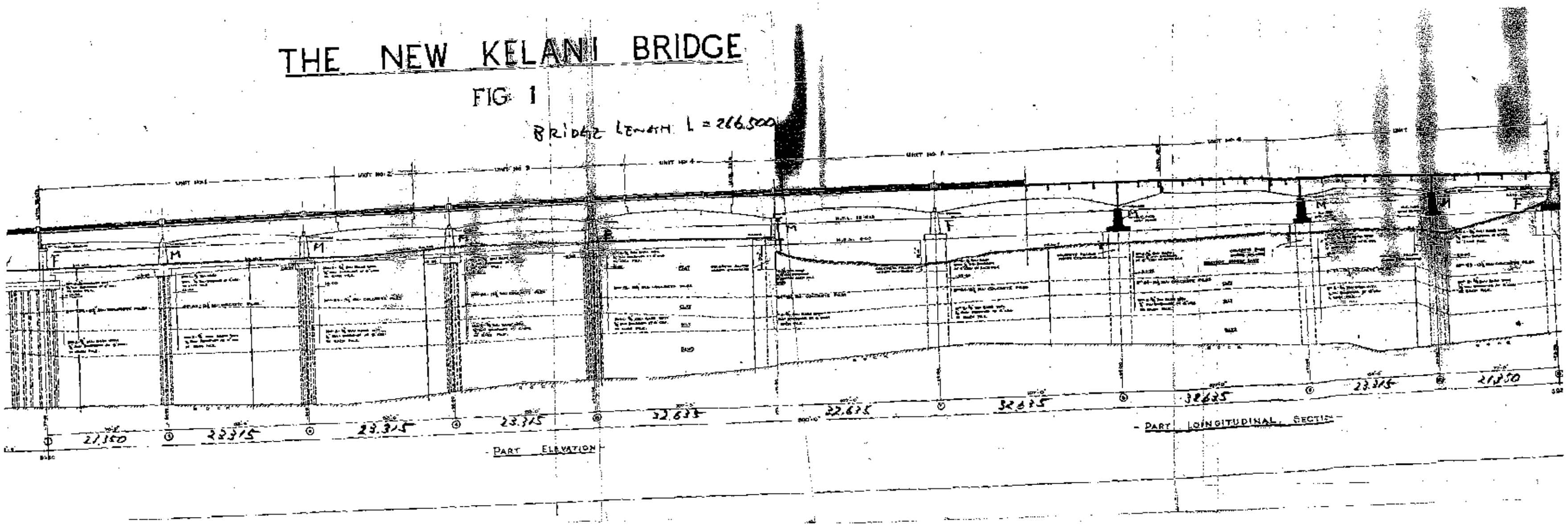
APPENDIX

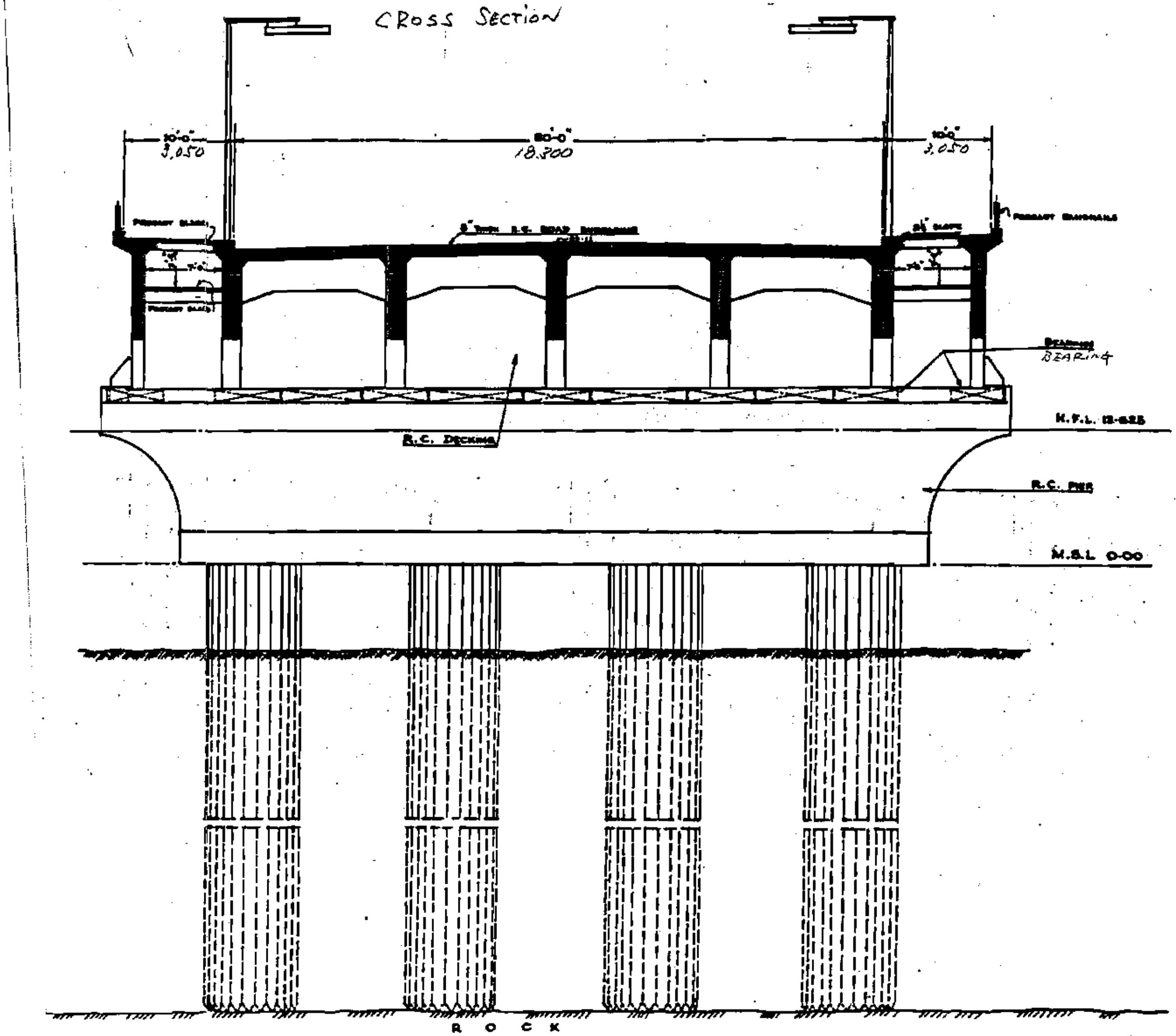
APPENDIX-1

Drawing for Existing New Kelani Bridge, General View, Cross section

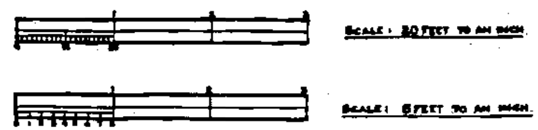
THE NEW KELANI BRIDGE

FIG 1





- CROSS SECTION -
BETWEEN PIERS Nos 7 & 5
SCALE: 5 FEET TO AN INCH



APPENDIX-2

Record of Schmidt Hammer Test

SCHMIDT HAMMER TEST ON CONCRETE STRUCTURES
TEST METHOD ASTM C - 805 - 94

Test Format No:	**ELS-ML-33**
Revision No.	**00**

Project details:

Project:	New Kelani Bridge Healthness Check
Client:	Oriental Consultants

Schmidt Hammer Details:

Model:	58-C0181/N
Serial No:	10008440
Capacity:	100
Resolution:	2
Readability:	1

Test Data:

Location:	Piers	**Job Ref:**	ML/FT/653
Element of Structure:	-	**Date of testing:**	06.03.2013
Concrete Grade:	- GIRDER	**Date of Report:**	07.03.2013
Direction of Impact:	α =0°		

	PIER	↓ GIRDER	PIER	↓ GIRDER	PIER	↓ GIRDER
Location No:	P-01	P-01(3)	P-02(1)	P-02(2)	P-03	P-03(2)
Readings	36	38	40	-	44	34
	36	44	36	34	44	36
	40	37	44	42	44	36
	37	37	46	40	43	38
	-	32	44	34	44	32
	36	32	44	34	44	34
	36	34	38	40	41	32
	36	36	44	38	40	-
	32	38	38	39	46	36
	34	37	38	42	42	33
Average Reading	36	37	41	38	43	35
Correction Factor(by calibration)	1	1	1	1	1	1
Corrected Rebound No.	36	37	41	38	43	35
Compressive Strength (N / mm^2)	35	37	44	39	48	33

Remarks: :*Readings differing from average more than 6 units have been discarded

* Average Reading	=	Average of the readings except discarded values
* Correction factor	=	Factor from calibration of the Schimith Hammer
* Corected Reading	=	Average Reading*Correction Factor
* Compressive Strength	=	A reading obtained from the chart appeared on the Schimith Hammer

*The decision on acceptability of concrete is taken by the consultant engineer

* All the test locations were selected by the client.

Tested By:	Checked By:	Certified By:
....	....	....

Engineering & Laboratory Services (Pvt) Ltd

ENGINEERING & LABORATORY SERVICES (PVT) LTD
62/3, Neelammahara Road, Katuwawala, Boralesgamuwa, Sri Lanka.
Telephone : 0094 011 4309494/ 2517037 / 2517365, Fax : 0094 01 2509806, E-Mail : els@elslanka.com.

	SCHMIDT HAMMER TEST ON CONCRETE STRUCTURES TEST METHOD ASTM C - 805 - 94	Test Format No:	ELS-ML-33
		Revision No.	00

Project details:

Project:	New Kelani Bridge Healthness Check
Client:	Oriental Consultants

Schmidt Hammer Details:

Model:	58-C0181/N
Serial No:	10008440
Capacity:	100
Resolution:	2
Readability:	1

Test Data:

Location:	Pier	**Job Ref:**	ML/FT/653
Element of Structure:	-	**Date of testing:**	06.03.2013
Concrete Grade:	-	**Date of Report:**	07.03.2013
Direction of Impact:	α =0°		

Location No:	P-04	P-04(2) Girder	P-05	P-05 (5) Girder
Readings	48	46	38	44
	46	48	38	46
	48	48	38	44
	46	42	35	42
	40	44	34	41
	42	40	34	40
	43	46	36	41
	42	42	36	40
	50	42	39	40
	44	44	41	40
Average Reading	45	44	37	42
Correction Factor(by calibration)	1	1	1	1
Corrected Rebound No.	45	44	37	42
Compressive Strength (N / mm^2)	52	50	37	46

Remarks: :*Readings differing from average more than 6 units have been discarded

* Average Reading	=	Average of the readings except discarded values
* Correction factor	=	Factor from calibration of the Schimith Hammer
* Corected Reading	=	Average Reading*Correction Factor
* Compressive Strength	=	A reading obtained from the chart appeared on the Schimith Hammer

*The decision on acceptability of concrete is taken by the consultant engineer

* All the test locations were selected by the client.

Tested By:	Checked By:	Certified By: ......

ENGINEERING & LABORATORY SERVICES (PVT) LTD
62/3, Neelammahara Road, Katuwawala, Boralesgamuwa, Sri Lanka.
Telephone : 0094 011 4309494/ 2517037 / 2517365, Fax : 0094 01 2509806, E-Mail : els@elslanka.com.

	SCHMIDT HAMMER TEST ON CONCRETE STRUCTURES TEST METHOD ASTM C - 805 - 94	Test Format No:	ELS-ML-33
		Revision No.	00

Project details:

Project:	New Kelani Bridge Healthness Check
Client:	Oriental Consultants

Schmidt Hammer Details:

Model:	58-C0181/N
Serial No:	10008440
Capacity:	100
Resolution:	2
Readability:	1

Test Data:

Location:	Abutment	**Job Ref:**	ML/FT/653
Element of Structure:	-	**Date of testing:**	06.03.2013
Concrete Grade:	-	**Date of Report:**	07.03.2013
Direction of Impact:	$\alpha = 0^{\circ}$		

Location No:	Abutment
Readings	36
	34
	33
	40
	32
	36
	40
	36
	34
	37
Average Reading	36
Correction Factor(by calibration)	1
Corrected Rebound No.	36
Compressive Strength (N / mm^2)	35

Remarks: :*Readings differing from average more than 6 units have been discarded

* Average Reading	=	Average of the readings except discarded values
* Correction factor	=	Factor from calibration of the Schimith Hammer
* Corected Reading	=	Average Reading*Correction Factor
* Compressive Strength	=	A reading obtained from the chart appeared on the Schimith Hammer

*The decision on acceptability of concrete is taken by the consultant engineer

* All the test locations were selected by the client.

Tested By:	Checked By:	Certified By: ....

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Telephone : 0094 011 4309494/ 2517037 / 2517365, Fax : 0094 01 2509806, E-Mail : els@elslanka.com.

SCHMIDT HAMMER TEST ON CONCRETE STRUCTURES TEST METHOD ASTM C - 805 - 94	Test Format No:	ELS-ML-33
	Revision No.	00

Project details:

Project:	New Kelani Bridge Healthness Check
Client:	Oriental Consultants

Schmidt Hammer Details:

Model:	58-C0181/N
Serial No:	10008440
Capacity:	100
Resolution:	2
Readability:	1

Test Data:

Location:	Piers	**Job Ref:**	ML/FT/653
Element of Structure:	-	**Date of testing:**	06.03.2013
Concrete Grade:	-	**Date of Report:**	07.03.2013
Direction of Impact:	α =0°		

	Pier	Pier	Pier	Pier	ABUT 2.	GIRDER
Location No:	P-06 (N)	P-07 (N)	P-08 (N)	P-09 (N)	P-10 (N)	P-10 (06) (N)
Readings	38	42	34	36	34	40
	36	40	36	40	32	41
	36	40	32	40	30	38
	33	46	36	38	33	38
	36	40	35	44	35	39
	35	42	38	36	32	42
	33	42	41	34	30	40
	37	39	32	40	40	36
	32	40	39	34	32	38
	34	40	40	36	40	40
Average Reading	35	41	36	38	34	39
Correction Factor(by calibration)	1	1	1	1	1	1
Corrected Rebound No.	35	41	36	38	34	39
Compressive Strength (N / mm^2)	34	44	35	39	32	40

Remarks: :*Readings differing from average more than 6 units have been discarded

* Average Reading = Average of the readings except discarded values
* Correction factor = Factor from calibration of the Schimith Hammer
* Corected Reading = Average Reading*Correction Factor
* Compressive Strength = A reading obtained from the chart appeared on the Schimith Hammer

*The decision on acceptability of concrete is taken by the consultant engineer

* All the test locations were selected by the client.

Tested By:	Checked By:	Certified By:
....	....	......

ENGINEERING & LABORATORY SERVICES (PVT) LTD
62/3, Neelammahara Road, Katuwawala, Boralesgamuwa, Sri Lanka.
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APPENDIX-3

Reference Data for Traffic Demand Forecast

REFERENCE DATA FOR TRAFFIC DEMAND FORECAST

This appendix shows the reference data for traffic demand forecast such as the results of transport survey consists with traffic turning volume survey, travel speed survey and traffic signal phasing survey, as well as the data in the each stage of demand forecast.

1 TRANSPORT SURVEY RESULTS

1.1 Traffic Turning Volume Survey

The main objective of this survey is to obtain the present turning movement of vehicles at intersections and junctions within the survey area. The obtained data was used as the basis of traffic simulation and vehicular Origin-Destination (OD) matrix estimation.

The survey was conducted at fourteen (14) locations which include two (2) Roundabouts, 4 Signalized Intersections, and 8 other locations as indicated in Figure 1.

Table 1 Survey locations

No	Location Code	Survey Method
1	R-1	Traffic Turning Volume Survey
2	R-2	
3	J-1	
4	J-2	
5	J-3	
6	J-4	
7	C-1	Classified Vehicle Count Survey (one direction*) *Inflow to the Survey Area
8	C-2	
9	C-3	
10	C-4	
11	C-5	
12	C-6	
13	C-7	
14	C-8	

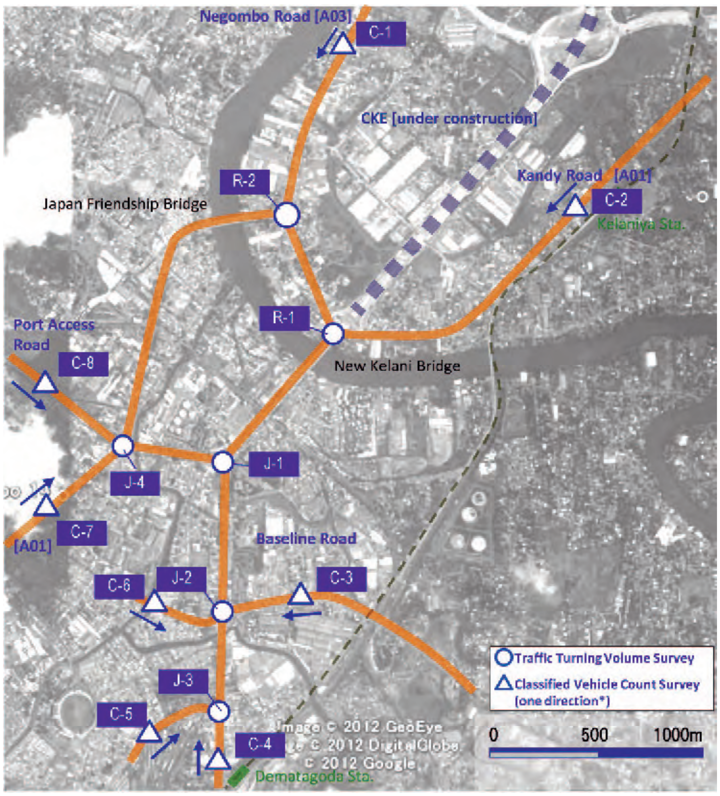


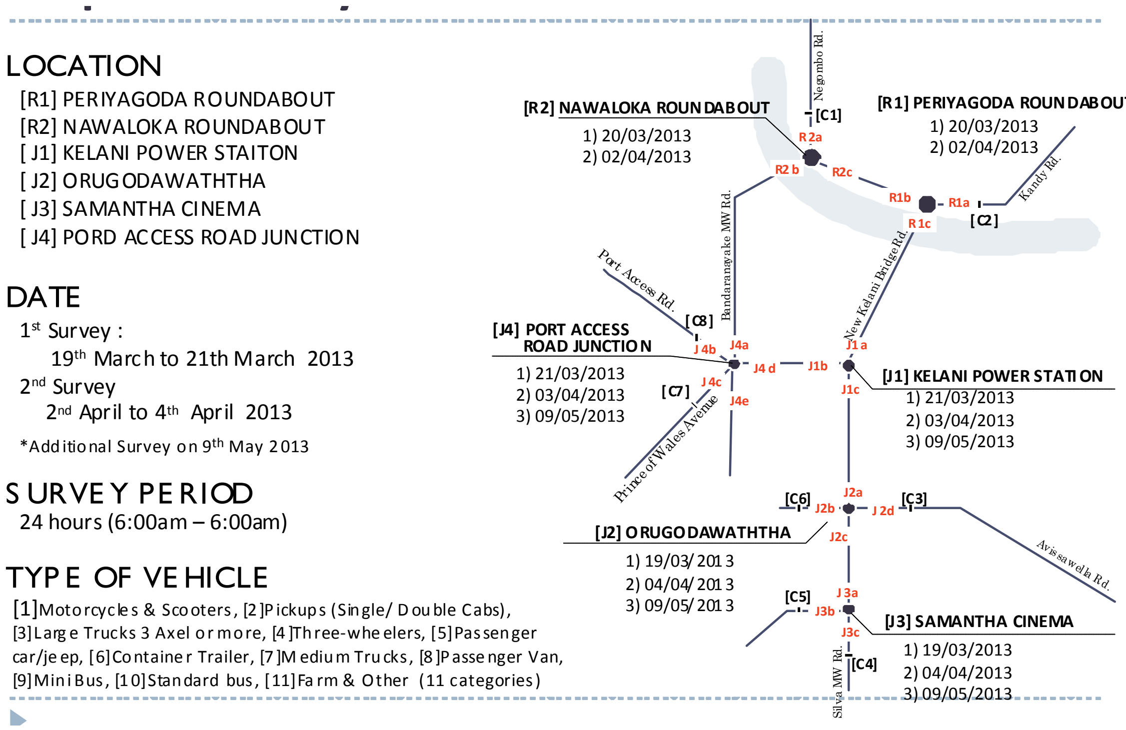
Figure 1 Survey Locations

The survey was conducted on 2 weekdays (either Tuesday, Wednesday or Thursday) for the duration of 24 hours (6:00 AM to 6:00 AM of the following day).

The types of vehicles for this survey are classified into the following 11 categories:

Type 1	Motor Bike	Type 7	Large Truck (3 axels and more)
Type 2	Three Wheeler	Type 8	Container Trailer
Type 3	Car, Jeep	Type9	Minibus (29 seats and below)
Type 4	Passenger Van	Type 10	Bus
Type 5	Pick-up (Single/ Double Cab)	Type 11	Others ( )
Type 6	Medium Truck (2 axels)		

Summary of the results is described below and each data imputed into the table is available in the MS excel file.



[R1] PERIYAGODA ROUNDABOUT

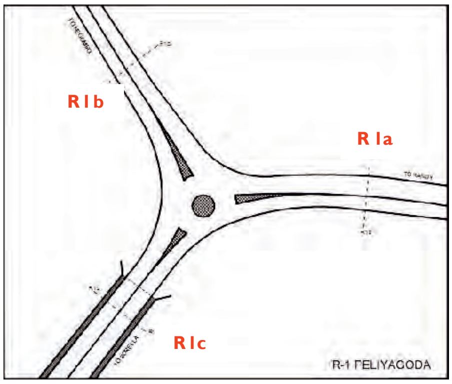
RESULT OF SURVEY

1st SURVEY 20th March 2013

	inflow	outflow	total
R1a	32,863	38,218	71,081
R1b	20,122	19,516	39,638
R1c	51,543	47,531	99,074
total	104,528	105,265	209,793

2nd SURVEY 2nd April 2013

	inflow	outflow	total
R1a	35,154	33,032	71,081
R1b	22,890	21,826	44,716
R1c	44,260	47,923	92,183
total	102,304	102,781	205,085



cf. PREVIOUS SURVEY 19th September 2012

		inflow	outflow	total
To KANDY	R1a	34,680	25,295	59,975
To WATTALA	R1b	18,304	25,417	43,721
To COLOMBO	R1c	40,739	43,011	83,750
	total	59,043	68,428	187,446

[R2] NAWALOKA ROUNDABOUT

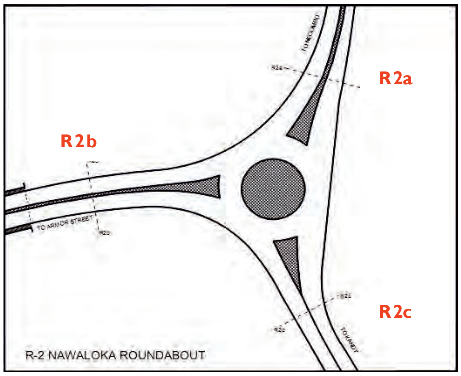
RESULT OF SURVEY

1st SURVEY 20th March 2013

	inflow	outflow	total
R2a	39,303	36,830	71,081
R2b	28,898	21,741	50,639
R2c	19,516	20,122	39,638
total	87,717	78,693	166,410

2nd SURVEY 2nd April 2013

	inflow	outflow	total
R2a	38,468	37,500	71,081
R2b	28,397	28,196	56,593
R2c	21,826	22,890	44,716
total	88,691	88,586	177,277



cf. PREVIOUS SURVEY 20th September 2012

		inflow	outflow	total
To NEGOMBO	R2a	40,775	44,634	85,409
To TOTALOANGA	R2b	28,933	24,209	53,142
To KANDY	R2c	21,998	22,863	44,861
	total	91,706	91,706	183,412

[J1] KELANI POWER STATION JUNCTION

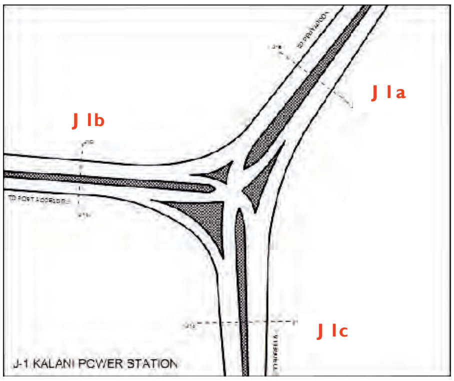
RESULT OF SURVEY

1st SURVEY 21th March 2013

	inflow	outflow	total
J1a	58,588	48,455	107,043
J1b	21,580	20,851	42,431
J1c	43,489	54,351	97,840
total	123,657	123,657	247,314

2nd SURVEY 4th April 2013

	inflow	outflow	total
J1a	56,555	46,071	102,626
J1b	21,776	20,883	42,659
J1c	40,995	52,372	93,367
total	119,326	119,326	238,652



cf. PREVIOUS SURVEY

20th September 2012

		inflow	outflow	total
To PELINGAYAGODA	J 1a	58,121	49,657	107,778
To INGURUKADE	J 1b	18,444	18,424	36,868
To COLOMBO	J 1c	43,820	52,304	96,124
	total	120,385	120,385	240,770

[J2] ORUGODAWATHTHA JUNCTION

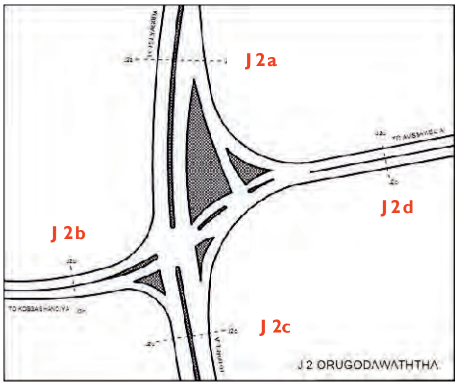
RESULT OF SURVEY

1st SURVEY 19th March 2013

	inflow	outflow	total
J 2a	38,041	39,671	77,712
J 2b	9,569	12,315	21,884
J 2c	44,265	43,148	87,413
J 2d	20,481	17,222	37,703
total	112,356	112,356	224,712

2nd SURVEY 4th April 2013

	inflow	outflow	total
J 2a	43,359	40,963	84,322
J 2b	8,769	11,607	20,376
J 2c	44,918	47,913	92,831
J 2d	19,764	16,327	36,091
total	116,810	116,810	233,620



cf. PREVIOUS SURVEY

No data available

[J3] SAMANTHA CINEMA JUNCTION

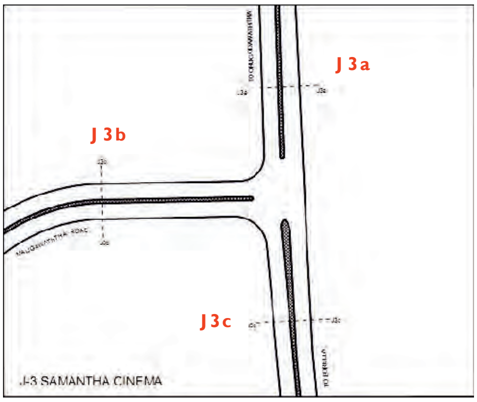
RESULT OF SURVEY

1st SURVEY 19th March 2013

	inflow	outflow	total
J 3a	47,703	46,211	93,914
J 3b	30,491	29,040	59,531
J 3c	41,812	44,755	86,567
total	120,006	120,006	240,012

2nd SURVEY 4th April 2013

	inflow	outflow	total
J 3a	50,587	42,969	93,556
J 3b	25,724	28,384	54,108
J 3c	38,372	43,330	81,702
total	114,683	114,683	229,366

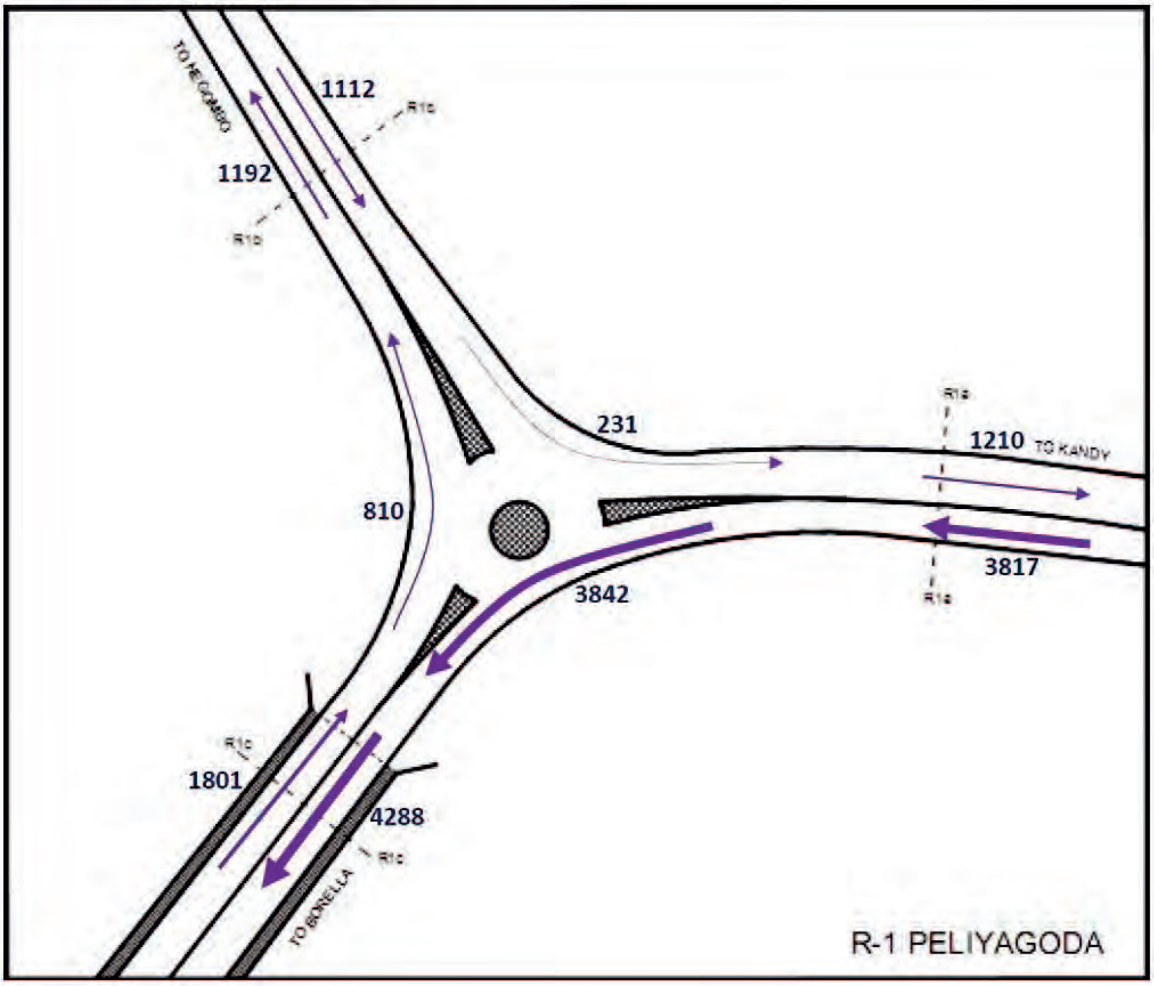


cf. PREVIOUS SURVEY

No data available

The peak hour turning volume diagrams were developed based on the results. Following show the sample of the results for each location. The original results were developed for three periods (7:00am-8:00am, 1:00pm-2:00pm, 5:00pm-6:00pm) with two survey dates for six survey locations (in total 36 diagrams).

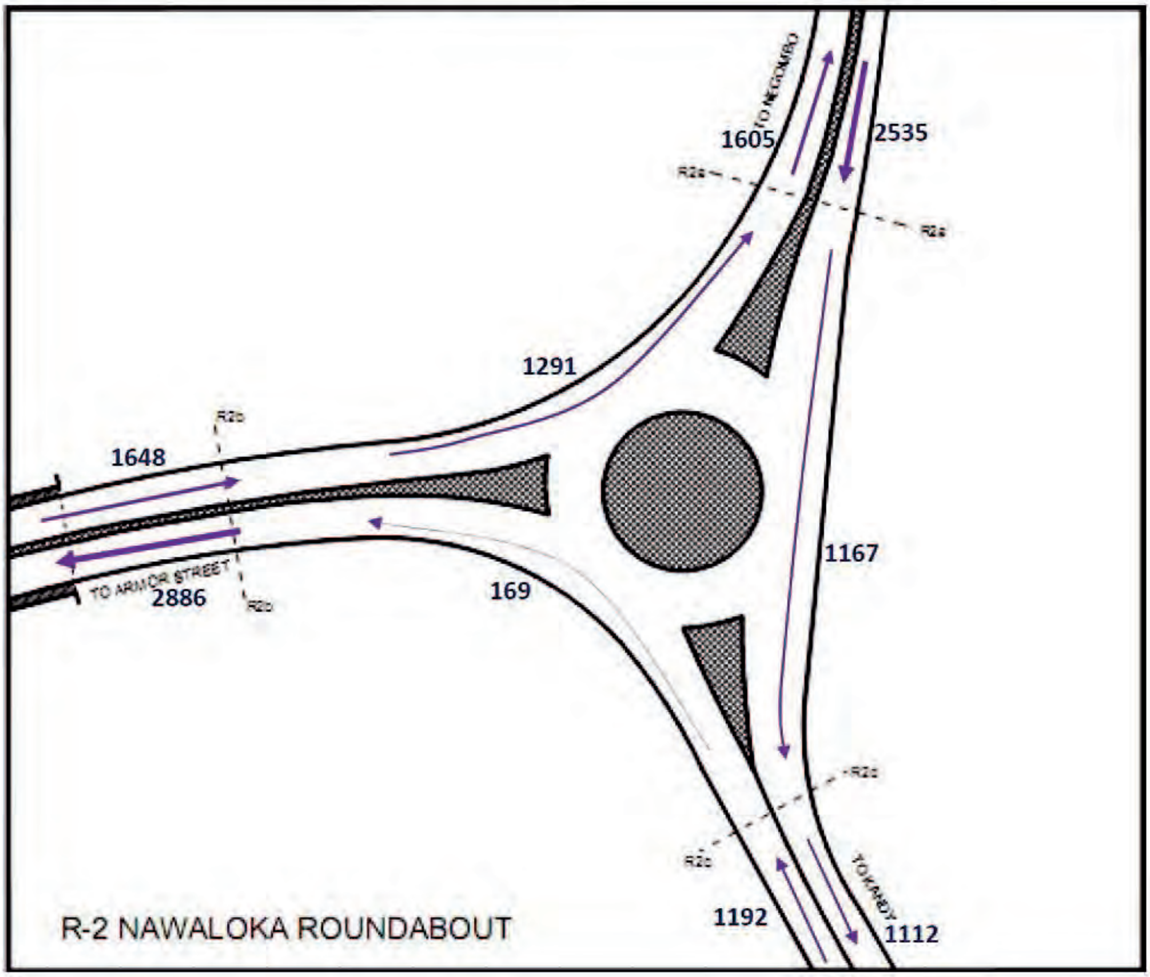
Vehicle count data @ R1 between from 7:00 am to 8:00 am



xxxxx - Vehicle count data @ R1 On 20-03-2013

Movement	No. of vehicles during 7:00 am to 8:00 am	Movement	No. of vehicles during 7:00 am to 8:00 am
C2-R1	3817	R1a-R1c	3842
R1-C2	1210	R1b-R1a	0231
R1-J1	4288	R1c-R1b	0810
J1-R1	1801		
R1-R2	1192		
R2-R1	1112		

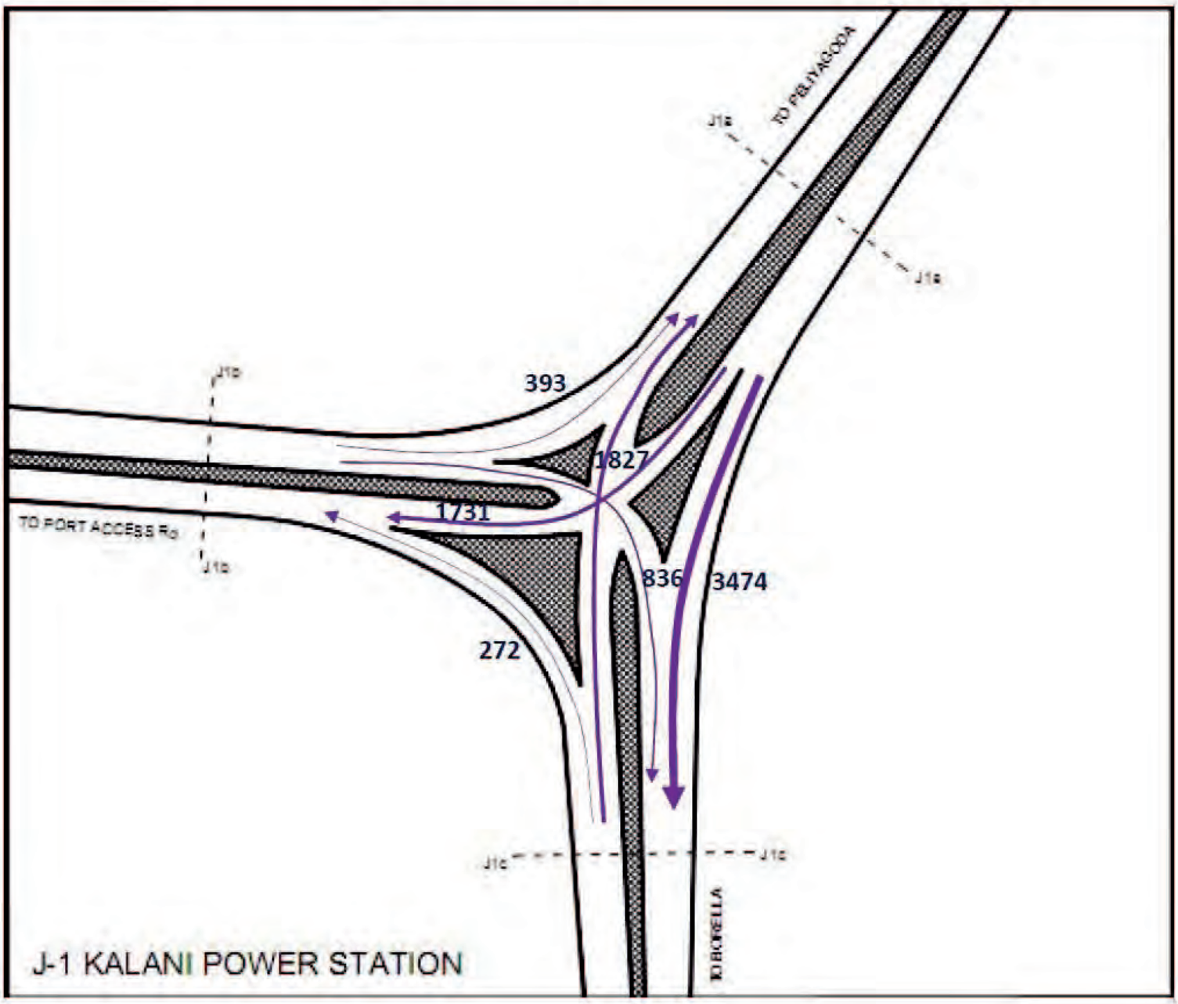
Vehicle count data @ R2 between from 7:00 am to 8:00 am



XXXXX - Vehicle count data @ R2 On 20-03-2013

Movement	No. of vehicles during 7:00 am to 8:00 am	Movement	No. of vehicles during 7:00 am to 8:00 am
C1-R2	2535	R2a-R2c	1167
R2-C1	1605	R2a-R2a	1291
R2-J4	2886	R2c-R2b	0169
J4-R2	1648		
R1-R2	1192		
R2-R1	1112		

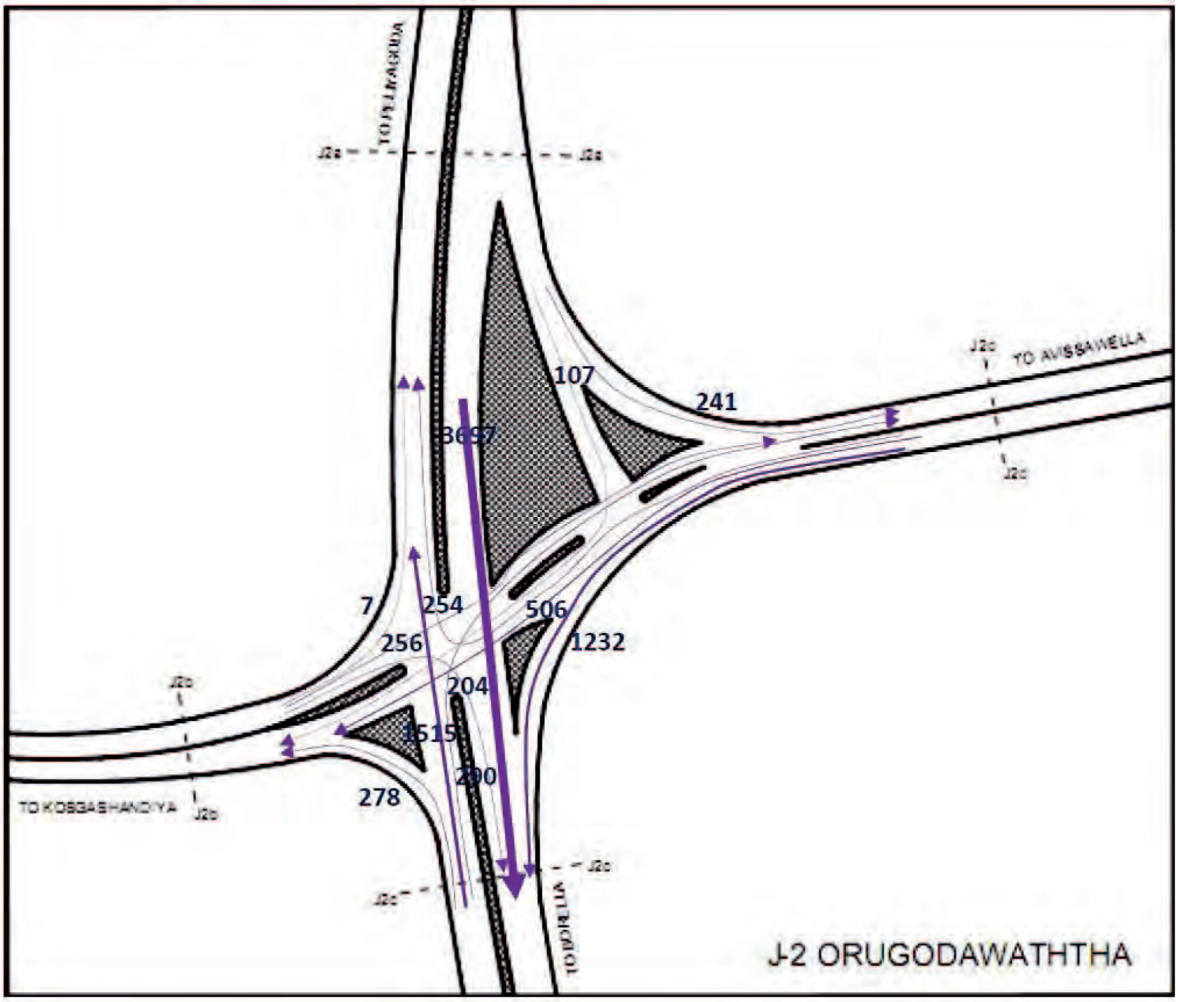
Vehicle count data @ J1 between from 7:00 am to 8:00 am



xxxxx - Vehicle count data @ J1 On 21-03-2013

Movement	No. of vehicles during 7:00 am to 8:00 am
J1a-J1b	1731
J1a-J1c	3474
J1b-J1a	0393
J1b-J1c	0836
J1c-J1a	1827
J1c-J1b	0272

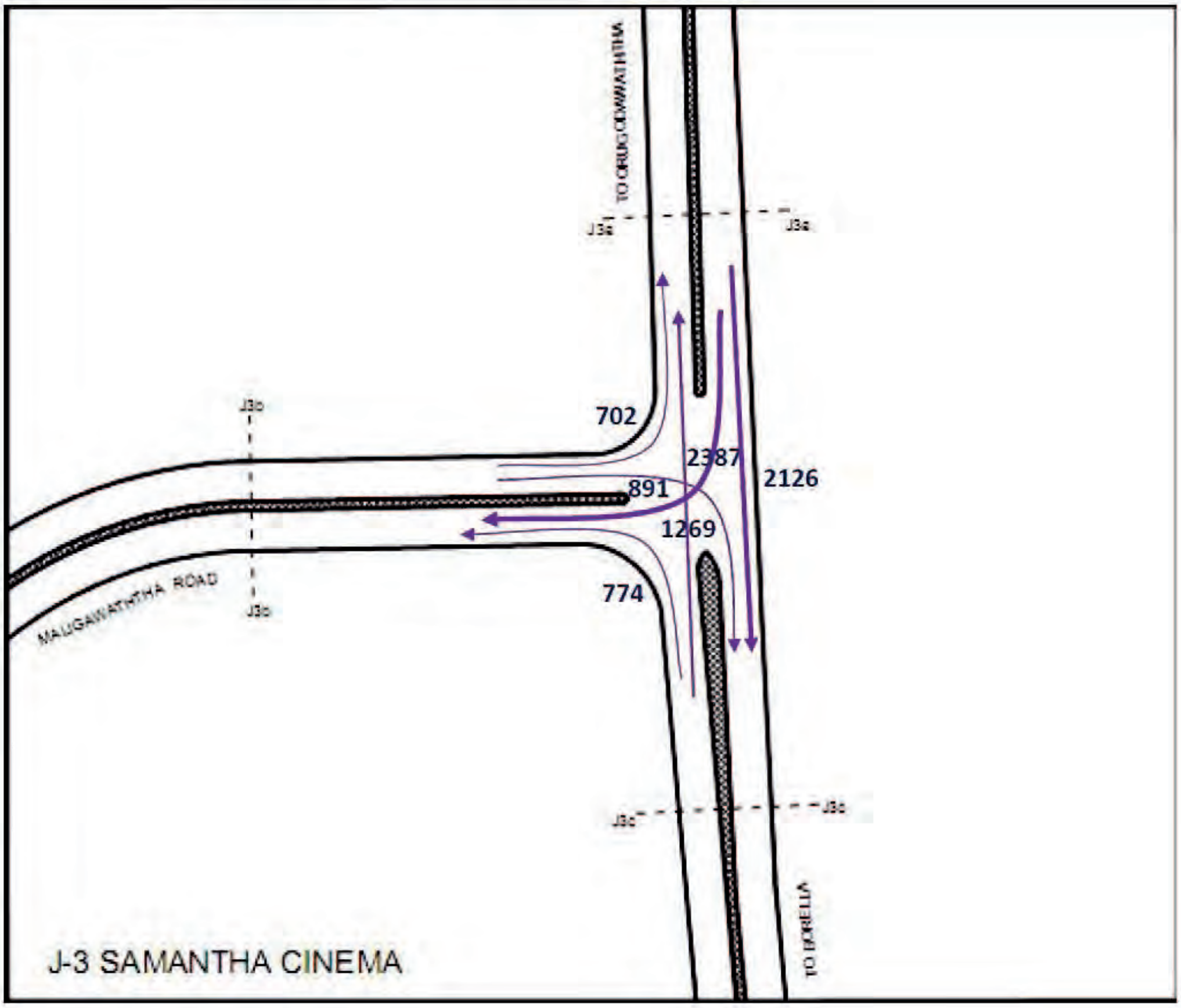
Vehicle count data @ J2 between from 7:00 am to 8:00 am



xxxxx - Vehicle count data @ J2 On 19-03-2013

Movement	No. of vehicles during 7:00 am to 8:00 am	Movement	No. of vehicles during 7:00 am to 8:00 am
J2a-J2b	0107	J2c-J2a	1515
J2a-J2c	3697	J2c-J2b	0278
J2a-J2d	0241	J2c-J2d	0290
J2b-J2a	0007	J2d-J2a	0254
J2b-J2c	0204	J2d-J2b	0506
J2b-J2d	0256	J2d-J2c	1232

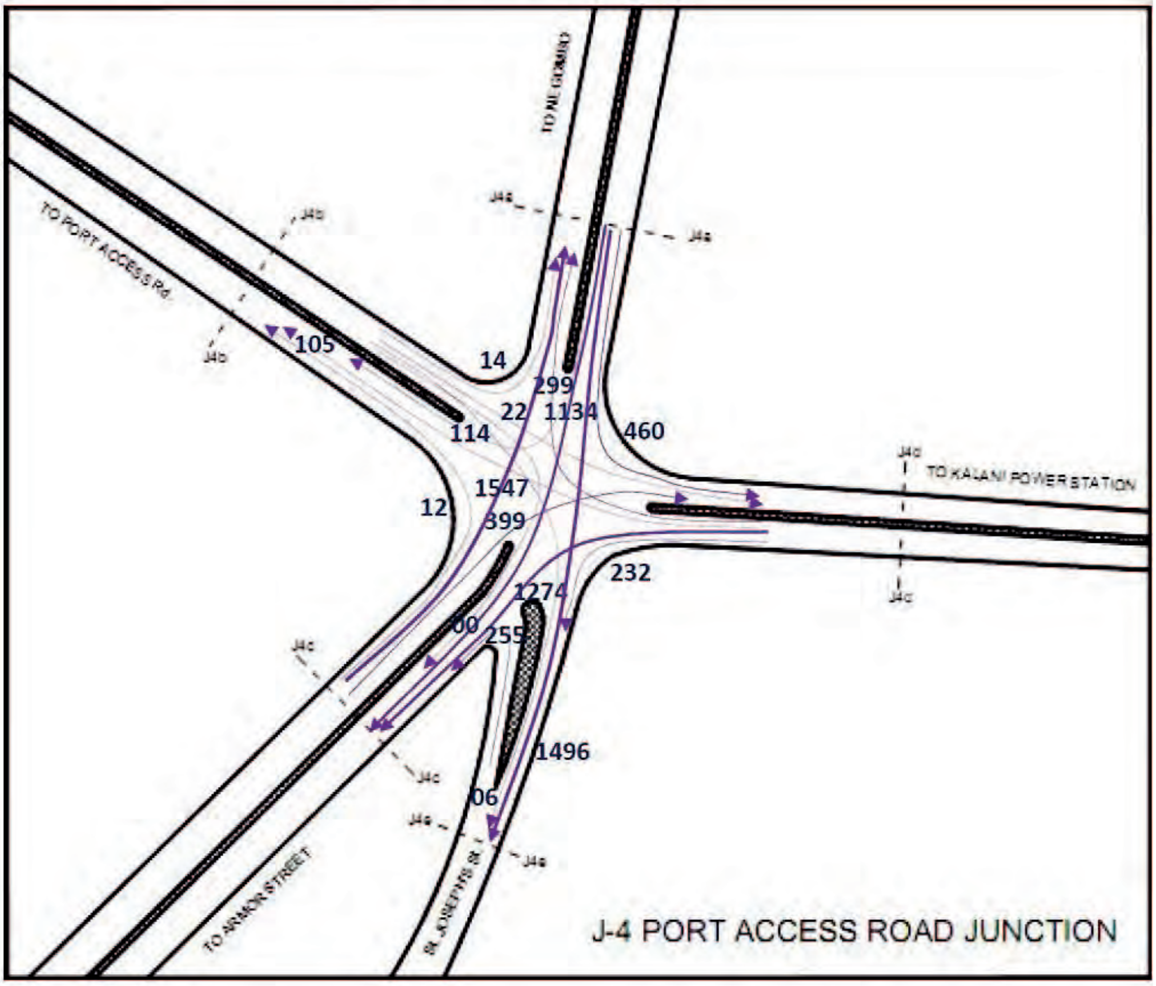
Vehicle count data @ J3 between from 7:00 am to 8:00 am



xxxxx - Vehicle count data @ J3 On 19-03-2013

Movement	No. of vehicles during 7:00 am to 8:00 am
J3a-J3b	2387
J3a-J3c	2126
J3b-J3a	0702
J3b-J3c	0891
J3c-J3a	1269
J3c-J3b	0774

Vehicle count data @ J4 between from 7:00 am to 8:00 am



xxxxx → - Vehicle count data @ J4 On 21-03-2013

Movement	No. of vehicles during 7:00 am to 8:00 am	Movement	No. of vehicles during 7:00 am to 8:00 am	Movement	No. of vehicles during 7:00 am to 8:00 am
J4a-J4b	0114	J4b-J4d	0022	J4d-J4b	0105
J4a-J4c	1134	J4b-J4e	0006	J4d-J4c	1274
J4a-J4d	0460	J4c-J4a	1547	J4d-J4e	0232
J4a-J4e	1496	J4c-J4b	0012	J4e-J4c	0255
J4b-J4a	0014	J4c-J4d	0399		
J4b-J4c	0000	J4d-J4a	0299		

1.2 Travel Speed Survey

In order to identify congested bottlenecks and its causes, Travel Speed Survey was conducted by utilizing vehicles equipped with the Global Positioning System (GPS).

Figure 1 shows the survey routes which consist of 4 routes described as follows;

- Route 1 (approx. 29.6 km): Yakkala junction (Gampaha) to CTO junction (Colombo Centre),
- Route 2 (approx. 29.0 km): Yakkala junction (Gampaha) to Kanatta Junction (Base Line),
- Route 3 (approx. 20.8 km): Ja-Ela junction (Gampaha) to CTO junction (Colombo Centre), and
- Route 4 (approx. 20.5 km): Ja-Ela junction (Gampaha) to Kanatta Junction (Base Line).

Each route was divided into intermediate sections where average speed was required to be identified. Figure 1 also shows the intermediate points.

Figure 1: Survey Routes and Section Points

The survey was carried out on two or more working days from Monday to Friday, excluding Monday and Friday. For the Route 1 to 3, the survey was conducted into four periods such as i) 6:30 AM to 9:00 AM, ii) 9:30 AM to 12:00 PM, iii) 1:00 PM to 3:30 PM and iv) 4:00 PM to 6:30 PM. For the Route 4, the survey was conducted into three periods such as i) 9:30 AM to 12:00 PM, ii) 1:00 PM to 3:30 PM and iii) 4:00 PM to 6:30 PM. The enumerator droved each entire route from the start point to end point and the way to back to start point.

Table 1 Details of Dates and Survey Period for Each Route

Ref. No.	Travel Speed Survey Date	Route			Survey Starting Time	Survey End Time
		No.	Starting Point	Ending Point		
1	13th Mar 2013	Route 2	Yakkala Junction	Kanaththa Junction	6:30 am	6:30 pm
2	14th Mar 2013	Route 4	Ja-Ela	Kanaththa Junction	6:30 am	6:30 pm
3	1st Apr 2013	Route 3	Ja-Ela	CTO Junction	6:45 am	6:45 pm
4	2nd Apr 2013	Route 1	Yakkala Junction	CTO Junction	6:30 am	6:30 pm
5	3rd Apr 2013	Route 3	Ja-Ela	CTO Junction	6:30 am	6:30 pm
6	4th Apr 2013	Route 1	Yakkala Junction	CTO Junction	6:45 am	6:45 pm
7	5th Apr 2013	Route 4	Ja-Ela	Kanaththa Junction	6:45 am	6:45 pm
8	9th Apr 2013	Route 2	Yakkala Junction	Kanaththa Junction	6:45 am	6:45 pm
9	10th Apr 2013	Route 3 (Missing Trip on 3rd Apr 2013)	Ja-Ela	CTO Junction	6:15 pm	-
		Route 4 (Missing 2 Trips on 5th Apr 2013)	Ja-Ela	Kanaththa Junction	3:15 pm & 6:15 pm	-

In order to obtain an average speed on the selected road sections a “Floating Vehicle Method”, with six GPS tracking devices (GPS logger) were used.

All the drivers were instructed always to follow road rules and follow the specified route unless instructed by the traffic police and maintain its own travel speed such a way that balancing passing vehicle and passed vehicle.

Each vehicle equipped with a GPS logger dispatched from starting point of each route at 30min intervals. All GPS loggers were set to record the location co-ordinate at 10 second intervals. Each surveyor recorded the time at each section check points and any special reasons for delays for his trip, while on the move. The time recording based on wrist watches synchronized with the GPS logger timer. After reaching to the terminus point of each route, vehicles were returned back immediately while recording was carried out as before.

The GPS track log data was retrieved by the software accompanied with the GPS Loggers. All the log files saved as raw file (.itm file) and each track log was converted to .kml file which compatible with Google Earth for the average speed calculation.

The methodology of calculation is described below;

1. Length of each segment was obtained, using Google Earth data and the lengths measured to the approximate middle of the junctions,
2. Each segment was given section ID for avoid confusion and errors in data processing,
3. Export data logger track file to Google Earth, and at each section point data logger time was extracted,
4. Data was sorted based on section ID and identified the trips at each section within each hourly time bands,
5. Average Speed was calculated based on the hourly data for each section. Common section such as, Ja-ela to Peliayagoda and Yakkala to Peliyagoda, have more trips within each hour at each section, and
6. The calculated average speed data for each hour, classified in to speed class range of 5km/h, marked on a map with graduated color bands.

Following figures are as sample results. Each diagrams for the route and time periods were available into the soft data set.

Figure 2 Diagram for Average Travel Speed toward to Colombo (8:00am to 9:00am)

Figure 3 Diagram for Average Travel Speed leaving from Colombo (7:00pm to 8:00pm)

1.3 Traffic Signal Phasing Survey

The objective of this survey is to obtain the present signal phase pattern of each intersection for use of micro-scopic traffic simulation.

The survey conducted at following four signalized junctions and shown in Figure 1, such as i) J1 – New Kelani Powerhouse Junction, ii) J2 – Orugodawatta Junction, iii) J3 – Samantha Cinema Junction, and iv) J4 – Port Access Road Junction.

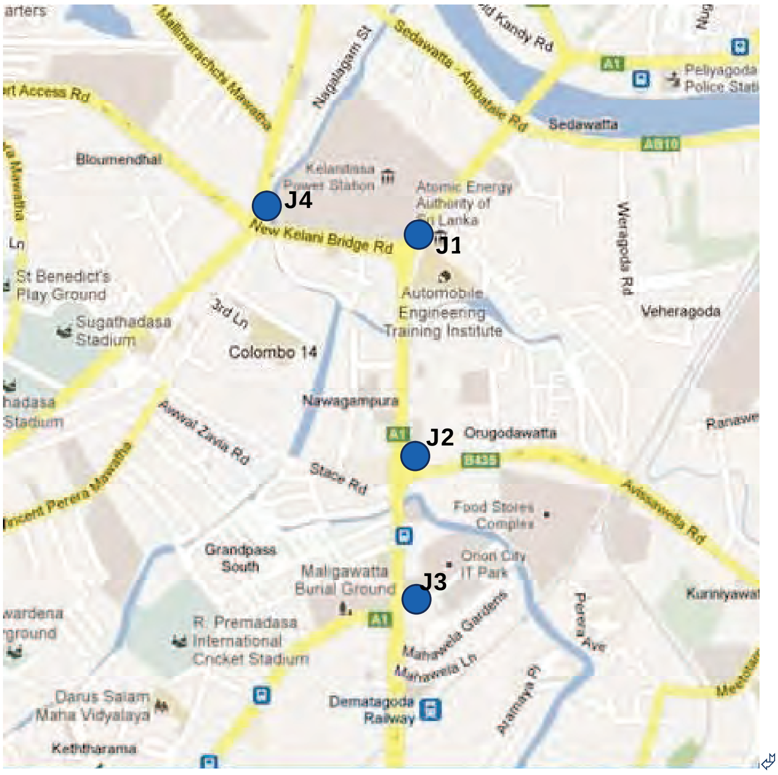


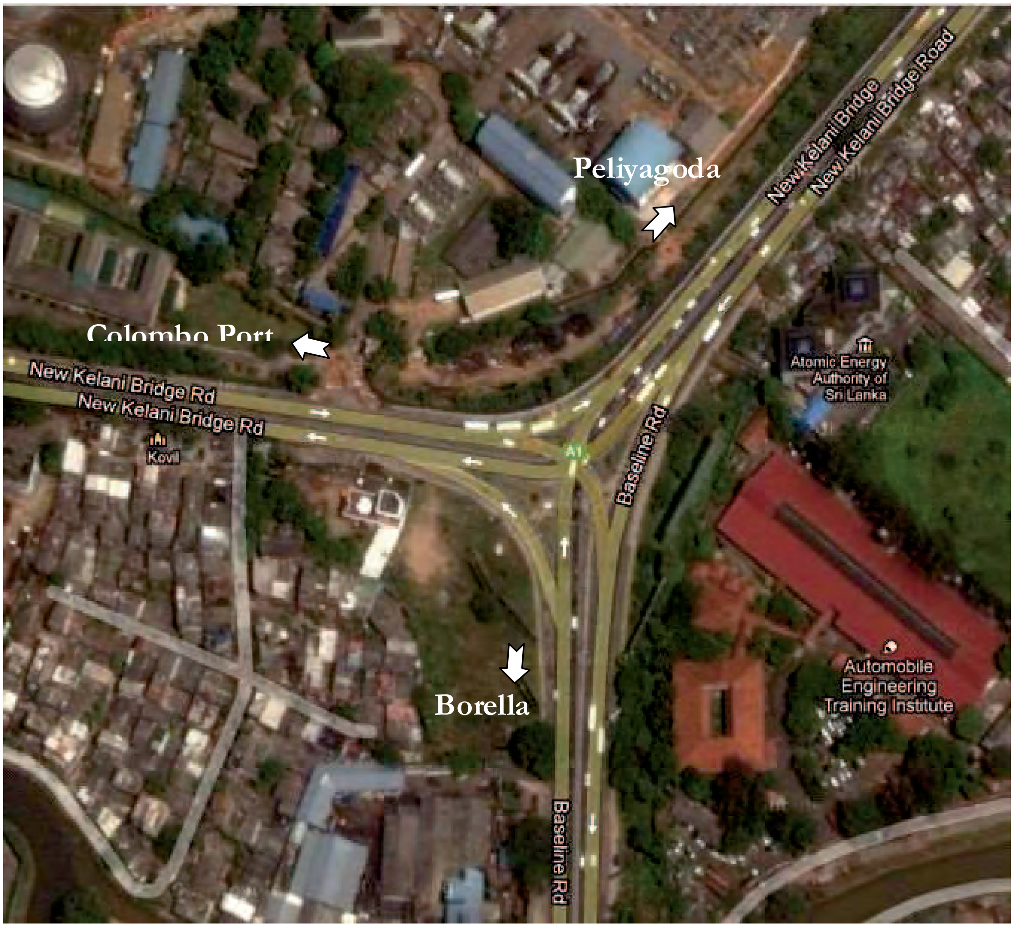
Figure 1 Survey Locations for Traffic Signal Survey

The survey to be conducted on 2 weekdays (either Tuesday, Wednesday or Thursday) and to be conducted for Four periods (6:30 AM to 9:00 AM, 9:30 AM to 12:00 PM, 1:00 PM to 3:30 PM and 4:00 PM to 6:30 PM). The table-1 below shows details of survey date for each location.

Table-1 Survey Date for each Survey Location

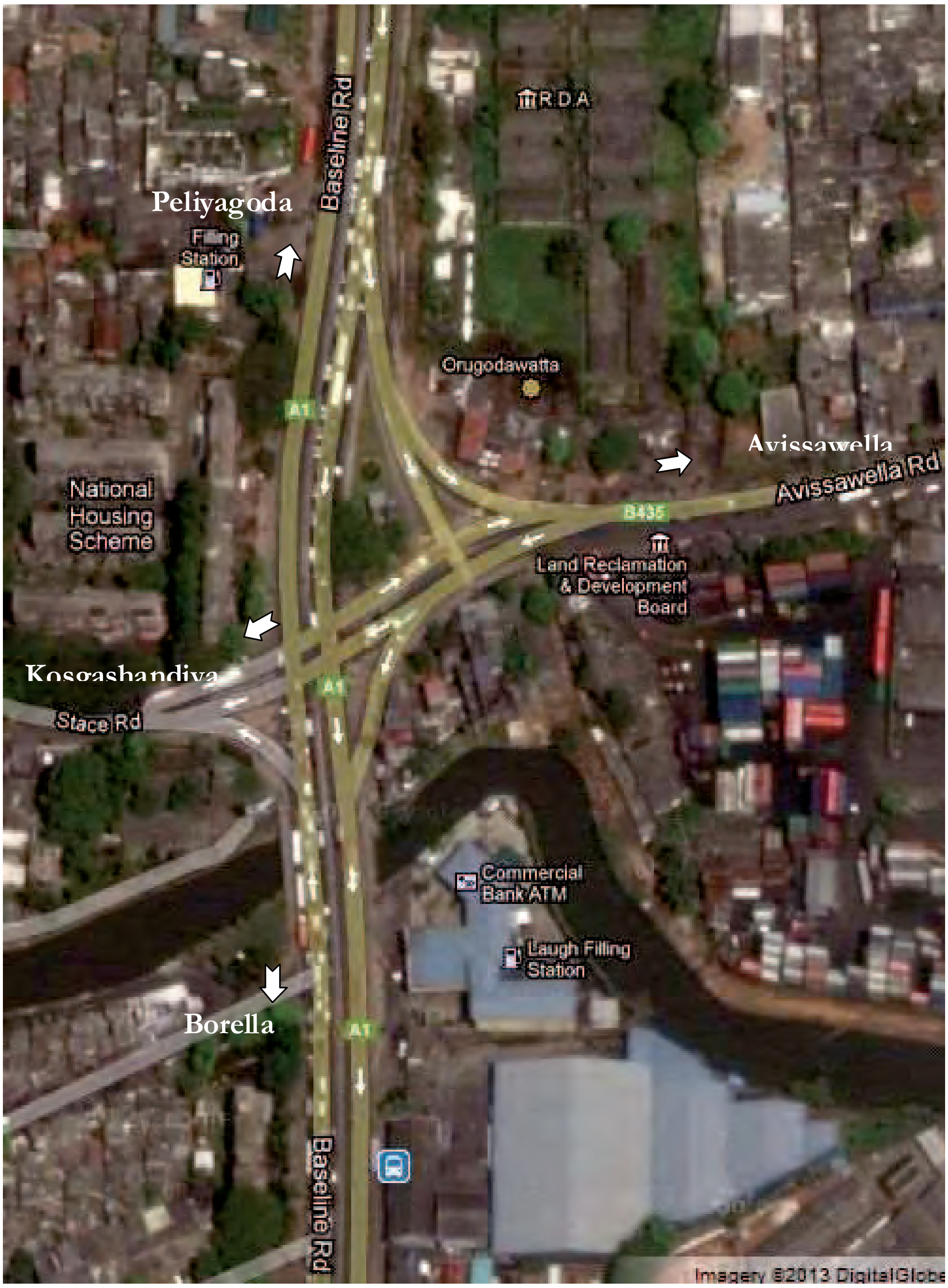
Ref. No.	junction	survey date 1	survey date 2
1	J1- Kelani Tissa Powerstation Junction	21 Mar 2013	03 Apr 2013
2	J2- Orugodawatta Junction	02 Apr 2013	04 Apr 2013
3	J3- Samantha Cinema Junction	02 Apr 2013	04 Apr 2013
4	J4- Port Access Road Junction	21 Mar 2013	03 Apr 2013

Prior to carry out the survey, Signal phasing pattern was obtained from corresponding authority (RDA and CMC) and survey forms were prepared accordingly. The signal phasing pattern obtained from each intersection is given on Figure 2a to 2d.



P1 P2 P3

Figure 2a: Signal Phasing at J1- Kelani Thissa Powerstatoin Junction



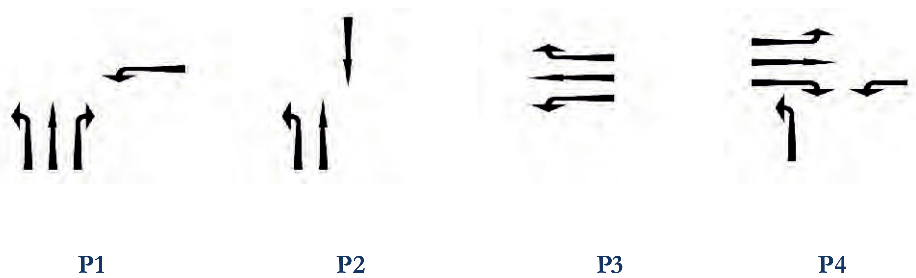
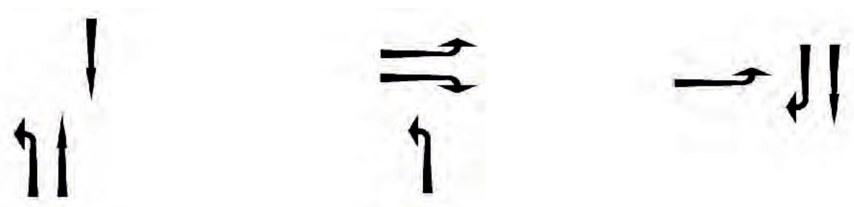
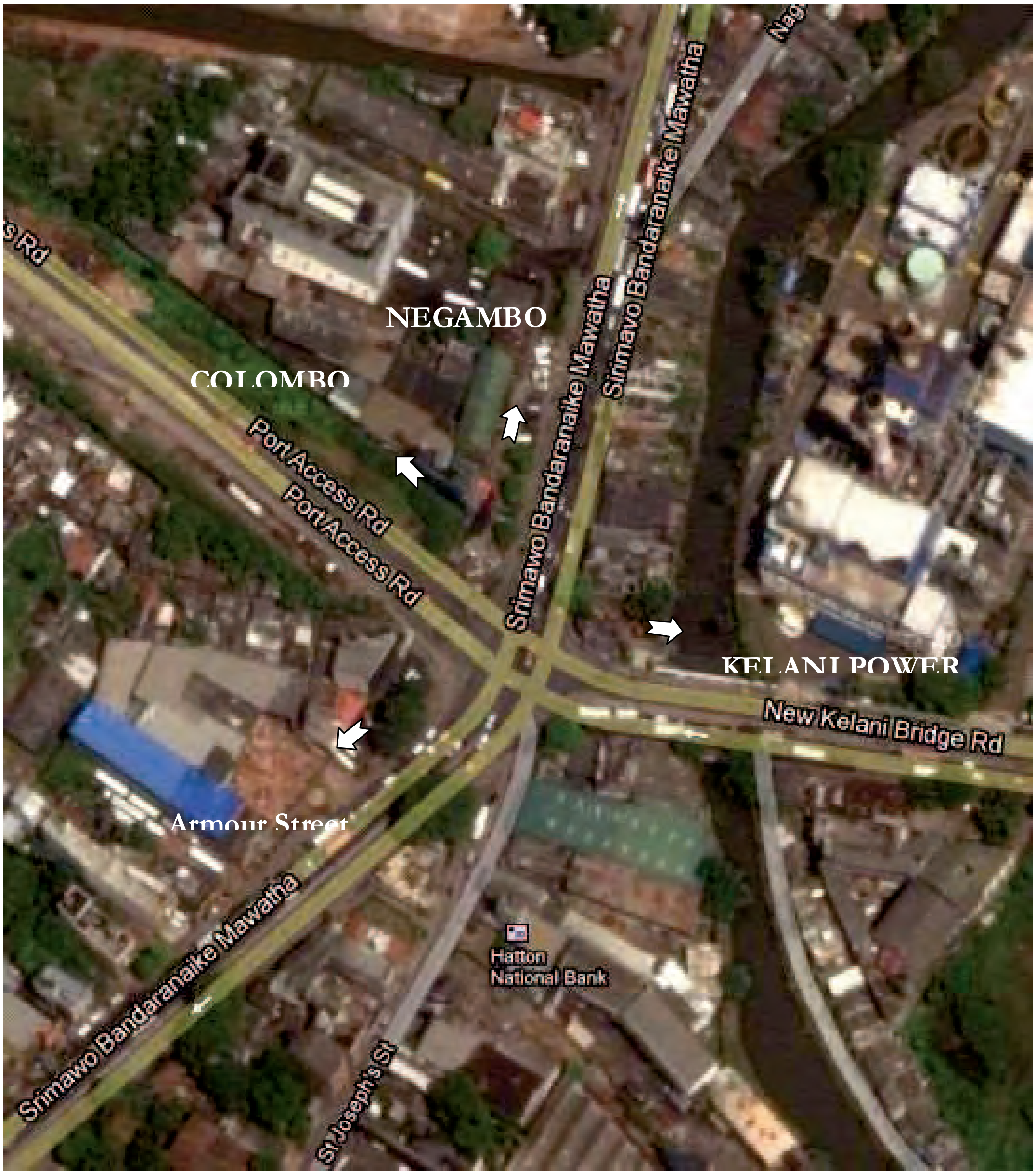


Figure 2b: Signal Phasing at J2- Orugodawatta Junction



P1 P2 P3

Figure 2c: Signal Phasing at J3 – Samantha Cinema Junction



P1 P2 P3 P4

Figure 2d: Signal Phasing at J4 – Port Access Road Junction

During busy hours, Police officers were controlling the traffic manually. In such instances the surveyors recorded the traffic directions controlled by the police officer with corresponding time and sketch. Following diagrams the results of field survey for each survey location.

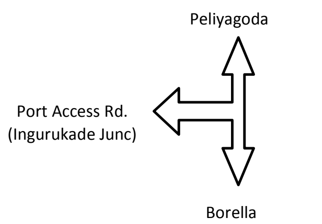
PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - SIGNAL CONTROL

Enumerators Name: Kumara K.D.L.P **Date: 21/03/2013** **Survey Location:** J1-Kalani Power Station Junction **Sheet No.:** ……………

Vehicle Que Direction; NA **Road Name:** ………………………………………………………

Weather: DRY/~~HEAVY RAIN/LIGHT RAIN~~

Signal Phasing Time / Observe Time	P 1 (Seconds)	P 2 (Seconds)	P 3 (Seconds)
6.30	65	30	40
7.30	50	30	180
8.00	70	50	180
8.30	100	60	160
9.00	60	30	120
9.30	60	30	105
10.00	60	30	100
11.00	60	45	45
12.00	60	45	45
13.00	75	30	45
14.00	75	30	45
15.00	60	30	50
16.00	80	50	45
16.30	125	35	44
17.00	75	25	37
17.30	70	40	41
18.00	94	45	40
18.30	133	40	39



Junction Schematic

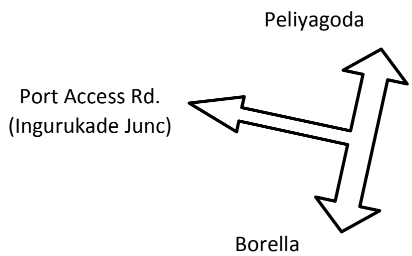
PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - SIGNAL CONTROL

Enumerators Name: Chathura Manoj **Date:** 03/04/201 **Survey Location:** J1 – Kelani Power Station **Sheet No.:** ……………

Vehicle Que Direction; turning from Paliyagoda to Port access road **Road Name:** ………Borella, Peliyagoda, Kotuwa, (Port access road)

Weather: DRY/~~HEAVY RAIN/LIGHT RAIN~~

Signal Phasing Time / Observe Time	P 1 (Seconds)	P 2 (Seconds)	P 3 (Seconds)
6.35 am	70	30	40
7.35 am	53	35	185
8.35 am	124	57	183
9.35 am	70	43	50
10.35 am	74	40	208
11.35 am	41	48	72
12.35 am	62	47	51
1.35 am	70	45	42
2.35 am	81	52	51
3.35 am	54	33	43
4.35 am	77	22	28
5.35 am	101	31	51
6.35 am	99	30	50



Junction Schematic

Figure 3a: Signal Phasing at J1- Kelani Thissa Powerstation Junction

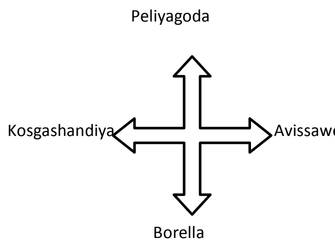
PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - SIGNAL CONTROL

Enumerators Name: ······· Kasun Thennakoon **Date:** 02.04.2013 **Survey Location:** J2–Orugodawaththa Junction **Sheet No.:** ·············

Vehicle Que Direction; NA **Road Name:** ···.

Weather: DRY/HEAVY RAIN/LIGHT RAIN

Signal Phasing Time / Observe Time	P 1 (Seconds)	P 2 (Seconds)	P 3 (Seconds)	P 4 (Seconds)
7.30 am	20	86	28	18
8.00 am	26	124	68	42
9.00 am	38	276	69	25
10.00 am	32	240	64	56
11.00 am	44	238	58	42
12.00 pm	96	184	76	47
1.00 pm	55	220	67	38
2.00 pm	110	170	97	85
3.00 pm	66	168	108	69
4.00 pm	170	185	92	52
5.00 pm	115	222	87	72
6.00 pm	168	165	80	82
6.30 pm	118	82	106	35



Junction Schematic

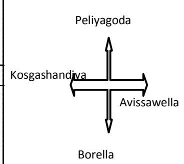
PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - POLICE CONTROL

Enumerators Name: ······· Kasun Thennakoon **Date:** 02.04.2013 **Survey Location:** J2–Orugodawaththa Junction **Sheet No.:** ···············.

Vehicle Que Direction; NA **Road Name:** ···.

Weather: DRY/HEAVY RAIN/LIGHT RAIN

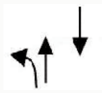
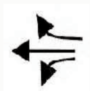
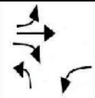
Signal Phase / Observe Time	P 1	P 2	P 3	P 4	P5
11.05 am	Duration (s) :	Duration (s) : 503	Duration (s) : 148	Duration (s) :	Duration (s) :
11.55 am	Duration (s) : 42	Duration (s) : 163	Duration (s) :	Duration (s) : 68	Duration (s) :
1.30 pm	Duration (s) : 38	Duration (s) : 272	Duration (s) : 94	Duration (s) :	Duration (s) :
2.30 pm	Duration (s) :	Duration (s) : 92	Duration (s) : 36	Duration (s) :	Duration (s) :
4.45 pm	Duration (s) : 74	Duration (s) : 160	Duration (s) : 130	Duration (s) : 82	Duration (s) :
5.15 pm	Duration (s) : 52	Duration (s) : 90	Duration (s) : 82	Duration (s) :	Duration (s) :
5.30 pm	Duration (s) : 67	Duration (s) : 58	Duration (s) : 75	Duration (s) :	Duration (s) :
5.45 pm	Duration (s) : 62	Duration (s) : 50	Duration (s) : 148	Duration (s) : 54	Duration (s) :
6.15 pm	Duration (s) : 145	Duration (s) : 115	Duration (s) : 65	Duration (s) : 92	Duration (s) :

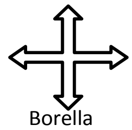


Junction Schematic

PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - SIGNAL CONTROL

Enumerators Name: ········Kusum **Date:** 04.04.2013 **Survey Location:** J2-Orugodawa **Sheet No.:** ················.
Vehicle Que Direction; NA **Road Name:** ···········Stace Road
Weather: DRY/HEAVY RAIN/LIGHT RAIN

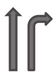
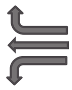
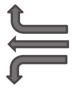
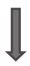
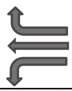
Signal Phasing Time / Observe Time	 P 1 (Seconds)	 P 2 (Seconds)	 P 3 (Seconds)	 P 4 (Seconds)
6.30 am	56	178	47	22
7.00 am	115	217	92	25
8.00 am	80	238	75	28
9.00 am	95	420	88	64
10.00 am	178	165	52	48
11.00 am	183	225	184	57
12.00 pm	117	204	105	38
1.00 pm	110	130	55	27
2.00 pm	181	138	43	52
3.00 pm	118	128	102	65
4.00 pm	129	182	125	68
5.00 pm	138	166	84	75
6.00 pm	83	124	132	34
6.30 pm	124	223	112	98

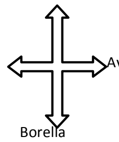


Junction Schematic

PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - POLICE CONTROL

Enumerators Name: ········ Kasun Thennakoon **Date:** 04.04.2013 **Survey Location:** J2-Orugodawaththa Junction **Sheet No.:** ················.
Road Name : Stace Road
Weather: DRY/HEAVY RAIN/LIGHT RAIN

Signal Phase / Observe Time	P 1	P 2	P 3	P 4	P5
9.15 am	Duration (s) :	 Duration (s) : 85	Duration (s) :	Duration (s) :	Duration (s) :
5.15 pm	 Duration (s) : 62	Duration (s) :	 Duration (s) : 46	Duration (s) :	Duration (s) :
5.30 pm	Duration (s) :	 Duration (s) : 42	 Duration (s) : 108	Duration (s) :	Duration (s) :
6.15 pm	Duration (s) :	 Duration (s) : 90	 Duration (s) : 34	Duration (s) :	Duration (s) :



Junction Schematic

Figure 3b: Signal Phasing at J2- Orugodawatta Junction

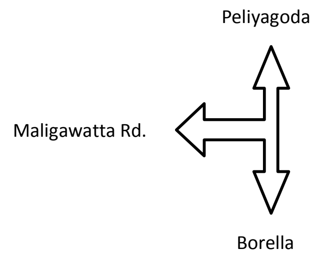
PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - SIGNAL CONTROL

Enumerators Name: ······· Kasun Thennakoon **Date:** 02.04.2013 **Survey Location:** J3–Samantha Cinema Junction **Sheet No.:** ·············

Vehicle Que Direction; NA **Road Name:** ···.

Weather: DRY/HEAVY RAIN/LIGHT RAIN

Signal Phasing Time / Observe Time	P 1 (Seconds)	P 2 (Seconds)	P 3 (Seconds)
6.30 am			
7.00 am	120	121	67
8.00 am	60	50	156
9.00 am	55	30	60
10.00 am	80	40	30
11.00 am	20	55	40
12.00 pm	15	60	35
1.00 pm	80	160	90
2.00 pm	25	40	66
3.00 pm	130	30	53
4.00 pm	63	37	52
5.00 pm	40	23	46
6.00 pm	137	25	40



Junction Schematic

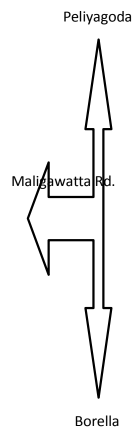
PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - POLICE CONTROL

Enumerators Name: ······· Chathura Manoj **Date:** 02.04.2013 **Survey Location:** J3–Samantha Cinema Junction **Sheet No.:** ················.

Vehicle Que Direction; NA **Road Name:** Baseline Road

Weather: DRY/HEAVY RAIN/LIGHT RAIN

Signal Phase / Observe Time	P 1	P 2	P 3	P 4	P5
10.15 am	Duration (s) : 50	Duration (s) : 40	Duration (s) : 60	Duration (s) :	Duration (s) :
10.30 am	Duration (s) : 50	Duration (s) : 30	Duration (s) : 40	Duration (s) : 42	Duration (s) : 40
1.15 pm	Duration (s) : 135	Duration (s) : 60	Duration (s) : 80	Duration (s) :	Duration (s) :
4.10 pm	Duration (s) : 40	Duration (s) :	Duration (s) :	Duration (s) :	Duration (s) :
4.15 pm	Duration (s) : 20	Duration (s) : 15	Duration (s) :	Duration (s) :	Duration (s) :



Junction Schematic

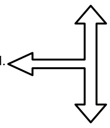
PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - SIGNAL CONTROL

Enumerators Name: ······· Nipun   **Date:** 04.04.2013   **Survey Location:** J3–Samantha Cinema Junction   **Sheet No.:** ················.

Vehicle Que Direction; NA   **Road Name:** ···.

Weather: DRY/HEAVY RAIN/LIGHT RAIN

Signal Phasing Time / Observe Time	 P 1 (Seconds)	 P 2 (Seconds)	 P 3 (Seconds)	Remarks
7.02 am	64.43	31.55	62.42	
7.17 am	67.89	39	176.77	Traffic
7.36 am	54.11	34.06	249.39	signals
7.55 am	62.41	19.88	161.96	controlled
8.28 am	63.44	24.8	156.78	by
8.43 am	66.29	35.16	96.39	traffic
8.55 am	91.6	59.16	116.81	police
9.10 am	86.77	57.49	23.84	
9.35 am	45.42	43	46.43	
9.51 am	43.7	41.46	65.89	Signal controll
11.51 am	56.7	35.99	41.15	
12.53 pm	68.65	38.71	51.49	
1.51 pm	42.79	49.51	78.35	
2.51 pm	108.1	77.16	15.41	Traffic signals are controlled by traffic police
3.06 pm	58.01	50.26	78	Traffic signals are controlled by traffic police
3.21 pm	66.39	65.02	25.82	Signal controll
4.21 pm	55.36			
5.21 pm	42.6	89.26	57.16	Traffic signals are controlled by traffic police
5.37 pm	78.23	38.28	50.48	Traffic signals are controlled by traffic police
5.53 pm			29.19	Signal controll
6.25 pm	108.87	83.98	83	Traffic signals are controlled by traffic police



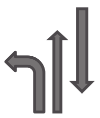
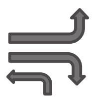
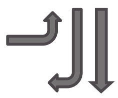
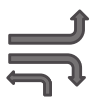
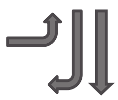
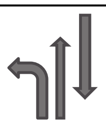
Junction Schematic

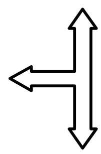
PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - POLICE CONTROL

Enumerators Name: ······· Nipun   **Date:** 04.04.2013   **Sheet No.:** ················.

Road Name: ....   **Survey Location:** J3–Samantha Cinema Junction

Weather: DRY/HEAVY RAIN/LIGHT RAIN

Signal Phase / Observe Time	P 1	P 2	P 3
10.51 am	 Duration (s) : 34.66	 Duration (s) : 41.97	 Duration (s) : 22.09
4.21 pm	Duration (s) :	 Duration (s) : 27.23	 Duration (s) : 38.25
5.53 pm	 Duration (s) : 79.54	 Duration (s) : 54.37	Duration (s) :



Junction Schematic

Figure 3c: Signal Phasing at J3 –Samantha Cinema Junction

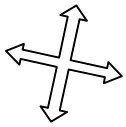
PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - SIGNAL CONTROL

Enumerators Name: .... **Date:** 03.04.2013 **Survey Location:** J4–Port Access Road Junction **Sheet No.:** ....

Vehicle Que Direction; NA **Road Name:** ....

Weather: DRY/HEAVY RAIN/LIGHT RAIN

Signal Phasing Time / Observe Time	P 1 (Seconds)	P 2 (Seconds)	P 3 (Seconds)	P 4 (Seconds)	P 5 (Seconds)
6.54 am	56.19	62.83	52.88	29.07	14.22
7.54 am	75.81	50.71	30.99	30.87	11.21
8.54 am	85.96	48	29.15	21.65	17.16
9.54 am	63.23	57.76	32.97	16.44	16.93
10.54 am	62.39	61.81	28.63	15.65	21.56
11.54 am	59.56	61	32.66	15.52	23.38
12.54 pm	58.16	77	24.07	13.34	18.59
1.54 pm	51.1	63.84	20.43	16.01	20.96
2.54 pm	57.62	73	24.09	20	20.31
3.54 pm	71.86	78.74		51.26	
4.54 pm		63.18	33.91	14.23	20.41



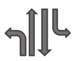
Junction Schematic

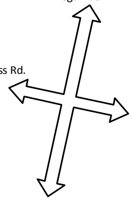
PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - POLICE CONTROL

Enumerators Name: .... Nipun **Date:** 03.04.2013 **Survey Location:** J4–Port Access Road Junction **Sheet No.:** ....

Vehicle Que Direction; NA **Road Name:** ....

Weather: DRY/HEAVY RAIN/LIGHT RAIN

Signal Phase / Observe Time	P 1	P 2	P 3	P 4	P5
3.58 pm					
	Duration (s) :	Duration (s) :	Duration (s) : 23.59	Duration (s) :	Duration (s) : 54.02
4.54 pm					
	Duration (s) : 93.00	Duration (s) :	Duration (s) :	Duration (s) :	Duration (s) :
5.54 pm					
	Duration (s) : 62.33	Duration (s) : 82.77	Duration (s) : 22.98	Duration (s) : 14.13	Duration (s) : 21.50
	Duration (s) :	Duration (s) :	Duration (s) :	Duration (s) :	Duration (s) :



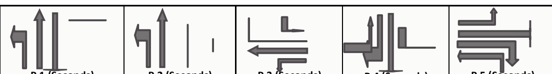
Junction Schematic

PREPARATORY SURVEY ON TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELENI BRIDGE
TRAFFIC SIGNAL PHASING AND QUE LENGTH SURVEY - SIGNAL CONTROL

Enumerators Name: .... **Date:** 21.03.2013 **Survey Location:** J4–Port Access Road Junction

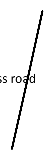
Vehicle Que Direction; NA **Road Name:** ....

Weather: DRY/HEAVY RAIN/LIGHT RAIN



Signal Phasing Time / Observe Time	P 1 (Seconds)	P 2 (Seconds)	P 3 (Seconds)	P 4 (Seconds)	P 5 (Seconds)
7.00 a.m.	55	50	30	25	20
8.00 a.m	70	20	40	20	15
9.00 a.m	60	60	40	14	25
10.00 a.m	66	56	33	20	22
11.00 a.m	68	49	34	18	19
12.00 p.m	67	55	62	16	35
1.00 p.m	66	58	23	24	25
2.00 p.m	17	54	28	15	15
3.00 p.m	76	81	56	35	12
4.00 p.m	54	43	15	22	18
5.00 p.m	120	66	22	39	30
6.00 p.m	81	129	38	37	31

Controlled by traffic police (2.00 p.m – 6.00 p.m)



Junction Schematic

Figure 4d: Signal Phasing at J4 – Port Access Road Junction

2 REFERENCE DATA FOR EACH STEPS IN THE METHODOLOGY OF TRAFFIC DEMAND FORECAST

Following sections show the reference data used for the each step in the methodology taken in traffic demand forecast, which are described in the chapter 3.

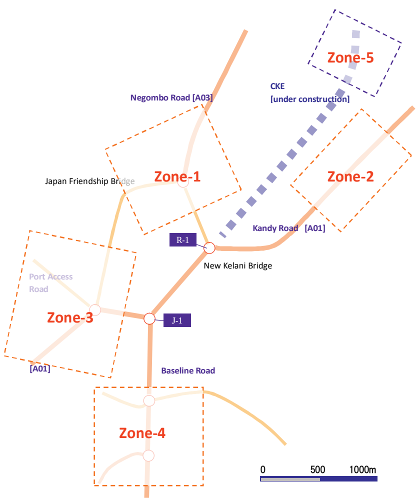
2.1 Origin-Destination Matrix Development

The current origin-destination matrix described in table 3.3.2 in the main report was developed by the result of traffic volume count survey, especially the tuning ratio at each intersection. The estimated traffic volume of inflow and outflow to each zone is based on the observed traffic volume at the cross section. Following table shows the cross section code for each inflow and outflow traffic in accordance with the traffic volume survey described in annex 1.1.1.

Table 1: Related Cross-section Code in the Traffic Volume Survey

Upper: Nos. of Vehicle
Middle: Nos. of Large Vehicle (Truck, Bus, Trailer)
*Bottom: **PCU***

Origin \ Destination	Zone-1	Zone-2	Zone-3	Zone-4	Total	Referenced cross section code in the traffic volume survey
Zone-1	0 (0) **0**	4,544 (691) **4,471**	2,986 (1,089) **4,043**	15,307 (2,684) **15,397**	22,837 (4,464) **23,911**	**R2c-out** **R1b-in**
Zone-2	6,535 (1,565) **7,875**	0 (0) **0**	5,191 (2,051) **6,898**	23,416 (3,645) **22,757**	35,142 (7,261) **37,530**	**R1a-in**
Zone-3	2,716 (919) **3,508**	6,692 (1,926) **7,373**	0 (0) **0**	4,765 (2,280) **8,151**	14,173 (5,125) **19,031**	**J1b-in** **J4d-out**
Zone-4	10,691 (2,090) **11,551**	25,722 (3,531) **24,128**	4,321 (988) **5,118**	0 (0) **0**	40,734 (6,609) 40,796	J2a-out J1c-in
Total	19,942 (4,574) **22,933**	36,958 (6,148) **35,972**	12,948 (4,128) **16,059**	43,488 (8,609) **46,305**	112,886 (23,459) **121,269**	
Referenced cross section code in the traffic volume survey	R2c-in R1b-out	R1a-out	J1b-out J4d-in	J2a-in J1c-out		

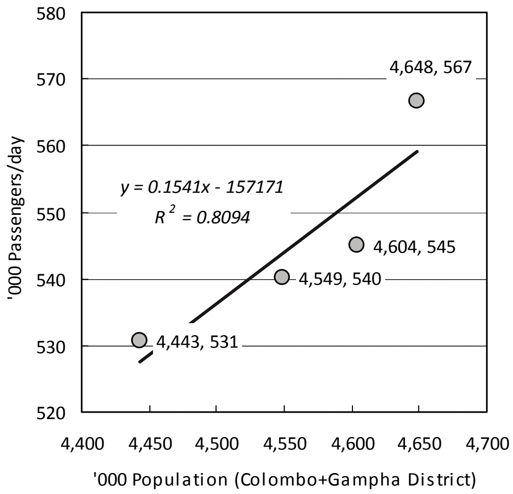


In the process of this estimation, each of six vehicle types was used, such as i) motor cycle, ii) 3-wheeler, iii) car, iv) bus, v) truck and vi) trailer. Above table is the result of total value of each categorised origin-destination traffic volume. Note that, due to the limitation of technical and enumerators' resources, different survey dates at the location, and two weekdays conducted at each location, the estimated results are not exactly the same of the survey results.

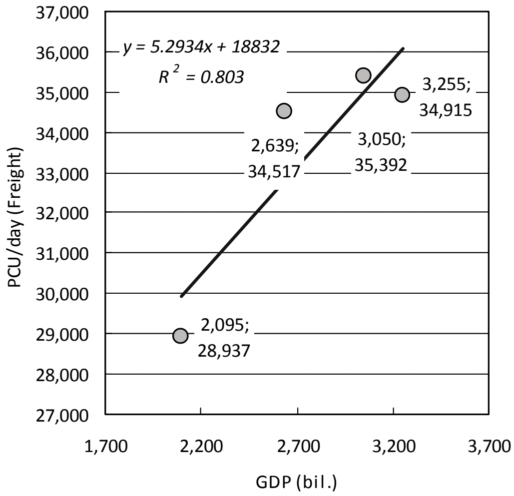
2.2 Liner Regression Model Development and Increments of Future Demand

In the section of 3.2.3, the linier regression models for passenger and freight transport at the target area were developed using the collected traffic volume in 2006, 2010, 2012 and 2013, which was described in table 3.2.1 in the main report.

Following figure shows the each value of independent and dependent variables and estimated parameters.



Passenger Traffic



Freight Traffic

In the case of future increment of traffic demands are calculated based on these formula and socio-economic frameworks.

Number of passenger is expected to increase from 567,000 in 2013 to 792,000 in 2035, which means 40 % increased in the future. Freight traffic volume in PCU basis is expected to increase from 35,000 in 2013 to 64,900 in 2035, which means 85% increased in the future.

These increased ratios were applied to the future OD matrix for each vehicle category, such as i) motor cycle, ii) 3-wheeler, iii) car, iv) bus, v) truck and vi) trailer.

As described in 3.2.6, the increased volume of passenger demand for car and bus is assumed to be increased, and the volume of motor cycle and 3-wheeler maintains status quo.

The freight traffic is assumed to be increased with same proportional of vehicle type structure.

APPENDIX-4

Geological Survey Works

GEOTECHNICAL ENGINEERING DIVISION
NBRO
NATIONAL BUILDING RESEARCH ORGANIZATION

ORIENTAL CONSULTANTS CO., LTD. AND
KATAHIRA & ENGINEERS INTERNATIONAL

GEOLOGICAL SURVEY WORKS FOR THE PROPOSED TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELANI BRIDGE

FINAL REPORT

JULY 2013

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DOCUMENT CONTROL SHEET

Client : **Oriental Consultants Co., Ltd. and Katahira & Engineers International.**

Project : **GEOLOGICAL SURVEY WORKS FOR THE PROPOSED TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELANI BRIDGE**

Project No: **30/24318**

	Prepared by			Reviewed by	Approved by
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11-07-2013			Nanthini.V		

REPORT	NAME	NAME	NAME	NAME	NAME
RIVISION I					
DATE	SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE

REPORT	NAME	NAME	NAME	NAME	NAME
RIVISION II					
DATE	SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE

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ABBREVIATIONS

(1) General

NBRO	-	National Building Research Organisation
BS	-	British Standards
HC	-	Highland Complex
WC	-	Wanni Complex
VC	-	Vijayan Complex
KC	-	Kadugannawa Complex
Ph	-	Photograph

Field Investigation

CD	-	Core Drilling
WB	-	Wash Boring
MSL	-	Mean Sea Level
BH	-	Borehole
SPT	-	Standard Penetration Test

(2) Explanation of Boring Logs

Sample Condition

SM	-	Silty Sand
MS	-	Sandy Silt
GM	-	Silty Gravel
MG	-	Gravelly Silt
SC	-	Clayey Sand
CS	-	Sandy Clay
GC	-	Clayey Gravel
CG	-	Gravelly Clay
SG	-	Gravelly Sand
GS	-	Sandy Gravel
GP	-	Gravel, poorly graded
GW	-	Gravel, well graded
SP	-	Sand, poorly graded
SW	-	Sand, Well graded

CV	-	Clay, very high plastic
CH	-	Clay, high plastic
CI	-	Clay, intermediate plastic
CL	-	Clay, low plastic
MV	-	Silt, very high plastic
MH	-	Silt, high plastic
MI	-	Silt, intermediate plastic
ML	-	Silt, low plastic
CHO	-	Clay, high plastic with organic matters
CIO	-	Clay, intermediate plastic with organic matters
CLO	-	Clay, low plastic with organic matters
MHO	-	Silt, high plastic with organic matters
MIO	-	Silt, intermediate plastic with organic matters
MLO	-	Silt, low plastic with organic matters
Pt	-	Peat
UDS	-	Undisturbed Sample
DS	-	Disturbed Sample
RQD	-	Rock Quality Designation
TCR	-	Total Core Recovery

(3) Laboratory tests

CU	-	Consolidated Undrained (Shear tests)
UCS	-	Uniaxial Compressive Strength
c	-	Cohesion
c'	-	Effective Cohesion
ϕ	-	Angle of internal friction
ϕ'	-	Effective Angle of Friction
LL	-	Liquid Limit
PL	-	Plastic Limit
PI	-	Plasticity Index

TABLE OF CONTENT

ORIENTAL CONSULTANTS CO., LTD. AND

KATAHIRA & ENGINEERS INTERNATIONAL

FINAL REPORT ON

GEOLOGICAL SURVEY WORKS FOR THE PROPOSED TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELANI BRIDGE

1 INTRODUCTION

The JICA Survey Team, which is a consortium of Oriental Consultants Co., Ltd. and Katahira & Engineers International, has been executing the preparatory survey on road improvement project, namely Traffic Improvement Project around New Kelani Bridge under the Road Development Authority (RDA), Government of Sri Lanka from 2013. One of the components of the project is pavement/ road design. Geological Survey, accordingly, to be conducted to grasp the existing ground level and the land use along Baseline road including Port access and Flyover, for pavement/ road design.

In order to carryout this task, Dr. Masaaki TATSUMI, Team Leader, Oriental Consultants Co., Ltd. requested National Building Research organisation (NBRO) to submit a quotation for the soil investigation of the proposed Traffic Improvement Project around New Kelani Bridge by his letter dated 4th March 2013.

In response to the request, NBRO submitted initial cost estimate on 7th March 2013 for the same.

Upon acceptance of the financial proposal by the Team Leader, contract agreement was signed on 19th March 2013 by both parties. Fieldwork for the above investigations was commenced on 23rd March 2013 and completed by 23rd May 2013. Laboratory tests were completed on 19th June 2013.

This factual report is based on the site reconnaissance, field investigation and laboratory tests conducted.

2 OBJECTIVE OF SOIL INVESTIGATION

The objective of this investigation is to provide information on,

- ❖ Geological and geotechnical reconnaissance throughout the proposed road trace.
- ❖ Subsurface profile along the proposed road trace with necessary soil parameters for the design purposes.

- Rock coring results such as Rock Quality Designation (RQD), Total Core Recovery (TCR) and Uniaxial Compressive Strength (UCS).

3 SCOPE OF SOIL INVESTIGATION

The initial scope of the work given by client as follows;

- Drilling twenty two (22 Nos.) boreholes through overburden and thereafter 5.0m depth into the rock layer (not weathered) or 40m depth.
- Conduct Standard Penetration Tests (SPT) at every 1.0m intervals within boreholes.
- Collect disturbed & undisturbed soil samples for the laboratory tests to determine the soil properties for the design purposes.
- Recommendation for suitable type of foundation for the piers.

While conducting field work depth of drilling in rock was changed as per the client instruction given as follows.

" If RQD > 85% and 6m depth into bearing layer (rock) then ok, otherwise, 10m depth into bearing layer is also acceptable."

Further, number of boreholes for drilling were reduced to 20 Nos. by the client as the availability of the geotechnical parameters for the CKE area.

4 PROPOSED STRUCTURE

It is intended to construct 2nd New Kelani Bridge and some approach roads to improve the traffic around New Kelani Bridge at the site. The proposed road trace has 3 links such as along Baseline road, New Kelani Bridge road and Flyover. The proposed road trace passes through high land, low land areas.

The proposed road contains 20 Nos. of boreholes for carryout the soil investigation and above road trace is proposed to support through piers at via duct area and cables for suspension bridge area as per the client.

Structural details of the proposed structures are not available at the time of preparation of this report.

5 FIELD INVESTIGATION

5.1 Codes & Standards

All field and laboratory testing were carried out as per the client requirement.

5.2 Qualification & Level of Supervision

The fieldwork for the soil investigation was carried out under the overview of a project engineer and a technical officer of NBRO whose were responsible for nominating and directing sampling and in-situ testing, and providing field logs of the soil profiles encountered.

Project Engineer (Geotechnical) co-ordinated from the NBRO head Office at Colombo and at the site when necessary.

5.3 Drilling

The objective of the drilling is to obtain geo-technical information and to grasp the sub-soil conditions. Twenty (20 Nos.) boreholes were advanced at the locations shown in **Figure I** in **Appendix I** by implementing three drilling crews.

Boreholes were carried out using core drilling techniques through overburden and thereafter into the rock. The termination depth of boreholes was decided as per the client.

Bore holes were carried out using rotary core drilling using ***TRD 80 S, NL 26 & YWD 45*** heavy drilling machines and NX size diamond core bits.

Coring in boulders, highly weathered and fractured rock was carried out by using the Triple Tube core barrel and in moderately weathered to fresh rock was done by using the double tube core barrels and impregnated diamond core bits in NX size. Boreholes were supported with NX size casings. Details of borehole investigation are given in **Table2** in **Appendix V.**

5.3.1 Rock Quality Designation (RQD) %

Rock Quality Designation (RQD) is the ratio of the sum of the lengths of the intact rock cores more than 10cm in each length to the length of the actual core run.

5.3.2 Total Core Recovery (TCR) %

Total Core Recovery (TCR) is the ratio of the core recovered (solid and non intact) to the length of the actual core run.

The core samples were kept and maintained on core boxes. These samples are placed in order, properly labeled and marked according the related depth. Photographs **(Ph 01 – Ph 20)** in **Appendix VI** show some core boxes.

5.4 Standard Penetration Test

Standard Penetration Tests (SPT) was conducted within the boreholes at every 1.0m depth intervals. Engineering logs of the boreholes along with the explanation sheets describing the terms and symbols used and the graphical representation of SPT values are presented in **Appendix II**.

For the purpose of preparing the logs of boreholes, compactness/consistency was classified according to the following **Tables 5.4.1 & 5.4.2**.

Table 5.4.1 - Cohesionless soil

Compactness	SPT No.
Very loose	0 - 4
Loose	4 - 10
Medium dense	10 - 30
Dense	30 - 50
Very dense	>50

Tables 5.4.2 - Cohesive soil

Consistency	SPT No.
Very soft	0 - 2
Soft	2 - 4
Firm	4 - 8
Stiff	8 - 15
Very Stiff	15 - 30
Hard	>30

5.5 Soil Sampling & Classification

All samples were collected under the supervision of the Site Engineer.

5.5.1 Disturbed

Disturbed soil samples from the bore holes were collected at every 1.0m depth intervals or at every change of soil layer in each borehole by using the split spoon sampler having a sharp cutting edge at its lowered end is forced into the ground by dynamic impact.

5.5.2 Undisturbed

UD Samples were collected by using 70mm diameter thin wall samplers for the soils that are particularly sensitive to sampling disturbance and a thin walled steel / Copper tubes whose lower end is shaped to form a cutting edge to form a small inside clearance.

The depths of the samplings are shown in the logs of the boreholes in **Appendix II**. Visual classification of the soils was done in the field by NBRO personnel for field logging of the boreholes.

5.6 Surveying of Borehole Locations

Elevations (Mean Sea Level) of the boreholes and co-ordinates to the national grid were estimated for actual borehole location using topographical drawing provided by the client and summerised in the **Table 1** in **Appendix V.**

5.7 Ground Water Table

Ground water table of the boreholes were observed during the period of field investigation. Then, depth of water table was measured from the ground surface and recorded in all borehole logs. The level of water table was measured daily and recorded before boring to be continued next morning.

5.8 Soil Profile

The interpreted vertical subsurface profiles through boreholes at the site are given as,

Fig. II(a), Appendix I – Assumed vertical subsoil profile along the Baseline Road and the Flyover section

Fig. II(b), Appendix I - Assumed vertical subsoil profile along the Port access road and New Kelani Bridge road section

6 SITE RECONNAISSANCE & GEOLOGY OF THE PROJECT AREA

6.1 General

Sri Lanka lies in the monsoon region of South Asia. The project area is situated on the Western coast of the island and experiences a humid tropical climate.

The proposed road trace is situated in the Colombo district and located around New Kelani Bridge at Peliyagoda. Details of respective borehole locations are given in the **Photographs** in **Appendix VI**.

The proposed site can be accessible through Baseline Road, New Kelani Bridge Road, port access road and Colombo – Kandy main road. (**Ref. Fig. I** in **Appendix I**).

Figure 6.1.1 – Some incidents of borehole investigation

6.2 General Geology of Project Area

About 90% of Sri Lanka basement is underlain by late proterozoic high grade metamorphic rock and the rest is made up of Mesozoic (Jurassic), Tertiary (Miocene) and quarternary sedimentary formation. The late proterozoic high grade basement of Sri Lanka is divided into three main and one subordinate lithotectonic units namely Highland Complex (HC), Wanni Complex (WC), Vijayan Complex (VC) and Kadugannawa Complex (KC).

The proposed project area is located in Wanni Complex with close to the western coast of Sri Lanka **(See Figure-6.2.1)**. This complex occupies the complex folded granitoid gneisses, granitic migmatites, cordierite gneiss, garnet cordierite gneisses, meta-quartzites, hornblende biotite gneiss, charnokitic gneiss, biotite hornblende gneiss, garnet hornblende biotite gneiss, garnet silimanite biotite gneiss, garnet silimanite graphite gneiss (khondalitic gneiss), granitic gneiss, biotite granitic gneiss, pegmatitic gneiss, charnockitic garnet biotite gneiss, charnockitic biotite gneiss and late microcline granitic intrusion (Tonigala granite). However, overburden of the western coastal of Wanni Complex is mainly formed by very thick alluvium (in the form of sand, silt or clay) deposit. (Ref. **Figure III** in **Appendix I)**

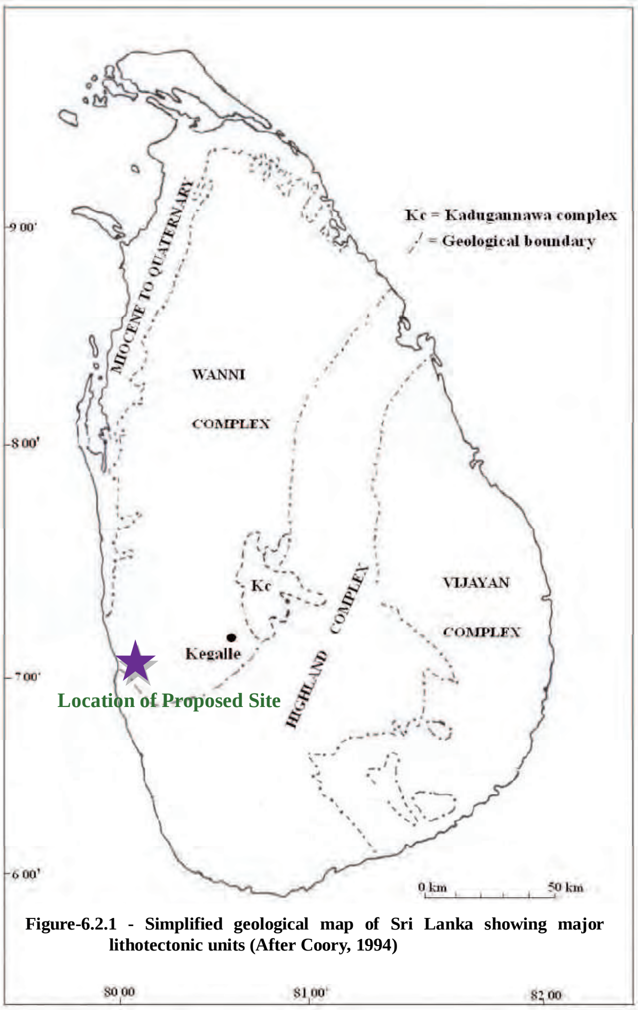

Figure-6.2.1 - Simplified geological map of Sri Lanka showing major lithotectonic units (After Coory, 1994)

As a result of chemical weathering of bedrock, laterite is formed above the bedrock specially into the country side within the south-west part of Wanni Complex. Laterite is a surface formation in hot and wet tropical areas which is enriched in iron and aluminium developed by long lasting weathering of the underlying parent rock. The percolating rain water causes dissolution of primary rock minerals and decrease of easily soluble elements such as sodium, potassium, calcium, magnesium and silicon. This gives rise to a residual concentration of insoluble elements predominantly iron and aluminium. Laterites consist mainly of the minerals kaolinite, goethite, hematite and gibbsite. The iron oxides, goethite and hematite cause the red-brown colour of laterite.

The rocks of Wanni Complex indicating younger Nd modal ages (1-2Ga) have undergone upper amphibolite to granulite facies metamorphism. Pressure and Temperature conditions for the rock formation of metamorphic rocks in Wanni Complex are ranging (3.5 kb - 7.5 kb) and (600˚C - 900˚C) respectively.

6.3 Geology of the Site

6.3.1 Rock & Mineralogy

The site is lying within a highly populated and build up region especially in the either side of Kelani River, and the area is comprises of dense road network. Lithologically there are no bedrock exposures in and around the proposed site. According to the lithological observations using borehole investigation at the site, the major rock types underlain at this location are biotite granitic gneiss, hornblende biotite gneiss, garnet hornblende biotite gneiss and charnockitic biotite gneiss which show the medium to coarse grained xenomorphic inequigranular texture. Based on the visual observation of rock core samples collected at the site, the major rock forming minerals of each rock type can be observed as follows.

Biotite granitic gneiss (Meta-igneous)	**Hornblende biotite gneiss (Meta-sedimentary)**	**Garnet hornblende biotite gneiss (Meta-sedimentary)**
- Quartz	- Quartz	- Quartz
- K-feldspar	- Plagioclase feldspar	- Plagioclase feldspar
- Plagioclase feldspar	- Orthoclase feldspar	- Orthoclase feldspar
- Orthoclase feldspar	- Hornblende	- Hornblende
- Microcline feldspar	- Biotite	- Biotite
- Biotite		- Garnet

Charnockitic biotite gneiss

(Meta-sedimentary)

- Quartz
- Plagioclase feldspar
- Orthoclase feldspar
- Biotite
- Hornblende
- Pyroxene (Hypersthene)

The river alluvium is present in substantial amounts in the flood plain of the Kelani river. However, bedrock at the proposed site was overlain by primary formation of residual soil and secondary formation of alluvium soil at the top of the overburden. It is identified that a thick bed of river alluvium around the BH-18, BH-19 and BH-20 area in the form of poorly graded sand and clayey silt. Rest of the site area is predominantly covered by residual soil (lateritic soil) and the surface layer is comprises of filling materials (aggregates, building refuse, debris) with organic clay and peat.

6.3.2 Structural Geology

Structural geologically, proposed site area is located on a large scale shear zone (approximately sensing to N 22^{o} W) and nearly two numbers of normal fault zones (approximately sensing to N 85^{o} W/81^{0} and N 79^{0} E). The general dip of the foliation plane of bedrock was observed about 40^{0}. However, dip of the foliation plane of bedrock is highly varied due to presence of highly folded bedding planes of bedrock formed as a result of layer parallel compression during the shearing of bedrock. According to the observation of structures of the rock core samples, the fracture index / fault intensity of bedrock was increased upto about 20 m^{-1}. Most of fractures in bedrock are present as tight condition and trending into different directions including parallel to the foliation plane of bedrock. With reference to the scale of shear zone, difference fracture index / joint intensity can be extent into the deep underground level of bedrock within the proposed site.

6.3.3 Origin of Rock

According to characteristics (grain type, grain size and grain shape) of rock forming minerals of each rock types of the bedrock, the initial rock type formed within the proposed site is hornblende biotite gneiss under amphibolites facies (medium pressure and temperature) metarmorphism condition as a metaisedimentary rock.

After development of the major geological structures of bedrock, biotite granitic gneiss was formed by a secondary granitic intrusion come through the major discontinuities of bedrock. After that, garnet hornblende biotite gneiss and charnockitic biotite gneiss were formed under pro-grade metamorphism process (amphibolite facies into granulite facies) by the following metamorphic reaction of hornblende biotite gneiss.

Hornblende + Alkali Feldspar $\longrightarrow$ Biotite + Quartz + H_2O (Under high P/T)

Biotite + Quartz $\longrightarrow$ Ortho Pyroxene + Alkali Feldspar + Garnet + H_2O (Under high P/T)

However, invisible tight fractured condition of bedrock was caused for suddenly decreasing of the actual rock strength according to the test results of uncompressive strength of rock core samples. Further, very small thickness of mafic-rich layers (hornblende and biotite) which shows low to intermediate rock strength was present through the bedding plane of bedrock. Therefore, most of mechanical breakdown of rock cores are developed along the mafic rich layers bedrock.

6.3.4 Geological Conclusion

According to the geological (lithological, structural geology and geomorphological) observations at the proposed site area, following geological conclusions can be made for the proposed site.

1) The proposed site is located on a large scale shear zone and nearly to the two numbers of normal fault zones. Therefore, different fracture condition (highly to slightly) of bedrock can be extent into the deep underground level of bedrock including low RQD (Rock Quality Designation) values within the proposed site area.

2) Most of fracture planes (formed due to shearing and faulting of bedrock) of bedrock have very steep dip angles of the foliation plane. Ground water table of the many locations within the proposed site area was encountered at shallow depth of the ground. Therefore, weathered bedrock may be encountered into deep underground level as a result of moving of ground water into the deeper level along the fracture planes of bedrock. The weathering condition (highly to slightly) of bedrock into the depth is depend on the fracture index (FI) of bedrock (When the FI of bedrock is increased, the weathering of bedrock is increased).

3) The most of rock core samples with good RQD values are present as tight fractured (visible or invisible) rock. Therefore, some rock core samples having good RQD value show low UCS (Unconfined Compressive Strength) value at the different depths of boreholes.

7 LABORATORY TESTING

All laboratory testing of soils was carried out under the supervision of Laboratory Engineer for the representative disturbed & undisturbed soil samples as requested by the client.

7.1 Index Property Tests

Following tests were carried out on disturbed soil samples to determine the index properties of the soil encountered at the site.

- Natural Moisture Content
- Atterberg Limits
- Sieve Analysis
- Hydrometer Analysis

The summary of test results is given in **Table 7.1** in **Appendix III** and the details are given in **Appendix IV.**

7.2 Geo-Mechanical Tests

As per the contract requirement, three undisturbed soil samples to be collected in marshy area. However, only one sample could be collected as sampling from other depths were not feasible due to the very soft nature of the sub soil.(with the consent of the client)

Undisturbed soil sample collected from borehole were used for Consolidated Undrained Triaxial test (CU test) and consolidation test (1 D test) to obtain geotechnical parameters for pavement/ road design.

The summary of test results is given in **Table 7.1** in **Appendix III** and the details are given in **Appendix IV.**

7.3 Uniaxial Compressive Strength (UCS) Tests on Rock

Rock samples collected from boreholes were used to carry out the Uniaxial Compressive Strength test to obtain the compressive strength of the rock.

Details of core box for the respective borehole locations are given in the **Photographs** in **Appendix VI**.

The summary of test results is given in **Table 7.2** in **Appendix III** and the details are given in **Appendix IV**.

8 ENGINEERING APPRECIATION OF SUBSOIL CONDITION

8.1 General Observations

The general observations of borehole investigation are summarized in the **Table 8.1** below.

Table 8.1- General observations of subsurface condition at different borehole locations

Borehole No.	Depth to Ground Water Table from the existing ground level/(m)	Depth to overburden soil from the existing ground level /(m)	Thickness of rock drilled/(m)	Depth to Termination from the existing ground level/(m)
BH-1	1.45	19.40	5.35	24.75
BH-2	3.35	19.00	6.00	25.00
BH-3	3.00	21.80	6.00	27.80
BH-4	2.30	15.20	5.80	21.00
BH-5	2.30	22.40	6.75	29.15
BH-6	2.20	22.10	6.00	28.10
BH-7	2.25	11.80	6.10	17.90
BH-8	2.10	23.65	9.95	33.60
BH-9	2.30	21.00	19.00	40.00
BH-10	0.80	18.70	10.00	28.70
BH-11	1.40	21.75	10.00	31.75
BH-12	0.80	21.00	9.00	30.00
BH-13	0.60	21.50	6.00	27.50
BH-14	0.85	22.75	10.00	32.75
BH-15	0.60	24.10	10.00	34.10
BH-16	6.20	31.50	7.40	38.90
BH-17	4.60	32.85	6.05	38.90
BH-18	0.50	28.20	11.80	40.00
BH-19	0.50	26.00	12.00	38.00
BH-20	1.45	23.00	14.80	37.80

Detailed observations of subsurface condition at different borehole locations from borehole investigation are given in **Table 2** in **Appendix V.**

8.2 Engineering Appreciation of Subsoil Condition

According to the borehole investigation results given in **Appendix II** (checked by the client), Assumed vertical subsoil profile through borehole were drawn and shown in **Figure II(a) & II(b)** in **Appendix I**.

Results of the field tests carried out as above indicate that the subsoil condition at the site of the proposed construction is highly heterogeneous both in respect of composition as well as penetration resistance.

9 SOIL PROPERTIES & FOUNDATION RECOMMENDATIONS

9.1 INTRODUCTION

The methods that are used to estimate the skin friction and end bearing from soil and rock layers on rock socketed bored and cast in-situ piles are outlined here using specimen calculations for the data obtained for BH 1. In addition to the procedures outlined in the respective references, the experience of the Geotechnical Engineer is also used in giving the skin friction and end bearing recommendations.

9.2 SPECIMEN CALCULATIONS

9.2.1 *Strength parameters of the soil layers*

The energy method of SPT correction (Bowles, 1996) was used to estimate the soil strength parameters of the soil layers. The energy method of SPT correction uses the following relationship to determine the N'_{70} from the field SPT blow counts (N_{Field}):

$$N'_{70} = N_{Field} C_N \eta_1 \eta_2 \eta_3 \eta_4$$

Where

$$C_N = \sqrt{\frac{95.76}{p'_o}}$$

$$\eta_1 = \frac{E_r}{70}$$

P'_o	=	Effective overburden pressure at the test level
E_r	=	Efficiency of the hammer used (taken as 55%)
η_i	=	Modification factors (Bowles, 1996)

The estimated N'_{70} together with the particle size could be used to estimate the soil strength parameters at respective depths, as outlined in Bowles (1996). Table 1 gives the estimated soil strength parameters at the location of BH 1 based on the above method.

Table 1 - Estimation of the soil strength based on Bowles (1996) for the location of BH 1

Depth (m)	SPT N	C_N	η_1	η_2	η_3	η_4	N'_{70}	Soil strength	
								ϕ_u^o	c_u (kPa)
1.3	10	2.09	0.79	0.75	1.00	1.00	12	33	
2.3	10	1.57	0.79	0.75	1.00	1.00	9	31	
3.3	21	1.31	0.79	0.85	1.00	1.00	18	34	
4.3	7	1.15	0.79	0.85	1.00	1.00	5		20
5.3	6	1.06	0.79	0.95	1.00	1.00	5		20
6.3	7	1.02	0.79	0.95	1.00	1.00	5		20
7.3	5	1.00	0.79	0.95	1.00	1.00	4		15
8.3	5	0.97	0.79	0.95	1.00	1.00	4		15
9.3	13	0.94	0.79	1	1.00	1.00	10		50
10.3	23	0.91	0.79	1	1.00	1.00	16		100
11.3	21	0.88	0.79	1	1.00	1.00	15		90
12.3	21	0.85	0.79	1	1.00	1.00	14		90
13.3	10	0.83	0.79	1	1.00	1.00	7	30	
14.3	10	0.81	0.79	1	1.00	1.00	6	30	
15.3	10	0.79	0.79	1	1.00	1.00	6	30	
16.3	13	0.78	0.79	1	1.00	1.00	8	31	
17.3	24	0.76	0.79	1	1.00	1.00	14	34	
18.3	50	0.74	0.79	1	1.00	1.00	29	38	
19.3	50	0.73	0.79	1	1.00	1.00	29	38	

9.2.2 Properties of the bedrock

The bedrock is classified into five groups depending on the reported core recovery (CR), rock quality designate (RQD) and unconfined compression strength (UCS). The rock mass rating (RMR), estimated based on the system proposed by Bieniawski (1989), is also used as a guidance in the determination of the grade of the bedrock. The guidelines used to determine the grade of rock is given in Table 2.

Table 2 – Rock classification system used

Grade	Description	Lithology	Approximate range of RMR
Grade I	Fresh rock	Clean rock	$60 \leq RMR$
Grade II	Slightly weathered rock	Increased fractures	$50 \leq RMR < 60$
Grade III	Moderately weathered rock	Partly changed to soil; rock > soil	$35 \leq RMR < 50$
Grade IV	Highly weathered rock	Partly changed to soil; rock < soil	$RMR < 35$
Grade V	Completely weathered rock	Some remnant rock structure; completely weathered to soil	-

9.2.3 Carrying capacities of bored and cast in-situ piles

9.2.3.1 Skin friction

9.2.3.1.1 Soil layers

Skin friction of the soil layers are determined using two different approaches for sand and clayey soils.

Sand

Estimation of the ultimate skin friction in sandy (cohesionless) soil layers is done using the average SPT *N* values in the sand layers. Based on ICTAD DEV 15, the ultimate skin frictional capacity of bored piles in sand, $f_{u,s}$ is given by:

$$f_{u,s} = 1.3\,N \quad kN/m^2; \quad f_{u,s} \leq 100\ kN/m^2$$

Clay

Estimation of the ultimate skin friction in clayey (cohesive), $f_{u,c}$, soil layers is done using the estimated undrained cohesion. Based on Bowels (1996), the ultimate skin frictional capacity of bored piles in clay, $f_{u,c}$, is given by:

$f_{u,c} = \alpha c_u$ (kPa)

Where

α – Factor depending on undrained strength, S_u (Bowles, 1996)

c_u - Undrained cohesion (kPa)

Based on the above procedures, the ultimate skin friction of soil layers at the location of BH 1 are estimated and given in Table 3.

Table 3 – Ultimate skin friction of soil layers

Layer	Depth (m)		Ultimate skin friction (kPa)
	From	To	
Medium dense silty sand/ sand	0.00	4.00	15
Firm peat/clay with organic material	4.00	9.00	15
Stiff clay	9.00	13.00	60
Medium dense silt	13.00	17.00	15
Very dense silty sand	17.00	19.40	65

9.2.3.1.2 Bedrock

The ultimate skin friction of the socketed region of the piles are estimated based on Tomlinson (1994) and ICTAD/DEV/15. It is generally assumed that bentonite slurry is used during drilling the pile bore. The estimated ultimate skin friction values of the bedrock at the location of BH 1 are given in Table 4.

Table 4 – Estimated ultimate skin friction of the bedrock at the location of BH 1

Depth (m)	Grade of rock	Ultimate skin friction

From	To		(kPa)
-19.40	-20.20	Grade III	200
-20.20	-21.50	Grade IV	200
-21.50	-22.20	Grade III	200
-22.20	-23.40	Grade III	200
-23.40	-24.75	Grade II	300

9.2.3.2 End bearing

9.2.3.2.1 Bedrock

The **allowable** end bearing capacity of bed rock is estimated based on ICTAD/DEV/15, and Hong Kong Guidelines (2006). The estimated **allowable** end bearing capacity values of the bedrock at the location of BH 1 are given in Table 5.

Table 5 – Estimated **allowable** end bearing capacity values of the bedrock at the location of BH 1

Depth (m)		Grade of rock	**Allowable** end bearing capacity (kPa)
From	To		
-19.40	-20.20	Grade III	3000
-20.20	-21.50	Grade IV	3000
-21.50	-22.20	Grade III	3500
-22.20	-23.40	Grade III	4000
-23.40	-24.75	Grade II	6500

9.3 RECOMMENDATIONS

The strength parameters of the subsurface soil layers are given at each borehole location together with the ultimate skin friction from each layer. If the clay layers in the subsurface are loaded by placing a fill layer at the ground surface level or any other means, there is a possibility of generation of negative skin friction from the layers above such clay layers and such layers are also indicated. However, if there is no possibility of generation of negative skin friction, the skin friction from such layers should be neglected in estimating the carrying capacity of piles.

At all the borehole locations, the grade of rock within the drilled depth of the bedrock is given. Based on the properties of the bedrock at different levels, the ultimate skin friction and the allowable end bearing capacity of bored piles are given.

9.3.1 BH 1

Strength parameters of different soil layers and Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock of borehole BH 1 is given above as specimen calculation.

9.3.2 BH 2

9.3.2.1 Subsurface layers

Following succession of layers, given in Table 6, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 6.

Table 6 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 2							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Medium dense silty SAND	0.00	3.00	31	0	-	15	Yes
Soft SILT/CLAY	3.00	6.20			15	15	Yes
Firm to stiff PEAT	6.20	8.90			35	30	Yes
Loose to medium dense SAND with organic matter	8.90	11.60	30	0		10	Yes
Stiff PEAT	11.60	12.10			35	30	Yes

Firm sandy CLAY	12.10	13.00			30	25	Yes
Medium dense SILT	13.00	15.75	30	0		10	No
Dense to very dense silty SAND	15.75	19.00	36	0		40	No

9.3.2.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 7.

Table 7 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 2				
-19.00	-20.70	Grade III/II	250	5000
-20.70	-22.20	Grade III/II	250	5000
-22.20	-23.50	Grade III/II	250	5000
-23.50	-25.00	Grade I	300	7000

9.3.3 BH 3

9.3.3.1 Subsurface layers

Following succession of layers, given in Table 8, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 8.

Table 8 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 3							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Very loose to medium dense sandy SILT/gravely SILT	0.00	3.50	25	5		8	Yes
Soft SILT/CLAY	3.50	5.00			15	15	Yes
Very loose to medium dense SILT	5.00	11.00	27	0		10	No
Medium dense to very dense Gravelly SAND/silty SAND	11.00	21.80	35	0		40	No

9.3.3.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 9.

Table 9 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 3				
-21.80	-23.50	Grade II	250	5000
-23.50	-25.00	Grade II	250	5000

-25.00	-26.80	Grade I	250	6000
-26.80	-27.80	Grade I	300	7000

9.3.4 BH 4

9.3.4.1 Subsurface layers

Following succession of layers, given in Table 10, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 10.

Table 10 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 4							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Loose to medium dense silty SAND	0.00	4.80	30	0		10	Yes
Soft to firm peat	4.80	7.00			25	25	Yes
Medium dense to dense silty SAND/clayey SAND	7.00	10.00	32	0		15	No
Very stiff SILT CLAY	10.00	10.80			100	60	No
SILT with pockets of clay	10.80	13.00	26	5		10	No
SILT with SAND	13.00	14.5	30	0		12	No
Very dense	14.50	15.20	38	0		65	No

silty SAND							

9.3.4.2 *Bedrock* layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 11.

Table 11 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 4				
-15.20	-16.50	Grade III/II	200	5000
-16.50	-18.00	Grade II	250	5000
-18.00	-19.50	Grdae II/I	250	6000
-19.50	-21.00	Grade I	300	6500

9.3.5 *BH 5*

9.3.5.1 Subsurface layers

Following succession of layers, given in Table 12, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 12.

Table 12 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 5						
Layer	Depth (m)		Strength parameters		Ultimate skin friction	Possibility of negative
	From	To	Drained	Undrained		

			$\phi^{o/}$	$c^{/}$ (kPa)	c_u (kPa)	(kPa)	skin friction
Medium dense to very dense silty SAND	0.00	3.30	34	0		25	Yes
Medium dense to loose silty SAND	3.30	4.50	31	0		13	Yes
Very soft to firm PEAT	4.50	10.00			20	20	Yes
Very dense silty SAND	10.00	11.00	38	0		65	No
Firm to stiff CLAY/SILT	11.00	13.00			60	45	No
Medium dense silty SAND/sandy SILT	13.00	19.50	32	0		25	No
Very dense silty SAND	19.50	22.40	38	0		65	No

9.3.5.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 13.

Table 13 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 5				
-22.40	-23.15	Grade V	150	2000
-23.15	-24.65	Grade III/II	200	4500
-24.65	-26.15	Grade II	250	5000

-26.15	-27.65	Grade I	300	7500
-27.65	-29.15	Grade I	300	7500

9.3.6 BH 6

9.3.6.1 Subsurface layers

Following succession of layers, given in Table 14, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 14.

Table 14 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 6							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Dense silty SAND	0.00	1.80	35	0		25	Yes
Concrete debris	1.80	3.40					Yes
Loose to medium dense SAND	3.40	5.80	29	0		10	Yes
Dense silty GRAVEL	5.80	6.70	35	0		40	Yes
Very stiff CLAY/SILT	6.70	8.50			100	70	Yes
Firm to soft SILT/CLAY	8.50	13.00			30	25	Yes
Loose to medium dense silty SAND/sandy SILT	13.00	18.00	30	0		25	No

Dense to very dense silty SAND/sandy SILT	18.00	22.10	36	0		50	No

9.3.6.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 15.

Table 15 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 6				
-22.10	-23.60	Grade III	200	3000
-23.60	-25.10	Grade IV	200	3500
-25.10	-26.60	Grade II/I	250	5500
-26.60	-28.10	Grade I	300	7000

9.3.7 BH 7

9.3.7.1 Subsurface layers

Following succession of layers, given in Table 16, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 16.

Table 16 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 7						
Layer	Depth (m)		Strength parameters		Ultimate skin friction	Possibility of negative
	From	To	Drained	Undrained		

			$\phi^{o/}$	$c^{/}$ (kPa)	c_u (kPa)	(kPa)	skin friction
Medium dense to very dense silty SAND	0.00	3.75	35	0		25	No
Very stiff PEAT	3.75	4.50			100	65	No
Very stiff to hard SILT/CLAY	4.50	10.85			150	100	No
Very dense silty SAND	10.85	11.80	38	0		65	No

9.3.7.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 17.

Table 17 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 7				
-11.80	-13.40	Grade II	250	6000
-13.40	-14.90	Grade II	250	6000
-14.90	-16.40	Grade I	300	7500
-16.40	-17.90	Grade I	300	7500

9.3.8 BH 8

9.3.8.1 Subsurface layers

Following succession of layers, given in Table 18, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 18.

Table 18 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 8							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Sand (Top soil)	0.00	1.00					Yes
Stiff to firm SILT/CLAY	1.00	3.75			30	25	Yes
Stiff to firm PEAT	3.75	6.35			30	25	Yes
Firm to stiff SILT/CLAY	6.35	9.00			40	30	-
Stiff to very stiff CLAY with sand	9.00	14.00			125	80	No
Firm CLAY/SILT	14.00	16.00			50	35	No
Stiff to very stiff sandy CLAY	16.00	18.60			120	90	No
Very dense Silt with sand	18.60	23.65	38	0		65	No

9.3.8.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 19.

Table 19 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 8				
-23.65	-24.50	Grade V/VI	150	2500
-24.50	-25.80	Grade III	200	3000
-25.80	-27.20	Grade III/II	200	5000
-27.20	-28.80	Grade III	200	3000
-28.80	-30.40	Grade IV	200	3000
-30.40	-32.00	Grade IV	200	3000
-32.00	-33.60	Grade IV	200	3000

9.3.9 BH 9

9.3.9.1 Subsurface layers

Following succession of layers, given in Table 20, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 20.

Table 20 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 9							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o\,/}$	$c^{/}$ (kPa)			
Medium dense silty/clayey GRAVEL (Lateritic fill)	0.00	4.00	30	5		15	Yes

Medium dense silty SAND	4.00	4.25	30	0		10	Yes
Firm to stiff Sandy CLAY	4.25	7.00			40	30	Yes
Stiff to very stiff CLAY	7.00	11.00			100	70	-
Firm sandy CLAY/CLAY	11.00	17.00			30	25	-
Dense to very dense silty SAND	17.00	21.00	35	0		50	No

9.3.9.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 21.

Table 21 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 9				
-21.00	-23.30	Grade V	150	2000
-23.30	-24.80	Grade V	150	2000
-24.80	-26.30	Grade V	150	2000
-26.30	-27.80	Grade V	150	2000
-27.80	-29.30	Grade V	150	2000
-29.30	-30.80	Grade V/IV	200	2500
-30.80	-32.30	Grade V	150	2500
-32.30	-33.80	Grade V	150	2500

-33.80	-35.30	Grade IV	200	2500
-35.30	-36.80	Grade IV	200	2500
-36.80	-38.30	Grade IV	200	2500
-38.30	-39.80	Grade IV	200	2500

9.3.10 BH 10

9.3.10.1 Subsurface layers

Following succession of layers, given in Table 22, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 22.

Table 22 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 10							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Medium dense silty SAND	0.00	2.75	30			10	No
Medium dense to dense silty SAND/SILT/sandy SILT/clayey SILT	2.75	10.0	33			20	No
Firm to very stiff CLAY/SILT	10.0	15.0			75	50	No
Very dense SILT	15.0	18.70	38	0		65	No

9.3.10.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 23.

Table 23 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 10				
-20.20	-21.70	Grade V	150	2000
-21.70	-23.20	Grade V/VI	200	2500
-23.20	-24.70	Grade V/VI	200	2500
-24.70	-26.20	Grade VI	200	2500
-26.20	-27.20	Grade VI	200	2500
-27.20	-28.70	Grade V	200	2500

9.3.11 BH 11

9.3.11.1 Subsurface layers

Following succession of layers, given in Table 24, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 24.

Table 24 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 11							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Medium dense silty SAND	0.00	1.70	31	0		12	Yes

(Lateritic fill)							
Loose to medium dense SAND with pockets of organic matter	1.70	6.00	29	0		10	Yes
Firm PEAT	6.00	8.00			25	25	Yes
Firm to stiff sandy CLAY	8.00	11.00			75	50	No
Firm CLAY/ sandy CLAY	11.00	14.00			50	40	No
Medium dense to dense sandy SILT	14.00	16.50	33	0		25	No
Very dense sandy SILT	16.50	21.75	38	0		65	No

9.3.11.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 25.

Table 25 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 11				
-21.75	-23.25	Grade IV	200	2500
-23.25	-24.75	Grade IV	200	2500
-24.75	-26.25	Grade IV	200	2500
-26.25	-27.75	GradeIV/ III	200	2500
-27.75	-29.25	Grade III	200	3000

-29.25	-30.75	Grade III	200	3000
-30.75	-31.75	Grade III/II	200	5000

9.3.12 BH 12

9.3.12.1 Subsurface layers

Following succession of layers, given in Table 26, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 26.

Table 26 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 12							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Medium dense to dense	0.00	2.20	34	0		20	Yes
Soft to firm PEAT	2.20	6.80			20	20	Yes
Medium dense SILT with organic matter	6.80	7.60	28	0		10	Yes
Firm PEAT	7.60	8.60			50	40	Yes
Very stiff to hard SILT/CLAY/sandy CLAY	8.60	12.50			150	90	-
Firm CLAY with organic matter	12.50	18.50			25	25	-
Dense to very dense silty SAND	18.50	21.00	35	0		60	No

9.3.12.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 27.

Table 27 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 12				
-21.00	-22.50	Grade V/IV	150	2000
-22.50	-24.00	Grade IV	200	2500
-24.00	-25.50	Grade IV	200	2500
-25.50	-27.00	Grade V/VI	150	2500
-27.00	-28.50	Grade III	200	3000
-28.50	-30.00	Grade II/I	250	6000

9.3.13 BH 13

9.3.13.1 Subsurface layers

Following succession of layers, given in Table 28, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 28.

Table 28 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 13							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Loose silty	0.00	3.00	28	0		5	Yes

SAND							
Soft to firm PEAT	3.00	9.60			20	20	Yes
Very stiff SILT/CLAY	9.60	12.00			125	75	Yes
Stiff CLAY/CLAY with organic matter	12.00	19.75			30	25	Yes
Very dense silty SAND	19.75	21.50	37	0		60	No

9.3.13.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 29.

Table 29 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
		BH 13		
-21.50	-23.00	Grade IV	200	2500
-23.00	-24.00	Grade III	200	3000
-24.00	-25.00	Grade III	200	3000
-25.00	-26.00	Grade III	200	3000
-26.00	-27.50	Grade II/I	300	6500

9.3.14 BH 14

9.3.14.1 Subsurface layers

Following succession of layers, given in Table 30, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 30.

Table 30 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 14							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Dense silty SAND	0.00	1.70	35	0	35	30	Yes
Soft to firm CLAY with organic matter/PEAT	1.70	3.35			30	25	Yes
Very dense silty Gravel	3.35	5.00	38	0		65	No
Stiff to hard SILT/CLAY	5.00	11.00			150	100	No
Medium dense to dense SILT	11.00	15.60	35	0		30	No
Very dense SILT	15.60	22.75	38	0		65	No

9.3.14.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 31.

Table 31 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 14				
-22.75	-24.25	Grade IV/III	200	3000
-24.25	-25.75	Grade III	200	3000
-25.75	-27.25	Grade III/II	200	5000
-27.25	-28.75	Grade III	200	4000
-28.75	-30.25	Grade III	200	3000
-30.25	-31.75	Grade III	200	3500
-31.75	-32.75	Grade III	200	3000

9.3.15 BH 15

9.3.15.1 Subsurface layers

Following succession of layers, given in Table 32, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 32.

Table 32 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 15							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Loose silty SAND (Lateritic fill)	0.00	3.50	28	0		5	Yes
Soft PEAT	3.50	4.75			15	15	Yes

Medium dense to dense SAND/SILT with organic matter	4.75	6.90	34	0		30	No
Medium dense SAND with little organic matter	6.90	8.50	30	0		15	No
Stiff gravelly CLAY	8.50	11.00			100	75	No
Soft to firm SILT/CLAY	11.00	19.50			25	25	No
Firm to stiff CLAY	19.50	23.00			60	40	No
Very dense silty SAND	23.00	24.10	38	0		65	No

9.3.15.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 33.

Table 33 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 15				
-24.10	-25.60	Grade V/VI	150	2000
-25.60	-27.10	Grade V/VI	150	2000
-27.10	-28.60	Grade III	200	250

-28.60	-30.10	Grade III	200	3000
-30.10	-31.55	Grade III	200	4000
-31.55	-33.05	Grade III/II	200	4000
-33.05	-34.10	Grade III	200	4000

9.3.16BH 16

9.3.16.1 Subsurface layers

Following succession of layers, given in Table 34, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 34.

Table 34 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 16							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Loose GRAVEL (lateritic fill)	0.00	9.00	26	5		8	
Medium dense SAND	9.00	16.00	32	0		30	
Stiff sandy CLAY	16.00	19.00			75	50	
Soft to firm CLAY	19.00	23.00			20	20	
Firm PEAT/CLAY with organic matter	23.00	25.00			40	30	

Medium dense to dense SILT/silty SAND	25.00	30.50	32	0		40	
Very dense silty SAND	30.50	31.50	38	0		65	

9.3.16.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 35.

Table 35 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 16				
-31.50	-33.00	Grade V	0	2000
-33.00	-34.50	Grade III/II	88	3500
-34.50	-36.00	Grade III	82	4000
-36.00	-37.50	Grade IV	30	3000
-37.50	-38.90	Grade II	94	5500

9.3.17BH 17

9.3.17.1 Subsurface layers

Following succession of layers, given in Table 36, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 36.

Table 36 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 17							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Medium dense silty SAND/sandy SILT (lateritic fill)	0.00	5.80	29	0		12	Yes
Firm CLAY	5.80	8.20			40	30	Yes
Medium dense clayey SAND/SAND	8.20	13.00	30	0		20	Yes
Loose SAND	13.00	13.50	28	0		10	Yes
Soft to firm PEAT	13.50	15.60			20	20	Yes
Stiff CLAY	15.60	18.00			80	60	Yes
Firm PEAT	18.00	19.50			25	25	Yes
Stiff sandy CLAY	19.50	22.00			50	40	-
Firm organic SILT	22.00	24.80			30	25	-
Medium dense SAND with organic matter	24.80	25.00	32	0		30	No
Very dense SAND	25.00	32.85	38	0		65	No

9.3.17.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 37.

Table 37 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 17				
-32.85	-34.35	Grade IV	40	2500
-34.35	-35.10	Grade V/IV	20	2500
-35.10	-36.10	Grade III	48	3000
-36.10	-37.40	Grade III	50	3500
-37.40	-38.90	Grade II	98	6000

9.3.18 BH 18

9.3.18.1 Subsurface layers

Following succession of layers, given in Table 38, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 38.

Table 38 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 18							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Very loose clayey Gravel	0.00	2.00	24	5		5	Yes

Soft CLAY/SILT	2.00	3.00			15	15	Yes
Loose silty SAND	3.00	4.00	27	0		5	Yes
Soft PEAT	4.00	9.00			15	15	Yes
Medium dense SAND with little organic matter	9.00	11.00	29	0		15	No
Very stiff CLAY	11.00	13.00			100	70	No
Firm to stiff CLAY/organic SILT	13.00	14.50			35	30	No
Medium dense SAND	14.50	16.00	30	0		20	No
Loose SILT/Silty SAND	16.00	23.70	27	0		7	No
Medium dense to dense silty SAND	23.70	28.20	33	0		30	No

9.3.18.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 39.

Table 39 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 18				
-28.20	-30.50	Grade IV	200	2500
-30.50	-31.70	Grade IV	200	2500

-31.70	-33.20	Grade IV	200	2500
-33.20	-35.00	Grade IV	200	2500
-35.00	-36.50	Grade IV	200	2500
-36.50	-37.50	Grade IV	200	2500
-37.50	-39.00	Grade III	200	3000
-39.00	-40.00	Grade III	200	3000

9.3.19BH 19

9.3.19.1 Subsurface layers

Following succession of layers, given in Table 40, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 40.

Table 40 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 19							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Medium dense silty GRAVEL/SAND with garbage (Fill)	0.00	2.15	28	0		10	Yes
Firm SILT/CLAY	2.15	5.40			25	25	Yes
Firm PEAT	5.40	9.00			20	20	Yes
Very soft PEAT	9.00	11.00			10	10	Yes
Very dense silty SAND	11.00	12.80	38	0		65	Yes
Firm to stiff PEAT	12.80	18.00			35	30	Yes

Loose sandy SILT/silty SAND	18.00	22.00	27	0		8	No
Dense to very dense silty SAND/SAND	22.00	26.00	35	0		50	No

9.3.19.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 41.

Table 41 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 19				
-26.00	-26.50	Grade V	100	2000
-26.50	-28.00	Grade V	100	2000
-28.00	-30.40	Grade V	100	2000
-30.40	-32.00	Grade V	100	2000
-32.00	-34.00	Grade V	100	2000
-34.00	-35.50	Grade V	100	2000
-35.50	-36.50	Grade V	100	2000
-36.50	-38.00	Grade V	100	2000

9.3.20BH 20

9.3.20.1 Subsurface layers

Following succession of layers, given in Table 42, are encountered during drilling for the boreholes. The estimated soil strength parameters together with the ultimate skin friction are also given in Table 42.

Table 42 – Strength parameters of different soil layers at the borehole locations together with the ultimate skin friction

BH 20							
Layer	Depth (m)		Strength parameters			Ultimate skin friction (kPa)	Possibility of negative skin friction
	From	To	Drained		Undrained c_u (kPa)		
			$\phi^{o/}$	$c^{/}$ (kPa)			
Loose silty GRAVEL (Lateritic fill)	0.00	3.20	26	5		5	Yes
Medium dense GRAVEL	3.20	10.65	30	0		12	Yes
Firm gravelly CLAY/CLAY	10.65	17.00			25	25	Yes
Medium dense SAND	17.00	19.00	32	0		25	No
Loose silty SAND	19.00	20.50	29	0		12	No
Very dense silty SAND	20.50	23.00	38	0		65	No

9.3.20.2 Bedrock layer

The grade of the rock with the ultimate skin friction and the allowable end bearing capacities from different rock layers encountered within the drilled depth of the bedrock are given in Table 43.

Table 43 – Grade of the bedrock with the recommended ultimate skin friction and allowable end bearing capacity of the rock at the borehole locations

Depth (m)		Grade of rock	Ultimate skin friction (kPa)	Allowable end bearing capacity (kPa)
From	To			
BH 20				
-23.00	-24.50	Grade V	150	2000

-24.50	-26.30	Grade V	150	2000
-26.30	-27.80	Grade IV	200	2500
-27.80	-29.30	Grade IV	200	2500
-29.30	-30.80	Grade IV/III	200	2500
-30.80	-32.30	Grade IV	200	2500
-32.30	-33.80	Grade III/II	200	3500
-33.80	-35.30	Grade III	200	3500
-35.30	-36.30	Grade III	200	3500

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APPENDIX I

Figures

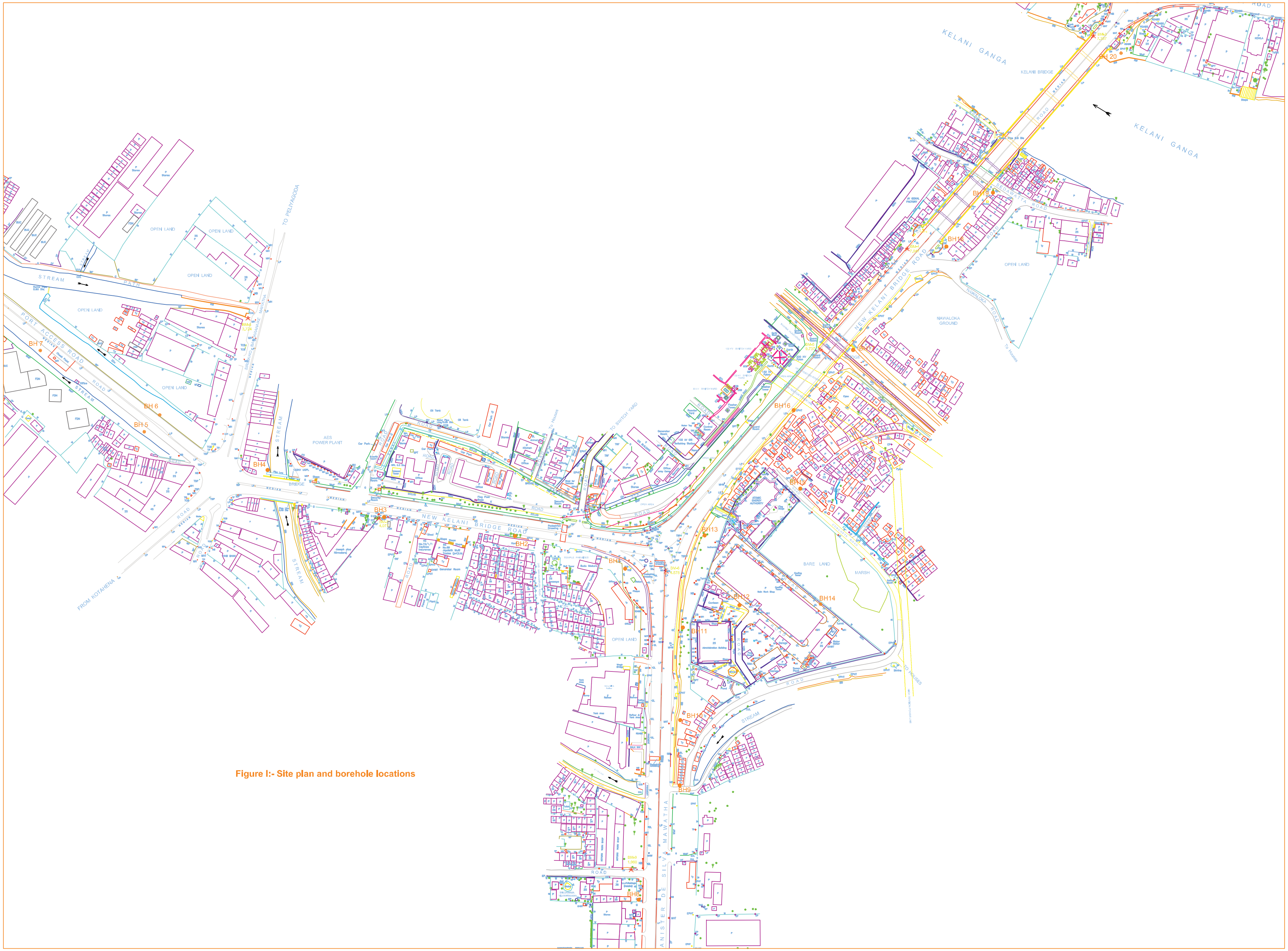
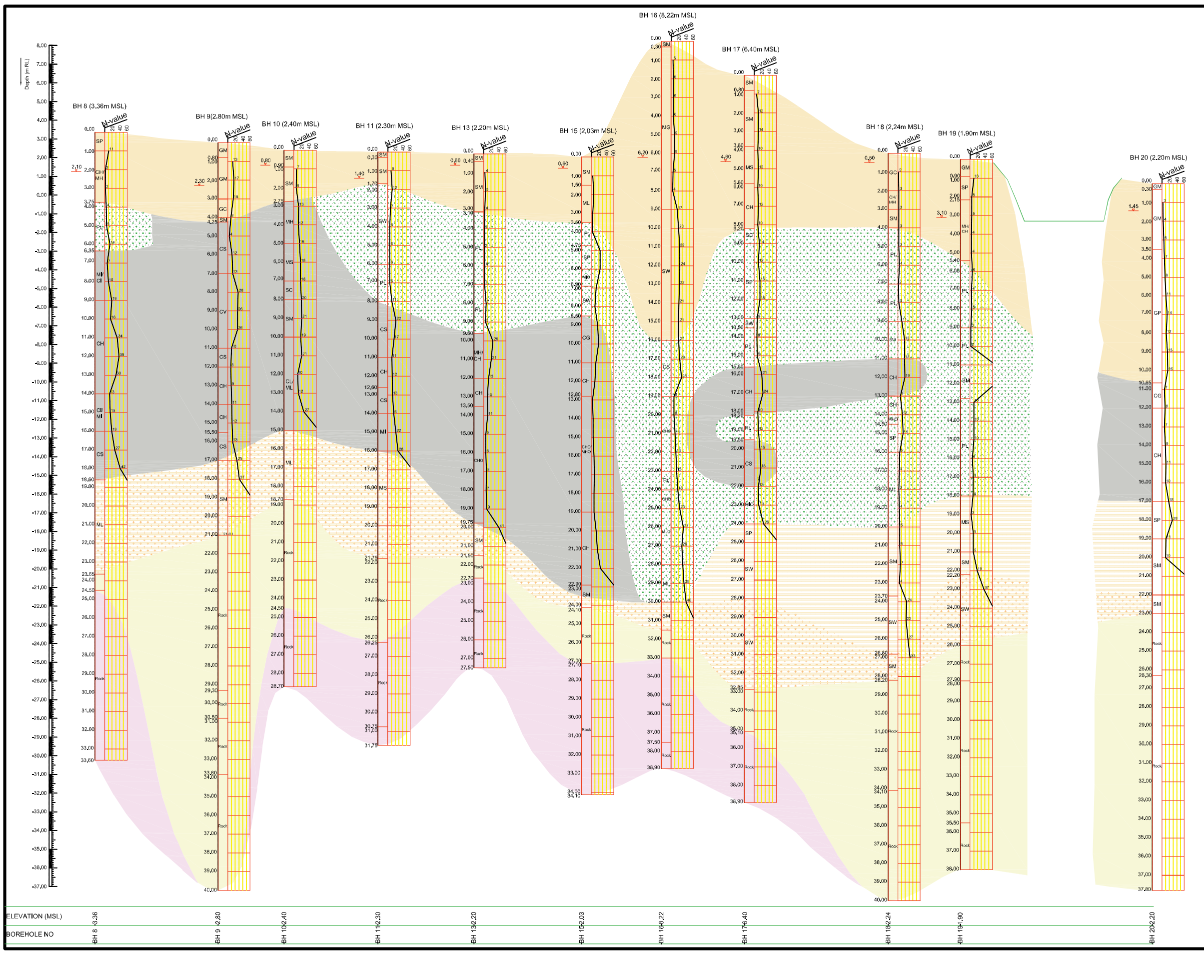


Figure I:- Site plan and borehole locations

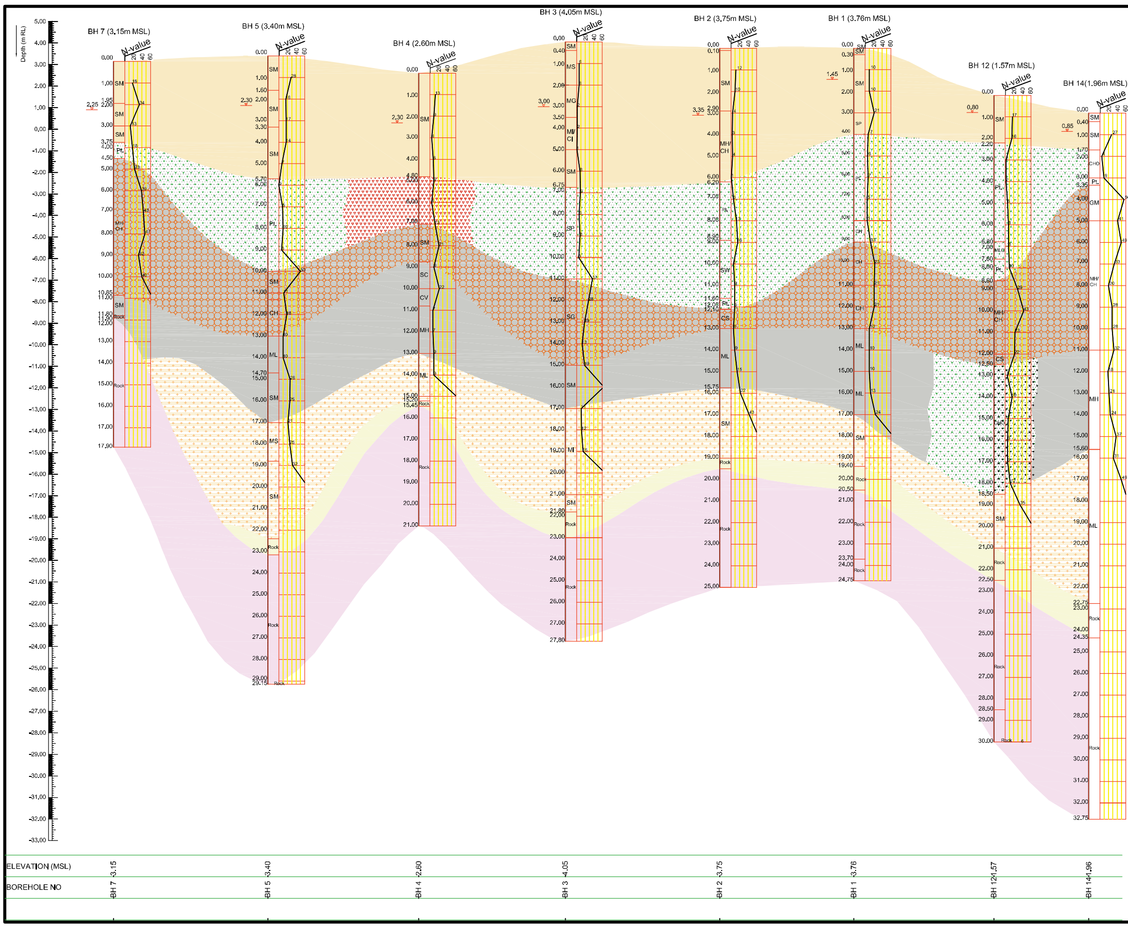


LEGEND

- Laterite fill combination of sand, silt, clay and gravel.
- Laterite fill combination of sand, silt, clay and gravel.
- Soft to stiff peat/ clay/ loose to very dense sand/ silt with organic matters.
- Soft to stiff clay/ loose to very dense silt with traces of sand.
- Stiff to very stiff clay/ loose to very dense sand mixed with silt and occasional gravel.
- Loose to very dense silt/ silty sand.
- Medium dense to very dense silt/ silty sand (completely weathered rock)
- Highly to moderately weathered rock in the form of various mineral combination
- Moderately weathered to fresh rock in the form of various mineral combination

NATIONAL BUILDING RESEARCH ORGANIZATION
99/1, JAWATTA ROAD, COLOMBO 05.
GEOTECHNICAL ENGINEERING DIVISION

PROJECT	GEOLOGICAL SURVEY WORKS FOR THE PROPOSED TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELANI BRIDGE				
DRG. TITLE	ASSUMED VERTICAL SUBSOIL PROFILE ALONG THE BASELINE ROAD AND THE FLYOVER SECTION				
DRAWN		PROJECT ENG.		DRG.NO.FIGURE II(a)	
CHECKED		APPROVED		SHEET NO. 01 OF 02	
DATE	20.05.2013	SCALE	VERTICAL	1:100	
			HORIZONTAL	1:500	

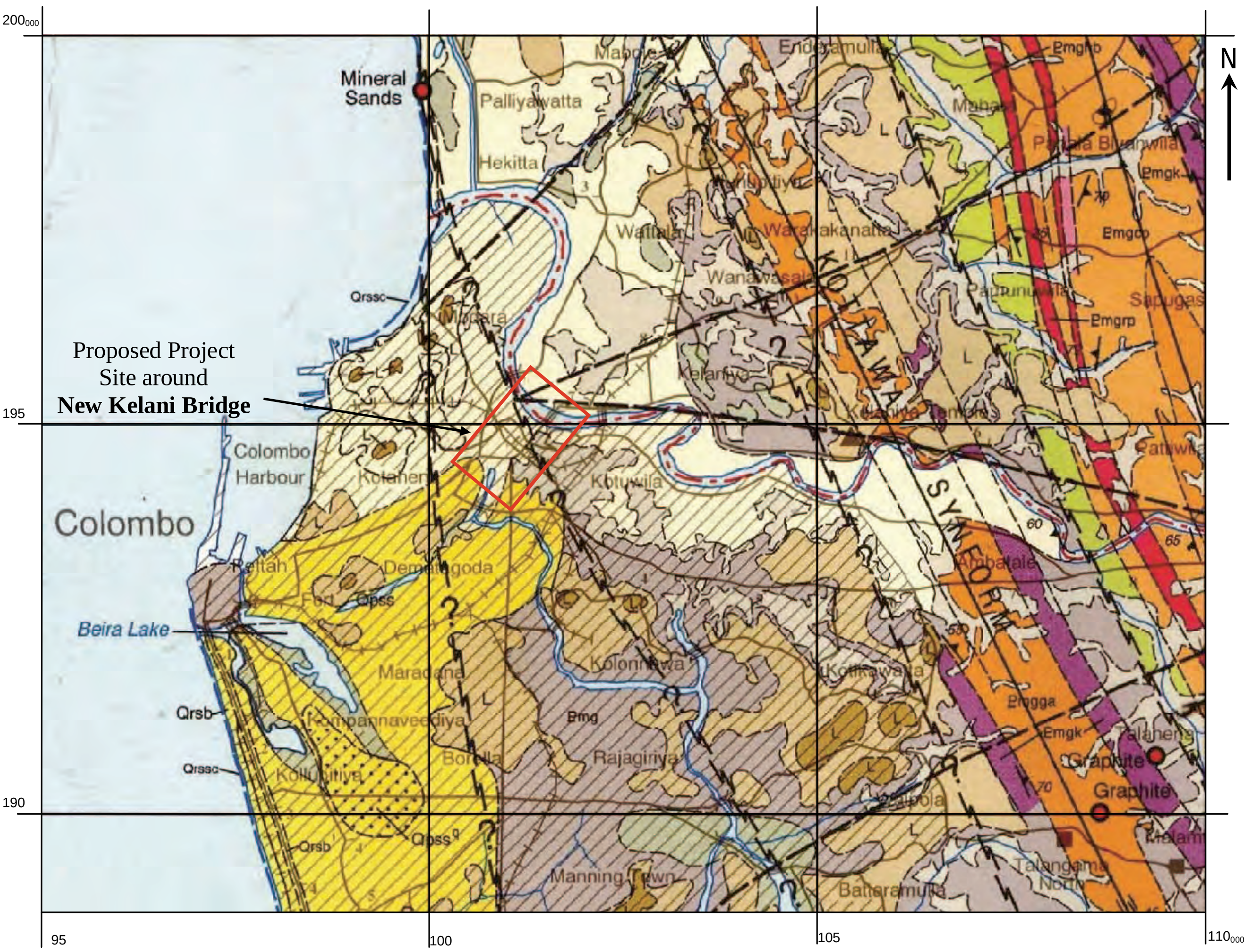


LEGEND

- Laterite fill combination of sand, silt, clay and gravel.
- Laterite fill combination of sand, silt, clay and gravel.
- Soft to stiff peat/ clay/ loose to very dense sand/ silt with organic matters.
- Soft to stiff clay/ loose to very dense silt with traces of sand.
- Stiff to very stiff clay/ loose to very dense sand mixed with silt and occasional gravel.
- Loose to very dense silt/ silty sand.
- Medium dense to very dense silt/ silty sand (completely weathered rock)
- Highly to moderately weathered rock in the form of various mineral combination
- Moderately weathered to fresh rock in the form of various mineral combination

NATIONAL BUILDING RESEARCH ORGANIZATION
99/1, JAWATTA ROAD, COLOMBO 05.
GEOTECHNICAL ENGINEERING DIVISION

PROJECT	GEOLOGICAL SURVEY WORKS FOR THE PROPOSED TRAFFIC IMPROVEMENT PROJECT AROUND NEW KELANI BRIDGE			
DRG. TITLE	ASSUMED VERTICAL SUB SOIL PROFILE ALONG THE PORT ACCESS ROAD AROUND NEW KELANI BRIDGE			
DRAWN		PROJECT ENG.		DRG.NO.FIGURE II(b)
CHECKED		APPROVED		SHEET NO. 02 OF 02
DATE	20.05.2013	SCALE	VERTICAL 1:100 HORIZONTAL 1:500	



Legend

Figure III – Geology Map of the Project Area