

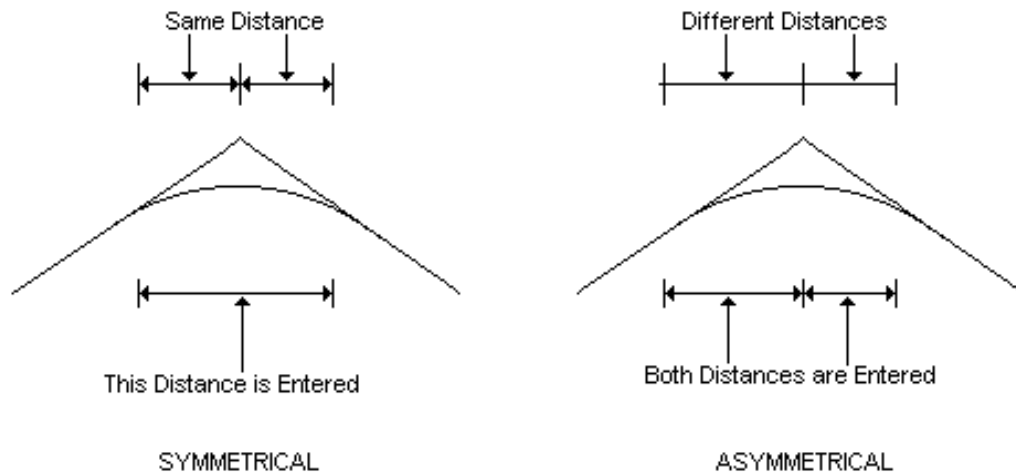
**APPENDIX D**

**PROFILE GRADE - VERTICAL ALIGNMENT**

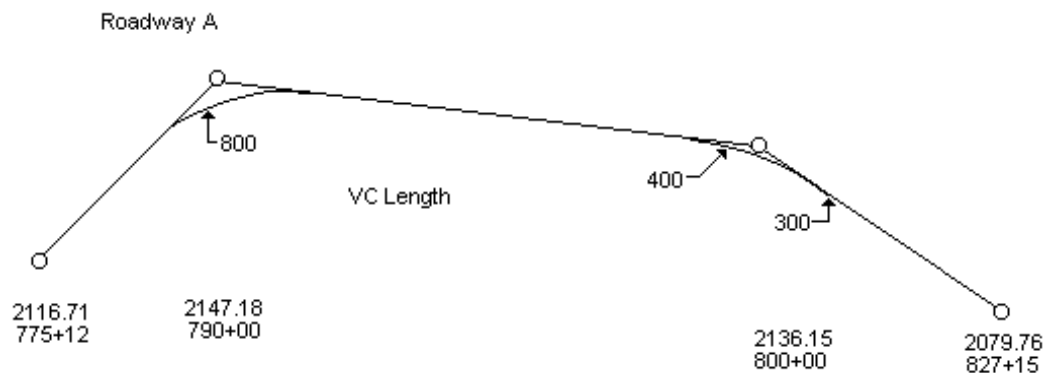
Vertical alignments (profile grades) are required for all roadway design computations. A vertical alignment must be stored for each roadway. This storage is accomplished by entering data for each VPI with appropriate vertical curve parameters. Sufficient vertical alignment data must be provided to adequately describe the alignment in design areas. (See Automatic Data Generation.)

The IGrds/IG Option provides interactive dynamic tools for defining vertical alignments and controlling displays. See the discussion below and the IGrds/IG User Manual for a complete description of this dynamic capability. Another set of commands provides vertical geometry features to help define vertical alignment elements. An input record format is provided for entry of vertical alignments in the IGrds/AN Option.

A vertical curve may be either symmetrical or asymmetrical as indicated below.



Typical profile grade data is shown below.



## USING THE DYNAMIC VERTICAL ALIGNMENT PROCESS

Defining a vertical alignment requires simple basic data: the station, elevation and length of vertical curve for a series of vertical PIs. There are actually two methods that can be used: dynamic and non-dynamic. The dynamic method is very similar to the old string line method used by designers, except that it allows the user to see vertical curves rather than just straight lines as the PI location is moved. A description of the typical process for using this dynamic process follows.

1. Define the vertical reference line for the selected design roadway.
2. Select the vertical alignment command and draw an original profile from cross sections or DTM for reference.
3. Select the design profile editor and select the add mode and dynamic mode.
4. Select C (compute) vertical curve length and option, then select compute missing and adjust computed options. Note: If roadway design parameters have not been defined, the user will be alerted and must enter these data.
5. Digitize or select a location for the first PI (note the user could move the cursor to the input screen and enter station and elevation and select apply, but that is better suited for precision input using the non-dynamic mode which will be described later).
6. Move the cursor to the next PI location, see the string line from the previous PI. Note that the string line disappears when the defined maximum or minimum grade is exceeded. Selecting the data button will store the second PI.
7. Repeat this process for the third PI and note the dynamic string line now shows the vertical curve.
8. Repeat this process for the additional PIs.
9. At this point, select update file to save the design profile. The file could also be closed without saving, or the profile can be deleted and restarted.

This completes the typical process for adding PIs. The user can come back at any time and add additional intermediate PIs using the same method. The following describes the process for using the dynamic\revise mode of the design profile editor.

1. Select the design profile editor and select the revise and dynamic mode.
2. Select a PI for revision and notice that it becomes attached to wherever the cursor is moved. The data button will relocate the PI or the reject button will reset the PI to its original location.

3. Now for some more sophisticated dynamic revision. First lock the back grade and then select a PI for revision. As the cursor moves the PI slides along the locked grade. The user can unlock the grade, then change it and lock it again, and move the PI along the revised grade. This same technique can be used to move the PI by holding the forward grade, the station or the elevation.

Once again, when the user is finished, the file is updated. This dynamic mode makes it very easy to define preliminary vertical alignments. However in final design, precision input is often required to match design constraints such as bridge clearances or intersecting roadways, and the non-dynamic mode is better to use. The primary difference is that the PI string lines do not become attached to the cursor. The user can still select PI locations with the cursor or enter station elevation and VCL, but must select Apply to draw the PI and update the alignment display. This non-dynamic mode is also used for revising a vertical curve to fit through a VPT and for adding PNG PIs.

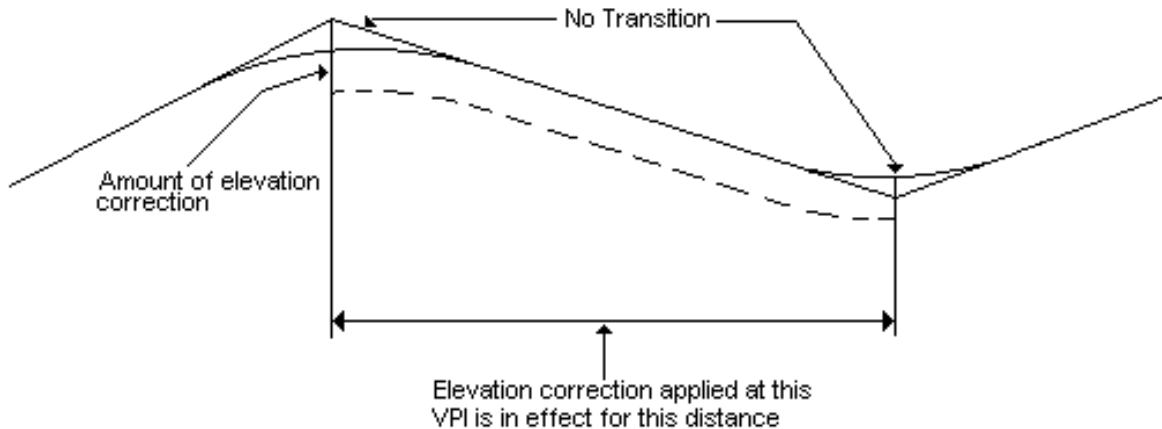
The recompute profile allows the user to recompute VCLs for PIs based on the design parameters. The user can recompute all or compute just those that have no VCL. This could easily change some VCLs that should not change so care should be used when recomputing the profiles.

## **ELEVATION CORRECTIONS**

Within IGrds, the user has the capability of applying an elevation correction to VPI's as they are defined or revised. Traditionally, the elevation correction was only used for Earthwork calculations and within the Design Section Display process. All other calculations using a vertical alignment to perform elevation calculations ignored the elevation correction. This was the way that the Elevation Correction feature was originally designed and implemented by TxDOT when RDS was being developed. The reason for this is that TxDOT did subgrade design instead of finished grade design and the elevation correction was used to "lower" the profile grade to subgrade for earthwork calculations. Since all other calculations represented finished grade (without the elevation correction), this was not a problem for TxDOT. Today, most IGrds user agencies use finished grade design and the elevation correction is used to "raise" the profile grade for overlay type projects, and should always be taken into account.

To accommodate both methods, there are two flags in the IGrds Preferences (.ini) file that control the application of this elevation correction and the display of VPI's. If set one way the elevation correction is employed in the traditional manner, if set the other way than the elevation correction is always employed.

In concert with the flag settings described above, profile grades may be modified by an elevation correction if needed. For instance, if the vertical alignment describes finished grade, then an elevation correction, representing the thickness of the surfacing material, could be entered. This would allow the design and earthwork to be computed along the subgrade. Note that any elevation correction specified remains in effect only between the indicated vertical PI station and the next succeeding one.



Likewise, an elevation correction of one foot applied at all vertical PIs results in the raising of the entire roadway and its resulting design by one foot. Using this correction, the change in earthwork volumes caused by a one foot change in elevation can be calculated by having IGrds perform two design and earthwork computations. One computation would contain the one foot elevation correction. The difference in earthwork quantities between the two runs is the change in quantities due to the one foot correction.

### **VPIs FROM DTM**

VPIs can be established by extraction from the current DTM surface as reflected in a 3D design file over a particular station range. The VPI from DTM calculation process stores the intersection points with the DTM triangle edges and other retrieval points as design profile VPIs without vertical curves, taking the elevation correction into account. Once the profile is established, any of the design VPIs can be edited using the Regular or VC through Point process. A DTM surface must be set to execute this process. If one is not, the user will be alerted. Likewise, if the roadway or geometry element extends outside the limits of the DTM surface, the user will be alerted and no elevations will be established for these areas.

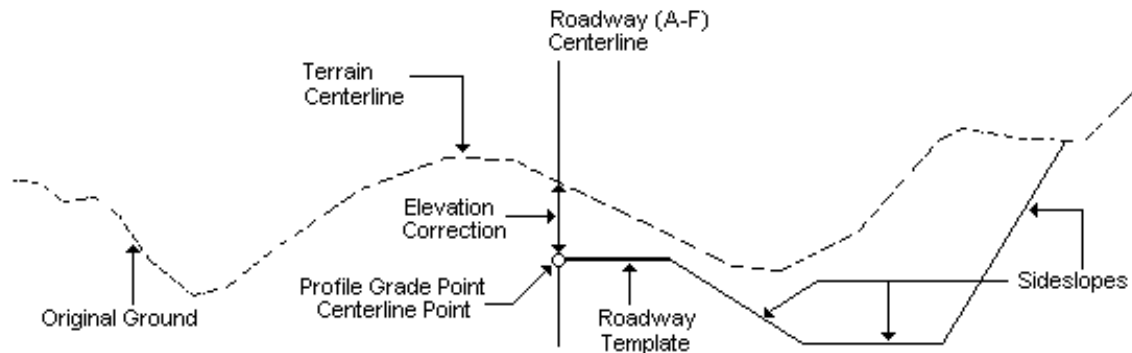
### **VPIs FROM IGrds DESIGN SURFACES**

VPIs can be established from IGrds finish grade or subgrade design surfaces; the two extraction processes are identical, except for the design surface being processed. The VPIs from the design extraction process establish design VPIs without vertical curves from the specified design surface at a given increment from a baseline roadway and at all ridgelines for the design roadways, taking elevation correction into account. Once the profile is established, any of the design VPIs can be edited using the Regular or VC through Point process. The selected design surface (from catch-to-catch with DTM or shoulder-to-shoulder without) must be available over the requested station range. If the roadway or geometry element extends outside the catch and a DTM surface is available, then the user will be alerted and the process will use the DTM to establish VPIs outside the catch point. If no DTM surface is available, then the user will be alerted and no elevations will be returned for the incremental step points outside the shoulder points (e.g., flat terrain conditions).

## PROFILE GRADE FROM NATURAL GROUND

For design roadways, portions of an original ground profile may be converted to a design profile to be used ONLY in design. This feature is useful in reconstruction projects, overlay projects and erosion control ditch and berm design.

The design process calculates an elevation from the original cross sections on the centerline (or offset) of the given roadway and supplies that elevation to the design template. A sketch of a typical application (widening of an existing roadway) is shown below.



## AUTOMATIC DATA GENERATION

The process which creates vertical alignments includes options for computing vertical curve lengths based on sight distance criteria and resolving overlaps. Sight distance criteria is obtained from the design criteria table and roadway design parameter dialog box.

### Design Criteria Table

The design criteria table contains AASHTO Green Book standards for horizontal and vertical alignment related data in both Metric and Imperial units for both the 1990/1994 editions and the 2001 edition. The table contains horizontal curvature and superelevation criteria for rural, high speed urban and low speed urban design. Eye and object heights and sight distance (stopping, decision and passing) criteria are also included for automatic vertical curve length calculations. This design criteria table is an ASCII editable file that can be customized by user agencies whenever an agency's standards differ from the AASHTO Standards.

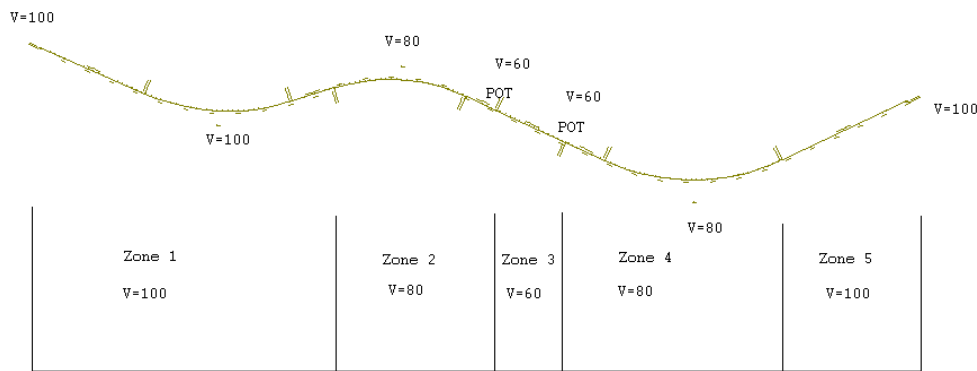
### Roadway Design Parameters Dialog Box

The key to assigning attributes to an IGrds alignment is the roadway design parameters dialog box. These parameters are usually defined as the horizontal alignment is being included. If not, the user is able to select design characteristics from the option buttons. The available options for each of these elements come directly from AASHTO nomenclature or are stored in the design criteria table.

## Automatic Vertical Curve Lengths and Adjustments

Based on the selected criteria for an alignment, the user can request automatic vertical curve length calculations for any or all VPIs for an alignment. The user can specify whether passing sight distance should be considered. Using the appropriate formula and coefficients based on eye and object heights, the process calculates lengths of sag or crest curve based on the sight distance, design speed and grades within the design criteria zone for the VPI being processed. The process checks the computed grades versus the maximum and minimum specified grades for the alignment. The user can specify whether any or all curve lengths can be adjusted if there are curve overlaps. The user is alerted if grades are violated. A report is provided that analyzes the vertical alignment on a PI-by-PI basis.

The Horizontal Alignment Create/Update process outputs a station range and design speed table used in the automatic vertical curve computations. The zones break at the PC/TS or PT/ST and the tangent is controlled by the PI with the higher design speed. POT's are used to change the design parameters on a tangent. See the sketch below.



The design criteria defines minimum and desired stopping sight distance. It also defines passing and decision sight distance. IGrds is delivered with AASHTO design criteria tables, but these can be modified by user agencies.

The user selects the options for computing vertical curve lengths and resolving overlaps. The options are:

- Vertical Curve Length Options
  - Compute All  
Curve length will be computed for each interior VPI
  - Computing Missing  
Curve length will be computed for interior VPIs which have a zero length
  - Compute None

- Overlap Adjustment Options
  - All Lengths  
All curve lengths are eligible for adjustment
  - Computed Lengths  
Curve lengths which were computed during the execution of this command are eligible for adjustment
  - No Adjustment  
No curve lengths will be adjusted

Curve lengths are honored first. Then any resulting overlaps are independently adjusted according to the overlap options (see Figure D-1).

The process considers each VPI in order. If the curve length is to be computed, the criteria is used to compute the curve length as follows:

Sag -            Compute length based on desirable sight distance and round up

Crest -           Compute length based on desirable sight distance and round up

Crest Passing - Compute length based on desirable passing sight distance and round up

Computed lengths are based on individual PIs, and overlaps may result. The grade between VPIs is also checked for compliance with design criteria.

After processing the curve length options, the tangents between VPIs are checked for overlaps. If overlaps are found, an attempt is made to resolve them by shortening curves in accordance with the selected overlap option. See Figure D-1.

Curve lengths computed for passing sight distance will be reduced, but not below the length for minimum stopping sight distance. Curve lengths computed for desired stopping sight distance will be reduced, but not below the length for minimum stopping sight distance. When overlaps cannot be resolved in this manner, they are reported as overlaps on the sight distance check report (see Figure D-1).

The strategy for resolving overlaps is shown in Figure D-2. This strategy attempts to make crest curves as long as possible, while satisfying minimum stopping sight distance. Vertical curve lengths and sight distances are computed based on the AASHTO formulas and values in the AASHTO Design Criteria Tables, but the specifications shown in the following table should be noted.

	Crest or Sag Stopping	Crest Passing
Basis of computation	Desirable stopping sight distance from criteria table	Minimum passing sight distance from criteria table
Rounding of computed VCL lengths	Up to next whole number	Up to next whole number
When computed VCL less than the minimum length in the criteria table	Recommend 3 x Design Speed - Imperial 0.6 x Design Speed - Metric	Up to next whole number
When the value of A (algebraic difference in grades) is small, these values are used	Crest Stop Use A = 0.5 if A < 0.5 Sag Stop Use A = 2.0 if A < 2.0	Use A = 0.5 if A < 0.5



VA OPTION COMBINATIONS			
VCL Compute	Compute All	Compute Missing VCLs (VCL = 0)	Compute None
VCL Adjust			
Adjust Computed Lengths	<ul style="list-style-type: none"> <li>◦ Sight Distance Report</li> <li>◦ Compute Interior VCLS*</li> <li>◦ Computed VCLs eligible for Adjustment</li> </ul>	<ul style="list-style-type: none"> <li>◦ Sight Distance Report</li> <li>◦ Compute Interior VCLs when not entered</li> <li>◦ Computed VCLs eligible for Adjustment*</li> </ul>	<ul style="list-style-type: none"> <li>◦ Sight Distance Report</li> </ul>
Adjust Any Length	<ul style="list-style-type: none"> <li>◦ Sight Distance Report</li> <li>◦ Compute Interior VCLS*</li> <li>◦ Any VCL - eligible for Adjustment</li> </ul>	<ul style="list-style-type: none"> <li>◦ Sight Distance Report</li> <li>◦ Compute Interior VCLS* when not entered</li> <li>◦ Any VCL - eligible for Adjustment*</li> </ul>	<ul style="list-style-type: none"> <li>◦ Sight Distance Report</li> <li>◦ Any VCL - eligible for Adjustment*</li> </ul>
Do Not Adjust	<ul style="list-style-type: none"> <li>◦ Sight Distance Report</li> <li>◦ Compute Interior VCLS*</li> </ul>	<ul style="list-style-type: none"> <li>◦ Sight Distance Report</li> <li>◦ Compute Interior VCLs* when not entered</li> </ul>	<ul style="list-style-type: none"> <li>◦ Sight Distance Report</li> </ul>

\* No VCL computation or adjustment when VCL2 is not zero (in this case, the total VCL = VCL1 + VCL2. Sight Distance is computed based on 2x, the shortest VCL1 or VCL2).

SIGHT DISTANCE CHECK for Roadway 'road 2 '

Compute Passing : No  
Max Grade : 4.00  
Min Grade : 0.00  
Options: Generate All VCLs - Adjust Any length

- DESIGN SPEED CRITERIA TABLE -

Begin Station	End Station	Design Speed	Minimum Stopping	Sight Distance		
				Design Stopping	Decision	Passing
30+00.000	42+31.090	60	75	85	175	407
42+31.090	47+20.662	30	30	30	145	217
47+20.662	59+09.983	70	95	111	200	482

Station	Elev	VCL1	VCL2	VCL	SAG Crest	VCL Basis	overlap Status	Sight Dis	Sight Dis check	Grade Fwd	Grade Check	K
30+00.000	759.160	0.000	0.000	0.000				0		0.5262	ok	0.000
30+37.000	759.355	36.000	0.000	36.000	crest	computed		88	stopping	-2.4031	ok	12.290
31+15.000	757.480	36.000	0.000	36.000	crest	computed		152	stopping	-3.9198	ok	23.735
33+91.000	746.662	125.000	0.000	125.000	sag	computed		84	stopping	3.4772	ok	16.899
37+81.000	760.223	36.000	0.000	36.000	crest	computed		137	stopping	1.7627	ok	20.998
40+11.000	764.277	36.000	0.000	36.000	sag	computed		208	decision	4.0000	ok	16.091
44+71.000	782.677	18.000	0.000	18.000	crest	set-stop		79	FAIL	1.0661	ok	6.135
44+83.792	782.813	18.000	0.000	18.000	crest	set-stop	overlap	164	FAIL	-0.2465	ok	13.713

VCL1 and VCL2 columns show input values. VCL column shows the final value of VCL or VCL1

Indicates VCL was:

- entered
- computed
- adjusted
- set-stop
- held

Indicates Overlap between current and previous VPI

Stopping means OK for minimum stopping  
Decision means OK for decision  
Passing means OK for passing  
Fail Stop means not OK for minimum stopping  
Fail-OL means the VPI contributes to an overlap that cannot be resolved

Figure D-1 - Sight Distance Check Report

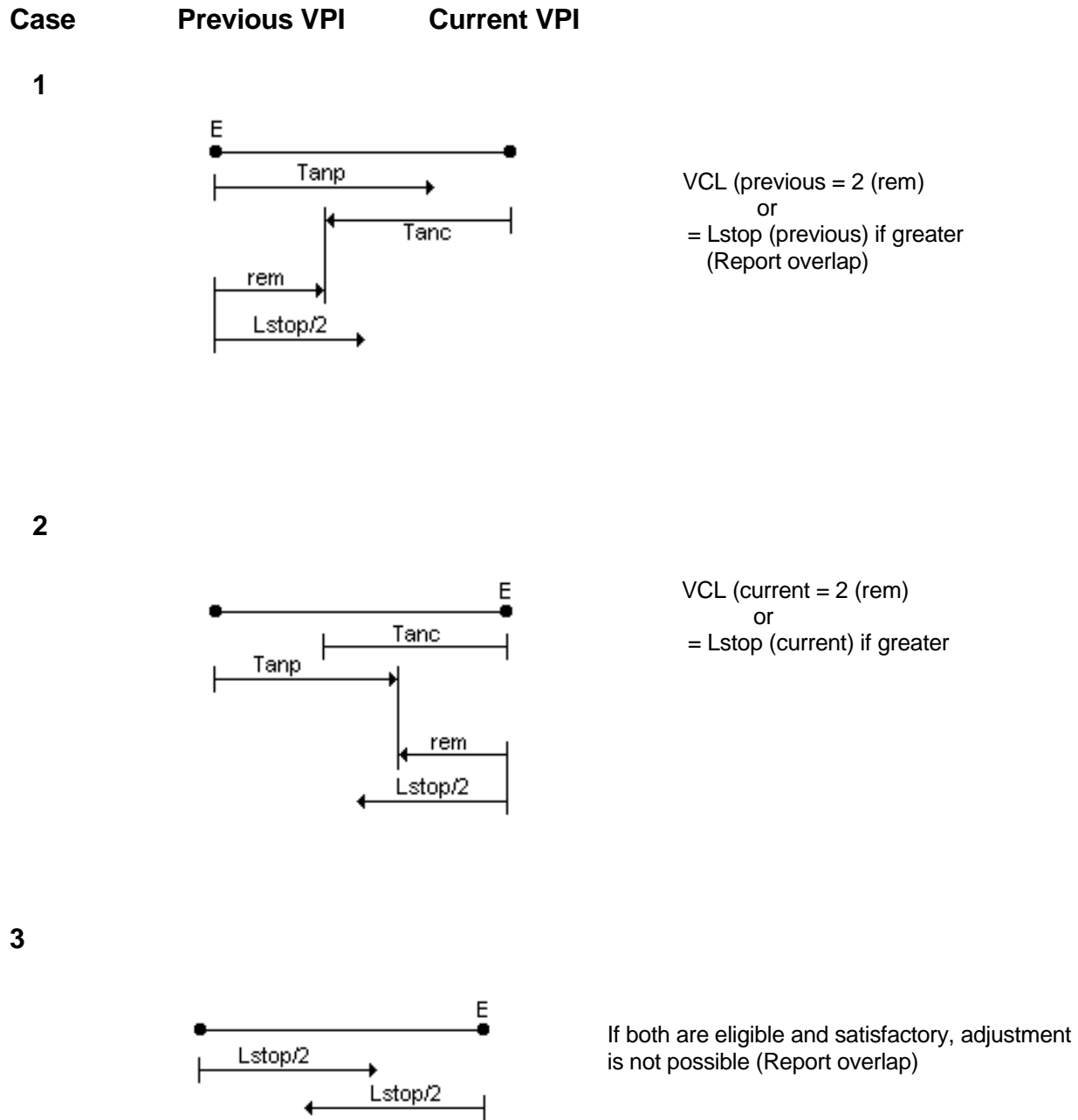
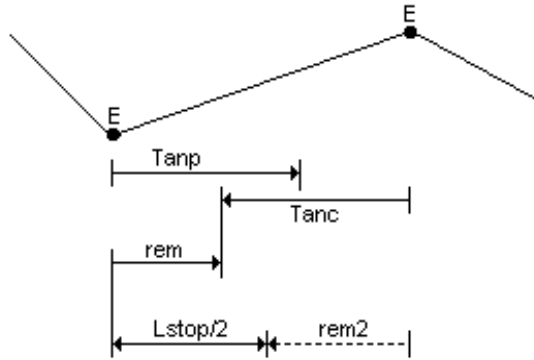


Figure D-2

Adjustment Strategy - When Overlap Exists  
 (E indicates VCL is eligible for adjustment  
 Lstop is curve length for minimum stopping SD)

Case Previous VPI Current VPI

4



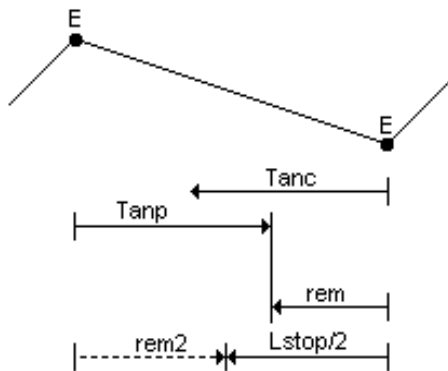
VCL (previous) = 2 (rem)  
or  
= Lstop (previous) if greater

Then

VCL ( current) = 2 (rem 2)  
or

(Report overlap)

5



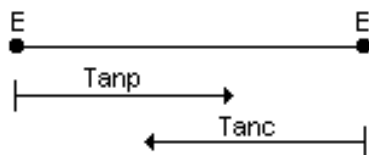
VCL (current) = 2 (rem)  
or  
= Lstop (previous) if greater

If VCL (current) = LSTOP (current)

Then

VCL ( previous) = 2 (rem 2)  
or  
= Lstop (previous) if greater

6



Both Sag or both Crest and can  
resolve without overlap

Compute both VCLs with same  
K value

Figure -D2 - Continued

## VERTICAL GEOMETRY COMMANDS

The vertical geometry commands perform geometry computations in the vertical plane, defined by a reference line. The reference line defines a plane based on station and elevation coordinates. The system observes distorted scales. The results of these computations may be used to define elements of vertical alignments.

These commands facilitate fitting vertical alignments to the constraints imposed by rehabilitation and other projects, that must meet constraints. VPoints can be set at the peak and sag points of any displayed profile. These are very useful for locating drainage structures, determining inadvertent ponding area, determining clearances, etc.

Vertical Geometry commands both compute and store points and lines in the reference line plane. These elements are called VPoints and VLines.

- When VPoints are created, they are stored as 3D geometry points and displayed in both the vertical reference plane and 3D space. An optional offset value can be entered with VPoints.
- VLines are stored as a point and percent grade and are relative to the reference line only. They are not displayable in normal 3D space.

See the IGrds User Manual for the specific VPoint and VLine commands.