Table of Contents

Table of Contents

1 Executive Summary

1.1 Objectives

Highway geometric design refers to the calculations and analysis made by transportation engineers to fit the highway to the topography of the site while meeting the safety, service and performance standards. It mainly concerns with the elements of the highways that are visible to the drivers and users. However, the engineer must also take into consideration the social and environmental impacts of the highway geometry on the surrounding facilities.

Usually, highway geometric design has the following objectives:
1. Determine, within the allowance permitted by the design standard and right-of-way, the routing of proposed highway.
2. Incorporate, within the design standard, various physical features of the road alignment to ensure that drivers have sufficient view of the road (and obstacles) ahead for them to adjust their speed of travel to maintain safety and ride quality.
3. Provide a basis for the highway engineers to evaluate and plan for the construction of a section of the proposed highway.

1.2 Design Considerations

To meet the objective of fitting the highway to site topography and yet satisfy the safety, service and performance standards, the following considerations have to be properly addressed in the design process.

- Design speed
- Design traffic volume
- Number of lanes
- Level of service (LOS)
- Sight distance
- Alignment, super-elevation and grades
- Cross section
- Lane width
- Horizontal and vertical clearance

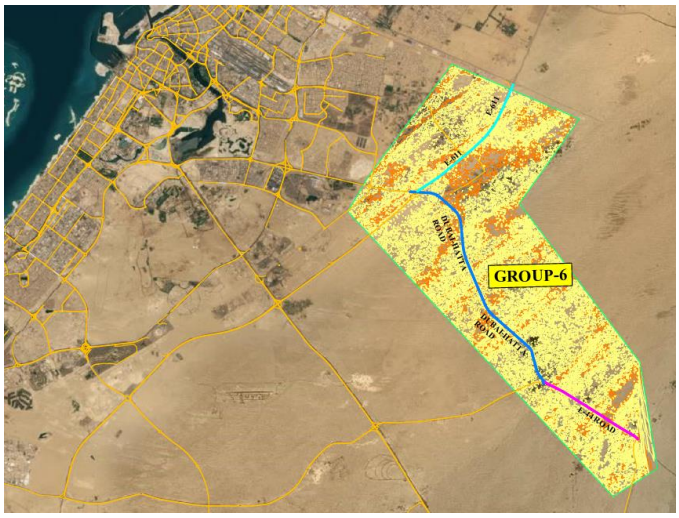
The above factors are interactive as drivers react to the combination of them (and among themselves) to produce the observable operational performance of the highway.

1.3 Assignment Details

Group-6 has been assigned with following roads

Table 1: Group 6 assigned roads

S. No.	Road Name	Classification	Terrain Type	ADT	Design Speed
1	E611	Major Rural Arterial	Rolling	10000	135
2	Dubai-Hatta Rd	Minor Rural Arterial	Rolling	4000	130
3	E44	Minor Urban Collector	Rolling	3000	100



Map of the Assigned Roads

1.4 Design Controls

Following are the design control based upon AASHTO

Table 2: Design Control Parameters

S. No.	Design Control Component	Road wise design control values as per AASHTO		
		E611	**Dubai-Hatta Rd**	**E44**
1	Design Vehicles	W-20	W-20	W-20
2	Design Speed (km/h)	135	130	100
3	Minimum radius of Curvature (m)	798	740	358
4	Lane Width and slope (m, %)	3.6m, 2%	3.6m, 2%	3.6m 2%
5	Shoulder/Parking Width and slope (%)	2.4m, 2%	2.4m, 2%	1.2m, 2%
6	K Value-Crest vertical curve	140	124	52
7	K Value-Sag vertical curve	80	73	45
8	Maximum vertical grade	4%	4%	7%
9	Minimum vertical grade	0.3%	0.3%	0.3%
10	Maximum allowed superelevation	10	10	10
11	Median (m)	2.4	2.4	1.2

1.5 Option Studies

Alignment option study was done for all the corridors. At least 2 options were created and best of them with consideration of length, nearby built-up areas, number of structures, intersections and environment has been picked for detailed design.

1.6 Detailed Design

Autodesk Civil3d software has been used for detailed design of the roads. Civil3d is one of the robust software and international reclaimed for design purpose. the following workflow performed for road design in AutoCAD Civil 3D.

1. Import points.

2. Create existing ground surface.
3. Create the proposed alignment.
4. Modify proposed alignment. (Label properties and curves)
5. Create the proposed profile and add data bands.
6. Modify the proposed profile. (Cut and fill volumes and design levels)
7. Create the proposed assembly.
8. Create corridor.
9. Create sample lines group.
10. Compute materials.
11. Modify profile for balance earthworks.
12. Create multiple section views.

1.7 Earthworks

Roads	**Length km)**	**Cum. Cut Vol. (Cu.m.)**	**Cum. Reusable Vol. (Cu.m.)**	**Cum. Fill Vol. (Cu.m.)**	**Cum. Net Vol. (Cu.m.)**
E611	10	341834	341834	341833	0.49
Dubai-Hatta Rd	17.5	561028	561028	561013	14.64
E44	8.35	211481	211481	211441	39.75

Earthworks are almost balanced and at the same time design fully conform the control as per AASHTO
Detailed design of all three road to conform the geometry standards and to balance the earthworks. In way forward structures, drainage, Geotech and hydrology to be considered to design the best route which provides the social and economic benefits to the people and agencies.

2 Introduction and an Overview of the Highway Design Process

2.1 Design Process

A highway designer is concerned with at least four major areas of design at different stages of project planning and design phases:
(1) location design;
(2) alignment design;
(3) cross sectional design; and
(4) access design.

Location Design: Location design takes place at the earlier stage of project planning. It refers to the macro-level routing of a planned highway connecting two points through the existing highways, communities, natural terrain. Normally, information such as lane-use master plan; existing and projected population distribution; survey maps; maps of existing infrastructure; geology, ecological, biological, and environmental information; and aerial photographs are among the essential inputs. Inputs are also sought from civil engineers, planners, economists, ecologists, sociologists, environmental experts, and lawyers. With all the necessary inputs, several potential routes are drawn up by the designer on a contour map (e.g., on a scale of 1:10,000).
The designer then goes through the various iterative and consultative steps with the stake holders to modify and select the most feasible layout. The consultative process is perhaps the most time consuming, which may take several months. A more detailed site survey is then carried out to locate the key control points of the alignments, in terms of geocoordinates and elevations. The designer then proceeds with the detailed alignment, cross sectional and assess design

Alignment Design: The alignment of a highway is a three-dimensional problem because the highway itself negotiates through the terrain in connecting two points. The highway may be visualized as segments of connected horizontal and vertical curves (ortheir combination). The alignment of a highway is best represented by its centre line in a three-dimensional coordinate system (e.g., longitude, latitude, and elevation). However, for the ease of interpretation of the construction drawing, the convention of plan and profile views has been adopted. The plan view gives the horizontal alignment of a highway. The length of the highway is measured along the plan view, on a horizontal plane. The length is expressed in terms of distance from a reference station, in terms of stations. Each station is 100 m. A highway normally starts from a fixed reference station. The distance from the reference station, together with the direction from the reference station or subsequent stations, spells out the horizontal alignment. The vertical alignment (including the gradients and vertical curves) are represented in a profile view. The profile view is the view along the length (including the true length of horizontal curve) of the highway. The elevations of all the points at regular intervals or when necessary are specified in the profile view.

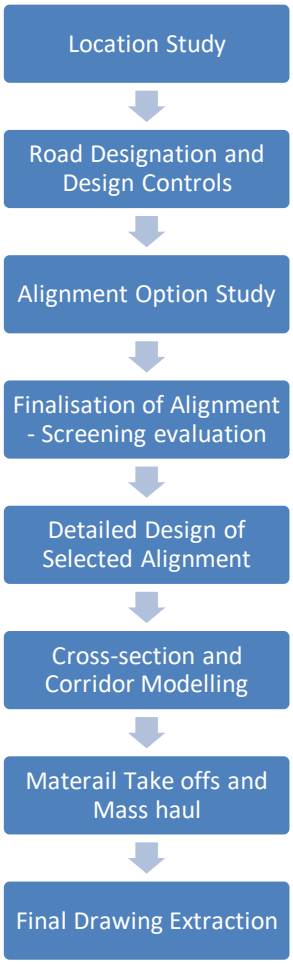
2.2 Assignment Details and Methodology

Group-6 has been assigned with following roads

Table 1: Group 6 assigned roads

S. No.	Road Name	Fuc Classification	Terrain Type	ADT	Design Speed
1	E611	Major Rural Arterial	Rolling	10000	135
2	Dubai-Hatta Rd	Minor Rural Arterial	Rolling	4000	130
3	E44	Minor Urban Collector	Rolling	3000	100

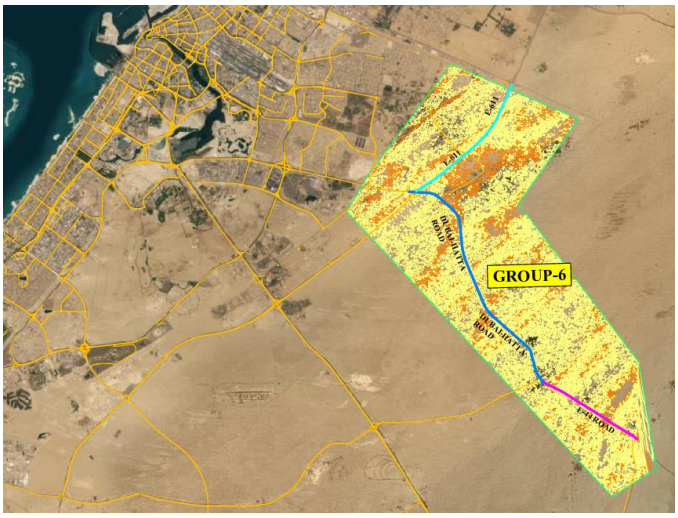
Flow chart presented below depicts the methodology and steps adopted to complete the assignment



Flow Chart for Highway Design Assignment

3 Map

Map of assigned roads is provided in drawing set of term project. Although a snapshot is presented in figure below,



4 Design Controls

Following are the design control based upon AASHTO

Table 2: Design Control Parameters

S. No.	Design Control Component	Road wise design control values as per AASHTO		
		E611	**Dubai-Hatta Rd**	**E44**
1	Design Vehicles	W-20	W-20	W-20
2	Design Speed (km/h)	135	130	100
3	Minimum radius of Curvature (m)	798	740	358
4	Lane Width and slope (m, %)	3.6m, 2%	3.6m, 2%	3.6m 2%
5	Shoulder/Parking Width and slope (%)	2.4m, 2%	2.4m, 2%	1.2m, 2%
6	K Value-Crest vertical curve	140	124	52
7	K Value-Sag vertical curve	80	73	45
8	Maximum vertical grade	4%	4%	7%
9	Minimum vertical grade	0.3%	0.3%	0.3%
10	Maximum allowed superelevation	10	10	10
11	Median (m)	2.4	2.4	1.2

5 Detailed Design Description

This section deals with calculation of design components based upon AASHTO. Description and calculation of design components such as curves radius, sigh distance based upon the input criteria of roads has been derived in following sub-sections:

5.1 Horizontal Alignment

This subsection includes the following information:

5.1.1 Plan view for every horizontal curve

Plan view and details of horizontal curves for each road assigned to group is presented in Annexure A1

5.1.2 Road wise Minimum radii/design radii as per AASHTO guidelines

$$Rmin = \frac{V^2}{g(e+f)}$$

V= Speed in km/h
e= allowed maximum super elevation in %
f= side friction

R_{min} for "E-611" Road

V=135km/h
e=10%
f=0.08 for (135km/h, 130km/h), 0.12(100km/h) and from Table 3.3 of AASHTO

$$Rmin = 797.25\ say\ 798m$$

R_{min} for Dubai-Hatta Road

$$Rmin = 739.25\ say\ 740m$$

R_{min} for E-44 Road

$$Rmin = 357.9\ say\ 358m$$

5.1.3 Curve layout/setting out and Station of PC and PT for every curve

Plan view and details of horizontal curves for each road assigned to group is presented in Appendix A.

5.1.4 SSD and PSD & calculations

Stopping Sight Distance (SSD)

Sight distance is the length of the roadway ahead that is visible to the driver. The available sight distance on a roadway should be sufficiently long to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path. Although greater lengths of visible roadway are desirable, the sight distance at every point along a roadway should be at least that needed for a below-average driver or vehicle to stop.

Stopping sight distance is the sum of two distances: (1) the distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied, and (2) the distance needed to stop the vehicle from the instant brake application begins.

Stopping Sight Distances for Group-6 Roads

S. No.	Road Name	Design Speed (V)	Reaction time (t) in seconds	Deceleration rate (a) in m/s^2	SSD in meters
1	E611	135	2.5	3.4	303
2	Dubai-Hatta Rd	130	2.5	3.4	285
3	E44	100	2.5	3.4	185

Passing Sight Distance

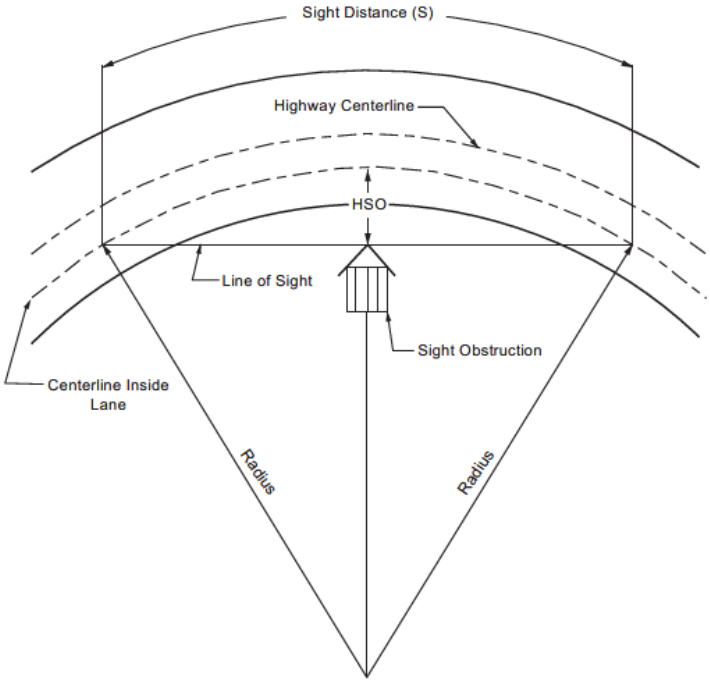
Most roads and many streets are two-lane, two-way highways on which vehicles frequently overtake slower moving vehicles. Passing maneuvers in which faster vehicles move ahead of slower vehicles are accomplished on lanes regularly used by opposing traffic. If passing is to be accomplished without interfering with an opposing vehicle, the passing driver should be able to see a sufficient distance ahead, clear of traffic, so the passing driver can decide whether to initiate and to complete the passing maneuver without cutting off the passed vehicle before meeting an opposing vehicle that appears during the maneuver.

PSD as per AASHTO

S. No.	Road Name	Design Speed (V)	Speed of Passed Veh	Speed of passing Veh	PSD in meters
1	**E611**	**135**	**-**	**-**	**-**
2	**Dubai-Hatta Rd**	**130**	**111**	**130**	**440**
3	**E44**	**100**	**81**	**100**	**320**

5.1.5 Sight obstruction distance

On a tangent roadway, the obstruction that limits the driver's sight distance is the road surface at some point on a crest vertical curve. On horizontal curves, the obstruction that limits the driver's sight distance may be the road surface at some point on a crest vertical curve or it may be some physical feature outside of the traveled way, such as a longitudinal barrier, a bridge-approach fill slope, a tree, foliage, or the backslope of a cut section. Accordingly, all highway construction plans should be checked in both the vertical and horizontal plane for sight distance obstructions.



$$HSO = Rv\left[1 - \cos\frac{90 * SSD}{pi * Rv}\right]$$

where:

HSO = Horizontal sight line offset, m

SSD = Stopping sight distance, m

R = Radius of curve, m

Horizontal Sight line Offset for Group-6 Roads

S. No.	Road Name	Design Speed (V)	H Radius	SSD in meters	HSO in meters
1	E611	135	798	303	14.34
2	Dubai-Hatta Rd	130	740	285	13.70
3	E44	100	358	185	11.89

5.1.6 Super elevation transition

The design of transition sections includes consideration of transitions in the roadway cross slope and possible transition curves incorporated in the horizontal alignment.

The superelevation transition section consists of the superelevation runoff and tangent runout sections. The superelevation runoff section consists of the length of roadway needed to accomplish a change in outside-lane cross slope from zero (flat) to full superelevation, or vice versa. The tangent runout section consists of the length of roadway needed to accomplish a change in outside-lane cross slope from the normal cross slope rate to zero (flat), or vice versa. To limit lateral acceleration, the pavement rotation in the superelevation transition section should be achieved over a length that is enough to make such rotation imperceptible to drivers. To be pleasing in appearance, the pavement edges should not appear distorted to the driver.

Transition length(L) = Minimum length of runoff (Lr) + Minimum length of tangent runout (Lt)

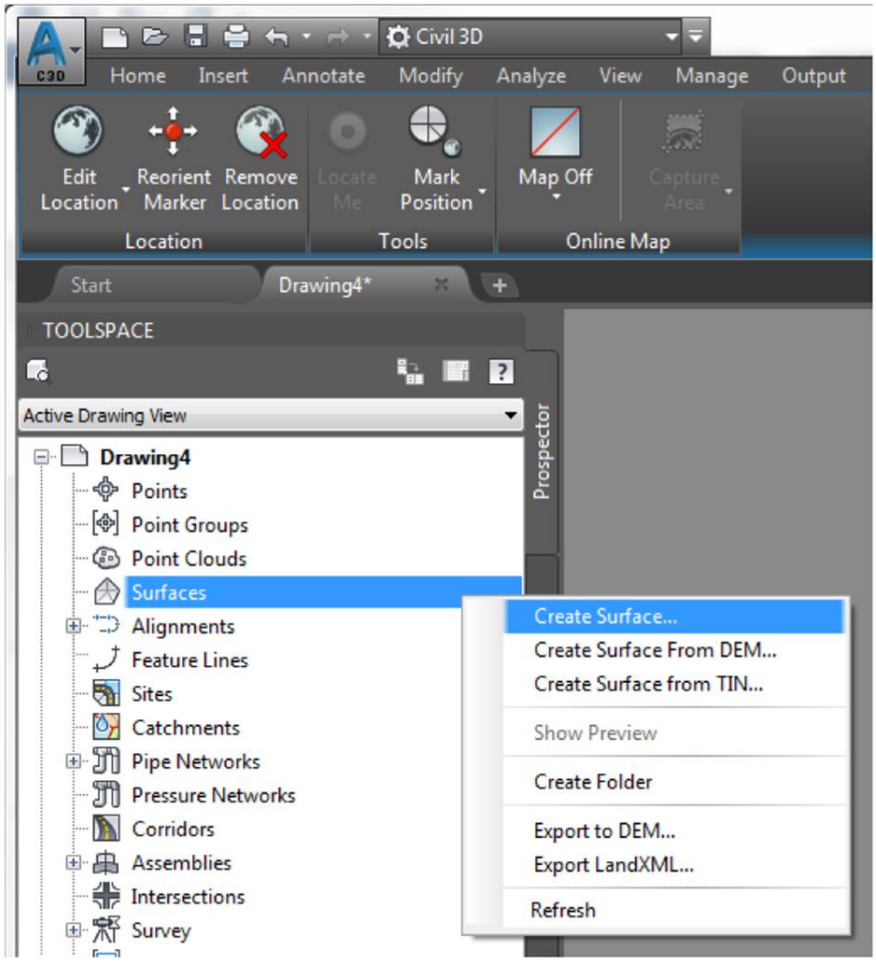
Minimum length of runoff calculated based upon AASHTO

Transition Length for Group-6 Roads

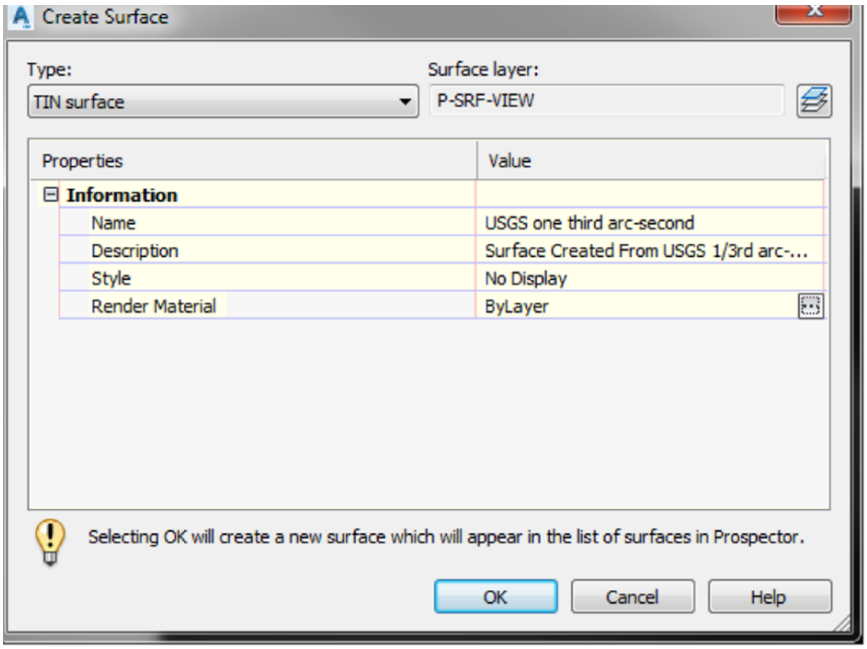
S. No.	Road Name	Design Speed (V)	Super elevation (%)	Width of lane	No. of lanes rotated	Adjustment factor	Max. relative gradient*	Lr,m	Lt,m	Transition Length, L=Lr+Lt
1	E611	135	10	3.6	2	0.75	0.31	174	35	209
2	Dubai-Hatta Rd	130	10	3.6	2	0.75	0.35	154	31	185
3	E44	100	10	3.6	2	0.75	0.44	123	25	147

5.1.7 Creation of Surface using DEM

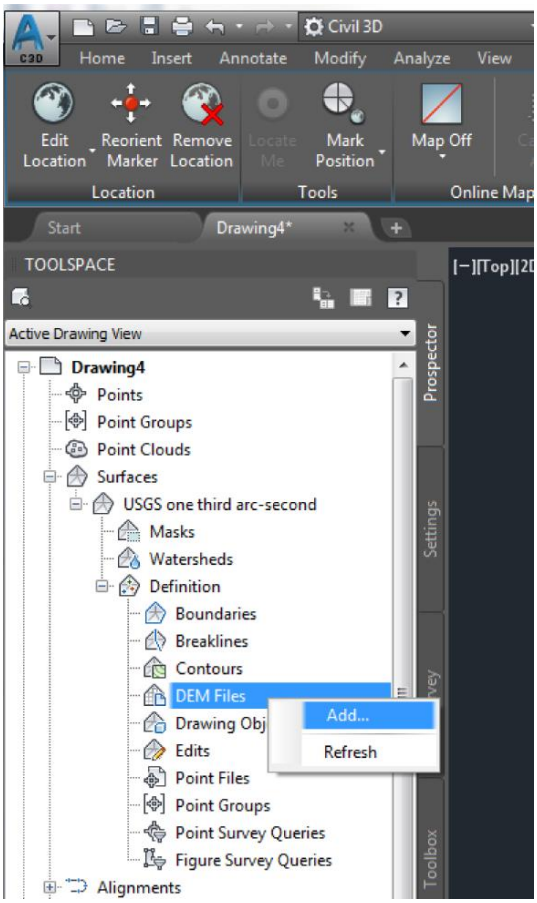
1) Open Civil3D, go to the prospector pane and right click on surface, select “Create Surface” as shown in image below.



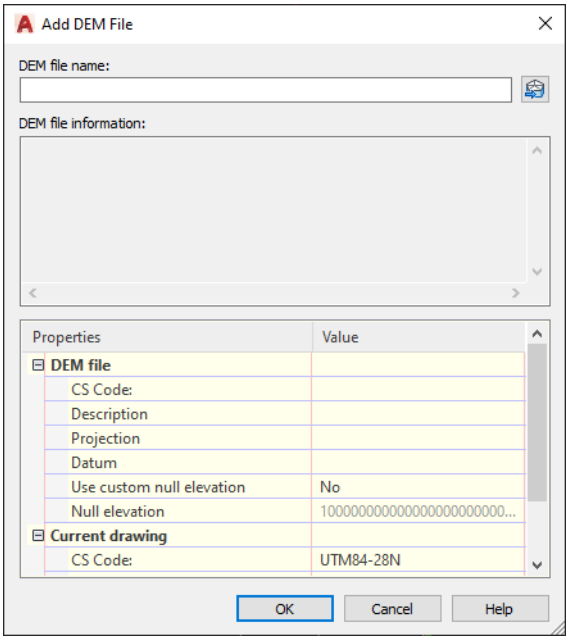
2) Select a surface style that will have all display options turned off. Typically, this style is called “No Display”



3) In the prospector expand the Surface Menu then Expand the Surface you just created then expand the “Definition” menu and right click “DEM Files” then choose “add”.

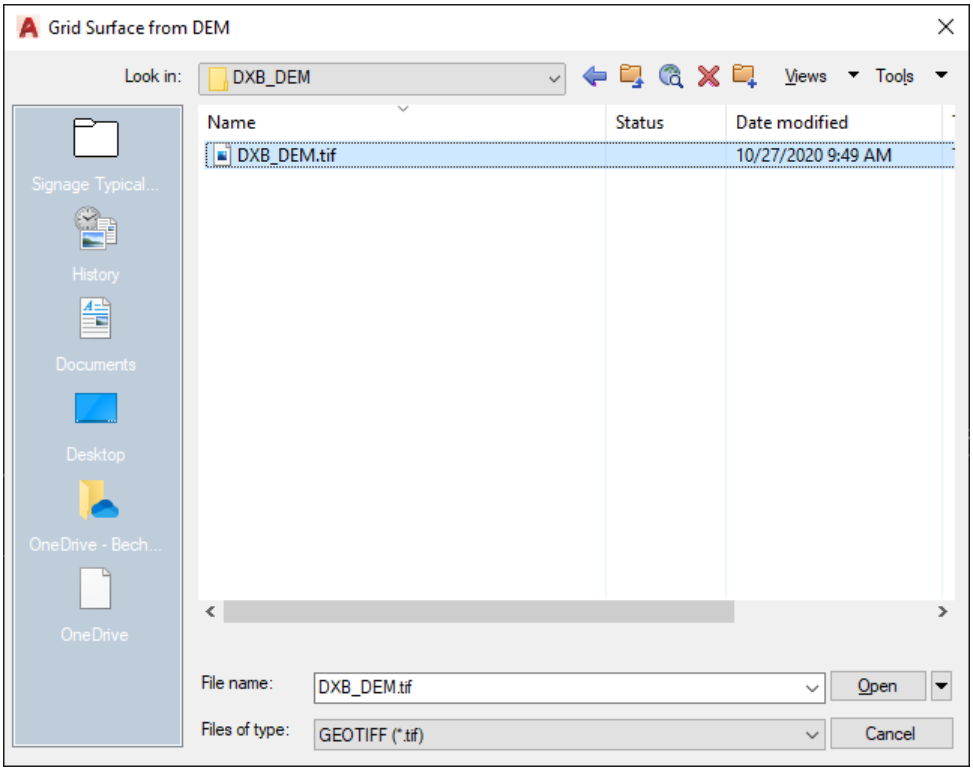


4) Click the button to browse for your DEM file.

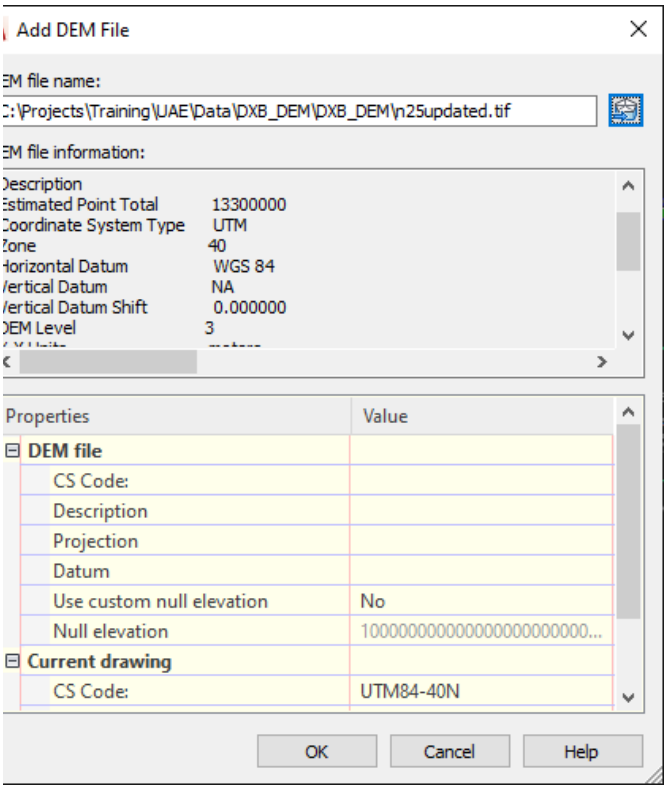


Note: Please make sure drawing should already be saved with UTM coordinates of that project influence area. (in case of UAE it is UTM WGS84-40N)

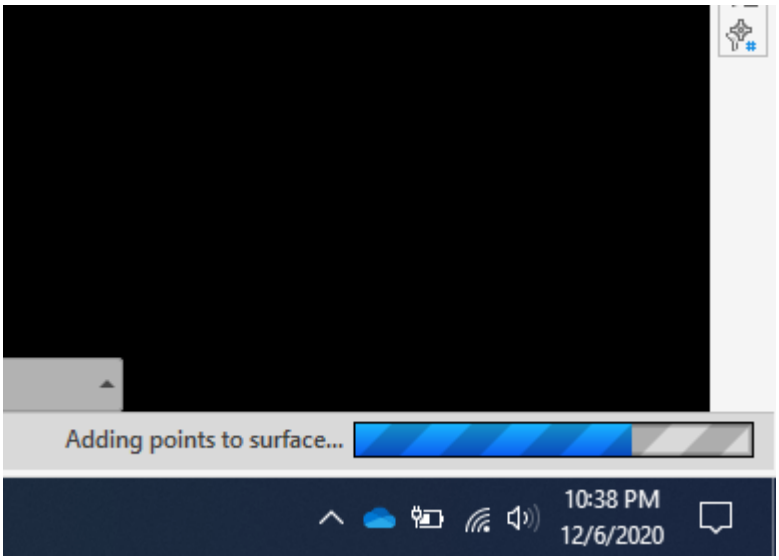
5) Open the folder where converted tiff image is parked. Select the tiff image and click "**open"**.



6) Click "ok" on next window

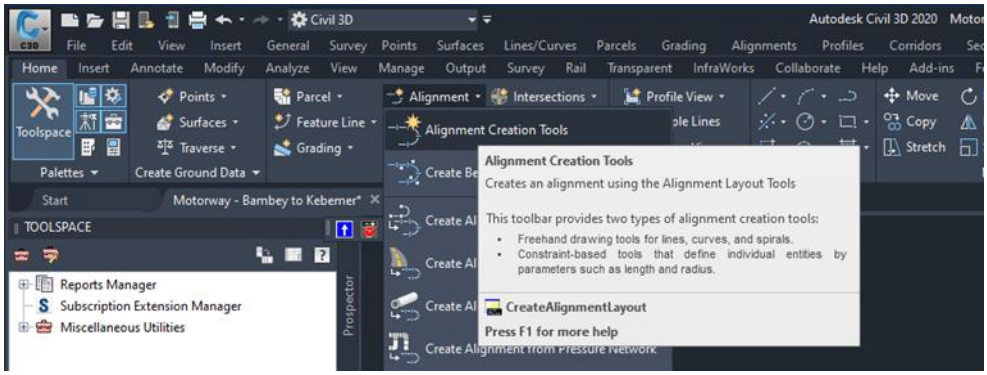


7) AutoCad Civil 3d will now process the data. You will notice a blue bar in the lower right corner sweeping from left to right while Autocad inserts points into your drawing. And surface is ready to use.

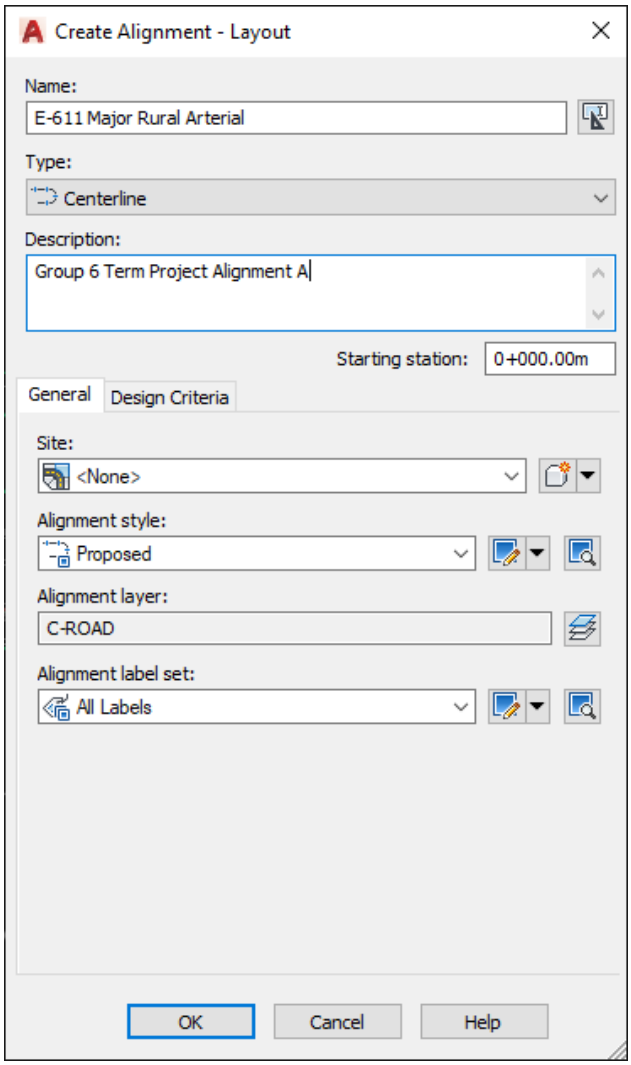


5.1.8 Horizontal Alignment creation in Civil3D

1) Click Home tab → Create Design Panel → Alignment drop-down → Alignment Creation Tools Find.



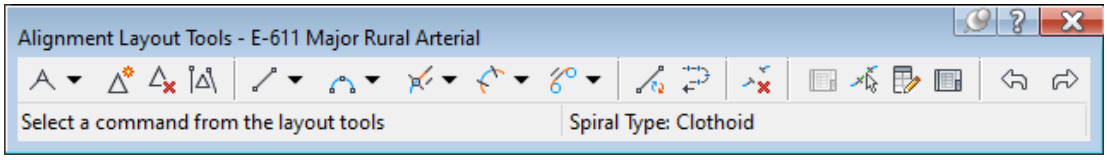
2) In the Create Alignment - Layout dialog box, enter a unique name for the alignment.



3) Specify the alignment Type-**Centerline**
4) Enter an optional description- such as "E611 Major Rural Arterial **"**
5) Enter a starting station value- **0+000**
6) On the General tab, specify the following settings:

- Site Specify a site with which to associate the alignment or accept the default <None>.
- Alignment Style- "Proposed"
- Alignment Layer- Default
- Alignment Label Set –Major station at every 100m and minor station at every 50m

7) On the Design Criteria tab, specify a Starting Design Speed as per **design control**.
8) Click OK to display the Alignment Layout Tools toolbar.

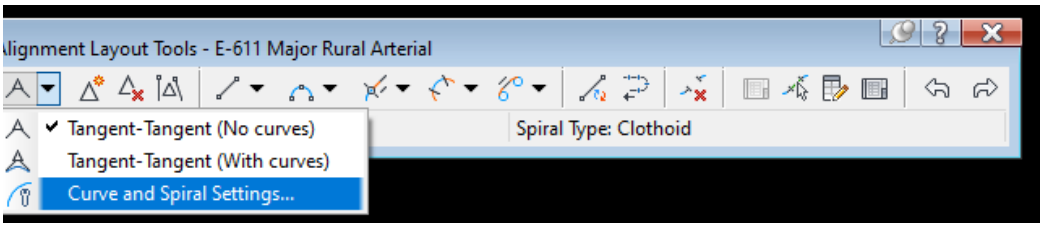


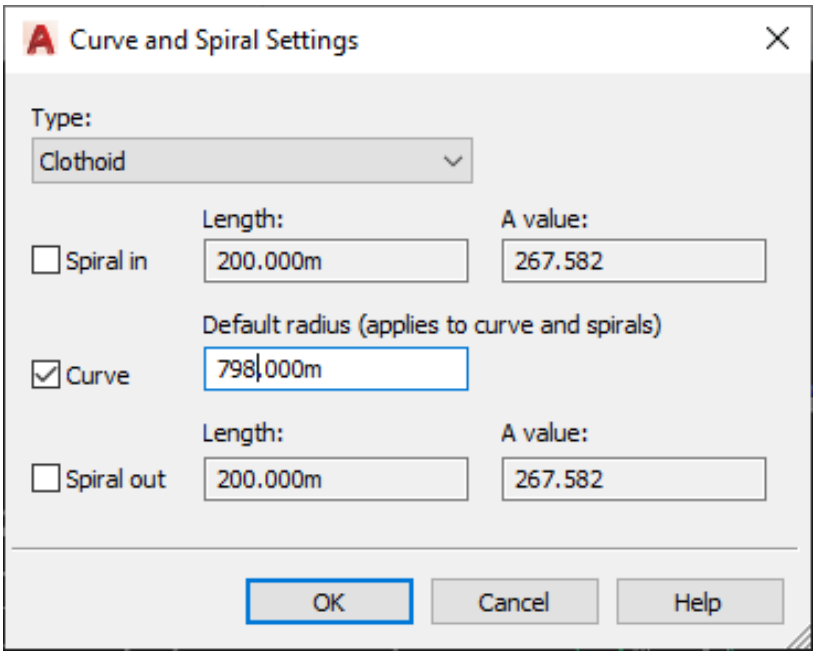
9) Use the commands on the Alignment Layout Tools toolbar to draw the alignment.

The Civil 3D Alignment by Layout (Alignment creation tools) has several tools to perform site specific design by layout. For example, you can:

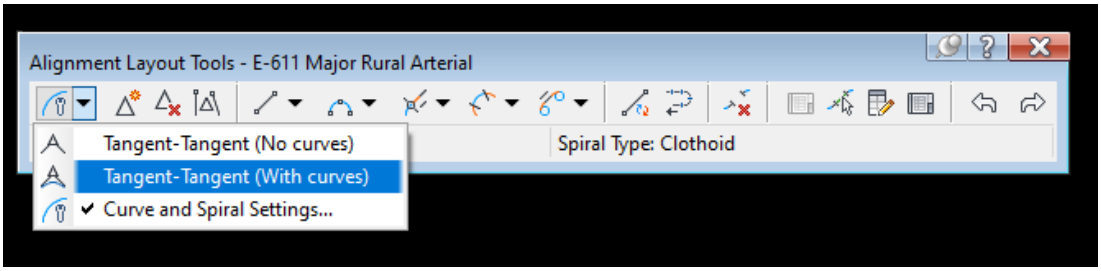
- Design tangents, curves, and spirals, with specifics tangency requirements.
- Add or remove PIs (Point of Intersections),
- Convert AutoCAD lines or arcs to alignment entities,
- Reverse or edit created layout entities,
- Delete or select sub-entities, and
- Display a tabular view of design elements.

10) Design horizonal radius is 798m (minimum for E611) is being used. So, let's set that parameter. On the creation tools toolbar, click on **Curve and spiral settings.**





11) Now, start designing the alignment by running the **Tangent-Tangent (With curves)** command from the creation tools. It will automatically create a curve with a radius value. Exactly like we specified in the **Curve and Spiral Settings**, whenever we create two subsequent tangents. Whenever possible, always design your alignment from west to east and south to north.



12) 10% of superelevation is provided. However, alignment has horizontal curves with large radius and curves are capable for safe movement of road users.

5.2 Vertical Alignment

5.2.1 Philosophy of design

Normally, the goal of the road engineer is to balance earthwork so that the volume of fill equals the volume of cut plus any gain from bulking less any loss from shrinkage. Road cuts and fills tend to increase with smooth, horizontal and vertical alignment. Conversely, short vertical and horizontal tangents tend to reduce cuts and fills. Erosion rates can be expected to be lower in the latter case.

Vertical curves require proper consideration to minimize earthwork, cost, and erosion damage. Proper evaluation requires an analysis of vertical curve requirements based on traffic characteristics (flow and safety), vehicle geometry, and algebraic difference of intersecting grades. Vertical curves should be simple in application and should result in a design that enables the driver to see the road ahead, enhances vehicle control, is pleasing in appearance, and is adequate for drainage.

Vertical curves provide the transition between an incoming grade and an outgoing grade. For convenience in design, a parabolic curve is used because the grade change is proportional to the horizontal distance. The grade change is the difference between incoming grade and outgoing grade. The shorter the vertical curve can be kept, the smaller the earthwork required.

Although earthworks are an important parameter to be considered but at the same time for mobility and safety of road users, following design parameters are also considered in design of the assigned roads to group-6,

5.2.2 Minimum vertical curves lengths

Length of a crest vertical curve

Minimum vertical curve lengths (Crest) for Group-6 Roads

S. No.	Road Name	Design Speed (V)	Curve Length (Every change of grade, A)				
			1	2	3	4	5
1	E611	135	698	558	419	279	140
2	Dubai-Hatta Rd	130	617	494	370	247	123
3	E44	100	258	206	155	103	52

Length of a sag vertical curve

Minimum vertical curve lengths (Sag) for Group-6 Roads

S. No.	Road Name	Design Speed (V)	Curve Length (Every change of grade, A)				
			1	2	3	4	5
1	E611	135	231	185	138	92	46
2	Dubai-Hatta Rd	130	214	171	128	86	43

3	E44	100	127	101	76	51	25

5.2.3 Minimum and Maximum Gradients

Highways and streets should be designed to encourage uniform operation throughout. The grades of vertical alignment depend upon the vehicle type, speed and other geometric and human parameters. AASHTO provides detailed literature and justification on grades for safety of road users. Please refer table 2 of this report to get the of assigned roads based upon the type of functional class of roads.

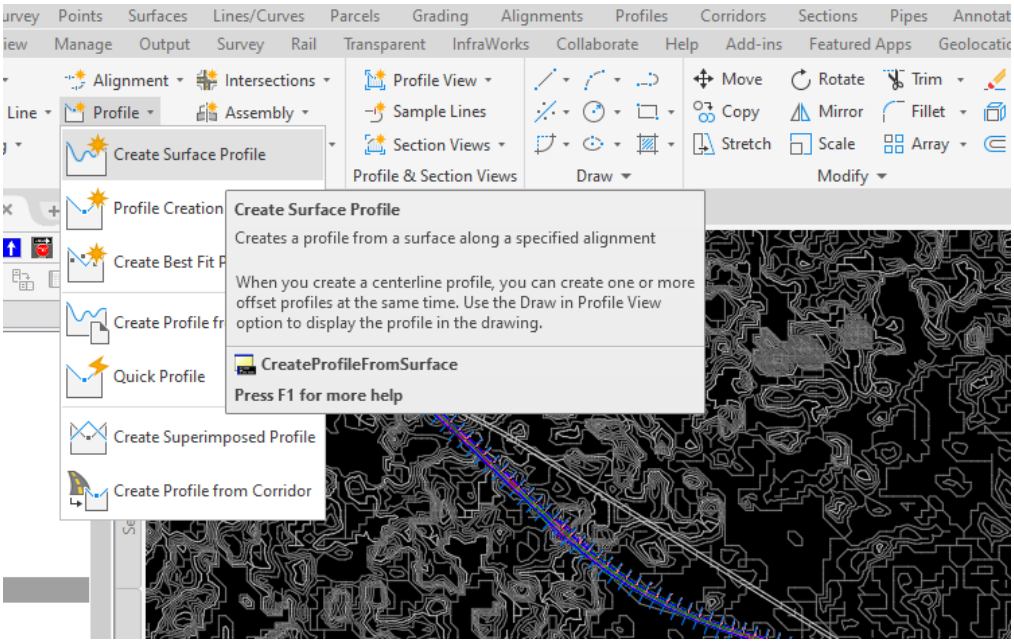
5.2.4 Curve layout/setting out and Stations of PVC & PVT

Plan view and details of verticals curves for each road assigned to group is presented in Appendix A (in Tabular or Graphic format)

5.2.5 Creation of Vertical Alignment creation in Civil3D

A. Creation of Surface Profile

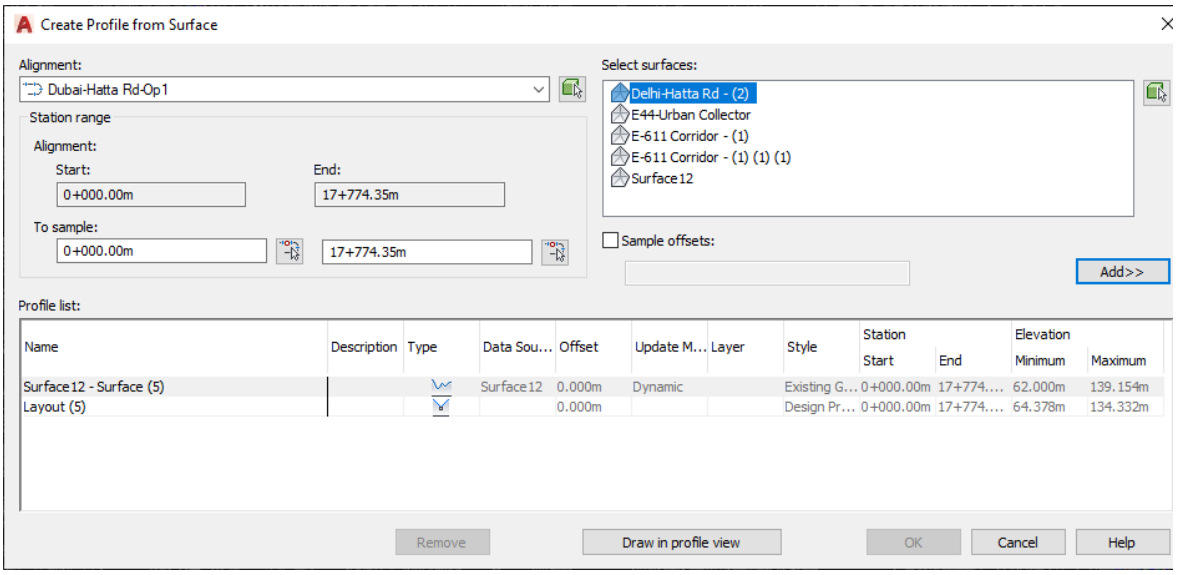
1) From the Home Ribbon →*Create Design Tab* →*Profile* →*Create Surface Profile*



- The profile will use the entire alignment unless you edit the stations you wish to assign the profile to under the Station Range section.

  *(*Note: sample distances left of centerline are designated as a "negative" distance. Left bank and right banks, in this case, are sampled 15' off centerline, with 0 marking the centerline of the alignment).*

2) Select the Surfaces which is created ("Existing Surface") and click the Add button. The data will show up in the Profile List.



3) To change how the profile line will look in the Profile View, Click in the Style Column on the Profile you wish to change.
   - Use the pull downs to choose an appropriate style.
   - Pick OK.

4) Click the Draw in Profile View Button
   - Select your alignment
   - Name the profile you are creating
   - Choose a Profile View Style-Keep Default
   - Click Next
   - Adjust the Station Range if needed by clicking the User Specified Range Button*
   - Click Next
   - Adjust the Profile View Height if needed by clicking the User Specified Button*
   - Click Next
   - Double check or change your Profile Display Options
   - Click Next
   - Click Next to advance through the Pipe/Pressure Network Option
   - Choose the Data Band style (Typically No Display)*
   - Click Next
   - If using hatching in your profile choose your hatch style*
   - Click Create Profile View

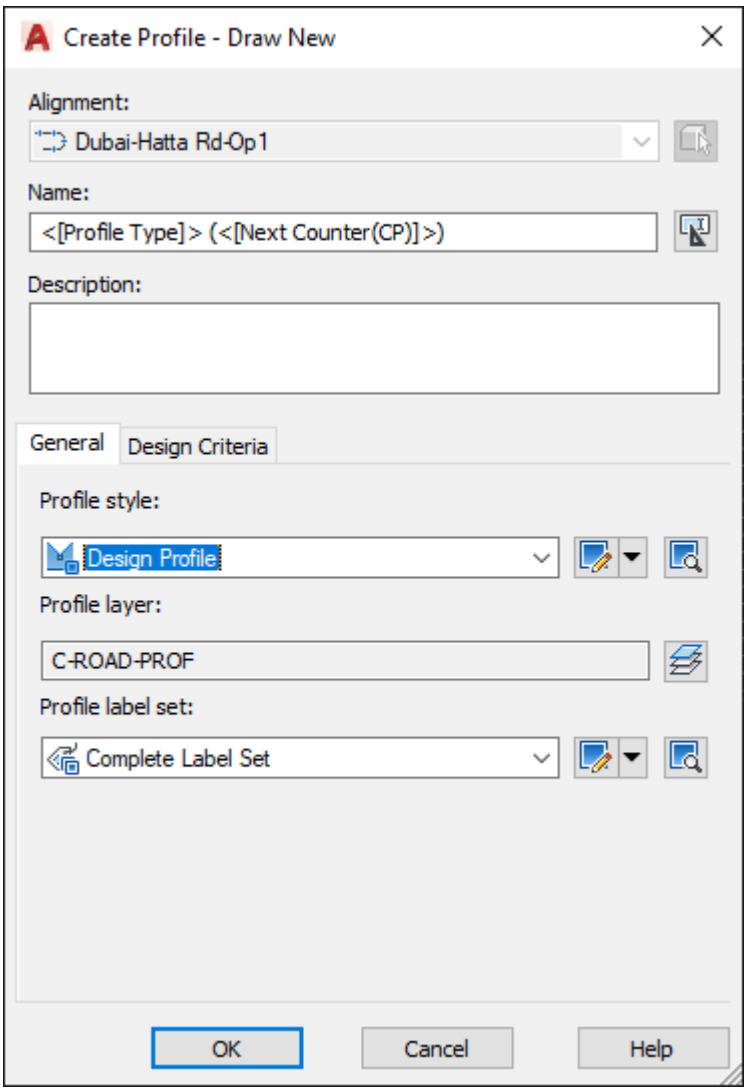
** Many of the Profile View options can be added/changed after the profile is created by clicking, then right clicking on a grid line and choosing Profile View Properties or Profile View Style as shown below. You can click the Create Profile View button at any time after naming your profile and selecting the Profile View Style to quickly create a profile.*

5) Select Profile View Origin by clicking in a blank area of Model Space and surface profile linked with alignment is created.

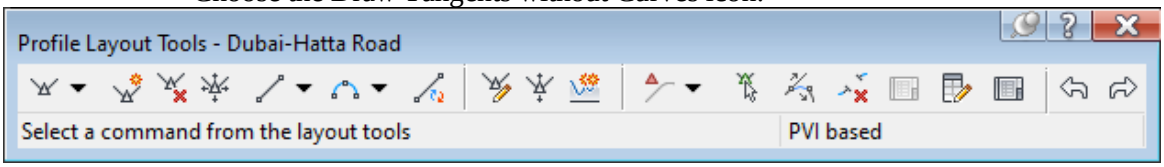
B. Creation of Vertical Alignment

1) From the Home Ribbon →Create Design Tab →Profile →Profile Creation Tools
   - Click on the Profile View you want to add a profile to
   - The Create Profile dialog box opens →Name the Profile
   - Choose a Profile Style
   - Choose a Profile Label Set such as Finished Ground – Default

- Click OK



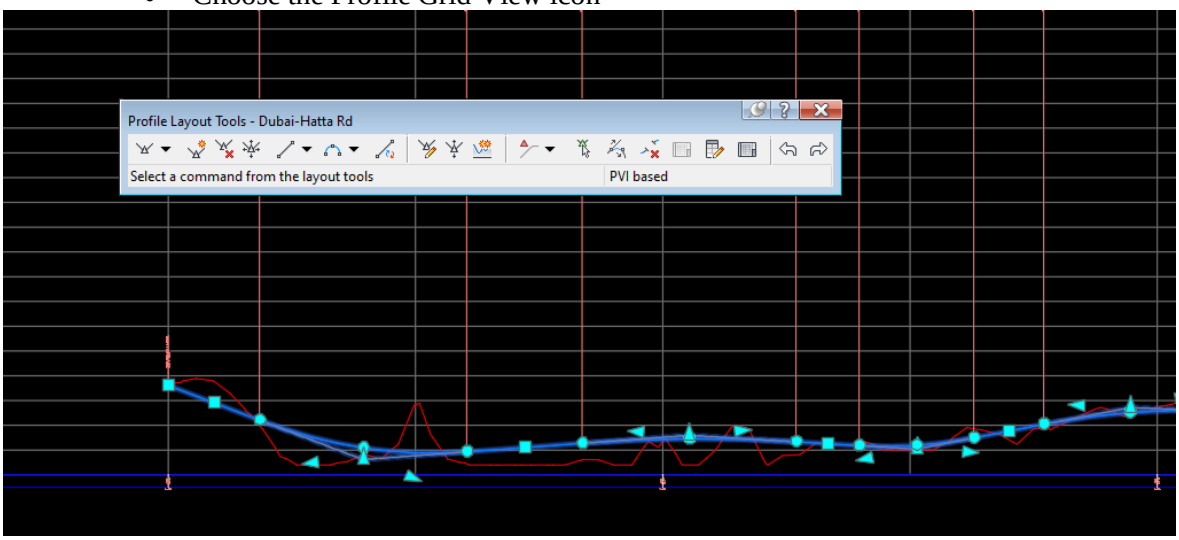
2) The Profile Layout Tools toolbar will automatically pop up.
   - Choose the Draw Tangents without Curves icon.



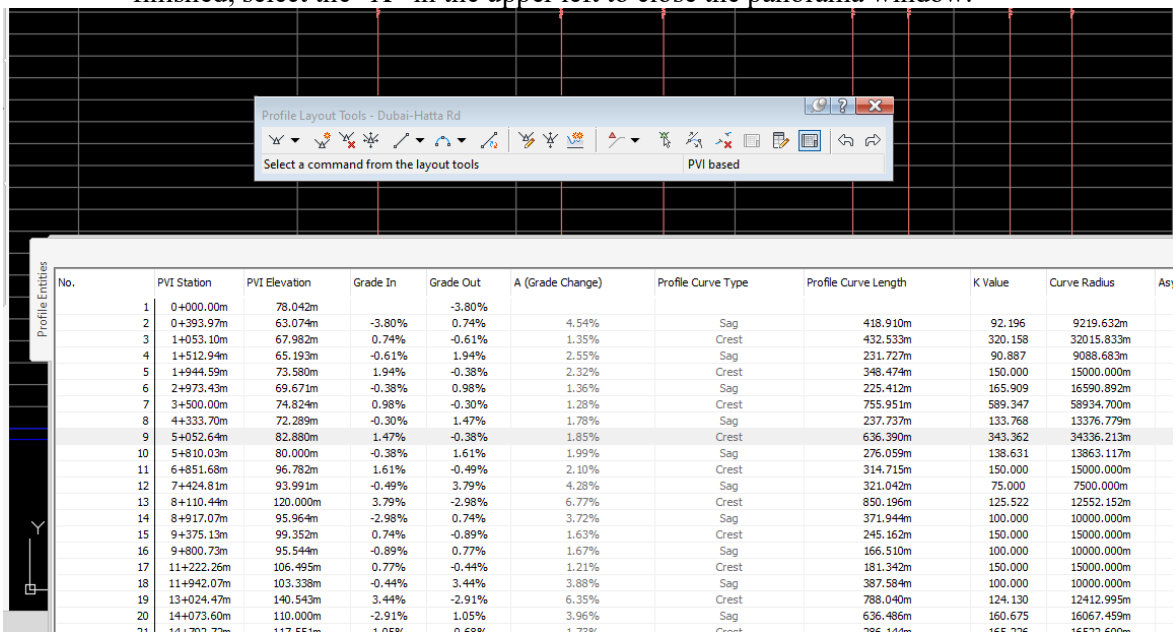
   - Starting at the beginning of your profile (0+00), draw roughly the grades and grade breaks (PVIs) you want along the profile.*
     **It is helpful to have Object Snap (F3) turned on at this point with Endpoint enabled. For best results snap to the endpoints of the Existing Ground (EG) profile when drawing your Finished Ground (FG) profile.*
   - When done, hit Enter.

3) To edit the line to exact grades, grade changes, and/or elevations:
   - Pick the FG line you just drew. Right-click.
   - From the menu, choose Edit Profile Geometry
   - Alternatively you can click on your FG line and choose the Geometry Editor icon from the contextual ribbon.
   - Either method will bring up the Profile Layout Tools toolbar.

- Choose the Profile Grid View icon



4) The panorama window opens up and you can edit grades, grade break locations, and elevations as needed by double-clicking in the boxes and editing the numbers. When finished, select the "X" in the upper left to close the panorama window.



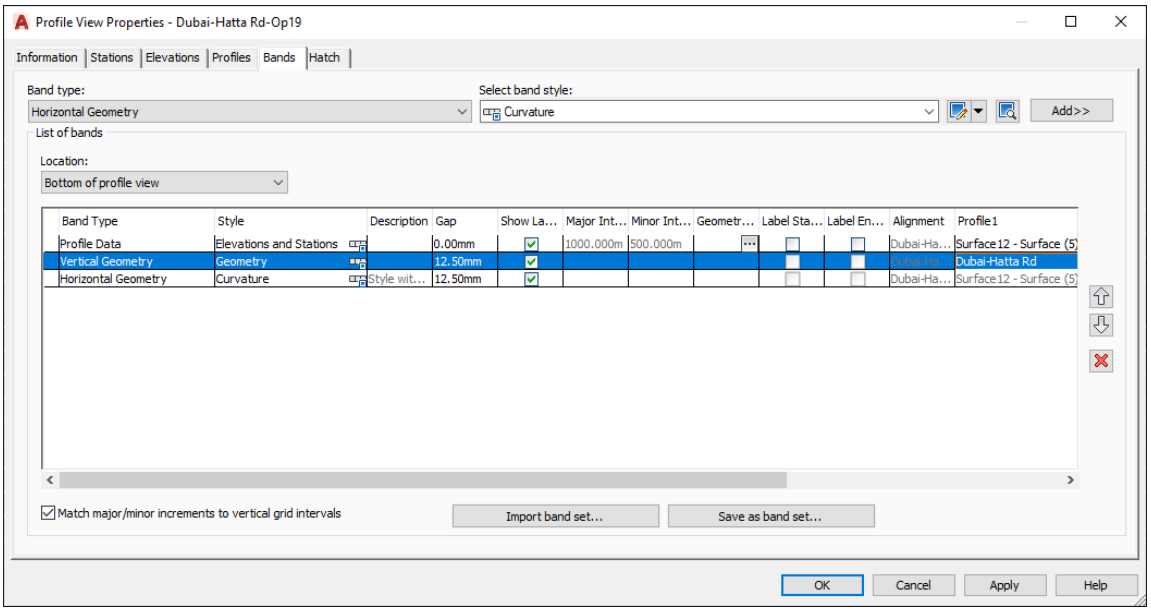
No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value	Curve Radius
1	0+000.00m	78.042m		-3.80%					
2	0+393.97m	63.074m	-3.80%	0.74%	4.54%	Sag	418.910m	92.196	9219.632m
3	1+053.10m	67.982m	0.74%	-0.61%	1.35%	Crest	432.533m	320.158	32015.833m
4	1+512.94m	65.193m	-0.61%	1.94%	2.55%	Sag	231.727m	90.887	9088.683m
5	1+944.59m	73.580m	1.94%	-0.38%	2.32%	Crest	348.474m	150.000	15000.000m
6	2+973.43m	69.671m	-0.38%	0.98%	1.36%	Sag	225.412m	165.909	16590.892m
7	3+500.00m	74.824m	0.98%	-0.30%	1.28%	Crest	755.951m	589.347	58934.700m
8	4+333.70m	72.289m	-0.30%	1.47%	1.78%	Sag	237.737m	133.768	13376.779m
9	5+052.64m	82.880m	1.47%	-0.38%	1.85%	Crest	636.390m	343.362	34336.213m
10	5+810.03m	80.000m	-0.38%	1.61%	1.99%	Sag	276.059m	138.631	13863.117m
11	6+851.68m	96.782m	1.61%	-0.49%	2.10%	Crest	314.715m	150.000	15000.000m
12	7+424.81m	93.991m	-0.49%	3.79%	4.28%	Sag	321.042m	75.000	7500.000m
13	8+110.44m	120.000m	3.79%	-2.98%	6.77%	Crest	850.196m	125.522	12552.152m
14	8+917.07m	95.964m	-2.98%	0.74%	3.72%	Sag	371.944m	100.000	10000.000m
15	9+375.13m	99.352m	0.74%	-0.89%	1.63%	Crest	245.162m	150.000	15000.000m
16	9+800.73m	95.544m	-0.89%	0.77%	1.67%	Sag	166.510m	100.000	10000.000m
17	11+222.26m	106.495m	0.77%	-0.44%	1.21%	Crest	181.342m	150.000	15000.000m
18	11+942.07m	103.338m	-0.44%	3.44%	3.88%	Sag	387.584m	100.000	10000.000m
19	13+024.47m	140.543m	3.44%	-2.91%	6.35%	Crest	788.040m	124.130	12412.995m
20	14+073.60m	110.000m	-2.91%	1.05%	3.96%	Sag	636.486m	160.675	16067.459m

- Remove or add a grade break by picking the appropriate tool on the Profile Layout Tools dialog box

C. Working with Data Bands

1) To Add or Modify Data Bands
   - Click anywhere on the profile grid. Right-click. Choose Profile View Properties. A window pops up with the same name.
   - Click the Bands tab. Select the Band Style you want and click ADD.

2) For the "Elevations and Stations" row, make sure the Profile 1 column has the Existing Ground (EG) centerline data and Profile 2 column has Finished Ground (FG) data.



3) When finished, click Apply and click OK. Elevation data on the bottom of the graph should match the profile lines for the existing and finished ground

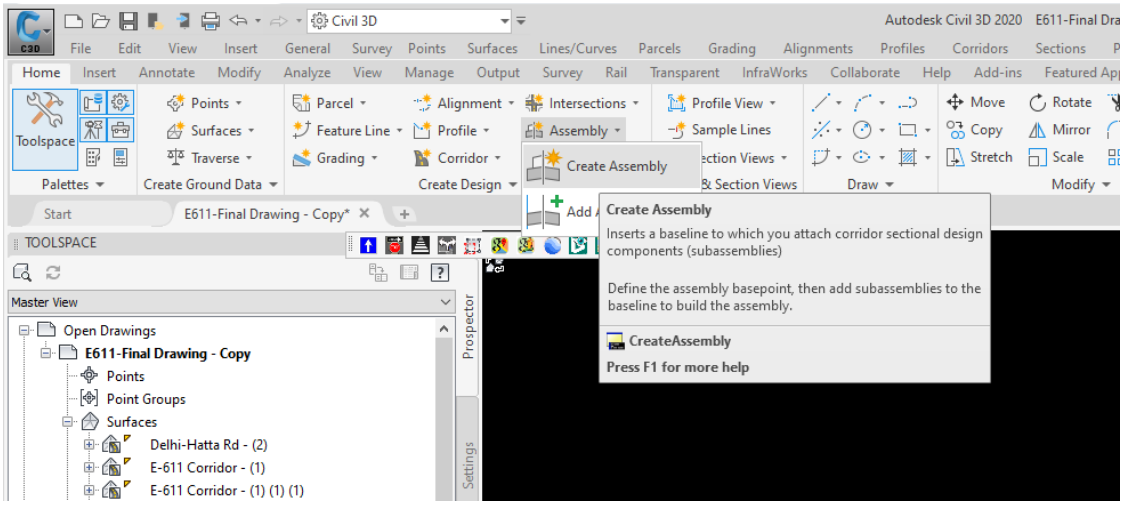
5.3 Cross Section and Assembly Creation:

5.3.1 Input Data

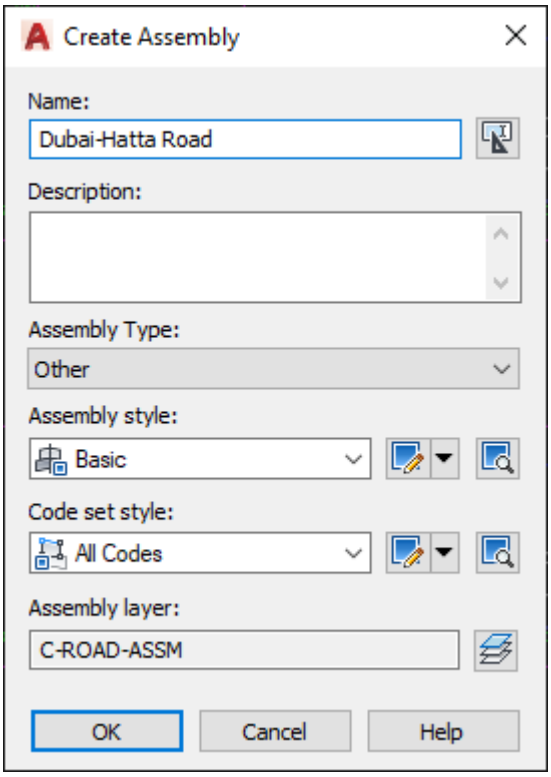
- Typical Cross sections of Cut and Fill both;
- Details of Paving and Earthworks (Slope protection, H:V etc.);
- Material associated with various components of cross-sections.

5.3.2 Create Assembly

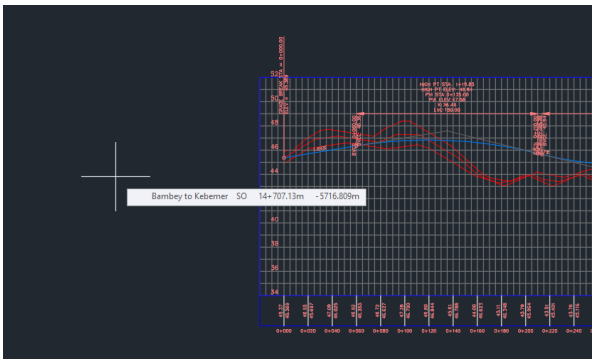
1) From the Home Ribbon →Create Design → Assembly→ Create Assembly

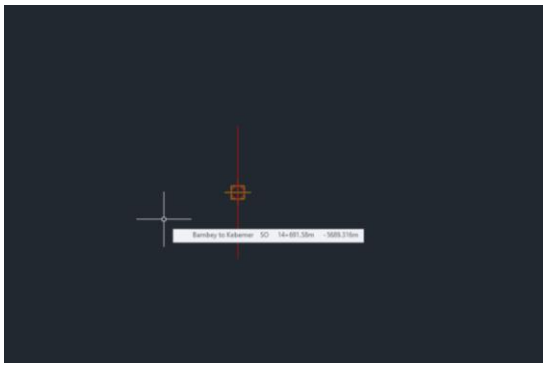


2) Name: “Dubai-Hatta Road-4 Lane” , Assembly Type- “ Divided Planar Road” and Press “OK”



3) Click somewhere in model (near to profile) to place the basic lane assembly, the viewport zooms to the assembly baseline, which looks like as image 2 on the right;



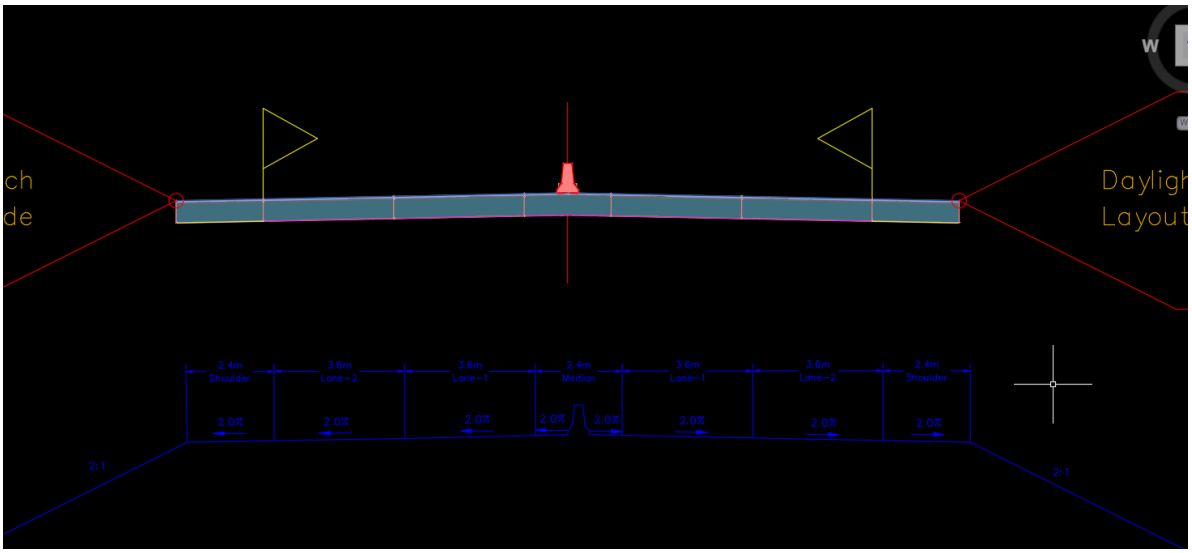


4) Click on the assembly baseline, "Assembly: Dubai-Hatta Road-4 Lane" tab will be activate and Click on "Tool Palette", Assembly library will open.

5) Assembly Library will open
6) Click on tab-"Assembly Metric", Common assemblies will be shown. Click on "Divided Highway"
7) Editing Assembly
   - "Divided Assembly" is one of the default assembly available in Civil3D, change the name of the assembly by right click on baseline and go to assembly properties.
   - "Divided assembly" contain various components called sub-assemblies. Select any subassembly→ right click → subassemblies properties to change the parameters as per proposed cross section.
   - Subassemblies can be deleted from assembly (default) which are not useful.

- Also added from toll palette to assembly to get the proposed cross section.

Following assembly used for corridor modelling of Dubai-Hatta Road. Details of the same is presented in term project drawing set.



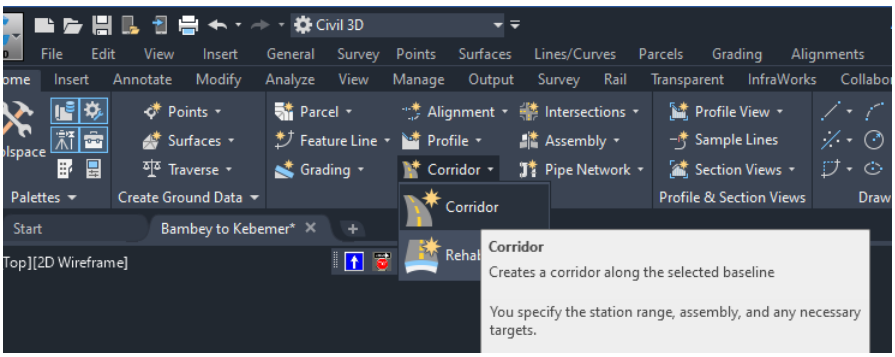
5.4 Corridor Generation:

5.4.1 Input Data

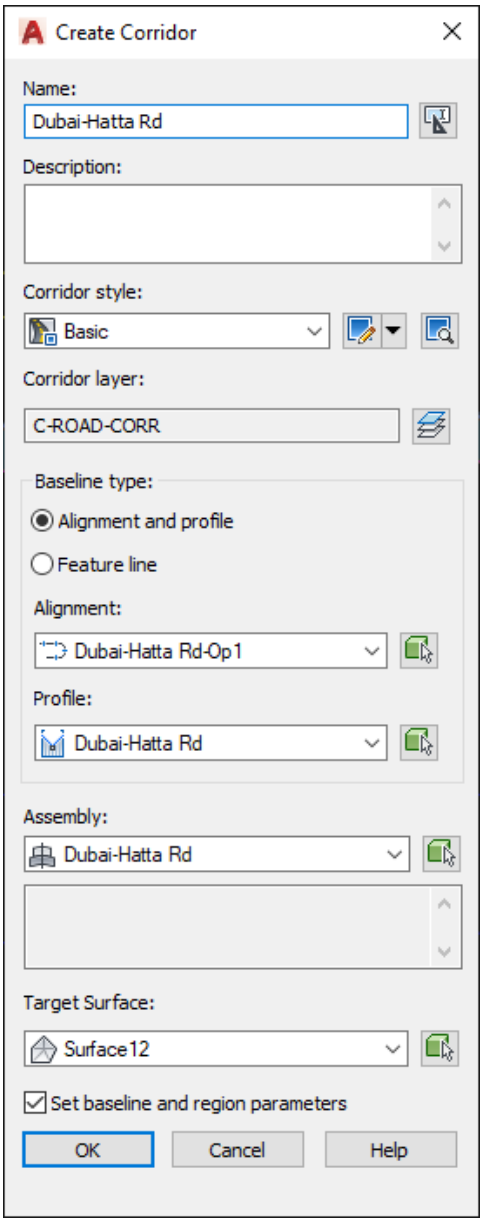
- Assembly for cut/fill sections
- Homogenous section details
- Target Surfaces
- Frequency of cross section

5.4.2 Creating Corridor

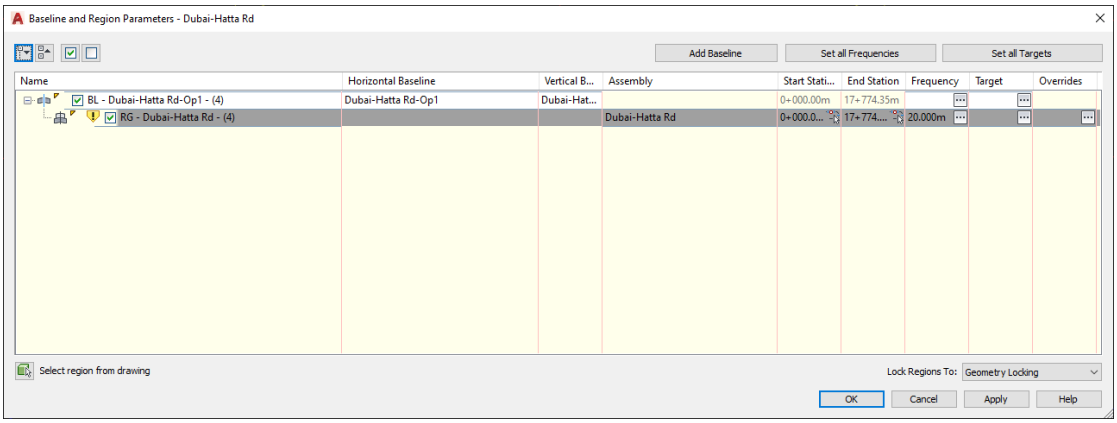
1) Click the Corridor command under the Home tab > Create Design panel > Corridor button.



2) Enter the Name: “Dubai-Hatta Road”, select the concerned aalignment, pprofile and assembly” , select Target Surface: “Existing Ground” . Click OK.



3) **Corridor Parameters:** The Baseline and Region Parameters dialog box organizes the display of the objects you selected to make the corridor. The first row contains the Baseline information meaning, the alignment, the profile, and the Starting and Ending Stations. The second row represents the first Region. The Region is nothing more than a station range between a starting and ending station typically representing something less than the full length of the Baseline alignment. There can be more than one Region under the Baseline. Regions can not have overlapping station ranges.

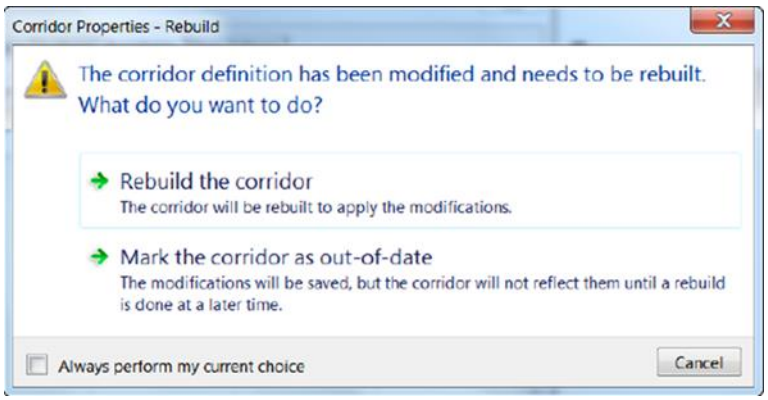


4) Frequencies of Corridor:

- After the baselines, the next main parameters we can change are the Frequencies. Frequencies dictate how often crosssections are inserted. This is particularly important at curves and vertical geometry locations.
- Frequency can be set individually for each region. For that, just click on the icon with three little dots, in the "Frequency" column, on each frequency line. Or, we can do it globally, for the entire corridor, by clicking on the "Set all Frequencies" button. Let's choose the latter option.
- In the Frequency to Apply Assembly dialog box, for now apply **50m** for all the baselines. Click **OK.**

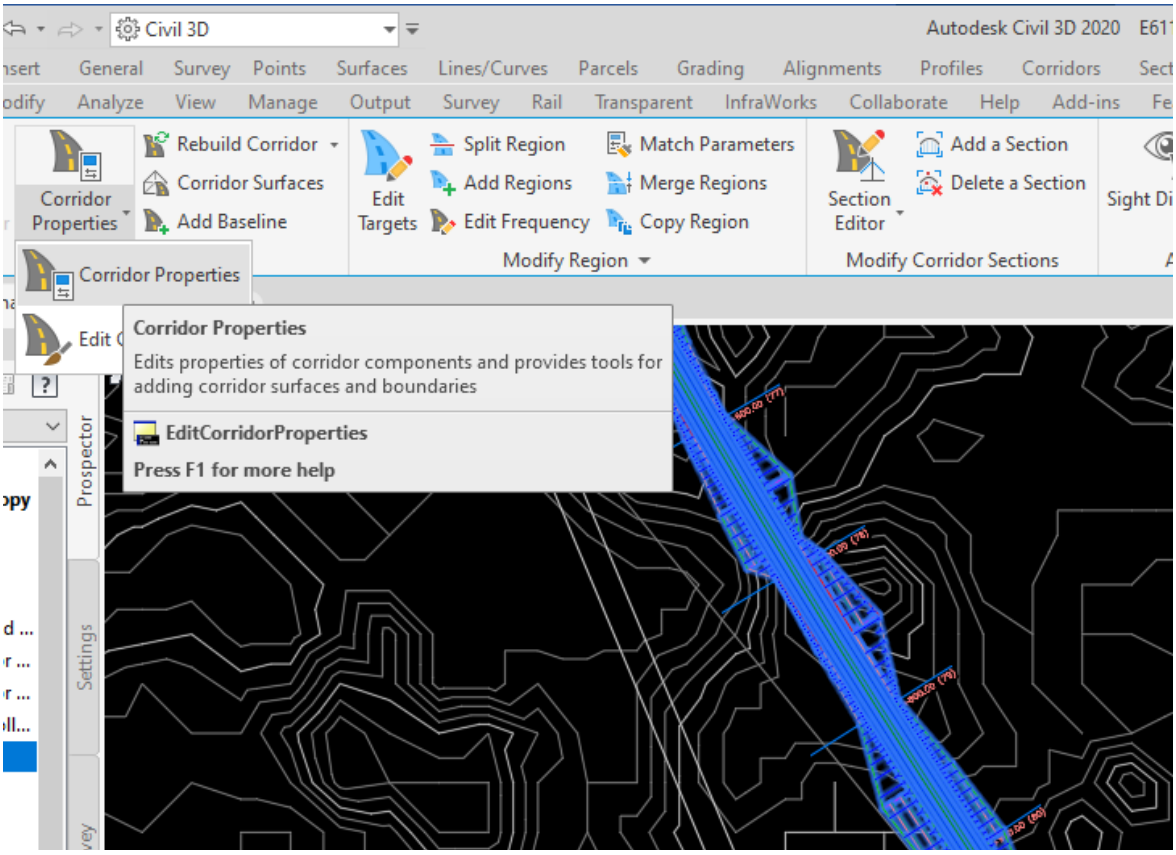
5) Target Surfaces of Corridor:

- After **baselines** and **frequencies**, the third type of parameter we can manage are **targets**. Targets enable us to connect to existing features, either by offset, elevation or projection to a surface. In this project, we have an existing surface that we need to tie to for embankment limit in cut/fill(daylight).
- Click on **Set All Targets** on the Parameters window.
- On the **Target Mapping** dialog box, we can set the three type of targets: **Surface, Width or Offset** and **Slope or Elevation.** Click OK. Click Rebuild the corridor.

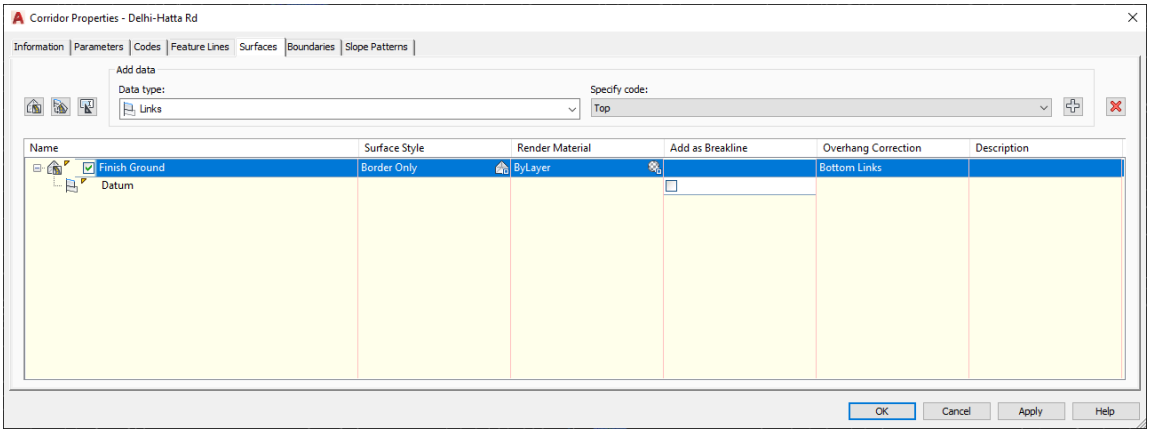


6) **Corridor Surface and Boundaries**

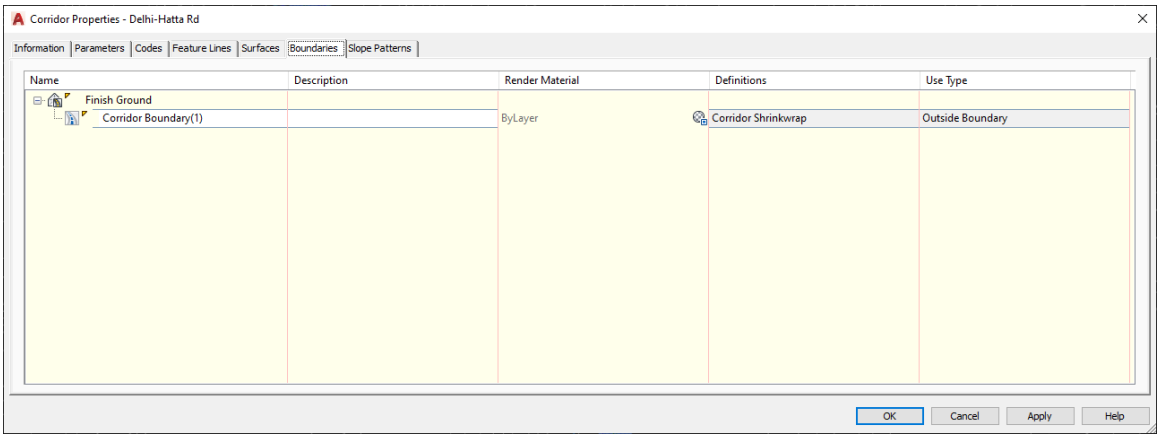
- Click the Corridor to activate Corridor: "Dubai Hatta Rd Corridor" tab and click on the corridor properties as shown in image below,



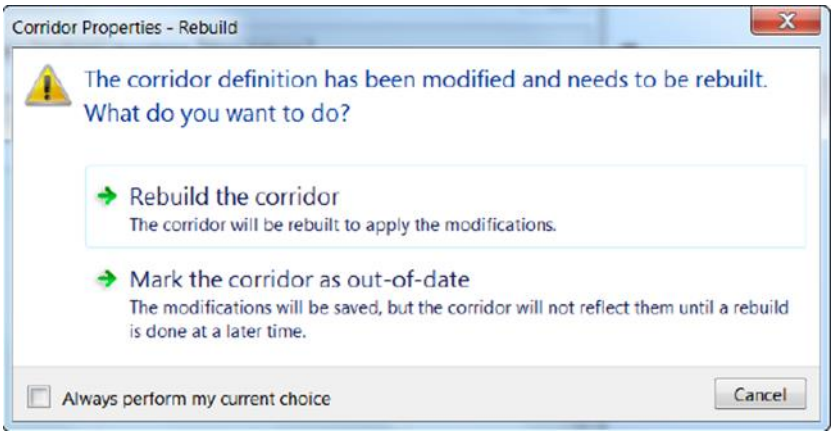
- Click the Surfaces tab. Click the Create a corridor surface button on the far left.
- Edit the surface name to **Finish Ground Sec-I**. Set the Surface Style to Border Only. With the Data type set to **Links** and the Specify code: set to **Top** click the + Add surface item button. Overhang Correction: **Bottom links**



- Click the Boundaries tab. Right click the **Finish Ground Sec-I** and click **Corridor extents as outer boundary**.



- Click OK. Click Rebuild the corridor.

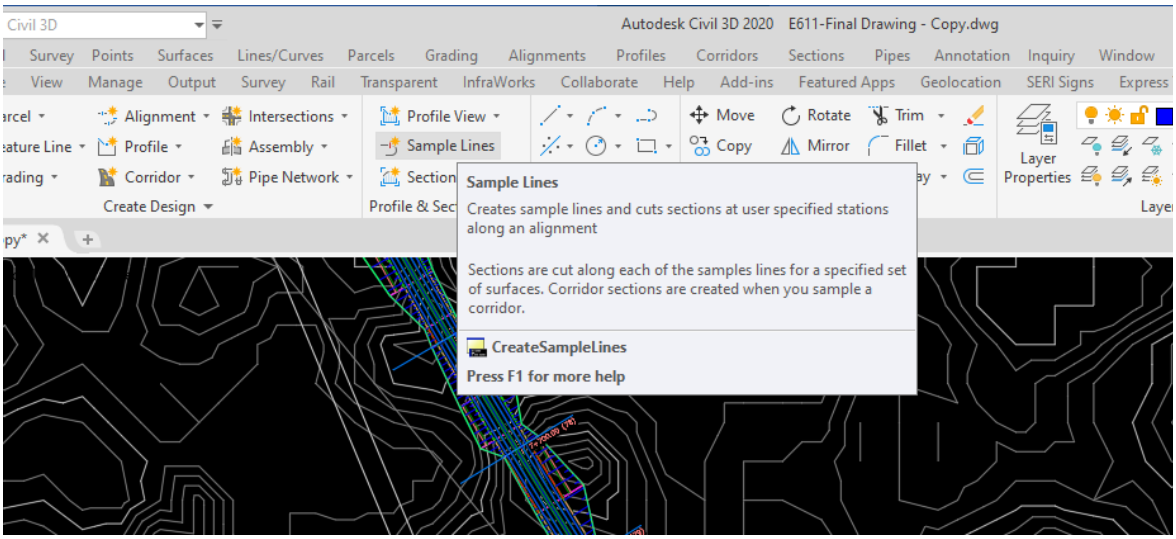


5.5 Sample Line and Cross Section Views

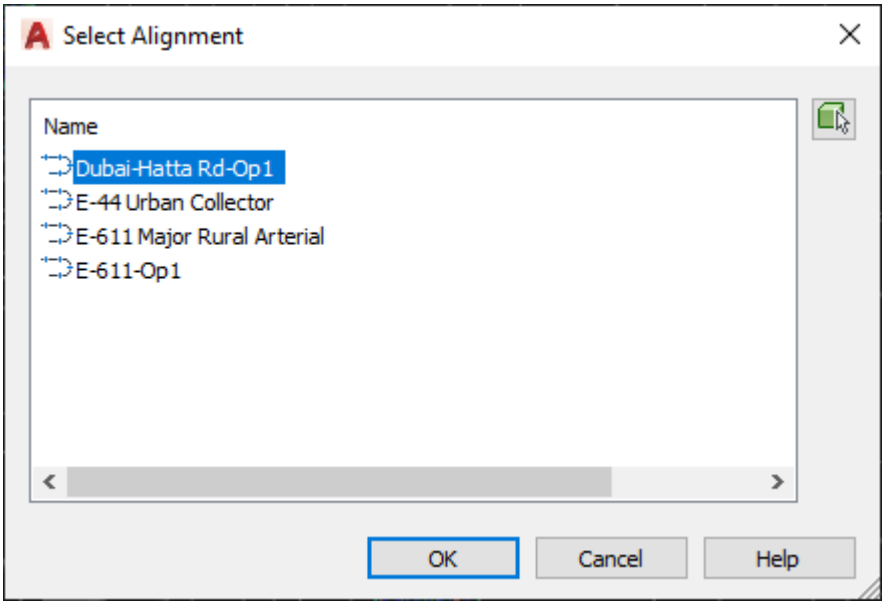
5.5.1 Sample Lines

The Civil 3d sample line creation wizard allows us to create crosssections. We can create them at given intervals, and at a specified left and right distance from the alignment centerline. In this project, we will create cross-sections at 50m intervals. To do this, we need to create sample lines that will represent the stations where the sections will be cut.

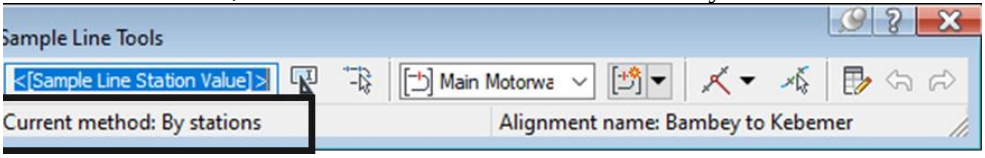
1) From the Home Tab → Profile and Sections Panel, select Sample Lines, then press Enter.



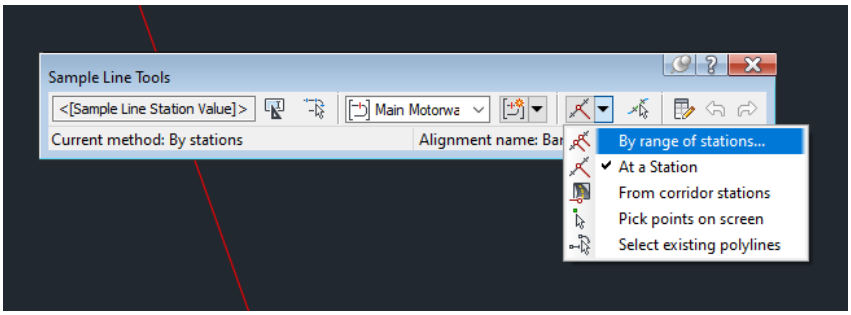
2) **"Right Click"** in Model Space, From the Select Alignment dialog, select **"Dubai -Hatta Rd-Op1"**, then Click OK.



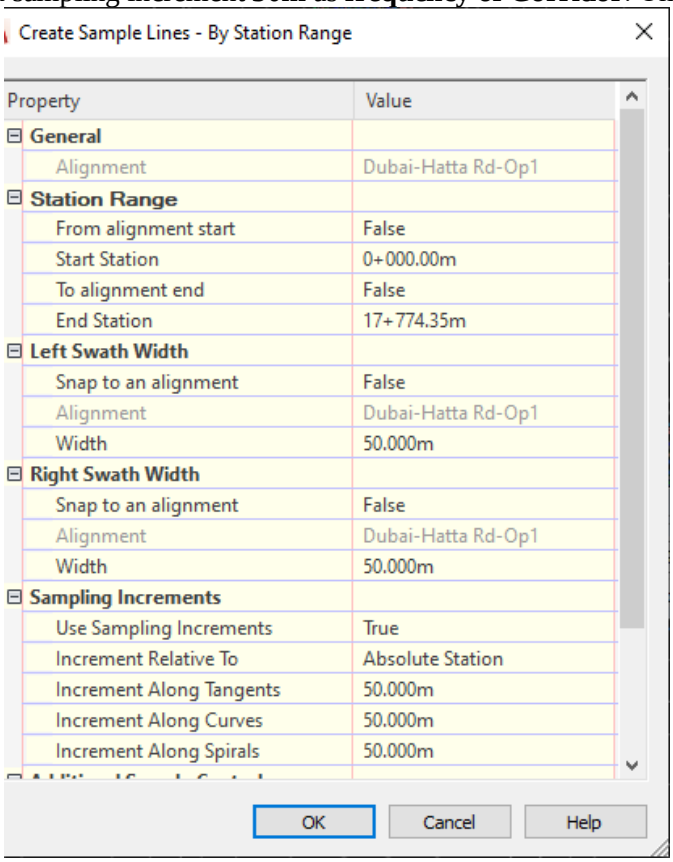
3) Next, we are presented with the Sample Line Tools that will enable us to create sample lines according to our specifications. It's not the most obvious thing to notice. But, the sample line creation method and the working alignment are displayed at the bottom of the toolbar. In this case, we can see that the current method is By Station.



4) Let's go ahead and provide more details for the sample lines creation. On the **Sample Line Tools**, create new sample lines **By range of stations**.



5) In the Create Sample Lines–By Station Range window, keep **Swath width-50m** both the sides and sampling increment **50m** as **frequency of Corridor**. Click "OK".

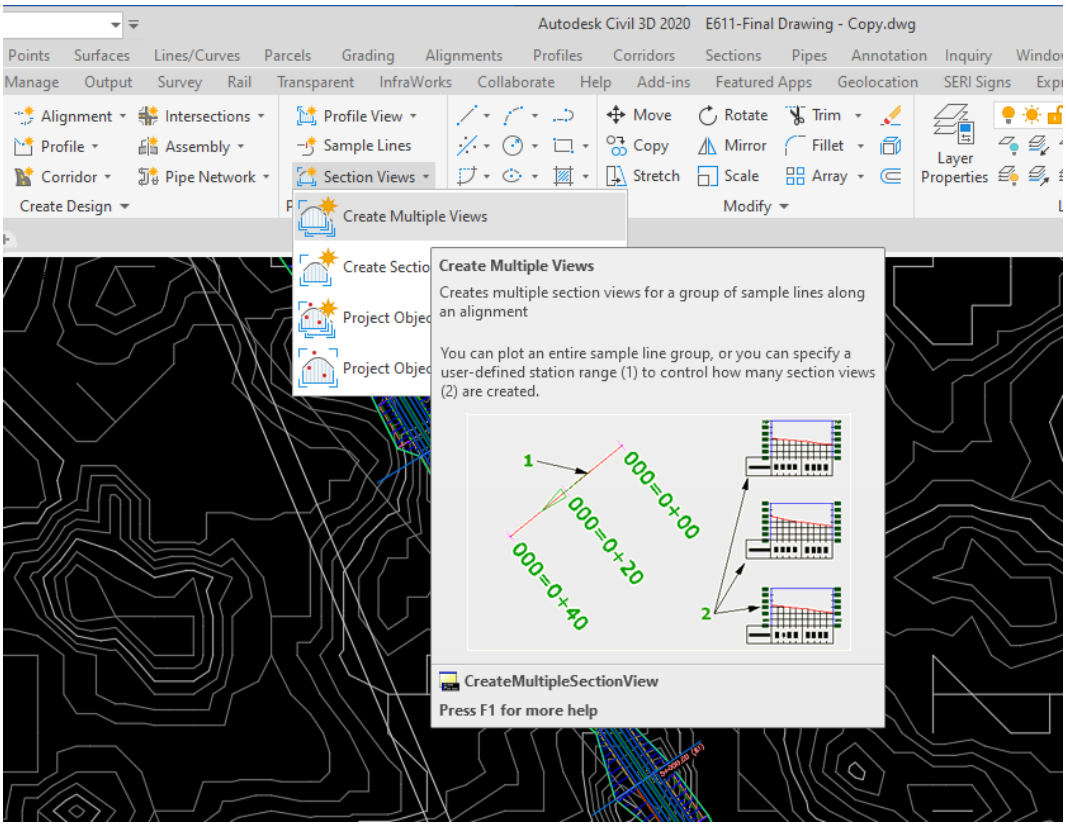


6) When requested to choose additional locations to create sample lines at the command line, hit Enter or Escape. Observe the sample lines created at each major station every 50m

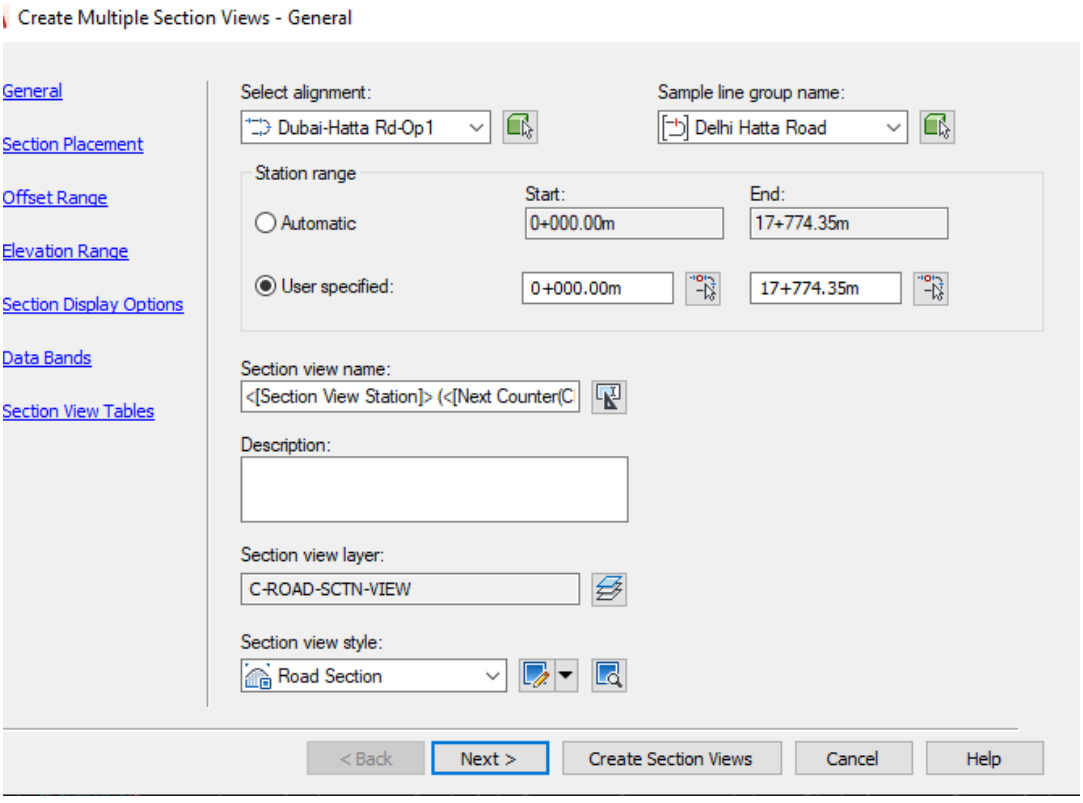
5.5.2 Cross Sections

In this exercise, Cross Section Views created for the Dubai-Hatta Road Centerline Alignment.

1) From the Home Tab → Profile and Sections Panel, select Section Views, then select Create Multiple Views.

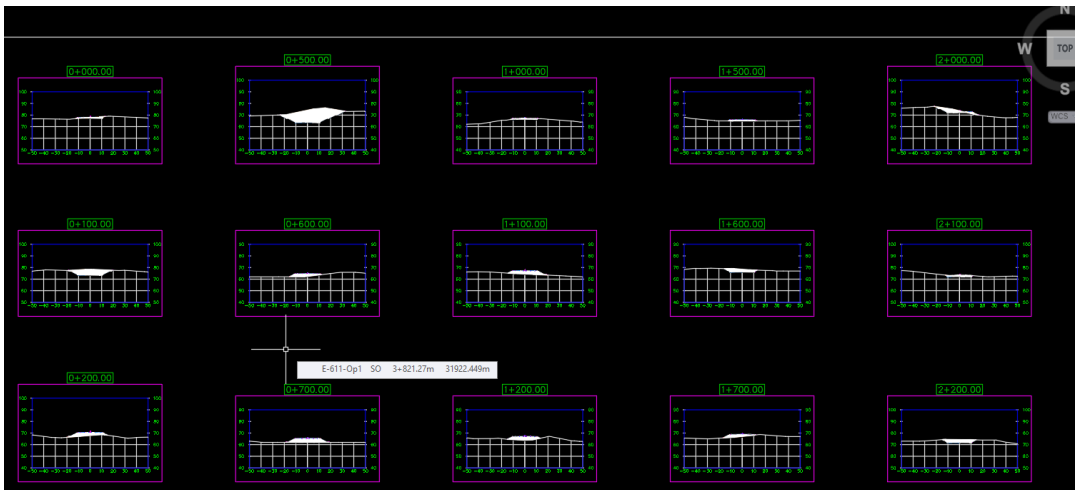


2) From Create Multiple Section Views - General dialog, Set Station Range to User specified, set Start to 0+000, set End station as per alignment end, set Section view style to "Road Section", then click on **Create Section Views** to create the sections.



3) Next, we are prompted at the command line to specify the origin of the section views.

4) Click somewhere on the screen to create the section views. Here, we see an example of sections of the existing and final surfaces:

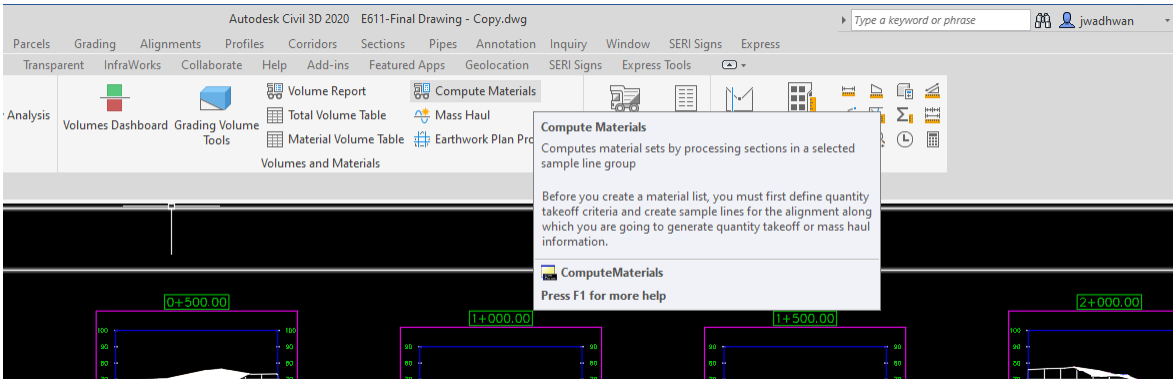


5.6 Total Volume Report:

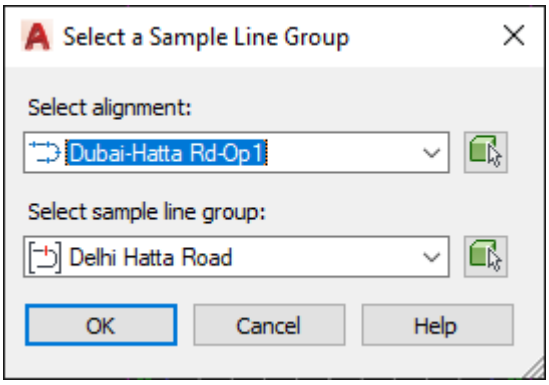
When a design is complete, we need to estimate material quantities for construction cost estimation. The quantity of each of the components and their management on-site will impact the bottom line of the project. So, it's in the designer's best interest to provide an accurate quantity estimation. In addition, operation, maintenance, and management of materials can also add a cost. For example, identifying cut and fill material locations along a road would enable better earthworks cost management. For instance, we can identify borrow and storage locations. Civil 3D provides tools to both estimate quantities and locate them, including asphalt, concrete, gravel base, subbase, earthworks, and more. This is done by using surfaces or subassembly structures.

5.6.1 Setting up Template

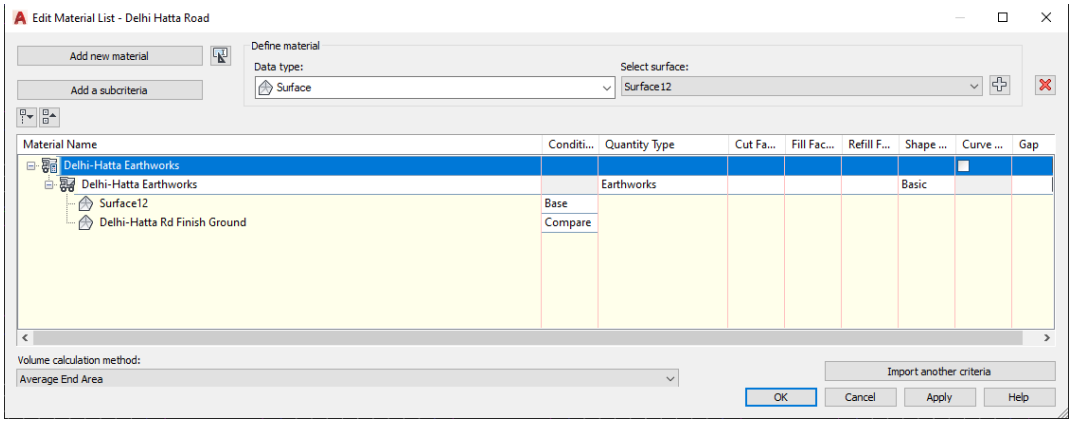
1) Activate the **Analyze** tab and run the **Compute Material** command.



1) In the Select Sample Line Group window, select the Dubai-Hatta Rd alignment and the associated sample line group, then click on OK.



2) In the **Compute Material** window, we are provided with a default material list called Earthworks.

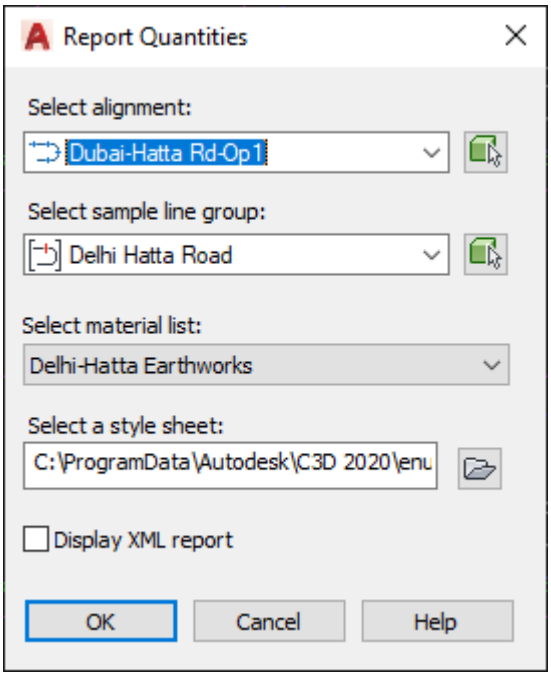


3) Click **OK** to close the **Quantity take Off Criteria** window.
4) Next, on the **Compute Materials** page, we need to **Map Objects with name,** to match the criteria and the drawing's surface or corridor shape names.
5) Click "OK" to compute material.

5.6.2 Volume Report

To generate volume report, do the following

1) Activate the **Analyze** tab and click the **Volume Report**.



2) Provide the input of alignment and associated sample line group and material list.
3) Browse the style sheet after clicking on folder icon and select earthworks.xsl to get the cut/fill volumes.
4) Following table will be appear with estimated cut/fill volume. Get the quantity for the paving material in a same way, if required.

Earthworks tables, road wise presented in appendix C of this report

6 Conclusion

A robust software Autodesk Civil3D was used for detailed design of the assigned road stretches. To meet the objective of fitting the highway to site topography and yet satisfy the safety, service and performance standards, design speed, traffic volume, sight distance, alignment, super-elevation and grades, cross section, lane width., horizontal and vertical clearance have been properly addressed in the design process.

Alignment option study was done for all the corridors. At least 2 options were created and best of them with consideration of length, nearby built-up areas, number of structures, intersections and environment has been picked for detailed design.

Earthworks are almost balanced and at the same time design fully conform the control as per AASHTO.

Detailed design of all three road to conform the geometry standards and to balance the earthworks. In way forward structures, drainage, Geotech and hydrology to be considered to design the best route which provides the social and economic benefits to the people and agencies.

Appendix A: Alignment Station and Curve Report

Alignment: E-611

A. Description: Horizontal Curve Details

Tangent Data

Description	PT Station	Northing	Easting
Start:	0+00.000	2783999.046	348332.091
End:	2+065.613	2785108.713	350074.330

Tangent Data

Parameter	Value	Parameter	Value
Length:	2065.613	Course:	N 57° 30' 22.0893" E

Curve Point Data

Description	Station	Northing	Easting
PC:	2+065.613	2785108.713	350074.330
RP:		2792753.191	345205.411
PT:	4+253.341	2786494.224	351760.543

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	13° 49' 48.5238"	Type:	LEFT
Radius:	9063.356		
Length:	2187.727	Tangent:	1099.206
Mid-Ord:	65.930	External:	66.413
Chord:	2182.420	Course:	N 50° 35' 27.8274" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	4+253.341	2786494.224	351760.543
End:	4+413.916	2786610.361	351871.433

Tangent Data

Parameter	Value	Parameter	Value
Length:	160.575	Course:	N 43° 40' 33.5655" E

Curve Point Data

Description	Station	Northing	Easting
PC:	4+413.916	2786610.361	351871.433
RP:		2780493.769	358277.454
PT:	5+104.742	2787090.904	352367.495

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	04° 28' 07.8447"	Type:	RIGHT
Radius:	8857.190		
Length:	690.826	Tangent:	345.588
Mid-Ord:	6.734	External:	6.739
Chord:	690.651	Course:	N 45° 54' 37.4878" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	5+104.742	2787090.904	352367.495
End:	5+981.292	2787675.782	353020.379

Tangent Data

Parameter	Value	Parameter	Value
Length:	876.550	Course:	N 48° 08' 41.4102" E

Curve Point Data

Description	Station	Northing	Easting
PC:	5+981.292	2787675.782	353020.379
RP:		2793139.840	348125.473
PT:	9+629.974	2790673.247	355034.305

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	28° 29' 50.0591"	Type:	LEFT
Radius:	7335.942		
Length:	3648.682	Tangent:	1862.904
Mid-Ord:	225.677	External:	232.840
Chord:	3611.190	Course:	N 33° 53' 46.3807" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	9+629.974	2790673.247	355034.305
End:	10+763.564	2791740.837	355415.457

Tangent Data

Parameter	Value	Parameter	Value
Length:	1133.590	Course:	N 19° 38' 51.3511" E

B. Profile Vertical Curve Report

Station Range: Start: 0 + 004.20, End: 10 + 026.27

Vertical Curve Information: (sag curve)

PVC Station:	0 + 182.99	Elevation:	76.718m
PVI Station:	0 + 300.00	Elevation:	76,000m
PVT Station:	0 + 417.01	Elevation:	77.404m
Low Point:	0 + 262.20	Elevation:	76.475m
Grade in:	-0.61%	Grade out:	1.20%
Exchange:	1.81%	K:	129,000m
Curve Length:	234.016m	Curve Radius	12,900,000m
Headlight Distance:	6,012.385m		

Vertical Curve Information: (crest curve)

PVC Station:	0 + 631.30	Elevation:	79.976m
PVI Station:	0 + 883.29	Elevation:	83,000m
PVT Station:	1 + 135.28	Elevation:	76.953m
High Point:	0 + 799.32	Elevation:	80.984m
Grade in:	1.20%	Grade out:	-2.40%
Exchange:	3.60%	K:	140,000m
Curve Length:	503.979m	Curve Radius	14,000,000m
Passing Distance:	681.552m	Stopping Distance:	431.371m

Vertical Curve Information: (sag curve)

PVC Station:	1 + 192.01	Elevation:	75.592m
PVI Station:	1 + 300.00	Elevation:	73,000m
PVT Station:	1 + 407.99	Elevation:	73.324m
Low Point:	1 + 383.99	Elevation:	73.288m
Grade in:	-2.40%	Grade out:	0.30%
Exchange:	2.70%	K:	80,000m
Curve Length:	215.981m	Curve Radius	8,000,000m
Headlight Distance:	515.110m		

Vertical Curve Information: (crest curve)

PVC Station:	1 + 602.11	Elevation:	73.906m
PVI Station:	1 + 693.96	Elevation:	74.182m
PVT Station:	1 + 785.81	Elevation:	73.334m
High Point:	1 + 647.16	Elevation:	73.974m
Grade in:	0.30%	Grade out:	-0.92%
Exchange:	1.22%	K:	150.165m
Curve Length:	183.694m	Curve Radius	15,016.502m
Passing Distance:	1,355.960m	Stopping Distance:	635.121m

Vertical Curve Information: (sag curve)

PVC Station:	1 + 903.39	Elevation:	72.248m
PVI Station:	2 + 010.08	Elevation:	71.263m
PVT Station:	2 + 116.78	Elevation:	72.873m
Low Point:	1 + 984.38	Elevation:	71.874m
Grade in:	-0.92%	Grade out:	1.51%
Exchange:	2.43%	K:	87.725m
Curve Length:	213.388m	Curve Radius	8,772.503m
Headlight Distance:	668.931m		

Vertical Curve Information: (crest curve)

PVC Station:	2 + 122.77	Elevation:	72.964m
PVI Station:	2 + 257.69	Elevation:	75,000m
PVT Station:	2 + 392.60	Elevation:	74.586m
High Point:	2 + 347.02	Elevation:	74.656m
Grade in:	1.51%	Grade out:	-0.31%
Exchange:	1.82%	K:	148.588m
Curve Length:	269.826m	Curve Radius	14,858.825m
Passing Distance:	986.468m	Stopping Distance:	500.883m

Vertical Curve Information: (sag curve)

PVC Station:	2 + 500.00	Elevation:	74.257m
PVI Station:	2 + 600.00	Elevation:	73.950m
PVT Station:	2 + 700.00	Elevation:	75.961m
Low Point:	2 + 526.47	Elevation:	74.216m
Grade in:	-0.31%	Grade out:	2.01%
Exchange:	2.32%	K:	86.286m
Curve Length:	199.999m	Curve Radius	8,628.627m
Headlight Distance:	754.414m		

Vertical Curve Information: (crest curve)

PVC Station:	2 + 799.52	Elevation:	77.963m
PVI Station:	3 + 050.00	Elevation:	83,000m
PVT Station:	3 + 300.48	Elevation:	79.075m
High Point:	3 + 081.08	Elevation:	80.794m
Grade in:	2.01%	Grade out:	-1.57%
Exchange:	3.58%	K:	140,000m
Curve Length:	500.956m	Curve Radius	14,000,000m
Passing Distance:	682.633m	Stopping Distance:	431.371m

Vertical Curve Information: (sag curve)

PVC Station:	3 + 354.05	Elevation:	78.235m
PVI Station:	3 + 441.06	Elevation:	76.872m
PVT Station:	3 + 528.07	Elevation:	77.401m
Low Point:	3 + 479.42	Elevation:	77.253m
Grade in:	-1.57%	Grade out:	0.61%
Exchange:	2.18%	K:	80,000m
Curve Length:	174.014m	Curve Radius	8,000,000m
Headlight Distance:	905.942m		

Vertical Curve Information: (crest curve)

PVC Station:	3 + 619.94	Elevation:	77.959m
PVI Station:	3 + 750.00	Elevation:	78.750m
PVT Station:	3 + 880.06	Elevation:	77.124m
High Point:	3 + 705.06	Elevation:	78.218m
Grade in:	0.61%	Grade out:	-1.25%
Exchange:	1.86%	K:	140,000m
Curve Length:	260.124m	Curve Radius	14,000,000m
Passing Distance:	962.321m	Stopping Distance:	487.739m

Vertical Curve Information: (sag curve)

PVC Station:	3 + 971.72	Elevation:	75.979m
PVI Station:	4 + 050.00	Elevation:	75,000m
PVT Station:	4 + 128.28	Elevation:	75.553m
Low Point:	4 + 071.72	Elevation:	75.354m
Grade in:	-1.25%	Grade out:	0.71%
Exchange:	1.96%	K:	80,000m
Curve Length:	156.562m	Curve Radius	8,000,000m
Headlight Distance:	1,669.785m		

Vertical Curve Information: (crest curve)

PVC Station:	4 + 372.68	Elevation:	77.281m
PVI Station:	4 + 474.31	Elevation:	78,000m
PVT Station:	4 + 575.94	Elevation:	77.243m
High Point:	4 + 471.67	Elevation:	77.631m
Grade in:	0.71%	Grade out:	-0.74%
Exchange:	1.45%	K:	140,000m
Curve Length:	203.253m	Curve Radius	14,000,000m
Passing Distance:	1,166.758m	Stopping Distance:	559.384m

Vertical Curve Information: (sag curve)

PVC Station:	4 + 657.06	Elevation:	76.639m
PVI Station:	4 + 742.85	Elevation:	76,000m
PVT Station:	4 + 828.64	Elevation:	77.201m
Low Point:	4 + 716.64	Elevation:	76.417m
Grade in:	-0.74%	Grade out:	1.40%
Exchange:	2.14%	K:	80,000m
Curve Length:	171.579m	Curve Radius	8,000,000m
Headlight Distance:	961.838m		

Vertical Curve Information: (crest curve)

PVC Station:	5 + 025.00	Elevation:	79.950m
PVI Station:	5 + 100.00	Elevation:	81,000m
PVT Station:	5 + 175.00	Elevation:	81.718m
High Point:	5 + 175.00	Elevation:	81.718m
Grade in:	1.40%	Grade out:	0.96%
Exchange:	0.44%	K:	338.454m
Curve Length:	150,000m	Curve Radius	33,845.402m
Passing Distance:	3,564,151m	Stopping Distance:	1,574.521m

Vertical Curve Information: (crest curve)

PVC Station:	5 + 224.32	Elevation:	82.189m
PVI Station:	5 + 430.13	Elevation:	84.159m
PVT Station:	5 + 635.95	Elevation:	80.076m
High Point:	5 + 358.26	Elevation:	82.830m
Grade in:	0.96%	Grade out:	-1.98%
Exchange:	2.94%	K:	140,000m
Curve Length:	411.636m	Curve Radius	14,000,000m
Passing Distance:	731.746m	Stopping Distance:	431.844m

Vertical Curve Information: (sag curve)

PVC Station:	5 + 650.63	Elevation:	79.785m
PVI Station:	5 + 799.31	Elevation:	76.836m
PVT Station:	5 + 947.99	Elevation:	79.375m
Low Point:	5 + 810.41	Elevation:	78.200m
Grade in:	-1.98%	Grade out:	1.71%
Exchange:	3.69%	K:	80.557m
Curve Length:	297.360m	Curve Radius	8,055.715m
Headlight Distance:	384.843m		

Vertical Curve Information: (crest curve)

PVC Station:	6 + 171.57	Elevation:	83.194m
PVI Station:	6 + 314.19	Elevation:	85.629m
PVT Station:	6 + 456.80	Elevation:	85.159m
High Point:	6 + 410.66	Elevation:	85.235m
Grade in:	1.71%	Grade out:	-0.33%
Exchange:	2.04%	K:	140,000m
Curve Length:	285.231m	Curve Radius	14,000,000m
Passing Distance:	901.617m	Stopping Distance:	468.809m

Vertical Curve Information: (sag curve)

PVC Station:	6 + 824.58	Elevation:	83.947m
PVI Station:	6 + 899.58	Elevation:	83.700m
PVT Station:	6 + 974.58	Elevation:	84.416m
Low Point:	6 + 863.07	Elevation:	83.884m
Grade in:	-0.33%	Grade out:	0.95%
Exchange:	1.28%	K:	116.801m
Curve Length:	150,000m	Curve Radius	11,680.088m
Headlight Distance:			

Vertical Curve Information: (crest curve)

PVC Station:	7 + 194.19	Elevation:	86.513m
PVI Station:	7 + 350.00	Elevation:	88,000m
PVT Station:	7 + 505.81	Elevation:	86.442m
High Point:	7 + 346.39	Elevation:	87.239m
Grade in:	0.95%	Grade out:	-1.00%
Exchange:	1.95%	K:	159.421m
Curve Length:	311.618m	Curve Radius	15,942.149m
Passing Distance:	946.918m	Stopping Distance:	495.801m

Vertical Curve Information: (crest curve)

PVC Station:	7 + 633.33	Elevation:	85.167m
PVI Station:	7 + 750.00	Elevation:	84,000m
PVT Station:	7 + 866.67	Elevation:	81.039m
High Point:	7 + 633.33	Elevation:	85.167m
Grade in:	-1.00%	Grade out:	-2.54%
Exchange:	1.54%	K:	151.704m
Curve Length:	233.333m	Curve Radius	15,170.401m
Passing Distance:	1,122.050m	Stopping Distance:	548.747m

Vertical Curve Information: (sag curve)

PVC Station:	7 + 972.32	Elevation:	78.357m
PVI Station:	8 + 051.00	Elevation:	76.360m
PVT Station:	8 + 129.68	Elevation:	75.757m
Low Point:	8 + 129.68	Elevation:	75.757m
Grade in:	-2.54%	Grade out:	-0.77%
Exchange:	1.77%	K:	88.868m
Curve Length:	157.364m	Curve Radius	8,886.836m
Headlight Distance:	13,438.394m		

Vertical Curve Information: (crest curve)

PVC Station:	8 + 288.64	Elevation:	74.537m
PVI Station:	8 + 381.77	Elevation:	73.822m
PVT Station:	8 + 474.90	Elevation:	71.869m
High Point:	8 + 288.64	Elevation:	74.537m
Grade in:	-0.77%	Grade out:	-2.10%
Exchange:	1.33%	K:	140,000m
Curve Length:	186.261m	Curve Radius	14,000,000m
Passing Distance:	1,255.426m	Stopping Distance:	592.647m

Vertical Curve Information: (sag curve)

PVC Station:	8 + 745.63	Elevation:	66.189m
PVI Station:	8 + 850.00	Elevation:	64,000m
PVT Station:	8 + 954.37	Elevation:	64.534m
Low Point:	8 + 913.45	Elevation:	64.429m
Grade in:	-2.10%	Grade out:	0.51%
Exchange:	2.61%	K:	80,000m
Curve Length:	208.736m	Curve Radius	8,000,000m
Headlight Distance:	546.857m		

Vertical Curve Information: (crest curve)

PVC Station:	9 + 172.83	Elevation:	65.651m
PVI Station:	9 + 309.76	Elevation:	66.351m
PVT Station:	9 + 446.69	Elevation:	64.373m
High Point:	9 + 244.43	Elevation:	65.834m
Grade in:	0.51%	Grade out:	-1.44%
Exchange:	1.96%	K:	140,000m
Curve Length:	273.860m	Curve Radius	14,000,000m
Passing Distance:	927.446m	Stopping Distance:	476.667m

Alignment: Dubai-Hatta Rd-Op1

A. Horizontal Curve Details

Tangent Data

Description	PT Station	Northing	Easting
Start:	0+00.000	2783997.950	348332.789
End:	2+283.598	2782906.913	350338.894

Tangent Data

Parameter	Value	Parameter	Value
Length:	2283.598	Course:	S 61° 27' 36.2295" E

Curve Point Data

Description	Station	Northing	Easting
PC:	2+283.598	2782906.913	350338.894
RP:		2780688.066	349132.155
PT:	4+676.236	2781003.940	351638.093

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	54° 16' 32.8669"	Type:	RIGHT
Radius:	2525.767		
Length:	2392.638	Tangent:	1294.609
Mid-Ord:	278.058	External:	312.456
Chord:	2304.175	Course:	S 34° 19' 19.7961" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	4+676.236	2781003.940	351638.093
End:	5+351.322	2780334.154	351722.520

Tangent Data

Parameter	Value	Parameter	Value
Length:	675.086	Course:	S 07° 11' 03.3626" E

Curve Point Data

Description	Station	Northing	Easting
PC:	5+351.322	2780334.154	351722.520

RP:		2781029.996	357242.869
PT:	8+462.910	2777511.413	352932.645

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	32° 02' 30.0047"	Type:	LEFT
Radius:	5564.032		
Length:	3111.588	Tangent:	1597.650
Mid-Ord:	216.099	External:	224.831
Chord:	3071.200	Course:	S 23° 12' 18.3650" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	8+462.910	2777511.413	352932.645
End:	8+537.995	2777453.248	352980.128

Tangent Data

Parameter	Value	Parameter	Value
Length:	75.085	Course:	S 39° 13' 33.3673" E

Curve Point Data

Description	Station	Northing	Easting
PC:	8+537.995	2777453.248	352980.128
RP:		2768307.346	341776.503
PT:	11+453.910	2775024.424	354584.687

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	11° 33' 06.4208"	Type:	RIGHT
Radius:	14462.667		
Length:	2915.915	Tangent:	1462.916
Mid-Ord:	73.425	External:	73.800
Chord:	2910.978	Course:	S 33° 27' 00.1569" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	11+453.910	2775024.424	354584.687
End:	13+331.781	2773361.376	355456.850

Tangent Data

Parameter	Value	Parameter	Value
Length:	1877.871	Course:	S 27° 40' 26.9465" E

Curve Point Data

Description	Station	Northing	Easting
PC:	13+331.781	2773361.376	355456.850
RP:		2777235.335	362843.750

PT:	15+166.141	2771843.227	356479.866

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	12° 36' 01.4398"	Type:	LEFT
Radius:	8341.094		
Length:	1834.361	Tangent:	920.895
Mid-Ord:	50.375	External:	50.682
Chord:	1830.666	Course:	S 33° 58' 27.6664" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	15+166.141	2771843.227	356479.866
End:	16+123.185	2771113.045	357098.548

Tangent Data

Parameter	Value	Parameter	Value
Length:	957.044	Course:	S 40° 16' 28.3863" E

Curve Point Data

Description	Station	Northing	Easting
PC:	16+123.185	2771113.045	357098.548
RP:		2769095.176	354717.016
PT:	16+867.251	2770493.659	357507.667

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	13° 39' 27.6094"	Type:	RIGHT
Radius:	3121.456		
Length:	744.066	Tangent:	373.804
Mid-Ord:	22.144	External:	22.302
Chord:	742.305	Course:	S 33° 26' 44.5816" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	16+867.251	2770493.659	357507.667
End:	17+774.349	2769682.693	357914.068

Tangent Data

Parameter	Value	Parameter	Value

B. Vertical Curve Details

Station Range: Start: 0 + 000.00, End: 17 + 774.35

Vertical Curve Information: (sag curve)			
PVC Station:	0 + 184.51	Elevation:	71.032m

PVI Station:	0 + 393.97	Elevation:	63.074m
PVT Station:	0 + 603.42	Elevation:	64.634m
Low Point:	0 + 534.78	Elevation:	64.378m
Grade in:	-3.80%	Grade out:	0.74%
Exchange:	4.54%	K:	92.196m
Curve Length:	418.910m	Curve Radius	9,219.632m
Headlight Distance:	411.482m		

Vertical Curve Information: (crest curve)

PVC Station:	0 + 836.83	Elevation:	66.371m
PVI Station:	1 + 053.10	Elevation:	67.982m
PVT Station:	1 + 269.37	Elevation:	66.670m
High Point:	1 + 075.19	Elevation:	67.259m
Grade in:	0.74%	Grade out:	-0.61%
Exchange:	1.35%	K:	320.158m
Curve Length:	432.533m	Curve Radius	32,015.833m
Passing Distance:	1,360.874m	Stopping Distance:	708.181m

Vertical Curve Information: (sag curve)

PVC Station:	1 + 397.07	Elevation:	65.895m
PVI Station:	1 + 512.94	Elevation:	65.193m
PVT Station:	1 + 628.80	Elevation:	67.444m
Low Point:	1 + 452.20	Elevation:	65.728m
Grade in:	-0.61%	Grade out:	1.94%
Exchange:	2.55%	K:	90.887m
Curve Length:	231.727m	Curve Radius	9,088.683m
Headlight Distance:	616.089m		

Vertical Curve Information: (crest curve)

PVC Station:	1 + 770.35	Elevation:	70.195m
PVI Station:	1 + 944.59	Elevation:	73.580m
PVT Station:	2 + 118.83	Elevation:	72.918m
High Point:	2 + 061.82	Elevation:	73.027m
Grade in:	1.94%	Grade out:	-0.38%
Exchange:	2.32%	K:	150,000m
Curve Length:	348.474m	Curve Radius	15,000,000m
Passing Distance:	839.866m	Stopping Distance:	460.302m

Vertical Curve Information: (sag curve)

PVC Station:	2 + 860.72	Elevation:	70.099m

PVI Station:	2 + 973.43	Elevation:	69.671m
PVT Station:	3 + 086.13	Elevation:	70.773m
Low Point:	2 + 923.77	Elevation:	69.979m
Grade in:	-0.38%	Grade out:	0.98%
Exchange:	1.36%	K:	165.909m
Curve Length:	225.412m	Curve Radius	16,590.892m
Headlight Distance:			

Vertical Curve Information: (crest curve)

PVC Station:	3 + 122.02	Elevation:	71.125m
PVI Station:	3 + 500.00	Elevation:	74.824m
PVT Station:	3 + 877.98	Elevation:	73.674m
High Point:	3 + 698.77	Elevation:	73.947m
Grade in:	0.98%	Grade out:	-0.30%
Exchange:	1.28%	K:	589.347m
Curve Length:	755.951m	Curve Radius	58,934.700m
Passing Distance:	1,583.535m	Stopping Distance:	896.085m

Vertical Curve Information: (sag curve)

PVC Station:	4 + 214.83	Elevation:	72.650m
PVI Station:	4 + 333.70	Elevation:	72.289m
PVT Station:	4 + 452.57	Elevation:	74.040m
Low Point:	4 + 255.51	Elevation:	72.588m
Grade in:	-0.30%	Grade out:	1.47%
Exchange:	1.78%	K:	133.768m
Curve Length:	237.737m	Curve Radius	13,376,779m
Headlight Distance:	12,961.423m		

Vertical Curve Information: (crest curve)

PVC Station:	4 + 734.45	Elevation:	78.192m
PVI Station:	5 + 052.64	Elevation:	82.880m
PVT Station:	5 + 370.84	Elevation:	81.670m
High Point:	5 + 240.28	Elevation:	81.918m
Grade in:	1.47%	Grade out:	-0.38%
Exchange:	1.85%	K:	343.362m
Curve Length:	636.390m	Curve Radius	34,336,213m
Passing Distance:	1,152.529m	Stopping Distance:	676.764m

Vertical Curve Information: (sag curve)

PVC Station:	5 + 672.00	Elevation:	80.525m

PVI Station:	5 + 810.03	Elevation:	80,000m
PVT Station:	5 + 948.06	Elevation:	82.224m
Low Point:	5 + 724.72	Elevation:	80.425m
Grade in:	-0.38%	Grade out:	1.61%
Exchange:	1.99%	K:	138.631m
Curve Length:	276.059m	Curve Radius	13,863.117m
Headlight Distance:	1,931,772m		

Vertical Curve Information: (crest curve)

PVC Station:	6 + 694.32	Elevation:	94.247m
PVI Station:	6 + 851.68	Elevation:	96.782m
PVT Station:	7 + 009.03	Elevation:	96.015m
High Point:	6 + 935.98	Elevation:	96.193m
Grade in:	1.61%	Grade out:	-0.49%
Exchange:	2.10%	K:	150,000m
Curve Length:	314.715m	Curve Radius	15,000,000m
Passing Distance:	894.388m	Stopping Distance:	474.109m

Vertical Curve Information: (sag curve)

PVC Station:	7 + 264.29	Elevation:	94.772m
PVI Station:	7 + 424.81	Elevation:	93.991m
PVT Station:	7 + 585.33	Elevation:	100.080m
Low Point:	7 + 300.82	Elevation:	94.683m
Grade in:	-0.49%	Grade out:	3.79%
Exchange:	4.28%	K:	75,000m
Curve Length:	321.042m	Curve Radius	7,500,000m
Headlight Distance:	349.941m		

Vertical Curve Information: (crest curve)

PVC Station:	7 + 685.34	Elevation:	103.874m
PVI Station:	8 + 110.44	Elevation:	120,000m
PVT Station:	8 + 535.53	Elevation:	107.333m
High Point:	8 + 161.51	Elevation:	112.906m
Grade in:	3.79%	Grade out:	-2.98%
Exchange:	6.77%	K:	125.522m
Curve Length:	850.196m	Curve Radius	12,552.152m
Passing Distance:	623.060m	Stopping Distance:	408.457m

Vertical Curve Information: (sag curve)

PVC Station:	8 + 731.10	Elevation:	101.506m

PVI Station:	8 + 917.07	Elevation:	95.964m
PVT Station:	9 + 103.05	Elevation:	97.340m
Low Point:	9 + 029.08	Elevation:	97.066m
Grade in:	-2.98%	Grade out:	0.74%
Exchange:	3.72%	K:	100,000m
Curve Length:	371.944m	Curve Radius	10,000,000m
Headlight Distance:	451.743m		

Vertical Curve Information: (crest curve)

PVC Station:	9 + 252.55	Elevation:	98.446m
PVI Station:	9 + 375.13	Elevation:	99.352m
PVT Station:	9 + 497.71	Elevation:	98.255m
High Point:	9 + 363.50	Elevation:	98.856m
Grade in:	0.74%	Grade out:	-0.89%
Exchange:	1.63%	K:	150,000m
Curve Length:	245.162m	Curve Radius	15,000,000m
Passing Distance:	1,068.707m	Stopping Distance:	529.195m

Vertical Curve Information: (sag curve)

PVC Station:	9 + 717.48	Elevation:	96.289m
PVI Station:	9 + 800.73	Elevation:	95.544m
PVT Station:	9 + 883.98	Elevation:	96.186m
Low Point:	9 + 806.95	Elevation:	95.889m
Grade in:	-0.89%	Grade out:	0.77%
Exchange:	1.67%	K:	100,000m
Curve Length:	166.510m	Curve Radius	10,000,000m
Headlight Distance:			

Vertical Curve Information: (crest curve)

PVC Station:	11 + 131.59	Elevation:	105.797m
PVI Station:	11 + 222.26	Elevation:	106.495m
PVT Station:	11 + 312.93	Elevation:	106.098m
High Point:	11 + 247.14	Elevation:	106.242m
Grade in:	0.77%	Grade out:	-0.44%
Exchange:	1.21%	K:	150,000m
Curve Length:	181.342m	Curve Radius	15,000,000m
Passing Distance:	1,369.770m	Stopping Distance:	640.385m

Vertical Curve Information: (sag curve)

PVC Station:	11 + 748.28	Elevation:	104.188m

PVI Station:	11 + 942.07	Elevation:	103.338m
PVT Station:	12 + 135.86	Elevation:	109.999m
Low Point:	11 + 792.14	Elevation:	104.092m
Grade in:	-0.44%	Grade out:	3.44%
Exchange:	3.88%	K:	100,000m
Curve Length:	387.584m	Curve Radius	10,000,000m
Headlight Distance:	446.459m		

Vertical Curve Information: (crest curve)

PVC Station:	12 + 630.45	Elevation:	126.999m
PVI Station:	13 + 024.47	Elevation:	140.543m
PVT Station:	13 + 418.49	Elevation:	129.072m
High Point:	13 + 057.11	Elevation:	134.332m
Grade in:	3.44%	Grade out:	-2.91%
Exchange:	6.35%	K:	124.130m
Curve Length:	788.040m	Curve Radius	12,412.995m
Passing Distance:	619.596m	Stopping Distance:	406.186m

Vertical Curve Information: (sag curve)

PVC Station:	13 + 755.36	Elevation:	119.265m
PVI Station:	14 + 073.60	Elevation:	110,000m
PVT Station:	14 + 391.84	Elevation:	113.342m
Low Point:	14 + 223.12	Elevation:	112.456m
Grade in:	-2.91%	Grade out:	1.05%
Exchange:	3.96%	K:	160.675m
Curve Length:	636.486m	Curve Radius	16,067.459m
Headlight Distance:	659.197m		

Vertical Curve Information: (crest curve)

PVC Station:	14 + 649.65	Elevation:	116.049m
PVI Station:	14 + 792.72	Elevation:	117.551m
PVT Station:	14 + 935.80	Elevation:	116.576m
High Point:	14 + 823.15	Elevation:	116.960m
Grade in:	1.05%	Grade out:	-0.68%
Exchange:	1.73%	K:	165.226m
Curve Length:	286.144m	Curve Radius	16,522.609m
Passing Distance:	1,035.977m	Stopping Distance:	526.813m

Vertical Curve Information: (sag curve)

PVC Station:	15 + 479.02	Elevation:	112.873m

PVI Station:	15 + 567.87	Elevation:	112.267m
PVT Station:	15 + 656.71	Elevation:	112.714m
Low Point:	15 + 581.29	Elevation:	112.524m
Grade in:	-0.68%	Grade out:	0.50%
Exchange:	1.18%	K:	150,000m
Curve Length:	177.688m	Curve Radius	15,000,000m
Headlight Distance:			

Vertical Curve Information: (crest curve)

PVC Station:	16 + 680.70	Elevation:	117.862m
PVI Station:	16 + 926.20	Elevation:	119.097m
PVT Station:	17 + 171.69	Elevation:	118.322m
High Point:	16 + 982.40	Elevation:	118.621m
Grade in:	0.50%	Grade out:	-0.32%
Exchange:	0.82%	K:	600,000m
Curve Length:	490.996m	Curve Radius	60,000,000m
Passing Distance:	2,135,161m	Stopping Distance:	1,057.612m

Alignment: E-44 Urban Collector

A. Horizontal Curve Details

Tangent Data

Description	PT Station	Northing	Easting
Start:	0+000.000	2769684.561	357914.170
End:	0+904.968	2769297.128	358732.010

Tangent Data

Parameter	Value	Parameter	Value
Length:	904.968	Course:	S 64° 39' 06.6052" E

Curve Point Data

Description	Station	Northing	Easting
PC:	0+904.968	2769297.128	358732.010
RP:		2768384.370	358299.612
PT:	1+221.828	2769119.138	358992.585

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	17° 58' 30.2452"	Type:	RIGHT
Radius:	1009.998		
Length:	316.861	Tangent:	159.743
Mid-Ord:	12.400	External:	12.555
Chord:	315.563	Course:	S 55° 39' 51.4826" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	1+221.828	2769119.138	358992.585
End:	1+967.036	2768607.840	359534.720

Tangent Data

Parameter	Value	Parameter	Value
Length:	745.208	Course:	S 46° 40' 36.3599" E

Curve Point Data

Description	Station	Northing	Easting
PC:	1+967.036	2768607.840	359534.720
RP:		2769971.147	360820.479
PT:	2+844.014	2768174.437	360287.924

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	26° 48' 47.2174"	Type:	LEFT
Radius:	1873.975		
Length:	876.978	Tangent:	446.671
Mid-Ord:	51.067	External:	52.498
Chord:	868.997	Course:	S 60° 04' 59.9686" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	2+844.014	2768174.437	360287.924
End:	4+270.793	2767768.968	361655.877

Tangent Data

Parameter	Value	Parameter	Value
Length:	1426.779	Course:	S 73° 29' 23.5773" E

Curve Point Data

Description	Station	Northing	Easting
PC:	4+270.793	2767768.968	361655.877
RP:		2766620.912	361315.586
PT:	5+248.650	2767158.945	362385.330

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	46° 47' 22.3773"	Type:	RIGHT
Radius:	1197.427		
Length:	977.857	Tangent:	518.043
Mid-Ord:	98.439	External:	107.257
Chord:	950.911	Course:	S 50° 05' 42.3887" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	5+248.650	2767158.945	362385.330
End:	5+394.623	2767028.536	362450.920

Tangent Data

Parameter	Value	Parameter	Value
Length:	145.974	Course:	S 26° 42' 01.2000" E

Curve Point Data

Description	Station	Northing	Easting
PC:	5+394.623	2767028.536	362450.920
RP:		2767451.110	363291.103
PT:	6+078.626	2766576.859	362944.461

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	41° 40' 16.6995"	Type:	LEFT
Radius:	940.466		
Length:	684.002	Tangent:	357.919
Mid-Ord:	61.502	External:	65.806
Chord:	669.026	Course:	S 47° 32' 09.5498" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	6+078.626	2766576.859	362944.461
End:	6+986.869	2766242.094	363788.759

Tangent Data

Parameter	Value	Parameter	Value
Length:	908.243	Course:	S 68° 22' 17.8996" E

Curve Point Data

Description	Station	Northing	Easting
PC:	6+986.869	2766242.094	363788.759
RP:		2763426.330	362672.306
PT:	8+218.887	2765570.688	364811.634

Circular Curve Data

Parameter	Value	Parameter	Value
Delta:	23° 18' 15.6344"	Type:	RIGHT
Radius:	3029.025		
Length:	1232.018	Tangent:	624.644
Mid-Ord:	62.423	External:	63.736
Chord:	1223.543	Course:	S 56° 43' 10.0824" E

Tangent Data

Description	PT Station	Northing	Easting
Start:	8+218.887	2765570.688	364811.634
End:	8+387.325	2765451.725	364930.877

Tangent Data

Parameter	Value	Parameter	Value
Length:	168.438	Course:	S 45° 04' 02.2652" E

B. Vertical Curve Details

Station Range: Start: 0 + 000.00, End: 8 + 383.79

Vertical Curve Information: (sag curve)

PVC Station:	0 + 820.22	Elevation:	123.479m
PVI Station:	1 + 000.00	Elevation:	125,000m
PVT Station:	1 + 179.78	Elevation:	130.566m
Low Point:	0 + 820.22	Elevation:	123.479m
Grade in:	0.85%	Grade out:	3.10%
Exchange:	2.25%	K:	159.768m
Curve Length:	359.553m	Curve Radius	15,976.807m

Headlight Distance: 1,197.285m

Vertical Curve Information: (crest curve)

PVC Station:	1 + 651.45	Elevation:	145.171m
PVI Station:	1 + 827.68	Elevation:	150.627m
PVT Station:	2 + 003.91	Elevation:	144.139m
High Point:	1 + 812.46	Elevation:	147.664m
Grade in:	3.10%	Grade out:	-3.68%
Exchange:	6.78%	K:	52,000m
Curve Length:	352.457m	Curve Radius	5,200,000m
Passing Distance:	404.372m	Stopping Distance:	262.899m

Vertical Curve Information: (sag curve)

PVC Station:	2 + 080.38	Elevation:	141.324m
PVI Station:	2 + 209.36	Elevation:	136.575m
PVT Station:	2 + 338.34	Elevation:	136.125m
Low Point:	2 + 338.34	Elevation:	136.125m
Grade in:	-3.68%	Grade out:	-0.35%
Exchange:	3.33%	K:	77.399m
Curve Length:	257.964m	Curve Radius	7,739.888m
Headlight Distance:	396.801m		

Vertical Curve Information: (sag curve)

PVC Station:	2 + 693.41	Elevation:	134.887m
PVI Station:	2 + 787.98	Elevation:	134.557m
PVT Station:	2 + 882.55	Elevation:	134.841m
Low Point:	2 + 794.95	Elevation:	134.710m
Grade in:	-0.35%	Grade out:	0.30%
Exchange:	0.65%	K:	291.146m
Curve Length:	189.146m	Curve Radius	29,114.610m
Headlight Distance:			

Vertical Curve Information: (sag curve)

PVC Station:	3 + 863.85	Elevation:	137.794m
PVI Station:	4 + 028.06	Elevation:	138.288m
PVT Station:	4 + 192.27	Elevation:	143.511m
Low Point:	3 + 863.85	Elevation:	137.794m
Grade in:	0.30%	Grade out:	3.18%
Exchange:	2.88%	K:	114.046m
Curve Length:	328.423m	Curve Radius	11,404.607m

Headlight Distance: 593.252m

Vertical Curve Information: (crest curve)

PVC Station:	4 + 481.38	Elevation:	152.706m
PVI Station:	4 + 735.30	Elevation:	160.783m
PVT Station:	4 + 989.21	Elevation:	155.882m
High Point:	4 + 797.44	Elevation:	157.733m
Grade in:	3.18%	Grade out:	-1.93%
Exchange:	5.11%	K:	99.370m
Curve Length:	507.831m	Curve Radius	9,937.014m
Passing Distance:	556.501m	Stopping Distance:	363.425m

Vertical Curve Information: (sag curve)

PVC Station:	5 + 209.82	Elevation:	151.625m
PVI Station:	5 + 300.48	Elevation:	149.875m
PVT Station:	5 + 391.14	Elevation:	150.157m
Low Point:	5 + 365.95	Elevation:	150.118m
Grade in:	-1.93%	Grade out:	0.31%
Exchange:	2.24%	K:	80.902m
Curve Length:	181.317m	Curve Radius	8,090.153m
Headlight Distance:	813.363m		

Vertical Curve Information: (crest curve)

PVC Station:	5 + 616.84	Elevation:	150.860m
PVI Station:	5 + 668.78	Elevation:	151.022m
PVT Station:	5 + 720.73	Elevation:	150.853m
High Point:	5 + 667.61	Elevation:	150.939m
Grade in:	0.31%	Grade out:	-0.33%
Exchange:	0.64%	K:	163.072m
Curve Length:	103.896m	Curve Radius	16,307.244m
Passing Distance:	2,479,069m	Stopping Distance:	1,095.044m

Vertical Curve Information: (sag curve)

PVC Station:	5 + 846.72	Elevation:	150.442m
PVI Station:	5 + 982.45	Elevation:	150,000m
PVT Station:	6 + 118.18	Elevation:	155.701m
Low Point:	5 + 866.26	Elevation:	150.410m
Grade in:	-0.33%	Grade out:	4.20%
Exchange:	4.53%	K:	59.979m
Curve Length:	271.468m	Curve Radius	5,997.919m

Headlight Distance: 292.871m

Vertical Curve Information: (crest curve)

PVC Station:	6 + 364.72	Elevation:	166.056m
PVI Station:	6 + 596.37	Elevation:	175.786m
PVT Station:	6 + 828.01	Elevation:	165.019m
High Point:	6 + 584.64	Elevation:	170.675m
Grade in:	4.20%	Grade out:	-4.65%
Exchange:	8.85%	K:	52.360m
Curve Length:	463.295m	Curve Radius	5,235.967m
Passing Distance:	402.410m	Stopping Distance:	263.806m

Vertical Curve Information: (sag curve)

PVC Station:	7 + 081.29	Elevation:	153.246m
PVI Station:	7 + 215.52	Elevation:	147.007m
PVT Station:	7 + 349.75	Elevation:	146.577m
Low Point:	7 + 349.75	Elevation:	146.577m
Grade in:	-4.65%	Grade out:	-0.32%
Exchange:	4.33%	K:	62.039m
Curve Length:	268.461m	Curve Radius	6,203.925m
Headlight Distance:	302.448m		

Vertical Curve Information: (sag curve)

PVC Station:	7 + 788.94	Elevation:	145.168m
PVI Station:	7 + 833.83	Elevation:	145.024m
PVT Station:	7 + 878.72	Elevation:	145.127m
Low Point:	7 + 841.19	Elevation:	145.084m
Grade in:	-0.32%	Grade out:	0.23%
Exchange:	0.55%	K:	162.884m
Curve Length:	89.783m	Curve Radius	16,288.364m
Headlight Distance:			