Wolkite University College of Engineering and Technology
Civil Engineering Department

Geometric and Pavement Design for Upgrading Gravel Road to Paved Road

B.Sc. Thesis /Project (CENG5281) Submitted as a partial fulfillment of the requirement for the Degree of Bachelor Science in Civil Engineering

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CERTIFICATE

This is to certify that this project entitledGeometric and Pavement Design for upgrading Gravel Road to Paved Road is a record of the project work carried out by group members

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ABSTRACT

The highway transportation system is one of the most commonly used modes of the transportation system in Ethiopia. Our Proposed Project covers the design of Local Street.In our country there are different problems on the highway, most of the problems are regarding the design and material quality. With regarding this problem we will try to give a clampdown on the problem associated with this. Therefore as much as possible as streamline we are performing the project consideration as follows: identifying topography of project terrain type, perform geometric design, Pavement design through conducting essential test and providing adequate thickness and providing well drainage system.

The main report is divided into eight chapters. In this project design Report, the first chapter includes Overview of Transportation System and the second chapter is details and description of the location project, critical evaluation of climate, topography, traffic survey and analysis which is design period entails traffic volume (AADT), traffic growth rate and the third chapter deals with Data Collection and Analysis, Topographic surveying, Soils investigation, and Sub-grade material investigation. And the fourth chapter details design control, Road Functional classification, Design speed, Level of service (LOS), Design Vehicles, Traffic Study (traffic volume determination), Traffic forecasting, Limitations of traffic forecasting, and Topography.

The fifth chapter deals on the geometric design of those areasTerrain, horizontal alignment, vertical alignment, gradient, cross-section element, selection and configuration of the elements that comprise the roadway cross-section,and describes the elements used in carrying out detailed cross-section design.

The sixth chapter is referees pavement design which is flexible pavement by both AACRA and ERA with the help of traffic analysis and soil laboratory results. Chapter seventh is also a study about highway drainage and culvert design using annual average rainfall &climate of our project area and the sixth chapter describes earthwork including earthwork quantity and mass haul diagram. The last chapter describes the general conclusions and recommendations of this project.

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ACRONYMS

AADT: Average Annual Daily Traffic

AASHTO: American Association of State Highway and Transportation Officials

ADT: Average Daily Traffic

AACRA: Addis Ababa city road's Authority

CBR: California Bearing Ratio

CL: Chord length

DTM: Digital terrain model

DV: Design Vehicle

ERA: Ethiopian Roads Authority

ESA: Equivalent Standard Axle

ESAL: Equivalent standard axle load

FHD: Free haul distances

GDP: Gross domestic product

LL: Liquid Limit

MDD: Maximum Dry Density

OMC: Optimum Moisture Content

PC: Point of curvature

PC: Point of tangency

PI: Plasticity Index

PL: Plastic Limit

PSD: Passing site distance

ROW: Right Of Way

SN: Structural Number

1. Introduction

1.1 Overview of Transportation System

Transportation is the movement of people and goods which is undertaken to accomplish basic objectives or tasks and for traveling from one area to another area. The pattern of growth of towns and cities is determined by the transport network and its efficiency. But the speed, cost, and capacity of available transportation facilities have the greatest impact on the economic activity of the society. The pattern of growth of towns and cities is determined by the transport network and its efficiency. Even though there are various types of transportations like rail way, air, and water, the road transportation system is the most usable and accessible means due to the following reasons.

- It is more economical compared to the others.
- Gives door to door service
- Construction is flexible
- It covers a large area etc.

As road transportation has so much benefit, it has its negative impacts such as: -

- Air pollution (smoke during construction and after construction)
- Noise pollution
- Energy consumption
- The initial cost is high (construction cost).

Road transportation system is essential infrastructure for a nation's development and growth both for the public and private sector. It is almost impossible to think about Development without having accessible and safe transportation means.

The road project we are going to design is located in Wolkite town, Gubre sub-city from wolkite university specialized hospital to Sillase church which is a gravel road and upgrading this road to paved road. This road is 1.42 km& is almost fair with its vertical & horizontal alignments.

We intensively depend on the AACRA pavement design manual for the design of all components of the road starting from the selection of the road type to drainage design. We have also roughly referred ERA pavement design manual & other related scriptures on the highway for some data that are vague on AACRA.

1.2 Objectives of the project

Transportation systems and highways play a vital role in simplifying the day-to-day activities of humankind. The main objective of our project is to select and design the best road alignment for the university which underlines the safety and economy of the road as well as the users. The road at the end is also expected to confirm this objective without any failures and accidents. Thus the pedestrians, as well as the vehicles, should easily maneuver from one place to another place. The related objectives of the project are listed below. it helps us to;

- ❖ Analyze and design the geometry as well as each of the layers of the pavement as per the criteria on the AACRA design manuals.
- ❖ Analyze and design the drainage system and its structures (both the cross drainages and longitudinal drainages.
- ❖ Conducting different laboratory tests while designing the structure of the pavement.
- ❖ Select different types or classes of the road by the purpose of the related structures and buildings which are expected to get access from the road.
- ❖ Calculating and determining the amount of earth work (which includes site clearance as well as cut and fill volumes etc.
- ❖ Develop our past knowledge from the courses learned through 5 years stay in the university.
- ❖ Develop Team working skills and communication skills.
- ❖ Develop patience through the work and become a hard worker and to make students familiar with the road project Softwares like AUTO CAD, Civil 3D, etc.

1.3. General Methodology

In this project, reconnaissance surveying is conducted to obtain general information about the area.The next centerline of the proposed road was set out and detail topographic data were collected. Then, soil samples were taken at different stations, and required tests were undertaken. Based on the test result a detailed pavement design was conducted. Using collected data and additional information gathered from different sources, the hydraulics and geometric design were done. Finally, the earthwork was computed and a plan was prepared. For surveying data collection the latest surveying instrument (Total station) was used. For data processing, the popular engineering software (Civil-3D) was utilized. In addition, the AACRA Design manual is fully consulted.

2. Project Environment and Data Collection

2.1Study Area

The study was conducted at the wolkite station, Gurage zone of SNNPRS, Ethiopia. The geographical coverage of the study area is 8° 17' 22.6 " N and 37° 46' 55.98" E at an elevation ranging from 1050 to 1883m.a.s.l. Wolkite university is 164.2 Km far from Addis Ababa city.(*Google*, n.d.)

The project road can be reached from the wolkite university specialized hospital and pass behind wolkite university stadium with a total length of around 1.4km. Construction of this road will shorten the length of the road and saving travel time and creating access for areas in between the project ends. The project's important in enhancing the socio-economic development of the towns crossed by the route. In addition, it also Providing access to employment, social, health and education service; Open up more areas and stimulate economic and social development; Important role in making travel easier and more expedient and May relieve road congestion and also improve safety.

Figure 2.1:- Location of Wolkite University from Addis Abeba city(*Google Map*, n.d.)

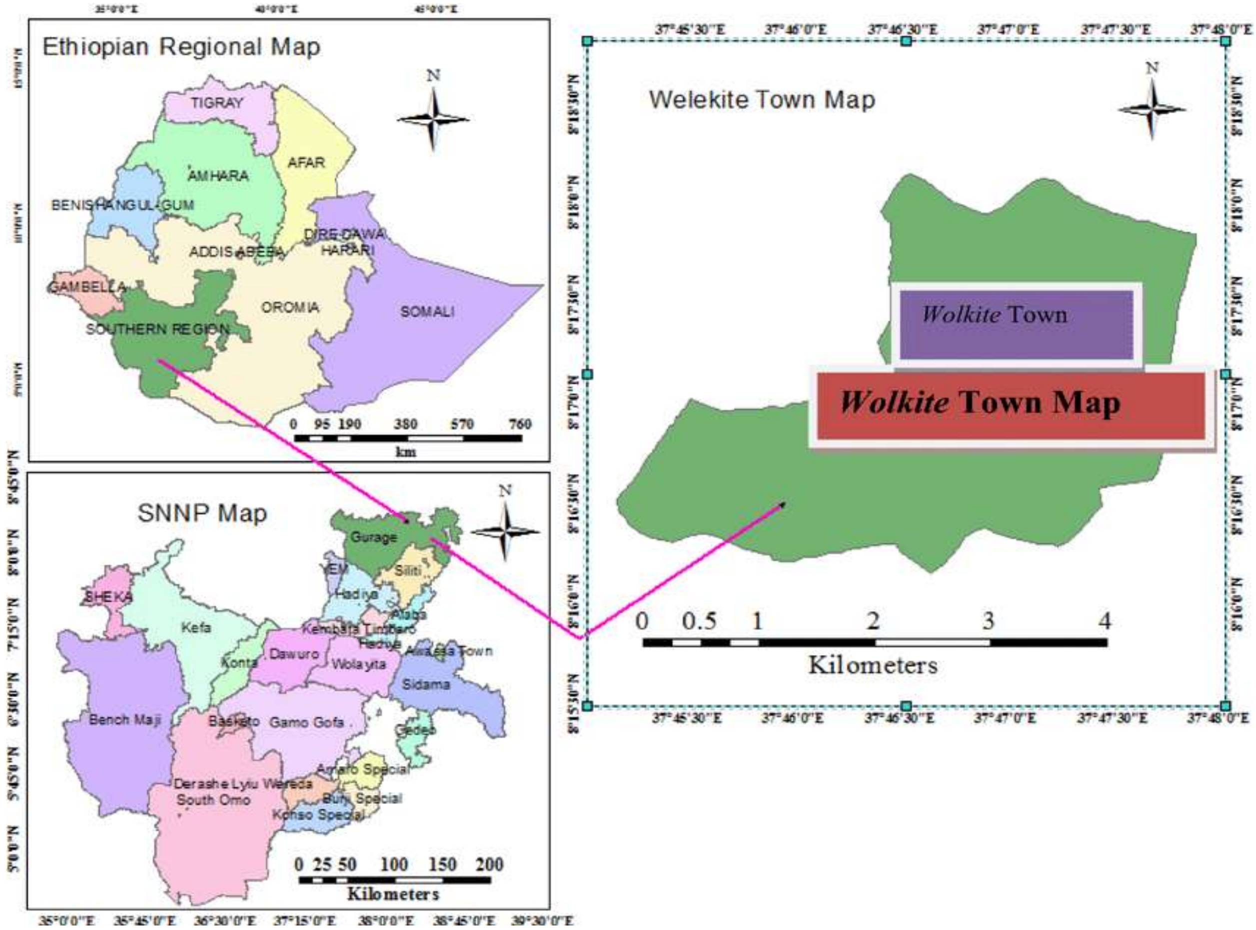


Figure 2.2:- Map of Wolkite Town. Source: (*Google Map*, n.d.)

SNNP (SNNP is one of the regional administrations in Ethiopia. Wolkite Town is one of the zone administrations in SNNP according to the 1995 constitution of Ethiopia)Stands for Southern Nations Nationalities and Peoples of Ethiopia.

Figure 2.3:- Our route location (*Google Map*, n.d.)

2.2Climate

The external influence of environmental factors such as rainfall, temperature variation, and atmospheric conditions can cause deterioration of the pavement. Climate has an influence on the selection of pavement material, surfacing material, and construction material. Some of the environmental factors that cause deterioration of pavements are:

- **Rain fall: -** It causes erosion of shoulders, side slopes, and ingress of water in pavement structure and sub grade and it affects the performance of drainage structure. The annual rainfall amount for the study area ranged from 309.8 mm to 1738.4 mm, while belg and kiremt rainfall amounts varied from 99.55 mm to 481.3 mm and 162.7 mm to 1202 mm respectively.
- **Temperature: -** Its variation can affect the binder and performance of bituminous surface and cement concrete pavement. The annual maximum temperature varied between 23.35 and 29.02 ^{0}C and the mean annual average maximum temperature over the study area was 27.03 ^{0}C.

2.3Limitation

During performing the overall activity of this work, we have got challenges lab class limitation which has an internet connection, availability of data limitation, and economical limitation. As a whole, there is less coordination of government and society in the design and construction of infrastructure that plays a great role to develop our country.

2.4Data Collection and Analysis

2.4.1 Topographic surveying: In this project, the team undertook route location and detailed topographic surveying along the project route. Detailed topographic surveys along the length of the alignment have been carried out using the total station and Google Earth. The surveying includes:

Figure 2.4:- Data Collection using total station

Reconnaissance surveying to rough examination the route, determine minimum possible gradients, approximate length, and selection of stations, etc.

Collection of detail topographic data: Detailed ground survey along the length of the project road was carried out to examine the road alignment and collection of cross-sectional data at 20m intervals and 60m width. In addition, other topographic data were collected that are considered necessary to complete the detailed design and the estimation of quantities.

Finally, the data was downloaded to a Desktop computer for further design.

2.4.2 Soils investigation

The team carried out a Site investigation to identify the material formation along the alignment, evaluate the present performance and condition of the existing roadand assess the suitability of the sub-grade materials along the alignment as roadbed materials.

During the fieldwork, investigation, and sampling of subgrade and construction materials were carried out. After the fieldwork laboratory tests were conducted for the sampled materials. Based on the field study and laboratory test results further desk study and analysis were carried out. The task includes Laboratory testing.

Figure2.5:- Collecting soil sample for CBR test.

Detailed discussion about the field works undertaken is presented hereunder.

2.4.2.1 Sub-grade material investigation

The soil extension survey along the project road is carried out by visual observation of the texture and appearance of the soil along the road and the samples collected from the route at about 500m intervals. And based on the soil extension survey, the different soils are properly identified.

Based on the field investigations, the materials observed along the project road are categorized as:

- Black cotton soil;

The Black cotton soil covers about 96% of the project alignment. These materials can be considered unsuitable for roadbed materials.

During the field investigation, samples were collected and taken to the Soil laboratory for laboratory testing. A total of two (2) sub-grade samples were collected.

The collected samples were subjected to laboratory tests to assess the engineering properties of the materials and determine their suitability for road making.

Accordingly, the sub grade samples were tested for:

- Classification tests (Sieve analysis and Atterberg limits tests)
- Modified Proctor Density test (for determining OMC and MDD)
- 1–point CBR tests.

3. Design Control

The choice of design controls and criteria is influenced by the following factors: the functional classification of the road; the nature of the terrain; the design vehicle; the traffic volumes expected on the road; the design speed; the density and character of the adjoining land use; and economic and environmental considerations.

As these factors usually vary along a route of some length, the design does not have to be constant for the whole length of a road. On the contrary, changes in the design are usually required to obtain a proper correlation between the road layout and the above factors, whilst maintaining construction costs at realistic levels.

3.1 Road Functional classification

According to AACRA, there are four broad classifications based on the function they give. And the categories are

- Freeway
- Urban arterial
- Sub arterial
- Collector road
- Local streets

Freeways: freeway status is applied only to high-speed, high-volume arterial roads with full control of access. Freeways are grade-separated multi-lane roads with no property access allowed.

Urban arterial and sub-arterial: are the major traffic routes in Addis Ababa. Urban arterials are usually dual function facilities providing service to;

- Through traffic (primary function)
- Local traffic and property access (secondary function)

Feeder and local streets: the road layout should conform to the requirements of the external road network and satisfy the transport provisions of the city master plan. The internal road system should not provide routes that are more convenient than the external road network. Where a road is needed that provides a convenient through route, then sub arterial road (local crossing route) could be considered with appropriate capacity and abutting land use. (*Addis Ababa City Roads Authority (AACRA)*, 2004)

Table 3.1:- Typical AADT Values in Addis Ababa (AACRA table 6.2)

Road Classification	AADT (two way)	Typical Percentage				
		Car	Light	Medium	Heavy	Articulated
Freeway	-	-	-	-	-	-
Arterial	10,000	80%	17%	2%	0%	1%
Sub-arterial	9000	89%	9%	1%	0%	1%
Collector	4000	91%	8%	1%	0%	0%
Local	1500	97%	3%	0%	0%	0%

Our give data exactly coincide with the typical percentage of vehicle classes for Local streets. Also, the property access criteria are satisfied. Therefore we choose our road section to be local Streets.

After carefully analyzing the land use and travel condition, we categorized our road as a Local street road

The reasons for selecting this category for our road are as follows;

Our road section has a primary goal of providing service for traffics who are traveling from Wolkite university specialized hospital to Sillase church than to their destination (through traffic service)and secondly to give service for local property which is found between Wolkite university specialized hospital and Sillase church(local traffic and property access). So we can say that the only category that has the above objectives in an orderly manner is Local street road.

3.2 Design speed

A fundamental aim of geometric road design is to provide road geometry (curvature, sight distance, super elevation, etc.) that is suitable for the speeds of the vehicles that operate on the road. The actual operating speeds of vehicles can vary with time due to changes in traffic conditions and from point to point due to changes in the road environment, road characteristics, speed limits, Driver behavior, and vehicle types. In urban areas, operating speeds are more aligned with speed limits, but tend to be above these limits. Accordingly, recommended design speeds for Local residential streetsare based upon the proposed speed limit plus 40 km/h.

Table 3.2:- Minimum design speed and Speed limits by road types (AACRA table 6.2-A)

Road Type	**Proposed speed limit or speed**	**Minimum Design Speed**
Suburban freeway Through carriageway	100	110
Suburban freeway to freeway ramp	80	80
Suburban freeway to Arterial Road Ramp	60/70	60/70
Suburban freeway Collector-Distributor road	80	90
Inner urban freeway Through carriageway	80	90
Inner urban freeway to freeway Ramp	60	60
Inner urban freeway to Arterial Road Ramp	60/70	60/70
Inner urban freeway Collector-Distributor road	70	80
Freeway Loop Ramp	Truck Advisory sign	40
Continuous Frontages Road	70	80
Arterial Road Controlled Access	70	80
Discontinuous Frontage Road	60	60
Arterial and Sub-arterial road with a frontage	60	70
Feeder Roads andindustrial/commercial access roads.	60	60
Low Volume Residential Feeder Roads(<3000)	50	50
Local Residential Streets	30	30
Access place	15	15
Temporary roads(Construction sidetracks)	40-60	40-60

Based on the above table for our road section, we proposed 40km/h design speed since we got only two access points which indicate minimal property access and the interchange that is going to be designed are widely spaced. And other conditions fall between the first and the second range categories.

3.3 Level of service (LOS)

Based on Highway Capacity Manual (HCM), AACRA recommends the LOS of Local roads during off-peak hours. So during the design of our road, we are aiming at the mentioned LOS.

The level-of-service concept was introduced in the 1965 HCM as a convenient way to describe the general quality of operations on a facility with defined traffic, roadway, and control conditions. Using a letter scale from A to F, a terminology for operational quality was created that has become an important tool in communicating complex issues to decision-makers and the general public. The HCM 2000 defines the level of service as follows: "Level of service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience." A term level-of-service closely related to capacity and often confused with it is service volume. When capacity gives a quantitative measure of traffic, level of service or LOS tries to give a qualitative measure. Service volume is the maximum number of vehicles, passengers, or the like, which can be accommodated by a given facility or system under given conditions at a given level of service. Level of service (LOS) qualitatively measures both the operating conditions within a traffic system and how these conditions are perceived by drivers and passengers. It is related to the physical characteristics of the highway and the different operating characteristics that can occur when the highway carries different traffic volumes. Speed-flow-density relationships are the principal factor affecting the level of service of a highway segment under ideal conditions. For a given road or facility, capacity could be constant.

But actual flow will be different for different days and different times in a day itself. LOS intends to relate the traffic service quality to a given flow rate of traffic. It is a term that designates a range of operating conditions on a particular type of facility. The highway capacity manual (HCM) provides some procedures to determine the level of service. It divides the quality of traffic into six levels ranging from level A to level F. Level A represents the best quality of traffic where the driver has the freedom to drive with free-flow speed and level F represents the worst quality of traffic.(*Addis Ababa City Roads Authority (AACRA)*, 2004)

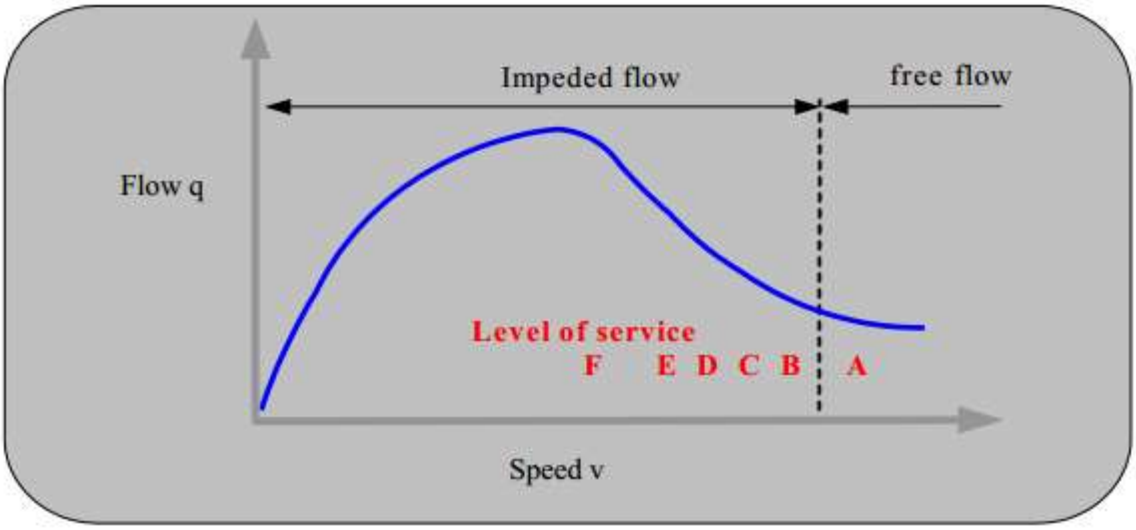


Figure 3.1:-Level of service (AACRAfig.5.2.4)

Table3.3:-Level of service (AACRA 5.2.4-A)

Level of Service	Freeways	Other Arterial Roads
A	Free flow. Average travel Speeds at or greater than 112Km/hr. The service flow rate of 700 passenger cars per hour per lane, or 32% of capacity	Average Travel speed of about 90% of free-flow speed. Stopped delay at the signalized intersection is minimal.
B	Reasonably free-flow conditions. Average travel speed at or greater than 112Km/hr. Service flow rate not greater than 1120 passenger cars per hour per lane, or 51% of Capacity.	Average travel speeds droop due to intersection delay and inter-vehicular conflicts but remain at 70% of free-flow speed. Delay is not unreasonable.
C	Operation Stable, but becoming more critical. Average travel speed of 110km/hr. Service flow at 75% of Capacity or not more than the flow rate of 1650 passenger cars per hour per lane.	Stable operations. Longer queues at signals result in an average travel speed of about 50% of free-flow speeds. Motorists will experience appreciable tension.
D	Lower speed range of stable flow. Operation approaches instability and is susceptible to changing conditions. Average travel Speed is approximately 101km/hr. Service flow rate at 92% of Capacity. Flow rate cannot exceed 2015 passenger cars per hour per lane.	Approaching unstable flow. Average travel speeds down to 40% of free-flow speed. Delays at intersections may become extensive.

E	Unstable flow Average travel speed of 96km/hr. Flow rate at capacity or 2200 passengers' car per hour per lane. Traffic stream cannot dissipate even minor disruptions. Any incident may produce a serious breakdown.	Average travel speeds 33% of free flow speed. Unstable flow. Continuous backup on approaches to intersections.
F	Forced flow. Freeway acts as a storage for vehicle backed up from downstream bottleneck. Average travel speeds range from near 50% km/hr to stop and go operation.	Average travel speed between 25% and 33% of free flow speed. Vehicular backups, and high approach delays at signalized intersection.

Factors affecting level of service

One can derive from a road under different operating characteristics and traffic volumes. The factors affecting level of service (LOS) can be listed as follows:

1. Speed and travel time
2. Traffic interruptions/restrictions
3. Freedom to travel with desired speed
4. Driver comfort and convenience
5. Operating cost.

Factors such as lane width, lateral obstruction, traffic composition, grade and driver population also affect the maximum flow on a given highway segment. The effect of each of these factors on flow is discussed.

- **Lane Width -**Traffic flow tends to be restricted when lane widths are narrower than 12 ft (3.65m). This is because vehicles have to travel closer together in the lateral direction, and motorists tend to compensate for this by driving more cautiously and by increasing the spacing between vehicles, thus reducing the maximum flow on the highway.
- **Lateral Obstruction -**In general, when roadside or median objects are located too close to the edge of the pavement, motorists in lanes adjacent to the object tend to shy away from the object, resulting in reduced lateral distances between vehicles. This lateral reduction in space also results in longer spacing's between vehicles and a reduction in the maximum flow on the highway. This effect is eliminated if the object is located at least 6ft (1.8m) from the edge of the roadway. Note, however, that lateral clearances are based mainly on safety considerations and not on flow consideration.
- **Traffic Composition -**The presence of vehicles other than passenger cars-such as trucks, buses, and recreational vehicles-in a traffic stream reduces the maximum flow on the highway because of their size, operating characteristics, and interaction with other vehicles.

- **Grade -**The effect of a grade depends on both the length and the slope of the grade. Traffic operations are significantly affected when grades of 3 percent or greater are longer than 1/4 mi (400m) and when grades are less than 3 percent and longer than l/2 mi (800m). The effect of heavy vehicles on such grades is much greater than that for passenger vehicles.
- **Speeds -**Space mean speed, are also used in level-of-service analysis because flow has a significant effect on speed.
- **Driver Population -**Under ideal conditions, a driver population consisting primarily of weekday commuters is assumed. However, it is known that other driver populations do not exhibit the same behaviour.

Because these factors affect traffic operations on the highway, it is essential that they be considered in any LOS analysis. Highway Capacity Manual (HCM) used travel speed and volume by capacity ratio (v/c ratio) to distinguish between various levels of service. The value of v/c ratio can vary between 0 and 1. Depending upon the travel speed and v/c ratio, HCM has defined six levels of service as shown in the figure below.

These operating conditions can be expressed graphically with reference to the basic speedflow relationship. At the level of service A, speed is near its maximum value, restricted only by the geometry of the road, and flows are low relative to the capacity of the highway, given the small number of vehicles present. At the level of service D, flows are maximized, with speed at approximately 50% of its maximum value. Level of service F denotes the 'breakdown' condition at which both speeds and flow levels tend towards zero.

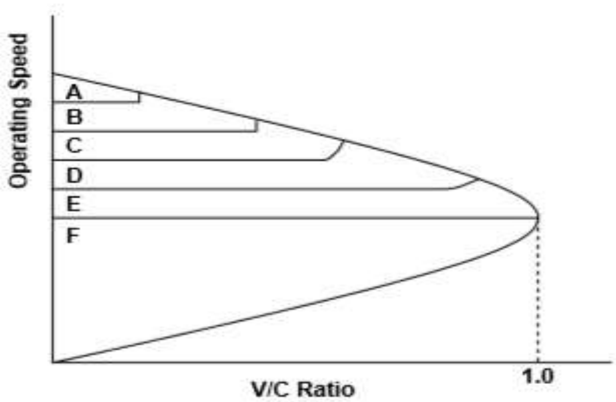


Figure 3.2**:-** The LOS of a Mid-Block Section

3.4 Design Vehicles

The Design Vehicle is a hypothetical vehicle whose dimensions and operating characteristics are used to establish certain aspects of road and intersection layout and geometry. The design vehicle is not necessarily the largest of the vehicles but is intended to represent an economical level of design catering for at least 85% of vehicles operating in accordance with the relevant regulations.

Larger vehicles will not be precluded from the road but they will need to encroach on adjacent lanes in some circumstances.

While this may inconvenience some other road users, the low frequency of the occurrence of these vehicles makes this acceptable. The design vehicle to be used in various circumstances is identified as appropriate throughout the text. In some cases - e.g. intersections, the design is undertaken in accordance with the design vehicle characteristics but is checked with a larger vehicle to ensure that it will be able to navigate the intersection. The larger vehicle will be chosen according to the potential for such vehicles to use the facility and will be at least the next larger vehicle to the design vehicle.

The following design vehicles are used for most purposes:

A. Design Car.

The design car is used for access into residential driveways (unless access for a larger vehicle such as a refuse truck is required) and for checking maneuvers on a property that are dependent on the location of the access. In other cases, a car will be able to operate with ease on elements designed for the larger vehicles. The design driver's eye height is 1.05m.

B. **Design Single-Unit Truck/Bus.**

This vehicle is often used as the design vehicle for minor road intersections on arterial roads and for intersections between secondary arterials, particularly in urban areas. This unit is also used as the design vehicle for works on collector roads.

On minor residential streets, a design service truck may be adequate. The single unit truck /bus vehicle should be used as the minimum for all intersections involving two or more arterial roads.

C. **Design Semi-Trailer.**

The design semi-trailer is the minimum vehicle for the design of intersections between two arterial roads or an arterial road and a freeway ramp.They are also the check vehicles for those designs where a single-unit truck or bus has been the design vehicle.

Higher order check vehicles may be required to check for occasional use of larger vehicles at intersections. In industrial areas, the check vehicle should be a large low-loader or prime-mover and long semi-trailer. For oversize vehicle routes, the design vehicle should be the design low-loader.(*Addis Ababa City Roads Authority (AACRA)*, 2004)

3.5 Traffic Study (traffic volume determination)

Road Agencies require traffic data for various purposes. The type of information and the accuracy required differs according to the reason for which it is to be used. The main requirements for the purpose of pavement design and rehabilitation are:

- **Annual Average Daily Traffic (AADT) -** the total year volume at a specific location divided by the number of days in the year;
- **Traffic composition** – the proportion of each type of vehicle within the total traffic stream based on a predetermined vehicle classification system
- **Equivalent Standard Axles (ESA)** – the damaging effect of each vehicle or each vehicle classification with respect to a standard axle weight.
- **Traffic Growth**– the growth rate in traffic counts at a specific location.

Traffic study was required to determine current and future traffic volume expected to use the project road.

It includes the study of the following types of traffic;

- **Normal Traffic:** Traffic volume currently using the roads without any improvements.
- **Diverted traffic:**Traffic that will be diverted to the project road from adjacent road network either due to shorter travel time or improved facilities. This traffic amount is estimated by carefully performing an origin destination (OD) survey. This couldn't be done because of data limitation therefore we took the value which is used for most designs which is 3-6%. For our road project we took 5% of the total traffic as a diverted traffic..
- **Generated traffic:** Traffic that would be generated due to developments brought about by the improvement of the road. Here the development of the area and GDP growth of the areas should be also be analyzed in order to forecast the generated traffic, but in our case we have some data limitations. Thus we adopt the generated traffic. For our road we took a generated traffic of 10% of the total traffic.

3.6 Design period

The design period is the length of time expected in years before it is anticipated that rehabilitation of the pavement will be necessary to restore shape, repair other forms of distress, or to provide additional pavement strength. Rehabilitation which may consist of granular or asphalt overlay, major patching or improvements or removal of selected areas of pavement materials, initiates a new design period. The design period starts when the completed pavement is opened to public traffic over the entire length of a construction project. From AACRA manual for most road projects an economic period of 20 years from the date of opening is appropriate. Therefore for our road project a design period of 20 years is selected.

Growth rate

Based on road traffic survey information, it is reasonable in most circumstances to assume traffic volumes will increase geometrically in the absence of growth figures (mainly GDP) AACRA recommends to select the growth rate based on economic growth zone in which the road project is located and the design period. The following growth rate matrix provides an appropriate growth rate for road projects in Addis Ababa. By considering our project area as city and we use this table for growth rate of our project, thus taking 5.5% growth rate for our road project.

Table 3.4:- Growth rate Matrics 0f Addis Ababa city

Classification	Economic Growth zone					
	1	2	3	4	5	6
Arterial	7.0	11.2	7.0	11.1	7.2	9.3
Sub arterial	6.5	9.3	6.5	9.2	6.6	8.2
Collector	6.0	7.4	6.0	7.4	6.1	6.8
Local	5.5	5.5	5.5	5.5	5.5	5.5

3.7 Traffic Count

Average Annual Daily Traffic (AADT) indicates the volume and composition of vehicular traffic moving along the roads throughout the year and is the most important information used in economic, financial and technical analysis and decisions on road projects.

The Average Annual Daily Traffic is the total yearly traffic volume divided by 365. Only where continuous counts are made under perfect conditions can a true AADT or total year's flow is computed. Any count of less than one-year duration must be regarded as a sample. Since the traffic count in Ethiopia is three times a year, the following procedure is applied to compute the average annual daily traffic volume.

The traffic count in this project is 7-days count. From the 7-days count; the first five is working day traffic counted for 12 hr. at day time and the remaining 2-days are weekends and counted for 24 hr. the traffic data are showed in Table below(*Highway II*, n.d.)

Table 3.4:-12hrs traffic count data from gubrea wolkite university main entrance.

Day	**Car**		**Pick up**		**Small bus**		**Medium bus**		**Large bus**		**Light truck**		**Medium truck**	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	87	89	0	0	7	6	2	3	4	3	1	2	0	0
2	91	90	0	0	4	4	6	4	6	7	0	3	0	0
3	76	76	0	0	6	7	5	3	5	5	0	0	2	1
4	89	90	0	1	8	7	2	4	3	4	0	0	0	0
5	73	78	0	0	9	7	3	3	1	3	1	2	2	0

6 - Day	75	76	2	0	7	6	4	4	4	2	0	2	1	0
6 - Night	20	20	0	0	6	7	0	1	0	0	1	0	0	0
7 - Day	69	67	1	0	1	0	1	2	1	1	0	0	1	2
7 - Night	19	18	0	0	0	0	0	0	0	0	0	0	0	0

The positions of the traffic count is shown in the following picture

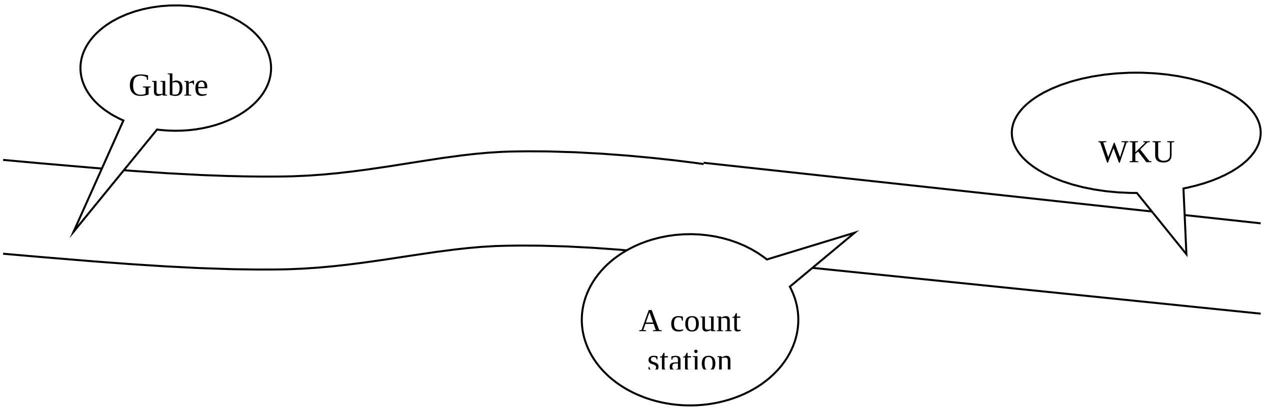


Figure 3.3:- Position of traffic count

Determination of ADT and AADT

The two days 24-hour count results were used to determine the night factors for each vehicle class. The night factors are used to convert the 12-hour count data to the equivalent 24-hour count data.

To obtain reasonable results, the night factors were determined by averaging the factors that had been obtained using the two days 24-hour count.

The determination of night factors is shown in the following tables. The above day count traffic data is 12hour count data thus changing this count data into 24hours count by using interpolation method. 24hours count data can be determined by multiplying 12hour count data by night factor (N.F).

Night Count

Since the day count was made from (6-Am to 6-Pm), night count was carried for 2 days in order to determine the evening traffic volume. Based on the night traffic count, night factor was calculated from ratio of 24hr count to 12 hr count. The night factor obtained at the count stations is shown in Table below.

Night factor = (Day count + night count)/ Day count ………………………….. (Equation 3.1)

Table 3.6:- The night factor at the count station.

	Car		pick up		Small Bus		Medium bus		Large Bus		Light Truck		Medium Truck	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L
AVG. DAY	72	71.5	1.5	0	4	3	2.5	3	2.5	1.5	0	1	1	1
AVG. NIGHT	19.5	19	0	0	3	3.5	0	0.5	0	0	0.5	0	0	0
NF(Night factor)	1.27	1.27	1	0	1.75	2.17	1	1.17	1	1	0	1	1	1

The night factors so determined were used to convert the 12-hours count data to 24-hours traffic data. These adjusted 24-hour traffic data was used to calculate the prevailing Average Daily Traffic [ADT] of the project area during the count period.

ADT=(the sum of each class of vehicle)/7 days …………………………. (Equation 3.2)

Table 3.7:- The 12hr Average daily traffic of the project area.

Day	car		pick up		small bus		medium bus		large bus		light truck		medium truck	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	87	89	0	0	7	6	2	3	4	3	1	2	0	0
2	91	90	0	0	4	4	6	4	6	7	0	3	0	0
3	76	76	0	0	6	7	5	3	5	5	0	0	2	1
4	89	90	0	1	8	7	2	4	3	4	0	0	0	0
5	73	78	0	0	9	7	3	3	1	3	1	2	2	0
6-Day	75	76	2	0	7	6	4	4	4	2	0	2	1	0
6-Night	20	20	0	0	6	7	0	1	0	0	1	0	0	0
7-Day	69	67	1	0	1	0	1	2	1	1	0	0	1	2
7-Night	19	18	0	0	0	0	0	0	0	0	0	0	0	0
ADT	80	81	1	1	7	6	4	4	4	4	1	2	1	1

The adjusted 24-hours traffic and the ADT on the existing road are shown in the following tables.

Table3.8:-The adjusted 24hrs Average Daily traffic of the project Area.

Day	Car		Pick up		Small Bus		Medium Bus		Large Bus		Light Truck		Medium Truck	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L
ADT	80	81	1	1	7	6	4	4	4	4	1	2	1	1
ADT*N.F	102	103	1	0	13	14	4	5	4	4	0	1	1	1

Table 3.9:-Average Daily traffic for both direction.

TOTAL ADT		BOTH DIRECTION ADT
R	L	
125	128	253

Calculation of AADT (Average annual daily traffic)

AADT is the Annual Average Traffic for a particular road, and is obtained by multiplying the ADT obtained from actual traffic count for a week by the Seasonal Conversion Factor (SCF). In order to include the effect of night traffic volume the night factor was multiplied by Average daily traffic volume (ADT) obtained from day count.

Another factor to be included in the determination of normal traffic is seasonal variation of traffic based on economic activities. Since there is no available traffic counts on the project roads, Seasonal Variation factor of **1** is taken (SCF= 1).

AADT0(right) = ADT(R)*SCF = 125*1 = 125

AADTO(left) = ADT(L)*SCF = 128*1 = 128

TOTAL AADTo= 253

3.8 Traffic forecasting

For our road segment wolkite university specialized hospital to Sillase churchesa seven day count and the total count is given. Thus only forecasting will be required. The above given data is for the normal traffic only. But there are other types of traffic to account in the analysis process. Now the traffic volume at the opening year can now be easily determined as:

$$AADTnb = AADT0\ (1+i)^{n} \quad \text{…………………………….. (Equation 3.3)}$$

Where:-

AADTnb: the normal base year (road opening year) traffic volume

AADT0: initial traffic volume as counted

i: growth rate

n: the road construction period;n=2 years.

$AADTnb = 1500(1+0.055)^2 = 1670$; only the normal traffic.

The generated and diverted traffic are accounted in percentage to be = (10%+5%)*1670= 251: Totally, the traffic volume at the base year will be 1670+ 4251= **1921.**

Table 3.10:-Traffic forecast to the base year

Vehicle class	Normal traffic	Generated traffic	Diverted traffic	Sum
Cars	1620	161	81	1863
Light	51	6	3	60
Medium	0	0	0	0
Articulated	0	0	0	0

For the purpose of pavement design the traffic volume can further be extended to the end of design period with the respective growth factor (will be discussed later) and the corresponding load of traffic is calculated.

3.8.1 Limitations of traffic forecasting

Forecasting of traffic is dependent up on the forecasts of factors such as, population, gross product, vehicle ownership, fuel consumption and so on. Future pattern of change in these factors can be estimated with only a limited degree of accuracy and hence traffic forecasting cannot be done accurately. In spite of its drawbacks, traffic forecasting is a very important decision for transport planning

3.9 Topography

The geometric design elements of a road depend on the transverse terrain through which the road passes. And for our road section to know the dominant transverse terrain type on which the road passes and to know the transverse terrain type at which each curve passes we did the following analysisFirst, we import elevation of the road corridor at some distance from the center line from both directions, which is to right and left from the Civil 3D software.Secondly, using the above data’s we calculate the slope of the road corridor at each 20 meter interval, Then finally, we classify the transverse terrain type based the slope we got and using ERA manual.

In general construction costs will be greater as the terrain becomes more quantities are considerable with transverse slope in excess of 50 percent difficult and higher standards will become less justifiable or achievable in such situations than for roads in either flat or rolling terrain.

In order to know the type of terrain along the selection center line or corridor, we took horizontal distance perpendicular to the center line and vertical elevation measurement across the road.

$$\text{Slope, (\%)} = \frac{\text{Vertical elevation Difference}}{\text{Horizontal distance}} * 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{(Equation 3.4)}$$

Table 3.11:-Terrain type classification based on ERA manual 2013

Terrain type	Transverse terrain slope (%)
Flat	0-3
Rolling	3-25
Mountainous	25-50
Escarpment	>50

Table 3.12:-Terrain types for our route

No	**Station**	**Terrain**	**No**	**Station**	**Terrain**
1	0+000	Flat	36	0+720	Flat
2	0+020	Flat	37	0+740	Flat
3	0+040	Rolling	38	0+760	Rolling
4	0+060	Rolling	39	0+780	Flat
5	0+080	Flat	40	0+800	Rolling
6	0+100	Flat	41	0+820	Rolling
7	0+120	Flat	42	0+840	Rolling
8	0+140	Flat	43	0+860	Rolling
9	0+160	Rolling	44	0+880	Rolling
10	0+180	Rolling	45	0+900	Flat
11	0+200	Rolling	46	0+920	Flat
12	0+220	Rolling	47	0+940	Flat
13	0+240	Rolling	48	0+980	Flat
14	0+260	Rolling	49	1+000	Flat
15	0+280	Flat	50	1+020	Flat
16	0+300	Flat	51	1+040	Flat

17	0+320	Flat	52	1+060	Rolling
18	0+340	Flat	53	1+080	Rolling
19	0+360	Flat	54	1+100	Flat
20	0+380	Rolling	55	1+120	Flat
21	0+400	Rolling	56	1+140	Flat
22	0+420	Flat	57	1+160	Flat
23	0+440	Flat	58	1+180	Flat
24	0+460	Flat	59	1+200	Flat
25	0+480	Flat	60	1+220	Flat
26	0+500	Flat	61	1+240	Rolling
27	0+520	Flat	62	1+260	Rolling
28	0+540	Flat	63	1+280	Flat
29	0+560	Rolling	64	1+300	Flat
30	0+580	Rolling	65	1+320	Flat
31	0+600	Flat	66	1+340	Flat
32	0+620	Flat	67	1+360	Flat
33	0+640	Rolling	68	1+380	Flat
34	0+660	Flat	69	1+400	Flat
34	0+680	Flat	70	1+420	Flat
35	0+700	Flat			

In this project, the cross slope of the alignment at different station includes only flat and rolling. Even though the terrain category includes flat and rolling terrain, the road way alignment is mostly flat. Therefore, our terrain category will be flat.

4. Geometric Design

4.1 Introduction

Geometric design for transportation facilities includes the design of geometric cross sections, horizontal alignment, vertical alignment, intersections, and various design details. These basic elements are common to all linear facilities, such as roadways, railways, and airport runways and taxiways. Although the details of design standards vary with the mode and the class of facility, most of the issues involved in geometric design are similar for all modes. In all cases, the goals of geometric design are to maximize the comfort, safety, and economy of facilities, while minimizing their environmental impacts. This chapter focuses on the fundamentals of geometric design, and presents standards and examples from different modes.

4.2 Number of lane determination

We used highway capacity manual (HCM) as reference to determine the number of lanes demanded to accommodate traffic on our road network. The procedures used in HCM areused to analyze the capacity, level of service (LOS), lane requirements, and impacts of traffic and design features of urban areas. The methodology followed by HCM is to define the base conditions in urban multi-lane highways, to identify the factors which affect base condition and the extent of their effect.

A set of base conditions for developing flow relationships and adjustments to speed are 3.6 m minimum lane widths, 3.6 m minimum total lateral clearance in the direction of travel, this total represents the lateral clearances from the edge of the traveled lanes to obstructions along the edge of the road and in the median. Lateral clearances greater than 1.8 m are considered in computations to be equal to 1.8 m. the other base conditions are only passenger cars in the traffic stream, no direct access points along the roadway, a divided highway, and free-flow speed higher than 100 km/h.(Gibreel et al., 1999)

4.3 Application of the methodology

The methodology of may be used to analyze the capacity and level of service of multilane highways. To apply the methodology, we must address two fundamental questions. First, the primary output that is being solved for must be identified. Primary outputs that typically are solved for in a variety of applications include level of service (LOS), number of lanes required (N), and flow rate achievable (Vp). Performance measures related to density (D) and speed (S) are also achievable as outputs and are considered as secondary outputs.

Second items which must be identified are the default values orestimated values which will be used in the analysis. Basically, we have threesources which provide input data. Default values found in this manual, estimates and/or\ locally derived default values developed by the user, and values derived from fieldmeasurements and observation are the three categories of inputs. For each of the inputvariables, a value must be supplied if the outputs, both primary and secondary, are to becalculated.

A commonly used application for the method is to compute the LOS of an existing facility or of a changed facility in the near term or distant future. This type of application is often termed operational and its primary output is LOS, with secondary outputs for density and speed. Another application type is when we wish to check the adequacy or to recommend the required number of lanes for the multilane highway given the volume or flow rate and level-of-service goal. This application type has been termed design since it has as its primary output the number of lanes required to serve the assumed conditions. Other outputs from this type of application include speed and density. Finally, the achievable flow rate, Vp, can be solved for as the primary output. This analysis requires that a level-of-service goal and number of lanes for the multilane highway be stated as inputs. This analysis is typically used to establish an estimate of when a flow rate will be exceeded, causing the highway to operate at an unacceptable level of service.

Another general type of analysis can be defined by the term planning. These analyses imply the use of estimates, HCM default values, and/or local default values on the input side of the calculation. As outputs, LOS, number of lanes, or flow rate can be determined along with the secondary outputs of density and speed.

The difference between this type of analysis and those identified as operational or design is simply that most or all of the input values come from estimates or default values, while the operational and design analyses tend to utilize field measured values or use known values for most or all of the input variables. Note that for each of the analyses described, free flow speed, either measured or estimated, is required on the input side of the computation.(Daniel Getachew, 2021)

4.4 Procedure for determining number of lane

The procedures which are used during the determination of number of lane for our road network will be discussed along with their concept.

4.4.1 Determination of free-flow speed

Free-flow speed is measured using the mean speed of passenger cars operating in low to moderate flow conditions (up to 1,400 pc/h/ln). Mean speed is virtually constant across this range of flow rates. Two general methods can be used to determine the free-flow speed for the highway: field measurement, and estimation with guidelines.

The free-flow speed of a highway can be determined directly from a speed study conducted in the field. If field-measured data are used, no subsequent adjustments are made to free-flow speed. The speed study should be conducted at a representative location within the highway segment being evaluated; for example, an upgrade should not be selected within a site that is generally level.

The speed study should measure the speeds of all passenger cars or a systematic sample of passenger cars (e.g., every 10th passenger car).

The speed study should not only measure speeds for unimpeded vehicles but should also include representative numbers of impeded vehicles. A sample of at least 100 passenger-car speeds should be obtained.

For our case we estimated free-flow speed indirectly using formula and procedures which will be discussed as follows;

$$FFS = BFFS - f_{LW} - f_{LC} - f_M - f_A \quad \text{…………………………………… (Equation 4.1)}$$

Where;

BFFS= base free-flow speed, km/h

f_{LW}= adjustment for lane width, km/h

f_{LC} = adjustment for lateral clearance

km/h, f_M = adjustment for median type

fA = adjustment for access points

If field measurements are unavailable, FFS can be estimated by applying adjustments to a base FFS. A base FFS of 100km/hr may be used for a rular or a sub urban multilane highway. The base FFS must reduced to account for the effects of lateral clearance at the shoulder and median; median type; lane width and density of access points. Thus our BFFS is 100km/hr.

f_{LW}= adjustment for lane width, km/h,

Base conditions for multilane highways are based on 3.6m lane widths. And there is an adjustment to modify the estimated free-flow speed to account for narrower lanes. i.e. 3.0 m, 3.3 m and 3.5m lanes reduce free-flow speeds by 10.6 km/h, 3.1 km/h and 1 km/h respectively.

Table 4.1:-Adjustment for lane width.

Lane Width(m)	Reduction in FFS (km/h)
3.6	0.0
3.5	1.0
3.4	2.1
3.3	3.1
3.2	5.6

3.1	8.1
3.0	10.6

Since the lane width on our road network is3m adjustment for lane width will be

f_{LW}=10.6km/h

f_{LC} = adjustment for lateral clearance, km/h,

Fixed obstructions whose lateral clearance effects should be considered include light standards, signs, trees, abutments, bridge rails, traffic barriers, and retaining walls. Standard raised curbs are not considered as obstructions.

The Adjustment for Lateral Clearance, to consider reduction of free flow speed, depends on lateral clearance from the right edge of the travel lanes to roadsideobstructions (if greater than 1.8 m, 1.8 m will be adopted) and lateral clearance from the left edge of the travel lanes to obstructions in the roadway median (if the lateral clearance is greater than 1.8 m, 1.8 m will be adopted). For undivided highways, the lateral clearance on the left edge is always 1.8m. Lateral clearance in the median of roadways with two-way left turn-lanes(TWLTLs) is considered to be 1.8m.

Table 4.2:-Adjustment for lateral clearance

Four-lane Highways	Four-lane Highways	Six-lane Highways	Six-lane Highways
Total Lateral Clearance(m)	Reduction in FFS (m)	Total Lateral Clearance(m)	Reduction in FFS (m)
3.6	0.0	3.6	0.0
3.0	0.6	3.0	0.6
2.4	1.5	2.4	1.5
1.8	2.1	1.8	2.1
1.2	3.0	1.2	2.7
0.6	5.8	0.6	4.5
0.0	8.7	0.0	6.3

The lateral clearance we got on our road network is from the right edge of the travel lanes to roadside obstructions i.e. 1.8m and the adjustment factor for 1.8m lateral clearance is 2.1km/h.

f_{LC} =2.1km/h

f_M = adjustment for median type,

The average free-flow speed should be decreased by 2.6 km/h for undivided highways, to account for the friction caused by opposing traffic in an adjacent lane, and 0km/h for divided highways.

Table 4.3:-Adjustment for median type

Median Type	Reduction in FFS (km/hr)
Undivided highways	2.6
Divided highways (including TWLTLs)	0.0

Since our road network have no median, adjustment for median type will be 0km/hr.

F_M=0km/h

fA = adjustment for access points

Adjustment to free-flow speed for various levels of access-point density is different and that is, every access point per kilometer decreases the estimated free-flow speed by approximately 0.4 km/h, regardless of the type of median. The access-point density on a divided roadway is found by dividing the total number of access points (intersections and driveways) on the right side of the roadway in the direction of travel being studied. An intersection or driveway should only be included if it is considered to have an influence on traffic flow. Access points that are unnoticed by the driver or those with little activity should not be included in the determination of access-point density.

On our road network there are only two intersections in 1.42km so there is no effect on the reduction of free flow speed.

fA=0km/h

FFS = estimated free-flow speed, km/h, FFS = BFFS - f_{LW} - f_{LC} - f_M – f_A

FFS=100km/h-10.6km/h-2.1km/h-0km/h-0km/h

= **87.3km/h**

4.4.2 Determination of flow rate

Two adjustments must be made to hourly volume counts or estimates to arrive at the equivalent passenger-car flow rate used in LOS analyses. These adjustments are the peak-hour factor and the heavy vehicle adjustment factor. The number of lanes is also used so that the flow rate can be expressed on a per-lane basis. These adjustments are applied following the equation below

$$Vp = \frac{V}{PHFNfhvfp} \quad \text{………………………………………………………… (Equation 4.2)}$$

Where; N= number of lane;

PHF = peak-hour factor,

Peak hourly volume (V) The peak hourly volume is the highest hourly volume within a 24-hour period. Since the traffic count data is not on hourly basis assuming a percentage of the total traffic count (10% of the average annual daily traffic AADT for our project), we get V=0.1*1921=192veh/hr.

Peak-hour factor (PHF**) -** The ratio of the hourly volume to the peak 15 minute flow (V15) enlarged to an hourly value**.**

$$PHF = V \div V15 \times 4 \quad \text{(Equation 4.3)}$$

Where:-

V=the highest hourly volume within a 24-hour period enlarged to an hourly value

V15=Peak 15 minute flow.

Peak-hour factor (PHF) represents the temporal variation in traffic flow within an hour. Observations of traffic flow consistently indicate that the flow rates found in the peak 15-minute period within an hour are not sustained throughout the entire hour. Application of PHF in the above equation accounts for this phenomenon. In the absence of field measurement0f peak hour flow (PHF), Approximations can be used. For congested condition, 0.92 is a reasonable approximation for PHF. For conditions in which there is fairly uniform throughout the peak hour but a recognizable peak does occur, 0.88 is a reasonable estimate of PHF.

Thus for our road network peak-hour factor is **-**

PHF=0.88

V = hourly volume, vehicle/hr,

Is calculated using AADT and to convert AADT to DDHV we used the following formula.

$$DDHV = AADT*K*D \quad \text{(Equation 4.4)}$$

Where;

K=peak hour volume,

Since the Peak hour volume is 10% of the daily K is taken as 0.1

D=directional factor

From the traffic survey flow of traffic in both direction is equal 50/50, so D is taken as 0.5.

Our AADT value from traffic survey and analysis is 1921vehicle/hr

DDHV=design daily hourly volume

=AADT*K*D

=1921*0.1*0.5

= 97veh/h

f_{HV} = heavy vehicle adjustment factor,

The presence of heavy vehicles in the traffic stream decreases the free-flow speed Heavy-vehicle factor (f_{HV}) because under base conditions the traffic stream is composed only of passenger cars.Therefore, traffic volumes must be adjusted to reflect an equivalent flow rate expressed in passenger cars per hour per lane. This is accomplished through application of the factorf_{HV}. And heavy vehicle adjustment factor is calculated using the following formula

$$f_{HV} = \frac{1}{1+PT(ET-1)+PR(ER-1)} \quad \text{………………………………………… (Equation 4.5)}$$

Where;

ET, ER = passenger-car equivalents for trucks and buses and for RVs, respectively,

Table 4.4:- Passenger-car Equivalents for trucks and RVS to determine speeds on Two-way and directional segment.

Vehicle Type	Range of two way flow rates(pc/h)	Range of Directional flow rates(pc/h)	Terrain type Level	Terrain type Rolling
Trucks,ET	0-600	0-300	1.7	2.5
	>600-1200	>300-600	1.2	1.9
	>1200	>600	1.1	1.5
RVs,ER	0-600	0-300	1.0	1.1
	>600-1200	>300-600	1.0	1.1
	>1200	>600	1.0	1.1

Passenger-car equivalents can be selected for two conditions: extended general highway segments and specific grades.

A long multilane highway segment may be classified as an extended general highway segment if no grade exceeding 3 percent is longer than 0.8 km, and grades of 3 percent or less do not exceed 1.6 km. and as isolated specific grade if grade of 3 percent or less that is longer than 1.6 km or any grade greater than 3percent that is longer than 0.8 km. based on this criteria we select our passenger-car equivalent for extended general highway segment.

According to highway capacity manual passenger-car equivalents on extended general highway segments for rolling terrain is given as

ET (trucks and buses) = 2.5

ER (RVs) = 1.1

PT, PR = proportion of trucks and buses, and RVs, respectively, in the traffic stream (expressed as a decimal fraction),

From traffic survey the vehicles composition is 0% truck and 01% (recreational vehicle)RVs

PT=0

PR=0.1

Adjustment for the presence of heavy vehicles in the traffic stream applies for three types of vehicles: trucks, recreational vehicles (RV's), and buses. There is no evidence to indicate any distinct differences in performance characteristics between the truck and bus population on multilane highways, and thus buses are considered as trucks in this method.

fp = driver population factor

The adjustment factor fp reflects the effect (weekend recreational, perhaps even midday) drivers have on the facility. The values for fp range from 0.85-1.00. When greater accuracy is needed, comparative field studies of weekday and weekend traffic flow and speeds are recommended. Typically, we select 1.00, which reflects weekday commuter traffic (i.e., users familiar with the highway), since there is no sufficient evidence that a lesser value, reflecting more recreational or weekend traffic characteristics, should be applied.

The level of service (LOS) of our road network is c and from the above calculation we have free-flow speed of 87.3km/hr and which is approximated to 90km/h for design purpose.

Using the above two data's we can read flow rate from the following table

Table 4.5:- Free-flow speed Vs Level of service

Free-Flow Speed	Criteria	Level of service (LOS)				
		A	B	C	D	E
100 km/h	Max density (pc/km/ln)	7	11	16	22	25
	Average speed (km/h)	100.0	100.0	98.4	91.5	88.0
	Max v/c	0.33	0.50	0.72	0.94	1.00

	Max service flow rate (pc/h/ln)	700	1100	1575	2015	2200
90km/h	Max density (pc/km/ln)	7	11	16	22	26
	Average speed (km/h)	90.0	90.0	89.8	84.7	80.8
	Max v/c	0.31	0.47	0.68	0.89	1.00
	Max service flow rate (pc/h/ln)	630	990	1435	1860	2100
80km/h	Max density (pc/km/ln)	7	11	16	22	27
	Average speed (km/h)	80.0	80.0	80.0	77.6	74.1
	Max v/c	0.30	0.44	0.64	0.85	1.00
	Max service flow rate (pc/h/ln)	560	880	1280	1705	2000
70km/h	Max density (pc/km/ln)	7	11	16	22	28
	Average speed (km/h)	70.0	70.0	70.0	69.6	67.9
	Max v/c	0.28	0.41	0.59	0.81	1.00
	Max service flow rate (pc/h/ln)	490	770	1120	1530	1900

For a given LOS (c) and free-flow speed (90km/h); Flow rate, Vp is 990 up to 1435. Then we fixed the maximum flow rate which is 1435.

Then we used the following formula to determine number of lane (in one direction)

$$N = \frac{V}{PHFVpfhvfp} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Equation 4.6)}$$

Since every unknown is already determined before, we can substitute them in to the formula $N = \frac{97}{0.88*0.87*1435*1}$

N = 0.88 we adopt 1 for design purpose.

Total number of lanes(two - direction) = N*2 = 1*2 = (Two)

4.5 Cross section design

The prime determinants of cross-section design are the function that the road is intended to Serve, the nature and volume of traffic to be accommodated and the speed of the traffic.

Road function refers to a spectrum of needs ranging from accessibility to mobility. Furthermore, a road can be classified on a variety of different bases. A common feature of these considerations is that they largely concern addressing the needs of the occupants of a moving vehicle. These needs may find expression in a desire for ready access to or from a property adjacent to the road, freedom to maneuver in a terminal or intersection area or for high-speed long distance travel. High-speed traffic requires more space than relatively slow moving traffic. Space takes the form of wider lanes, wider shoulders and (possibly) the inclusion of a median in the cross-section. All these needs have to be met in terms of overall objectives of safety, economy, convenience and minimum side effects.

In urban areas, road functions also have to include considerations of living space. People enjoy casual encounters, meeting people on neutral territory, as it were, without the obligation of having to act as host or hostess in the home. The sidewalk café, the flea market and window-shopping all have to be accommodated within the road reserve. All of these activities impact on the cross-section, which has to be designed accordingly.

Traffic does not exclusively comprise motorized vehicles. In developing areas, it may be necessary to make provision for animal-drawn vehicles and, in this context, developing areas are not necessarily exclusively rural. The volume of motorized vehicles will have an impact on the design of the cross-section with regard to the number of lanes that have to be provided. High volumes of moving vehicles will generate a need for special lanes such as for turning, passing, climbing or parking.

In urban areas, the presence of large numbers of pedestrians will require adequate provision to be made in terms of sidewalk widths. Pedestrians are also to be found on rural roads. On rural roads, speeds are high so that crashes involving pedestrians are inevitably fatal. It is thus sensible to make at least modest provision for pedestrians on rural roads, even though their numbers may be low.

Cyclists can often be accommodated on the normal travelled lanes but, when the number of cyclists increases, it may be necessary to widen these lanes or, as a further development, to provide cycle paths adjacent to or, for preference, removed from the travelled lanes.

Although the horizontal and vertical alignments are disaggregated in the sense that they are a combination of tangents and curves, the cross section is heavily disaggregated, comprising a multitude of individual elements. Design is thus concerned primarily with the selection of elements that have to be incorporated within the cross-section, followed by sizing of these individual elements.

4.5.1 Safety of cross section

Safety is a primary consideration in the design of the cross-section. The safety of the road user refers to all those within the road reserve, whether in vehicles or not. Wide lanes supposedly promote the safety of the occupants of vehicles although current evidence suggests that there is an upper limit beyond which safety is reduced by further increases in lane width. The reverse side of the coin is that wide lanes have a negative impact on the safety of pedestrians attempting to cross the road or street. In devising safe cross-sections, it is therefore necessary to consider the needs of the entire population of road users and not just those in vehicles.

In urban areas, it is necessary to make provision for boarding and alighting public transport passengers, disabled persons and other non-vehicular users of the facility in addition to accommodating pedestrians and cyclists. In these areas, design speed usually plays a lesser role in the design of the cross-section.

4.5.2 Cross section elements

In the following section we will discuss the cross section elements incorporated in our road section, the service they provide in the road network and consideration which are made during their design will be discussed.

Border

The border includes a footpath and space for services, landscape planting, and roadside furniture including signs, street lights and bus stop shelters and seats, and indented bus bays and possibly indented parking bays.

On our road section the terms boarder and footpath are different only at two stations where there is bus seat, in which the term boarder will be applicable rather than footpath and we locate our foot path.away from kerb side placement of wheeled bins for collection of household garbage and recycling waste and opening car doors when cars are parked at the kerb

Borders on arterial roads and local streets provide room for:

i. Pedestrian movement on footpaths
ii. Off road bicycle travel
iii. Turning movements between the carriageways and adjacent property entrances
iv. Road signs and lighting standards
v. Landscaping vi. Bus bays
vi. Providing space for the provision of underground and above ground services
vii. Providing space for landscaping to improve the appearance of the street environment
viii. Providing a drainage function for overland flows
ix. Providing adequate sight distances for traffic on the road (including cyclists and pedestrians on a path) to see vehicles pedestrians or cyclists entering the roadway from blocks.
x. Providing a buffer area for reduction in traffic noise level at dwellings xii. Providing for level differences between carriageway and blocks
xi. providing areas for parking off the carriageway if the road pavement is narrow

The co-location of public telephones, post boxes, bus stops and drop-off bays to create activity nodes on borders is good practice.

Border Cross fall

It is usual to slope the footpath and the rest of the border towards the road so that water does not drain on to adjoining properties. Where it is not possible to do this, drainage onto adjacent properties will have to be arranged with the property owners. The slope of the footpath should be 2% - 2.5% so that it drains but is useable by wheelchairs. An area of approximately 2.5 metres at 2% grade towards the kerb is required adjacent to the kerb for the following reasons:

(i) To enable driveway access to blocks without vehicles scraping

(ii) To provide freeboard for stormwater gutter flows.

(iii) For rubbish bin placement if kerbside collection is required

(iv) For pedestrian and cycle refuge.

Carriageway

Each carriageway will provide two, three or four through lanes depending on design flows. At intersections, additional lanes for left turns and right turns are usually necessary. Lane widths are normally 3.5m, but lanes as narrow as 3.0m may be appropriate if the right of way is restricted. We selected the carriageway width to be 6m.

Table 4.6:-Cross sections for local streets in residential Area

Border Width	Footpath Width	Carriageway Width
2x 4.0	1 x 1.2	6.0

Shoulders

The shoulder is that portion of freeway carriageway beyond the traffic lanes, adjacent to, and flush with the surface ofthe pavement. Its purpose is to accommodate stopped vehicles and provide lateral support to the road pavement layers. It also forms part of the clear zone. The shoulder width is measured from the edge of the traffic lane to the verge. All safety barriers, signs, guide posts, drains and kerbs are to be contained outside the shoulder within the verge. Shoulders are not used on urban roads other than freeways. On these roads, parking lanes perform similar functions.

Crossfall

Cross fall is defined as the side slope, normal to the alignment, of the surface of any part of the carriageway. And it is Expressed as a percentage, this is the cross slope of the road surface at right angles to the road alignment. The cross falls provided for each cross section element on our road network will be discussed in the following section.

Pavement Cross fall

Cross fall is provided primarily to facilitate pavement drainage. The usual arrangement for straight sections of road is for the pavement cross fall to slope down from either the centerline or the median.

However inward sloping cross fall or one way cross fall may be useful for certain grades, drainage or side slope situations.

For wide multilane pavements, it may be appropriate to crown the pavement with one or two lanes draining to the median. This minimizes the depth of flow on the pavement surface, reducing aquaplaning potential. Cross fall has the important function of shedding water from the roadway to reduce the possibility of a vehicle aquaplaning in wet conditions.

On curved section of highway, Cross fall is up slope and is known as super elevation. Super elevation design on our road section will be discussed in detail in the horizontal alignment design.

Table 4.7:-Typical Pavement Crossfall (AACRA table7.8.14-A)

Road Surface	Traffic Lane(%)	Shoulder(%)
Cement Concrete	2.0-3.0	2.0-4.0
Asphaltic Concrete	2.5-3.0	2.5-4.0
Sprayed Seal	3.0-3.5	3.0-4.0

Based on AACRA manual the typical pavement Cross fall for asphaltic concrete is 2.5-3. Based on this recommendation we designed our pavement Cross fall to be 2.5%. And the term pavement Cross fall refers to both through carriageway and frontage road.

Cross-over Crown Line

On straight sections of road, the maximum algebraic change in crossfall over a crown line is 7%. According to AACRA where a turning roadway with average running speed of greater than 50km/h through road exits from a carriageway, and a different crossfall is required on the through road and the turning roadway, the algebraic change in crossfall over the crown line formed must be limited to 5%.

Median Crossfall

Medians up to 8 m wide are generally level or follow the crossfall of the road. Depressed medians greater than 8 m wide should have a desirable crossfall of 1 on 10. At intersections where signals are to be installed, the median cross slope must match the slope of the road through the intersection and should not be greater than 6%. Since our maximum width of median is 2.5m, we adopt a level median.

Border Crossfall

It is usual to slope the footpath and the rest of the border towards the road so that water does not drain on to adjoining properties. Where it is not possible to do this, drainage onto adjacent properties will have to be arranged with the property owners. The slope of the footpath should be 2% - 2.5% so that it drains but is useable by wheelchairs.We designed our border (footpath) Crossfall as 2%.

4.6 Sight distance

Sight distance is the distance over which visibility occurs between a driver and an object or between two drivers at specific heights above the carriageway. For safety on the road, sufficient sight distance must be provided to enable drivers to control their vehicles to avoid collisions with other vehicles or objects on the road.

Simply put, sight distance is the distance visible to the driver of a passenger car. For highway safety, the designer must provide sight distances of sufficient length that drivers can control the operation of their vehicles. They must be able to avoid striking an unexpected object on the traveled way. Two-lane highways should also have sufficient sight distance to enable drivers to occupy the opposing traffic lane for passing maneuvers, without risk of accident.

Minimum sight distance based on car braking performance must be obtained at all points along the roadway for the chosen design speed. In some circumstances, additional sight distance for trucks may be desirable. These situations include (but are not limited to): horizontal curves on downgrades sag vertical curves with overpass structures or sign gantries and intersections.

4.6.1 Sight Distance Parameters

The parameters that are going to be checked for calculation of different types of sight distances will be discussed in detail in the following section.

Truck Sight Distance Check

Roads and junctions must be designed to provide safe operating conditions for both cars and trucks. Both truck and car stopping distance requirements need to be considered. The design speed for cars in urban areas is usually 10km greater than the posted speed limit. The truck sight distance check shall be undertaken using the speed limit (usually 10km/h less than the car design speed) or the estimated truck operating speed, whichever is the lower. Allowance for the different operating speeds of cars and trucks should be made. For example, on an uphill grade truck speeds will be reduced and the truck stopping distance will be reduced by the effect of gravity.

The increased height of the truck gives better visibility over crests, median barriers and bridge parapets. In some circumstances, this extra visibility compensates for the longer stopping distance of trucks. In other cases, such as on horizontal curves with adjacent retaining walls (or in curved tunnels) the truck driver eye height does not increase sight distance.

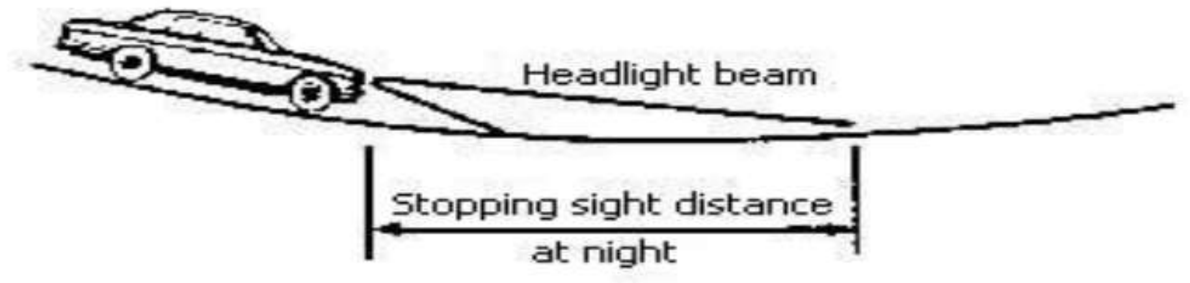


Figure 4.1:- Stopping sight distance at Sag(*Ethiopian Roads Authority (ERA)*, 2013)

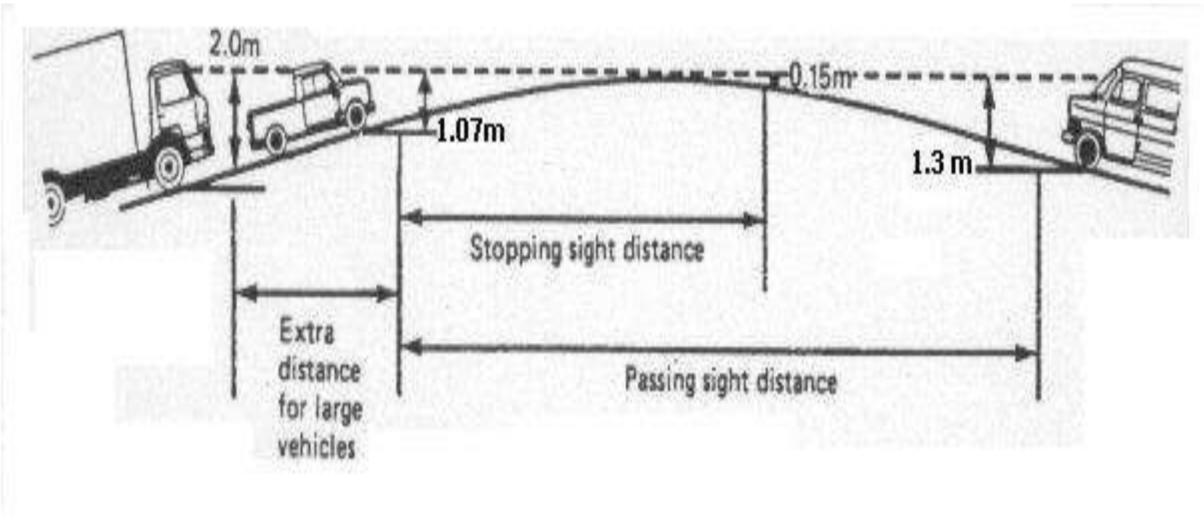


Figure 4.2:-Stopping sight distance at Crest(*Ethiopian Roads Authority (ERA)*, 2013)

Trucks require significantly greater time to cross intersections and to turn on and off main roads. The recognition of the longer gap in opposing traffic flows requires longer sight distances for trucks than cars. The additional eye height assists obtain the longer sight distance if a crest vertical curve is in the vicinity of the intersection. However, horizontal curvature and sight distance obstruction by roadside development may limit the visibility. Intersections with significant truck usage and restricted visibility may require the installation of traffic signals for safety reasons.

Truck Speeds on Grades

Using charts which are constructed based on the observed performance of trucks with 120kg weight for each kW of power we estimated truck operating speed and the appropriate truck sight distance checks carried out For a given grade and grade distance. On downgrades, the truck should be assumed not to exceed the speed limit.

The following two charts can be used for to estimate Trucks speeds on upgrades and acceleration of trucks on upgrades and downgrades

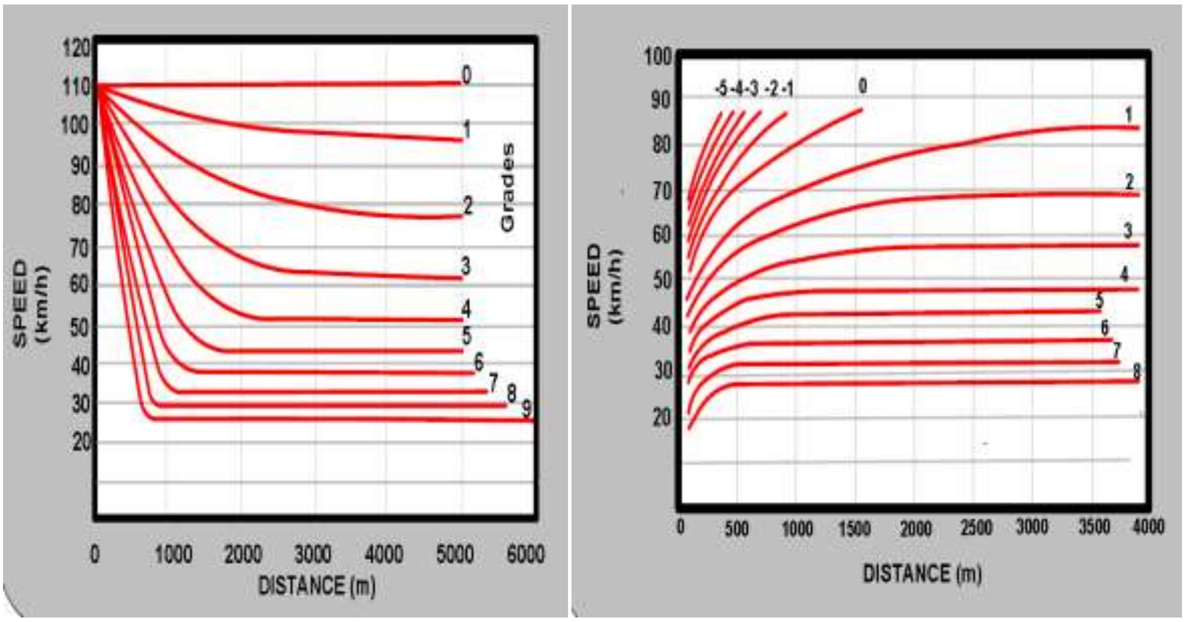


Figure 4.3:- Truck speed on uphill grade and on grade.

A. Driver Reaction Time

The representative driver reaction time for sight distance calculation purposes is 2.5 seconds. Absolute minimum stopping sight distances based on a 2.0 second reaction time may be used for mid-block sections where an economic design cannot be achieved using 2.5 second reaction time. Junction design must be based on 2.5 second reaction time. And for our road network we adopt a 2.5 second reaction time.

B. Driver Eye Height

The representative height for design calculations of the car driver's eye is 1.05m. And the representative height of a truck driver's eye for design calculations is 2.40m. For our road network we used the above figures for calculation purpose.

C. Object Height

The height of object that is to be used during sight distance calculations is different for varying situations. And the following table will illustrate this scenario.

Table 4.8:- Object height

Object Height (m)	Situation
0.0 (Pavement)	Intersection design (ASD) Sight line to line marking Sight line to freeway exit lane Sight line to freeway exit nose
0.2 (Object on road)	Mid-block crest vertical curve design (SSD) Horizontal curve line of sight (SSD): • generally • on bridges and where crash barrier present • in tunnels, past bridge abutments and retaining walls
0.6 (Car tail lights and turn indicators)	Sight lines under bridges/sign gantries at sag vertical curves (SSD) Sight lines to ends of queues at intersections (SSD) Sight line used for gap acceptance object (MGSD)
1.05 (Car)	Intersection design (SISD)
1.3 (Car roof)	Horizontal curve line of sight over roadside safety barrier or bridge parapet

4.6.2 Mid- block Sight Distance

The term mid-block sight distance accounts for stopping sight distance, overtaking sight distance and sight distance on horizontal curves. And each of them will be discussed in detail in the following section.

Stopping sight distance derivation

SSD=d1 +d2 ………………………………………………………………. (Equation 4.7)

Where;

d1 = reaction distance=RT*V/3.6

RT= reaction time: 2.5 sec

V = operating speed:

d2 = braking distance =V2/254(F1+0.01G)

F1 = longitudinal friction factor:

Longitudinal friction factor

Table 4.9:-Longitudinal friction factor

Operating Speed (km/hr)								
Vehicle	40	50	60	70	80	90	100	110
Car	0.56	0.52	0.48	0.45	0.43	0.41	0.39	0.37
Truck	0.29	0.29	0.29	0.29	0.29	0.29	0.28	0.26

Car Stopping Sight Distance

- ❖ Car stopping sight distancecalculation

SSD = d_1 +d_2

d1 = reaction distance=RT*V/3.6

RT= reaction time: 2.5 sec (from the above discussion)

V = operating speed: 40km/h (design speed of the road network)

d_1 = (2.5sec*40km/hr/3.6) =27.78m

d2 = braking distance =V2/254(F1+0.01G)

F1 = longitudinal friction factor: for bituminous and concrete surfaces with a design speed of 40km/h AACRA recommends longitudinal friction factors for cars to be 0.56 and longitudinal friction factors for trucks to be 0.29.

G=longitudinal grade in % (+ for upgrade, – for down grade and 0 for level grade)

d_2= (40km/hr*40km/hr)/254(0.56+0) = 11.25m

SSD = 27.78m +11.25m = 39.03m.

= 39.03m approximately39m

Table4.10:-Car stopping sight distance

Car Speed (Km/hr)									
		40	50	60	70	80	90	100	110
Friction factor		0.56	0.52	0.48	0.45	0.43	0.41	0.39	0.37
SSD Level Grade	2.5 sec reaction time	39	54	71	91	114	140	170	205
SSD Level Grade	2.0 sec reaction time	33	47	63	82	103	128	157	190
Correction for grade Upgrade	2%	0	0	-1	-2	-3	-4	-5	-7
	4%	0	-1	-2	-4	-5	-7	-9	-13
	6%	-1	-2	-3	-5	-7	-10	- 14	-18
	8%	-1	-3	- 4	-7	- 9	- 13	-17	-23
Correction for grade Upgrade	-2%	-	-	1	2	3	4	6	7
	-4%	-	2	3	4	6	8	12	16
	-6%	1	3	4	7	10	13	18	25
	-8%	2	4	6	9	13	19	26	36

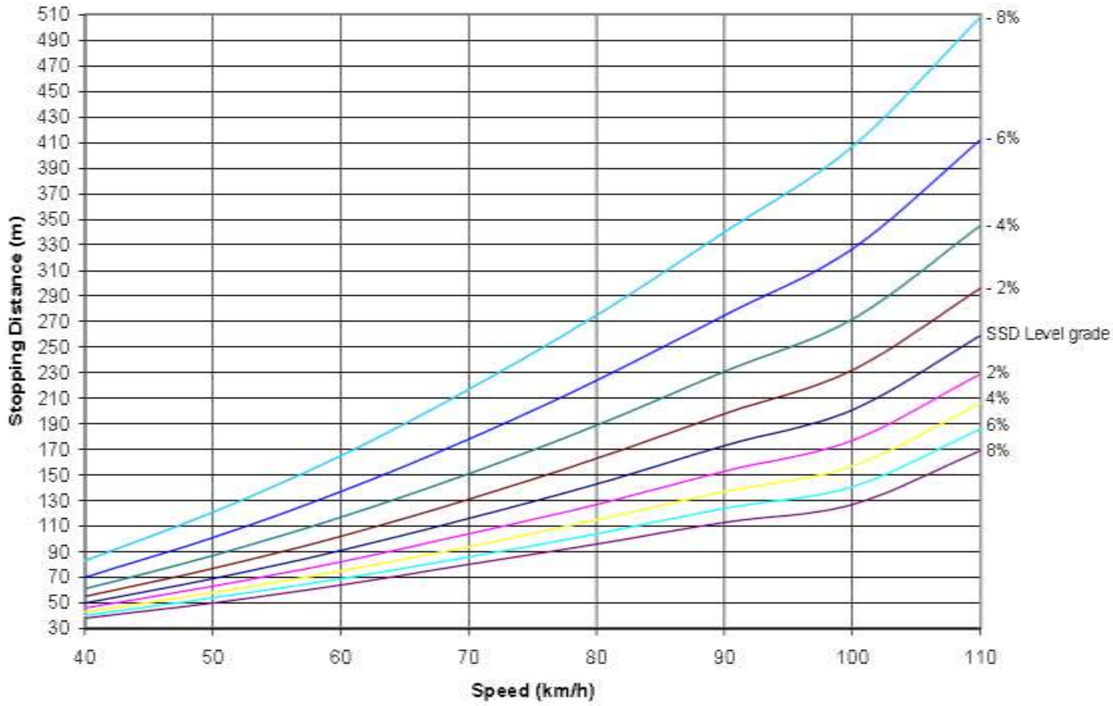


Chart 4.1:-Car stopping sight distance

Truck Stopping Sight Distance

- Truck stopping sight distance calculation

SSD=d_1 +d_2

$$d1 = \frac{2.5sec * 40km/h}{3.6} = 27.78\text{m}$$

$$\text{d2} = \frac{40\text{km/h} * 40\text{km/h}}{254(0.29 + 0)} = 21.72\text{m}$$

SSD = $27.78m$+21.72m= 49.5

=49.5 approximately 50m.

Table 4.11:-Truck stopping sight distance

Truck Operating Speed (Km/hr)									
		40	50	60	70	80	90	100	110
Friction factor		0.29	0.29	0.29	0.29	0.29	0.29	0.28	0.26
SSD Level Grade	2.5 sec reaction time	50	69	91	116	143	173	201	259
SSD Level Grade	2.0 sec reaction time	44	62	82	106	131	160	197	244
Correction for grade Upgrade	2%	-4	-6	-9	-12	-16	-20	-24	-30
	4%	-7	-11	-16	-22	-28	-36	-44	-53
	6%	-10	-15	-22	-30	-39	-49	- 60	-73
	8%	-12	-19	- 27	-36	- 47	- 60	-74	-90
Correction for grade Upgrade	-2%	5	8	11	15	20	25	31	37
	-4%	11	18	26	35	46	58	71	86
	-6%	20	32	46	62	81	102	126	153
	-8%	33	52	74	101	132	167	206	249

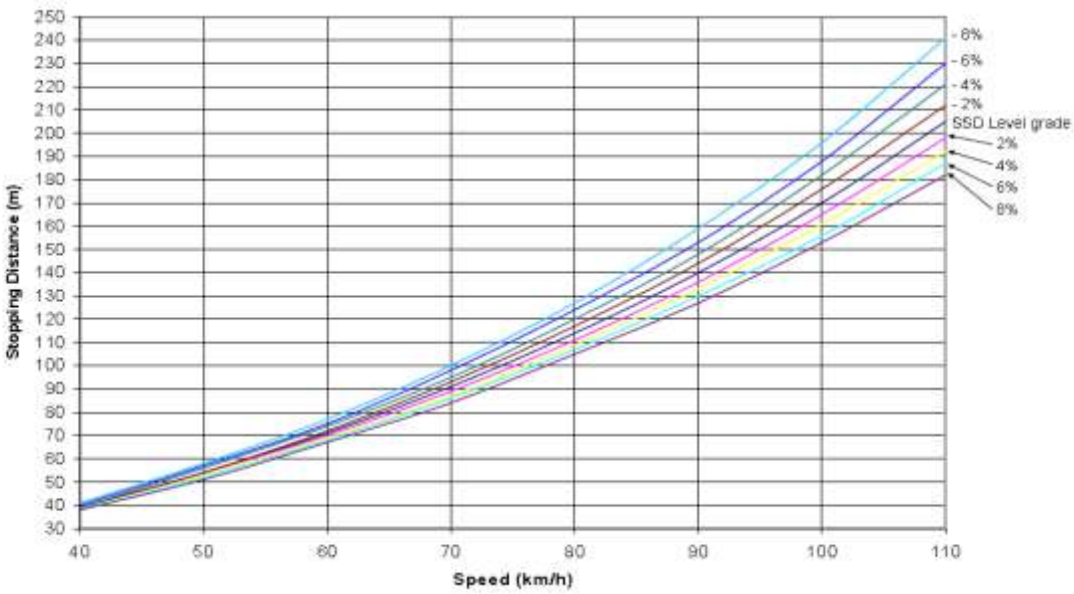


Chart 4.2:-Truck stopping sight distance

According to the above calculation the critical case is for trucks (truck SSD is greater than car SSD). Therefore the stopping distance of the road network will be 50m.

SSD for cars and truck can also be calculated from the following charts along with grade correction. But for our road network the critical condition is for level ground.

4.6.3 Overtaking Sight Distance

Overtaking sight distance is of relevance on two way roads in rural areas. In urban areas, overtaking sight distance is not usually a design consideration on local streets. Arterial roads and freeways are normally dual carriageway or multi-lane, and overtaking sight distance is again not an issue. However, the initial development of a freeway or arterial road may involve the construction of a single carriageway operated two-way until traffic volumes increase and duplication is necessary. Allowing overtaking sight distance will increase the capacity of the initial two way road, but any additional cost of achieving better sight distance would need to be considered.Since our road is a divided arterial road there is no need of considering Overtaking sight distance.(*Geometric Design*, 2004)

4.6.4 Sight Distance on Horizontal Curves

Sight distance on horizontal curves is frequently an issue in urban road design. This is due to the need to use curves of relatively low radius to meet site constraints on the road alignment. Obstructions such as bridge piers and abutments, tunnels, etc. all block truck sight lines as well as car sight lines.

Due to this reason structures alongside of a curve must have an offset distance from the center. These offset (visibility offset) can be calculated using the formula;Ms=R(1cos(28.65*SD/R)Where R; radius of curve SD; stopping sight distance.

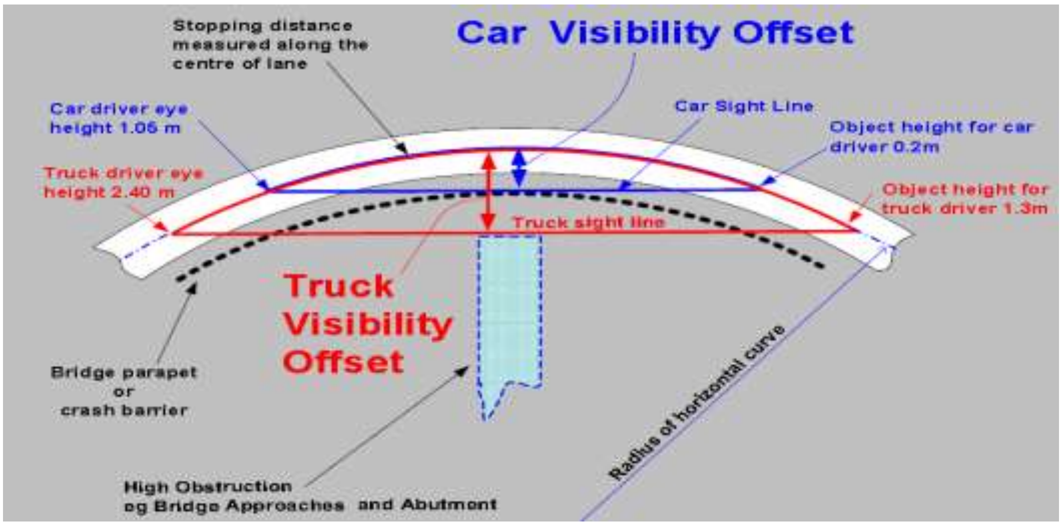


Figure 4.4:- Visibility offset on Horizontal Curves

These visibility offsets are calculated for each curve in the horizontal alignment section later depending on the radius of each curve.

4.7 Alignment design

The overall quality and appearance of a road will be determined by the quality of the alignment design (horizontal and vertical) and its relationship to the surrounding environment. An important concept in highway design is that every project is unique. The setting and character of the area, the values of the community, the needs of the highway users, and the challenges and opportunities are unique factors that designers must consider with each highway project. Whether the design to be developed is for a modest safety improvement or 10 miles of new-location rural freeway, there are no patented solutions. For each potential project, designers are faced with the task of balancing the need of the highway improvement with the need to safely integrate the design into the surrounding natural and human environments. And it is important that all of the necessary information on both physical constraints and community expectations is obtained early in the process.

A holistic approach to the design is required where the various elements of the road design are considered as a whole in the context of the environment through which the road passes and the expectations of the community affected by the road. To achieve the best result, we consider the engineering requirements of the road in question together with the characteristics of the area in which the road is located. The designer must consider the character of the area in the context of its physical location and give proper weight to: City Master Plan physical characteristics of the area including property access requirements, use of the corridor (destination spots, pedestrians, cyclists, industry, urban residential etc), the type and scale of the road to be designed vegetation in the corridor (density, type), views available, scenic values, historic features (including cultural heritage), features to preserve (including natural environment), existing roads in the corridor and the provision of intersections (if an at grade road) or road closures, grade separations or interchanges (if a freeway). We employed our imagination, ingenuity and flexibility to get the best result.

4.7.1 Design Principles

Design principles have to consider the entire range of factors impinging on the design -engineering, landscape, environmental, community expectations.

In engineering terms, road alignments have to service traffic in terms of providing a route that meets constraints imposed by vehicle dynamics, occupant comfort, and topography. This means that most road alignments are in fact complex three-dimensional splines that do not have a simple mathematical definition. This problem has historically been addressed by reducing the three-dimensional alignment to two-dimensional alignments. In each case, the alignments are made up of geometric elements that are convenient to calculate and construct yet still ensure that vehicle dynamics constraints are met.

4.7.2 Horizontal alignment

The horizontal alignment of a road is usually a series of straights (tangents) and circular curves which may or may not be connected by transition curves. A suitable horizontal alignment is chosen by an iterative process in which trial horizontal alignments are tested for vertical geometry and conformance to controls on the alignment.

Consistency

According to AACRA Design speeds of successive horizontal curves should decrease by not more than 15km/h, with a desirable change not exceeding 10km/h. Compound curves should be avoided, but if used the design speeds of the two curves should be within 5km/h of each other. And on our road section there is only one design which is 40km/h which will be more consistent for 1.42km. And the need to limit changes in side friction demand becomes a desirable secondary control for ensuring geometric consistency. Increases in side friction are considered to be a secondary control because drivers select their speed through their perception of the horizontal curvature. In turn, the selected speed reflects driver experience with a number of factors relating to vehicle control, including side friction demand.(*Vertical Alignment*, 2004)

Controls

Controls on the alignment may be conveniently considered as primary, secondary and tertiary.Primary controls are where the alignment must be adjusted to fit a situation such as the start and end points of the section, existing bridges that are to be re-used, land that cannot be acquired for the road reserve, interchange and intersection locations, sensitive environments etc.

And the primary controls on our road networks are the beginning and the end points.. And the road reserve made for signalized intersection and roundabout.

Secondary controls are those that should be accepted providing the resulting outcome is an acceptable and safe road. An example is existing services that could be repositioned, but at a significant cost. No secondary control on our road section.

Tertiary controls are controls that are sensible to conform to if this can be achieved without significant disadvantages arising.

4.7.3 Movement on a Circular Path

As a vehicle traverses a circular curve, it is subject to forces associated with the circular path. According to the principle of inertia, in the absence of forces, a moving body will travel in a straight line. A force must be applied to change direction. For a circular change of direction, the force is called centripetal force and, in road design, this is provided by side friction developed between the tires and the pavement, and by super elevation.

$$e + f = v^2 / gR = V^2 / 127R$$

$$R = V2 / 127 (e + f)\text{... (Equation 4.8)}$$

Where;

e= pavement super elevation (m/m or tangent of angle). This is taken as positive if the pavement falls towards the centre of the curve

f = coefficient of side friction force developed between the vehicle tires and the road pavement –this is taken as positive if the frictional force on the vehicle acts towards the centre of the curve.

g = acceleration due to gravity = 9.8 m/s^2

v = speed of vehicle (m/s)

V = speed of vehicle (km/h)

R = curve radius (m)

From the above formula we can easily deduct that, to have the minimum radius pavement super elevation and coefficient of side friction should me maximum. The above reasoning can be described using the following formula

$$R_{min} = V2 / 127 (e_{max} + f_{max})\text{ ....(Equation 4.9)}$$

Where; f equals zero in the formula, all of the centripetal force is provided by the super elevation.

This condition can occur on large radius curves with positive super elevation or for slow moving vehicles on curves of any radius. At low speeds, f can be negative, and the curve is then over super elevated for that speed. Curves are generally designed, however, so that a positive f is required for the range of vehicle speeds likely to occur.

4.7.4 Selection of Maximum Side Friction (f max)

AACRA recommends maximum Side Friction based on different design speeds for car and trucks. And the maximum side friction that is adopted for our road section will be discussed in the following table

Table 4.12:-Maximum design values for side frictions for both car and trunk.

Design speed	Type of vehicle	Maximum side friction (desirable)
40km/h	Car	0.3
	Truck	0.21

As we can see from the above table the maximum side friction from car and truck goes to car. Therefore we adopt the maximum side friction of our road network to 0.3.

Horizontal curves on which high values of side friction are likely to be demanded should be provided with a pavement surfacing capable of providing good skid resistance. And the following treatments will help decrease the likelihood of skidding on horizontal curves other than super elevation; surfacing with materials using aggregates with a high Polished Aggregate Friction Value and Crushing Value, applying larger aggregates with sprayed seals (provides good drainage routes if applied properly (i.e. texture depths up to 2.5mm)), using polymer modified surfacing (helps stone retention in asphalt and sprayed seals), applying specially designed surfacing (e.g. open graded asphalts, tar based binders, epoxy resins, slurry treatments), reducing drainage paths by designing appropriate crossfall and providing drainage inlets/structures, adopting pavement designs that reduce rutting during the life of the pavement.

4.7.5 Selection of maximum Super elevation

It is normal practice for horizontal curves to be super elevated. This allows a component of the vehicle weight to provide some of the centripetal force that is needed for the vehicle to move in a circular path. If a curve is not super elevated, the curve is said to have adverse or negative super elevation.

With adverse super elevation, there is a component of the vehicle weight that acts opposite to the centripetal force that is needed for the vehicle to move in a circular path. This in turn requires greater side friction than for a curve of given radius with positive super elevation if the vehicle is to take the curve at the same speed.

During the selection of the super elevation our primary base was safety, but other factors are comfort and appearance. The super elevation that is applied to the horizontal curve take into account the following points: tendency to increase the tracking of the rear wheels of slow moving vehicles towards the centre, stability of high laden commercial vehicles, stability of vehicle loads, difference between inner and outer formation level, especially in flat country, length available to introduce the necessary superelevation, the need to avoid major changes in side friction demand between successive horizontal curves, the amount of centripetal force provided by superelevation versus that provided by side.

A maximum value of superelevation to be used in urban areas is 5% and it is normal practice to superelevate all curves to a value that is at least equal to the normal crossfall on straights. We adopt 4% for our road network.

Minimum Length of Superelevation on Horizontal Curves

In constrained situations such as mountainous terrain or urban roads, curves should be fully superelevated even if only instantaneously.

But it is desirable that there be at least 30m of fully superelevated curve. For our road network the minimum length of fully superelevated curve is achieved and the detail calculation will be shown below.

Superelevation Development Length

Superelevation is developed by rotating the roadway cross-section about some axis; most commonly the horizontal control line.

Superelevation development length is defined as the length required rotating the pavement from the point of normal crossfall on the approach tangent (straight) to the point where the full superelevation for the curve is attained. In turn, this superelevation development length has two components:

Superelevation runoff length - this is the length from the point where the pavement has been rotated to zero crossfall to the point where the full curve superelevation has been attained

The normal minimum lengths for superelevation runoff for a curve are 40 m for transitioned curves, which ties to a 40 m minimum transition length, 50 m for an un-transitioned curve when the curve design speed is greater than 80 km/h, with this length normally being equidistant about the curve tangent point, 30 m for an un-transitioned curve when the curve design speed is less than or equal to 80 km/h, with this length normally being equidistant about the curve tangent point.

For our road network we provided 40m runoff length for transition curves and 30m for un-transition curve.

Tangent run out -this is the residual length from the point of normal crossfall to the point of zero crossfall (this component lies on the approach tangent)

There are two criteria that are used to determine the length of superelevation development: maximum rate of rotation of crossfall and relative grade between the edge of the carriageway and the control line.

The superelevation development length to be adopted will generally be the longer value calculated for the two criteria above, notwithstanding normal minimum lengths of superelevation runoff. The maximum rate of rotation criterion is a mandatory standard that must be adopted as a minimum. The relative grade criterion is for appearance purposes and should be obtained at all locations unless economic or safety considerations dictate otherwise e.g. between reverse curves on steep grades.(*Addis Ababa City Roads Authority (AACRA)*, 2004)

Criteria one

$$Le = 0.278\ V\ (e2-e1)/r \quad \text{(Equation 4.10)}$$

Where,

Le = superelevation development length (m)

V = design speed (km/h) (for our road network 40km/h is applicable)

e1, e2= crossfall or superelevation at ends of development length (m/m); +ve when sloping upwards from the control line;–ve when sloping downwards from the control line (for our road network 0.04 is applicable)

r = rate of rotation of the road crossfall (radians/second) for 40km/h AACRA recommends 0.04 radians per second.

Substituting the above values in the formula the development length will be 11.12<the minimum. Therefore we adopt 30m.

Criteria two

Le = 100W (e2-e1)/Gr ……………………………………..…………….. (Equation 4.11)

Where;

Le = superelevation development length (m)

W = maximum width from axis of rotation to edge of running lane (m) (for our road network 22.5m is applicable)

W= lateral clearance +lane width= 1+3=4m

e1, e2= crossfall or superelevation at ends of development length (m/m); +ve when sloping upwards from the control line; –ve when sloping downwards from the control line (for our road network 0.04 is applicable)

Gr = allowable relative grade AACRA recommends 1.3 for multilane highway with a design speed of 40km/h

Substituting the above values in the formula the development length will be 90m>the minimum. Therefore we adopt 90m.

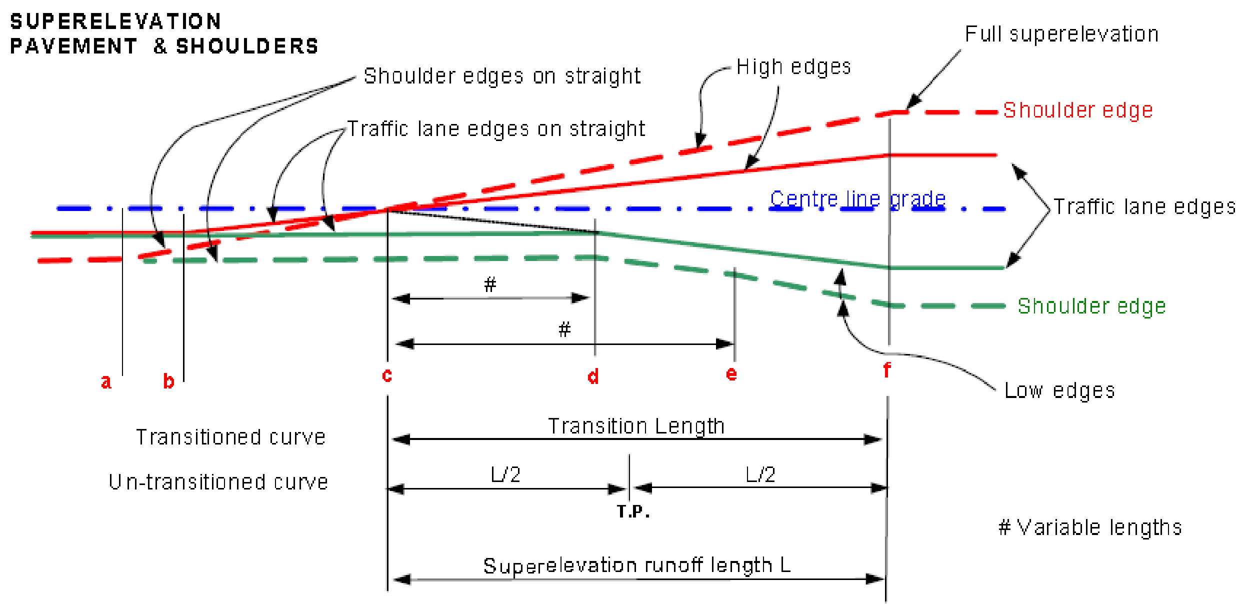


Figure 4.5:-Superelevation for Pavement and shoulder

Radius adopted for the curves

Using Rmin= $V^2/127\ (e_{max} + f_{max})$ and based on the maximum superelevation and side friction adopted earlier, the minimum radius that should be adopted for our road network is 110m. For curves on our alignment we use 140m radius which is above the minimum and therefore it's applicable. During radius selection we experienced one of urban road design problem, which is constraint from the adjoining land to have a large radius of curves.

Positioning of Superelevation Development

For curves with transitions, we matched superelevation runoff with the transition. That is, the point of 0% crossfall corresponds to the start of the transition (for a vehicle entering the curve) and the full superelevation for the curve (e%) is attained at the end of the transition. The superelevation development is extended back from the start at the same rotation rate to the point of normal crossfall on the approach tangent.

The theoretical basis for the uniform development of the superelevation along the length of the transition is that when combined with the uniform increase in curvature provided by the clothoid spiral transition, there will be a uniform attainment of the side friction demand that will be used on the horizontal curve.

Positioning of the superelevation development for curves on the road alignment without transitions is as follows: from Tangent to Curve and Vice Versa: Positioned such that 50% of the superelevation runoff length (from 0% crossfall to e% for the curve) is located on the tangent and 50% is located on the curve. This positioning is considered to correspond with the transition path that is described by the majority of vehicles entering or leaving the curve.

But in constrained situations such as mountainous areas or urban roads, shorter than desirable arc lengths may force the positioning to be 70% on the tangent and 30% on the curve Development of the superelevation entirely on the tangent for an un-transitioned curve is normally not preferred because the superelevation development will not correspond sufficiently with the transition path that is described by the majority of vehicles. Therefore when vehicles approach the curve, there will be a section where a vehicle will still be travelling straight and the crossfall is sufficient to affect tire slip angles. This will cause drivers to steer slightly in the direction opposite to the pending curve.

Adjacent Curves

On the horizontal alignment we designed different curves along the road. Their description and design will be discussed in the following sections separately.

Reverse Curves

Reverse Curves are horizontal curves turning in opposite directions that adjoin (have common tangent points) or have a short length of tangent between the curves. There are two reverse curves on our rod section

Figure 4.6:- Reverse Curve

Broken Back Curves

Broken back curves (also called similar curves) are horizontal curves turning in the same direction joined by a short length of straight or two relatively small unidirectional curves connected by a large radius curve. No broken back curve on our road section

Figure 4.7:- Broken Back Curves

Compound Curves

Compound curves are horizontal curves of different radii turning in the same direction with a common tangent point. No broken back curve on our road section

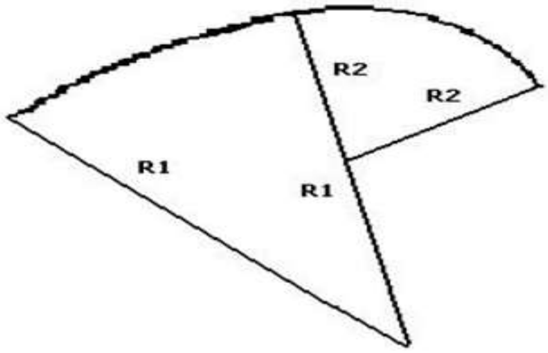


Figure 4.8:- Compound Curves

Transition Curves

It is the one that provides a transition path as it changes from a straight to a circular horizontal curve and vice versa, or between the elements of a compound curve.

A properly designed transition curve allows the vehicle's centripetal acceleration to increase or decrease gradually as the vehicle enters or leaves a circular curve. This transition curve minimizes encroachment on adjoining traffic lanes. The transition curve length provides a convenient desirable arrangement for superelevation runoff. The change in the cross fall can be effected along the length of the transition curve in a manner closely fitting the radius-speed relation for the vehicle traversing it.

N.B the length of each curve has been checked and all of them are above the minimum requirements of AACRA.

Elements of Circular Curves

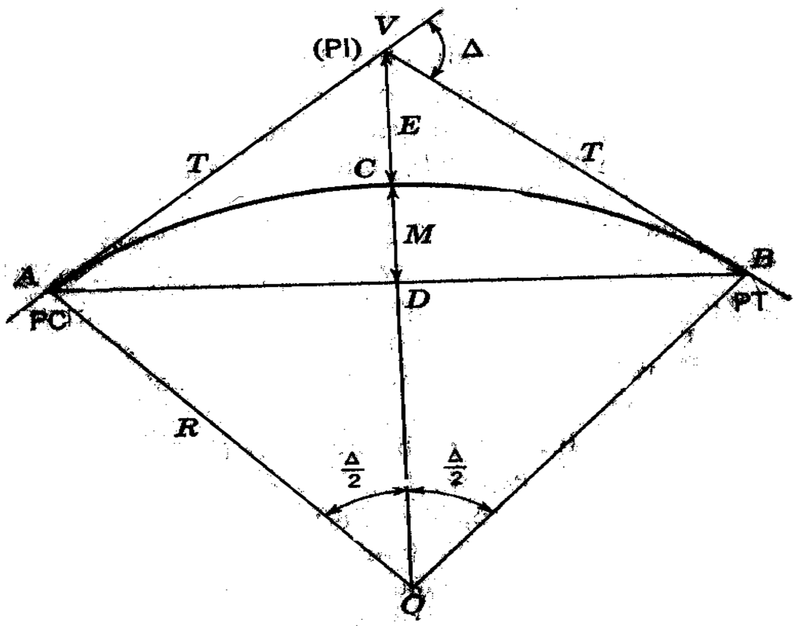


Figure 4.9:- Elements of Circular Curves

Where:

- Point of intersection (PI)
- Point of curve (PC)
- Point of tangency (PT)
- Deflection angle (Δ)
- Tangent length (T)
- Radius (R)
- Length of curve (L)
- Chord length (C)
- Middle ordinate (M)
- External Distance (E)

Detail calculations for Horizontal Curve Design

- Function of road: -Local street road
- Design Speed – 40Km/hr.
- Terrain Type - Flat
- Side friction factor (f)– 0.3
- Rate of super elevation(e) – 0.04

Table 4.13:- Data for horizontal curves.

Curve no	Radius (m)	Delta	Length (m)	PC	PI	PT
1	140	13.72°	33.52	0+065.33	0+082.17	0+98.85
2	140	4.25°	10.34	0+240.7	0+245.89	0+251.08
3	140	9.26°	22.63	0+396.85	0+407.41	0+404.09
4	140	23.34°	57.04	0+538.4	0+565.27	0+595.49
5	140	27.06°	66.13	0+612.57	0+644.25	0+678.65
6	140	24.90°	60.84	0+787.94	0+823.46	0+861.07
7	140	42.11°	102.90	0+929.5	0+941.71	1+032.34
8	140	30.56°	74.72	1+145.37	1+181.81	1+219.73

Horizontal Curve-1

$$R_{min} = \frac{V_D 2}{127(e+f)} = 40^2 / 127(0.3+0.04) = 37.05m$$

But, AACRA recommends R min= 110m, hence let us use Radius of Curve R1= 140m to smoothen the curve and with Deflection Angle Δ1= 13.72°.

Tangent Distance, T = R tan (Δ/2) =140tan (13.72° /2) = 16.84m

Length of curve, L = Δ R (2π/360o) = 13.72° x 140 (2π/360o) = 33.52m

External Distance E = R [sec (Δ/2) - 1] =140[sec (13.72°) -1] = 143.52m

Middle ordinate M = R [1 - Cos (Δ/2)] = 140 [1 - Cos (13.72°/2)] = 1.002m

Chord Length C = 2R Sin (Δ/2) = 2 x 140 Sin (13.72°/2) = 33.40m

Intersection Point Chainage, PI= 0+082.17

Point of Curvature, PC = PI –T=0+ 082.17- 16.84= 0+065.33m

Point of Tangency, PT = PC + L =0+065.33 + 33.52= 0+98.85m

Horizontal Curve-2

$$R_{min} = \frac{V_D 2}{127(e+f)} = 40^2 / 127(0.3+0.04) = 37.05m$$

But, AACRA recommends R min= 110m, hence let us use Radius of Curve R2= 140m to smoothen the curve and with Deflection Angle Δ2= 4.25°.

Tangent Distance, T = R tan (Δ/2) =140tan (4.25° /2) = 5.195m

Length of curve, L = Δ R (2π/360o) = 4.25° x 140 (2π/360o) = 10.38m

External Distance E = R [sec (Δ/2) - 1] =140[sec (4.25°) -1] = 0.39m

Middle ordinate M = R [1 - Cos (Δ/2)] = 140 [1 - Cos (4.25°/2)] = 0.1m

Chord Length C = 2R Sin (Δ/2) = 2 x 140 Sin (4.25°/2) = 10.38m

Intersection Point Chainage, PI= 0+245.89

Point of Curvature, PC = PI –T=0+ 245.89- 5.195= 0+240.7m

Point of Tangency, PT = PC + L =0+240.7 + 10.38= 0+251.08m

Horizontal Curve-3

$$R_{min} = \frac{V_D 2}{127(e+f)} = 40^2 / 127(0.3+0.04) = 37.05m$$

But, AACRA recommends R min= 110m, hence let us use Radius of Curve R3= 140m to smoothen the curve and with Deflection Angle Δ3= 9.26°.

Tangent Distance, T = R tan (Δ/2) =140tan (9.26° /2) = 10.25m

Length of curve, L = Δ R (2π/360o) = 9.26° x 140 (2π/36°) = 7.24m

External Distance E = R [sec (Δ/2) - 1] =140[sec (9.26°) -1] = 1.49m

Middle ordinate M = R [1 - Cos (Δ/2)] = 140 [1 - Cos (9.26°/2)] = 70.73m

Chord Length C = 2R Sin (Δ/2) = 2 x 140 Sin (9.26°/2) = 20.29m

Intersection Point Chainage, PI= 0+407.41

Point of Curvature, PC = PI –T=0+ 407.1- 10.25= 0+396.85m

Point of Tangency, PT = PC + L =0+396.85 + 7.24= 0+404.09m

Horizontal Curve-4

$$R_{min} = \frac{V_D 2}{127(e+f)} = 40^2 / 127(0.3+0.04) = 37.05m$$

But, AACRA recommends R min= 110m, hence let us use Radius of Curve R4= 140m to smoothen the curve and with Deflection Angle Δ4= 23.34°.

Tangent Distance, T = R tan (Δ/2) =140tan (23.34° /2) = 26.87m

Length of curve, L = Δ R (2π/360o) = 23.34° x 140 (2π/360o) = 57.09m

External Distance E = R [sec (Δ/2) - 1] =140[sec (23.34°) -1] = 9.96m

Middle ordinate M = R [1 - Cos (Δ/2)] = 140 [1 - Cos (23.34°/2)] = 74.65m

Chord Length C = 2R Sin (Δ/2) = 2 x 140 Sin (23.34°/2) = 50.18m

Intersection Point Chainage, PI= 0+565.27

Point of Curvature, PC = PI –T=0+565.27 – 26.87= 0+538.4m

Point of Tangency, PT = PC + L =0+538.4+ 57.09= 0+595.49m

Horizontal Curve-5

$$R_{min} = \frac{V_D 2}{127(e+f)} = 40^2 / 127(0.3+0.04) = 37.05m$$

But, AACRA recommends R min= 110m, hence let us use Radius of Curve R5= 140m to smoothen the curve and with Deflection Angle Δ5 = 27.06°.

Tangent Distance, T = R tan (Δ/2) =140tan (27.06° /2) = 31.68m

Length of curve, L = Δ R (2π/360o) = 27.06° x 140 (2π/360o) = 66.08m

External Distance E = R [sec (Δ/2) - 1] =140[sec (27.06°) -1] =126.32 m

Middle ordinate M = R [1 - Cos (Δ/2)] = 140 [1 - Cos (27.06°/2)] = 76.22m

Chord Length C = 2R Sin (Δ/2) = 2 x 140 Sin (27.06°/2) = 57.73m

Intersection Point Chainage, PI= 0+644.25

Point of Curvature, PC = PI –T=0+644.25- 31.68= 0+612.57m

Point of Tangency, PT = PC + L =0++612.57 + 60.08= 0+678.65m

Horizontal Curve-6

$$R_{min} = \frac{V_D2}{127(e+f)} = 40^2 / 127(0.3+0.04) = 37.05m$$

But, AACRA recommends R min= 110m, hence let us use Radius of Curve R6= 140m to smoothen the curve and with Deflection Angle Δ6= 29.90°.

Tangent Distance, T = R tan (Δ/2) =140tan (29.90° /2) = 35.52m

Length of curve, L = Δ R (2π/360o) = 29.90° x 140 (2π/360o) = 73.13m

External Distance E = R [sec (Δ/2) - 1] =140[sec (29.90°) -1] = 17.00m

Middle ordinate M = R [1 - Cos (Δ/2)] = 140 [1 - Cos (29.09°/2)] = 70.00m

Chord Length C = 2R Sin (Δ/2) = 2 x 140 Sin (29.09°/2) = 63.36m

Intersection Point Chainage, PI= 0+823.46

Point of Curvature, PC = PI –T=0+823.46 – 35.52= 0+787.94m

Point of Tangency, PT = PC + L = 0+787.94+ 73.13= 0+861.07m.

Horizontal Curve-7

$$R_{min} = \frac{V_D2}{127(e+f)} = 40^2 / 127(0.3+0.04) = 37.05m$$

But, AACRA recommends R min= 110m, hence let us use Radius of Curve R7= 140m to smoothen the curve and with Deflection Angle Δ7= 42.11°.

Tangent Distance, T = R tan (Δ/2) =140tan (42.11° /2) = 12.21m

Length of curve, L = Δ R (2π/360o) = 42.11° x 140 (2π/360o) = 102.84m

External Distance E = R [sec (Δ/2) - 1] =140[sec (42.11°) -1] = 37.41m

Middle ordinate M = R [1 - Cos (Δ/2)] = 140 [1 - Cos (42.11°/2)] = 84.76m

Chord Length C = 2R Sin (Δ/2) = 2 x 140 Sin (42.11°/2) = 85.99m

Intersection Point Chainage, PI= 0+941.71

Point of Curvature, PC = PI –T=0+941.71- 12.21= 0+929.5m

Point of Tangency, PT = PC + L =0+929.5 + 102.84= 1+032.34m

Horizontal Curve-8

$$R_{min} = \frac{V_D 2}{127(e+f)} = 40^2 / 127(0.3+0.04) = 37.05m$$

But, AACRA recommends R min= 110m, hence let us use Radius of Curve R8= 140m to smoothen the curve and with Deflection Angle Δ8= 30.56°.

Tangent Distance, T = R tan (Δ/2) =140tan (30.56° /2) = 36.44m

Length of curve, L = Δ R (2π/360o) = 30.56° x 140 (2π/360o) = 74.63m

External Distance E = R [sec (Δ/2) - 1] =140[sec (30.56°) -1] = 17.83m

Middle ordinate M = R [1 - Cos (Δ/2)] = 140 [1 - Cos (30.56°/2)] = 77.9m

Chord Length C = 2R Sin (Δ/2) = 2 x 140 Sin (30.56°/2) = 64.65m

Intersection Point Chainage, PI= 1+181.81

Point of Curvature, PC = PI –T=1+181.81 – 36.44= 1+145.37m

Point of Tangency, PT = PC + L = 1+145.37 + 74.63= 1+219.73

Setting out of the curves is performed using the method of offset from tangent. The formula used is:$Y=(R^2+X^2)^{0.5}-R$ Where,R=radius(m) X=the intended distance along the tangent of length Y=offset distance for the corresponding value of x The calculations are done using Microsoft excel.

Table 4.14:-Setting out data for horizontal Curve one

R(m)	**X(m)**	**Y(m)**
140	5	0.0179
140	10	0.0357
140	15	0.0536
140	16.84	0.0601

Table 4.15:-Setting out data for horizontal Curve Two

R(m)	X(m)	Y(m)
140	5	0.0179
140	5.195	0.0186

Table 4.16:-Setting out data for horizontal Curve Three(*Civil 3D*, n.d.)

R(m)	X(m)	Y(m)
140	5	0.0179
140	7.24	0.0259

Table 4.17:-Setting out data for horizontal Curve Four(*Civil 3D*, n.d.)

R(m)	X(m)	Y(m)
140	5	0.0l79
140	10	0.0357
140	15	0.0536
140	20	0.0714
140	25	0.0893
140	30	0.1071
140	35	0.1249
140	40	0.1428
140	45	0.1606
140	50	0.1785
140	55	0.1963
140	57.09	0.2037

Table 4.18:-Setting out data for horizontal Curve Five

R(m)	X(m)	Y(m)
140	5	0.0l79
140	10	0.0357
140	15	0.0536
140	20	0.0714
140	25	0.0893
140	30	0.1071
140	35	0.1249

140	40	0.1428
140	45	0.1606
140	50	0.1785
140	55	0.1963
140	60	0.2141
140	65	0.2319
140	66.05	0.2487

Table 4.19:-Setting out data for horizontal Curve

R(m)	X(m)	Y(m)
140	5	0.0l79
140	10	0.0357
140	15	0.0536
140	20	0.0714
140	25	0.0893
140	30	0.1071
140	35	0.1249
140	40	0.1428
140	45	0.1606
140	50	0.1785
140	55	0.1963
140	60	0.2141
140	65	0.2319
140	70	0.2498
140	73.13	0.2609354

Table 4.20:-Setting out data for horizontal Curve Seven

R(m)	X(m)	Y(m)
140	5	0.0l79
140	10	0.0357
140	15	0.0536
140	20	0.0714
140	25	0.0893
140	30	0.1071

140	35	0.1249
140	40	0.1428
140	45	0.1606
140	50	0.1785
140	55	0.1963
140	60	0.2141
140	65	0.2319
140	70	0.2498
140	75	0.2676
140	80	0.2854
140	85	0.3032
140	90	0.3211
140	95	0.3567
140	100	0.3745
140	102.84	0.3668

Table 4.21:- Setting out data for horizontal Curve Eight(*Civil 3D*, n.d.)

R(m)	**X(m)**	**Y(m)**
140	5	0.0l79
140	10	0.0357
140	15	0.0536
140	20	0.0714
140	25	0.0893
140	30	0.1071
140	35	0.1249
140	40	0.1428
140	45	0.1606
140	50	0.1785
140	55	0.1963
140	60	0.2141
140	65	0.2319
140	70	0.2498

4.7.5 Vertical alignment

Vertical alignment (referred to as grade line or longitudinal section) consists of straight grades joined by vertical curves. The principal vertical alignment design objectives are to obtain the necessary sightdistance and to fit to the natural terrain. In designing the vertical alignment we give consideration to the maximum allowable grades, the volume and balancing of the earthworks, the appearance, property acquisition, environmental impacts, and the co-ordination with the horizontal alignment.

The sight distance requirements include obtaining minimum radius vertical curves for stopping sight distance (SSD) and the sight distance to intersections. The design criteria which dominate in deciding on the appropriate vertical alignment vary with the type of road being considered. On minor urban roads, obtaining sight distance to property access points and intersections and minimizing the impacts on adjacent property dominate. On major roads, sight distance to intersections (or ramps) and appearance will tend to dominate other factors such as earthworks balance, but the need to provide an economically sound design cannot be ignored. It may be possible with good design and appropriate co-ordination with the horizontal alignment to achieve all of the design objectives.

On undivided roads, the vertical alignment is designed as the surface of the pavement along the construction centre line. On divided roads, the vertical alignment is usually represented by the line along the lane edge against the median (residual median if there are median shoulders).

Grades

Generally, grades should be as flat as possible consistent with economy. Flat grades permit all vehicles to operate at similar speeds (away from intersections). Steeper grades produce variation in speeds between lighter vehicles and the heavier vehicles both in the uphill and downhill directions. This speed variation leads to higher relative speeds of vehicles producing the potential for higher accident rates and lower traffic capacity. This speed variation also results in increased queuing and overtaking requirements on single carriageway roads which give rise to further safety problems particularly at higher traffic volumes. In addition, freight costs are increased due to the slow speed of heavy vehicles.

For a given design (40km/h) AACRA recommends the maximum grade on our road section to be 5% and we satisfied this criterion during the design of our road section.

Grades for pedestrian footpaths are 5-7% or less and roads with significant pedestrian movement should be located so that pedestrian grades are not excessive. Where access to sloping ground is required (e.g. for residential development) the collector road and principal footpath may be located to run along the contours of the land, with local roads and access places running up the slope, possibly at an angle to minimize the grade. This will reduce the length of travel on steep roads and footpaths for both vehicles and pedestrians. (*Addis Ababa City Roads Authority (AACRA)*, 2004)

Since the footpath on our road section is designed along with the carriage way the maximum grade is limited to 4%.

General Maximum Lengths of Steep Grade

It is undesirable to have a very long length of steep grade. On both the upgrade and downgrade, the lower operating speed of trucks may cause inconvenience to other traffic. On arterial roads, consideration should be given to providing an auxiliary lane both in the uphill and downhill directions where traffic volumes and numbers of trucks are high.

Cross checking the above results with the AACRA manual requirement for the maximum length for the steep grade, our road alignment grade satisfies the requirement.

Steep Grade Considerations

Although speeds of cars may be reduced slightly on steep upgrades, large differences between speeds of light and heavy vehicles will occur and speeds of the latter will be quite slow. It is important, therefore, to provide adequate horizontal sight distance to enable faster vehicle operators to recognize when they are catching up to a slow vehicle and to adjust their speed accordingly.

On any generally rising or generally falling section of road, adverse grades (grades opposite to the general rise or fall of the section) should be avoided as much as practicable, as they are wasteful of energy.

On steep downgrades, it is desirable to increase the design speed of the individual geometric elements progressively towards the foot of the steep grade. Where this cannot be achieved and where percentages of heavy vehicles are high, consideration should be given to construction of runaway vehicle facilities.

On our road network there is no adverse grade. So there is no need of special consideration for our alignment.

Minimum Grades

Very flat grades may make it difficult to provide longitudinal drainage in table drains, kerb and channel and medians, where these parallel the road grade. As far as possible, these drainage requirements should not dictate the road grade; rather the drainage facility should be designed to accommodate the road grade. This may require greater recourse to sub-surface drains with closely spaced inlets, or independently graded table drains, or other solutions to suit the circumstances.

Care should be taken in cases where a flat grade is combined with superelevated horizontal curves. The rotation of the pavement may create a situation where the flow path crosses from one side of a lane to the other, resulting in undesirable depths of water on the pavement surface. Worse conditions can occur on steep grades combined with successive curves in opposite directions.

The combination of grade and pavement rotation can create a situation where the flow path meanders from one side of the road to the other with the depth of flow becoming excessive.

AACRA recommends the minimum grade to be 0.5% and from the above table we can see that every grade has satisfied this requirement.(*Vertical Alignment*, 2004)

Curve Geometry

Generally, the type of vertical curve used is a parabolic curve. The parabola is normally used because of its simplicity and because all formulae are exact whereas the same formulae used with the circle would be approximate. The vertical offsets from a tangent are proportional to the square of the distances measured horizontally from the tangent point to the offset point.

It is convenient to specify parabolic vertical curves by the length of curve required for a change of grade of 1%, this being a constant for the parabola:

$K = L/A$ ………………………………………………………………………….. (Equation 4.12)

And the detail calculation for each of our curve geometry will be discussed later.

Minimum K Values of Crest Vertical Curves

Generally, large radii vertical curves should be used provided they are reasonably economical. However in difficult situations, vertical curves approaching the minimum may be considered where there are significant additional costs (e.g. deep excavation in rock).

There are cases where the provision of a sharper crest vertical curve with a longer uniform grade adjacent will result in better designs. On freeways, the sight distance to ramps can sometimes be improved in this way. On roads with at-grade intersections, a section of uniform grade interposed between a crest and an intersection will often give both SSD on the crest and ASD, SISD and MGSD (see Sight distance section) to an intersection, whereas a long vertical curve encompassing the intersection may give better than minimum SSD on the crest but fail to provide all of the sight requirements for the intersection. On two way roads, longer and safer overtaking opportunities may be achieved by this approach.

Vertical curves are based on achieving stopping sight distance (SSD) and sometimes intersection sight distance. While SSD needs to be adjusted for the effects of longitudinal grade, on a crest these corrections are not usually applied. For cars, the upgrade and downgrade corrections are numerically similar for uphill and downhill, and the crest **K** values are calculated on the basis of SSD on a level grade. Truck crest **K** values are also calculated for level road SSD, although in the case of trucks, the braking distance increase downhill is much greater than the decrease uphill. For simplicity, it is recommended that crests for both cars and trucks be checked on the basis of SSD on level ground. Crest K Values based on SSD will be discussed in the following table.(*Vertical Alignment*, 2004)

Table 4.22:- Minimum K value for both car and truck

Design speed	Type of vehicle	Minimum K value
40km/h	Car	4
	Truck	6

But during the design of our road section the minimum crest K value is 10 which Satisfies the requirement of the manual.

Sag Vertical Curves

We provide K values for sags based upon comfort criteria. Discomfort is felt by a person subjected to rapid changes in vertical acceleration. To minimize such discomfort when passing from one grade to another, it is usual to limit the vertical acceleration generated on the vertical curve to a value less than 0.05g where g is the acceleration due to gravity. On low standard roads, at intersections or where economically justified, a limit of 0.10g may be used.

Sight distance on sag curves is not restricted by the vertical geometry in daylight conditions or at night with full roadway lighting unless overhead obstructions are present. Under night conditions on unlit roads, limitations of vehicle headlights on high beam restrict sight distance to between 120-50m for modern vehicles. On high standard roads not likely to be provided with roadway lighting, consideration may be given to providing headlight sight distance. Nevertheless, where horizontal curvature would cause the light beam to shine off the pavement (assuming 3 degrees lateral spread each way), little is gained by flattening the sag curves other than improved appearance. In all cases adequate sight distance to the tail lights is provided.

Minimum K Values for Sag Vertical Curves Based on Headlight Criterion and Truck SSD is 9 but on our vertical alignment the minimum K value used is 12 therefore it satisfies the requirement.

Minimum Lengths of Curves

According to AACRA, for design speed of 40km/h the minimum length should be20-30 and on our vertical design the minimum length is 20.5 which Satisfies the requirement of the manual.

Reverse Vertical Curves

Reverse vertical curves with common tangent points are considered quite satisfactory and this geometry is often used in grading interchange ramps to achieve the maximum elevation in the shortest acceptable distance. In the case of short radius reverse vertical curves it is necessary to check that the sum of the radial accelerations at the common tangent point does not exceed the tolerable allowance for riding comfort i.e. 0.1g or 0.05g, whichever is appropriate. No reverse curve was designed on our alignment.

Broken Back/Compound Vertical Curves

Broken back vertical curves consist of two curves, either both sag or both crest, usually of different radii, joined by a short length of straight grade. They should be avoided, particularly in the case of sag curves, and it is usually easy to do so. However, where the length of grade exceeds 0.4Vm (V = design speed in km/h) the curves are not then deemed to be broken-backed. If there is no grade, that is, the tangent points are common, the curves are compound, not broken-backed, and are permitted. On our road alignment there is no Broken Back/Compound Vertical Curves design.

The length of curve required for sight distance is given by the following expressions

$L = 2D - \frac{c}{A}$ ………………………………………………….……………. (Equation 4.13)

When the length of curve is less than the sight distance and

$$L = \frac{D^2}{c} \times A \text{ and } K = \frac{D^2}{c}$$

When the length of curve is greater than the sight distance

A = Algebraic difference of vertical grades (%)

D = sight distance

- **For Crest curve the value of C is**

$C = 200[\sqrt{h_1} + \sqrt{h_2}]^2$ ……………………………………….. (Equation 4.14)

Where;

h1=height of eyes above the road level way surface

h2=height of object above the road way surface

- **For Sag curve the value of C is**

$C = 200[h + D \tan q]$ ……………………………………….. (Equation 4.15)

Where;

h = headlight mounting height (m)

D = sight distance

q = headlight elevation angle

- **For the crest curves**

h_1=2.4m, h_2=0.2m

$C = 200[\sqrt{h_1} + \sqrt{h_2}]^2$

$C = 200[\sqrt{2.4} + \sqrt{0.2}]^2$

$C = 797.13$

- **For the sag curves**

h=0.75m, $q = 1°$

$C = 200[h + D \tan q]$

$C = 200[0.75 + 50 \tan 1]$

$C = 324.55$

Curve no.1

Station: 0+169.77

Type of curve: Sag curve

Approaching grade= -5.53%

Exit grade= 1.29%

The sight distance is (D) =50m

$A = 1.29 - (-5.53) = 6.82$

$$K = \frac{D^2}{c} = \frac{50^2}{324.55} = 7.702$$

$K_{provided} = 12$

$$L = \frac{D^2}{c} \times A = 12 \times 6.82 = 81.84$$

$L = 81.84$

Curve no.2

Station: 0+404.5

Type of curve: Crest curve

Approaching grade= 1.29%

Exit grade= -0.72%

The sight distance is (D) =50m

$A = 1.29 - (-0.72) = 2.02$

$K = \frac{D^2}{c} = \frac{50^2}{797.13} = 3.14$

$K_{provide} = 10$

$L = \frac{D^2}{c} \times A = K \times A = 10 \times 5.41$

$L = 54.1$

Curve no.3

Station: 0+538.18

Type of curve: Crest curve

Approaching grade= -0.72

Exit grade= -0.88%

The sight distance is (D) =50m

$A = -0.72 - (-0.88) = 0.16$

$K = \frac{D^2}{c} = \frac{50^2}{797.13} = 3.14$

$K_{provide} = 10$

$L = \frac{D^2}{c} \times A = 10 \times 0.16 = 1.6$

$L = 1.6$

Curve no.4

Station: 0+756.79

Type of curve: Crest curve

Approaching grade= -0.88%

Exit grade= -2.6%

The sight distance is (D) =120m

$A = -0.88 - (-2.6) = 1.76$

$K = \frac{D^2}{c} = \frac{50^2}{797.13} = 3.14$

$K_{provide} = 10$

$L = \frac{D^2}{c} \times A = K \times A = 10 \times 3.14$

$L = 31.4$

Curve no.5

Station: 0+963.67

Type of curve: Sag Curve

Approaching grade= -2.6%

Exit grade= 2.35%

The sight distance is (D) =50m

$A = 2.35 - (-2.6) = 4.95$

$K = \frac{D^2}{c} = \frac{50^2}{324.55} = 7.702$

$K_{provided} = 12$

$L = \frac{D^2}{c} \times A = K \times A = 12 \times 4.95$

$L = 59.4$

Curve no.6

Station: 1+171.74

Type of curve: Crest Curve

Approaching grade= 2.35%

Exit grade= -1.55%

The sight distance is (D) = 50m

$A = 2.35 — (-1.55) = 3.9$

$$K = \frac{D^2}{c} = \frac{50^2}{797.13} = 3.14$$

$K_{provide} = 10$

$$L = \frac{D^2}{c} \times A = K \times A = 10 \times 3.9$$

$L = 39$

5. Pavement Design

5.1 Introduction

Highways are vitally important to a country's economic development. The construction of a high quality road network directly increases a nation's economic output by reducing journey times and costs, making a region more attractive economically. The actual construction process will have the added effect of stimulating the construction market.

A highway pavement is composed of a system of overlaid strata of chosen processed materials that is positioned on the in-situ soil, termed the sub grade. Its basic requirement is the provision of a uniform skid-resistant running surface with adequate life and requiring minimum maintenance. The chief structural purpose of the pavement is the support of vehicle wheel loads applied to the carriageway and the distribution of them to the sub grade immediately underneath. The pavement designer must develop the most economical combination of layers that will guarantee adequate dispersion of the incident wheel stresses so that each layer in the pavement does not become overstressed during the design life of the highway.

The major variables in the design of a highway pavement are:

- ❖ The thickness of each layer in the pavement
- ❖ The material contained within each layer of the pavement
- ❖ The type of vehicles in the traffic stream
- ❖ The volume of traffic predicted to use the highway over its design life
- ❖ The strength of the underlying sub grade soil.

There are three basic components of the highway pavement which are Foundation, Road base& Surfacing. Their general definitions are given as shown below.

Foundation

The foundation consists of the native sub grade soil and the layer of graded stone (sub base and possibly capping) immediately overlaying it. The function of the sub base and capping is to provide a platform on which to place the road base material as well as to insulate the sub grade below it against the effects of inclement weather. These layers may form the temporary road surface used during the construction phase of the highway.

Road base

The road base is the main structural layer whose main function is to withstand the applied wheel stresses and strains incident on it and distribute them in such a manner that the materials beneath it do not become overloaded.

Surfacing

The surfacing combines good riding quality with adequate skidding resistance, while also minimizing the probability of water infiltrating the pavement with consequent surface cracks. Texture and durability are vital requirements of a good pavement surface as are surface regularity and flexibility.

General Types

In broad terms, the two main pavement types can be described briefly as:

- **Flexible pavements:-**The surfacing and road base materials, bound with bitumen binder, overlay granular unbound or cement-bound material.
- **Rigid pavements:-**Pavement quality concrete, used for the combined surfacing and road base, overlays granular cement-bound material. The concrete may be reinforced with steel.

For flexible pavements, the surfacing is normally applied in two layers – base course and wearing course – with the base course an extension of the road base layer but providing a regulating course on which the final layer is applied. In the case of rigid pavements, the structural function of both the road base and surfacing layers are integrated within the concrete slab.

The general layout of these two pavement types is shown in Figs 1 and 2 below.

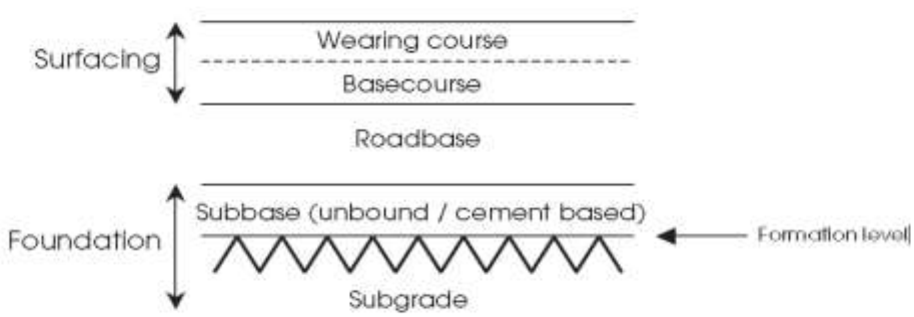


Figure 5.1:- Layers within a typical flexible highway pavement.

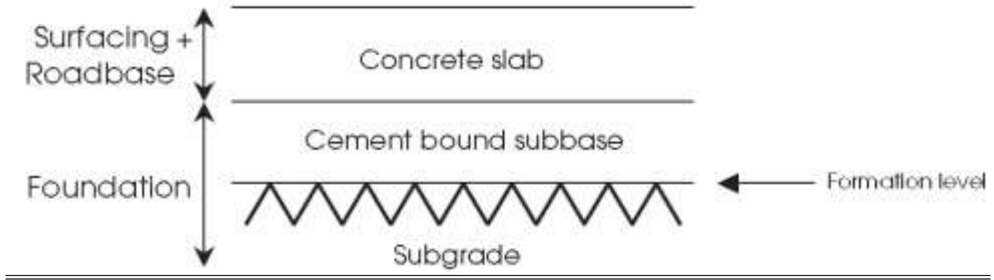


Figure5.2:-Layers within a typical rigid highway pavement.(*Pavement Design*, 2004)

5.2 Pavement Types (According to AACRA)

AACRA Pavement design manual deals with the structural design of pavements containing:

- Entirely granular materials which are defined as **flexible pavements** or
- One or more stabilized bound or thick bituminous layers which are defined as **semi-rigid pavements.**

5.2.1 Flexible Pavements

A commonly used pavement structure is the flexible pavement type whereby a surface treatment or a bituminous mix is placed over a base course made of granular materials. Other flexible pavement types being used in Addis Ababa currently consist of base courses made of penetration macadam. The typical mode of distress in fully granular pavements is deformation arising from shear or densification within the granular pavement materials or deformation of the subgrade. This pavement type is sensitive to timely periodic maintenance by resealing.

5.2.2 Semi-Rigid Pavements

Semi-rigid pavements are those utilizing cemented or bituminous materials in the base course layer or both the base course and sub base layer. Where both base course and sub base are cemented, this pavement type is a viable option for high traffic conditions. Pavements with only the base course cemented with granular sub base have limitations in the upper ranges of traffic loading. The use of a cemented material improves the load bearing capacity of the pavement by reducing surface deflections and hence strains in the bituminous surfacing. The typical mode of distress is by fatigue cracking of the cemented material until its structural behavior eventually approaches that of a granular layer.

The post-cracked phase of the cemented material can be expected to add considerable useful life to the pavement because the material will then function as a granular layer. The modes of distress in bituminous base courses can be deformation or fatigue cracking depending on site conditions and material properties. The preferred method to minimize the risk of fatigue cracking is primarily by providing the stiffest possible support for the base course and thereby minimizing strain in the layer. Strongly cemented sub base however may lead to crack reflection from the sub base through the bituminous base course and is not a desirable option.

- For our road project we selected a flexible pavement since it is the most commonly used type in the country!!

5.3 DESIGN OF FLEXIBLE ASPHALT PAVEMENT

The objective of structural pavement design is to provide a road surface which can withstand the expected traffic loading over a specified time without deteriorating below a predetermined level of service. This is achieved by providing a pavement structure whereby stresses on the sub grade induced by traffic are reduced to acceptable levels. Stresses within pavement layers must in addition be kept within acceptable limits depending on the properties of the materials being used.

Design Traffic

Traffic load is being the main input for pavement design, which needs proper attention and consideration. The effect of traffic loads on road pavement is evaluated in terms of number of traffic, representing repetition of load application and axle loads representing the magnitude of the load. Thus, the design traffic is expressed in terms of the number of the cumulative equivalent standard axles over the design period of the road.

The structural deterioration of paved roads caused by traffic mainly depends on (MoW, 1999):

- Magnitude of the loads (axle loads)
- Number of load repetitions

The damage that vehicles do to a road depends greatly on the magnitude of the axle loads and as such, the damaging effect of an axle loading follows an exponential function.

The damaging effect of all axles expected to traverse the road, as stated above, is converted into Equivalent Standard Axles (ESA) and added up over a chosen design period to become the basis for the structural pavement design. (*Pavement Design*, 2004)

The deterioration of paved roads caused by traffic results from both the magnitude of the individual wheel loads and the number of times these loads are applied. For pavement design purposes it is necessary to consider not only the total number of vehicles that will use the road but also the wheel loads (or for convenience, the axle loads) of these vehicles. (TRL,1993).

Percentage ESAs per Lane for Multiple Lanes

When the pavement design is for carriageways with more than one traffic lane in each direction, a reduction may be considered in the cumulative ESA to take into account for the design. The ranges given in Table below are suggested for the percentage of design ESAs to consider in the design lane (ERA):

Table 5.1:-Percentage ESAs Per Lane for Multiple Lanes

Number of Lanes in each Direction	Percent of ESAs in design lane
1	100
2	80-100
3	60-80

The pavement design thicknesses required for the design lane are usually applied to the whole carriageway width.

5.4 Vehicle classification system

The following table shows vehicle classifications system of AACRA Pavement design manual.

Table 5.2:- Vehicle Classification System

Vehicle class	Vehicle Type
Cars	• Car- Standard Cars • Wagons and Pickups • Minibus and Vans(seats <12)
Light vehicles	• Small bus(Seats Less than 24) • Medium bus(Seats b/n 25 and 44) • Large Bus(seats greater than 44) • Single Rear axle Truck(total of two
Heavy vehicles	• Two rear axle trucks(Total of three axles)(Carrying capacity between 3.5 ton and 7 ton) • Three rear axle trucks(Total of Four axles)(capacity between 7 ton and 12 ton)

Articulated	• Articulated Trucks with more than 4 axles (carrying capacity > 12 ton) • Truck Trailers

Design Period

The design period is the length of time expressed in years before it is anticipated that rehabilitation of the pavement will be necessary to restore shape, repair other forms of distress, or to provide additional pavement strength (Austroads, 1992).

The design period starts when the completed pavement is opened to public traffic over the entire length of a construction project. Any public traffic or construction traffic using the completed pavement before the start of the design period shall be estimated separately and included in the design traffic loading for the purpose of pavement design (MoW, 1999).

Strengthening of the pavement is normally required for the road to carry further traffic at an acceptable level of serviceability after the end of the design period. Normal maintenance is assumed to take place throughout the design period for the design to be valid. Premature failures may result if normal maintenance is neglected during the design period (MoW, 1999).

For most road projects an economic analysis period of 20 years from the date of opening is appropriate**.** Whatever time period is chosen for the appraisal of a project, the road will always have some residual value at the end of this period.

Choosing a pavement design life that is the same as the analysis period simplifies the economic appraisal by minimizing the residual value, which is normally difficult to estimate accurately (TRL, 1993).

The recommended design periods for pavements in Addis Ababa are:

- New granular and semi-rigid pavements = 20 years
- New rigid pavements = 40 years
- New gravel pavements = 10 years
- Asphalt overlays = 15 years
- Granular overlays = 10 years

Rehabilitation, which may consist of granular or asphalt overlay, major patching or improvements or removal of selected areas of pavement materials, initiates a new design period. In this regard, resurfacing a pavement with a sprayed seal or a very thin asphalt overlay does not in itself constitute rehabilitation in the pavement design sense.For our road project, we selected a design period of 20 years.

Axle Loads and Equivalency Factors

- All design of bitumen surfaced road pavements shall be based on axle load surveys. The surveys shall be carried out separately from weigh-bridge measurements undertaken for the purpose of enforcing axle load limits.
- The damaging effect of an axle passing over the pavement is expressed by the equivalency factor related to an equivalent standard axle (ESA) of 8160 kg load:

$$\text{Equivalency Factor} = \left[\frac{Axle\ load(kg)}{8160}\right]^{4.5}$$

- According to AACRA, generic values may be used based on results from previous studies completed in Addis Ababa. These are shown in the following table below (Typical Equivalency Factors for Addis Ababa Traffic) taken from AACRA pavement design manual.

Table 5.3:- Typical Equivalency factor for Addis Ababa

Vehicle Class	Typical	Lower	Upper
Car	0.03	0.00	0.10
Light	0.73	0.39	1.07
Medium	1.31	0.73	1.89
Heavy	1.61	1.05	2.18
Articulated	3.15	2.15	4.14

- Since we don't have an axle load survey data we took the typical EF for each vehicle class.

In order to determine the initial daily traffic loading from the survey data, the following procedure should be followed (TRL, 1993; Austroads, 1992):

(1) Determine the daily traffic flow for each class of vehicle from the results of this traffic survey and other recent traffic count information that is available.

(2) Adjust the flows for two way traffic, lane factors and seasonal adjustment

(3) Determine the mean equivalence factor for each class of vehicle from the results of the axle load survey or default values from Table.

(4) Determine the initial daily traffic loading by summing the products of the daily flow in each class by the mean equivalence factor for each respective class:

$$N = N_L EF_L + N_M EF_M + N_H EF_H + N_A EF_A$$

Where; N = initial daily Equivalent Standard Axles

N_L is the daily number of light vehicles in the current year

N_M is the daily number of medium vehicles in the current year

N_H is the daily number of heavy vehicles in the current year

N_A is the daily number of articulated vehicles in the current year

EF_L the equivalency factor for the average light vehicle

EF_M the equivalency factor for the average medium vehicles

EF_H the equivalency factor for the average heavy vehicles

EF_A the equivalency factor for the average articulated vehicles

N_L= 1863 (including the diverted and generated traffic), similarly

N_M = 60, N_H =0, N_A =0.

EF_L =0.1, EF_M =1.07, EFH =0 and EF_A =0

Now; $N = N_L EF_L + N_M EF_M + N_H EF_H + N_A EF_A$

N= 1863*0.1 + 60*1.07 + 0*0 + 0*0

N = 250.5

Growth Rate

The forecasting of traffic growth shall include separate estimates for the 5 vehicle categories. It is necessary to assess future traffic in respect of the following types:

- Normal traffic that would use the route regardless of the condition of the road
- Diverted traffic that moves from an alternative route due to the improvement of the road, but at otherwise unchanged origin and destination
- Generated traffic: Additional traffic occurring due to the improvement of the road

There is a considerable uncertainty and risk of making large errors in estimations of traffic growth since anumber of individually uncertain factors are brought together in the analysis. Where little information is available, historical data, origin-destination surveys and records from AACRA are among the sources ofinformation for assessment of traffic growth. The designer may have to resort to the use of growth figures forGDP in the estimation of movement of goods (MoW, 1999).

Based on road traffic survey information, it is reasonable, in most circumstances, to assume that traffic volumes will increase geometrically either for the entire design period or up to a stage where "road capacity" is reached (in which case traffic volumes are assumed to remain constant for the remainder of the design period (Austroads, 1992).

If there is an indication that "road capacity" is likely to be reached within the design period, it is recommended that the designer establish that there is no planned upgrading of the road geometry within the design period before he adopts "no growth" traffic volume for the period of "full capacity". Adoption of "no-growth" traffic volumes for a period of "saturation" will entail modification of the approach used below to aggregate daily traffic volumes for total design traffic.

For geometric traffic growth throughout the design period, total traffic over the design period is determined by multiplying the total traffic in the first year by the appropriate Cumulative Growth Factor from the table below (AACRA Table 6-4) or calculated exactly using the following equation:

$$GF = \frac{(1+0.01i)[(1+0.01i)^y - 1]}{0.01i} \quad \text{(Equation 5.1)}$$

Where; i - Growth Rate (%) = 5.5%

y - Design Period (years) = 20yrs

Table 5.4:- Cumulative Growth Factors (GF)

Design Period (Year)	**Growth Rate (%)**					
	0	2	4	6	8	10
5	5	5.2	5.4	5.6	5.9	6.1
10	10	10.9	12.0	13.2	14.5	15.9
15	15	17.3	20.0	23.3	27.2	31.8
20	20	24.3	29.8	36.8	45.8	57.3
25	25	32.0	41.6	54.9	73.1	98.3
30	30	40.6	56.1	79.1	113.3	164.5
35	35	50.0	73.7	111.4	172.3	271.0
40	40	60.4	95.0	154.8	259.1	442.8

In the absence of specific traffic survey and study results, typical values for growth rates can be adopted with caution based on the economic growth zones shown in Figure 6-1(AACRA pavement design manual section 6) and the zone / road classification matrix presented in Table 6-5 (AACRA).These values should be used with the recommended design period to determine the appropriate approximate Growth Factor.

While using the table interpolation could be done for intermediate values.

4% = 29.8
5.5% = X
6% = 36.8

Thus, X = GF=35.05

5.5 Calculation of Design Traffic

Because asphalt, cemented materials and sub-grades each have different performance relationships, it is necessary to determine separately for each material the number of standard axles which will cause the same level of accumulated damage as the actual traffic load spectrum.

The design loading is then calculated as the design number of standard axles for:

Asphalt = Nsa x 365 x GF

Sub-grade = Nss x 365 x GF

Cemented materials = Nsc x 365 x GF

GF has been explained above.

Nsa = 1.1 N

Nss = 1.1 N

Nsc = 10.0 N

And N is the initial daily traffic loading.

Where:- GF is the cumulative growth factor from the Table or equation and a lane distribution factor of 1 (two way two lane road) and direction factor of 0.5(only one direction flow should be considered) has to be introduced in the equation.

Nsa =1.1N

Nss =1.1N

Nsc = 10.0N, N is the initial daily traffic loading.

Thus,ESA=365*1*0.5*1.1* 250.5*35.05=$\underline{1.76*10^6}$

Here 1.0 ⇒ 100% ESAs for the design lane provided the road has one lanes in both directions (Percentage ESAs per Lane for Multiple Lanes ERA, 2013 table 2.4 shown in the theoretical part above).

Table 5.5:- Traffic Classification

Traffic Class(10^6) ESA	
T1	˂0.3
T2	0.3-0.7
T3	0.7-1.5
T4	1.5-3.0
T5	3.0-6.0
T6	6.0-10.0
T7	10.0-17.0
T8	17.0-30.0
T9	30.0-50.0
T10	50.0-80*

Based on the given ranges from ERA our road project falls under **T4.**

5.6Sub Grade Soil Strength

The dominate sub grade soil type will be determined by the test result of the sample for CBR value and swell potential.

5.6.1 Material Investigation

The soil and material investigation is an important component of detail engineering design project. Investigation, sampling and identification of construction materials involve complex techniques accomplished by many different procedures and interpretations. These are frequently site specific and are influenced by geological and geographical conditions. Sub grade consists of the following major activities.

5.6.2 Soiltesting results

For the project road, samples were taken by manually digging test pits for tests including, particle size distribution, moisture content, Atterberg limit Bering capacity tests etc. For pavement design purposes, soil properties at subgrade level are required. Samples from the designed subgrade level were taken for CBR evaluations. This is considered appropriate for design purpose. The number of CBR tests required will very much depend on the uniformity of the sub grade soil. Since the project road subgrade has uniformity, fewer CBR tests were carried out.

A. **Tests conducted on Subgrade Soil**

It is recommended that laboratory tests should be carried out to determine the particle size distribution and in-situ moisture content for every sample taken. Generally, the tests conducted on the subgrade soil sample are;

- Particle size distribution (Sieve Analysis)
- Atterbergue limits
- Proctor Compaction test
- CBR test

Sampling is done by hand-dug pits. The detail laboratory test results for all the subgrade tests are attached in table below.

1-Proctor compaction' test (test method ASTM d 698)

Theory: Optimum moisture content (OMC) is the water content at which a soil can be compacted to a maximum dry unit weight by a given compaction effort and maximum dry density is the peak value of the compaction curve.

We use standard test method while in our design cause the percentage of retain on the sieve number 4 is 23.3% and the assumed load on the road is relatively small.

Table 5.6:- Standard Proctor Compaction Tests

Type of test	Hammer mass (Kg)	Hammer drop (m)	Blows /layer	Number of layers
Standard proctor	2.5	0.24	25	3

The proctor test is adequate for most applications like highway embankments earth dams, retaining back fill while modified proctor is usually favoured for heavier load application like airport runway base courses.

Objective

To determine the relation between 'moisture content' and the 'dry density' of soils using proctor compaction and determine the 'optimum water content' and 'maximum dry density'.

Equipment used –

- Molds
- Manual rammer
- Extruder, Balance
- Drying oven
- Mixing pan
- Trowel
- #4 sieve
- Moisture cans
- Graduated cylinder
- Straight Edge.

Computation

Calculate the 'moisture content' and 'dry density' for each compacted specimen as below

Moisture content -

$W = (Ww/W_S) \times 100$ .... (Equation 5.2)

Where; Ww= Weight of water.

Ws= Weight of dry soil.

Dry density -

$$\gamma_{dry} = \frac{\gamma_{wet}}{1 + w_t}$$

Where;

γ_{wet} = Wet unit weight of the soil

γ_{dry} = Dry unit weight of the soil

w = Water content

Table 5.7:- Moisture density relation of soil

A	Mold No		1	2	3	4
B	Wt. of Mold + Wet Soil (g)	W1	4675	4855	4866	4859
C	Wt. of Mold(g)	W2	3246	3246	3246	3246
D	Wt. Wet Soil(g)	W3=W1-W2	1429	1609	1620	1613
E	Volume of Mold(cm3)	V	2117	2117	2117	2117
F	Wet Density(g/cm3)	Wd=W3/V	0.68	0.76	0.77	0.76
G	Container	No.	2-A	5-A	6-A	18-A
H	Wt. Cont + Wet soil (g)	A	63.80	69.10	63.40	59.50
I	Wt. Cont + Dry soil (g)	B	56.10	58.20	53.60	48.90
J	Weight of Water (g)	c=a-b	7.70	10.90	9.80	10.60
K	Weight of Container (g)	D	25.50	25.50	25.40	25.40

L	Weight of Dry Soil (g)	e=b-d	30.60	32.70	28.2	23.5
M	Moisture Content (g)	m=(C)/(100+e)*100	25.16	33.33	34.7	45.1
N	Dry Density	Dd=wd/(100+m)*100	0.54	0.57	0.57	0.53

Test result;

MDD = 2.11%
OMC = 9.22%

2- Liquid Limit' determination using CassaGrande apparatus (Test method ASTM D 4318)

The liquid limit is the dividing line between the liquid and plastic states. It is quantified for a given soil as specific water content; and from a physical standpoint, it is the water content at which the shear strength of the soil becomes so small that the soil "flows" to close standard groove cut.

Figure 5.3:- During laboratory test

3-Plastic limit (Test method ASTM D 4318)

Theory - The 'plastic limit' of a soil is the water content at the boundary between the plastic and semisolid state. The water content at this boundary is arbitrarily defined as the water content at which soil begins to crumble when rolled into threads of specified size (3mm).

Objective - to determine the plastic limit of soils.

Sample preparation

Dry the soil in air until is dried and pulverize. Take a representative of it and sieve on sieve No 40 (0.425mm opening).

Figure 5.4:-Soil Sample used for liquid limit test

The plasticity of index (PI) is defined as the difference between the liquid limit (LL) and the plastic limit (PL), and is calculated from the equation

PI=LL-PL…………………………………………………………………..…. (Equation5.3)

Test result;

Liquid limit = 45

Plastic limit = 25

Plastic index = 20

3. California Bearing Ratio (CBR) Test

Developed by California division of highways in 1930, give a relative strength of the material for a pavement structure with respect to crushed rock, which is considered an excellent base coarse material.

There are two types of CBR test methods and the selection of this method can be depending up on the following criteria;

❖ Gradation of the soil particles -if the percentage of retain on No-4 sieve is less than 25%, use the standard test method if not use modified test method.

❖ The magnitude of loading – if the intensity of load on the pavement layer is higher, we should use modified test method and if the load on the pavement is less we should use standard test method. For example if we design for higher design road that is exposed to high frequency loading we use modified test method and if we design for lower standard(like gravel road), we use standard test method.

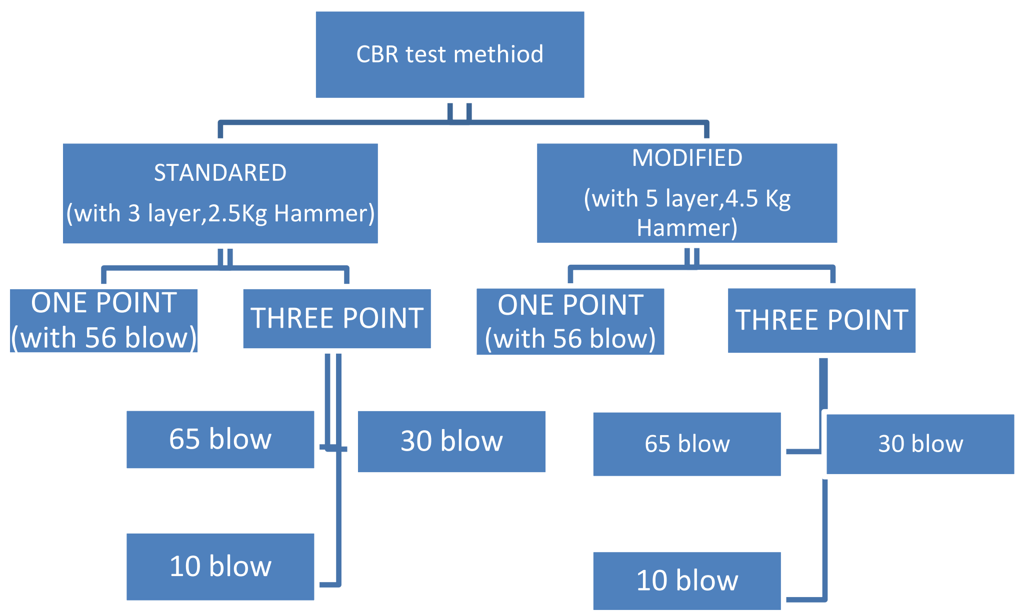


Diagram 5.1:- Representation for CBR Test

Objective

The strength of the subgrade is the main factor in determining the required thickness of flexible pavements for roads and airfield's. The strength of subgrade, sub base and base course material are expressed in terms of their California bearing ratio (CBR) value.

CBR (%) =(X/Y)*100…..……. (Equation 5.4)

Where;

x = material resistance or the unit load on the piston (pressure) for 2.54 mm (0.1") or 5.08 mm (0.2") of penetration

y = standard unit load (pressure) for well graded crushed stone

For 2.54 mm (0.1") penetration **y**= 6.9 MPa (1000 psi)

For 5.08 mm (0.2") penetration **y**= 10.3 MPa (1500 psi).

The strength of the road subgrade for flexible pavements is commonly assessed in terms of the California Bearing Ratio (CBR) and this is dependent on the;

- Type of soil, (route location)
- Density (level of compaction)
- Moisture content (GWT and environment)

Therefore, the design CBR of the subgrade soil should be evaluated at the moisture content and density representative to the subgrade condition during construction and the service time of the pavement structure.The dominate sub grade soil type will be determined by the test result of the sample for CBR value and swell potential.

The required pavement layer is determined based on the strength of the sub grade soil and traffic loading. Sub grade strength being the main design input for determining the pavement layers, its strength has been assessed using laboratory CBR test. Summary of laboratory CBR carried on sub grade soils is presented as follows.

5.7 Determination of Design CBR

The required pavement layer is determined based on the strength of the sub grade soil and traffic loading. Sub grade strength being the main design input for determining the pavement layers, its strength has been assessed using laboratory CBR test.

AACRA recommends the following if the design value is less than three;

1. Construct embankment [capping layer with sufficient thickness]
2. Construct with equilibrium moisture (Close to OMC)
3. Sealing to prevent surface runoff [drainage]
4. Use subgrade improvement

- ❖ CBR < 3% Replace bed material with better quality material.
- ❖ Swell > 3(5) % Use stabilization techniques to improve the Engineering property of existing soil.

In cases where there are unsuitable subgrade materials, the design CBR value shall be determined based on the CBR values the improved subgrade. Since we have CBR value less than three, which is not suitable soil material to withstand the supper imposed load,we use replacement mechanism (replacement of the existing soil with an improved soil that have CBR value of 5%**)** depending up on the following criteria**.**

1. Availability of material
2. Easy of construction (Mechanization requirement)
3. Requirement of maintenance and rehabilitation
4. Interest of the designer
5. Total cost the project (economic viability) and etc.

5.7.1 Sub-Grade Class

For the purpose of pavement design, the sub grade classes of uniform sections are determined by the different manuals used in pavement design. The sub grade categories specified in ERA manual and summary of the subgrade class is shown in table 5.8 presented below.

Table 5.8:- Subgrade Strength Classes

Class	Range (CBR %)
S1	2
S2	3-4
S3	5-7
S4	8-14
S5	15-29
S6	30+

Since we use an improved soil with CBR value of 4%; the sub grade is classified under class S2.

5.8 Basic Pavement Design Factors

Pavement design is governed by a number of factors. Some of them are design life, traffic loading, environment, materials, and Failure Criteria.

For satisfactorily per forming of this designed the pavement should have;

1. Structurally sound enough to withstand the stresses imposed on it.
2. Sufficiently thick to distribute the loads and stresses to a safe value on the sub grade soil.
3. Provide a reasonably hard wearing surface, so that the abrading Catron of wheels.
4. Should be impervious so that water does not get into the lower layers of the pavement and the sub – grade and cause deterioration.
5. Long life and the cost of maintaining it annually should below.

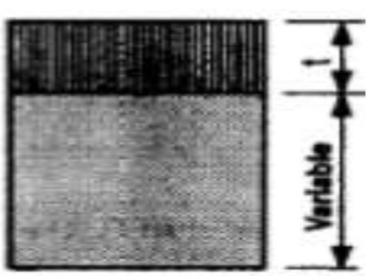
As stated the soil located in the site is an expansive clayey soil with small CBR values, these implies the subgrade has to be compacted well and a protective capping layer is inserted to prevent the load transferred to the subgrade from exceeding allowable stress limits. Where borrow materials are scarce or obtaining them is uneconomical black cotton soil could be used to form shallow embankment up to 3m, provided that a protective blanket is placed on the slopes to prevent moisture variation in the underlying black cotton soil. The blanketing material should have at least CBR of 7%, and be impermeable and resist erosion. The blanket thickness should be at least 300mm. compacting the material at lower dry density, 97 – 98% MDD (standard compaction), could reduce the potential volume increase. This can be achieved by using excess moisture, i.e. up to 1.05% OMC for compaction. Avoiding moisture changes under the pavement could reduce the swell and shrink effects of the black cotton soil.

5.8.1 Course Thickness determination using AACRA manual.

Because of normal construction level tolerance and Consequential variation in pavement course thickness, minimum course thickness must be applied to ensure the assumptions of the structural design are achived.

Granular courses should not normally be less than a minimum of 125mm thick. However, where the granular portion of the pavement is between 200mm and 250mm thick, this may reduced to a minimum of 100mm for two separate courses if required.

Asphalt courses of less than 50mm thick should not be seen as contributing structurally to the pavement but as a surfacing only. Surfacing asphalt courses are generally 35mm thick. Asphalt Courses 50mm and greater are treated as structural courses.



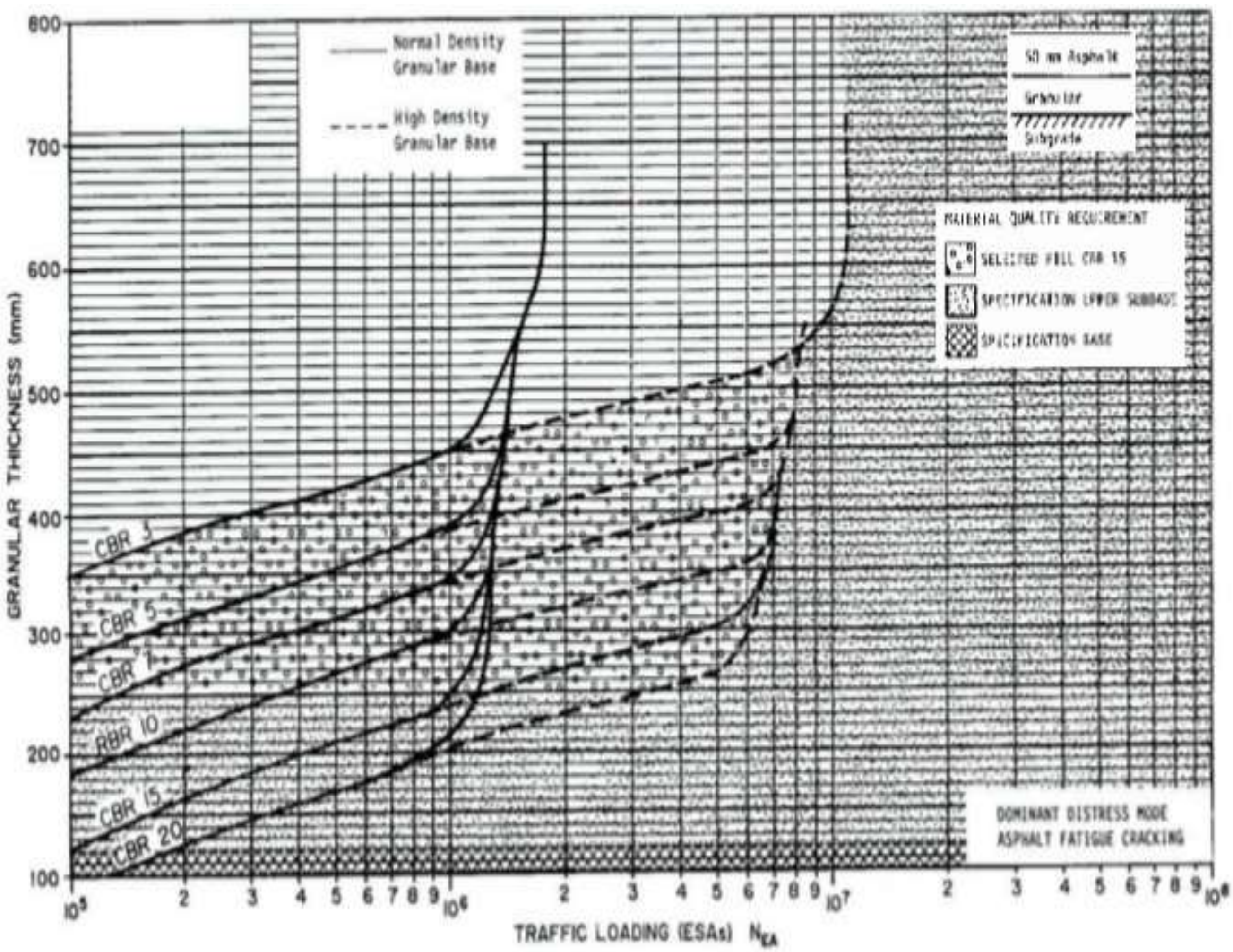
From the Flexible Pavement Design Catalog of AACRA described in the appendix section, for that class of traffic, charts 2.

Where; t = Asphalt layer

Variable = Granular Thickness

(Base course + Sub base course)

Figure 5.5:- Thickness of pavement



Reading from the chart gives the following thicknesses.

Thus our design subgrade class is S2 (CBR=3%) and our design traffic is $1.76*10^6$ (traffic class isT4)

Available materials;- CBR 15 Measured at Design moisture condition.

Asphalt layer (t=50mm)

Total granular pavement thickness = 470mm

Thickness of CBR 15 material = 470mm - 250mm = 220mm

Thickness of upper sub-base material = 250mm – 125mm = 125mm

Thickness of base material = 125mm(minimum).

6. Drainage Design

6.1 Introduction

Highway drainage may be defined as the process of interception and removal of water from over, under and the vicinity of the road surface. Road drainage is very important for safe and efficient design of the road way and hence it is an essential part of highway design and construction. A part of rain water falling on road surface and adjoining area is lost by evaporation and percolation. The remaining water known as surface, either remains on the surface of the road and adjoining area or flows away from it, depending upon the topography and general slope of the area. Removal and diversion of this surface water from highway and adjoining land is known as surface draining. Due to percolation, if water table does not rise near of the road sub grade, it does not create any problem as it does not affect the road sub grade. If water table rises to the vicinity of road sub grade, it requires to be lowered as it will definitely affect road sub grade. Measures adopted to lower the sub soil water table are called sub surface drainage. Some of the retained water which cannot be drained off by normal methods of drainage is called held water and special measures have to be taken either to drain it off or to keep it low so that it not affect the road sub-grade. For this particular project we go through the detail design of surface drainage since only this type is applicable to the area under consideration

6.1.1 Effects of Improper drainage

One of the major causes of road failure is improper drainage. Improper drainage of the road causes destruction in the following ways:

1. Road surface if made of soil or gravel becomes soft and losses strength.
2. The road sub-grade may be softened and its bearing capacity reduced.
3. Variation in moisture content in expansive soils causes variation in the volume of sub grade and thus causes failure of roads.
4. Failure of formation slopes is also attributed to poor drainage.
5. Presence of water in sub grade at places of freezing temperature in winter causes considerable drainage to the road, due to frost action.
6. If rain water is not properly drained and allowed to flow along the road side for long distances, slips and landslides may occur causing road failures.
7. Erosion of side slopes, side drains, and formation of gullies may result if proper drainage conditions are not maintained.

8. Flexible pavement's failure by formation of waves and corrugations is due to poor drainage.
9. Continuous contact of water, with bituminous pavements causes failures due to stripping of bitumen from aggregates like loosening or detachment of some of the bituminous pavement layers and formation of pot holes.
10. Rigid pavement's prime cause of failure in by mud pumping which occurs due to water in fine sub grade soil.
11. Excess moisture causes increase in weight and thus increase in stress and simultaneous reduction in strength of the soil mass. This is main reason of failure of earth slopes and embankment foundation.
12. Erosion of soil from the top of un surfaced roads and embankment slopes is also due to surface water.

6.1.2 High way drainage requirements

1. Surface water should not be allowed to remain standing on the road pavement and shoulders.
2. The surface rain water from the adjoining area should not be allowed to come towards the road surface.
3. Side drains, should be of sufficient capacity and having sufficient longitudinal slope so that it may drain of all the collected surface water, efficiently.
4. Surface water flowing across the road pavement should not develop cross ruts or erosions on road surface and shoulders.
5. Seepage water and other capillary waters should be drained off by suitable underground drainage system.
6. Minimum level of underground water table should be maintained well below the sub grade level of the sand.
7. In water logged areas special measures should be taken to keep down the harmful salts.
8. Road formation should be designed in such a way that at no point should it be less than 60 cm above the H.F.L

6.1.3 Surface drainage

Rainfall water or due to other causes, the surface water is generally collected inside drains and then disposed off in the nearest stream; depression or water course etc. For the disposal of surface water, cross drainage structures such as bridge, culverts are also necessary.

6.1.4 Structures required for drainage

The most drainage structures we selected for this particular project are as stated below:

Roadside Ditches (Drains)

A. **The Need-** simultaneous to providing protection cover on earth slopes, it is necessary to provide collection of surface water otherwise the water concentrated by roadway surfaces and cut slopes can quickly reach erosive quantities and velocities and cause serious damage. Besides the collection of surface water, another function of roadside ditches is to drain the base course of the road, failing which saturation of the base course and consequent loss on its shear strength can occur resulting in rapid deterioration of the road system.

B. cross- section

The three main types of x- sections for roadside ditches are shown below. Of the three shapes, the parabolic section is hydraulically the best and most resistant to erosion, even though not as easy in construction as the trapezoidal and triangular shapes.

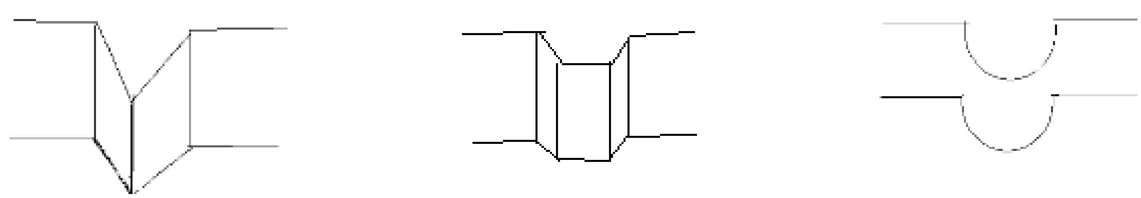


Figure 6.1:- Triangular, Trapezoidal and Circular Cross-sections

The triangular section although easy to construct is very much susceptible to erosion and gets easily blocked with debris and is generally not recommended.

The most commonly used cross section is the trapezoidal section as it is accepted from both consideration, hydraulic as well as ease of construction.

The side slopes of the ditches as earth slopes should be flat lying in the range 2:1 to 4:1; while the quantity of water to be drained, the length of drain and the gradient will actually determine the width at bottom, it should normally be not less than 0.3m.

To fulfill the requirement of the roadside ditch, the base course of the road pavement, the bottom of the ditch has to be taken at least to a depth 0.3 to 0.6m below the shoulder level.

6.4 Design of Urban Road Drainage Runoff

The Rational Formula

One of the most commonly used equations for the calculation of peak discharges from small areas is the rational formula. The rational formula is given as:

$$Q = \frac{CiA}{360} \text{ ……………………………………….. (Equation 6.1)}$$

Where, Q = peak flow in m³/s

i = rainfall intensity for the design storm (mm/h)

A = drainage area (hectares)

C = dimensionless runoff coefficient

The quotient, 1/360, is a unit conversion that can be approximated as 0.00278.

- The drainage area should be smaller than 80 hectares.
- The peak discharge occurs when the entire watershed is contributing.
- A storm that has duration equal to t_c produces the highest peak discharge for this frequency.
- The rainfall intensity is uniform over time duration equal to the time of concentration.
- The frequency of the computed peak flow is equal to the frequency of the
- Rainfall intensity. In other words, the 10-year rainfall intensity, i, is assumed to produce the 10-year peak discharge.

Ground cover determines the runoff coefficient, C. Some tables of C provide for variation due to slope, soil, and the return period of the design discharge. The runoff coefficient is a volumetric coefficient that relates the peak discharge to the "theoretical peak" or 100 percent runoff, occurring when runoff matches the net rain rate. Hence C is also a function of infiltration and other hydrologic abstractions. Some typical values of C for the rational formula are given in Table below.

Table 6.1**:-** Runoff Coefficients for Rational Formula

Types of Drainage Area	**C**
Business:	
Commercial area	0.70 - 0.95
Neighborhood areas	0.50 - 0.70
Residential:	
Single-Family areas	0.30 - 0.50
Multi-Units, detached	0.40 – 0.60
Multi-Units, attached	0.60 – 0.75
Sub urban	0.25 – 0.40
Apartment dwelling areas	0.50 – 0.70
Industrial:	
Light areas	0.50 – 0.80
Heavy areas	0.60 – 0.90
Parks; cemeteries	0.10 – 0.25
Playgrounds	0.20 – 0.40
Railroad Yard areas	0.20 – 0.40
Unimproved areas	0.10 – 0.30
Lawns	
Sandy soil, flat, $<$ 2%	0.05 – 0.10
Sandy soil, average, 2% to 7%	0.10 – 0.15
Sandy soil , steep, $>$ 7%	0.15 – 0.20
Heavy soil, flat, $<$ 2%	0.13 – 0.17
Heavy soil, average, 2% to 7%	0.18 – 0.22
Heavy soil , steep, $>$ 7%	0.25 – 0.35
Streets:	
Asphaltic	0.70 – 0.95
Concrete	0.80 – 0.95
Brick	0.70 – 0.85
Drives and Walks	0.75 – 0.85
Roofs	0.75 – 0.95

We used this table to read the Runoff coefficients (C)!

6.4.1 Intensity-Duration-Frequency Curves

Essential data for design of a drainage structure includes the intensity of rainfall that can be expected for a specific time period for a given recurrence interval. Intensity is defined as the rate of rainfall and is typically given in units of millimeters per hour. Although rainfall intensity varies during precipitation events, many of the procedures used to derive peak flow are based on assumed constant rainfall intensity.

Pre-developed Intensity-Duration-Frequency (IDF) curves are used to determine peak design discharges. The IDF curves provide a summary of a site's rainfall characteristics by relating storm duration and exceedence probability (frequency) to rainfall intensity (assumed constant over the duration).

To interpret an IDF curve, find the rainfall duration along the X-axis, go vertically up the graph until reaching the proper return period, then go horizontally to the left and read the intensity off of the Y-axis (The duration of rainfall is first fixed to be equal to time of concentration and the frequency will be left to be equal to the design period of the system and the intensity magnitude can be read from y axis.). If the IDF curves are not available, the designer needs to develop them on a project by project basis.

The following figure shows an IDF curve for bole sub town provided in ERA drainage design manual.

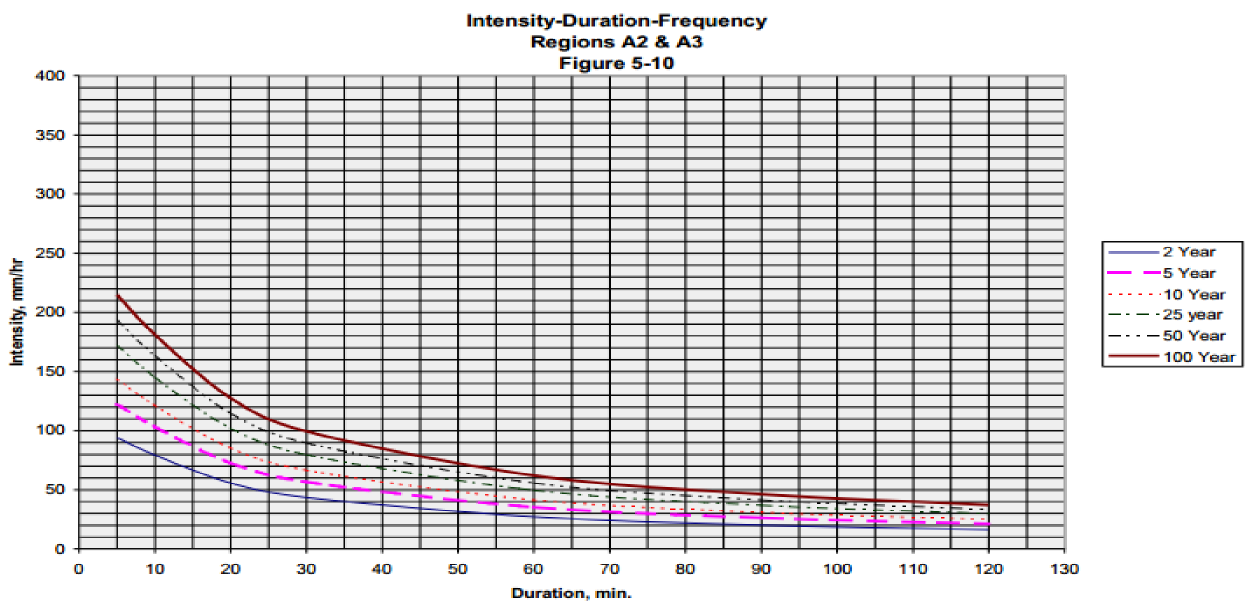


Chart 6.1**:-** Intensity- Duration- Frequency Curve

- We used this curve to read the rainfall intensity (I)!

Design Floods

A complete drainage system is composed of minor and major drainage systems. Minor system consists of components historically considered to be part of 'storm drainage system'. These components include curbs, gutters, ditches, inlets, pipes and other conduits.

We used the design flood of 10yrs for our design.

6.5 Delineating Catchment Areas

To design the drainage system for our road, we started from delineating the catchment areas using Google Earth technology and to delineate the areas, we tried to inspect the topography of each area with Google Earth. We used Elevation as basis to decide the runoff contributing areas. Thus our Catchment area is around 28.56ha (Source: Google Earth).

Figure 6.2:- Catchment area(*Google Map*, n.d.)

6.5.1 Calculation of Discharges

Since all the areas are less than 80ha, according to AACRA, we used the rational formula for the calculation of Discharge. Also the velocity method, explained above, will be used for the calculation of time of concentration.

The detailed calculations for each catchment area will be shown in the coming pages. The areas have been found using AutoCAD in which the coordinates of the vertexes of each polygon has been entered from Google Earth.

Design of Efficient and Economical Trapezoidal Cross Sectional Channel

The following criterion applies to roadside channels:-

(i) Stone pitching or grouted riprap must be used for channel side slopes steeper than 2:1.
(ii) Flexible linings are calculated using the method of allowable tractive force.
(iii) The design discharge frequency for permanent, roadside, ditch linings and for temporary linings is based on ERA drainage manual.
(iv) Channel freeboard shall be 0.3 meters.

6.5.2 Trapezoidal Ditch

The most common channel shape for large flows is the trapezoidal section. Trapezoidal Channels are easily constructed by machinery and are often the most economical to Construct. When a wide trapezoidal section is proposed, both traffic safety and aesthetics can be improved by rounding all angles of the channel cross section with vertical curves. And by applying all these basic consideration during selection of types of cross drainage, we choose trapezoidal cross-section for these specific project.

Manning's Equation –For a given depth of flow in a channel with a steady, uniform flow, the mean velocity, V, can be computed with Manning's equation:

$$V=\left(\frac{1}{n}\right)*R^{\frac{2}{3}}*S^{1/2} \text{...} \quad \text{(Equation 6.2)}$$

Where;

V = velocity, m/s

n = Manning's roughness coefficient

R = hydraulic radius = A/P, m

P = wetted perimeter, m

S = slope of the energy grade line, m/m

A .Sample calculation

For ditch

$$Q = \frac{Cf*I*c*A}{360} \text{..} \quad \text{(Equation 6.3)}$$

Where:

Q=peak discharge (m3/sec)

C= run of coefficient

C_f=frequency factor

I= average rainfall intensity (mm/hr)

A= influencing catchments area (ha)

From ERA drainage manual, the Wolkite average rainfall intensity is 41.46mm/min[(2)]. In our design the area is give as A= 28.56ha (Source: Google Earth) and total concentration time is give as 51min (From Intensity- Duration- Frequency Curve).

$$Q = \frac{0.375*28.56*41.46}{360} = 1.23m^3/s$$

For safety case and for some inconvenience of runoff determination the calculated discharge is increased by 50%

Q_d=1.23m^3*1.5= 1.845m^3/s

For Grass, some weeds Values of Roughness Coefficient n =0.025, and bed slope of 1 in 4000, side slope= 1:1.

Check the capacity of the ditch

Thecapacity of the ditch for the largest cut section is given by

$$\mathbf{Q}=A*(\frac{1}{n}*R^{2/3}*S^{1/2}) \ldots\ldots\ldots\ldots \text{(Equation 6.4)}$$

$$A = (b+my)*y \ldots\ldots\ldots\ldots \text{(Equation 6.5)}$$

$$P= b+2y\sqrt{m^2+1} \ldots\ldots\ldots\ldots \text{(Equation 6.6)}$$

R= y/2, y for economical trapezoidal section

Let assume the depth of the ditch is 0.6m and side slope is (1H: 1V) and also slope of the energy grade line S = 0.00025 which is the minimum value.

$$A = (b+1*0.6)*0.6 = 0.6b+0.36 \ldots\ldots\ldots\ldots \text{(Equation 6.7)}$$

$$P= b+2*0.6\sqrt{1^2+1} = b+1.697 \ldots\ldots\ldots\ldots \text{(Equation 6.8)}$$

R = 0.6/2 =0.3, R = A/P …………………………………. (Equation 6.9)

By substituting (Equation 6.7) & (Equation 6.8)

$$0.3=\frac{0.6b+0.36}{b+1.697}$$

It can be simplified as and we get width (b) is 0.497m, use b = 0.5m

By substituting the value of b=0.5m in Equation 7.7 &Equation 7.8 the area and wetted perimeters are $0.66m^2$and 2.197m respectively.

Q= $\frac{0.66}{0.025}*0.301^{2/3} * 0.00025^{1/2}$ = Q = $0.187m^3/S$

The capacity of ditch =$4.813m^3/s$ and it is greater than expected run off (Qd).

i.e. Q>Qd ($1.23m^3/S > 0.187m^3/S$).

Therefore, the provided ditch is adequate and the layout of trapezoidal cross section is drawn as follow;

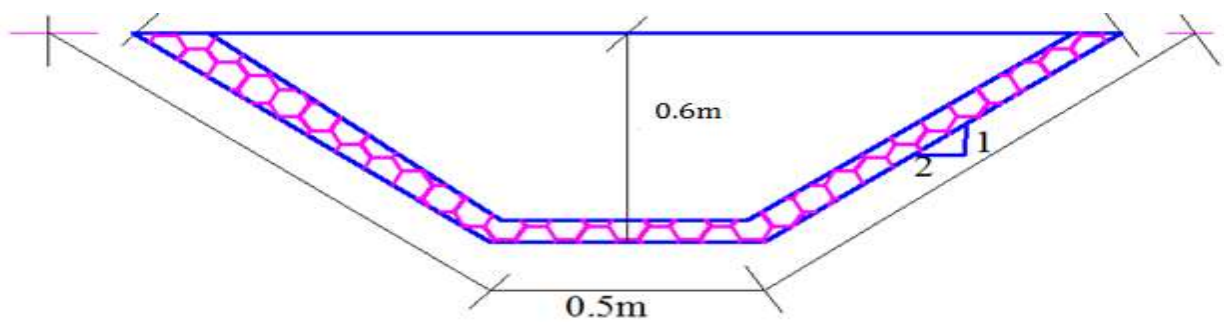


Figure 6.3:- Cross Section of Trapezoidal Ditch

7. Earth Work and Quantity

7.1 Introduction

Earth work is conversion of natural condition to required section and grade. Earth work in highway design includes determination of cuts and fills, location of borrow, waste sites, the free haul and over haul distance determination. The most common item of work encountered in high project is earth work. The estimation of earth quantities deserves a detailed treatment.

The quantity of work in embankment and cuts are computed by the cross sectional end area method. The area of earth work in each cross section is computed by the help of AutoCAD software.

7.2 Main Earthwork operations

Clearing and garbing (m^2):-The removal of top soil, trees, bushes and soon by using dozer and other type of machine.

Excavation (m^3):- the process of losing and removal of soil and rocks. It can be done for three reasons:-In order to maintain the grades for road drainage, for structure foundation and for borrow excavation.

Classification of excavation

- **Borrow excavation**: It is the work done in obtaining material for embankment of fill from a source other than required excavation
- **Rock excavation:**It consists of removal of formation that can't be remove without systematicdrillingand blasting.
- **Earthexcavation:**Itistheremovaloflayerofsoilimmediatelyunderthe topsoilandontopofrockthiscanbereadily removedwithany earth movingequipment.

Waste-materialexcavation:removalanddisposalofunsuitablematerialsforthe road.

Hauldistance-Itisdistancefrompointofexcavationtopointwherethematerialis to be tipped.

Free Haul-themaximumdistancethroughwhichexcavatedmaterialmaybe transported withoutthe added cost abovethe unitbid price.

Overhaul-excavatedmaterialtransportedtoadistancebeyondthe free haul distance.

Averagehaulsdistance-Thedistancefromthecenterofthegravityofthe excavation to the centerofgravityof thetip.

Grading /shaping the road bed: Shapingthe road bed (m^2)

The stepsinvolvedinthecomputationof earthworkquantitiesandthedevelopmentof the optimal mass haul diagram are:

- Areacalculations
- Volume Calculations
- Earthwork calculations
- Preparation ofmass haul diagram
- Balancing earthworks usingthe mass haul diagram

Thesestepsarepresentedinthefollowingtext.Ofnoteisthefactthatmostcurrent highwaydesigncomputerprograms,including Civil 3D,willproducethemass hauldiagramaspartofthe outputwhentypicalsectionsandhorizontal andvertical alignmentsareinputs.Afinalstageofgeometricdesignisthenusually tomake adjustments to the alignments in the interests of balancing or minimizing the earthwork quantities.

Area Calculations

The area of the cross section can be calculated by the coordinate method called Simpson‘srule i.e. for any irregular polygon of coordinates(X_1, Y2), (X_2, Y2),(X_3.Y_3)…(X_n, Yn).

A=0.5[(y1x2+y2x3+ … ynx1) - (y2x1+y3x2+ …y1xn)] ……………….. (Equation 7.1)

But in our project the area of earthwork in each cross-section is computed by the help ofsoftware programs.

Volume Calculation

The volume of earthwork may be calculated by means of either average end areaor primordial formula.

1. **Average end area method**

The volume of a right prism equal the average area multiplied by the length

Assume the averageendto be as the average endarea.

Volume =1/2(A1+A2)*L ……………………………….…………….. (Equation 7.2)

Thisformulaisappliedtoareaofany shapebuttheresultsareslightlytoo large.Theareaissmallifthesectionsdonotchangerapidly.Forthisparticular project weused averageend areamethod to calculatethe volume ofearthwork.

2. Prismodal formula

The primordial is a solid whose ends are parallel and whose sides are plane or wrapped surface.

Thevolumeof aprimordial is,

$V=L/6(A1+4A_m+A2)$……………………………………………..… (Equation 7.3)

Where;L=the distancebetween the two parallelbases

A1&A2=end areaofcross section in sq.m

Am=Areaof cross-section midwaybetweenthe end areas

Calculating Earthwork

There are several ways of calculating earthwork but the most common is theaverage end area" method. This method consists of averaging the cut and fill quantities of adjacent stations and multiplying by the distance between stations to produce cubic meters of excavation and embankment between the two stations. This procedure is followed when manual methods are used. Projects designed by computer will be tabulated on the mass plot listing and these calculations are integral parts of the alignment design program.

Table 7.1:- Volume of cut and fill (taken from software Civil 3D)

Station	Cut Area (Sq.m.)	Cut Volume (Cu.m.)	Reusable Volume (Cu.m.)	Fill Area (Sq.m.)	Fill Volume (Cu.m.)	Cum. Cut Vol. (Cu.m.)	Cum. Reusable Vol. (Cu.m.)	Cum. Fill Vol. (Cu.m.)	Cum. Net Vol. (Cu.m.)
0+000.000	13.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0+020.000	14.15	276.97	276.97	0.00	0.00	276.97	276.97	0.00	276.97
0+040.000	17.73	318.79	318.79	0.00	0.00	595.77	595.77	0.00	595.76
0+054.122	20.10	267.09	267.09	0.00	0.00	862.86	862.86	0.00	862.86
0+060.000	21.11	121.13	121.13	0.00	0.00	983.99	983.99	0.00	983.99
0+061.622	21.39	34.47	34.47	0.00	0.00	1018.46	1018.46	0.00	1018.46
0+074.122	22.59	274.91	274.91	0.00	0.00	1293.37	1293.37	0.00	1293.37

0+080.000	24.04	137.06	137.06	0.00	0.00	1430.43	1430.43	0.00	1430.42
0+086.622	25.67	164.30	164.30	0.00	0.00	1594.73	1594.73	0.00	1594.73
0+089.122	26.63	64.90	64.90	0.00	0.00	1659.64	1659.64	0.00	1659.63
0+100.000	27.33	291.47	291.47	0.00	0.00	1951.11	1951.11	0.00	1951.10
0+108.490	19.44	198.18	198.18	0.00	0.00	2149.29	2149.29	0.00	2149.28
0+110.990	15.63	44.09	44.09	0.00	0.00	2193.38	2193.38	0.00	2193.37
0+120.000	10.16	116.87	116.87	0.04	0.18	2310.24	2310.24	0.19	2310.06
0+123.490	10.54	36.13	36.13	0.04	0.13	2346.37	2346.37	0.32	2346.05
0+135.990	5.65	101.18	101.18	0.02	0.37	2447.55	2447.55	0.69	2446.86
0+140.000	6.14	23.62	23.62	0.01	0.07	2471.18	2471.18	0.76	2470.41
0+143.490	6.56	22.16	22.16	0.00	0.03	2493.33	2493.33	0.80	2492.54
0+160.000	0.68	59.75	59.75	3.99	32.95	2553.08	2553.08	33.75	2519.33
0+169.376	0.28	4.50	4.50	6.48	49.06	2557.58	2557.58	82.81	2474.76
0+176.876	0.37	2.46	2.46	5.75	45.86	2560.03	2560.03	128.67	2431.36
0+180.000	0.38	1.17	1.17	5.57	17.68	2561.20	2561.20	146.36	2414.84
0+189.376	0.46	3.92	3.92	4.64	47.88	2565.12	2565.12	194.24	2370.88
0+200.000	0.93	7.41	7.41	3.90	45.36	2572.53	2572.53	239.61	2332.92
0+201.876	0.77	1.60	1.60	3.89	7.30	2574.13	2574.13	246.91	2327.22
0+203.098	0.74	0.93	0.93	3.93	4.78	2575.06	2575.06	251.68	2323.37
0+204.376	0.59	0.85	0.85	4.07	5.11	2575.91	2575.91	256.80	2319.11
0+205.598	0.41	0.61	0.61	4.26	5.09	2576.52	2576.52	261.89	2314.63

0+218.098	0.05	2.87	2.87	5.01	58.20	2579.39	2579.39	320.09	2259.30
0+220.000	0.06	0.10	0.10	5.29	9.80	2579.49	2579.49	329.88	2249.61
0+230.598	0.26	1.70	1.70	6.32	61.53	2581.19	2581.19	391.42	2189.78
0+238.098	0.51	2.89	2.89	5.13	42.95	2584.08	2584.08	434.36	2149.72
0+240.000	0.58	1.04	1.04	4.80	9.45	2585.12	2585.12	443.81	2141.31
0+260.000	2.07	26.57	26.57	2.45	72.51	2611.69	2611.69	516.32	2095.37
0+280.000	8.57	106.45	106.45	0.03	24.78	2718.14	2718.14	541.10	2177.04
0+291.946	10.31	112.81	112.81	0.00	0.22	2830.95	2830.95	541.32	2289.62
0+299.446	11.11	80.33	80.33	0.00	0.04	2911.27	2911.27	541.36	2369.91
0+300.000	11.13	6.15	6.15	0.00	0.00	2917.43	2917.43	541.36	2376.06
0+311.946	13.88	149.36	149.36	0.00	0.00	3066.79	3066.79	541.37	2525.41
0+320.000	15.89	119.87	119.87	0.00	0.00	3186.65	3186.65	541.37	2645.28
0+324.446	17.28	73.63	73.63	0.00	0.00	3260.28	3260.28	541.37	2718.91
0+326.946	19.24	45.45	45.45	0.00	0.00	3305.74	3305.74	541.37	2764.36
0+328.020	20.01	21.06	21.06	0.00	0.00	3326.80	3326.80	541.37	2785.43
0+330.520	20.67	50.88	50.88	0.00	0.00	3377.68	3377.68	541.37	2836.31
0+340.000	19.75	192.07	192.07	0.00	0.00	3569.75	3569.75	541.37	3028.38
0+343.020	18.90	58.35	58.35	0.00	0.00	3628.10	3628.10	541.37	3086.73
0+355.520	15.01	211.95	211.95	0.27	1.67	3840.06	3840.06	543.04	3297.01
0+360.000	14.87	66.94	66.94	0.29	1.25	3907.00	3907.00	544.29	3362.71
0+363.020	14.77	44.75	44.75	0.33	0.94	3951.75	3951.75	545.23	3406.52

0+380.000	14.42	247.85	247.85	0.69	8.67	4199.60	4199.60	553.90	3645.70
0+400.000	18.50	329.23	329.23	0.00	6.93	4528.83	4528.83	560.83	3968.01
0+420.000	28.60	470.98	470.98	0.00	0.00	4999.81	4999.81	560.83	4438.98
0+440.000	27.95	565.43	565.43	0.00	0.00	5565.24	5565.24	560.83	5004.41
0+460.000	34.07	620.17	620.17	0.00	0.00	6185.41	6185.41	560.83	5624.58
0+480.000	33.47	675.38	675.38	0.00	0.00	6860.79	6860.79	560.83	6299.97
0+500.000	34.39	678.52	678.52	0.00	0.00	7539.31	7539.31	560.83	6978.49
0+520.000	34.01	683.95	683.95	0.00	0.00	8223.26	8223.26	560.83	7662.44
0+529.007	28.91	283.35	283.35	0.00	0.00	8506.62	8506.62	560.83	7945.79
0+536.507	26.14	206.44	206.44	0.00	0.00	8713.05	8713.05	560.83	8152.23
0+540.000	24.97	89.25	89.25	0.00	0.00	8802.31	8802.31	560.83	8241.48
0+549.007	21.40	208.82	208.82	0.00	0.00	9011.13	9011.13	560.83	8450.30
0+560.000	20.06	227.91	227.91	0.00	0.00	9239.04	9239.04	560.83	8678.21
0+561.507	19.70	29.97	29.97	0.00	0.00	9269.01	9269.01	560.83	8708.18
0+564.007	19.81	48.07	48.07	0.00	0.00	9317.08	9317.08	560.83	8756.25
0+565.128	19.64	22.12	22.12	0.00	0.00	9339.19	9339.19	560.83	8778.37
0+567.628	18.59	46.54	46.54	0.00	0.00	9385.73	9385.73	560.83	8824.90
0+580.000	16.07	213.62	213.62	0.00	0.00	9599.35	9599.35	560.83	9038.52
0+580.128	16.04	2.06	2.06	0.00	0.00	9601.41	9601.41	560.83	9040.58
0+592.628	15.55	197.46	197.46	0.00	0.00	9798.86	9798.86	560.83	9238.04
0+600.000	14.46	110.60	110.60	0.00	0.00	9909.46	9909.46	560.83	9348.63

0+600.128	14.44	1.86	1.86	0.00	0.00	9911.32	9911.32	560.83	9350.49
0+620.000	12.41	266.81	266.81	0.00	0.00	10178.12	10178.12	560.83	9617.30
0+640.000	7.45	198.64	198.64	0.00	0.02	10376.76	10376.76	560.85	9815.91
0+660.000	3.96	114.13	114.13	0.23	2.31	10490.89	10490.89	563.16	9927.73
0+680.000	1.61	55.71	55.71	0.32	5.54	10546.60	10546.60	568.70	9977.90
0+700.000	10.52	121.25	121.25	0.00	3.25	10667.85	10667.85	571.95	10095.90
0+720.000	19.25	297.63	297.63	0.00	0.00	10965.48	10965.48	571.96	10393.52
0+740.000	23.14	423.84	423.84	0.00	0.00	11389.31	11389.31	571.96	10817.35
0+760.000	50.15	732.89	732.89	0.00	0.00	12122.20	12122.20	571.96	11550.24
0+780.000	64.95	1151.02	1151.02	0.00	0.00	13273.23	13273.23	571.96	12701.26
0+800.000	67.77	1327.22	1327.22	0.00	0.00	14600.44	14600.44	571.96	14028.48
0+820.000	62.36	1301.36	1301.36	0.00	0.00	15901.80	15901.80	571.96	15329.84
0+840.000	53.16	1155.20	1155.20	0.00	0.00	17057.00	17057.00	571.96	16485.04
0+849.550	49.94	492.27	492.27	0.00	0.00	17549.28	17549.28	571.96	16977.32
0+857.050	46.26	360.73	360.73	0.00	0.00	17910.01	17910.01	571.96	17338.05
0+860.000	44.63	134.06	134.06	0.00	0.00	18044.07	18044.07	571.96	17472.11
0+869.550	40.59	406.94	406.94	0.00	0.00	18451.00	18451.00	571.96	17879.04
0+880.000	37.83	409.73	409.73	0.00	0.00	18860.73	18860.73	571.96	18288.77
0+882.050	37.04	76.74	76.74	0.00	0.00	18937.47	18937.47	571.96	18365.51
0+883.954	36.63	70.14	70.14	0.00	0.00	19007.61	19007.61	571.96	18435.65
0+884.550	36.44	21.77	21.77	0.00	0.00	19029.38	19029.38	571.96	18457.42

0+900.000	29.80	510.17	510.17	0.00	0.00	19539.54	19539.54	571.96	18967.58
0+920.000	24.50	543.00	543.00	0.00	0.00	20082.54	20082.54	571.96	19510.58
0+931.655	21.49	265.82	265.82	0.00	0.00	20348.36	20348.36	571.96	19776.40
0+940.000	16.17	152.37	152.37	0.00	0.01	20500.72	20500.72	571.97	19928.75
0+960.000	11.65	267.59	267.59	0.06	0.62	20768.31	20768.31	572.60	20195.72
0+980.000	3.01	141.34	141.34	0.46	5.33	20909.66	20909.66	577.92	20331.73
1+000.000	2.84	57.38	57.38	0.39	8.75	20967.03	20967.03	586.68	20380.36
1+020.000	2.10	48.52	48.52	0.89	13.20	21015.55	21015.55	599.88	20415.68
1+020.016	2.10	0.03	0.03	0.89	0.01	21015.59	21015.59	599.89	20415.70
1+022.516	1.83	4.83	4.83	0.84	2.21	21020.42	21020.42	602.10	20418.32
1+035.016	1.80	22.66	22.66	0.34	7.35	21043.08	21043.08	609.45	20433.63
1+040.000	2.10	9.74	9.74	0.37	1.76	21052.81	21052.81	611.21	20441.60
1+047.516	2.19	16.13	16.13	0.44	3.03	21068.94	21068.94	614.24	20454.70
1+055.016	1.90	15.32	15.32	0.56	3.74	21084.26	21084.26	617.98	20466.28
1+060.000	1.73	9.04	9.04	0.65	3.02	21093.30	21093.30	621.00	20472.31
1+080.000	2.30	40.37	40.37	1.51	21.68	21133.68	21133.68	642.68	20491.00
1+100.000	1.44	37.43	37.43	2.49	40.00	21171.11	21171.11	682.68	20488.43
1+120.000	5.31	67.48	67.48	0.54	30.22	21238.59	21238.59	712.90	20525.69
1+140.000	8.15	134.57	134.57	1.35	18.91	21373.16	21373.16	731.80	20641.36
1+160.000	11.25	194.01	194.01	0.34	16.93	21567.17	21567.17	748.73	20818.44
1+180.000	16.51	277.58	277.58	0.02	3.58	21844.75	21844.75	752.31	21092.44

1+200.000	18.44	349.46	349.46	0.00	0.20	22194.21	22194.21	752.50	21441.70
1+220.000	21.88	403.17	403.17	0.00	0.00	22597.38	22597.38	752.50	21844.88
1+240.000	17.08	389.58	389.58	0.00	0.00	22986.96	22986.96	752.50	22234.46
1+260.000	4.72	218.06	218.06	0.05	0.50	23205.02	23205.02	753.01	22452.01
1+280.000	10.45	151.73	151.73	0.04	0.88	23356.75	23356.75	753.89	22602.86
1+300.000	20.82	312.65	312.65	0.00	0.38	23669.39	23669.39	754.27	22915.13
1+320.000	20.54	413.51	413.51	0.00	0.00	24082.90	24082.90	754.27	23328.64
1+340.000	9.80	303.32	303.32	0.00	0.00	24386.23	24386.23	754.27	23631.96
1+343.554	0.00	17.41	17.41	0.00	0.00	24403.64	24403.64	754.27	23649.37

7.3 MASS HAUL DIAGRAM

It is a graphical representation of the amount of earth work and embankment involved in a project and the manner in which the earth is to be moved. Mass haul diagram is a continuous curve showing the accumulated algebraic sum of the cut (+ve) and fill (-ve) volume from some initial station for any succeeding section. The horizontal or x-axis represents distance and is usually expressed in meters or stations. The vertical or y- axis represents the cumulative quantity of earth work in cubic meter. The quantity of excavation on the mass diagram is considered positive, and embankment is negative.

To draw the mass haul diagram it is convenient to tabulate the cumulative volumes of cuts and fill at each station. The mass diagram allows a high way engineer to determine direction of haul and the quantity of earth taken from or hauled to any location. It shows ‘’balance point ‘’ the station between which is the volume of excavation. In this project X-axis represent stations from 0+000 to 1+420 and the Y- axis represents the cumulative volume.

Note that properties of mass haul diagrams are as follows:

1. An upward slope on the mass curve indicates excavation, and conversely, a downward slope indicates embankment. The steeper the slope of the mass curve, the greater the cubic meters of excavation or embankment.

2. The maximum ordinate of the mass curve occurs at the point where excavation ends and embankment starts. Similarly, the minimum ordinate occurs at the point where embankment ends and excavation starts.
3. Cut and fill quantities between the points at which any horizontal line cuts off a loop of the mass curve will exactly balance. Such horizontal lines are called balance lines and the points at which these lines intersect the mass curve are called balance points.
4. Areas below the balance line indicate that hauling of excavation to embankment is from right to left, whereas areas above the balance line indicate that the haul is from left to right.
5. The area between a balance line and its corresponding loop of the mass curve is a measure of haul (product of the volume and distance in station-meters).
6. The ordinate at any station represents the accumulated amount of surplus or deficit of material at the station. It does not indicate the amount of cut or fill volume at that station.

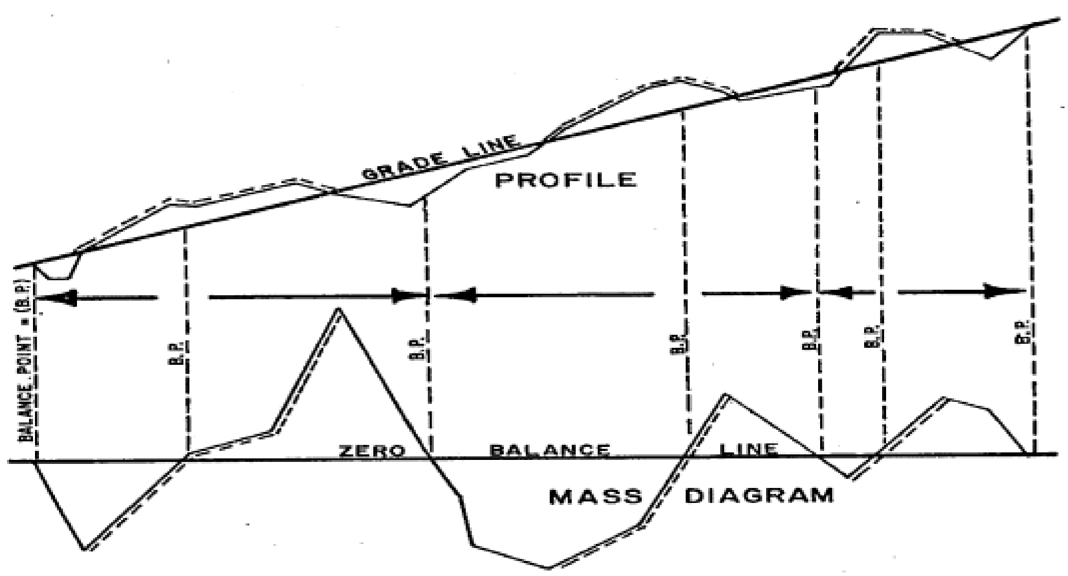


Figure 7.1:- Relationshipof Profile Grade and HaultoMass HaulDiagram

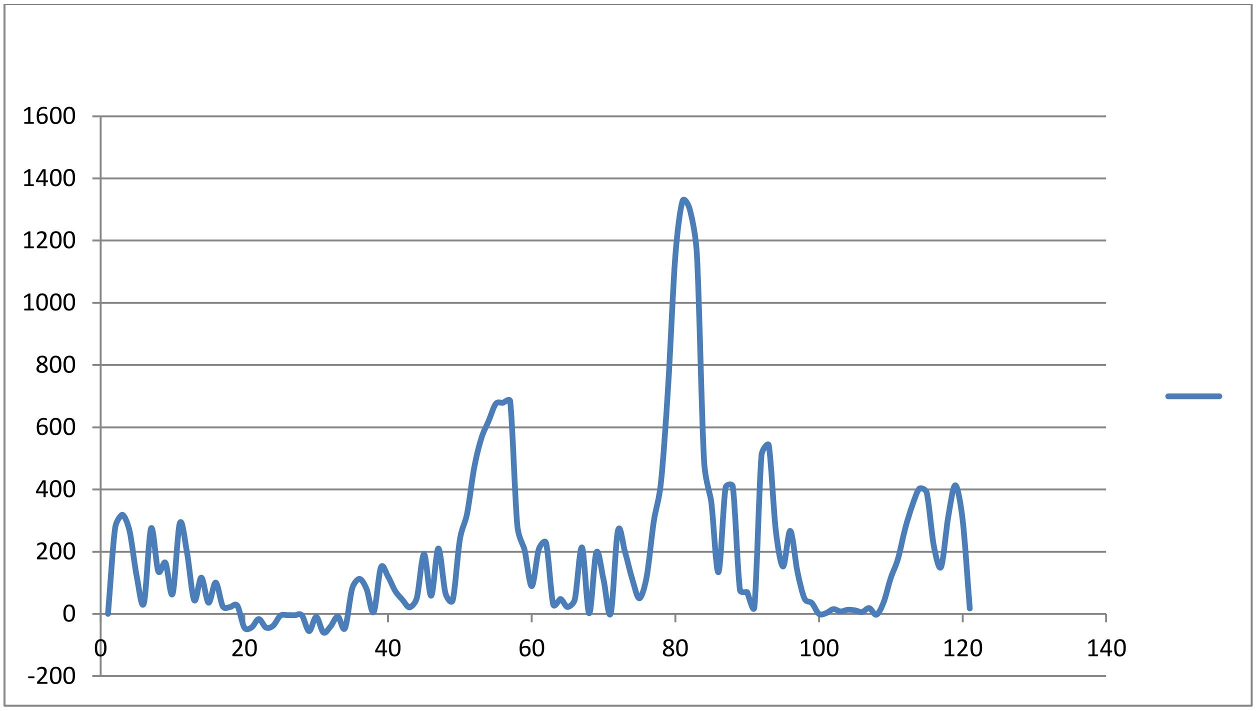


Figure 7.2:- Mass haul diagram

7.4 USE OF MASS HAUL DIAGRAM

- If mass haul is drawn for each trial grade line it can be used for selecting the most economical gradient.
- Once the formation level is designed it can be used to indicate the most economical method of moving the earth.
- In proportion and enabling suitable plant, equipment or machinery.

Free haul is defined as the maximum distance through which excavated material may be transported without added cost above the unit bid price. Prior to the use of high-speed pneumatic-tired earth moving equipment, free haul distances were limited to approx. 1000 meters, but distances of up to 2000 meters are not uncommon now. Special conditions on a project may require longer hauls, where restrictions do not allow excavation or borrow in the immediate area. A note on the mass haul diagram, in the plans, or in the specifications shall state that the contractor may be required to haul material a specified distance, or within balance points shown on the plans, without additional compensation.

7.5 Balancing Earthwork Using the Mass Haul Diagram

The designer should carefully assess the project before start of design and set certain guidelines for balancing the earthwork. A determination should be made as to the maximum haul distance or distance between balance points, whether tight balances will be used or whether it will be more economical to excavate to spoil in some areas and obtain borrow material in others. Listed below are a few considerations in determining the best earthwork design:

a) Right-of-way restrictions may necessitate importing borrow material for the required embankments.

b) Where large quantities of inferior or deleterious material are encountered in the excavation, it will be necessary to waste this material, which is unsuitable for use as embankment.

c) Special conditions through deep cuts, such as sloughing, sight distance requirements, or sand drift conditions may require very flat back slopes resulting in large amounts of excavation and no large embankments within a reasonable haul distance. This situation will require that some excavated material will be wasted.

d) The need to carry the road level considerably above the existing ground for extended distances through flood plain areas will generally require borrow excavation. After the designer has analyzed all of the above factors and determined how he proposes to balance the earthwork, he is ready to start calculations as previously outlined. In order to obtain a better perspective of the work the project should be broken down to sections not to exceed 5 kilometers in length. Longer hauls, where restrictions do not allow excavation or borrow in the immediate area.

The economical limit of haul is defined as the distance through which it is more economical to haul excavated material than to waste and borrow. The following formula is presented as a guide to assist the designer in determining the economic limit of haul:

E.L.H. = F.H. distance + Unit Price of Borrow/ Unit Price of Overhaul ………………… (Equation 7.4)

Where:

E.L.H = Economic limit of haul

F.H. = Free haul distance

8. Conclusion and Recommendation

8.1Conclusion

Basically highway design project considered safety and economy for the design of the particular road mentioned within the desired design period, social and environmental factors and the traffic volume collected. Safety was maintained on the road horizontal and vertical alignment to give comfort for the road users and minimize the accidental risk that may occur on the road. The other important consideration is economy. After we give a safe geometric alignment for the road we bother about the pavement materials. And the most economical material that is easily available near the project area was selected.

The geometric alignment design is provided based on the chosen manuals and engineering judgments which are related to the condition of the project. Survey data and hydrological data were the basic information's for the design. Addis Ababa road's authority (AACRA) was used as a clear guidance for the geometric design, pavement design. Based on the AACRA specification and other manuals, selection was done on the most economical pavement thickness using traffic analysis and the minor drainage structure and the major drainage structure were also designed for the two most important factors. The side ditch was designed in the allowable range of velocity.

Generally, this project has covered the most important portions of Highway and Transportation Engineering in particular and it considered the safety of the users and the economy as a whole.

8.2 Recommendation

Among the construction activities in Ethiopia road construction uses the huge budget and hence it needs proper design as well as supervision. It is known that deep site investigation should have been done to identify the soil and ground condition as well as the hydrologic condition along the proposed route. To do this the department should fund the student. To select the best alignment, proper surveying data like easting, northing and elevation should be available. And several corridor routes should be considered and evaluated for selection purpose. While designing roads, tiresome computations should be avoided, especially grade selection, earthwork calculation and drawing cross-Sectional elements. Thus it is better to use software programs such as EAGLE POINT, Inroads, Mx-road, civil 3Dand AUTO Cad. For any project; hence improper drainage is the main cause of road failure, appropriate rain fall data of the project area, full information about the topography (legends) should be known. If not site visit is necessary to guess the maximum flood level from the existing streams or drainage structures. The university should bring students with all necessary data and material like surveying instruments and design offices. There should also be laboratory inside the campus to conduct different testes such as CBR test and Material Strength Test Laboratories. The campus should provide students with computers and internet connections should be available to make students well informed about the current modern design and construction systems in our country as well as in the world. It should also give enough time for graduating students for their final project work. Generally road design and construction work needs a good care from conception up to completion and care should be given accordingly.

Appendix A: Alignment Curve Report

Tangent Data

Length:	65.409	Course:	S 48° 43' 53.4139" E

Circular Curve Data

Delta:	13° 43' 01.6790"	Type:	RIGHT
Radius:	140.000		
Length:	33.517	Tangent:	16.839
Mid-Ord:	1.002	External:	1.009
Chord:	33.437	Course:	S 41° 52' 22.5744" E

Tangent Data

Length:	141.770	Course:	S 35° 00' 51.7349" E

Circular Curve Data

Delta:	04° 15' 11.0743"	Type:	LEFT
Radius:	140.000		
Length:	10.392	Tangent:	5.199
Mid-Ord:	0.096	External:	0.096
Chord:	10.390	Course:	S 37° 08' 27.2720" E

Tangent Data

Length:	145.011	Course:	S 39° 16' 02.8092" E

Circular Curve Data

Delta:	09° 15' 37.3060"	Type:	RIGHT
Radius:	140.000		
Length:	22.627	Tangent:	11.338
Mid-Ord:	0.457	External:	0.458
Chord:	22.603	Course:	S 34° 38' 14.1562" E

Tangent Data

Length:	118.029	Course:	S 30° 00' 25.5032" E

Circular Curve Data

Delta:	23° 20' 31.7454"	Type:	LEFT
Radius:	140.000		
Length:	57.036	Tangent:	28.919

Mid-Ord:	2.894	External:	2.956
Chord:	56.642	Course:	S 41° 40' 41.3759" E

Tangent Data

Length:	17.398	Course:	S 53° 20' 57.2486" E

Circular Curve Data

Delta:	27° 03' 45.6829"	Type:	RIGHT
Radius:	140.000		
Length:	66.127	Tangent:	33.692
Mid-Ord:	3.886	External:	3.997
Chord:	65.514	Course:	S 39° 49' 04.4072" E

Tangent Data

Length:	115.730	Course:	S 26° 17' 11.5657" E

Circular Curve Data

Delta:	24° 53' 49.5754"	Type:	LEFT
Radius:	140.000		
Length:	60.835	Tangent:	30.905

Mid-Ord:	3.291	External:	3.371
Chord:	60.358	Course:	S 38° 44' 06.3534" E

Tangent Data

Length:	36.379	Course:	S 51° 11' 01.1412" E

Circular Curve Data

Delta:	42° 06' 40.7269"	Type:	RIGHT
Radius:	140.000		
Length:	102.897	Tangent:	53.897
Mid-Ord:	9.348	External:	10.016
Chord:	100.597	Course:	S 30° 07' 40.7777" E

Tangent Data

Length:	151.299	Course:	S 09° 04' 20.4143" E

Circular Curve Data

Delta:	30° 34' 38.5001"	Type:	RIGHT
Radius:	140.000		
Length:	74.715	Tangent:	38.270

Mid-Ord:	4.955	External:	5.136
Chord:	73.831	Course:	S 06° 12' 58.8357" W

Tangent Data

Length:	146.245	Course:	S 21° 30' 18.0858" W

Appendix B: Alignment PI Station Report

Station	Northing	Easting	Distance	Direction
0+000.00	908,057.5400m	367,545.0600m		
			82.248m	S48° 43' 53"E
0+082.25	908,003.2900m	367,606.8800m		
			163.808m	S35° 00' 52"E
0+245.94	907,869.1300m	367,700.8700m		
			161.547m	S39° 16' 03"E
0+407.49	907,744.0600m	367,803.1200m		
			158.286m	S30° 00' 26"E
0+565.74	907,606.9900m	367,882.2800m		
			80.009m	S53° 20' 57"E
0+645.17	907,559.2300m	367,946.4700m		
			180.328m	S26° 17' 12"E
0+824.60	907,397.5500m	368,026.3300m		
			121.182m	S51° 11' 01"E
0+945.09	907,321.5900m	368,120.7500m		
			243.466m	S9° 04' 20"E

1+185.05	907,081.1700m	368,159.1400m		
			184.515m	S21° 30' 18"W
1+368.27	906,909.5000m	368,091.5000m		

Appendix C: Profile Design Criteria Verification Report

1 Sag Curve:Parabolic

PVC Station:	0+103.90
PVI Station:	0+165.00
PVT Station:	0+226.10
Grade in(%):	-5.53%
Grade out(%):	1.25%
Curve Length:	122.191m
K:	18.03
Design Speed:	40

<u>Design Criteria:</u>

Minimum K for Headlight Sight Distance:

<u>Design Checks:</u>

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2 Crest Curve:Parabolic

PVC Station:	0+357.63
PVI Station:	0+407.79
PVT Station:	0+457.95

Grade in(%):	1.25%
Grade out(%):	-0.76%
Curve Length:	100.323m
K:	50.00
Design Speed:	40

Design Criteria:

Minimum K for Stopping Sight Distance:

Minimum K for Passing Sight Distance:

Design Checks:

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3 Crest Curve:Parabolic

PVC Station:	0+531.18
PVI Station:	0+535.00
PVT Station:	0+538.82
Grade in(%):	-0.76%
Grade out(%):	-0.91%
Curve Length:	7.635m
K:	50.00

Design Speed: 40

Design Criteria:

Minimum K for Stopping Sight Distance:

Minimum K for Passing Sight Distance:

Design Checks:

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4 Crest Curve:Parabolic

PVC Station:	0+712.56
PVI Station:	0+747.81
PVT Station:	0+783.06
Grade in(%):	-0.91%
Grade out(%):	-2.32%
Curve Length:	70.494m
K:	50.00
Design Speed:	40

Design Criteria:

Minimum K for Stopping Sight Distance:

Minimum K for Passing Sight Distance:

<u>Design Checks:</u>

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5 Sag Curve:Parabolic

PVC Station:	0+905.00
PVI Station:	0+980.00
PVT Station:	1+055.00
Grade in(%):	-2.32%
Grade out(%):	2.38%
Curve Length:	150.000m
K:	31.91
Design Speed:	40

<u>Design Criteria:</u>

Minimum K for Headlight Sight Distance:

<u>Design Checks:</u>

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6 Crest Curve:Parabolic

PVC Station:	1+084.51
PVI Station:	1+185.00
PVT Station:	1+285.49
Grade in(%):	2.38%
Grade out(%):	-1.64%
Curve Length:	200.980m
K:	50.00
Design Speed:	40

Design Criteria:

Minimum K for Stopping Sight Distance:

Minimum K for Passing Sight Distance:

Design Checks:

Appendix D: Profile Elevation Differences Report

PVI	Station	Easting	Northing	Elevation Existing	Elevation Design	Elevation Difference	Point Type
0	0+099.22	367616.6814	907989.2996	1,939.000m	1,938.996m	0.004m	Existing
1	0+100.00	367617.1316	907988.657	1,938.953m	1,938.952m	0.000m	Regular
2	0+103.90	367619.372	907985.4592	1,938.716m	1,938.737m	-0.020m	Start Vertical TP
3	0+115.20	367625.8516	907976.2102	1,938.033m	1,938.148m	-0.115m	Existing
4	0+115.57	367626.0674	907975.9022	1,938.029m	1,938.129m	-0.100m	Existing
5	0+125.00	367631.4762	907968.1818	1,938.023m	1,937.694m	0.330m	Regular
6	0+128.18	367633.298	907965.5813	1,938.021m	1,937.558m	0.463m	Existing
7	0+128.55	367633.5133	907965.274	1,938.000m	1,937.543m	0.457m	Existing
8	0+140.46	367640.3476	907955.5189	1,938.000m	1,937.086m	0.914m	Existing
9	0+140.90	367640.6015	907955.1564	1,938.000m	1,937.071m	0.929m	Existing
10	0+148.27	367644.8296	907949.1213	1,938.000m	1,936.830m	1.170m	Existing
11	0+148.47	367644.9438	907948.9583	1,938.000m	1,936.824m	1.176m	Existing
12	0+149.24	367645.3867	907948.3261	1,938.000m	1,936.801m	1.199m	Existing
13	0+150.00	367645.8207	907947.7066	1,937.950m	1,936.778m	1.172m	Regular
14	0+163.45	367653.5384	907936.6905	1,937.061m	1,936.428m	0.633m	Existing

15	0+164.12	367653.9203	907936.1453	1,937.057m	1,936.414m	0.643m	Existing
16	0+165.00	367654.4274	907935.4214	1,937.058m	1,936.395m	0.664m	PVI
17	0+175.00	367660.1653	907927.2314	1,937.073m	1,936.209m	0.865m	Regular
18	0+175.37	367660.3754	907926.9314	1,937.074m	1,936.203m	0.871m	Existing
19	0+176.23	367660.8687	907926.2272	1,937.066m	1,936.190m	0.877m	Existing
20	0+186.73	367666.8972	907917.6223	1,937.069m	1,936.061m	1.008m	Existing
21	0+200.00	367674.5098	907906.7562	1,937.062m	1,935.986m	1.076m	Regular
22	0+202.89	367676.1674	907904.3901	1,937.060m	1,935.983m	1.078m	Existing
23	0+203.55	367676.5495	907903.8447	1,937.049m	1,935.982m	1.067m	Low Point
24	0+203.77	367676.6723	907903.6694	1,937.046m	1,935.982m	1.063m	Existing
25	0+205.14	367677.4578	907902.5482	1,937.000m	1,935.983m	1.017m	Existing
26	0+225.00	367688.8544	907886.281	1,937.000m	1,936.110m	0.890m	Regular
27	0+226.10	367689.4829	907885.3837	1,937.000m	1,936.123m	0.877m	End Vertical TP
28	0+226.37	367689.6427	907885.1556	1,937.000m	1,936.127m	0.873m	Existing
29	0+226.75	367689.8567	907884.8503	1,937.000m	1,936.131m	0.869m	Existing
30	0+242.23	367698.7394	907872.1712	1,937.000m	1,936.325m	0.675m	Existing
31	0+242.23	367698.7394	907872.1712	1,937.000m	1,936.325m	0.675m	Line - Curve

32	0+244.70	367700.1841	907870.1624	1,937.000m	1,936.356m	0.644m	Existing
33	0+245.92	367700.9153	907869.1844	1,937.000m	1,936.371m	0.629m	Existing
34	0+245.94	367700.9249	907869.1716	1,937.000m	1,936.371m	0.629m	
35	0+245.99	367700.9557	907869.1311	1,937.000m	1,936.372m	0.628m	Existing
36	0+247.18	367701.678	907868.19	1,937.000m	1,936.387m	0.613m	Existing
37	0+249.65	367703.2202	907866.2552	1,937.000m	1,936.418m	0.582m	Existing
38	0+249.65	367703.2202	907866.2552	1,937.000m	1,936.418m	0.582m	Curve - Line
39	0+250.00	367703.4412	907865.985	1,937.000m	1,936.422m	0.578m	Regular
40	0+274.36	367718.86	907847.125	1,937.000m	1,936.727m	0.273m	Existing
41	0+274.84	367719.1662	907846.7505	1,937.020m	1,936.733m	0.287m	Existing
42	0+275.00	367719.2647	907846.63	1,937.020m	1,936.735m	0.285m	Regular
43	0+295.80	367732.4291	907830.5276	1,937.028m	1,936.995m	0.033m	Existing
44	0+296.44	367732.8371	907830.0285	1,937.025m	1,937.003m	0.022m	Existing
45	0+300.00	367735.0882	907827.275	1,937.025m	1,937.047m	-0.022m	Regular
46	0+325.00	367750.9118	907807.92	1,937.030m	1,937.360m	-0.330m	Regular
47	0+327.52	367752.5073	907805.9684	1,937.030m	1,937.391m	-0.361m	Existing
48	0+328.29	367752.9963	907805.3702	1,937.060m	1,937.401m	-0.342m	Existing

49	0+350.00	367766.7353	907788.565	1,937.030m	1,937.673m	-0.643m	Regular
50	0+351.60	367767.7456	907787.3292	1,937.028m	1,937.693m	-0.665m	Existing
51	0+351.99	367767.9973	907787.0213	1,937.026m	1,937.698m	-0.671m	Existing
52	0+357.63	367771.5626	907782.6603	1,937.016m	1,937.768m	-0.752m	Start Vertical TP
53	0+366.50	367777.1766	907775.7934	1,937.000m	1,937.871m	-0.871m	Existing
54	0+375.00	367782.5588	907769.21	1,936.981m	1,937.955m	-0.974m	Regular
55	0+382.00	367786.9881	907763.7922	1,936.966m	1,938.013m	-1.048m	Existing
56	0+383.12	367787.6956	907762.9268	1,936.959m	1,938.022m	-1.063m	Existing
57	0+399.39	367797.9939	907750.3301	1,936.986m	1,938.116m	-1.129m	Existing
58	0+399.39	367797.9939	907750.3301	1,936.986m	1,938.116m	-1.129m	Line - Curve
59	0+400.00	367798.3809	907749.8538	1,936.987m	1,938.118m	-1.131m	Regular
60	0+402.08	367799.6706	907748.2219	1,936.988m	1,938.126m	-1.138m	Existing
61	0+404.77	367801.2899	907746.0693	1,936.985m	1,938.135m	-1.150m	Existing
62	0+407.01	367802.5915	907744.2471	1,936.978m	1,938.142m	-1.164m	Existing
63	0+407.47	367802.8506	907743.8739	1,936.998m	1,938.143m	-1.145m	Existing
64	0+407.47	367802.8506	907743.8739	1,936.998m	1,938.143m	-1.145m	
65	0+407.52	367802.8784	907743.8336	1,937.000m	1,938.143m	-1.143m	Existing

66	0+407.79	367803.0325	907743.6097	1,937.007m	1,938.144m	-1.136m	PVI
67	0+410.16	367804.3516	907741.6372	1,937.071m	1,938.149m	-1.078m	Existing
68	0+412.85	367805.7919	907739.361	1,937.143m	1,938.153m	-1.011m	Existing
69	0+415.55	367807.1703	907737.0467	1,937.214m	1,938.157m	-0.942m	Existing
70	0+415.55	367807.1703	907737.0467	1,937.214m	1,938.157m	-0.942m	Curve - Line
71	0+420.15	367809.4689	907733.0664	1,937.336m	1,938.159m	-0.823m	High Point
72	0+425.00	367811.8969	907728.8622	1,937.465m	1,938.156m	-0.692m	Regular
73	0+435.71	367817.2521	907719.5895	1,937.748m	1,938.135m	-0.386m	Existing
74	0+446.10	367822.4499	907710.5892	1,937.512m	1,938.091m	-0.579m	Existing
75	0+450.00	367824.3996	907707.2131	1,937.527m	1,938.070m	-0.542m	Regular
76	0+457.95	367828.3753	907700.3291	1,937.558m	1,938.016m	-0.458m	End Vertical TP
77	0+462.47	367830.6343	907696.4175	1,937.575m	1,937.982m	-0.406m	Existing
78	0+474.46	367836.6321	907686.0319	1,937.592m	1,937.891m	-0.299m	Existing
79	0+475.00	367836.9023	907685.564	1,937.590m	1,937.887m	-0.297m	Regular
80	0+490.55	367844.6793	907672.0978	1,937.552m	1,937.769m	-0.218m	Existing
81	0+500.00	367849.405	907663.915	1,937.563m	1,937.698m	-0.135m	Regular
82	0+503.22	367851.0174	907661.123	1,937.567m	1,937.674m	-0.106m	Existing

83	0+516.82	367857.8181	907649.3472	1,937.459m	1,937.571m	-0.112m	Existing
84	0+525.00	367861.9077	907642.2659	1,937.467m	1,937.509m	-0.042m	Regular
85	0+531.18	367864.9996	907636.912	1,937.473m	1,937.462m	0.010m	Start Vertical TP
86	0+532.14	367865.4798	907636.0805	1,937.474m	1,937.455m	0.019m	Existing
87	0+535.00	367866.9087	907633.6062	1,937.433m	1,937.432m	0.001m	PVI
88	0+538.82	367868.8178	907630.3005	1,937.379m	1,937.399m	-0.019m	End Vertical TP
89	0+545.08	367871.9496	907624.8777	1,937.291m	1,937.342m	-0.050m	Existing
90	0+545.08	367871.9496	907624.8777	1,937.291m	1,937.342m	-0.050m	Line - Curve
91	0+547.80	367873.3397	907622.5444	1,937.255m	1,937.317m	-0.062m	Existing
92	0+550.00	367874.5141	907620.679	1,937.230m	1,937.297m	-0.067m	Regular
93	0+550.51	367874.7926	907620.2498	1,937.224m	1,937.292m	-0.068m	Existing
94	0+553.23	367876.3072	907617.9956	1,937.198m	1,937.268m	-0.070m	Existing
95	0+555.94	367877.8826	907615.7832	1,937.176m	1,937.243m	-0.067m	Existing
96	0+558.66	367879.5174	907613.6145	1,937.160m	1,937.218m	-0.059m	Existing
97	0+560.45	367880.6291	907612.2069	1,937.152m	1,937.202m	-0.050m	Existing
98	0+561.38	367881.2105	907611.4909	1,937.131m	1,937.194m	-0.063m	Existing

99	0+564.09	367882.9607	907609.4142	1,937.069m	1,937.169m	-0.100m	Existing
100	0+565.24	367883.7171	907608.5511	1,937.044m	1,937.158m	-0.115m	Existing
101	0+565.45	367883.8568	907608.3938	1,937.044m	1,937.157m	-0.113m	
102	0+566.81	367884.7666	907607.3857	1,937.044m	1,937.144m	-0.100m	Existing
103	0+567.27	367885.0818	907607.0428	1,937.044m	1,937.140m	-0.096m	Existing
104	0+569.52	367886.627	907605.407	1,937.050m	1,937.120m	-0.069m	Existing
105	0+572.24	367888.5404	907603.4796	1,937.059m	1,937.095m	-0.036m	Existing
106	0+574.96	367890.5054	907601.6048	1,937.069m	1,937.070m	-0.002m	Existing
107	0+575.00	367890.5381	907601.5745	1,937.069m	1,937.070m	-0.001m	Regular
108	0+577.67	367892.5206	907599.7841	1,937.080m	1,937.046m	0.034m	Existing
109	0+580.39	367894.5846	907598.0187	1,937.092m	1,937.021m	0.072m	Existing
110	0+583.10	367896.6957	907596.3101	1,937.106m	1,936.996m	0.110m	Existing
111	0+585.82	367898.8524	907594.6595	1,937.122m	1,936.971m	0.150m	Existing
112	0+585.82	367898.8524	907594.6595	1,937.122m	1,936.971m	0.150m	Curve - Line
113	0+588.13	367900.7082	907593.2787	1,937.135m	1,936.950m	0.185m	Existing
114	0+600.00	367910.2294	907586.1945	1,937.107m	1,936.843m	0.264m	Regular
115	0+613.11	367920.7513	907578.3658	1,937.075m	1,936.723m	0.351m	Existing

116	0+617.04	367923.8993	907576.0235	1,937.074m	1,936.688m	0.387m	Existing
117	0+619.32	367925.7323	907574.6597	1,937.000m	1,936.667m	0.333m	Existing
118	0+621.11	367927.1623	907573.5957	1,937.000m	1,936.651m	0.349m	Existing
119	0+621.11	367927.1623	907573.5957	1,937.000m	1,936.651m	0.349m	Line - Curve
120	0+623.88	367929.3681	907571.9064	1,937.000m	1,936.626m	0.374m	Existing
121	0+625.00	367930.2405	907571.2109	1,937.000m	1,936.615m	0.385m	Regular
122	0+626.66	367931.5261	907570.1565	1,937.000m	1,936.600m	0.400m	Existing
123	0+629.44	367933.6346	907568.3473	1,937.000m	1,936.575m	0.425m	Existing
124	0+632.22	367935.6921	907566.4802	1,937.000m	1,936.550m	0.450m	Existing
125	0+635.00	367937.6969	907564.5567	1,937.000m	1,936.525m	0.475m	Existing
126	0+636.02	367938.424	907563.8321	1,937.000m	1,936.515m	0.485m	Existing
127	0+637.78	367939.6475	907562.5782	1,937.000m	1,936.499m	0.501m	Existing
128	0+640.55	367941.5424	907560.5463	1,937.000m	1,936.474m	0.526m	Existing
129	0+643.33	367943.3801	907558.4626	1,937.000m	1,936.449m	0.551m	Existing
130	0+644.72	367944.2771	907557.4018	1,937.000m	1,936.436m	0.564m	
131	0+645.68	367944.8893	907556.6602	1,937.000m	1,936.427m	0.573m	Existing
132	0+646.11	367945.1592	907556.3286	1,936.982m	1,936.424m	0.558m	Existing

133	0+648.89	367946.8784	907554.146	1,936.863m	1,936.398m	0.465m	Existing
134	0+650.00	367947.548	907553.2609	1,936.816m	1,936.388m	0.428m	Regular
135	0+651.67	367948.5362	907551.9165	1,936.746m	1,936.373m	0.373m	Existing
136	0+654.39	367950.102	907549.685	1,936.632m	1,936.348m	0.284m	Existing
137	0+654.45	367950.1315	907549.6418	1,936.631m	1,936.348m	0.283m	Existing
138	0+657.23	367951.6629	907547.3236	1,936.537m	1,936.323m	0.215m	Existing
139	0+660.00	367953.1294	907544.9638	1,936.443m	1,936.297m	0.146m	Existing
140	0+662.78	367954.5297	907542.5642	1,936.348m	1,936.272m	0.076m	Existing
141	0+665.56	367955.8629	907540.1266	1,936.251m	1,936.247m	0.005m	Existing
142	0+668.34	367957.1278	907537.6529	1,936.154m	1,936.222m	-0.067m	Existing
143	0+668.34	367957.1278	907537.6529	1,936.154m	1,936.222m	-0.067m	Curve - Line
144	0+670.76	367958.2016	907535.479	1,936.069m	1,936.199m	-0.131m	Existing
145	0+673.71	367959.5069	907532.8362	1,936.000m	1,936.173m	-0.173m	Existing
146	0+675.00	367960.0776	907531.6808	1,936.000m	1,936.161m	-0.161m	Regular
147	0+700.00	367971.1491	907509.266	1,936.000m	1,935.934m	0.066m	Regular
148	0+712.56	367976.7132	907498.0013	1,936.000m	1,935.820m	0.180m	Start Vertical TP
149	0+713.17	367976.981	907497.4592	1,936.000m	1,935.814m	0.186m	Existing

150	0+717.42	367978.863	907493.6489	1,936.000m	1,935.773m	0.227m	Existing
151	0+723.34	367981.4842	907488.3423	1,936.169m	1,935.710m	0.459m	Existing
152	0+725.00	367982.2206	907486.8513	1,936.124m	1,935.691m	0.433m	Regular
153	0+747.81	367992.3227	907466.3992	1,935.499m	1,935.375m	0.124m	PVI
154	0+747.81	367992.3227	907466.3992	1,935.499m	1,935.375m	0.124m	Existing
155	0+750.00	367993.2922	907464.4365	1,935.564m	1,935.339m	0.225m	Regular
156	0+770.30	368002.2805	907446.2392	1,936.167m	1,934.962m	1.206m	Existing
157	0+774.15	368003.9875	907442.7834	1,936.166m	1,934.881m	1.286m	Existing
158	0+775.00	368004.3637	907442.0218	1,936.164m	1,934.862m	1.301m	Regular
159	0+783.06	368007.9322	907434.7971	1,936.138m	1,934.682m	1.456m	End Vertical TP
160	0+794.53	368013.0138	907424.5093	1,936.101m	1,934.416m	1.685m	Existing
161	0+798.43	368014.7419	907421.0106	1,936.000m	1,934.326m	1.674m	Existing
162	0+800.00	368015.4352	907419.607	1,935.940m	1,934.289m	1.651m	Regular
163	0+802.53	368016.5537	907417.3425	1,935.844m	1,934.231m	1.613m	Existing
164	0+802.53	368016.5537	907417.3425	1,935.844m	1,934.231m	1.613m	Line - Curve
165	0+805.24	368017.7894	907414.9241	1,935.740m	1,934.168m	1.573m	Existing
166	0+807.96	368019.0903	907412.5402	1,935.639m	1,934.105m	1.534m	Existing

167	0+810.67	368020.4554	907410.1925	1,935.538m	1,934.042m	1.496m	Existing
168	0+813.39	368021.8838	907407.8827	1,935.439m	1,933.979m	1.460m	Existing
169	0+816.10	368023.3744	907405.6125	1,935.341m	1,933.916m	1.425m	Existing
170	0+818.82	368024.926	907403.3837	1,935.245m	1,933.853m	1.392m	Existing
171	0+821.54	368026.5377	907401.1978	1,935.150m	1,933.790m	1.360m	Existing
172	0+823.80	368027.9243	907399.4119	1,935.073m	1,933.737m	1.335m	Existing
173	0+824.25	368028.208	907399.0565	1,935.057m	1,933.727m	1.330m	Existing
174	0+824.25	368028.208	907399.0565	1,935.057m	1,933.727m	1.330m	
175	0+825.00	368028.6779	907398.4752	1,935.031m	1,933.710m	1.322m	Regular
176	0+826.97	368029.936	907396.9613	1,934.963m	1,933.664m	1.299m	Existing
177	0+829.68	368031.7201	907394.9139	1,934.871m	1,933.601m	1.270m	Existing
178	0+832.40	368033.5593	907392.9156	1,934.781m	1,933.538m	1.243m	Existing
179	0+835.12	368035.452	907390.968	1,934.693m	1,933.475m	1.218m	Existing
180	0+837.83	368037.3969	907389.0726	1,934.607m	1,933.412m	1.195m	Existing
181	0+840.55	368039.3925	907387.2306	1,934.523m	1,933.349m	1.174m	Existing
182	0+843.26	368041.4374	907385.4435	1,934.442m	1,933.286m	1.156m	Existing
183	0+845.98	368043.5302	907383.7126	1,934.362m	1,933.223m	1.139m	Existing
184	0+845.98	368043.5302	907383.7126	1,934.362m	1,933.223m	1.139m	Curve -

							Line
185	0+850.00	368046.6629	907381.1924	1,934.246m	1,933.130m	1.116m	Regular
186	0+857.41	368052.4328	907376.5506	1,934.032m	1,932.958m	1.074m	Existing
187	0+857.92	368052.8368	907376.2256	1,934.013m	1,932.946m	1.067m	Existing
188	0+863.77	368057.3892	907372.5632	1,933.794m	1,932.811m	0.984m	Existing
189	0+875.00	368066.1419	907365.5217	1,933.395m	1,932.550m	0.845m	Regular
190	0+886.12	368074.8085	907358.5495	1,933.000m	1,932.292m	0.708m	Existing
191	0+889.48	368077.4203	907356.4483	1,932.902m	1,932.215m	0.687m	Existing
192	0+900.00	368085.6208	907349.8511	1,932.587m	1,931.971m	0.616m	Regular
193	0+905.00	368089.5166	907346.7169	1,932.437m	1,931.855m	0.582m	Start Vertical TP
194	0+906.59	368090.754	907345.7215	1,932.389m	1,931.818m	0.571m	Existing
195	0+906.59	368090.754	907345.7215	1,932.389m	1,931.818m	0.571m	Line - Curve
196	0+909.41	368092.9312	907343.9187	1,932.305m	1,931.755m	0.549m	Existing
197	0+912.24	368095.0566	907342.055	1,932.220m	1,931.695m	0.525m	Existing
198	0+915.07	368097.1285	907340.132	1,932.135m	1,931.637m	0.498m	Existing
199	0+917.90	368099.1452	907338.1512	1,932.051m	1,931.582m	0.469m	Existing
200	0+919.59	368100.3269	907336.9369	1,932.000m	1,931.550m	0.450m	Existing

201	0+920.72	368101.1051	907336.1142	1,931.956m	1,931.529m	0.427m	Existing
202	0+923.55	368103.0067	907334.0227	1,931.845m	1,931.478m	0.367m	Existing
203	0+925.00	368103.9594	907332.9286	1,931.789m	1,931.454m	0.335m	Regular
204	0+926.38	368104.8483	907331.8782	1,931.735m	1,931.431m	0.304m	Existing
205	0+929.20	368106.6287	907329.6825	1,931.625m	1,931.385m	0.240m	Existing
206	0+932.03	368108.3462	907327.4374	1,931.516m	1,931.342m	0.174m	Existing
207	0+934.86	368109.9996	907325.1446	1,931.408m	1,931.302m	0.106m	Existing
208	0+937.68	368111.5876	907322.806	1,931.300m	1,931.264m	0.036m	Existing
209	0+938.60	368112.0869	907322.0402	1,931.265m	1,931.252m	0.013m	Existing
210	0+940.51	368113.1088	907320.4235	1,931.191m	1,931.229m	-0.038m	Existing
211	0+943.34	368114.562	907317.9989	1,931.082m	1,931.196m	-0.114m	Existing
212	0+943.34	368114.562	907317.9989	1,931.082m	1,931.196m	-0.114m	
213	0+945.49	368115.6231	907316.1242	1,931.000m	1,931.173m	-0.173m	Existing
214	0+946.16	368115.9462	907315.5342	1,930.981m	1,931.166m	-0.184m	Existing
215	0+948.99	368117.2601	907313.0314	1,930.904m	1,931.138m	-0.234m	Existing
216	0+950.00	368117.7119	907312.1291	1,930.876m	1,931.129m	-0.252m	Regular
217	0+951.82	368118.5028	907310.4924	1,930.827m	1,931.113m	-0.286m	Existing
218	0+954.64	368119.6732	907307.9194	1,930.750m	1,931.090m	-0.339m	Existing

219	0+957.47	368120.7704	907305.3142	1,930.675m	1,931.069m	-0.394m	Existing
220	0+960.30	368121.7935	907302.6791	1,930.601m	1,931.052m	-0.451m	Existing
221	0+963.13	368122.7418	907300.0162	1,930.528m	1,931.036m	-0.508m	Existing
222	0+965.95	368123.6144	907297.3275	1,930.456m	1,931.024m	-0.568m	Existing
223	0+968.78	368124.4106	907294.6152	1,930.385m	1,931.013m	-0.628m	Existing
224	0+971.61	368125.1299	907291.8815	1,930.315m	1,931.005m	-0.690m	Existing
225	0+974.43	368125.7716	907289.1285	1,930.247m	1,931.000m	-0.754m	Existing
226	0+975.00	368125.891	907288.5737	1,930.233m	1,930.999m	-0.766m	Regular
227	0+977.26	368126.3353	907286.3585	1,930.179m	1,930.997m	-0.818m	Existing
228	0+978.98	368126.6399	907284.6655	1,930.139m	1,930.997m	-0.858m	Low Point
229	0+980.00	368126.8068	907283.6588	1,930.116m	1,930.997m	-0.881m	PVI
230	0+980.09	368126.8204	907283.5737	1,930.114m	1,930.997m	-0.884m	Existing
231	0+980.09	368126.8204	907283.5737	1,930.114m	1,930.997m	-0.884m	Curve - Line
232	0+982.09	368127.1362	907281.5959	1,930.067m	1,930.998m	-0.931m	Existing
233	0+984.53	368127.521	907279.1863	1,930.000m	1,931.002m	-1.002m	Existing
234	1+000.00	368129.9604	907263.909	1,930.314m	1,931.066m	-0.752m	Regular
235	1+025.00	368133.9025	907239.2218	1,930.821m	1,931.329m	-0.508m	Regular

236	1+030.76	368134.811	907233.5322	1,930.938m	1,931.417m	-0.479m	Existing
237	1+033.07	368135.1755	907231.2494	1,931.000m	1,931.455m	-0.455m	Existing
238	1+050.00	368137.8445	907214.5345	1,931.501m	1,931.787m	-0.287m	Regular
239	1+055.00	368138.6329	907209.5971	1,931.649m	1,931.903m	-0.254m	End Vertical TP
240	1+063.90	368140.0364	907200.8078	1,931.912m	1,932.115m	-0.203m	Existing
241	1+067.45	368140.5953	907197.3072	1,932.000m	1,932.199m	-0.199m	Existing
242	1+071.62	368141.2541	907193.1816	1,932.123m	1,932.299m	-0.176m	Existing
243	1+075.00	368141.7865	907189.8473	1,932.282m	1,932.379m	-0.097m	Regular
244	1+084.51	368143.2861	907180.4563	1,932.728m	1,932.606m	0.122m	Start Vertical TP
245	1+100.00	368145.7286	907165.16	1,933.455m	1,932.951m	0.504m	Regular
246	1+109.47	368147.2222	907155.8061	1,933.900m	1,933.138m	0.761m	Existing
247	1+114.34	368147.9896	907151.0001	1,934.000m	1,933.227m	0.773m	Existing
248	1+125.00	368149.6706	907140.4728	1,934.000m	1,933.406m	0.594m	Regular
249	1+137.57	368151.6534	907128.0556	1,934.000m	1,933.588m	0.412m	Existing
250	1+141.32	368152.2447	907124.3522	1,934.143m	1,933.637m	0.506m	Existing
251	1+150.00	368153.6126	907115.7855	1,934.448m	1,933.737m	0.711m	Regular
252	1+157.72	368154.8297	907108.1637	1,934.720m	1,933.814m	0.906m	Existing

253	1+157.72	368154.8297	907108.1637	1,934.720m	1,933.814m	0.906m	Line - Curve
254	1+160.53	368155.2336	907105.3842	1,934.819m	1,933.839m	0.980m	Existing
255	1+163.34	368155.5592	907102.5944	1,934.918m	1,933.862m	1.056m	Existing
256	1+165.64	368155.7677	907100.3015	1,935.000m	1,933.881m	1.119m	Existing
257	1+166.14	368155.8064	907099.7966	1,935.000m	1,933.884m	1.116m	Existing
258	1+168.95	368155.9749	907096.9929	1,935.000m	1,933.905m	1.095m	Existing
259	1+171.76	368156.0646	907094.1856	1,935.000m	1,933.923m	1.077m	Existing
260	1+174.57	368156.0755	907091.3769	1,935.000m	1,933.940m	1.060m	Existing
261	1+175.00	368156.0702	907090.9482	1,935.000m	1,933.943m	1.057m	Regular
262	1+177.38	368156.0074	907088.569	1,935.000m	1,933.956m	1.044m	Existing
263	1+180.19	368155.8605	907085.7641	1,935.000m	1,933.970m	1.030m	Existing
264	1+180.29	368155.8537	907085.6619	1,935.000m	1,933.970m	1.030m	Existing
265	1+183.00	368155.6349	907082.9645	1,935.000m	1,933.982m	1.018m	Existing
266	1+184.40	368155.4927	907081.5673	1,935.000m	1,933.988m	1.012m	
267	1+184.73	368155.4565	907081.2405	1,935.000m	1,933.989m	1.011m	Existing
268	1+185.00	368155.4262	907080.9731	1,934.991m	1,933.990m	1.001m	PVI
269	1+185.81	368155.3308	907080.1722	1,934.964m	1,933.993m	0.971m	Existing

270	1+188.62	368154.9484	907077.3897	1,934.870m	1,934.002m	0.867m	Existing
271	1+191.42	368154.4879	907074.6189	1,934.776m	1,934.010m	0.766m	Existing
272	1+194.23	368153.9499	907071.8622	1,934.682m	1,934.016m	0.666m	Existing
273	1+197.04	368153.3346	907069.1217	1,934.589m	1,934.021m	0.569m	Existing
274	1+199.85	368152.6426	907066.3996	1,934.497m	1,934.023m	0.473m	Existing
275	1+200.00	368152.6037	907066.2554	1,934.492m	1,934.024m	0.468m	Regular
276	1+202.66	368151.8744	907063.6979	1,934.405m	1,934.025m	0.380m	Existing
277	1+203.64	368151.588	907062.7586	1,934.373m	1,934.025m	0.348m	High Point
278	1+205.47	368151.0307	907061.0189	1,934.314m	1,934.025m	0.289m	Existing
279	1+208.28	368150.112	907058.3647	1,934.224m	1,934.023m	0.201m	Existing
280	1+211.09	368149.1192	907055.7373	1,934.134m	1,934.019m	0.115m	Curve - Line
281	1+213.76	368148.1376	907053.246	1,934.049m	1,934.015m	0.035m	Existing
282	1+215.16	368147.6241	907051.9426	1,934.000m	1,934.012m	-0.012m	Existing
283	1+225.00	368144.0186	907042.7918	1,934.000m	1,933.979m	0.021m	Regular
284	1+231.26	368141.7227	907036.9649	1,934.000m	1,933.949m	0.051m	Existing
285	1+233.22	368141.0049	907035.1433	1,934.000m	1,933.937m	0.063m	Existing
286	1+250.00	368134.854	907019.5322	1,934.000m	1,933.810m	0.190m	Regular

287	1+251.23	368134.4035	907018.389	1,934.000m	1,933.798m	0.202m	Existing
288	1+255.29	368132.9139	907014.6083	1,934.000m	1,933.758m	0.242m	Existing
289	1+275.00	368125.6894	906996.2726	1,933.280m	1,933.516m	-0.236m	Regular
290	1+279.00	368124.2233	906992.5515	1,933.134m	1,933.457m	-0.323m	Existing
291	1+282.60	368122.9023	906989.1989	1,933.000m	1,933.401m	-0.401m	Existing
292	1+285.49	368121.8439	906986.5127	1,933.000m	1,933.355m	-0.355m	End Vertical TP
293	1+300.00	368116.5248	906973.0129	1,933.000m	1,933.117m	-0.117m	Regular
294	1+304.41	368114.9077	906968.9087	1,933.000m	1,933.045m	-0.045m	Existing
295	1+305.78	368114.4063	906967.6362	1,933.000m	1,933.023m	-0.023m	Existing
296	1+325.00	368107.3603	906949.7533	1,933.000m	1,932.708m	0.292m	Regular
297	1+330.42	368105.3722	906944.7076	1,933.000m	1,932.619m	0.381m	Existing
298	1+334.51	368103.8758	906940.9098	1,932.994m	1,932.553m	0.442m	Existing
299	1+334.71	368103.7999	906940.7171	1,932.993m	1,932.549m	0.444m	Existing
300	1+350.00	368098.1957	906926.4937	1,932.540m	1,932.299m	0.241m	Regular
301	1+368.27	368091.5	906909.5	1,932.000m	1,932.000m	-0.000m	End

Appendix E: PVI Station Increment Report

Station Range: Start: 0+099.14, End: 1+368.27

Station Increment: 20.00

Station	**Elevation**	**Grade Percent (%)**	**Location**
0+099.14	1,939.000m		
0+103.90	1,938.737m	-5.53%	PVC
0+119.14	1,937.959m	-5.11%	
0+139.14	1,937.133m	-4.13%	
0+159.14	1,936.530m	-3.02%	
0+165.00	1,936.395m	-2.30%	Sag
0+179.14	1,936.148m	-1.75%	
0+199.14	1,935.988m	-0.80%	
0+219.14	1,936.050m	0.31%	
0+226.10	1,936.123m	1.06%	PVT
0+239.14	1,936.286m	1.25%	
0+259.14	1,936.536m	1.25%	
0+279.14	1,936.787m	1.25%	
0+299.14	1,937.037m	1.25%	

0+319.14	1,937.287m	1.25%	
0+339.14	1,937.537m	1.25%	
0+357.63	1,937.768m	1.25%	PVC
0+359.14	1,937.787m	1.24%	
0+379.14	1,937.991m	1.02%	
0+399.14	1,938.115m	0.62%	
0+407.79	1,938.144m	0.33%	Crest
0+419.14	1,938.159m	0.13%	
0+439.14	1,938.123m	-0.18%	
0+457.95	1,938.016m	-0.57%	PVT
0+459.14	1,938.007m	-0.76%	
0+479.14	1,937.856m	-0.76%	
0+499.14	1,937.704m	-0.76%	
0+519.14	1,937.553m	-0.76%	
0+531.18	1,937.462m	-0.76%	PVC
0+535.00	1,937.432m	-0.79%	Crest
0+538.82	1,937.399m	-0.87%	PVT
0+539.14	1,937.396m	-0.91%	

0+559.14	1,937.214m	-0.91%	
0+579.14	1,937.032m	-0.91%	
0+599.14	1,936.850m	-0.91%	
0+619.14	1,936.669m	-0.91%	
0+639.14	1,936.487m	-0.91%	
0+659.14	1,936.305m	-0.91%	
0+679.14	1,936.123m	-0.91%	
0+699.14	1,935.942m	-0.91%	
0+712.56	1,935.820m	-0.91%	PVC
0+719.14	1,935.756m	-0.97%	
0+739.14	1,935.507m	-1.24%	
0+747.81	1,935.375m	-1.53%	Crest
0+759.14	1,935.179m	-1.73%	
0+779.14	1,934.771m	-2.04%	
0+783.06	1,934.682m	-2.28%	PVT
0+799.14	1,934.309m	-2.32%	
0+819.14	1,933.845m	-2.32%	
0+839.14	1,933.382m	-2.32%	

0+859.14	1,932.918m	-2.32%	
0+879.14	1,932.454m	-2.32%	
0+899.14	1,931.990m	-2.32%	
0+905.00	1,931.855m	-2.32%	PVC
0+919.14	1,931.558m	-2.10%	
0+939.14	1,931.246m	-1.56%	
0+959.14	1,931.059m	-0.94%	
0+979.14	1,930.997m	-0.31%	
0+980.00	1,930.997m	0.02%	Sag
0+999.14	1,931.061m	0.33%	
1+019.14	1,931.250m	0.95%	
1+039.14	1,931.564m	1.57%	
1+055.00	1,931.903m	2.13%	PVT
1+059.14	1,932.001m	2.38%	
1+079.14	1,932.478m	2.38%	
1+084.51	1,932.606m	2.38%	PVC
1+099.14	1,932.933m	2.24%	
1+119.14	1,933.311m	1.89%	

1+139.14	1,933.609m	1.49%	
1+159.14	1,933.827m	1.09%	
1+179.14	1,933.965m	0.69%	
1+185.00	1,933.990m	0.43%	Crest
1+199.14	1,934.023m	0.23%	
1+219.14	1,934.001m	-0.11%	
1+239.14	1,933.899m	-0.51%	
1+259.14	1,933.717m	-0.91%	
1+279.14	1,933.455m	-1.31%	
1+285.49	1,933.355m	-1.57%	PVT
1+299.14	1,933.132m	-1.64%	
1+319.14	1,932.804m	-1.64%	
1+339.14	1,932.477m	-1.64%	
1+359.14	1,932.149m	-1.64%	
1+368.27	1,932.000m	-1.64%	PVI

Appendix F: Profile PVI Station & Curve Report

PVI	Station	Grade Out	Curve Length
0.00	0+165.00	1.25%	122.191m

Vertical Curve Information:(sag curve)

PVC Station:	0+103.90	Elevation:	1,938.737m
PVI Station:	0+165.00	Elevation:	1,935.359m
PVT Station:	0+226.10	Elevation:	1,936.123m
Low Point:	0+203.55	Elevation:	1,935.982m
Grade in:	-5.53%	Grade out:	1.25%
Change:	6.78%	K:	18.027292529749
Curve Length:	122.191m		
Headlight Distance:	122.027m		

PVI	Station	Grade Out	Curve Length
1.00	0+407.79	-0.76%	100.323m

Vertical Curve Information:(crest curve)

PVC Station:	0+357.63	Elevation:	1,937.768m
PVI Station:	0+407.79	Elevation:	1,938.395m
PVT Station:	0+457.95	Elevation:	1,938.016m
High Point:	0+420.15	Elevation:	1,938.159m

	-- Grade in: 1.25% Grade out: -0.76% Change: 2.01% K: 49.9999999999985 Curve Length: 100.323m Passing Distance: 820.855m Stopping Distance: 381.380m		
2.00	0+535.00	-0.91%	7.635m
	Vertical Curve Information:(crest curve) -- PVC Station: 0+531.18 Elevation: 1,937.462m PVI Station: 0+535.00 Elevation: 1,937.433m PVT Station: 0+538.82 Elevation: 1,937.399m High Point: 0+531.18 Elevation: 1,937.462m Grade in: -0.76% Grade out: -0.91% Change: 0.15% K: 49.9999999996304 Curve Length: 7.635m Passing Distance: 10,130.830m Stopping Distance: 4,356.071m		
3.00	0+747.81	-2.32%	70.494m
	Vertical Curve Information:(crest curve) -- PVC Station: 0+712.56 Elevation: 1,935.820m		

PVI Station:	0+747.81	Elevation:	1,935.499m
PVT Station:	0+783.06	Elevation:	1,934.682m
High Point:	0+712.56	Elevation:	1,935.820m
Grade in:	-0.91%	Grade out:	-2.32%
Change:	1.41%	K:	49.9999999999958
Curve Length:	70.494m		
Passing Distance:	1,132.051m	Stopping Distance:	506.617m

4.00	0+980.00	2.38%	150.000m

Vertical Curve Information:(sag curve)

PVC Station:	0+905.00	Elevation:	1,931.855m
PVI Station:	0+980.00	Elevation:	1,930.116m
PVT Station:	1+055.00	Elevation:	1,931.903m
Low Point:	0+978.98	Elevation:	1,930.997m
Grade in:	-2.32%	Grade out:	2.38%
Change:	4.70%	K:	31.9060744308729
Curve Length:	150.000m		
Headlight Distance:	186.954m		

5.00	1+185.00	-1.64%	200.980m

Vertical Curve Information:(crest curve)

PVC Station:	1+084.51	Elevation:	1,932.606m
PVI Station:	1+185.00	Elevation:	1,935.000m
PVT Station:	1+285.49	Elevation:	1,933.355m
High Point:	1+203.64	Elevation:	1,934.025m
Grade in:	2.38%	Grade out:	-1.64%
Change:	4.02%	K:	50.0000000000036
Curve Length:	200.980m		
Passing Distance:	485.195m	Stopping Distance:	265.824m

AppendixG: Profile Vertical Curve Report

Vertical Curve Information:(sag curve)

PVC Station:	0+103.90	Elevation:	1,938.737m
PVI Station:	0+165.00	Elevation:	1,935.359m
PVT Station:	0+226.10	Elevation:	1,936.123m
Low Point:	0+203.55	Elevation:	1,935.982m
Grade in:	-5.53%	Grade out:	1.25%
Change:	6.78%	K:	18.027m
Curve Length:	122.191m	Curve Radius	1,802.729m
Headlight Distance:	122.027m		

Vertical Curve Information:(crest curve)

PVC Station:	0+357.63	Elevation:	1,937.768m
PVI Station:	0+407.79	Elevation:	1,938.395m
PVT Station:	0+457.95	Elevation:	1,938.016m
High Point:	0+420.15	Elevation:	1,938.159m
Grade in:	1.25%	Grade out:	-0.76%
Change:	2.01%	K:	50.000m

Curve Length:	100.323m	Curve Radius	5,000.000m
Passing Distance:	820.855m	Stopping Distance:	381.380m

Vertical Curve Information:(crest curve)

PVC Station:	0+531.18	Elevation:	1,937.462m
PVI Station:	0+535.00	Elevation:	1,937.433m
PVT Station:	0+538.82	Elevation:	1,937.399m
High Point:	0+531.18	Elevation:	1,937.462m
Grade in:	-0.76%	Grade out:	-0.91%
Change:	0.15%	K:	50.000m
Curve Length:	7.635m	Curve Radius	5,000.000m
Passing Distance:	10,130.830m	Stopping Distance:	4,356.071m

Vertical Curve Information:(crest curve)

PVC Station:	0+712.56	Elevation:	1,935.820m
PVI Station:	0+747.81	Elevation:	1,935.499m
PVT Station:	0+783.06	Elevation:	1,934.682m
High Point:	0+712.56	Elevation:	1,935.820m

Grade in:	-0.91%	Grade out:	-2.32%
Change:	1.41%	K:	50.000m
Curve Length:	70.494m	Curve Radius	5,000.000m
Passing Distance:	1,132.051m	Stopping Distance:	506.617m

Vertical Curve Information:(sag curve)

PVC Station:	0+905.00	Elevation:	1,931.855m
PVI Station:	0+980.00	Elevation:	1,930.116m
PVT Station:	1+055.00	Elevation:	1,931.903m
Low Point:	0+978.98	Elevation:	1,930.997m
Grade in:	-2.32%	Grade out:	2.38%
Change:	4.70%	K:	31.906m
Curve Length:	150.000m	Curve Radius	3,190.607m
Headlight Distance:	186.954m		

Vertical Curve Information:(crest curve)

PVC Station:	1+084.51	Elevation:	1,932.606m
PVI Station:	1+185.00	Elevation:	1,935.000m
PVT Station:	1+285.49	Elevation:	1,933.355m

High Point:	1+203.64	Elevation:	1,934.025m
Grade in:	2.38%	Grade out:	-1.64%
Change:	4.02%	K:	50.000m
Curve Length:	200.980m	Curve Radius	5,000.000m
Passing Distance:	485.195m	Stopping Distance:	265.824m

Appendix H: Profile Vertical Curve Report

Description:
Station Range: Start: 0+099.14, End: 1+368.27

Vertical Curve Information:(sag curve)

PVC Station:	0+103.90	Elevation:	1,938.737m
PVI Station:	0+165.00	Elevation:	1,935.359m
PVT Station:	0+226.10	Elevation:	1,936.123m
Low Point:	0+203.55	Elevation:	1,935.982m
Grade in:	-5.53%	Grade out:	1.25%
Change:	6.78%	K:	18.027m
Curve Length:	122.191m	Curve Radius	1,802.729m
Headlight Distance:	122.027m		

Vertical Curve Information:(crest curve)

PVC Station:	0+357.63	Elevation:	1,937.768m
PVI Station:	0+407.79	Elevation:	1,938.395m
PVT Station:	0+457.95	Elevation:	1,938.016m
High Point:	0+420.15	Elevation:	1,938.159m
Grade in:	1.25%	Grade out:	-0.76%
Change:	2.01%	K:	50.000m
Curve Length:	100.323m	Curve Radius	5,000.000m
Passing Distance:	820.855m	Stopping Distance:	381.380m

Vertical Curve Information:(crest curve)

PVC Station:	0+531.18	Elevation:	1,937.462m
PVI Station:	0+535.00	Elevation:	1,937.433m
PVT Station:	0+538.82	Elevation:	1,937.399m
High Point:	0+531.18	Elevation:	1,937.462m
Grade in:	-0.76%	Grade out:	-0.91%
Change:	0.15%	K:	50.000m
Curve Length:	7.635m	Curve Radius	5,000.000m
Passing Distance:	10,130.830m	Stopping Distance:	4,356.071m

Vertical Curve Information:(crest curve)

PVC Station:	0+712.56	Elevation:	1,935.820m
PVI Station:	0+747.81	Elevation:	1,935.499m
PVT Station:	0+783.06	Elevation:	1,934.682m
High Point:	0+712.56	Elevation:	1,935.820m
Grade in:	-0.91%	Grade out:	-2.32%
Change:	1.41%	K:	50.000m
Curve Length:	70.494m	Curve Radius	5,000.000m
Passing Distance:	1,132.051m	Stopping Distance:	506.617m

Vertical Curve Information:(sag curve)

PVC Station:	0+905.00	Elevation:	1,931.855m

PVI Station:	0+980.00	Elevation:	1,930.116m
PVT Station:	1+055.00	Elevation:	1,931.903m
Low Point:	0+978.98	Elevation:	1,930.997m
Grade in:	-2.32%	Grade out:	2.38%
Change:	4.70%	K:	31.906m
Curve Length:	150.000m	Curve Radius	3,190.607m
Headlight Distance:	186.954m		

Vertical Curve Information:(crest curve)

PVC Station:	1+084.51	Elevation:	1,932.606m
PVI Station:	1+185.00	Elevation:	1,935.000m
PVT Station:	1+285.49	Elevation:	1,933.355m
High Point:	1+203.64	Elevation:	1,934.025m
Grade in:	2.38%	Grade out:	-1.64%
Change:	4.02%	K:	50.000m
Curve Length:	200.980m	Curve Radius	5,000.000m
Passing Distance:	485.195m	Stopping Distance:	265.824m

Appendix I: Mass Haul Report

Start Sta: 0+000.000

End Sta: 1+365.416

	Area Type	Area	Inc.Vol.	Cum.Vol.	MassHaul
		Sq.m.	Cu.m.	Cu.m.	Cu.m.
Station: 0+000.000					
	Adjusted Cut	9697.34	0.00	0.00	
	Adjusted Usable	9697.34	0.00	0.00	
	Adjusted Fill	0.00	0.00	0.00	
					0.00
Station: 0+020.000					
	Adjusted Cut	19394.67	290920.09	290920.09	
	Adjusted Usable	19394.67	290920.09	290920.09	
	Adjusted Fill	0.00	0.00	0.00	
					290920.09
Station: 0+040.000					
	Adjusted Cut	19394.67	387893.46	678813.55	
	Adjusted Usable	19394.67	387893.46	678813.55	
	Adjusted Fill	0.00	0.00	0.00	
					678813.55

Station: 0+060.000					
	Adjusted Cut	19394.67	387893.46	1066707.00	
	Adjusted Usable	19394.67	387893.46	1066707.00	
	Adjusted Fill	0.00	0.00	0.00	
					1066707.00
Station: 0+080.000					
	Adjusted Cut	22099.94	414129.34	1480836.34	
	Adjusted Usable	22099.94	414129.34	1480836.34	
	Adjusted Fill	0.00	0.00	0.00	
					1480836.34
Station: 0+100.000					
	Adjusted Cut	21662.00	436212.83	1917049.17	
	Adjusted Usable	21662.00	436212.83	1917049.17	
	Adjusted Fill	0.00	0.00	0.00	
					1917049.17
Station: 0+120.000					
	Adjusted Cut	4.98	216669.80	2133718.97	
	Adjusted Usable	4.98	216669.80	2133718.97	
	Adjusted Fill	0.65	6.50	6.50	
					2133712.47
Station: 0+140.000					

	Adjusted Cut	20.12	250.97	2133969.94	
	Adjusted Usable	20.12	250.97	2133969.94	
	Adjusted Fill	0.15	8.00	14.50	
					2133955.44
Station: 0+160.000					
	Adjusted Cut	24.05	441.62	2134411.56	
	Adjusted Usable	24.05	441.62	2134411.56	
	Adjusted Fill	0.00	1.50	15.99	
					2134395.57
Station: 0+180.000					
	Adjusted Cut	29.95	539.95	2134951.51	
	Adjusted Usable	29.95	539.95	2134951.51	
	Adjusted Fill	0.00	0.00	15.99	
					2134935.52
Station: 0+200.000					
	Adjusted Cut	30.77	607.21	2135558.73	
	Adjusted Usable	30.77	607.21	2135558.73	
	Adjusted Fill	0.00	0.00	15.99	
					2135542.73
Station: 0+220.000					
	Adjusted Cut	19.54	503.13	2136061.86	

	Adjusted Usable	19.54	503.13	2136061.86	
	Adjusted Fill	0.30	2.98	18.97	
					2136042.89
Station: 0+240.000					
	Adjusted Cut	12.89	324.35	2136386.21	
	Adjusted Usable	12.89	324.35	2136386.21	
	Adjusted Fill	0.00	2.99	21.96	
					2136364.26
Station: 0+280.000					
	Adjusted Cut	8.26	176.24	2136784.22	
	Adjusted Usable	8.26	176.24	2136784.22	
	Adjusted Fill	0.00	0.67	23.30	
					2136760.92
Station: 0+300.000					
	Adjusted Cut	4.81	130.69	2136914.91	
	Adjusted Usable	4.81	130.69	2136914.91	
	Adjusted Fill	0.00	0.00	23.30	
					2136891.61
Station: 0+320.000					
	Adjusted Cut	2.14	69.54	2136984.45	
	Adjusted Usable	2.14	69.54	2136984.45	

	Adjusted Fill	0.20	1.98	25.28	
					2136959.17
Station: 0+340.000					
	Adjusted Cut	1.08	32.26	2137016.71	
	Adjusted Usable	1.08	32.26	2137016.71	
	Adjusted Fill	1.33	15.25	40.53	
					2136976.19
Station: 0+360.000					
	Adjusted Cut	0.00	10.85	2137027.56	
	Adjusted Usable	0.00	10.85	2137027.56	
	Adjusted Fill	9.59	109.13	149.65	
					2136877.91
Station: 0+380.000					
	Adjusted Cut	0.00	0.00	2137027.56	
	Adjusted Usable	0.00	0.00	2137027.56	
	Adjusted Fill	17.79	273.77	423.42	
					2136604.14
Station: 0+400.000					
	Adjusted Cut	0.56	5.42	2137032.98	
	Adjusted Usable	0.56	5.42	2137032.98	
	Adjusted Fill	20.65	382.45	805.87	

					2136227.11
Station: 0+420.000					
	Adjusted Cut	1.40	18.13	2137051.11	
	Adjusted Usable	1.40	18.13	2137051.11	
	Adjusted Fill	8.91	291.78	1097.65	
					2135953.46
Station: 0+440.000					
	Adjusted Cut	3.63	50.22	2137101.33	
	Adjusted Usable	3.63	50.22	2137101.33	
	Adjusted Fill	4.57	134.85	1232.51	
					2135868.83
Station: 0+460.000					
	Adjusted Cut	5.04	86.71	2137188.05	
	Adjusted Usable	5.04	86.71	2137188.05	
	Adjusted Fill	4.17	87.49	1319.99	
					2135868.05
Station: 0+480.000					
	Adjusted Cut	6.37	114.15	2137302.19	
	Adjusted Usable	6.37	114.15	2137302.19	
	Adjusted Fill	2.57	67.45	1387.45	
					2135914.74

Station: 0+500.000					
	Adjusted Cut	7.72	140.92	2137443.11	
	Adjusted Usable	7.72	140.92	2137443.11	
	Adjusted Fill	1.46	40.34	1427.79	
					2136015.32
Station: 0+520.000					
	Adjusted Cut	7.93	156.48	2137599.59	
	Adjusted Usable	7.93	156.48	2137599.59	
	Adjusted Fill	0.70	21.67	1449.46	
					2136150.13
Station: 0+540.000					
	Adjusted Cut	6.63	144.24	2137743.83	
	Adjusted Usable	6.63	144.24	2137743.83	
	Adjusted Fill	0.48	11.86	1461.33	
					2136282.50
Station: 0+560.000					
	Adjusted Cut	4.04	102.79	2137846.62	
	Adjusted Usable	4.04	102.79	2137846.62	
	Adjusted Fill	2.27	25.75	1487.08	
					2136359.54
Station: 0+580.000					

	Adjusted Cut	5.34	92.75	2137939.37	
	Adjusted Usable	5.34	92.75	2137939.37	
	Adjusted Fill	1.04	30.46	1517.53	
					2136421.83
Station: 0+600.000					
	Adjusted Cut	7.50	127.89	2138067.26	
	Adjusted Usable	7.50	127.89	2138067.26	
	Adjusted Fill	0.11	10.85	1528.38	
					2136538.87
Station: 0+620.000					
	Adjusted Cut	9.12	166.18	2138233.44	
	Adjusted Usable	9.12	166.18	2138233.44	
	Adjusted Fill	0.00	1.12	1529.50	
					2136703.94
Station: 0+640.000					
	Adjusted Cut	12.41	213.70	2138447.14	
	Adjusted Usable	12.41	213.70	2138447.14	
	Adjusted Fill	0.00	0.00	1529.50	
					2136917.63
Station: 0+660.000					
	Adjusted Cut	6.23	184.61	2138631.75	

	Adjusted Usable	6.23	184.61	2138631.75	
	Adjusted Fill	0.66	6.26	1535.77	
					2137095.98
Station: 0+680.000					
	Adjusted Cut	2.90	90.85	2138722.60	
	Adjusted Usable	2.90	90.85	2138722.60	
	Adjusted Fill	3.36	38.51	1574.28	
					2137148.32
Station: 0+700.000					
	Adjusted Cut	5.37	82.62	2138805.22	
	Adjusted Usable	5.37	82.62	2138805.22	
	Adjusted Fill	0.92	42.79	1617.07	
					2137188.15
Station: 0+720.000					
	Adjusted Cut	10.25	156.20	2138961.42	
	Adjusted Usable	10.25	156.20	2138961.42	
	Adjusted Fill	0.22	11.36	1628.43	
					2137332.99
Station: 0+740.000					
	Adjusted Cut	11.26	215.11	2139176.53	
	Adjusted Usable	11.26	215.11	2139176.53	

	Adjusted Fill	1.23	14.45	1642.88	
					2137533.65
Station: 0+760.000					
	Adjusted Cut	20.46	317.15	2139493.68	
	Adjusted Usable	20.46	317.15	2139493.68	
	Adjusted Fill	0.69	19.17	1662.05	
					2137831.62
Station: 0+780.000					
	Adjusted Cut	39.91	603.68	2140097.36	
	Adjusted Usable	39.91	603.68	2140097.36	
	Adjusted Fill	0.00	6.89	1668.94	
					2138428.41
Station: 0+800.000					
	Adjusted Cut	45.15	836.45	2140933.80	
	Adjusted Usable	45.15	836.45	2140933.80	
	Adjusted Fill	0.00	0.00	1668.94	
					2139264.86
Station: 0+820.000					
	Adjusted Cut	38.21	794.80	2141728.60	
	Adjusted Usable	38.21	794.80	2141728.60	
	Adjusted Fill	0.00	0.00	1668.94	

					2140059.66
Station: 0+840.000					
	Adjusted Cut	31.28	665.41	2142394.02	
	Adjusted Usable	31.28	665.41	2142394.02	
	Adjusted Fill	7.02	79.31	1748.26	
					2140645.76
Station: 0+860.000					
	Adjusted Cut	26.05	561.49	2142955.50	
	Adjusted Usable	26.05	561.49	2142955.50	
	Adjusted Fill	29.14	410.53	2158.78	
					2140796.72
Station: 0+880.000					
	Adjusted Cut	20.25	462.99	2143418.49	
	Adjusted Usable	20.25	462.99	2143418.49	
	Adjusted Fill	25.06	542.08	2700.87	
					2140717.62
Station: 0+900.000					
	Adjusted Cut	17.28	375.96	2143794.45	
	Adjusted Usable	17.28	375.96	2143794.45	
	Adjusted Fill	25.47	438.58	3139.45	
					2140655.00

Station: 0+920.000					
	Adjusted Cut	15.10	323.83	2144118.27	
	Adjusted Usable	15.10	323.83	2144118.27	
	Adjusted Fill	27.61	385.12	3524.56	
					2140593.71
Station: 0+940.000					
	Adjusted Cut	10.51	255.54	2144373.81	
	Adjusted Usable	10.51	255.54	2144373.81	
	Adjusted Fill	38.05	479.48	4004.04	
					2140369.77
Station: 0+960.000					
	Adjusted Cut	5.79	162.55	2144536.36	
	Adjusted Usable	5.79	162.55	2144536.36	
	Adjusted Fill	52.37	667.75	4671.79	
					2139864.58
Station: 0+980.000					
	Adjusted Cut	0.07	58.40	2144594.77	
	Adjusted Usable	0.07	58.40	2144594.77	
	Adjusted Fill	68.37	905.62	5577.41	
					2139017.35
Station: 1+000.000					

	Adjusted Cut	0.00	0.66	2144595.43	
	Adjusted Usable	0.00	0.66	2144595.43	
	Adjusted Fill	76.17	1219.74	6797.15	
					2137798.28
Station: 1+020.000					
	Adjusted Cut	0.00	0.00	2144595.43	
	Adjusted Usable	0.00	0.00	2144595.43	
	Adjusted Fill	65.95	1421.18	8218.33	
					2136377.10
Station: 1+040.000					
	Adjusted Cut	0.00	0.00	2144595.43	
	Adjusted Usable	0.00	0.00	2144595.43	
	Adjusted Fill	57.15	1231.01	9449.34	
					2135146.08
Station: 1+060.000					
	Adjusted Cut	0.03	0.35	2144595.78	
	Adjusted Usable	0.03	0.35	2144595.78	
	Adjusted Fill	39.65	967.98	10417.32	
					2134178.46
Station: 1+080.000					
	Adjusted Cut	5.64	56.75	2144652.53	

	Adjusted Usable	5.64	56.75	2144652.53	
	Adjusted Fill	20.52	601.69	11019.01	
					2133633.52
Station: 1+100.000					
	Adjusted Cut	20.35	259.93	2144912.45	
	Adjusted Usable	20.35	259.93	2144912.45	
	Adjusted Fill	8.49	290.15	11309.16	
					2133603.29
Station: 1+120.000					
	Adjusted Cut	37.66	580.17	2145492.63	
	Adjusted Usable	37.66	580.17	2145492.63	
	Adjusted Fill	0.52	90.09	11399.25	
					2134093.37
Station: 1+140.000					
	Adjusted Cut	44.21	818.73	2146311.36	
	Adjusted Usable	44.21	818.73	2146311.36	
	Adjusted Fill	0.41	9.30	11408.55	
					2134902.81
Station: 1+160.000					
	Adjusted Cut	50.96	812.84	2147124.20	
	Adjusted Usable	50.96	812.84	2147124.20	

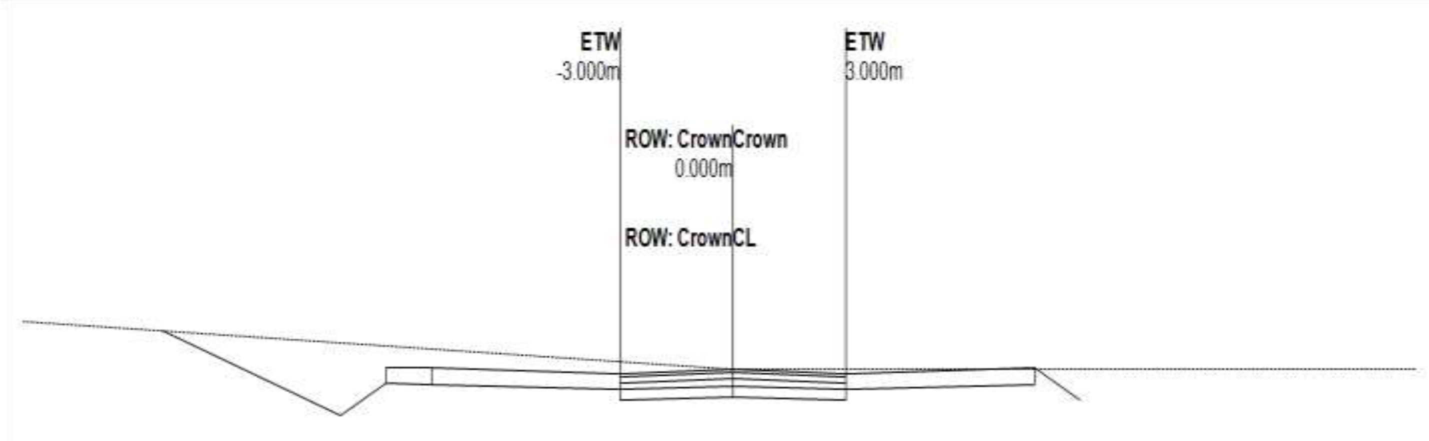
	Adjusted Fill	0.00	4.00	11412.55	
					2135711.65
Station: 1+180.000					
	Adjusted Cut	51.39	845.98	2147970.18	
	Adjusted Usable	51.39	845.98	2147970.18	
	Adjusted Fill	0.00	0.00	11412.55	
					2136557.63
Station: 1+200.000					
	Adjusted Cut	40.95	760.41	2148730.59	
	Adjusted Usable	40.95	760.41	2148730.59	
	Adjusted Fill	0.10	1.05	11413.60	
					2137316.99
Station: 1+220.000					
	Adjusted Cut	29.20	572.72	2149303.31	
	Adjusted Usable	29.20	572.72	2149303.31	
	Adjusted Fill	0.23	3.33	11416.93	
					2137886.38
Station: 1+240.000					
	Adjusted Cut	32.70	619.00	2149922.31	
	Adjusted Usable	32.70	619.00	2149922.31	
	Adjusted Fill	0.00	2.28	11419.21	

					2138503.11
Station: 1+260.000					
	Adjusted Cut	29.29	619.84	2150542.16	
	Adjusted Usable	29.29	619.84	2150542.16	
	Adjusted Fill	0.00	0.00	11419.21	
					2139122.95
Station: 1+280.000					
	Adjusted Cut	1.34	306.27	2150848.42	
	Adjusted Usable	1.34	306.27	2150848.42	
	Adjusted Fill	1.51	15.05	11434.26	
					2139414.16
Station: 1+300.000					
	Adjusted Cut	4.31	56.47	2150904.89	
	Adjusted Usable	4.31	56.47	2150904.89	
	Adjusted Fill	0.67	21.74	11456.00	
					2139448.90
Station: 1+320.000					
	Adjusted Cut	7.72	120.23	2151025.12	
	Adjusted Usable	7.72	120.23	2151025.12	
	Adjusted Fill	0.00	6.68	11462.68	
					2139562.44

Station: 1+340.000					
	Adjusted Cut	9.13	168.47	2151193.60	
	Adjusted Usable	9.13	168.47	2151193.60	
	Adjusted Fill	0.00	0.00	11462.68	
					2139730.92
Station: 1+360.000					
	Adjusted Cut	5.44	145.70	2151339.30	
	Adjusted Usable	5.44	145.70	2151339.30	
	Adjusted Fill	0.00	0.00	11462.68	
					2139876.62
Station: 1+365.416					
	Adjusted Cut	2.38	21.19	2151360.49	
	Adjusted Usable	2.38	21.19	2151360.49	
	Adjusted Fill	0.00	0.00	11462.68	
					2139897.81

Appendix J:- Corridor Slope Stake Report

Station Range: Start: 0+000.00, End: 1+343.55



Thesis Alignment Edited

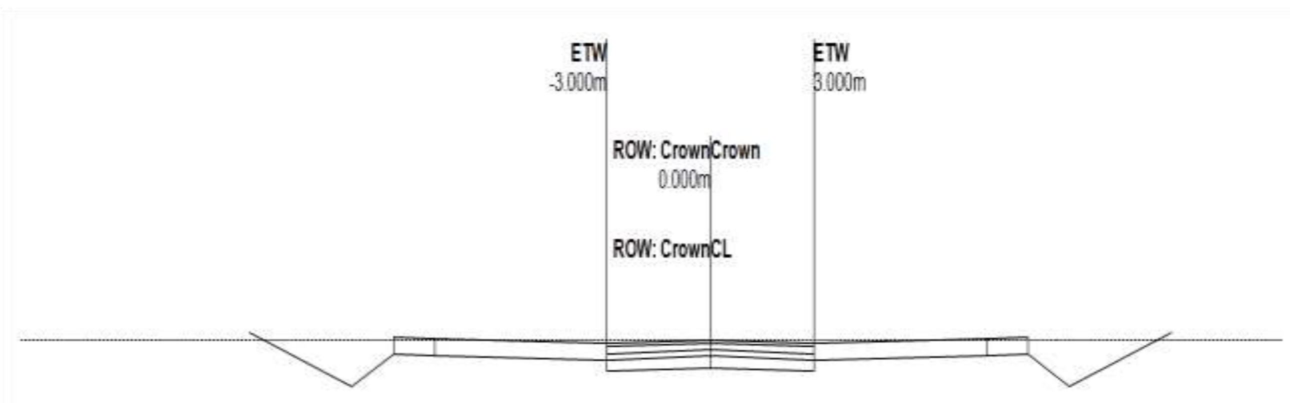
Station: 0+000.00

Cut Area: 13.54Sq.M.

Fill Area: 0.00Sq.M.

Cumulative Net Volume: 0.00Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.925m	1,939.000m	1,939.000m	1,938.925m	-2.50 %
	2.50 %		-2.50 %		



Thesis Alignment Edited

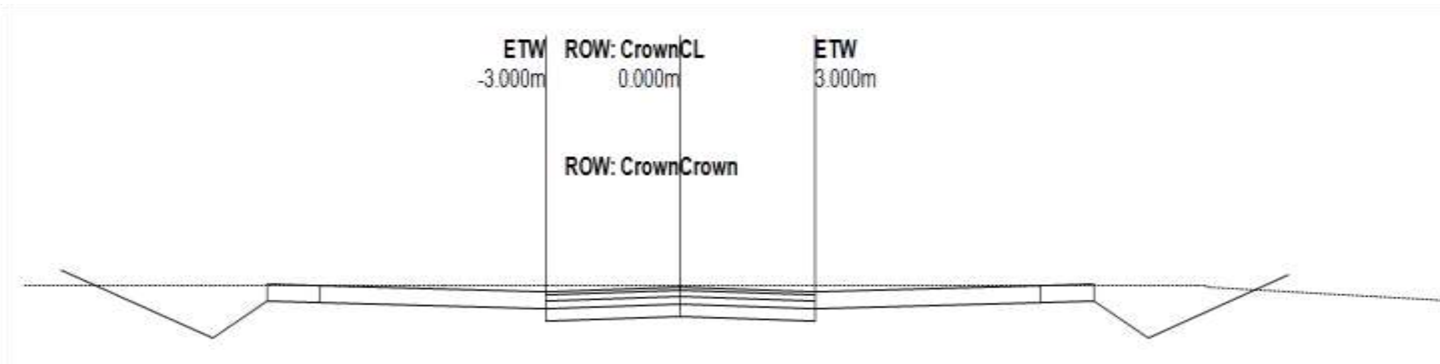
Station: 0+020.00

Cut Area: 14.15Sq.M.

Fill Area: 0.00Sq.M.

Cumulative Net Volume: 276.97Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.924m	1,938.999m	1,938.999m	1,938.924m	-2.50 %
	2.50 %		-2.50 %		



Thesis Alignment Edited

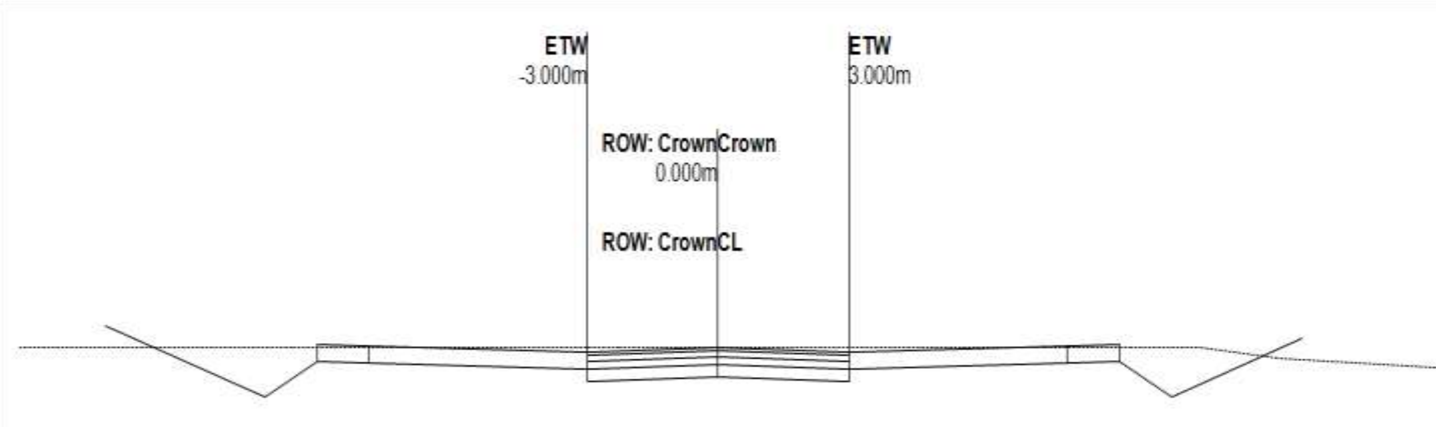
Station: 0+040.00

Cut Area: 17.73Sq.M.

Fill Area: 0.00Sq.M.

Cumulative Net Volume: 595.76Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.922m	1,938.997m	1,938.997m	1,938.922m	-2.50 %
	2.50 %		-2.50 %		



Thesis Alignment Edited

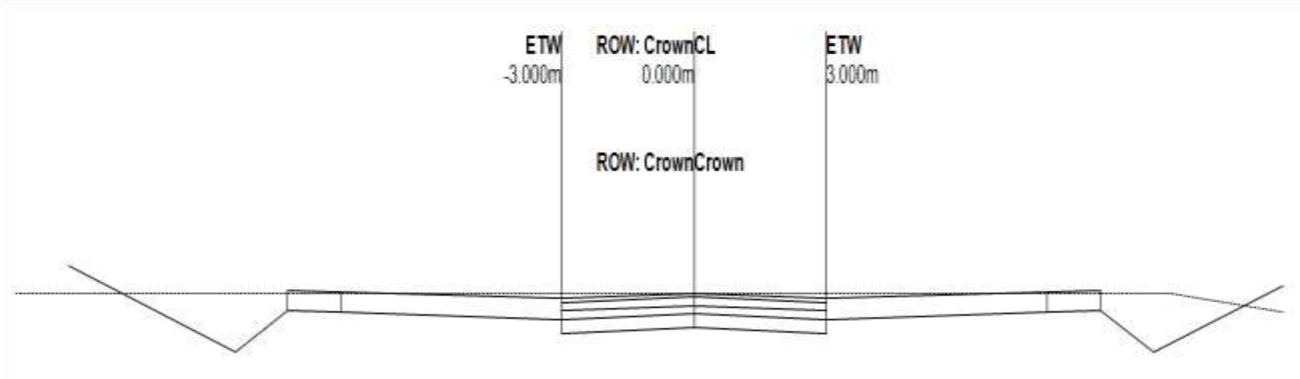
Station: 0+054.12

Cut Area: 20.10Sq.M.

Fill Area: 0.00Sq.M.

Cumulative Net Volume: 862.86Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.921m	1,938.996m	1,938.996m	1,938.921m	-2.50 %
	2.50 %		-2.50 %		



Thesis Alignment Edited

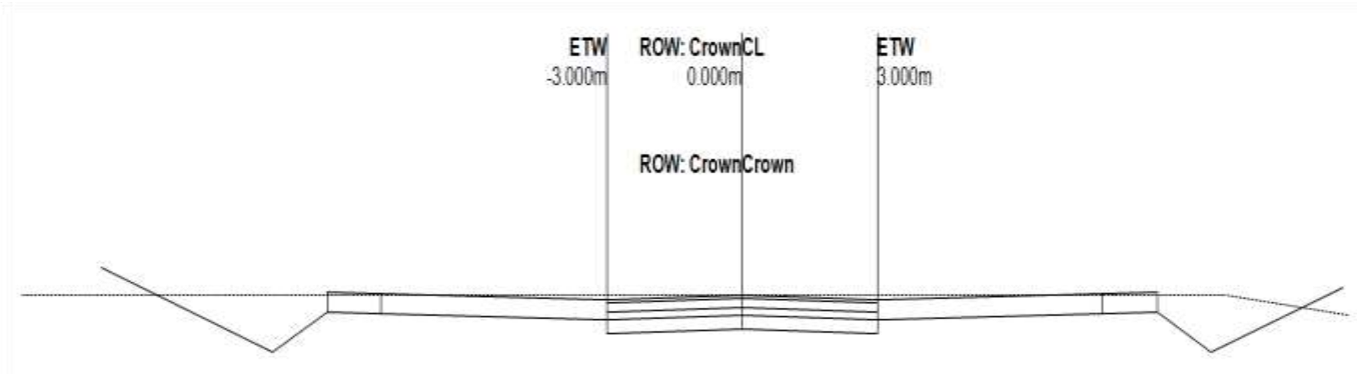
Station: 0+060.00

Cut Area: 21.11Sq.M.

Fill Area: 0.00Sq.M.

Cumulative Net Volume: 983.99Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.919m	1,938.994m	1,938.994m	1,938.919m	-2.50 %
	2.50 %		-2.50 %		



Thesis Alignment Edited

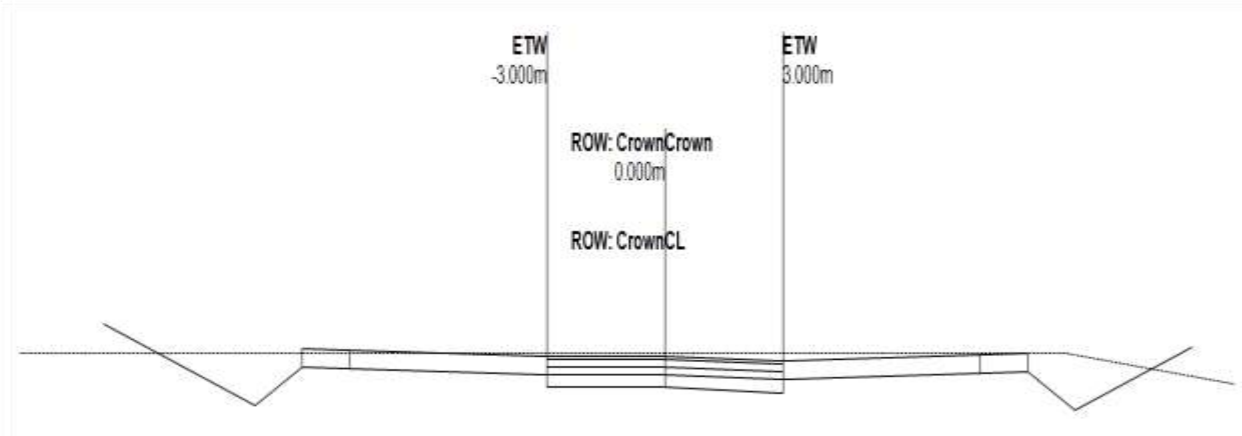
Station: 0+061.62

Cut Area: 21.39Sq.M.

Fill Area: 0.00Sq.M.

Cumulative Net Volume: 1,018.46Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.917m	1,938.992m	1,938.992m	1,938.917m	-2.50 %
	2.50 %		-2.50 %		



Thesis Alignment Edited

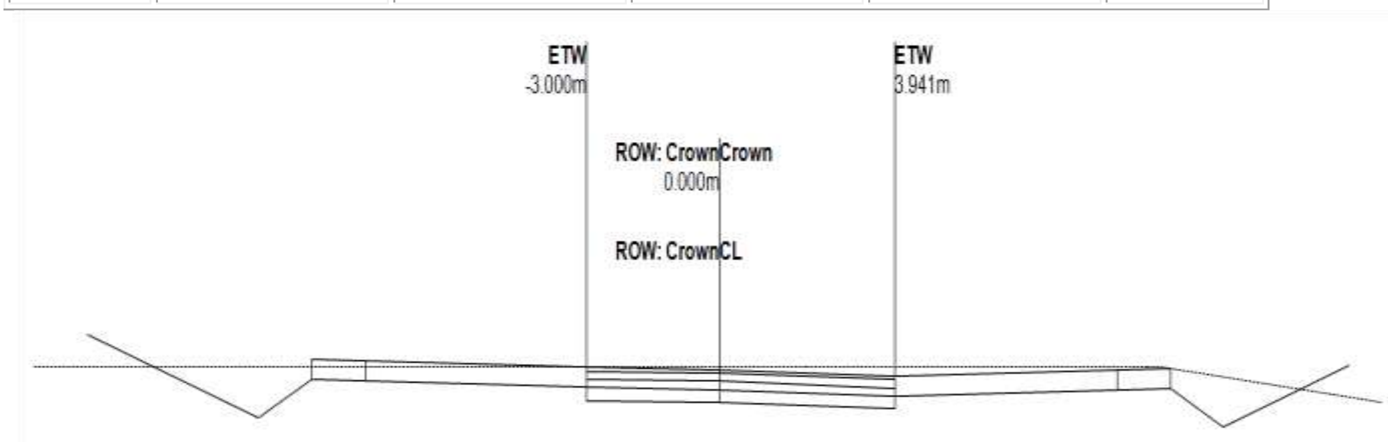
Station: 0+074.12

Cut Area: 22.59Sq.M.

Fill Area: 0.00Sq.M.

Cumulative Net Volume: 1,293.37Cu.M.

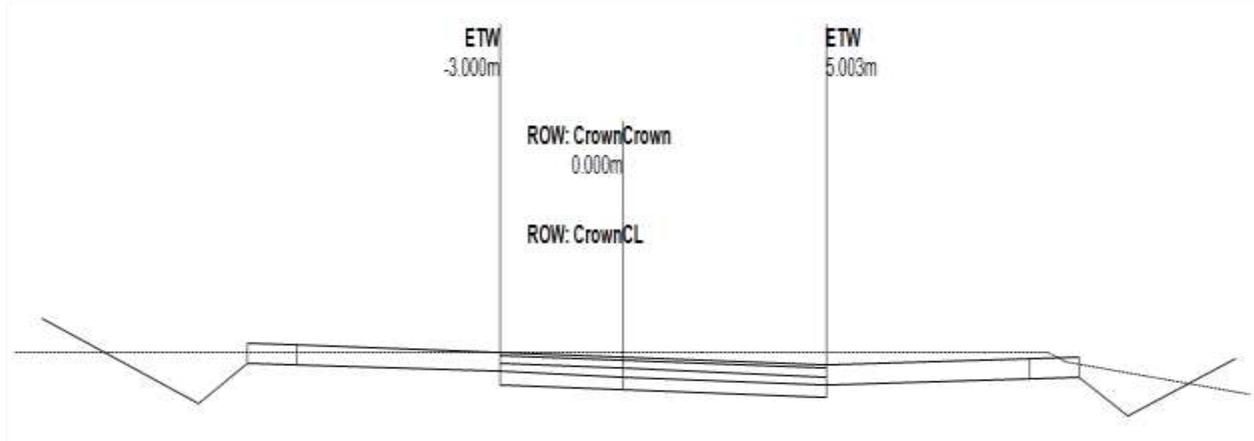
C0.00	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
0.00 %	1,938.970m	1,938.970m	1,938.970m	1,938.895m	-2.50 %
	0.00 %		-2.50 %		



Thesis Alignment Edited

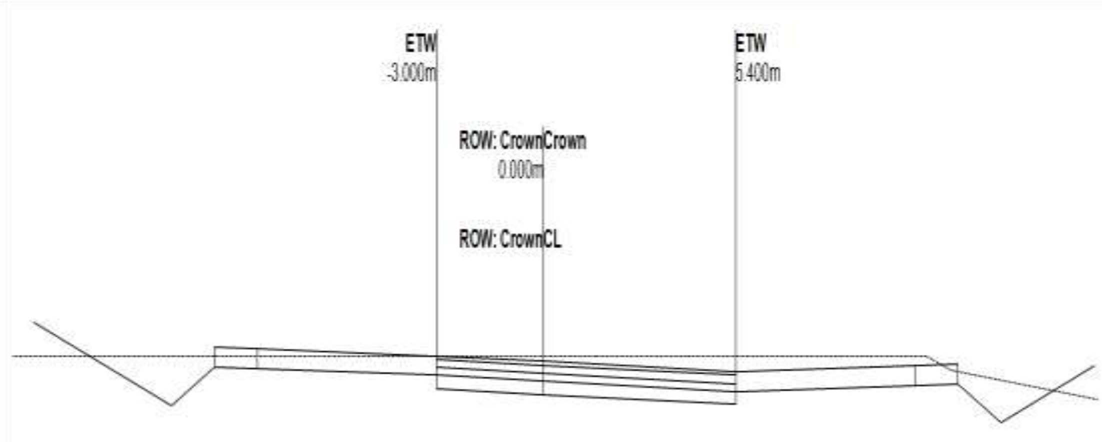
Station: 0+080.00
Cut Area: 24.04Sq.M.
Fill Area: 0.00Sq.M.
Cumulative Net Volume: 1,430.42Cu.M.

F0.04	ETW	CL	Crown	ETW	F0.10
@3.00	-3.000m	0.000m	0.000m	3.941m	@3.94
-1.18 %	1,938.987m	1,938.952m	1,938.952m	1,938.854m	-2.50 %
	-1.18 %		-2.50 %		



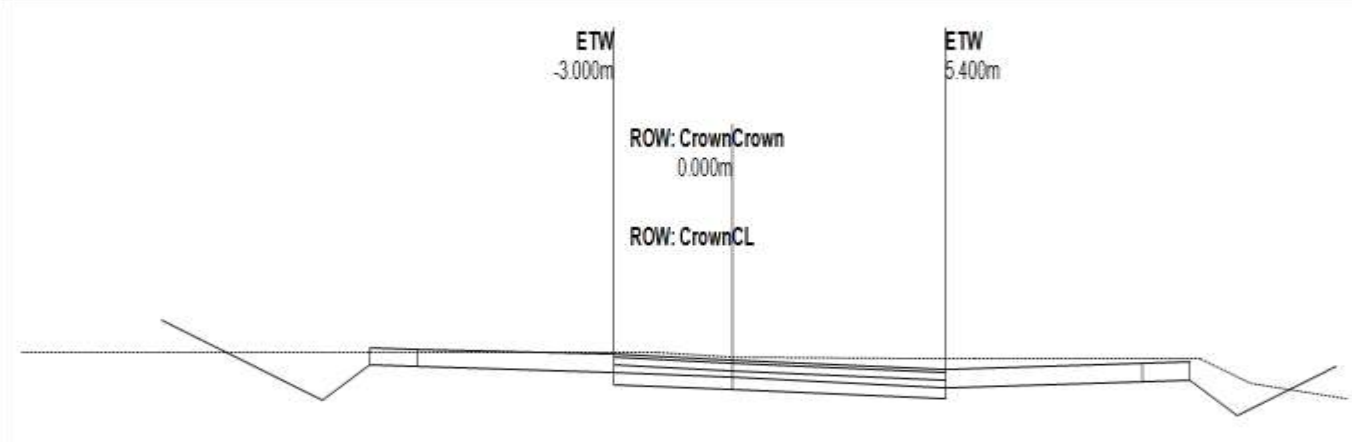
Thesis Alignment Edited
Station: 0+086.62
Cut Area: 25.67Sq.M.
Fill Area: 0.00Sq.M.
Cumulative Net Volume: 1,594.73Cu.M.

F0.08	ETW	CL	Crown	ETW	F0.13
@3.00	-3.000m	0.000m	0.000m	5.003m	@5.00
-2.50 %	1,939.002m	1,938.927m	1,938.927m	1,938.802m	-2.50 %
	-2.50 %		-2.50 %		



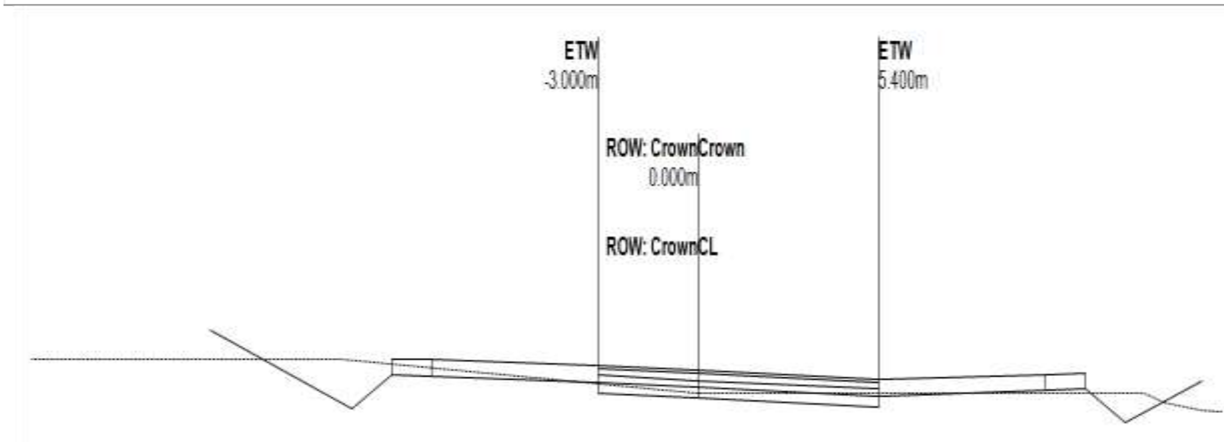
Thesis Alignment Edited
Station: 0+089.12
Cut Area: 26.63Sq.M.
Fill Area: 0.00Sq.M.
Cumulative Net Volume: 1,659.63Cu.M.

F0.09	ETW	CL	Crown	ETW	F0.16
@3.00	-3.000m	0.000m	0.000m	5.400m	@5.40
-3.00 %	1,939.006m	1,938.916m	1,938.916m	1,938.754m	-3.00 %
	-3.00 %		-3.00 %		



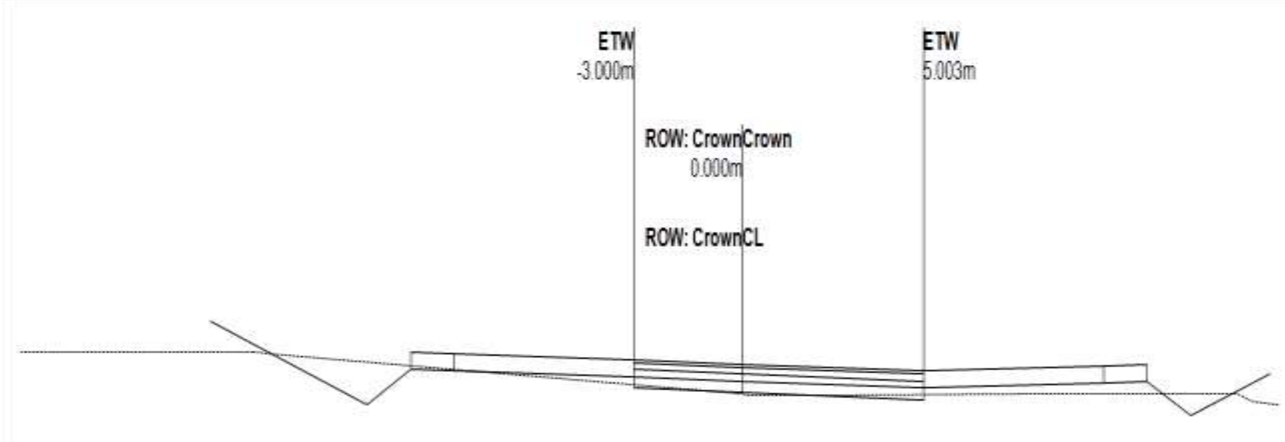
Thesis Alignment Edited
Station: 0+100.00
Cut Area: 27.33Sq.M.
Fill Area: 0.00Sq.M.
Cumulative Net Volume: 1,951.10Cu.M.

F0.09	ETW	CL	Crown	ETW	F0.16
@3.00	-3.000m	0.000m	0.000m	5.400m	@5.40
-3.00 %	1,938.949m	1,938.859m	1,938.859m	1,938.697m	-3.00 %
	-3.00 %		-3.00 %		



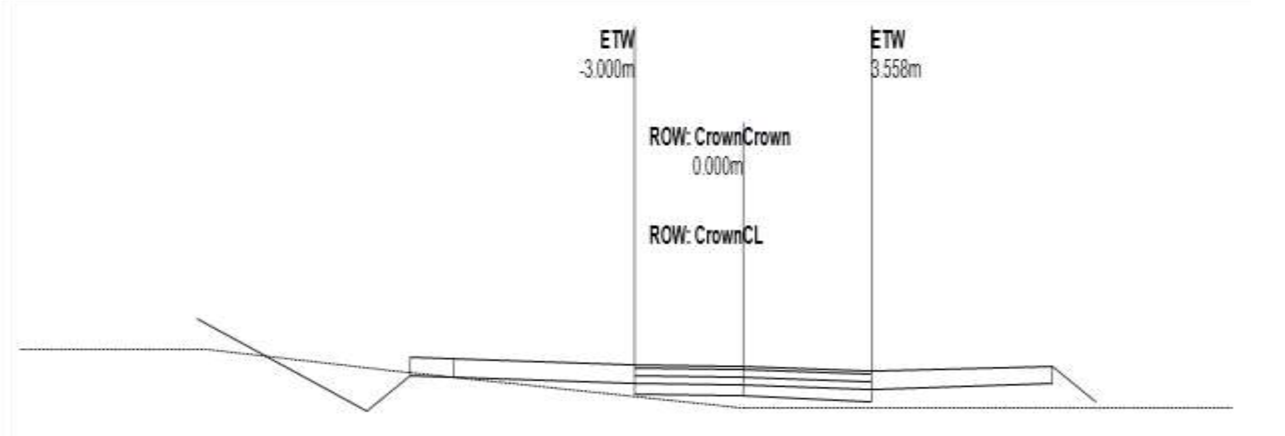
Thesis Alignment Edited
Station: 0+108.49
Cut Area: 19.44Sq.M.
Fill Area: 0.00Sq.M.
Cumulative Net Volume: 2,149.28Cu.M.

F0.09	ETW	CL	Crown	ETW	F0.16
@3.00	-3.000m	0.000m	0.000m	5.400m	@5.40
-3.00 %	1,938.893m	1,938.803m	1,938.803m	1,938.641m	-3.00 %
	-3.00 %		-3.00 %		



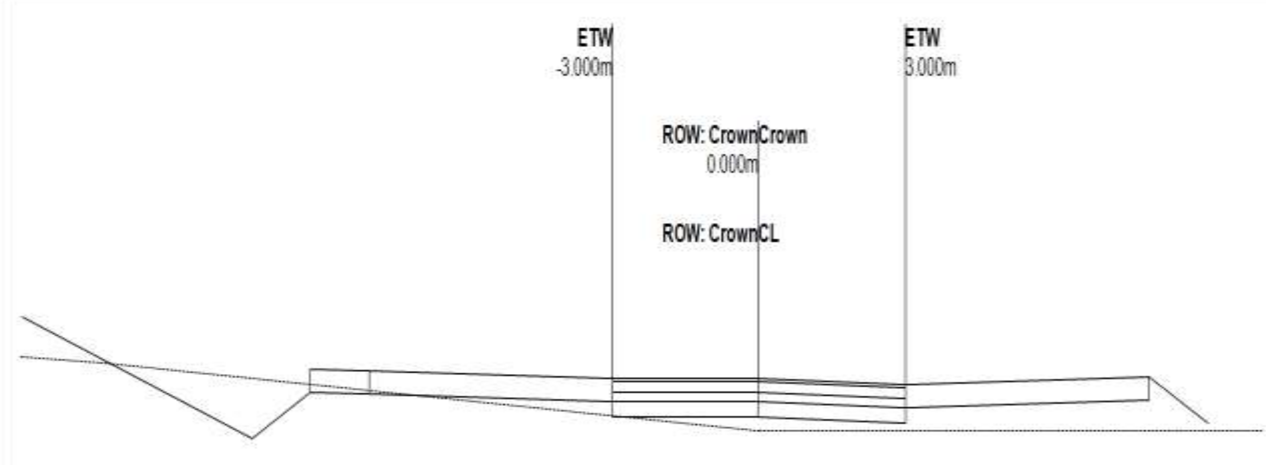
Thesis Alignment Edited
Station: 0+110.99
Cut Area: 15.63Sq.M.
Fill Area: 0.00Sq.M.
Cumulative Net Volume: 2,193.37Cu.M.

F0.08	ETW	CL	Crown	ETW	F0.13
@3.00	-3.000m	0.000m	0.000m	5.003m	@5.00
-2.50 %	1,938.860m	1,938.785m	1,938.785m	1,938.660m	-2.50 %
	-2.50 %		-2.50 %		



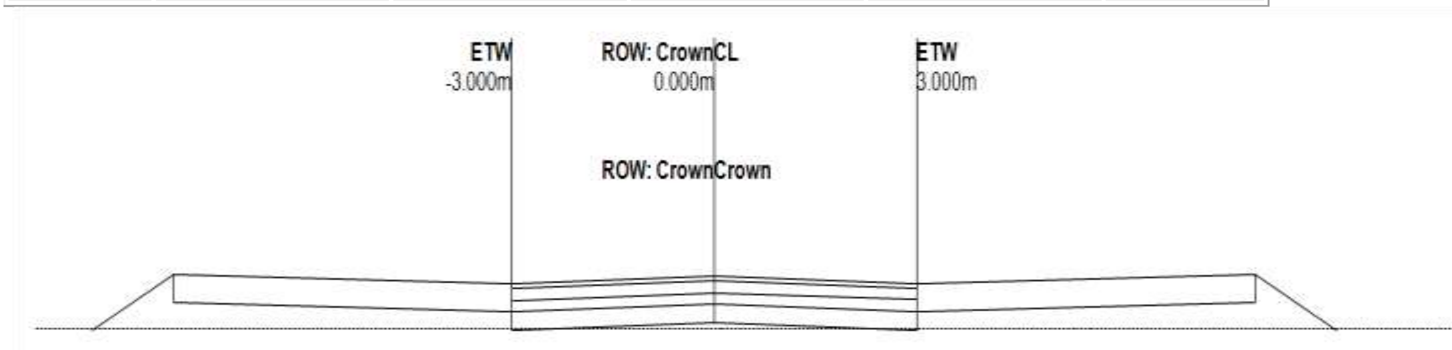
Thesis Alignment Edited
Station: 0+120.00
Cut Area: 10.16Sq.M.
Fill Area: 0.04Sq.M.
Cumulative Net Volume: 2,310.06Cu.M.

F0.02	ETW	CL	Crown	ETW	F0.09
@3.00	-3.000m	0.000m	0.000m	3.558m	@3.56
-0.70 %	1,938.734m	1,938.713m	1,938.713m	1,938.624m	-2.50 %
	-0.70 %		-2.50 %		



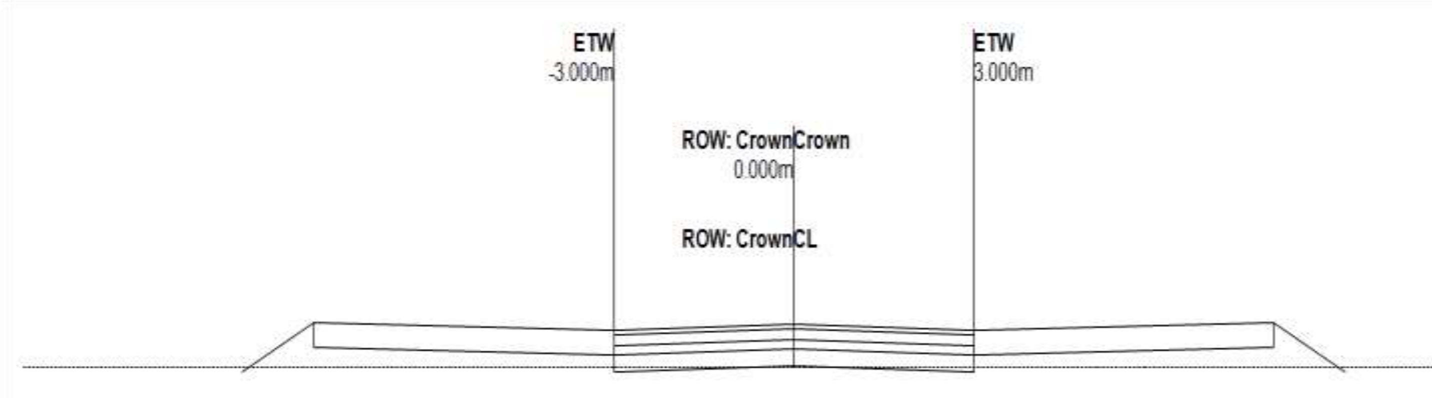
Thesis Alignment Edited
Station: 0+123.49
Cut Area: 10.54Sq.M.
Fill Area: 0.04Sq.M.
Cumulative Net Volume: 2,346.05Cu.M.

F0.00	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
0.00 %	1,938.682m	1,938.682m	1,938.682m	1,938.607m	-2.50 %
	0.00 %		-2.50 %		



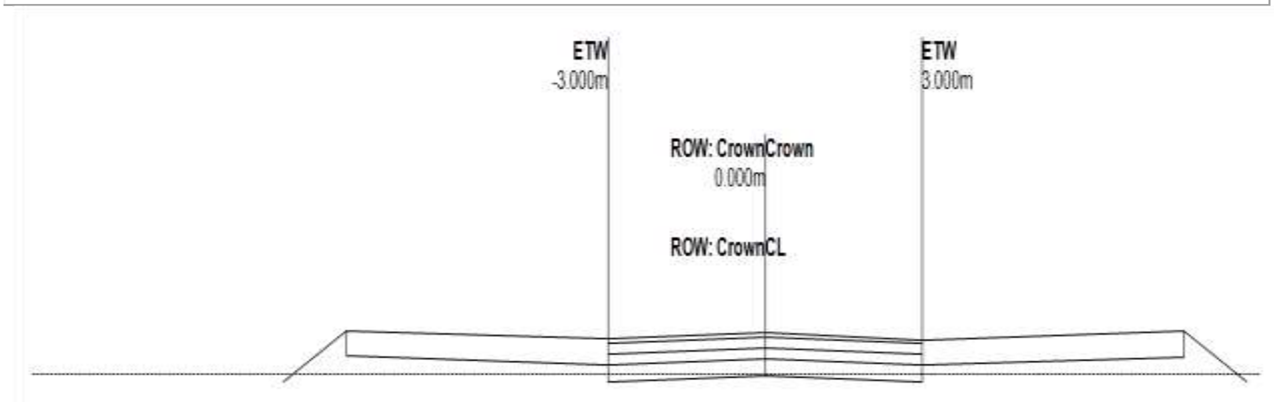
Thesis Alignment Edited
Station: 0+135.99
Cut Area: 5.65Sq.M.
Fill Area: 0.02Sq.M.
Cumulative Net Volume: 2,446.86Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.484m	1,938.559m	1,938.559m	1,938.484m	-2.50 %
	2.50 %		-2.50 %		



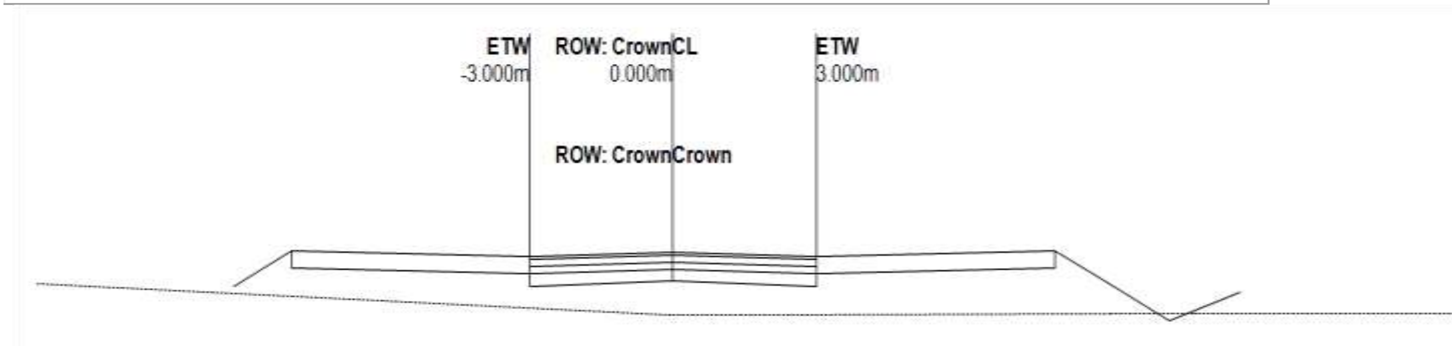
Thesis Alignment Edited
Station: 0+140.00
Cut Area: 6.14Sq.M.
Fill Area: 0.01Sq.M.
Cumulative Net Volume: 2,470.41Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.441m	1,938.516m	1,938.516m	1,938.441m	-2.50 %
	2.50 %		-2.50 %		



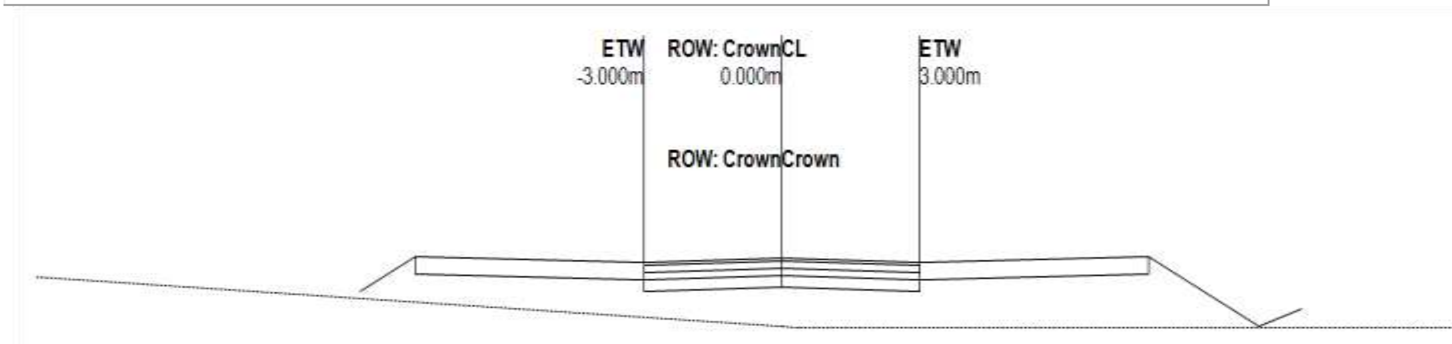
Thesis Alignment Edited
Station: 0+143.49
Cut Area: 6.56Sq.M.
Fill Area: 0.01Sq.M.
Cumulative Net Volume: 2,492.54Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.402m	1,938.477m	1,938.477m	1,938.402m	-2.50 %
	2.50 %		-2.50 %		



Thesis Alignment Edited
Station: 0+160.00
Cut Area: 0.68Sq.M.
Fill Area: 3.99Sq.M.
Cumulative Net Volume: 2,519.33Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.220m	1,938.295m	1,938.295m	1,938.220m	-2.50 %
	2.50 %		-2.50 %		



Thesis Alignment Edited
Station: 0+169.38
Cut Area: 0.28Sq.M.
Fill Area: 6.48Sq.M.
Cumulative Net Volume: 2,474.76Cu.M.

C0.08	ETW	CL	Crown	ETW	F0.08
@3.00	-3.000m	0.000m	0.000m	3.000m	@3.00
2.50 %	1,938.117m	1,938.192m	1,938.192m	1,938.117m	-2.50 %
	2.50 %		-2.50 %		

Appendix K: Volume Report

Start Sta: 0+000.000

End Sta: 1+343.554

Station	Cut Area (Sq.m.)	Cut Volume (Cu.m.)	Reusable Volume (Cu.m.)	Fill Area (Sq.m.)	Fill Volume (Cu.m.)	Cum. Cut Vol. (Cu.m.)	Cum. Reusable Vol. (Cu.m.)	Cum. Fill Vol. (Cu.m.)	Cum. Net Vol. (Cu.m.)
0+000.000	13.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0+020.000	14.15	276.97	276.97	0.00	0.00	276.97	276.97	0.00	276.97
0+040.000	17.73	318.79	318.79	0.00	0.00	595.77	595.77	0.00	595.76
0+054.122	20.10	267.09	267.09	0.00	0.00	862.86	862.86	0.00	862.86
0+060.000	21.11	121.13	121.13	0.00	0.00	983.99	983.99	0.00	983.99
0+061.622	21.39	34.47	34.47	0.00	0.00	1018.46	1018.46	0.00	1018.46
0+074.122	22.59	274.91	274.91	0.00	0.00	1293.37	1293.37	0.00	1293.37
0+080.000	24.04	137.06	137.06	0.00	0.00	1430.43	1430.43	0.00	1430.42
0+086.622	25.67	164.30	164.30	0.00	0.00	1594.73	1594.73	0.00	1594.73
0+089.122	26.63	64.90	64.90	0.00	0.00	1659.64	1659.64	0.00	1659.63
0+100.000	27.33	291.47	291.47	0.00	0.00	1951.11	1951.11	0.00	1951.10
0+108.490	19.44	198.18	198.18	0.00	0.00	2149.29	2149.29	0.00	2149.28
0+110.990	15.63	44.09	44.09	0.00	0.00	2193.38	2193.38	0.00	2193.37
0+120.000	10.16	116.87	116.87	0.04	0.18	2310.24	2310.24	0.19	2310.06
0+123.490	10.54	36.13	36.13	0.04	0.13	2346.37	2346.37	0.32	2346.05

0+135.990	5.65	101.18	101.18	0.02	0.37	2447.55	2447.55	0.69	2446.86
0+140.000	6.14	23.62	23.62	0.01	0.07	2471.18	2471.18	0.76	2470.41
0+143.490	6.56	22.16	22.16	0.00	0.03	2493.33	2493.33	0.80	2492.54
0+160.000	0.68	59.75	59.75	3.99	32.95	2553.08	2553.08	33.75	2519.33
0+169.376	0.28	4.50	4.50	6.48	49.06	2557.58	2557.58	82.81	2474.76
0+176.876	0.37	2.46	2.46	5.75	45.86	2560.03	2560.03	128.67	2431.36
0+180.000	0.38	1.17	1.17	5.57	17.68	2561.20	2561.20	146.36	2414.84
0+189.376	0.46	3.92	3.92	4.64	47.88	2565.12	2565.12	194.24	2370.88
0+200.000	0.93	7.41	7.41	3.90	45.36	2572.53	2572.53	239.61	2332.92
0+201.876	0.77	1.60	1.60	3.89	7.30	2574.13	2574.13	246.91	2327.22
0+203.098	0.74	0.93	0.93	3.93	4.78	2575.06	2575.06	251.68	2323.37
0+204.376	0.59	0.85	0.85	4.07	5.11	2575.91	2575.91	256.80	2319.11
0+205.598	0.41	0.61	0.61	4.26	5.09	2576.52	2576.52	261.89	2314.63
0+218.098	0.05	2.87	2.87	5.01	58.20	2579.39	2579.39	320.09	2259.30
0+220.000	0.06	0.10	0.10	5.29	9.80	2579.49	2579.49	329.88	2249.61
0+230.598	0.26	1.70	1.70	6.32	61.53	2581.19	2581.19	391.42	2189.78
0+238.098	0.51	2.89	2.89	5.13	42.95	2584.08	2584.08	434.36	2149.72
0+240.000	0.58	1.04	1.04	4.80	9.45	2585.12	2585.12	443.81	2141.31
0+260.000	2.07	26.57	26.57	2.45	72.51	2611.69	2611.69	516.32	2095.37
0+280.000	8.57	106.45	106.45	0.03	24.78	2718.14	2718.14	541.10	2177.04
0+291.946	10.31	112.81	112.81	0.00	0.22	2830.95	2830.95	541.32	2289.62

0+299.446	11.11	80.33	80.33	0.00	0.04	2911.27	2911.27	541.36	2369.91
0+300.000	11.13	6.15	6.15	0.00	0.00	2917.43	2917.43	541.36	2376.06
0+311.946	13.88	149.36	149.36	0.00	0.00	3066.79	3066.79	541.37	2525.41
0+320.000	15.89	119.87	119.87	0.00	0.00	3186.65	3186.65	541.37	2645.28
0+324.446	17.28	73.63	73.63	0.00	0.00	3260.28	3260.28	541.37	2718.91
0+326.946	19.24	45.45	45.45	0.00	0.00	3305.74	3305.74	541.37	2764.36
0+328.020	20.01	21.06	21.06	0.00	0.00	3326.80	3326.80	541.37	2785.43
0+330.520	20.67	50.88	50.88	0.00	0.00	3377.68	3377.68	541.37	2836.31
0+340.000	19.75	192.07	192.07	0.00	0.00	3569.75	3569.75	541.37	3028.38
0+343.020	18.90	58.35	58.35	0.00	0.00	3628.10	3628.10	541.37	3086.73
0+355.520	15.01	211.95	211.95	0.27	1.67	3840.06	3840.06	543.04	3297.01
0+360.000	14.87	66.94	66.94	0.29	1.25	3907.00	3907.00	544.29	3362.71
0+363.020	14.77	44.75	44.75	0.33	0.94	3951.75	3951.75	545.23	3406.52
0+380.000	14.42	247.85	247.85	0.69	8.67	4199.60	4199.60	553.90	3645.70
0+400.000	18.50	329.23	329.23	0.00	6.93	4528.83	4528.83	560.83	3968.01
0+420.000	28.60	470.98	470.98	0.00	0.00	4999.81	4999.81	560.83	4438.98
0+440.000	27.95	565.43	565.43	0.00	0.00	5565.24	5565.24	560.83	5004.41
0+460.000	34.07	620.17	620.17	0.00	0.00	6185.41	6185.41	560.83	5624.58
0+480.000	33.47	675.38	675.38	0.00	0.00	6860.79	6860.79	560.83	6299.97
0+500.000	34.39	678.52	678.52	0.00	0.00	7539.31	7539.31	560.83	6978.49
0+520.000	34.01	683.95	683.95	0.00	0.00	8223.26	8223.26	560.83	7662.44

0+529.007	28.91	283.35	283.35	0.00	0.00	8506.62	8506.62	560.83	7945.79
0+536.507	26.14	206.44	206.44	0.00	0.00	8713.05	8713.05	560.83	8152.23
0+540.000	24.97	89.25	89.25	0.00	0.00	8802.31	8802.31	560.83	8241.48
0+549.007	21.40	208.82	208.82	0.00	0.00	9011.13	9011.13	560.83	8450.30
0+560.000	20.06	227.91	227.91	0.00	0.00	9239.04	9239.04	560.83	8678.21
0+561.507	19.70	29.97	29.97	0.00	0.00	9269.01	9269.01	560.83	8708.18
0+564.007	19.81	48.07	48.07	0.00	0.00	9317.08	9317.08	560.83	8756.25
0+565.128	19.64	22.12	22.12	0.00	0.00	9339.19	9339.19	560.83	8778.37
0+567.628	18.59	46.54	46.54	0.00	0.00	9385.73	9385.73	560.83	8824.90
0+580.000	16.07	213.62	213.62	0.00	0.00	9599.35	9599.35	560.83	9038.52
0+580.128	16.04	2.06	2.06	0.00	0.00	9601.41	9601.41	560.83	9040.58
0+592.628	15.55	197.46	197.46	0.00	0.00	9798.86	9798.86	560.83	9238.04
0+600.000	14.46	110.60	110.60	0.00	0.00	9909.46	9909.46	560.83	9348.63
0+600.128	14.44	1.86	1.86	0.00	0.00	9911.32	9911.32	560.83	9350.49
0+620.000	12.41	266.81	266.81	0.00	0.00	10178.12	10178.12	560.83	9617.30
0+640.000	7.45	198.64	198.64	0.00	0.02	10376.76	10376.76	560.85	9815.91
0+660.000	3.96	114.13	114.13	0.23	2.31	10490.89	10490.89	563.16	9927.73
0+680.000	1.61	55.71	55.71	0.32	5.54	10546.60	10546.60	568.70	9977.90
0+700.000	10.52	121.25	121.25	0.00	3.25	10667.85	10667.85	571.95	10095.90
0+720.000	19.25	297.63	297.63	0.00	0.00	10965.48	10965.48	571.96	10393.52
0+740.000	23.14	423.84	423.84	0.00	0.00	11389.31	11389.31	571.96	10817.35

0+760.000	50.15	732.89	732.89	0.00	0.00	12122.20	12122.20	571.96	11550.24
0+780.000	64.95	1151.02	1151.02	0.00	0.00	13273.23	13273.23	571.96	12701.26
0+800.000	67.77	1327.22	1327.22	0.00	0.00	14600.44	14600.44	571.96	14028.48
0+820.000	62.36	1301.36	1301.36	0.00	0.00	15901.80	15901.80	571.96	15329.84
0+840.000	53.16	1155.20	1155.20	0.00	0.00	17057.00	17057.00	571.96	16485.04
0+849.550	49.94	492.27	492.27	0.00	0.00	17549.28	17549.28	571.96	16977.32
0+857.050	46.26	360.73	360.73	0.00	0.00	17910.01	17910.01	571.96	17338.05
0+860.000	44.63	134.06	134.06	0.00	0.00	18044.07	18044.07	571.96	17472.11
0+869.550	40.59	406.94	406.94	0.00	0.00	18451.00	18451.00	571.96	17879.04
0+880.000	37.83	409.73	409.73	0.00	0.00	18860.73	18860.73	571.96	18288.77
0+882.050	37.04	76.74	76.74	0.00	0.00	18937.47	18937.47	571.96	18365.51
0+883.954	36.63	70.14	70.14	0.00	0.00	19007.61	19007.61	571.96	18435.65
0+884.550	36.44	21.77	21.77	0.00	0.00	19029.38	19029.38	571.96	18457.42
0+900.000	29.80	510.17	510.17	0.00	0.00	19539.54	19539.54	571.96	18967.58
0+920.000	24.50	543.00	543.00	0.00	0.00	20082.54	20082.54	571.96	19510.58
0+931.655	21.49	265.82	265.82	0.00	0.00	20348.36	20348.36	571.96	19776.40
0+940.000	16.17	152.37	152.37	0.00	0.01	20500.72	20500.72	571.97	19928.75
0+960.000	11.65	267.59	267.59	0.06	0.62	20768.31	20768.31	572.60	20195.72
0+980.000	3.01	141.34	141.34	0.46	5.33	20909.66	20909.66	577.92	20331.73
1+000.000	2.84	57.38	57.38	0.39	8.75	20967.03	20967.03	586.68	20380.36
1+020.000	2.10	48.52	48.52	0.89	13.20	21015.55	21015.55	599.88	20415.68

1+020.016	2.10	0.03	0.03	0.89	0.01	21015.59	21015.59	599.89	20415.70
1+022.516	1.83	4.83	4.83	0.84	2.21	21020.42	21020.42	602.10	20418.32
1+035.016	1.80	22.66	22.66	0.34	7.35	21043.08	21043.08	609.45	20433.63
1+040.000	2.10	9.74	9.74	0.37	1.76	21052.81	21052.81	611.21	20441.60
1+047.516	2.19	16.13	16.13	0.44	3.03	21068.94	21068.94	614.24	20454.70
1+055.016	1.90	15.32	15.32	0.56	3.74	21084.26	21084.26	617.98	20466.28
1+060.000	1.73	9.04	9.04	0.65	3.02	21093.30	21093.30	621.00	20472.31
1+080.000	2.30	40.37	40.37	1.51	21.68	21133.68	21133.68	642.68	20491.00
1+100.000	1.44	37.43	37.43	2.49	40.00	21171.11	21171.11	682.68	20488.43
1+120.000	5.31	67.48	67.48	0.54	30.22	21238.59	21238.59	712.90	20525.69
1+140.000	8.15	134.57	134.57	1.35	18.91	21373.16	21373.16	731.80	20641.36
1+160.000	11.25	194.01	194.01	0.34	16.93	21567.17	21567.17	748.73	20818.44
1+180.000	16.51	277.58	277.58	0.02	3.58	21844.75	21844.75	752.31	21092.44
1+200.000	18.44	349.46	349.46	0.00	0.20	22194.21	22194.21	752.50	21441.70
1+220.000	21.88	403.17	403.17	0.00	0.00	22597.38	22597.38	752.50	21844.88
1+240.000	17.08	389.58	389.58	0.00	0.00	22986.96	22986.96	752.50	22234.46
1+260.000	4.72	218.06	218.06	0.05	0.50	23205.02	23205.02	753.01	22452.01
1+280.000	10.45	151.73	151.73	0.04	0.88	23356.75	23356.75	753.89	22602.86
1+300.000	20.82	312.65	312.65	0.00	0.38	23669.39	23669.39	754.27	22915.13
1+320.000	20.54	413.51	413.51	0.00	0.00	24082.90	24082.90	754.27	23328.64
1+340.000	9.80	303.32	303.32	0.00	0.00	24386.23	24386.23	754.27	23631.96

1+343.554	0.00	17.41	17.41	0.00	0.00	24403.64	24403.64	754.27	23649.37	

Appendix L:- Material Report

Start Sat: 0+000.000
End Sat: 1+343.554

	Area Type	Area	Inc.Vol.	Cum.Vol.
		Sq.m.	**Cu.m.**	**Cu.m.**
Station: 0+000.000				
	AC	0.30	0.00	0.00
	BASE	0.75	0.00	0.00
	SUB BASE	0.75	0.00	0.00
	CAPPING	1.20	0.00	0.00
Station: 0+020.000				
	AC	0.30	6.00	6.00
	BASE	0.75	15.00	15.00
	SUB BASE	0.75	15.00	15.00
	CAPPING	1.20	24.00	24.00
Station: 0+040.000				
	AC	0.30	6.00	12.00
	BASE	0.75	15.00	30.00
	SUB BASE	0.75	15.00	30.00
	CAPPING	1.20	24.00	48.00
Station: 0+054.122				
	AC	0.30	4.24	16.24
	BASE	0.75	10.59	40.59
	SUB BASE	0.75	10.59	40.59
	CAPPING	1.20	16.95	64.95
Station: 0+060.000				
	AC	0.30	1.76	18.00
	BASE	0.75	4.41	45.00
	SUB BASE	0.75	4.41	45.00
	CAPPING	1.20	7.05	72.00
Station: 0+061.622				
	AC	0.30	0.49	18.49
	BASE	0.75	1.22	46.22

	SUB BASE	0.75	1.22	46.22
	CAPPING	1.20	1.95	73.95
Station: 0+074.122				
	AC	0.30	3.75	22.24
	BASE	0.75	9.38	55.59
	SUB BASE	0.75	9.38	55.59
	CAPPING	1.20	15.00	88.95
Station: 0+080.000				
	AC	0.35	1.90	24.14
	BASE	0.87	4.75	60.35
	SUB BASE	0.87	4.75	60.35
	CAPPING	1.39	7.61	96.55
Station: 0+086.622				
	AC	0.40	2.47	26.61
	BASE	1.00	6.17	66.52
	SUB BASE	1.00	6.17	66.52
	CAPPING	1.60	9.87	106.43
Station: 0+089.122				
	AC	0.42	1.02	27.62
	BASE	1.05	2.54	69.06
	SUB BASE	1.05	2.54	69.06
	CAPPING	1.68	4.07	110.50
Station: 0+100.000				
	AC	0.42	4.53	32.15
	BASE	1.05	11.32	80.38
	SUB BASE	1.05	11.32	80.38
	CAPPING	1.68	18.12	128.61
Station: 0+108.490				
	AC	0.42	3.54	35.69
	BASE	1.05	8.84	89.22
	SUB BASE	1.05	8.84	89.22
	CAPPING	1.68	14.14	142.76
Station: 0+110.990				
	AC	0.40	1.02	36.71

	BASE	1.00	2.54	91.77
	SUB BASE	1.00	2.54	91.77
	CAPPING	1.60	4.07	146.82
Station: 0+120.000				
	AC	0.33	3.28	39.98
	BASE	0.82	8.19	99.95
	SUB BASE	0.82	8.19	99.95
	CAPPING	1.31	13.10	159.93
Station: 0+123.490				
	AC	0.30	1.10	41.08
	BASE	0.75	2.74	102.69
	SUB BASE	0.75	2.74	102.69
	CAPPING	1.20	4.38	164.31
Station: 0+135.990				
	AC	0.30	3.75	44.83
	BASE	0.75	9.38	112.07
	SUB BASE	0.75	9.38	112.07
	CAPPING	1.20	15.00	179.31
Station: 0+140.000				
	AC	0.30	1.20	46.03
	BASE	0.75	3.01	115.08
	SUB BASE	0.75	3.01	115.08
	CAPPING	1.20	4.81	184.12
Station: 0+143.490				
	AC	0.30	1.05	47.08
	BASE	0.75	2.62	117.69
	SUB BASE	0.75	2.62	117.69
	CAPPING	1.20	4.19	188.31
Station: 0+160.000				
	AC	0.30	4.95	52.03
	BASE	0.75	12.38	130.08
	SUB BASE	0.75	12.38	130.08
	CAPPING	1.20	19.81	208.12
Station: 0+169.376				

	AC	0.30	2.81	54.84
	BASE	0.75	7.03	137.11
	SUB BASE	0.75	7.03	137.11
	CAPPING	1.20	11.25	219.37
Station: 0+176.876				
	AC	0.30	2.25	57.09
	BASE	0.75	5.63	142.73
	SUB BASE	0.75	5.63	142.73
	CAPPING	1.20	9.00	228.37
Station: 0+180.000				
	AC	0.30	0.94	58.03
	BASE	0.75	2.34	145.08
	SUB BASE	0.75	2.34	145.08
	CAPPING	1.20	3.75	232.12
Station: 0+189.376				
	AC	0.34	3.00	61.03
	BASE	0.85	7.50	152.58
	SUB BASE	0.85	7.50	152.58
	CAPPING	1.36	12.00	244.12
Station: 0+200.000				
	AC	0.42	4.04	65.07
	BASE	1.05	10.09	162.67
	SUB BASE	1.05	10.09	162.67
	CAPPING	1.68	16.15	260.27
Station: 0+201.876				
	AC	0.42	0.79	65.86
	BASE	1.05	1.97	164.64
	SUB BASE	1.05	1.97	164.64
	CAPPING	1.68	3.15	263.42
Station: 0+203.098				
	AC	0.42	0.51	66.37
	BASE	1.05	1.28	165.92
	SUB BASE	1.05	1.28	165.92
	CAPPING	1.68	2.05	265.47

Station: 0+204.376				
	AC	0.42	0.54	66.91
	BASE	1.05	1.34	167.26
	SUB BASE	1.05	1.34	167.26
	CAPPING	1.68	2.15	267.62
Station: 0+205.598				
	AC	0.42	0.51	67.42
	BASE	1.05	1.28	168.55
	SUB BASE	1.05	1.28	168.55
	CAPPING	1.68	2.05	269.67
Station: 0+218.098				
	AC	0.34	4.74	72.16
	BASE	0.85	11.86	180.41
	SUB BASE	0.85	11.86	180.41
	CAPPING	1.36	18.98	288.65
Station: 0+220.000				
	AC	0.32	0.63	72.80
	BASE	0.81	1.58	181.99
	SUB BASE	0.81	1.58	181.99
	CAPPING	1.30	2.53	291.18
Station: 0+230.598				
	AC	0.30	3.31	76.11
	BASE	0.75	8.28	190.26
	SUB BASE	0.75	8.28	190.26
	CAPPING	1.20	13.24	304.42
Station: 0+238.098				
	AC	0.30	2.25	78.36
	BASE	0.75	5.62	195.89
	SUB BASE	0.75	5.62	195.89
	CAPPING	1.20	9.00	313.42
Station: 0+240.000				
	AC	0.30	0.57	78.93
	BASE	0.75	1.43	197.32
	SUB BASE	0.75	1.43	197.32

	CAPPING	1.20	2.28	315.71
Station: 0+260.000				
	AC	0.30	6.00	84.93
	BASE	0.75	15.00	212.32
	SUB BASE	0.75	15.00	212.32
	CAPPING	1.20	24.00	339.71
Station: 0+280.000				
	AC	0.30	6.00	90.93
	BASE	0.75	15.00	227.32
	SUB BASE	0.75	15.00	227.32
	CAPPING	1.20	24.00	363.71
Station: 0+291.946				
	AC	0.30	3.58	94.51
	BASE	0.75	8.96	236.28
	SUB BASE	0.75	8.96	236.28
	CAPPING	1.20	14.34	378.04
Station: 0+299.446				
	AC	0.30	2.25	96.76
	BASE	0.75	5.62	241.90
	SUB BASE	0.75	5.62	241.90
	CAPPING	1.20	9.00	387.04
Station: 0+300.000				
	AC	0.30	0.17	96.93
	BASE	0.75	0.42	242.32
	SUB BASE	0.75	0.42	242.32
	CAPPING	1.20	0.66	387.71
Station: 0+311.946				
	AC	0.30	3.58	100.51
	BASE	0.75	8.96	251.28
	SUB BASE	0.75	8.96	251.28
	CAPPING	1.20	14.34	402.04
Station: 0+320.000				
	AC	0.36	2.68	103.19
	BASE	0.91	6.69	257.96

	SUB BASE	0.91	6.69	257.96
	CAPPING	1.46	10.70	412.74
Station: 0+324.446				
	AC	0.40	1.69	104.88
	BASE	1.00	4.24	262.20
	SUB BASE	1.00	4.24	262.20
	CAPPING	1.60	6.78	419.52
Station: 0+326.946				
	AC	0.42	1.02	105.90
	BASE	1.05	2.54	264.74
	SUB BASE	1.05	2.54	264.74
	CAPPING	1.68	4.07	423.59
Station: 0+328.020				
	AC	0.42	0.45	106.35
	BASE	1.05	1.13	265.87
	SUB BASE	1.05	1.13	265.87
	CAPPING	1.68	1.80	425.39
Station: 0+330.520				
	AC	0.40	1.02	107.36
	BASE	1.00	2.54	268.41
	SUB BASE	1.00	2.54	268.41
	CAPPING	1.60	4.07	429.46
Station: 0+340.000				
	AC	0.32	3.43	110.79
	BASE	0.81	8.57	276.98
	SUB BASE	0.81	8.57	276.98
	CAPPING	1.30	13.72	443.18
Station: 0+343.020				
	AC	0.30	0.94	111.74
	BASE	0.75	2.36	279.34
	SUB BASE	0.75	2.36	279.34
	CAPPING	1.20	3.77	446.94
Station: 0+355.520				
	AC	0.30	3.75	115.49

	BASE	0.75	9.38	288.72
	SUB BASE	0.75	9.38	288.72
	CAPPING	1.20	15.00	461.94
Station: 0+360.000				
	AC	0.30	1.34	116.83
	BASE	0.75	3.36	292.08
	SUB BASE	0.75	3.36	292.08
	CAPPING	1.20	5.38	467.32
Station: 0+363.020				
	AC	0.30	0.91	117.74
	BASE	0.75	2.26	294.34
	SUB BASE	0.75	2.26	294.34
	CAPPING	1.20	3.62	470.94
Station: 0+380.000				
	AC	0.30	5.09	122.83
	BASE	0.75	12.74	307.08
	SUB BASE	0.75	12.74	307.08
	CAPPING	1.20	20.38	491.32
Station: 0+400.000				
	AC	0.30	6.00	128.83
	BASE	0.75	15.00	322.08
	SUB BASE	0.75	15.00	322.08
	CAPPING	1.20	24.00	515.32
Station: 0+420.000				
	AC	0.30	6.00	134.83
	BASE	0.75	15.00	337.08
	SUB BASE	0.75	15.00	337.08
	CAPPING	1.20	24.00	539.32
Station: 0+440.000				
	AC	0.30	6.00	140.83
	BASE	0.75	15.00	352.08
	SUB BASE	0.75	15.00	352.08
	CAPPING	1.20	24.00	563.32
Station: 0+460.000				

	AC	0.30	6.00	146.83
	BASE	0.75	15.00	367.08
	SUB BASE	0.75	15.00	367.08
	CAPPING	1.20	24.00	587.32
Station: 0+480.000				
	AC	0.30	6.00	152.83
	BASE	0.75	15.00	382.08
	SUB BASE	0.75	15.00	382.08
	CAPPING	1.20	24.00	611.32
Station: 0+500.000				
	AC	0.30	6.00	158.83
	BASE	0.75	15.00	397.08
	SUB BASE	0.75	15.00	397.08
	CAPPING	1.20	24.00	635.32
Station: 0+520.000				
	AC	0.30	6.00	164.83
	BASE	0.75	15.00	412.08
	SUB BASE	0.75	15.00	412.08
	CAPPING	1.20	24.00	659.32
Station: 0+529.007				
	AC	0.30	2.70	167.53
	BASE	0.75	6.76	418.83
	SUB BASE	0.75	6.76	418.83
	CAPPING	1.20	10.81	670.13
Station: 0+536.507				
	AC	0.30	2.25	169.78
	BASE	0.75	5.63	424.46
	SUB BASE	0.75	5.63	424.46
	CAPPING	1.20	9.00	679.13
Station: 0+540.000				
	AC	0.30	1.05	170.83
	BASE	0.75	2.62	427.08
	SUB BASE	0.75	2.62	427.08
	CAPPING	1.20	4.19	683.32

Station: 0+549.007				
	AC	0.30	2.70	173.53
	BASE	0.75	6.76	433.83
	SUB BASE	0.75	6.76	433.83
	CAPPING	1.20	10.81	694.13
Station: 0+560.000				
	AC	0.39	3.78	177.31
	BASE	0.97	9.45	443.29
	SUB BASE	0.97	9.45	443.29
	CAPPING	1.55	15.13	709.26
Station: 0+561.507				
	AC	0.40	0.59	177.91
	BASE	1.00	1.49	444.77
	SUB BASE	1.00	1.49	444.77
	CAPPING	1.60	2.38	711.63
Station: 0+564.007				
	AC	0.42	1.02	178.93
	BASE	1.05	2.54	447.31
	SUB BASE	1.05	2.54	447.31
	CAPPING	1.68	4.07	715.70
Station: 0+565.128				
	AC	0.42	0.47	179.40
	BASE	1.05	1.18	448.49
	SUB BASE	1.05	1.18	448.49
	CAPPING	1.68	1.88	717.59
Station: 0+567.628				
	AC	0.40	1.02	180.41
	BASE	1.00	2.54	451.03
	SUB BASE	1.00	2.54	451.03
	CAPPING	1.60	4.07	721.65
Station: 0+580.000				
	AC	0.30	4.33	184.75
	BASE	0.75	10.83	461.87
	SUB BASE	0.75	10.83	461.87

	CAPPING	1.20	17.33	738.99
Station: 0+580.128				
	AC	0.30	0.04	184.79
	BASE	0.75	0.10	461.96
	SUB BASE	0.75	0.10	461.96
	CAPPING	1.20	0.15	739.14
Station: 0+592.628				
	AC	0.30	3.75	188.54
	BASE	0.75	9.37	471.34
	SUB BASE	0.75	9.37	471.34
	CAPPING	1.20	15.00	754.14
Station: 0+600.000				
	AC	0.30	2.21	190.75
	BASE	0.75	5.53	476.87
	SUB BASE	0.75	5.53	476.87
	CAPPING	1.20	8.85	762.99
Station: 0+600.128				
	AC	0.30	0.04	190.79
	BASE	0.75	0.10	476.96
	SUB BASE	0.75	0.10	476.96
	CAPPING	1.20	0.15	763.14
Station: 0+620.000				
	AC	0.30	5.96	196.75
	BASE	0.75	14.90	491.87
	SUB BASE	0.75	14.90	491.87
	CAPPING	1.20	23.85	786.99
Station: 0+640.000				
	AC	0.30	6.00	202.75
	BASE	0.75	15.00	506.87
	SUB BASE	0.75	15.00	506.87
	CAPPING	1.20	24.00	810.99
Station: 0+660.000				
	AC	0.30	6.00	208.75
	BASE	0.75	15.00	521.87

	SUB BASE	0.75	15.00	521.87
	CAPPING	1.20	24.00	834.99
Station: 0+680.000				
	AC	0.30	6.00	214.75
	BASE	0.75	15.00	536.87
	SUB BASE	0.75	15.00	536.87
	CAPPING	1.20	24.00	858.99
Station: 0+700.000				
	AC	0.30	6.00	220.75
	BASE	0.75	15.00	551.87
	SUB BASE	0.75	15.00	551.87
	CAPPING	1.20	24.00	882.99
Station: 0+720.000				
	AC	0.30	6.00	226.75
	BASE	0.75	15.00	566.87
	SUB BASE	0.75	15.00	566.87
	CAPPING	1.20	24.00	906.99
Station: 0+740.000				
	AC	0.30	6.00	232.75
	BASE	0.75	15.00	581.87
	SUB BASE	0.75	15.00	581.87
	CAPPING	1.20	24.00	930.99
Station: 0+760.000				
	AC	0.30	6.00	238.75
	BASE	0.75	15.00	596.87
	SUB BASE	0.75	15.00	596.87
	CAPPING	1.20	24.00	954.99
Station: 0+780.000				
	AC	0.30	6.00	244.75
	BASE	0.75	15.00	611.87
	SUB BASE	0.75	15.00	611.87
	CAPPING	1.20	24.00	978.99
Station: 0+800.000				
	AC	0.30	6.00	250.75

	BASE	0.75	15.00	626.87
	SUB BASE	0.75	15.00	626.87
	CAPPING	1.20	24.00	1002.99
Station: 0+820.000				
	AC	0.30	6.00	256.75
	BASE	0.75	15.00	641.87
	SUB BASE	0.75	15.00	641.87
	CAPPING	1.20	24.00	1026.99
Station: 0+840.000				
	AC	0.30	6.00	262.75
	BASE	0.75	15.00	656.87
	SUB BASE	0.75	15.00	656.87
	CAPPING	1.20	24.00	1050.99
Station: 0+849.550				
	AC	0.30	2.87	265.61
	BASE	0.75	7.16	664.03
	SUB BASE	0.75	7.16	664.03
	CAPPING	1.20	11.46	1062.45
Station: 0+857.050				
	AC	0.30	2.25	267.86
	BASE	0.75	5.62	669.66
	SUB BASE	0.75	5.62	669.66
	CAPPING	1.20	9.00	1071.45
Station: 0+860.000				
	AC	0.30	0.88	268.75
	BASE	0.75	2.21	671.87
	SUB BASE	0.75	2.21	671.87
	CAPPING	1.20	3.54	1074.99
Station: 0+869.550				
	AC	0.34	3.06	271.80
	BASE	0.85	7.64	679.51
	SUB BASE	0.85	7.64	679.51
	CAPPING	1.36	12.22	1087.21
Station: 0+880.000				

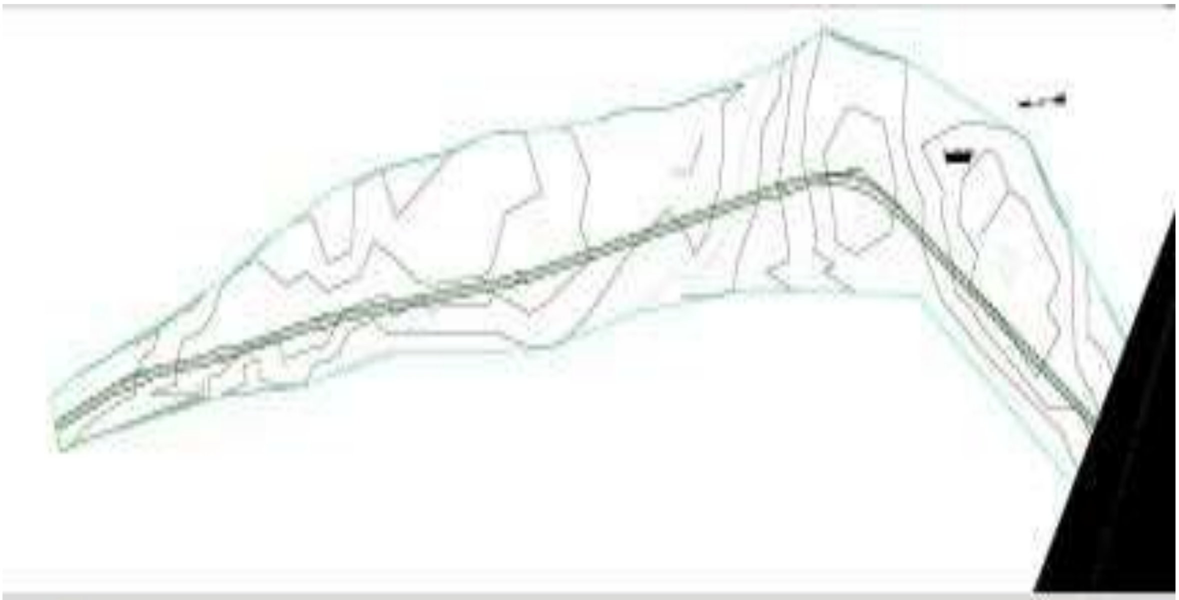
	AC	0.42	3.97	275.77
	BASE	1.05	9.93	689.44
	SUB BASE	1.05	9.93	689.44
	CAPPING	1.68	15.88	1103.10
Station: 0+882.050				
	AC	0.42	0.86	276.64
	BASE	1.05	2.15	691.59
	SUB BASE	1.05	2.15	691.59
	CAPPING	1.68	3.44	1106.54
Station: 0+883.954				
	AC	0.42	0.80	277.43
	BASE	1.05	2.00	693.59
	SUB BASE	1.05	2.00	693.59
	CAPPING	1.68	3.20	1109.74
Station: 0+884.550				
	AC	0.42	0.25	277.69
	BASE	1.05	0.63	694.21
	SUB BASE	1.05	0.63	694.21
	CAPPING	1.68	1.00	1110.74
Station: 0+900.000				
	AC	0.33	5.80	283.48
	BASE	0.83	14.49	708.70
	SUB BASE	0.83	14.49	708.70
	CAPPING	1.33	23.19	1133.93
Station: 0+920.000				
	AC	0.33	6.58	290.07
	BASE	0.82	16.46	725.16
	SUB BASE	0.82	16.46	725.16
	CAPPING	1.31	26.34	1160.26
Station: 0+931.655				
	AC	0.42	4.34	294.41
	BASE	1.05	10.85	736.02
	SUB BASE	1.05	10.85	736.02
	CAPPING	1.68	17.37	1177.63

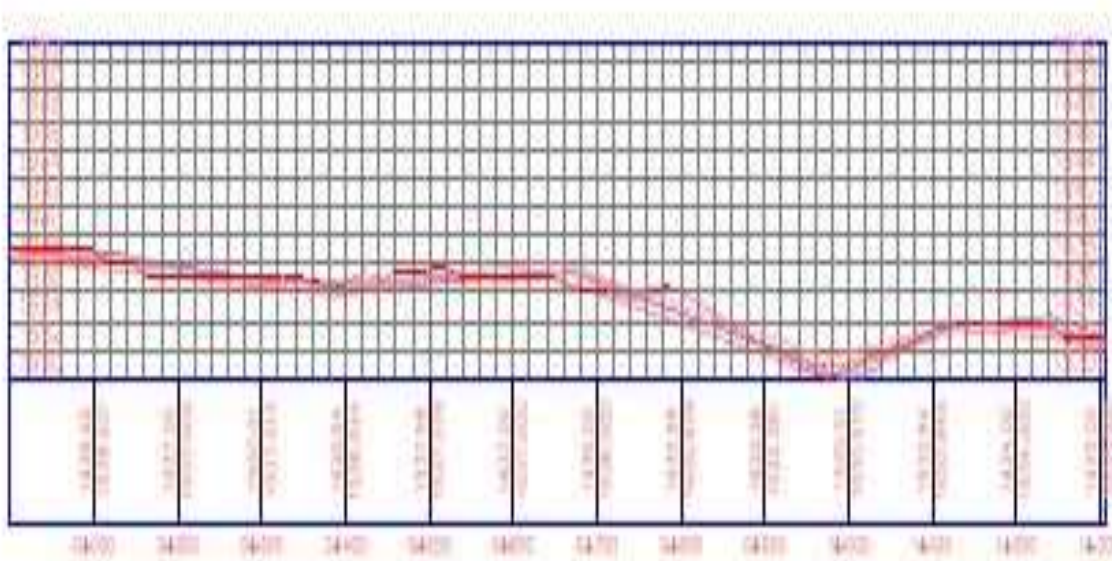
Station: 0+940.000				
	AC	0.42	3.47	297.88
	BASE	1.05	8.69	744.70
	SUB BASE	1.05	8.69	744.70
	CAPPING	1.68	13.90	1191.53
Station: 0+960.000				
	AC	0.42	8.33	306.21
	BASE	1.05	20.82	765.52
	SUB BASE	1.05	20.82	765.52
	CAPPING	1.68	33.31	1224.84
Station: 0+980.000				
	AC	0.42	8.33	314.54
	BASE	1.05	20.82	786.34
	SUB BASE	1.05	20.82	786.34
	CAPPING	1.68	33.31	1258.15
Station: 1+000.000				
	AC	0.42	8.33	322.87
	BASE	1.05	20.82	807.16
	SUB BASE	1.05	20.82	807.16
	CAPPING	1.68	33.31	1291.46
Station: 1+020.000				
	AC	0.42	8.33	331.19
	BASE	1.05	20.82	827.98
	SUB BASE	1.05	20.82	827.98
	CAPPING	1.68	33.31	1324.77
Station: 1+020.016				
	AC	0.42	0.00	331.20
	BASE	1.05	0.02	828.00
	SUB BASE	1.05	0.02	828.00
	CAPPING	1.68	0.03	1324.80
Station: 1+022.516				
	AC	0.40	1.02	332.22
	BASE	1.00	2.54	830.54
	SUB BASE	1.00	2.54	830.54

	CAPPING	1.60	4.07	1328.87
Station: 1+035.016				
	AC	0.30	4.37	336.59
	BASE	0.75	10.93	841.47
	SUB BASE	0.75	10.93	841.47
	CAPPING	1.20	17.49	1346.36
Station: 1+040.000				
	AC	0.30	1.50	338.08
	BASE	0.75	3.74	845.21
	SUB BASE	0.75	3.74	845.21
	CAPPING	1.20	5.98	1352.34
Station: 1+047.516				
	AC	0.30	2.25	340.34
	BASE	0.75	5.64	850.85
	SUB BASE	0.75	5.64	850.85
	CAPPING	1.20	9.02	1361.36
Station: 1+055.016				
	AC	0.30	2.25	342.59
	BASE	0.75	5.63	856.47
	SUB BASE	0.75	5.63	856.47
	CAPPING	1.20	9.00	1370.36
Station: 1+060.000				
	AC	0.30	1.50	344.08
	BASE	0.75	3.74	860.21
	SUB BASE	0.75	3.74	860.21
	CAPPING	1.20	5.98	1376.34
Station: 1+080.000				
	AC	0.30	6.00	350.08
	BASE	0.75	15.00	875.21
	SUB BASE	0.75	15.00	875.21
	CAPPING	1.20	24.00	1400.34
Station: 1+100.000				
	AC	0.30	6.00	356.08
	BASE	0.75	15.00	890.21

	SUB BASE	0.75	15.00	890.21
	CAPPING	1.20	24.00	1424.34
Station: 1+120.000				
	AC	0.30	6.00	362.08
	BASE	0.75	15.00	905.21
	SUB BASE	0.75	15.00	905.21
	CAPPING	1.20	24.00	1448.34
Station: 1+140.000				
	AC	0.30	6.00	368.08
	BASE	0.75	15.00	920.21
	SUB BASE	0.75	15.00	920.21
	CAPPING	1.20	24.00	1472.34
Station: 1+160.000				
	AC	0.30	6.00	374.08
	BASE	0.75	15.00	935.21
	SUB BASE	0.75	15.00	935.21
	CAPPING	1.20	24.00	1496.34
Station: 1+180.000				
	AC	0.30	6.00	380.08
	BASE	0.75	15.00	950.21
	SUB BASE	0.75	15.00	950.21
	CAPPING	1.20	24.00	1520.34
Station: 1+200.000				
	AC	0.30	6.00	386.08
	BASE	0.75	15.00	965.21
	SUB BASE	0.75	15.00	965.21
	CAPPING	1.20	24.00	1544.34
Station: 1+220.000				
	AC	0.30	6.00	392.08
	BASE	0.75	15.00	980.21
	SUB BASE	0.75	15.00	980.21
	CAPPING	1.20	24.00	1568.34
Station: 1+240.000				
	AC	0.30	6.00	398.08

	BASE	0.75	15.00	995.21
	SUB BASE	0.75	15.00	995.21
	CAPPING	1.20	24.00	1592.34
Station: 1+260.000				
	AC	0.30	6.00	404.08
	BASE	0.75	15.00	1010.21
	SUB BASE	0.75	15.00	1010.21
	CAPPING	1.20	24.00	1616.34
Station: 1+280.000				
	AC	0.30	6.00	410.08
	BASE	0.75	15.00	1025.21
	SUB BASE	0.75	15.00	1025.21
	CAPPING	1.20	24.00	1640.34
Station: 1+300.000				
	AC	0.30	6.00	416.08
	BASE	0.75	15.00	1040.21
	SUB BASE	0.75	15.00	1040.21
	CAPPING	1.20	24.00	1664.34
Station: 1+320.000				
	AC	0.30	6.00	422.08
	BASE	0.75	15.00	1055.21
	SUB BASE	0.75	15.00	1055.21
	CAPPING	1.20	24.00	1688.34
Station: 1+340.000				
	AC	0.30	6.00	428.08
	BASE	0.75	15.00	1070.21
	SUB BASE	0.75	15.00	1070.21
	CAPPING	1.20	24.00	1712.34
Station: 1+343.554				
	AC	0.30	1.07	429.15
	BASE	0.75	2.67	1072.88
	SUB BASE	0.75	2.67	1072.88
	CAPPING	1.20	4.26	1716.60





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