destination survey.



Figure 10: Traffic Survey Stations

Traffic counts were conducted at all six stations at locations shown on the survey map. Vehicles travelling in both east and west directions were counted and classified into cars, light goods vehicles, buses, heavy vehicles, motor cycles, non-motorized vehicles and pedestrians. The counts were done in hourly intervals from 6:00 a.m. to 6:00 p.m.

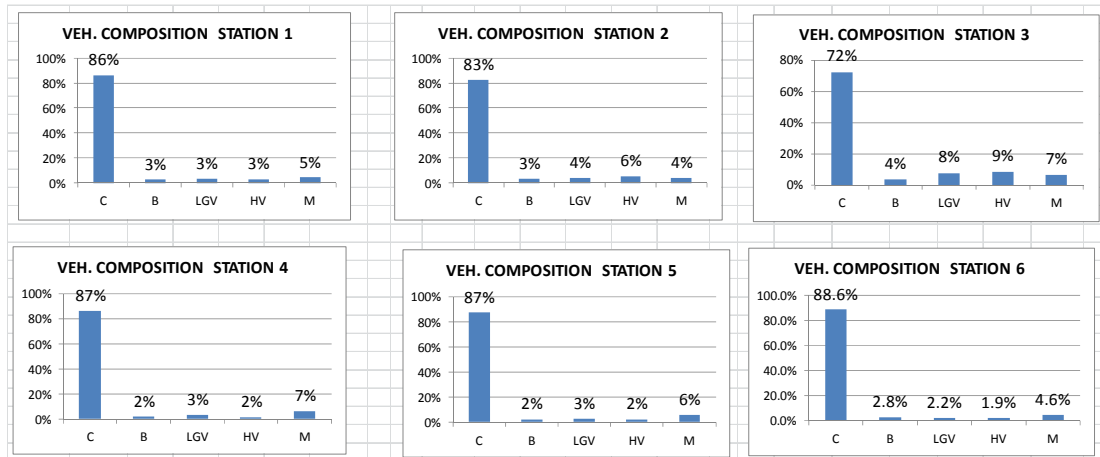
Vehicle Classification		Counting Hours	
C	Cars	1 - 6:00 a.m. to 7:00 a.m.	8 - 1:00 p.m. to 2:00 p.m.
LGV	Light Goods Vehicles	2 - 7:00 a.m. to 8:00 a.m.	9 - 2:00 p.m. to 3:00 p.m.
M	Buses	3 - 8:00 a.m. to 9:00 a.m.	10 - 3:00 p.m. to 4:00 p.m.
B	Motorcycles	4 - 9:00 a.m. to 10:00 a.m.	11 - 4:00 p.m. to 5:00 p.m.
HV	Heavy Vehicule	5 - 10:00 a.m. to 11:00 a.m.	12 - 5:00 p.m. to 6:00 p.m.
NMV	Non Motorized Vehicle	6 - 11:00 a.m. to 12:00 noon	
P	Pedestrian	7 - 12:00 noon to 1:00 p.m.	

As the above chart describes, five types of motorized vehicles are listed under vehicle classification. The classification also includes one item for non-motorized vehicles and one for pedestrians. Unfortunately, this survey classification does not fully cover the entire spectrum vehicles types on the road; in particular trailer trucks and their axle configurations. It is essential to consider heavy vehicles into a survey of this nature since it is apparent that these cause the most damage to the pavement structure and thus accelerating the deterioration of the road surface.

Origin and destination surveys were done at three stations, namely, Belmopan junction, San Ignacio Town and Benque Viejo Del Carmen Entrance. Drivers were asked to declare the starting point of their trip as well as their destination. The number of occupants in the vehicle and the vehicle type were recorded.

Upon completion of ATA's raw data processing, the following charts represent the vehicular traffic density in July 2014 and their respective histograms showing vehicular composition. This information was used by the Consultant to elaborate traffic projections for the 20 years starting in 2015. The detailed results are attached in Annex G to this report.

AVERAGE TRAFFIC VOLUMES BY STATION 6:00 - 18:00 (12 HOURS) - v/12h																				
Westbound							Eastbound							BOTH DIRECTIONS						
12345							12345							12345						
STATION	C	B	LGV	HV	M	TOTAL	C	B	LGV	HV	M	TOTAL	C	B	LGV	HV	M	TOTAL		
S1	2,186	66	76	82	128	2,538	S1	2,480	78	103	87	116	2,864	S1	4,666	144	179	169	244	5,402
S2	1,040	46	50	71	62	1,268	S2	1,100	44	53	73	51	1,321	S2	2,139	90	102	144	113	2,589
S3	1,130	51	105	142	113	1,541	S3	1,193	74	148	139	110	1,663	S3	2,323	125	252	281	222	3,204
S4	2,422	53	123	41	204	2,844	S4	3,071	65	89	63	212	3,500	S4	5,493	118	212	104	417	6,344
S5	1,286	36	37	36	93	1,487	S5	1,842	40	56	47	106	2,092	S5	3,128	76	93	83	199	3,579
S6	1,125	35	24	20	66	1,270	S6	1,174	39	32	28	52	1,325	S6	2,299	73	56	49	118	2,595
VEHICLE COMPOSITION %																				
Westbound							Eastbound							BOTH DIRECTIONS						
12345							12345							12345						
STATION	C	B	LGV	HV	M	TOTAL	C	B	LGV	HV	M	TOTAL	C	B	LGV	HV	M	TOTAL		
S1	86%	3%	3%	3%	5%	100%	S1	87%	3%	4%	3%	4%	100%	S1	86%	3%	3%	3%	5%	100%
S2	82%	4%	4%	6%	5%	100%	S2	83%	3%	4%	6%	4%	100%	S2	83%	3%	4%	6%	4%	100%
S3	73%	3%	7%	9%	7%	100%	S3	72%	4%	9%	8%	7%	100%	S3	72%	4%	8%	9%	7%	100%
S4	85%	2%	4%	1%	7%	100%	S4	88%	2%	3%	2%	6%	100%	S4	87%	2%	3%	2%	7%	100%
S5	86%	2%	2%	2%	6%	100%	S5	88%	2%	3%	2%	5%	100%	S5	87%	2%	3%	2%	6%	100%
S6	89%	3%	2%	2%	5%	100%	S6	89%	3%	2%	2%	4%	100%	S6	88.6%	2.8%	2.2%	1.9%	4.6%	100%



The results show an overwhelming proportion of light weight vehicles representing an average of 84% (including all stations), the remaining 16% is distributed among the buses that represent 3%, light/medium and heavy trucks are 4% each, and motorcycles account for 5% of the total. The directional distribution of traffic flows indicates that on average, 53% corresponds to the vehicular traffic flow along the Westbound.

Annual Average Daily Traffic (AADT)

As previously indicated the volumetric counts represent a daily 12 hour traffic flux from 6:00 am to 6:00 pm. This time period of the day constitutes daylight traffic; however the remainder 12 hours that constitute night time traffic is not reflected. The absence of vehicular count data for the night time does not allow to properly calculating the average annual daily volume (AADT). A successful calculation of an AADT for this study must include a vehicular count that is performed over the 24 hours in order to capture the heavy vehicles that predominately travel during night hours.

In this regard, to reduce the negative effect of not having available vehicular count information during night hours, a factor of 1.30 (30% increment) was assumed for as night time traffic., This assumption is based on historical data for 24 hour vehicular count survey in which night traffic volume fluctuates between 20% and 40% depending on site characteristics.

It is also necessary to take into account the seasonal variation during the year in order to apply a seasonal factor and expand (or contract if required) the results of partial appraisals made at a time of year (in this case in a week in July 2014). Thus, it was assumed a seasonal factor that would represent the average seasonal variations during the year factor. Under these conditions the Average Annual Daily Traffic – AADT, would be given by the following equation:

$$AADT = fe \times fn \times ADT$$

Where: AADDT = Annual Average Daily Traffic
ADT = Average Daily Traffic
fe = 1.0 Seasonal Factor
fn = 1.3 Nocturnal Factor

With these considerations the average volumes at each station are:

ADT - EXPANDED TRAFFIC VOLUMES BY STATION (24 HOURS) - vpd															
NIGHT VOLUME PROPORTION = 30%															
EXP.FACT= 1.30 1.30 1.3 1.3 1.3 1.3 1.3 1.3 1.3 1.3 1.3															
Westbound								Eastbound							
1 2 3 4 5								1 2 3 4 5							
STATION	C	B	LGV	HV	M	TOTAL		C	B	LGV	HV	M	TOTAL		
S1	2,842	85	99	107	166	3,299	S1	3,224	102	134	113	151	3,723		
S2	1,352	60	64	92	81	1,649	S2	1,429	58	69	95	66	1,717		
S3	1,469	67	136	185	147	2,004	S3	1,551	96	192	181	143	2,162		
S4	3,149	69	160	54	266	3,698	S4	3,992	85	115	82	276	4,550		
S5	1,671	47	48	47	121	1,933	S5	2,395	52	73	61	138	2,720		
S6	1,462	45	31	26	86	1,651	S6	1,526	50	41	37	67	1,722		

BOTH DIRECTIONS							
1 2 3 4 5							
C B LGV HV M TOTAL							
S1	6,065	187	233	220	317	7,022	
S2	2,781.1	117.4	133.0	187.4	147.3	3,366	
S3	3,020	163	328	365	289	4,165	
S4	7,140	154	276	136	542	8,248	
S5	4,066	99	121	108	259	4,653	
S6	2,988	95	73	63	154	3,373	

7. Geology and Wearing Course Condition

Background

The Belizean geology consists largely of varieties of limestone, with the notable exception of the Maya Mountains, a large intrusive block of granite and other Paleozoic sediments running northeast to southwest across the south-central part of the country. The Maya Mountains therefore form the high, rugged core of Belize. They are composed of igneous, metamorphic, and sedimentary rocks that are 125-320 million years old. During the Cretaceous period, what is now the western part of the Maya Mountains stood above sea level, creating the oldest land surface in Central America, the Mountain Pine Ridge plateau.

Belize is located near the junction of the North American and Caribbean tectonic plates, slabs of the earth's crust that have moved past each other over the last 80 million years. Eastward drift of the Caribbean plate resulted in the dominantly structurally-controlled, major features of Belize: the Maya Mts., offshore atolls surrounded by deep water, and the location of the coral barrier reef. Much of the northern half of Belize lies on the Yucatán Platform, a tectonically stable region.

Several major faults rive the highlands of Belize, but much of Belize lies outside the tectonically active zone that underlies most of Central America. Along its entire length, the modern barrier reef sits atop a prominent fault that separates the shallow platform to the west from the deeper Caribbean to the east, where water depths progressively approach 4000 meters. Turneffe, Lighthouse and Glovers Atolls all sit atop major fault blocks ("horsts") that formed as a result of the eastward sliding of the Caribbean plate past Belize and the North American plate. The major NE-trending faults shown in the accompanying map are "normal faults" that include portions that have dropped down on their eastern sides. The nearly EW-trending fault on the south is the boundary of the North American and Caribbean plates.

The similarity of Belizean geology to that of oil-producing areas of Mexico and Guatemala prompted oil companies, principally from the United States, to explore for petroleum at both offshore and on-land sites in the early 1980s. Initial results were promising, but the pace of exploration slowed later in the decade, and production operations never commenced. As a result, Belize remains almost totally dependent on imported petroleum for its energy needs.

Existing Road

The evaluation of pavement deterioration determines the functional condition that the pavement structure has as a set of surface characteristics related to user comfort and safety. In addition, the evaluation of pavement deterioration also measures the structural capacity of the pavement intended to support the traffic load requirements of the road.

Therefore, pavement deterioration is caused by the following: (i) Usage beyond the end of its designed life cycle; (ii) inaccurate pavement structure design; (iii) construction deficiencies such as the use of inadequate mixes and materials, thicknesses of bituminous and stone courses, construction operations, and drainage; (iv) extremely unfavorable weather conditions; and (v) maintenance deficiencies.

During the site visit a thorough visual analysis was performed on the existing condition of the pavement surface including wearing course degradation by observing the roughness, rutting, texture, cracking and asphalt fatigue. The survey was conducted along three sections, Roaring Creek to Iguana Creek Junction, Iguana Creek Junction to Red Creek Village and from Red Creek Village to the Belize-Guatemala Border.

Segment 1: From the intersection of GPH with Hummingbird Highway to the intersection of the GPH and the Iguana Creek Road. Segment one of the highway surveyed proved to be the most deteriorated, with pavement structure defects along most of its length. The most common defects include edge cracking and shoulder drop-off that is

evident almost along the entire length of this section. Additionally, medium to high severity patching was evident at the start of the survey and was evident at many other locations. The overall quality of this section is poor, with the some areas recently upgraded, including areas in Camelote, Ontario and Central Farm.

Segment 2: From the intersection of the GPH and Iguana Creek Road to Red Creek Bridge in Santa Elena on the GPH. Segment two included many areas with high levels of deterioration, with edge cracking and lane drop-offs evident along most of this portion of the highway. Defects for the most part include patching, depressions, weathering and raveling.

Segment 3: From the intersection of the GPH and Buena Vista Street in San Ignacio to the Belize-Guatemala Border in BVDC. This segment is the least deteriorated portion of the highway. The overall quality of this section is fair to good, with minimal defects in the form of patching, raveling, edge cracking and small pot holes between miles 75.8 to 75.9.

The general condition of the project route is poor to fair. Many areas include a range of different pavement defects for long lengths of the highway. While some efforts have been done to rehabilitate some of the worst affected areas, these are sparse and only fairly improve the overall quality of this portion of the GPH which the proposed project addresses. Common defects include edge cracking and lane drop-offs, which highlights the necessity to include well designed shoulders that merge adequately with the existing terrain.

Recently the ATA Consultant conducted the geotechnical evaluation of the existing road network. The exercise included a series of field and laboratory tests that seek to quantify the characteristics of the geotechnical conditions along the three main segments of the road system. The main activities that were carried out include the realization of Dynamic Cone Penetration tests, inspection pits, Dynamic Penetration Super Heavy tests (a variation of the Standard Penetration Test [SPT]), and deep borings. The survey commenced near the Roaring Creek Bridge and ended at the entrance of Benque Viejo Del Carmen Town.

Dynamic Cone Penetration tests [DCP's] were carried out along the project area, particularly where there was strong evidence of pavement deterioration and base failure. These tests were carried out directly over the existing pavement. The results obtained provided a fair indication of the bearing capacity of the road pavement structure, including correlated California Bearing Ratio [CBR] values. The majority of the results of the DCP tests indicate high bearing capacities and CBR values of above 10,000 pounds per square foot and 100 plus respectively, within the upper layer of road base. However, in general the bearing capacities and CBR values falls as with depth, exposing majority of the weak sub-structure at a depth of 5 to 10 inches. These values coincided with the deep depressions that have formed on the pavement surface, which serve as clear indicators of the existence of relatively weak and inadequate base and sub-base layers. Additionally, at lower depths, the bearing capacity and CBR values were even lower, indicating a weaker and less stiff soil stratum.

DCPT's in accordance with ASTM D6951 were conducted at twenty (20) locations along the length of the three main segments of the highway. The test is routinely used to design road pavement systems and includes continuous measurements down to a depth of up to just under

1 meter and more when an extension shaft is used. The test is routinely used to determine existing CBR values and for the identification of layers of different strengths. The test method is very convenient when such information is required for shoulders and main carriageways while causing minimal disruption of the traffic flow for narrow two lane systems such as the GPH.

In addition to the DCPT's, inspection pits have been dug along all three segments of the highway. These include a total of twenty (20) pits that were excavated to up to a depth of approximately 12 feet. Material samples were taken from each of the pits with lab tests scheduled to be done on representative samples. Such lab tests include soaked CBR, as well as atterbergs limits¹¹ for clay samples and sieve analysis for granular materials.

The DPC test data and inspection PIT results, obtained by the ATA Consultant, are attached in Annex F to this report.

Pavement Design

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements.

The pavement should meet the following requirements:

- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil.
- Structurally strong to withstand all types of stresses imposed upon it.
- Adequate coefficient of friction to prevent skidding of vehicles.
- Smooth surface to provide comfort to road users even at high speed.
- Produce least noise from moving vehicles.
- Dust proof surface so that traffic safety is not impaired by reducing visibility.
- Impervious surface, so that sub-grade soil is well protected.
- Long design life with low maintenance cost

¹¹ The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit. These limits were created by Albert Atterberg, a Swedish chemist.

In the absence of a Falling Weight Deflectometer (FWD) and pavement core testing to determine the structural capacity of the existing pavement to be used in this conceptual design, the geometry and structure components of the pavement, has been defined by the ATA Consultant, using the available data as mentioned in previous paragraphs.

The following alternatives have been identified to be implemented into the pavement system: rehabilitation of the road pavement using a flexible chip seal surfacing; rehabilitation of the road pavement using a semi-structural flexible hot-mix asphalt road surfacing; and rehabilitation of the road pavement using rigid concrete.

For apparent reasons these three main alternatives have advantages and disadvantages. With the first alternative having the lower initial capital cost followed by the second and third alternatives. However, the life cycle and maintenance cost is significantly lower for the second alternative followed by third and then first alternatives. The relative cost of these alternatives will be elaborated upon in the Economic Feasibility Study.

The layers of the pavement structure for each of the alternatives would be as follows:

- A: Scarification, new 6" sub-base, new 6" base and double layer chip seal.
- B: Scarification, new 6" sub-base, new 4" base and 2.0" thick Hot Mix asphalt.
- C: Scarification, new 6" sub-base and new 7" thick concrete.

8. Drainage System

Background

Belize has a tropical climate with pronounced wet and dry seasons, although there are significant variations in weather patterns by region. Temperatures vary according to elevation, proximity to the coast, and the moderating effects of the northeast trade winds off the Caribbean. Average temperatures in the coastal regions range from 24 °C (75 °F) in January to 27 °C (81 °F) in July. Temperatures are slightly higher inland, except for the southern highland plateaus, such as the Mountain Pine Ridge, where it is noticeably cooler year round. Overall, the seasons are marked more by differences in humidity and rainfall rather than in temperature.

Average rainfall varies considerably, ranging from 1,350 millimeters (53 in) in the north and west to over 4,500 millimeters (180 in) in the extreme south. Seasonal differences in rainfall are greatest in the northern and central regions of the country where, between January and April or May, fewer than 100 millimeters of rain fall per month. The dry season is shorter in the south, normally only lasting from February to April. A shorter, less rainy period, known locally as the "little dry", usually occurs in late July or August, after the initial onset of the rainy season.

Hurricanes have played key—and devastating—roles in Belizean history. In 1931 an unnamed hurricane destroyed over two-thirds of the buildings in Belize City and killed more than 1,000 people. In 1955, Hurricane Janet leveled the northern town of Corozal. Only six years later, Hurricane Hattie struck the central coastal area of the country with winds in excess of 300 kilometers per hour (190 mph) and 4-metre (13 ft.) storm tides. The devastation of Belize City for the second time in thirty years prompted the relocation of the capital some eighty kilometers inland to the planned city of Belmopan. Hurricane Greta caused more than US\$25 million in damages along the southern coast in 1978. On October 9, 2001, Hurricane Iris made landfall at Monkey River Town as a 145 mph Category Four storm. The storm demolished most of the homes in the village, and destroyed the banana crop.

On Thursday October 16, 2008, Tropical Depression No. 16 formed off the coast of Honduras. With sustained winds of 30 mph and moving further inland to the west southwest, the low pressure system produced heavy rainfall over Nicaragua, Honduras, Belize, Guatemala and the Yucatan peninsula.

In Belize, the Meteorological Office reported that the remnants of the system released over 15 inches of rainfall over western and southern Belize. The heavy rains caused the Mopan, Macal and upper Belize Rivers to overflow their banks at various locations, threatening communities in the Belize and Cayo Districts in Western Belize. The Chalillo Dam, located in the upper reaches of the Belize River, which is expected to buffer the impact of such rainfall events by controlling the flow in the River, was overtopped by the event.

As the flood waters moved downstream into the lower Belize River watershed, communities and infrastructure in these lower areas were affected for extended periods of time causing disruptions to everyday life in the country and placing hardships on the population in these areas. The most seriously affected areas were in the northern parts of Cayo and Orange Walk Districts; and the west-central part of Belize District. The flood events caused significant damage to road infrastructure, housing, and the agriculture and tourism sectors. Several communities remained under water for extended periods.

Currently the passage of water from one side of the road to the other is provided by bridges and a number of culverts as shown in next figures. The drainage along the road segment of study consists of bridge structures, drain crossing structures, and ditches (most of them not protected for erosion), alongside of the road.

Bridge Structures

A limited number of four (4) bridges have been identified along the segment of study. The first identified bridge structure is located at the entrance area of the Raring Creek settlement (Roaring Creek Bridge), the second structure is located near the Orange Gallery (Baron Creek Bridge), the third structure is located near the Galean University (Central Farm Bridge), and lastly, the fourth bridge structure was located at the entrance of the Santa Elena settlement (Red Creek Bridge). Drawings of the four existing bridges provided by the ATA Consultant are attached in Annex H to this report.

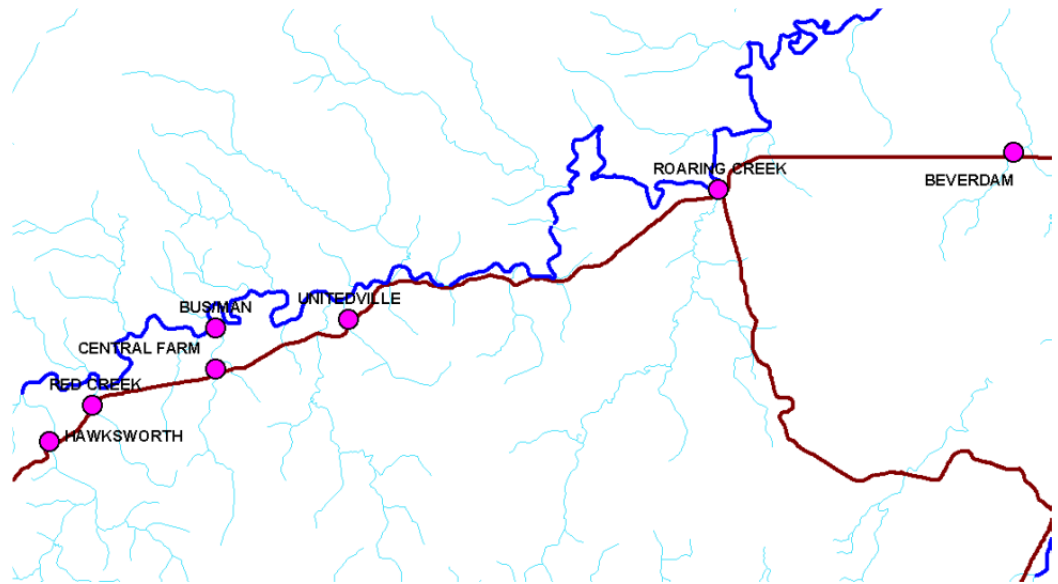


Figure 11: Main bridges in George Price Highway.¹²

The table below lists some of the principal characteristics of each of the four identified bridge structures.

Bridge	GPS Coordinates		Total Length	Roadway width	Type of Structure
	Latitude	Longitude	Meters	meters	
Roaring Creek Mile 48	17.260622	88.789639	76 (22.5+36+17.5)	6.6	Arc Concrete and concrete deck
Barton Creek Mile 60.9	17.203653	88.955814	50 (11+20+19)	7.4	Steel Beams & Concrete Deck
Central Farm Mile 64	17.186792	88.998864	60 (21+25+15)	9.5	Concrete Beams
Red Creek Mile 67.7	17.171644	89.050661	25	10.6	Box with concrete beams on the top

The observations described below are from the visual inspection performed on each of the bridge structures shown above.

Roaring Creek Bridge (milepost 48)

The Roaring Creek Bridge reportedly constructed in the 1940's is a fairly complicated reinforced concrete structure comprised of a compression arch structure in the middle and two unequal end spans, one consisting of three bays and the other consisting of two. Reinforced concrete portal frame bents are located at 10-ft. 10-in. along the compression arch as shown in the figure below.

¹² The Beverdam and Hawksworth bridges are located outside of the GPH segment under consideration.



Figure 12: Roaring Creek Bridge. View from upstream to downstream.

This bridge currently experiences the following deficiencies: (i) insufficient hydraulic section which was evident in many occasions over the past several years where its structure was practically found under water levels, clearly not designed to undergo this type of condition; (ii) deficient horizontal alignment which increases the lack of safety that this bridge provides to its users; (iii) insufficient lane width and lack of sidewalks that prevents normal two-way vehicle traffic as well as pedestrian traffic along its sides; and (iv) structural deficiencies that prevent adequate support for existing traffic loads.



Figure 13: Structural deficiencies.

Ideally, the rehabilitation of a structure of these characteristics would consist of raising the bridge structure at least three (3) meters and widening the width of the structure between 6 to 11 meters. This is not feasible because it is a structure that cannot be expanded in any of the senses at the same time (ie, transverse and longitudinal, vertical).

For this reason, it is recommended to replace the existing structure and build a new bridge following under adequate parameters. The construction of a new bridge structure can be possible with minimal impacts on private property, particularly at the entrance of the bridge (left side). A greater degree of impact on public property (Showground Agricultural) could be experienced at the entrance of the bridge (right side). This realignment will not affect the Guanacaste National Park.

It is estimated that the new bridge would maintain the length of the existing central span which is 35 meters and two adjacent spans of 22.5 meters each; these include the use of pre-stressed concrete AASHTO girders with a reinforced concrete deck and a similar structure with steel plate girders. It is suggested the structure be designed following the continuity approach¹³ for the live loads, superimposed dead loads, future wearing surface and time-dependent effects (shrinkage, creep and temperature).

Barton Bridge (milepost 61)

The Barton Creek Bridge, located near the village of George Ville is a relatively simple with a triple span structure with concrete deck supported on steel girders. The steel girders include 12 inches wide by 36 inches deep members spaced at 6 feet across the width of the bridge and braced every 18 1/3 feet with 12-inch deep channels. The steel girders are supported on bents comprised of 24-inch square reinforced concrete beams on two circular reinforced concrete columns. The beam bents are reported to be reinforced with eight 1-inch diameter rebars at the bottom with stirrups estimated to be 3/8-inch rebars and spaced at about 8 inches.



Figure 14: View from downstream to upstream.

¹³ Designing for continuity precast prestressed bridge girders made continues for live load offer many benefits: lower costs, improve durability, longer span, improved seismic performance, improved structural integrity, and improved ride quality.

The overall visual assessment of this bridge is that it is in acceptable condition. However, the following issues have been identified: (i) The exit of the bridge is in close proximity of the sharp angled curve which impacts the safety of motorists crossing the bridge; (ii) the width of the deck is less than 11 meters (currently 6.6 meters). Additional studies must be performed to identify safety flaws that could be addressed to improve the overall traffic safety for motorists. Both recommended studies must be accounted for in the overall project cost budget. With respect to increasing the width of the deck, additional structural studies must be performed. Should this result in a recommendation to widen the existing deck, measures to standardize the dimensions of this bridge with Macal Bridge must be taken. It is also recommended to study possible improvements to both access sides of the bridge. It also recommended to study the drainage capacity of the drain structures crossings the road near both access side of the bridge. An improvement of these drain structures crossings will alleviate extraordinary flooding conditions in the areas near the bridge access side.

Central Farm Bridge (milepost 64)

The Bridge, situated near the village of Central Farm, is a short span bridge comprising of two 18-foot end spans and a 34-foot center span. The bridge is of a reinforced concrete deck on reinforced concrete beams spaced at approximately 5 feet, supported on two middle bents and end abutments. The beams are 14 inches wide by 20 inches deep (excluding deck). Bent beams are 24 inches wide by 36 inches deep.



Figure 15: General view of the bridge and the reinforce abutment west side of the bridge.

The overall visual assessment of this bridge is that it is in acceptable condition. However, the exit side of the bridge has been eroded due to rising of water levels of the river, provisional repairs have been performed. It has been identified that an adequate material removal in the river upstream will benefit the overall condition of this bridge. It is estimated that the cost associated with the efforts to perform this work would be effective toward the total investment of the project. Similarly to Puente Barton, a study must be performed to determine the need to widen the deck. If so, the new deck width dimension should be standardized with Macal Bridge. Additionally, further studies must be performed to determine the stability of both access side of the bridge.

Red Bridge (milepost 68)

Red Creek Bridge is a 30 feet single span bridge. The structure includes a reinforced concrete deck on 12-inches by 18-inches deep reinforced concrete beams spaced at approximately five (5) feet on centers, with the two adjacent to the centerline being much closer together. The bridge includes a reinforced concrete base that has evidence of soil erosion. In general the bridge is fairly good structural condition, with no signs of significant deterioration.



Figure 16: View from downstream to upstream.

The Red Creek Bridge spans a very short distance at around 30 feet and is expected to be able to sustain the design loads for the project.

This box structure bridge is in acceptable conditions. Similarly to Puente Barton, a study must be performed to determine the need to widen the deck, if so; the new deck width dimension should be standardized with Macal Bridge.

Stream crossing culverts

As definition, a culvert is required where the roadway crosses a stream channel to allow water to flow from upstream to downstream. The inlet schedule provided by MOWT was reviewed, and ninety-eight (98) inlet structures have been identified between mileposts 47.5 and 74.5. A total of fifty-eight (58) structures are constructed of concrete with pipe openings between 2 to 3 feet in diameter, four (4) are box structures, and three (3) are Armco Multiplate transversal pipes with lengths between 14 to 26 feet. Generally, the majority of the drain ditches and storm water management structures do not function as designed due to obstructions caused by vegetation and sediments. Almost all circular culverts shaped with 600 mm tubes do not operate as designed since they have been obstructed by either the sediments or man-made covers. A significant number of them show major damage at their outlet point due to the absence of storm water dissipation measures.

The pipes constructed with an opening diameter less than 1 meter are practically impossible to be maintained. For this reason, it is recommended to install concrete pipes with an opening

diameter greater than 1 meter. Actually, installing concrete pipes with an opening diameter of 1.5 meters is preferred provided there is enough clearance between the top of the pipe and the subgrade of the road. Having the preferred 1.5 meters diameter pipe installed along the road will facilitate the removal of debris and sedimentation during periodic maintenance activities.



Figure 17: Culverts blocked by sediments or by the vegetation. It is an indication of lack of maintenance.

According to the inventory of zones prone to flooding along the GPH, the global study to propose specific interventions to reduce the Belizean road network vulnerability to flooding events¹⁴, detected some areas where apparently there is no presence of culverts. So they recommended 42 new culverts (12,000 ft³/sec) to prevent or minimize flooding on these areas. The next images show the inventory of zones prone to flooding (blue) in HPH, existing culverts (green), and proposed culverts (yellow).

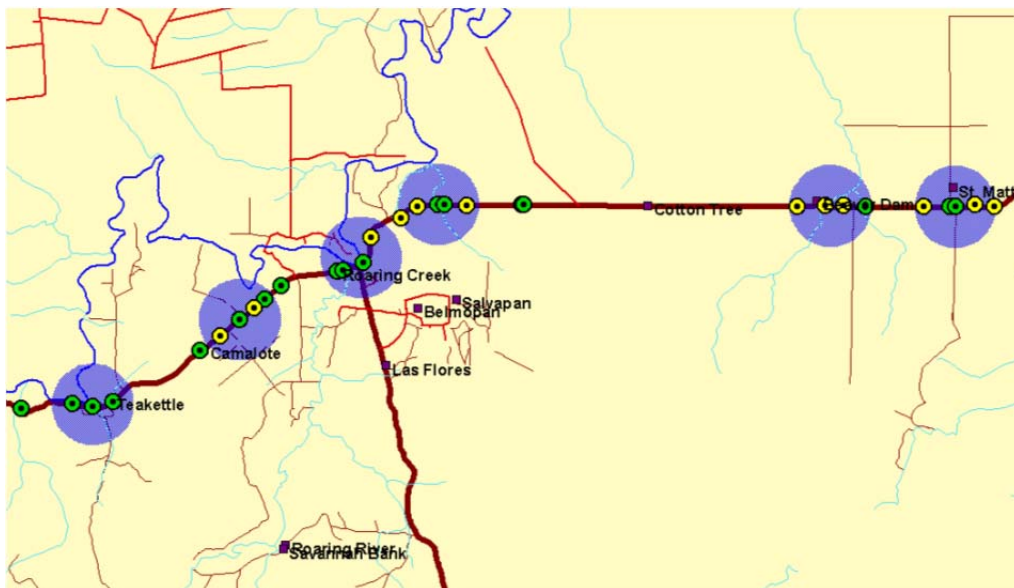


Figure 18: Proposed culverts near Belmopan.

¹⁴ Government of Belize, through its Ministry of Works, promotes this study aimed at analyzing the hydrological regime of the entire basin of the Belize River, and the vulnerability of their territories under relevant storm events. The study was conducted by the TYPASA Consultants in June 2010.

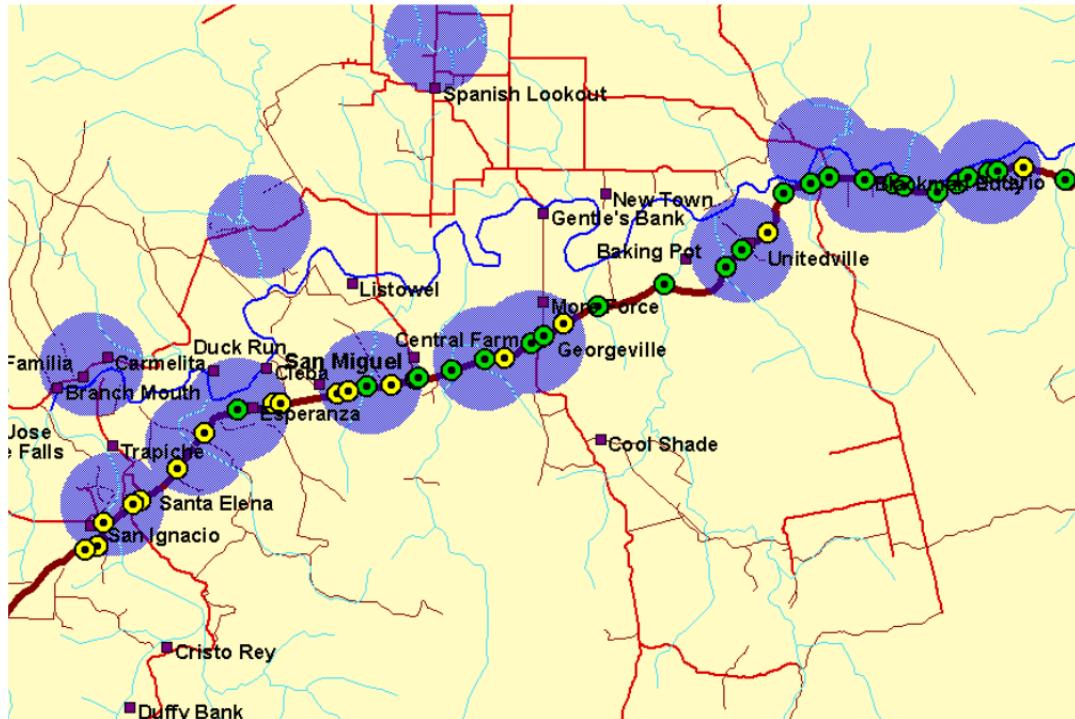


Figure 19: Proposed culverts near San Ignacio y Santa Elena.

The ATA Consultant recently conducted a preliminary assessment of the hydrological and hydraulic conditions that would affect the project. These preliminary hydrologic and hydraulic assessments address the areas of concern under the following categories: Flood Prone Areas and Minor culvert Infrastructure.

Specifically the assessment included the following areas:

- Roaring Creek Bridge
- Camelote at Mile 50
- Teakettle Village at Mile 53
- Blackman Eddy at 58
- Georgeville at 62 and 63
- Central Farm at Mile 64
- San Ignacio at Mile 67
- Succotz at Mile 71
- Benque Viejo at Mile 73

As a result, they provided a recommendation to improve the existing road drainage system particularly in the areas mentioned above. Annex I includes a comprehensive summary table of all culverts under the road system.

Longitudinal lined ditches. It was noted during the site visit that the majority of the existing V- ditches are in workable condition considering the evident lack of regular maintenance. Nevertheless, it should be noted that these ditches will have to be relocated to accommodate the new limits of the road after widening work is completed.

9. Work to be implemented

In order to define the level of intervention in the road the technical criteria contained in the standards of international design for highways has been followed. Activities that have been considered to improve traffic and safety conditions of the route are shown below:

- a) Replace Roaring Creek Bridge.
- b) Realignments at Z-curve and San Jose Succotz and Benque Viejo del Carmen settlements.
- c) Improve horizontal alignment of mileposts 49, 52, 53, 55, 56, 57, 58, 59, y 60.
- d) Raise the existing road platform in mileposts 50 (Camelote), 53 (Teakettle), 57 (Blackman Eddy), 59 (Uniteville), and 71 (Xunantunich)
- e) Widening and banking must be considered in all curves according to their design speeds.
- f) Replace the wearing course along the entire segment of study.
- g) It is possible that a replacement of the base course may not be required. However, an estimated cost for replacing 10% of the base course should be included in the project's contingency.
- h) Remove and replace the drainage system along the segment. This includes inlets and ditches. Replace all existing piping currently with diameters lower than 3 feet with new pipes greater than 1.0 meters of diameter. The lower diameters (less than 1.0 meters) are not recommended because they required a higher level of effort during cleaning and related maintenance. It is recommended that the existing 600 mm diameter culverts be upgraded to a higher diameter pipe to facilitate access to maintenance crews during scheduled pipe cleaning efforts. As for the remaining squared opening concrete pipe facilities, it is recommended they be properly maintained and be left in place and/or be extended to adjust to the proposed geometry of the road.
- i) In Z-curve section it is anticipated that slopes will need to be stabilized and that retaining walls be constructed where appropriate to accommodate the proposed widening areas the road.
- j) It must be noted that a significant number of utility poles installed along the sides of the road must be relocated prior to constructing the widening sections of the road.
- k) Bridge repair work should be considered for the bridge structures over the Barton Creek and Central Farm bridges, as indicated in the special section of this report.

- l) Sidewalks should be provided in the three urban areas.
- m) Construction of bus stops in urban concentration areas as well as pedestrian overpasses in the: Roaring Creek, Camalote, Teakettle, Ontario Village, United Ville, Blackman Eddy, Esperanza settlements, are deemed necessary.
- n) The establishment of the horizontal and vertical signaling is considered over the total length of the road.

New Roaring Creek Bridge

An essential component of the GPH rehabilitation consists in determining the most feasible option for crossing the Roaring River near the GPH and Hummingbird Highway junction. Currently, vehicular and pedestrian traffic cross over this section of the creek via the Roaring Creek Bridge. However, over the past years the inefficiency of this infrastructure has been evident, particularly during flooding events in the area. Flood waters constantly raise in the area and in few instances cover the deck of the bridge. Furthermore little indications of significant maintenance measures are evident. Considering the narrowness of the deck element of the structure as well as its out-of-alignment condition, a solution should be explored to achieve the desired functionality of this structure.

As mentioned in the assessment of this bridge, it is not feasible to consider the existing bridge part of the rehabilitated GPH. The best option is to construct a separate structure just upstream of the existing bridge. Thus, ATA Consultant recommends the construction of a separate bridge structure to be the best course of action. The existing bridge would remain operational during the construction of the new structure adjacently. Upon successful construction completion of the new bridge structure the existing bridge would be rehabilitated to maintain its historical significance and be used as a gateway to a recreational area soon to be developed in the vicinity. ATA Consultant elaborated a sketch depicting the new alignment of the bridge, which is included in this report as Annex J.

A conceptual design that facilitates the crossing of pedestrians, cyclist and vehicular traffic has been preliminary investigated. This solution considers a triple span bridge of two (2) 80 feet (24.38 m), external spans and a 110 feet (33.53 m) middle span. Other elements of the structure are two (2) reinforced concrete abutments at each end of the river bank and two (2) intermediate reinforced concrete piers. The width of the bridge will be approximately 37.7 feet (11.5 meters), allowing for two lanes of traffic, each 12.5 feet (3.81 meters) wide and two pedestrian sidewalks of 5 feet (1.5 meters) wide.

AASHTO Type IV girders are proposed for the two 24 meter exterior spans, while AASHTO Type V girders shall bridge the 33.5 meters middle span. The AASHTO girders manufactured in Belize are maintenance free and will provide several decades of usage. The reinforced concrete bridge deck and AASHTO girders will be designed to support AASHTO HS-20 loading; with the cold galvanized metal guard rails will be designed to withstand impact loads.

Z Curve Realignment

The curve at mile 56 is one of the most crucial areas in the project. This area consists of a sharp "Z" curve around a steep rock hill with a prominent drop towards the Belize River on the outside. The area is a hazardous one, prone to rock slides and vehicular collisions. ATA Consultant studied, in detail, three options.

One of the options involves the realignment of the road such that the horizontal curve is no longer an issue. Additionally, this option will allow for the cutting of the existing hill to a sufficient extent such that the vertical curve will not be an issue. Furthermore, executing this option would allow for significant decrease in land acquisition to extend ROW limits, and would also address the concern regarding the soil stability of the hill. This option has provisions for a temporary bypass road to be utilized during construction. A second option would yield further decrease in land acquisition. This option is simply to widen the road and cut back the sides of the hill. This option will not solve the horizontal alignment problem and is not the preferred option. The third sub-option is simply no action with the exception of installing additional signs and possible traffic calming measures. This is not a recommended option.

In this conceptual project, the first option studied by ATA Consultant, is a preferred option and will be part of the budget consideration. The drawings for this option are included in Annex K to this report.

Realignment at Succotz and Benque Viejo.

These two zones are interrelated and are located in the village of Succotz and the entrance to Benque Viejo. The problem that exists is the fact that a recent 50-year rainstorm has caused a significant portion of the road to flood in the village area and at the entrance of the town. In order to solve the problem, the ATA consultant studied various options and all of them include elevating the roadway above the flood lines.

Construction of a new side access road to the ferry is required; the existing configuration of this access shows this road to be extraordinarily steep. Additionally, reconstruction of the existing public river side tourist shops at a higher location to also avoid impacts caused by flooding needs to be considered. ROW encroachment issues exist along the route. Nevertheless, the intent is to utilize the river bank side of the ROW as much as possible to facilitate work activities with the intention to minimize construction impact on existing residents. This aspect of the project will therefore be geared at a visual enhancement of the public area including the entrance to the town.

Two sub-alternatives are being considered to address issues at the entrance to the Benque Viejo town. The first alternative considers the construction of a new roundabout that would be able to accommodate the designed truck dimensions for the project. However, this would

require a considerable amount of land acquisition to increase the current ROW limits. Existing conditions of this area include a fair amount of drain structures which may require the proposed roundabout to be a costly partially suspended structure. Alternatively, it is also considered to construct an intersection in lieu of the roundabout. However, in both cases the intention would be to enhance the entrance to the town.

It is recognized that a 50-year flood event will cover the road designed for a 20-year rainstorm event. As such, from a planning point of view, two alternative routes have been identified. One being a simple link, between the GPH and the existing road network, that would bypass the area in the event of the 50-years rainstorm event. Another option includes the construction of a significant bypass to the village. It is anticipated that the alternative road within the village can be accommodated within the project; however, the main bypass (a long term solution) is considered outside the scope as it will carry significant cost and will include significant new roads within private properties along with two bridges. Drawings depicting the aforementioned options are included in Annex L.

The Consultant agrees with the solution proposed by the ATA Consultant. The only adjustment would be to upgrade the existing street in the Benque Viejo, as shown in the next figure. This will include extending the existing street to reach the GPH. This additional work will include new street construction in a length of 200 meters and the construction of a bridge 20 meters long.

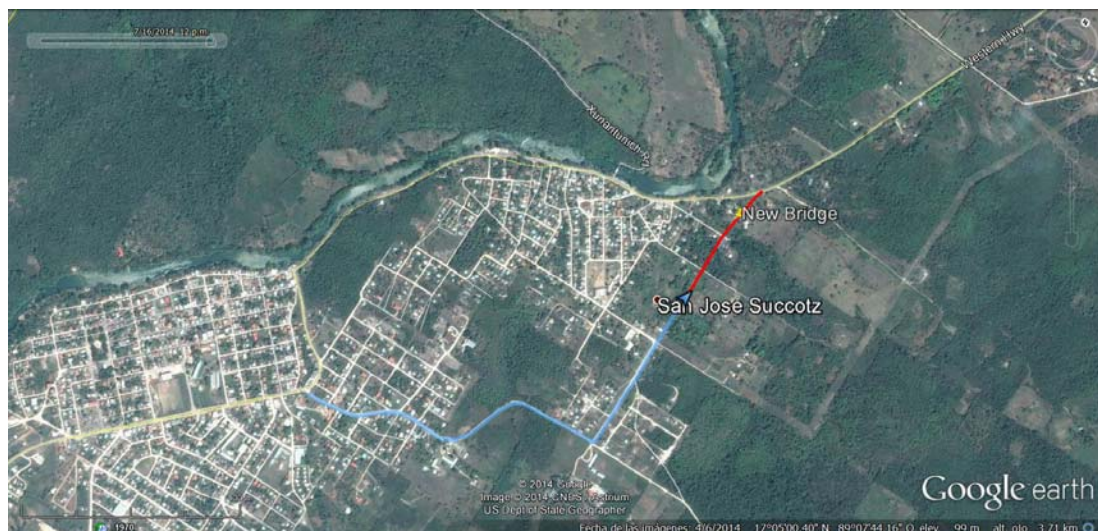


Figure 20: Street in Benque Viejo to be upgraded. In red the extension of the street.

This study limits the acquisition of land required for the improvement of the road to: (i) the acquisition of right-of-way for the expansion of existing roadway to allow the configuration of the specified typical cross sections, (ii) the acquisition of right-of-way for the improvement of certain dangerously sharp curves, and (iii) the acquisition of right-of-way for the construction of storm water sewer structures and other drainage facilities.

As a result, a significant decrease of 100% of the restricted curves in the existing route has been achieved. The restricted curves in the Z-curve segment were eliminated (curves C12, C13, C14, C15 and C16)¹⁵.

Segment	Radius	# of curves	Traffic Speed	Alignment Type
Roaring Creek (M48) to Santa Elena (M67)	R < 135 m	0	v < 60 km/h	Winding Road on flat terrain
	135 m ≤ R < 280 m	14	> 60 km/h v ≤ 80 km/h	
	280 m ≤ R < 492 m	24	> 80 km/h v ≤ 100 km/h	
	R ≥ 492 m	26	v > 100 km/h	
San Ignacio (M70) To Frontera Guatemala (M79)	R < 135 m	1	v < 60 km/h	Winding Road on flat terrain
	135 m ≤ R < 280 m	6	> 60 km/h v ≤ 80 km/h	
	280 m ≤ R < 492 m	3	> 80 km/h v ≤ 100 km/h	
	R ≥ 492 m	10	v > 100 km/h	
TOTAL		85		

10. Budget estimate

Major difficulties which arise while conducting cost estimation during the conceptual phase are lack of preliminary information, database of road works costs, and up-to date cost estimation methods. Additional difficulties arise due to larger uncertainties as result of engineering solutions, socio-economical, and environmental issues. Parametric cost estimation or estimation based on historic database during the conceptual estimate phase is widely used in developed countries. However, developing countries face difficulties related to the creation of a road work costs database, which may be used for cost estimation in either the conceptual stage or the feasibility study of a project cycle. The accuracy of an estimate is highly dependent on the available information about the proposed project at the time of estimate.

The information that the Consultant received for the MOWT and the ATA Consultant, in terms of unit prices was incomplete and quantities of work were never provided in reliable terms. In this scenario, the Consultant used the available information in conjunction with information available in similar projects under construction in Central American countries.

Quantities associated with road pavement structure (sub-base and base course, binder and wearing course, ditch, and sidewalk) were estimated with very close accuracy, since these quantities are a function of the total length of the road and the dimensions of typical cross sections for mountain and urban areas. At the same time, quantities and prices for signalization and road safety measures were adapted from other related projects that are currently under execution.

¹⁵ Curves listed in Annex A to this report.

The preliminary budget has been prepared following alternatives that have been identified to be implemented into the pavement system: rehabilitation of the road pavement using a flexible chip seal surfacing; rehabilitation of the road pavement using a semi-structural flexible hot-mix asphalt road surfacing; and rehabilitation of the road pavement using a rigid concrete.

A summary of the preliminary budget is tabulated below:

BUDGET SUMMARY				
Segment	Length	Alternatives		
	Km	A	B	C
1	15.8	11,583,185	13,210,309	16,712,576
2	15.4	7,883,405	9,469,336	12,882,938
3	13.8	8,551,785	9,975,944	12,919,886
Total	45	28,018,375	32,655,588	42,515,400
Per kilometer		622,631	725,680	944,787

Financing Scenarios

In order to ensure that the scope of the project adequately considers the availability of funding resources, a decision was made to reduce the scope of the original project to two possible scenarios. The aforementioned scenarios include, namely: (i) Scenario I which includes the rehabilitation of the section between Belmopan (mile 47.9) and George Ville (mile 62.8); and (ii) Scenario II which includes the rehabilitation of the section between Belmopan (mile 47.9) and San Elena (mile 67.3). Accordingly, this report presents the economic evaluation of both scenarios.

Scenario I includes two segments: (i) from the intersection of GPH with Hummingbird Highway to the intersection of the GPH and the Iguana Creek Road with a total length of 9.8 miles (15.8 km), (ii) and from the intersection of the GPH and Iguana Creek Road to the intersection of the George Price Highway with George Ville Road which spans a total length of 5.1 miles (8 km) with a combined length of 14.9 miles (23.8 km). See Figure 3 below for visual representation.

Scenario II also includes two road segments: (i) from the intersection of GPH with Hummingbird Highway to the intersection of the GPH and the Iguana Creek Road with a total length 9.8 miles (15.8 km) and from the intersection of the GPH and Iguana Creek Road to Red Creek Bridge in Santa Elena which extends a length of 9.5 miles (15.4 km) with a combined length of 19.3 miles (31.2 km).

SCENARIO I - BUDGET SUMMARY				
Segment	Length	Alternatives		
	Km	A	B	C
1	15.8	11,583,185	13,210,309	16,712,576
2A	8	4,570,600	5,394,460	7,167,760
Total	23.8	16,153,785	18,604,769	23,880,336

SCENARIO II - BUDGET SUMMARY				
Segment	Length	Alternatives		
	Km	A	B	C
1	15.8	11,583,185	13,210,309	16,712,576
2	15.4	7,883,405	9,469,336	12,882,938
Total	31.2	19,466,590	22,679,644	29,595,514
Per kilometer		623,929	726,912	948,574

Budget Considerations

The estimated budgets for all Alternatives do not include costs for land expropriation, compensation for arable land, buildings relocations, equipment or services.

The preliminary budget has been prepared considering the following Items:

- a. **Mobilization.** Includes preparatory work and operation including bonding and tasks necessary for the movement of personnel, equipment, supplies, and incidentals to the project site, and for all other work and operations which must be performed or costs incurred including obtaining permits.
- b. **Replacement of the structural pavement.** Includes the following activities: scarify existing asphaltic surfaces down to an average depth of 3", and dispose of materials from site; provide and place compacted road sub-base; and provide and place compacted road base to the road system.
- c. **Road Surfacing.** Provide and place double layer chip seal surfacing to road system including shoulders. Provide and place 2" thick HMA surfacing to the road system, including shoulders. Construct concrete surfacing to the road system complete.
- d. **Remove and replace the drainage system.** Remove select existing culverts, provide and install new culverts complete with end structures, and upgrade existing culverts.
- e. **Signalization and road safety measures.** Provide and install center, edge and other road markings throughout the project. Provide and install new retro-reflective road signs. Provide and install cat eyes to the entire road system. Provide and install galvanized steel guard rails to select areas. Construct complete standard pedestrian crossings to key locations within villages. Construct new concrete bus stops to select areas within villages.
- f. **Raise the existing road platform.** Provide and place compacted structural fill to select areas to lift road elevation.
- g. **Approaches to the new Roaring Creek Bridge.** Construct approaches to the new Roaring Creek Bridge complete with all associated works.

- h. **Reinforce Central Farm and Barton Creek Bridges.** Lift the existing deck of the two minor bridges, clear inlets and outlets and rehabilitate the abutment and protection system.
- i. **New Roaring Creek Bridge.** Construct new Roaring Creek Bridge complete with foundation system and other associated works.
- j. **Alternative in Z-Curve.** Cut into the hill and construct new road alignment. Develop public area as shown including baboon crossings and construct temporary bypass road around the Z curve to facilitate realignment of the road.
- k. **Alternative in Road in Benque Viejo.** Provide and place compacted structural fill to lift the area an average of 4 feet above the existing road elevation. Widen the flood and to fill in areas adjacent to the bank as necessary. Upgrade the existing segment of the alternative link into BVDC. Construct new short span bridges to the main road and the bypass road leading to BVDC.
- l. **Environment mitigation measures.** Work activities that were included in the EIA.
- m. **Miscellaneous Work.** Other minor activities not included in previous items.
- n. **Contingencies.** A 15% contingency has been added to the budget to fund potential volumes of work not included in the budget.

For the new Roaring Creek Bridge, the preliminary cost has been provided by a Local Construction Firm under the guidance of the Consultant. A Global Cost Estimate is shown in the following chart. The conceptual design is in Annex M.

Item	Description	Total
		Thousand of US\$
1	Preliminaries	436
2	Principal Piles	187
3	Wing-wall Approach Slab Piles	12
4	Piers and Abutment Works	534
5	AASHTO Girders Work	656
6	Bridge Deck Works	659
7	Auxiliar Works	36
	Total:	2,520

Detailed Budget by Road Segments

The preliminary estimated cost breakdown by Alternatives A, B and C are as follows:

SEGMENT 1 - ESTIMATED BUDGET					
SEGMENT 1: Intersection of GPH with Hummingbird Highway to the intersection of GPH with Iguana Creek Road					
				LENGTH (km):	15.8
ALTERNATIVE A: ROAD PAVEMENT USING A FLEXIBLE CHIP SEAL SURFACING					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			80,000
2	Replacement of the structural pavement	km	15.8	210,400	3,324,320
3	Road surfacing - Bituminous surface treatment (BST)	Km	15.8	119,600	1,889,680
4	Remove and replace the drainage system	km	15.8	13,500	213,300
5	Signalization and road safety measures	km	15.8	12,000	189,600
6	Raise the existing road platform	km	1	100,000	100,000
7	Approaches to the new Roarig Creek Bridge	km	0.5	350,000	175,000
8	New Roaring Creek Bridge	GL			2,500,000
9	Alternative in Z-Curve	GL			1,200,000
10	Environmental mitigation measures	GL			70,000
11	Micellaneous works	GL			400,000
12	Contingencies (15% of previous Items)	GL			1,521,285
				TOTAL	11,583,185
ALTERNATIVE B: ROAD PAVEMENT USING A SEMI-STRUCTURAL FLEXIBLE HOTMIX ASPHALT ROAD SURFACING					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			80,000
2	Replacement of the structural pavement	km	15.8	180,350	2,849,530
3	Road Surfacing - Hotmix Asphalt Road Surfacing	Km	15.8	239,200	3,779,360
4	Remove and replace the drainage system	km	15.8	13,500	213,300
5	Signalization and road safety measures	km	15.8	12,000	189,600
6	Raise the existing road platform	km	1	100,000	100,000
7	Approaches to the new Roarig Creek Bridge	km	0.5	350,000	175,000
8	New Roaring Creek Bridge	GL			2,500,000
9	Alternative in Z-Curve	GL			1,200,000
10	Environmental mitigation measures	GL			70,000
11	Micellaneous works	GL			400,000
12	Contingencies (15% of previous Items)	GL			1,733,519
				TOTAL	13,210,309
ALTERNATIVE C: ROAD PAVEMENT USING A RIGID CONCRETE					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			80,000
2	Replacement of the structural pavement	km	15.8	133,900	2,115,620
3	Road Surfacing - Rigid Concrete	Km	15.8	478,400	7,558,720
4	Remove and replace the drainage system	km	15.8	13,500	213,300
5	Signalization and road safety measures	km	15.8	12,000	189,600
6	Raise the existing road platform	km	1	100,000	100,000
7	Approaches to the new Roarig Creek Bridge	km	0.5	350,000	175,000
8	New Roaring Creek Bridge	GL			2,500,000
9	Alternative in Z-Curve	GL			1,200,000
10	Environmental mitigation measures	GL			70,000
11	Micellaneous works	GL			400,000
12	Contingencies (15% of previous Items)	GL			2,190,336
				TOTAL	16,712,576

SEGMENT 2 - ESTIMATED BUDGET					
SEGMENT 2: GPH between the intersection of GPH with Iguana Creek Road and Red Creek Village					
				LENGTH (km):	15.4
ALTERNATIVE A: ROAD PAVEMENT USING A FLEXIBLE CHIP SEAL SURFACING					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			80,000
2	Replacement of the structural pavement	km	15.4	210,400	3,240,160
3	Road Surfacing - Bituminous surface treatment (BST)	Km	15.4	119,600	1,841,840
4	Remove and replace the drainage system	km	15.4	13,500	207,900
5	Signalization and road safety measures	km	15.4	12,000	184,800
6	Raise the existing road platform	km	4	100,000	400,000
7	Reinforce Central Farm and Barton Creek Bridges	GL			500,000
8	Environmental mitigation measures	GL			70,000
9	Micellaneous works	GL			400,000
10	Contingencies (15% of previous Items)	GL			1,038,705
				TOTAL	7,883,405
ALTERNATIVE B: ROAD PAVEMENT USING A SEMI-STRUCTURAL FLEXIBLE HOTMIX ASPHALT ROAD SURFACING					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			80,000
2	Replacement of the structural pavement	km	15.4	180,350	2,777,390
3	Road Surfacing - Hotmix Asphalt Road Surfacing	Km	15.4	239,200	3,683,680
4	Remove and replace the drainage system	km	15.4	13,500	207,900
5	Signalization and road safety measures	km	15.4	12,000	184,800
6	Raise the existing road platform	km	4	100,000	400,000
7	Reinforce Central Farm and Barton Creek Bridges	GL			500,000
8	Environmental mitigation measures	GL			70,000
9	Micellaneous works	GL			400,000
10	Contingencies (15% of previous Items)	GL			1,245,566
				TOTAL	9,469,336
ALTERNATIVE C: ROAD PAVEMENT USING A RIGID CONCRETE					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			80,000
2	Replacement of the structural pavement	km	15.4	133,900	2,062,060
3	Road Surfacing - Rigid Concrete	Km	15.4	478,400	7,367,360
4	Remove and replace the drainage system	km	15.4	13,500	207,900
5	Signalization and road safety measures	km	15.4	12,000	184,800
6	Raise the existing road platform	km	4	100,000	400,000
7	Reinforce Central Farm and Barton Creek Bridges	GL			500,000
8	Environmental mitigation measures	GL			70,000
9	Micellaneous works	GL			400,000
10	Contingencies (15% of previous Items)	GL			1,690,818
				TOTAL	12,882,938

SEGMENT 3 - ESTIMATED BUDGET					
SEGMENT 3: GPH between the intersection of GPH with Buena Vista St. and Guatemala Border					
				LENGTH (km):	13.8
ALTERNATIVE A: ROAD PAVEMENT USING A FLEXIBLE CHIP SEAL SURFACING					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			80,000
2	Replacement of the structural pavement	km	13.8	210,400	2,903,520
3	Road surfacing - Bituminous surface treatment (BST)	Km	13.8	119,600	1,650,480
4	Remove and replace the drainage system	km	13.8	13,500	186,300
5	Signalization and road safety measures	km	13.8	12,000	165,600
6	Raise the existing road platform	km	4	100,000	400,000
7	Alternative in Succotz	GL			1,200,000
8	Alternative Road in Benque Viejo	km	3	150,000	450,000
9	Environmental mitigation measures	GL			70,000
10	Micellaneous works	GL			400,000
11	Contingencies (15% of previous Items)	GL			1,125,885
				TOTAL	8,551,785
ALTERNATIVE B: ROAD PAVEMENT USING A SEMI-STRUCTURAL FLEXIBLE HOTMIX ASPHALT ROAD SURFACING					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			100,000
2	Replacement of the structural pavement	km	13.8	180,350	2,488,830
3	Road Surfacing - Hotmix Asphalt Road Surfacing	Km	13.8	239,200	3,300,960
4	Remove and replace the drainage system	km	13.8	13,500	186,300
5	Signalization and road safety measures	km	13.8	12,000	165,600
6	Raise the existing road platform	km	4	100,000	400,000
7	Alternative in Succotz	GL			1,200,000
8	Alternative Road in Benque Viejo	km	3	150,000	450,000
9	Environmental mitigation measures	GL			70,000
10	Micellaneous works	GL			400,000
11	Contingencies (15% of previous Items)	GL			1,314,254
				TOTAL	9,975,944
ALTERNATIVE C: ROAD PAVEMENT USING A RIGID CONCRETE					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			100,000
2	Replacement of the structural pavement	km	13.8	133,900	1,847,820
3	Road Surfacing - Rigid Concrete	Km	13.8	478,400	6,601,920
4	Remove and replace the drainage system	km	13.8	13,500	186,300
5	Signalization and road safety measures	km	13.8	12,000	165,600
6	Raise the existing road platform	km	3	100,000	300,000
7	Alternative in Succotz	GL			1,200,000
8	Alternative Road in Benque Viejo	km	3	150,000	450,000
9	Environmental mitigation measures	GL			70,000
10	Micellaneous works	GL			400,000
11	Contingencies (15% of previous Items)	GL			1,698,246
				TOTAL	12,919,886

ESTIMATED BUDGET					
SEGMENT 2A: GPH between the intersection of GPH with Iguana Creek Road and George Ville					
				LENGTH (km):	8
ALTERNATIVE A: ROAD PAVEMENT USING A FLEXIBLE CHIP SEAL SURFACING					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			80,000
2	Replacement of the structural pavement	km	8	210,400	1,683,200
3	Road Surfacing - Bituminous surface treatment (BST)	Km	8	119,600	956,800
4	Remove and replace the drainage system	km	8	13,500	108,000
5	Signalization and road safety measures	km	8	12,000	96,000
6	Raise the existing road platform	km	4	100,000	400,000
7	Reinforce Barton Creek Bridge	GL			250,000
8	Environmental mitigation measures	GL			70,000
9	Micellaneous works	GL			400,000
10	Contingencies (15% of previous Items)	GL			606,600
				TOTAL	4,570,600
ALTERNATIVE B: ROAD PAVEMENT USING A SEMI-STRUCTURAL FLEXIBLE HOTMIX ASPHALT ROAD SURFACING					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			80,000
2	Replacement of the structural pavement	km	8	180,350	1,442,800
3	Road Surfacing - Hotmix Asphalt Road Surfacing	Km	8	239,200	1,913,600
4	Remove and replace the drainage system	km	8	13,500	108,000
5	Signalization and road safety measures	km	8	12,000	96,000
6	Raise the existing road platform	km	4	100,000	400,000
7	Reinforce Barton Creek Bridge	GL			250,000
8	Environmental mitigation measures	GL			70,000
9	Micellaneous works	GL			400,000
10	Contingencies (15% of previous Items)	GL			714,060
				TOTAL	5,394,460
ALTERNATIVE C: ROAD PAVEMENT USING A RIGID CONCRETE					
Item	Category	Unit	Quantity	Unit Price	Cost
1	Mobilization	GL			80,000
2	Replacement of the structural pavement	km	8	133,900	1,071,200
3	Road Surfacing - Rigid Concrete	Km	8	478,400	3,827,200
4	Remove and replace the drainage system	km	8	13,500	108,000
5	Signalization and road safety measures	km	8	12,000	96,000
6	Raise the existing road platform	km	4	100,000	400,000
7	Reinforce Barton Creek Bridge	GL			250,000
8	Environmental mitigation measures	GL			70,000
9	Micellaneous works	GL			400,000
10	Contingencies (15% of previous Items)	GL			945,360
				TOTAL	7,167,760

11. Conclusions and Recommendations

1. The conceptual design for the George Price Highway (GPH) segment, starting at the Junction of the GPH and Hummingbird Highway to Guatemala Border has been elaborated in accordance with the international standards currently implemented in Latin America. It is acknowledged that by executing the project with reasonable investment that it is possible to provide a roadway that is not only safe to motorists but also its construction as a whole remains within the allowable limits of environmental disturbance.

2. Despite the proposed road configuration follows the existing alignment, there is a significant amount of local residents who, over the years, settled alongside the existing road and within the right-of-way limits. As a result of this encroachment several housing structures are now found in direct conflict with the proposed widening of the road. Therefore, it is recommended to account for reasonable monetary resources in the budget of Project Operative Document (POD) to cover for project related impact compensation.

It would be beneficial to this and future road projects if resources in the POD budget be considered for institutional reinforcement. Related funds would be used to train the Executing Agency to effectively enforce national regulations that prohibit right-of-way encroachment along public roads. Minimally, the creation of a Pilot Project should be designed and implemented to ensure that encroachment be avoided for all road segments finance by thee IDB.

3. The Executing Agency must ensure that a Maintenance and Traffic Protection Plan (MTP) be designed specifically for this project and subsequently be executed during the entirety of its construction phase. The importance of executing an MTP plan is to alleviate any potential traffic congestion, safety hazards, and travel related inconveniences that typically arise from construction activities along a road with high traffic levels. The MTP plan should also account for uninterrupted traffic flow at all times.
4. The main problem in the Belize River Basin is the lack of altimetry data. The only information available is the contour lines every 100 meters generated by NASA and interpolated every 40 meters. This sort of mapping is used for general studies at national level but do not allow the development of a study of flooding as it has been done in this consultancy, where an error of a meter can be of consideration. Therefore, the main recommendation is to get accurate information on the altimetry of the basin. There are two main methods to produce this mapping, photogrammetric restitution and LIDAR technology.
5. The IDB should consider that the new roads currently part of the Bypass project, which connects the towns of San Ignacio and Santa Elena, are not located far enough from either town. Therefore, traffic delays for heavy transportation vehicles may occur in the near future. As for purposes of connectivity between segments 2 and 3 of the project, it is important to take into consideration the delayed start of the construction activities for Macal Bridge.
6. The MOWT does not have a data base with actual construction or maintenance costs from previous roadway network projects in Belize. The absence of such data base makes it difficult to perform construction cost estimates at the desired accuracy level. It is recommended that a financed by the Loan Component 3. Institutional Straightening, executes initiatives toward the creation of a cost and budgeting department within the MOWT.

12. List of Annex

Annex A – San Ignacio –Santa Elena Bypass.

Annex B - Cayo Road Network 2011.

Annex C – List of Documents.

Annex D – Detail of Horizontal Curves.

Annex E – Typical Cross Section.

Annex F - DPC test data and inspection PIT results.

Annex G – Traffic Projections.

Annex H – Drawings of the four existing bridges.

Annex I – Summary table of culverts under road system.

Annex J – Roaring Creek Road Alignment.

Annex K – Z – Curve Road Alignment.

Annex L – Succotz & Benque Viejo Alignments.

Annex M – Concept Design for the new Roaring Creek Bridge.