SCDOT Geotechnical Manual Updates

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SCDOT

Background

- GDM version 1.0 introduced in August 2008
  - Chapters 1 to 12
  - Appendix A
- GDM version 1.1 introduced in June 2010
  - Chapters 13 to 26
  - Appendices B to E

Why Update the GDM?

- Lessons learned from use of GDM v. 1.0 and 1.1
- New approaches to design issues
- New design methodologies available
- NHI manuals updated
- Changes to AASHTO

Table of Contents

- Version 1.1
  - Chapter 1 – Introduction
  - Chapter 2 Project Coordination Process
  - Chapter 3 – Consultant Services and Review
  - Chapter 4 – Subsurface Investigation Guidelines
  - Chapter 5 – Field and Laboratory Testing Procedures
- Version 2.0
  - Chapter 1 – Introduction
  - Chapter 2 – Glossary
  - Chapter 3 – Reserved
  - Chapter 4 – Subsurface Investigation Guidelines
  - Chapter 5 – Field and Laboratory Testing Procedures

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- Version 1.1
  - Chapters 7 to 26
  - Appendix A – GDS Forms
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  - Appendix E – Template Plans
  - Appendix F – Special Provisions List
  - Appendix G – Software List
- Version 2.0
  - Chapters 7 to 26
  - Appendix A – GDS Forms
  - Appendix B – Reserved
  - Appendix C – MSE Walls
  - Appendix D – RSSs
  - Appendix E – Template Plans
  - Appendix F – Special Provisions List
  - Appendix G – Software List

Table of Contents

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- Version 2.0
  - Appendix H – Shear Wave Velocity Profiles
  - Appendix I – Shear Strength Ratio Triggering Methods
  - Appendix J – Flow Charts
  - Appendix K – Performance Objective Development

Chapter 1

- Version 1.1
  - Describes how SCDOT is put together
  - Describes interplay between various offices both internal as well as external to SCDOT
- Version 2.0
  - Eliminates how SCDOT is put together
  - Clearly defines all applicability and interpretation of GDM are the responsibility of PCS/GDS
  - Describes revision process
    - Geotechnical Design Memoranda

Chapter 2

- Project Coordination Process in ver. 1.1
  - Describe in detail the flow of geotechnical work
- Glossary in ver. 2.0
  - Defines terms unique to geotechnical design
  - Allows for consistent definitions throughout GDM
  - Allows non-Geotechnical Engineers to understand some of the language

Chapter 3

- Consultant Services and Review in ver. 1.1
  - Described how consultants interacted with SCDOT
  - Described SCDOT review process
- Eliminated in ver. 2.0
  - Reserved for future use

Chapter 4

- Version 1.1
  - Preliminary exploration
- Version 2.0
  - Preliminary exploration
    - Index testing all samples with $N_{60} \leq 35$ bpf
    - Hydrometer analysis within scourable zone
    - Electro-chemical analysis to 6 pile diameters below groundwater

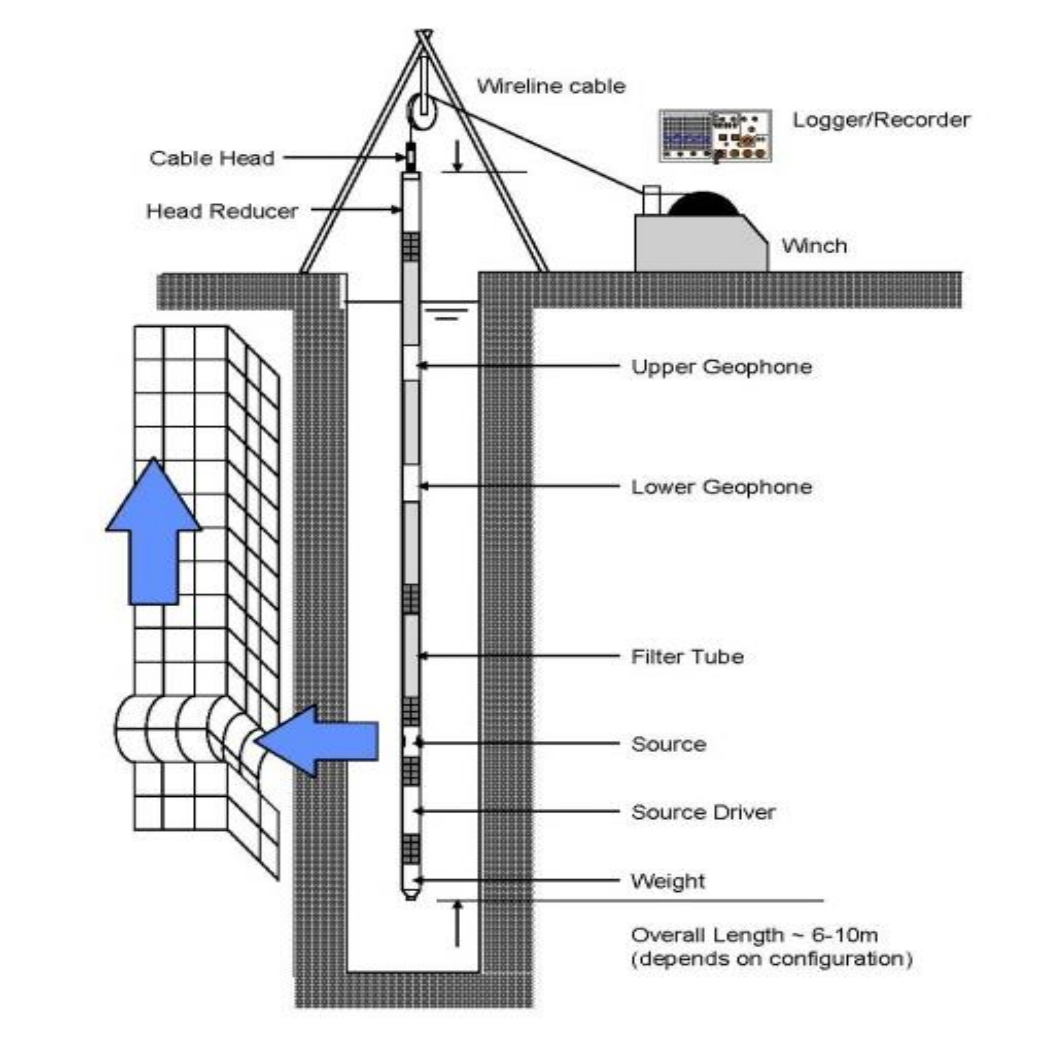
- Version 1.1
  - Final exploration
  - Depth and location of testing

- Version 2.0
  - Final exploration
    - Index testing on all samples from end of bridge and 100 feet from bridge
    - Index testing on 75% of samples from interior of bridge
    - 2 soil test locations at each end of bridge
      - At least 50% of testing locations must be soil test borings
      - CPTu must have a soil boring performed within 5 feet and must be continuously sampled for 50 feet
  - Depth and location of testing
    - Added a discussion of bridge scour

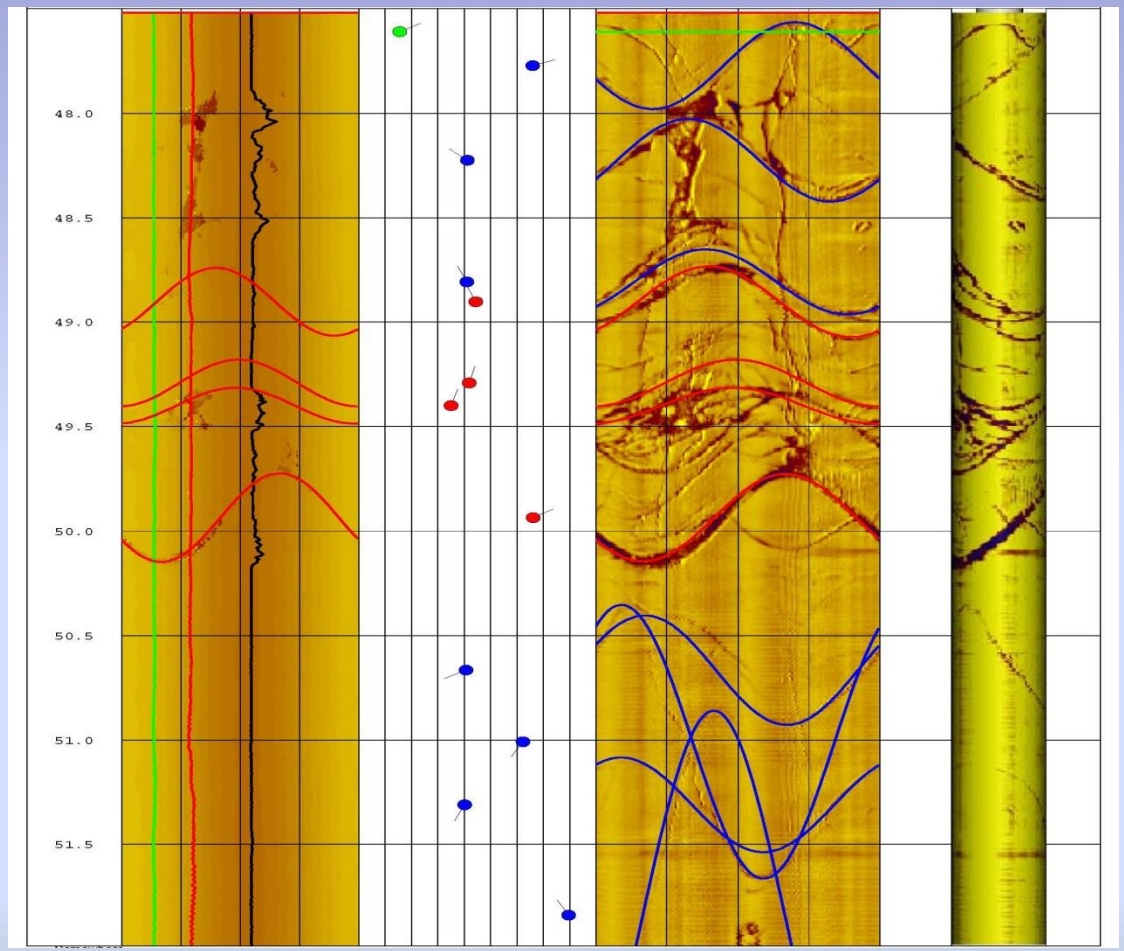
Chapter 5

- Version 1.1
  - Field Testing Procedures
    - SPT
    - CPT
    - DMT
- Version 2.0
  - Field Testing Procedures
    - SPT
    - CPTu
      - Calibration required
      - Zero readings before and after testing required
    - Suspension Logging
    - Acoustic Televiewer

Suspension Logging



Acoustic Televiewer



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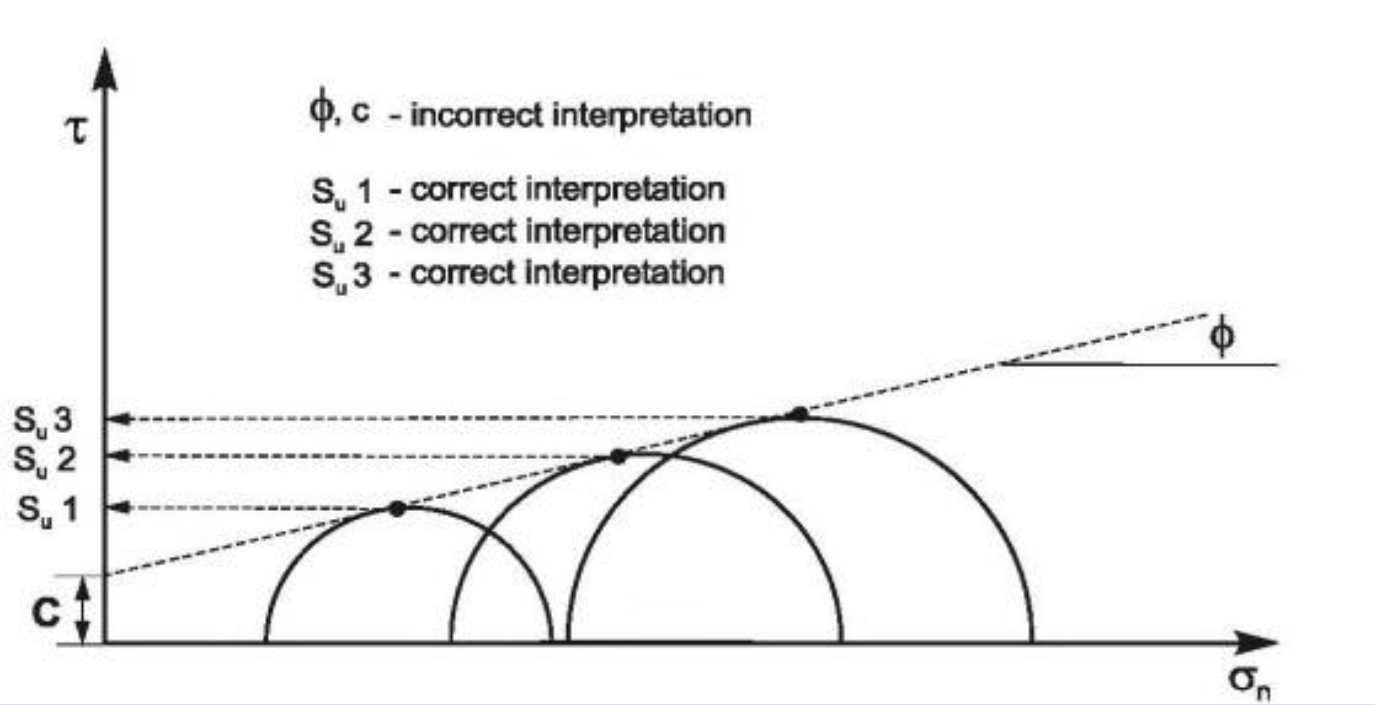
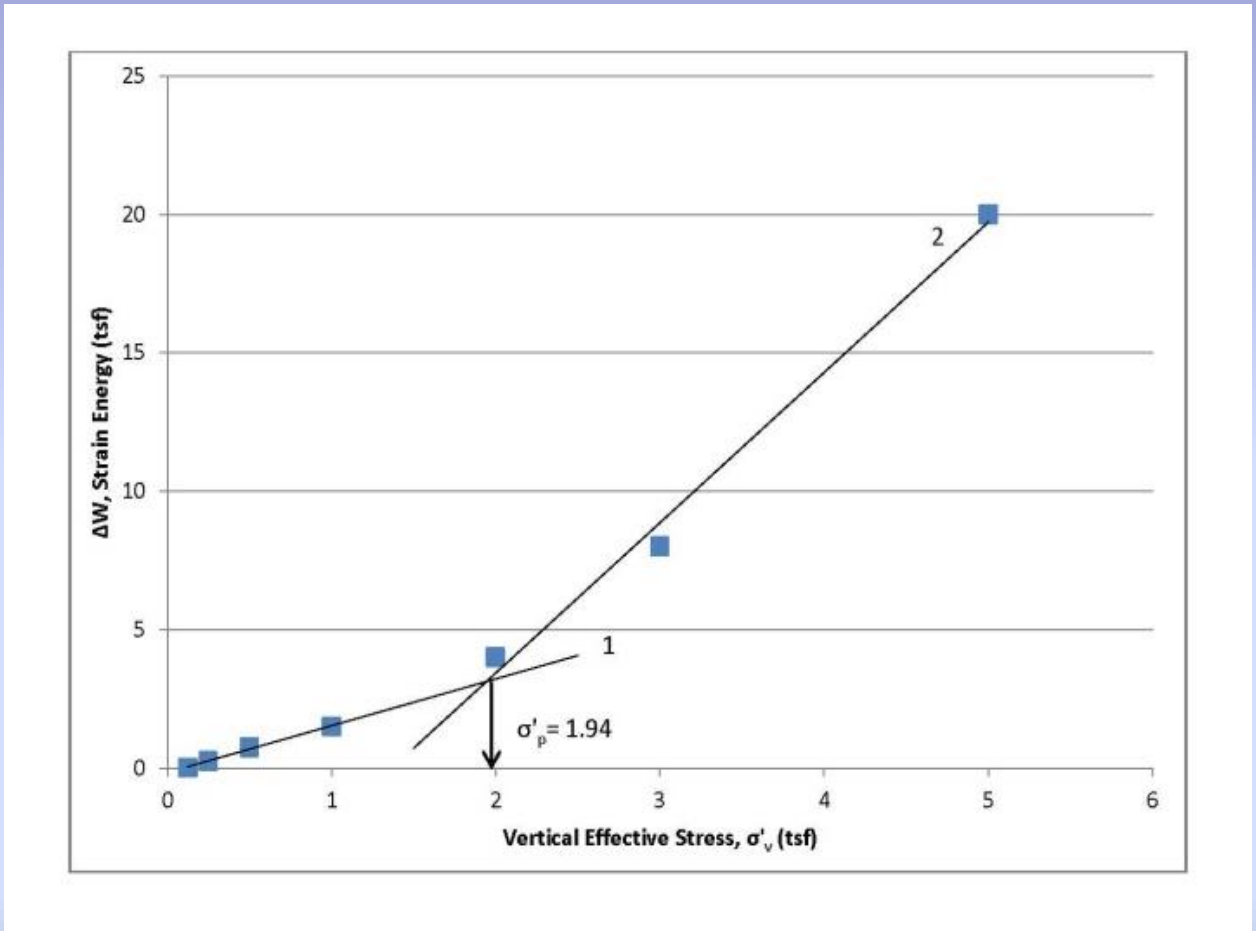
- Version 1.1
  - Laboratory Testing Procedures
    - Grain-Size Analysis
      - ASTM D422
    - Moisture-plasticity relationship

- Version 2.0
  - Laboratory Testing Procedures
    - Grain-Size Analysis
      - ASTM D6913 (sieve)
      - ASTM D7928 (hydrometer)
    - Unconsolidated-Undrained Triaxial
      - Interpretation of results different
    - Consolidation Test
      - Work Energy to determine σ'_p

Unconsolidated-Undrained Triaxial Test



Work Energy



- Version 1.1
  - Quality Assurance/ Quality Control (QA/QC)
    - Field
      - To be submitted by GEC
    - Laboratory
      - AMRL certification required

- Version 2.0
  - Quality Assurance/ Quality Control (QA/QC)
    - Field
      - ASTM D3740
    - Laboratory
      - AMRL certification required

Chapter 6

- Version 1.1
  - Soil Classification
    - Soil Test Borings
      - USCS
      - AASHTO
  - Rock Classification
    - Rock Mass Rating (RMR)

- Version 2.0
  - Soil Classification
    - Soil Test Borings
      - USCS
      - AASHTO
    - Cone Penetrometer Test
      - Soil Behavior Type
    - Dilatometer Test
      - Soil Type
  - Rock Classification
    - Rock Mass Rating (RMR)
    - Geological Strength Index (GSI)

- Version 1.1
  - Guidelines for Soil Test Boring Log
- Version 2.0
  - Guidelines for Field Testing Logs
  - Guidelines for Laboratory Testing Results

Chapter 7

- Version 1.1
  - Soil Response
    - Cohesionless
      - Sands
      - %#200 ≤ 50
    - Cohesive
      - Clays
      - %#200 > 50
    - Response based on grain-size distribution only
- Version 2.0
  - Soil Response Classification
    - Sand-Like
      - %#200 ≤ 20
    - Clay-Like
      - %#200 > 20
    - Response based on grain-size and moisture-plasticity relationship
    - Accounts for I_c and I_D

Soil Response Classification

Percent Fines	Soil Behavior	LL	PI	I_c [1,2]	I_D [1]	Loading Condition	Shear Strength	Stress Condition	Settlement	AASHTO (USCS) Classification
≤ 20	Sand-Like	N/A[3]	N/A[3]	≤ 2.05	≥ 1.8	Short-term	Drained	Effective	Elastic	A-1-a, A-1-b, A-3 (SP, SP-SM, SP-SC, SM, SC, SC-SM)[4]
						Long-term	Drained	Effective		
> 20	Sand-Like	≤ 40	≤ 10	≤ 2.05	≥ 1.8	Short-term	Drained	Effective	Elastic	A-1-b, A-2-4, A-4 (SM, SC, SC-SM, ML, CL-ML, CL)
						Long-term	Drained	Effective		
	Clay-Like	> 40	> 10	≥ 2.6	≤ 0.6	Short-term	Undrained	Total	Consolidation	A-2-7, A-7-5, A-7-6 (SM, SC, ML, CL, MH, CH)
						Long-term	Drained	Effective		
	Clay-Like[5,6]	≤ 40	> 10	> 2.05 to < 2.6	> 0.6 to < 1.8	Short-term	Undrained	Total	Consolidation	A-2-6, A-6 (SC, SM, CL, ML)
						Long-term	Drained	Effective		
	Sand-Like[5,6]	> 40	≤ 10	> 2.05 to < 2.6	> 0.6 to < 1.8	Short-term	Drained	Effective	Elastic	A-2-5, A-5 (SM, ML, MH)
						Long-term	Drained	Effective		

[1] These are typical values and may change based on the correlation between CPTu or DMT and soil test boring.
[2] I_c to be correlated with Soil Test Boring to verify soil classification.
[3] Not Applicable plasticity not expected to affect these soils
[4] Doesn't include gravels (GW, GP, etc.) and well graded sands (SW, etc.)
[5] Possible Transitional Soil may be either Sand-Like or Clay-Like additional laboratory testing may be required. Additional laboratory testing shall be approved by PC/GDS
[6] Pore pressure dissipation test during CPTu testing may be required to determine difference between Sand-Like and Clay-Like

Borrow Materials

- Version 1.1
  - Table of Maximum allowable shear strengths provided
- Version 2.0
  - Spreadsheet by county of maximum shear strengths provided
  - Based on available shear strength testing data
  - Spreadsheet either by county or by RPG

Engineering District	RPG	COUNTY	EFFECTIVE COHESION (c') in ksf							
			SW/SP/SW-SM/SW-SC/SP-SM/SP-SC	SM/SC/SC-SM	GW/GP/GW-GC/GW-GM/GP-GC/GP-GM/GC/GM/GC-GM	CL/ML/CL-ML	CH/MH	OL/OH	SW/SP/SW-SM/SW-SC/SP-SM/SP-SC	SM/SC/SC-SM
6	1	BEAUFORT	0.050	0.450	0.000	0.290	0.000	0.000	35.000	29.000
6	1	BERKELEY	0.050	0.450	0.000	0.290	0.000	0.000	35.000	29.000
6	1	CHARLESTON	0.050	0.450	0.000	0.290	0.000	0.000	35.000	29.000
6	1	COLLETON	0.050	0.450	0.000	0.290	0.000	0.000	35.000	29.000
6	1	DORCHESTER	0.050	0.450	0.000	0.290	0.000	0.000	35.000	29.000
7	1	HAMPTON	0.050	0.450	0.000	0.290	0.000	0.000	35.000	29.000
6	1	JASPER	0.050	0.450	0.000	0.290	0.000	0.000	35.000	29.000
4	2	CHESTERFIELD	0.000	0.500	0.000	0.000	0.000	0.000	34.000	33.000
7	2	CLARENDON	0.000	0.500	0.000	0.000	0.000	0.000	32.000	31.000
5	2	DARLINGTON	0.000	0.250	0.000	0.000	0.000	0.000	34.000	33.000
5	2	DILLION	0.000	0.250	0.000	0.000	0.000	0.000	34.000	33.000
5	2	FLORENCE	0.000	1.000	0.000	0.000	0.000	0.000	34.000	33.000
5	2	GEORGETOWN	0.000	0.000	0.000	0.000	0.000	0.000	34.000	33.000
5	2	HORRY	0.000	1.000	0.000	0.000	0.000	0.000	34.000	33.000
1	2	KERSHAW	0.000	0.250	0.000	0.000	0.000	0.000	34.000	33.000
1	2	LEE	0.000	0.500	0.000	0.000	0.000	0.000	32.000	31.000
5	2	MARION	0.000	1.000	0.000	0.000	0.000	0.000	34.000	33.000
5	2	MARLBORO	0.000	1.000	0.000	0.000	0.000	0.000	34.000	33.000
1	2	SUMTER	0.000	0.500	0.000	0.000	0.000	0.000	34.000	32.000
5	2	WILLIAMSBURG	0.000	0.250	0.000	0.000	0.000	0.000	34.000	32.000
7	3	AIKEN	0.100	0.200	0.000	0.300	0.400	0.000	36.000	32.000
7	3	ALLENDALE	0.100	0.200	0.000	0.300	0.400	0.000	36.000	32.000
7	3	BAMBERG	0.100	0.200	0.000	0.300	0.400	0.000	36.000	32.000
7	3	BARNWELL	0.100	0.200	0.000	0.300	0.400	0.000	36.000	32.000
7	3	CALHOUN	0.100	0.200	0.000	0.300	0.400	0.000	36.000	32.000
4	3	CHESTER	0.000	0.200	0.000	0.300	0.400	0.000	36.000	32.000
4	3	FAIRFIELD	0.000	0.200	0.000	0.300	0.400	0.000	36.000	32.000
4	3	LANCASTER	0.000	0.200	0.000	0.300	0.400	0.000	36.000	32.000
1	3	LEXINGTON A	0.000	0.200	0.000	0.300	0.400	0.000	36.000	32.000
1	3	LEXINGTON B	0.100	0.200	0.000	0.300	0.400	0.000	36.000	32.000
2	3	NEWBERRY	0.000	0.200	0.000	0.300	0.400	0.000	36.000	32.000
7	3	ORANGEBURG	0.100	0.200	0.000	0.300	0.400	0.000	36.000	32.000
1	3	RICHLAND A	0.000	0.200	0.000	0.300	0.400	0.000	36.000	32.000
1	3	RICHLAND B	0.100	0.200	0.000	0.300	0.400	0.000	36.000	32.000
4	3	UNION	0.000	0.200	0.000	0.300	0.400	0.000	36.000	32.000
4	3	YORK	0.000	0.200	0.000	0.300	0.400	0.000	36.000	32.000

Soil Dynamic Properties

- Version 1.1
  - Part of Chapter 12
- Version 2.0
  - Part of Chapter 7

Electro-Chemical Properties

- Version 1.1
  - Results of this testing not discussed
- Version 2.0
  - Aggressive
  - Non-aggressive

Environmental Classification	Electro-Chemical Component	Units	Soil	Water
Aggressive (if any of these conditions exist)	pH	-	< 5.5	< 5.5
	Cl	ppm	N.A.	> 500
	SO_4	ppm	> 1,000	> 500
	Resistivity	Ohm-cm	< 2,000	N.A.
Non-aggressive	This classification must be used at all sites not meeting the requirements for Aggressive Environments			
pH = acidity ($-\log_{10}H^+$; potential of hydrogen; Cl = chloride content; SO_4 = sulfate content				

Chapter 8

- Version 1.1
  - Operational Classification (OC) defined
  - Roadway Operational Classification (ROC) defined
    - Modified by DM0211
- Version 2.0
  - OC definition contained in Seismic Design Specifications for Highway Bridges (2008)
    - Revised 2017
  - ROC eliminated
  - Discussion on what is included at each limit state check

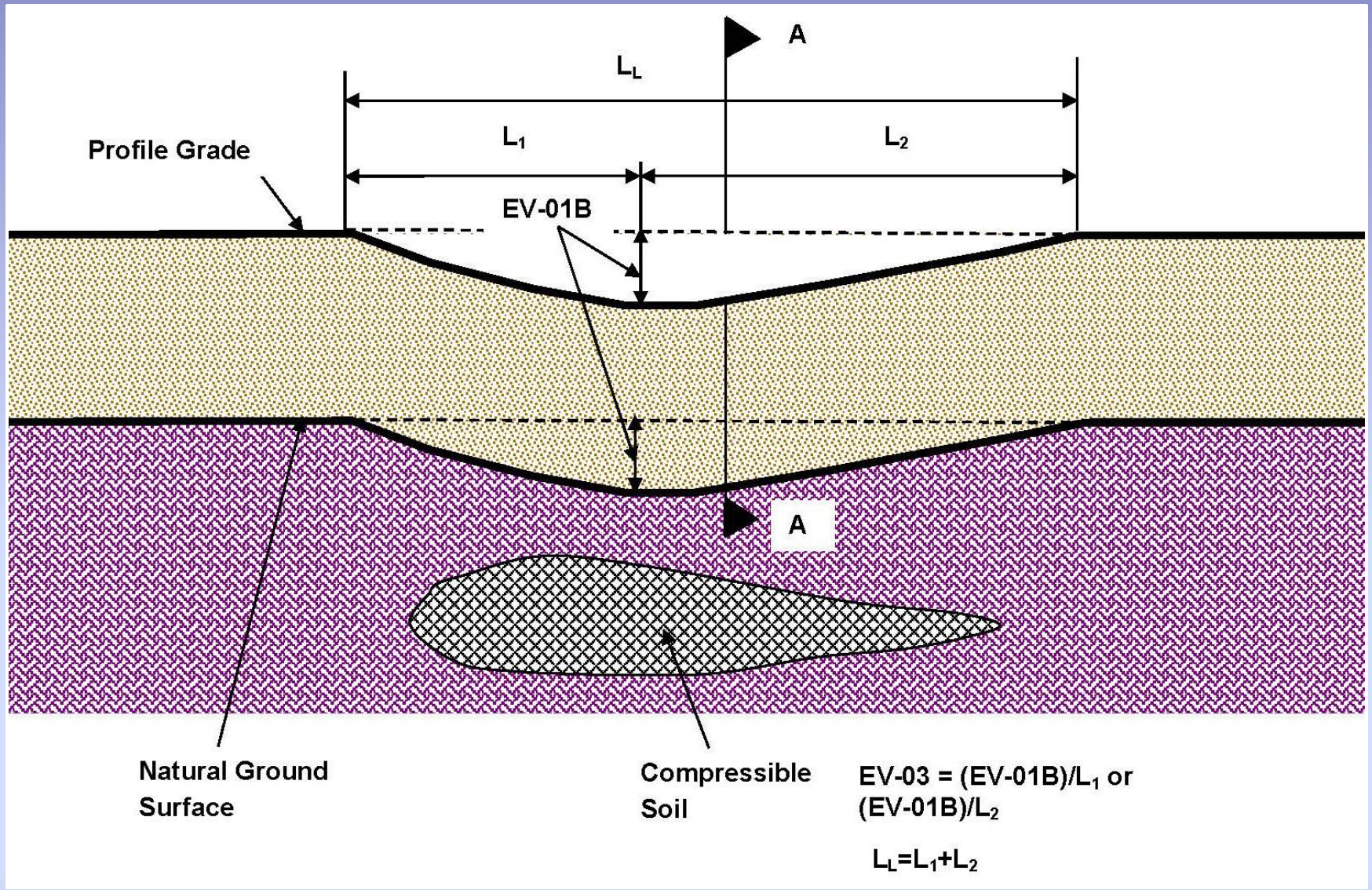
Chapter 9

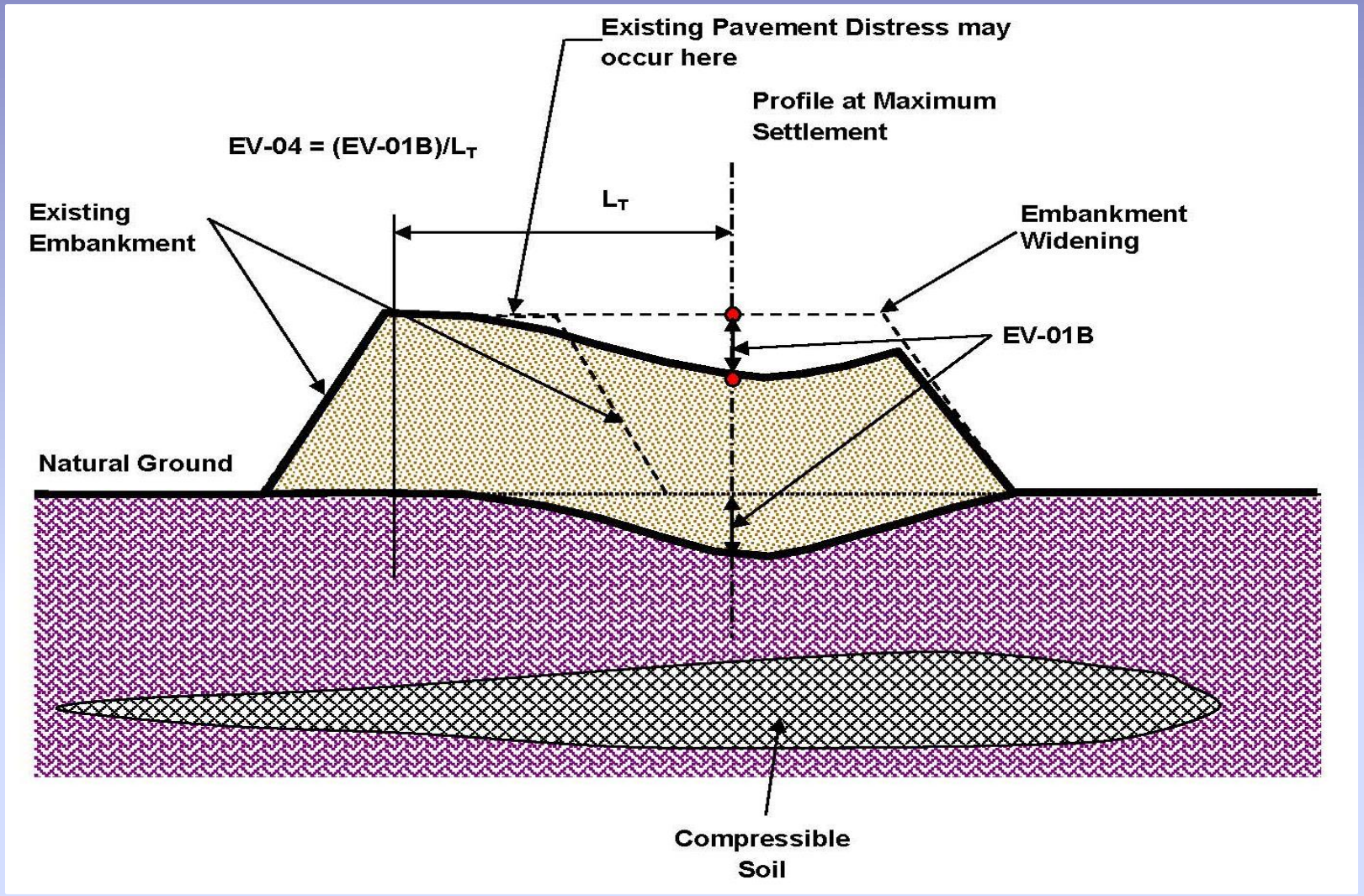
- No significant changes between versions 1.1 and 2.0

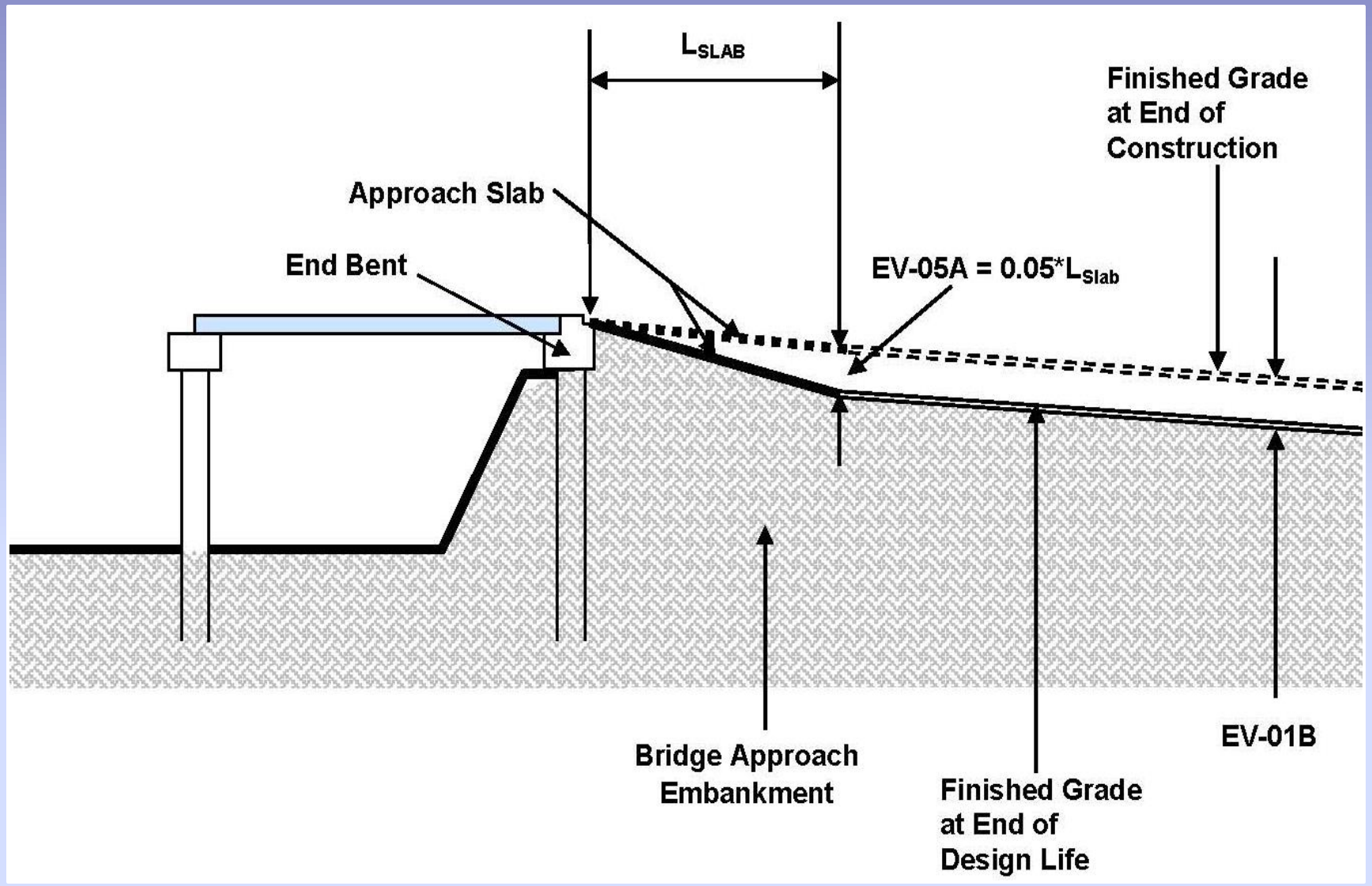
Chapter 10

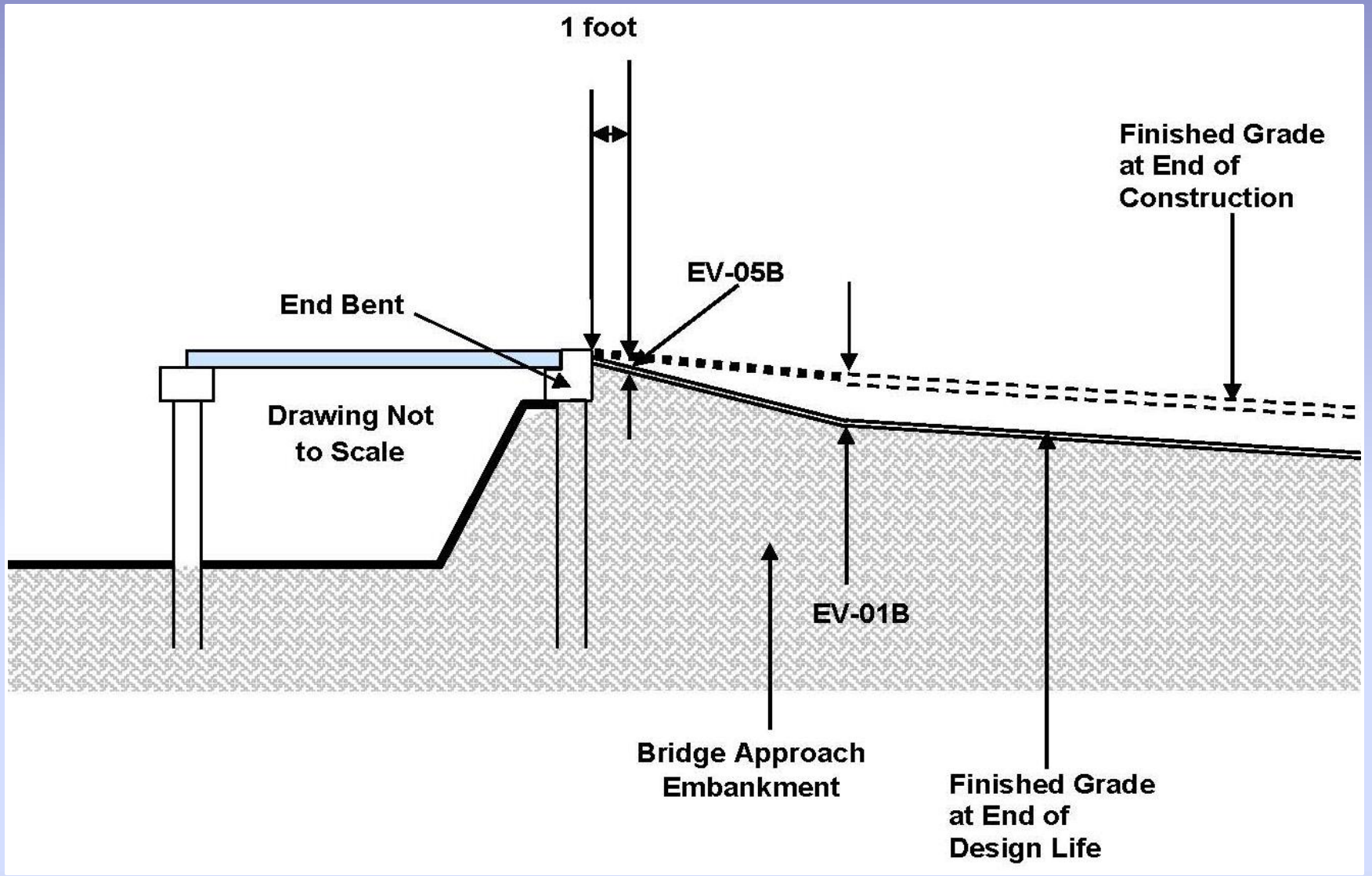
- Version 1.1
  - Performance Objective development process
  - Bridge Deformations and Performance Limits
- Version 2.0
  - Performance Objective development process moved to Appendix K
  - Bridge Deformations and Performance Limits eliminated
    - Bridge deflections still calculated
    - Loads induced by deflections to be calculated
    - Loads and deflections reported to project team

- Version 2.0
  - EV-01 spilt
    - EV-01A – Settlement that occurs during construction
    - EV-01B – Settlement that occurs over the design life
      - Design Life is 20 years for embankments
  - EV-02 eliminated
  - EV-03 – Longitudinal differential settlement between the end of approach slab toward a point on embankment or between 2 points on embankment
  - EV-04 – Transverse differential settlement between existing embankment and new embankment
  - EV-05 – Settlement between end of bridge and end of approach slab
    - EV-05A – Settlement that occurs between the end of the bridge and the end of the approach slab
    - EV-05B – Settlement that occurs between the end of the bridge and a point 1 foot from the bridge (for bridges without approach slabs)


A
L_L
L_1
L_2
Profile Grade
EV-01B
A
Natural Ground Surface
Compressible Soil
EV-03 = (EV-01B)/L_1 or (EV-01B)/L_2
$L_L=L_1+L_2$


Existing Pavement Distress may occur here
Profile at Maximum Settlement
EV-04 = (EV-01B)/L_T
L_T
Existing Embankment
Embankment Widening
EV-01B
Natural Ground
Compressible Soil


L_{SLAB}
Finished Grade at End of Construction
Approach Slab
End Bent
EV-05A = 0.05*L_{Slab}
Bridge Approach Embankment
Finished Grade at End of Design Life
EV-01B


1 foot
Finished Grade
at End of
Construction
EV-05B
End Bent
Drawing Not
to Scale
EV-01B
Bridge Approach
Embankment
Finished Grade
at End of
Design Life

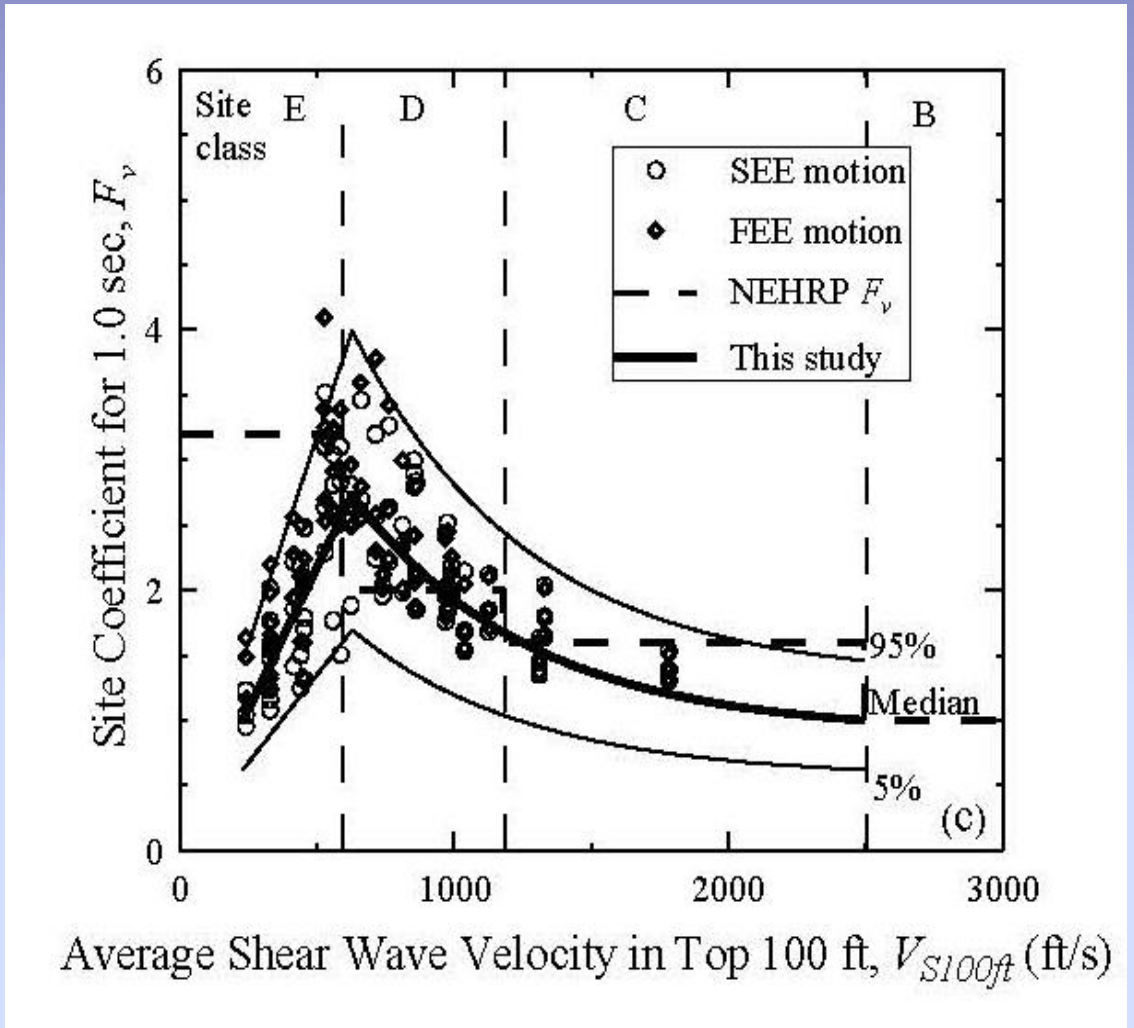
- Version 2.0
  - Only Service limit states Performance Limits provided
  - All EE I and EE II deflections and loads will be determined and reported to project team
  - Project team will determine if structure meets the assigned Performance Objective and if ground improvement is required

Chapter 11

- No significant changes between versions 1.1 and 2.0

Chapter 12

- Version 1.1
  - Geotechnical Earthquake Engineering
  - Site Class based on V_{s100}
    - A through E
    - Used to determine F_{PGA}, F_a, F_v
- Version 2.0
  - Geotechnical Seismic Analysis
  - Site Classes no longer used
  - Site amplification factors, F_{PGA}, F_a, F_V
    - Determined using Andrus, et al. (2014)
  - ADRS developed by PC/GDS



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- Version 1.1
  - PGA
  - S_{DS}
  - S_{D1}
  - D_{a5-95} - Duration
  - PGV – Peak Ground Velocity
  - M_w – Moment Magnitude
  - R - Distance
- Version 2.0
  - PGA
  - S_{DS}
  - S_{D1}
  - D_{a5-95} - Duration
  - PGV – Peak Ground Velocity
  - M_w – Moment Magnitude
  - R - Distance
  - T'_o – Predominant Period
  - T_0 – Period of Bridge

3-Point Acceleration Design Response Spectrum

SCDOT v3.0 - 03/26/2015

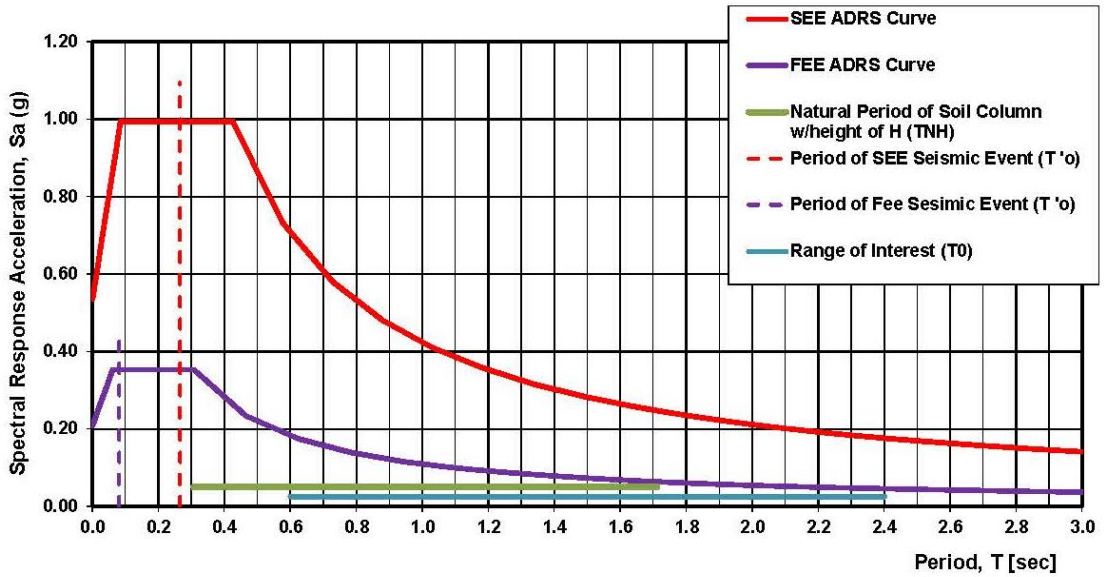
Project ID:	38.036984			Latitude:	33.4628
Route:	US 301	County:	38 - Orangeburg	Longitude:	80.4678
Project:	RBO I-95 (US 301 Extension)				

Designer:	N. Harman - Support
Date:	2/12/2015

Design EQ	PGA	S_{DS}	S_{D1}	M_W	R	PGV	$D_{s5\text{-}95}$	T'_o
	g	g	g	-	km	ft/sec	sec	sec
FEE	0.21	0.35	0.11	7.35	45.00	4.12	27.71	0.08
SEE	0.54	0.99	0.42	7.36	45.00	16.04	26.27	0.27

Damping:	5%
Geologic Condition:	Geologically Realistic (Q = 100)
ADRS Loction within Soil Column:	At Ground Surface

Fundamental Period of Structure, T_0	Range of Interest		$V^*_{s,H}$	H	T_{NH}	
	sec				sec	
sec	0.5^*T_0	2.0^*T_0	ft/sec	ft	$(4^*H)/V^*_{s,H}$	$(6^*H)/V^*_{s,H}$
1.20	0.60	2.40	1777.59	506.89	0.31	1.71



	FEE Data			SEE Data	
	T	S_a		T	S_a
	0.00	0.209		0.00	0.536
	0.01	0.233		0.01	0.612
	0.02	0.257		0.03	0.689
	0.03	0.281		0.04	0.765
	0.04	0.305		0.06	0.842
	0.05	0.329		0.07	0.918
To	0.06	0.353	To	0.08	0.995
	0.08	0.353		0.11	0.995
	0.10	0.353		0.14	0.995
	0.12	0.353		0.17	0.995
	0.14	0.353		0.20	0.995
	0.16	0.353		0.23	0.995
	0.18	0.353		0.25	0.995
	0.20	0.353		0.28	0.995
	0.23	0.353		0.31	0.995
	0.25	0.353		0.34	0.995
	0.27	0.353		0.37	0.995
	0.29	0.353		0.40	0.995
Ts	0.31	0.353	Ts	0.42	0.995
	0.47	0.233		0.58	0.733
	0.62	0.174		0.73	0.580
	0.78	0.139		0.88	0.480
	0.94	0.115		1.03	0.410
	1.10	0.099		1.18	0.357
	1.26	0.086		1.33	0.317
	1.42	0.077		1.48	0.284
	1.57	0.069		1.64	0.258
	1.73	0.063		1.79	0.236
	1.89	0.057		1.94	0.218
	2.05	0.053		2.09	0.202
	2.21	0.049		2.24	0.188
	2.37	0.046		2.39	0.176
	2.52	0.043		2.55	0.166
	2.68	0.040		2.70	0.156
	2.84	0.038		2.85	0.148
	3.00	0.036		3.00	0.141

Chapter 13

- Version 1.1
  - K_{DR} from equation or table
    - Table only for uncemented soils
  - Seismic Slope Stability required for 150 feet from either end of bridge
- Version 2.0
  - K_{DR} from equation only
    - Accounts for cementation better
  - No Seismic Slope Stability required (Bridge Embankment only)
    - 3H:1V; ≤ 0.3g & no SSL
    - 2H:1V; ≤ 0.2g & no SSL

Chapter 14

- Version 1.1
  - All ERSs checked for Seismic Slope Stability
- Version 2.0
  - ERSs in Bridge Embankments
    - No Seismic Slope Stability analysis if
      - PGA ≤ 0.4g
      - H ≤ 35 feet
      - No SSL
    - No Seismic Slope Stability analysis may be extended to PGA ≤ 0.8g, provided
      - $k_y/k_{max} \geq 0.5$
      - 2 inches of movement can be tolerated

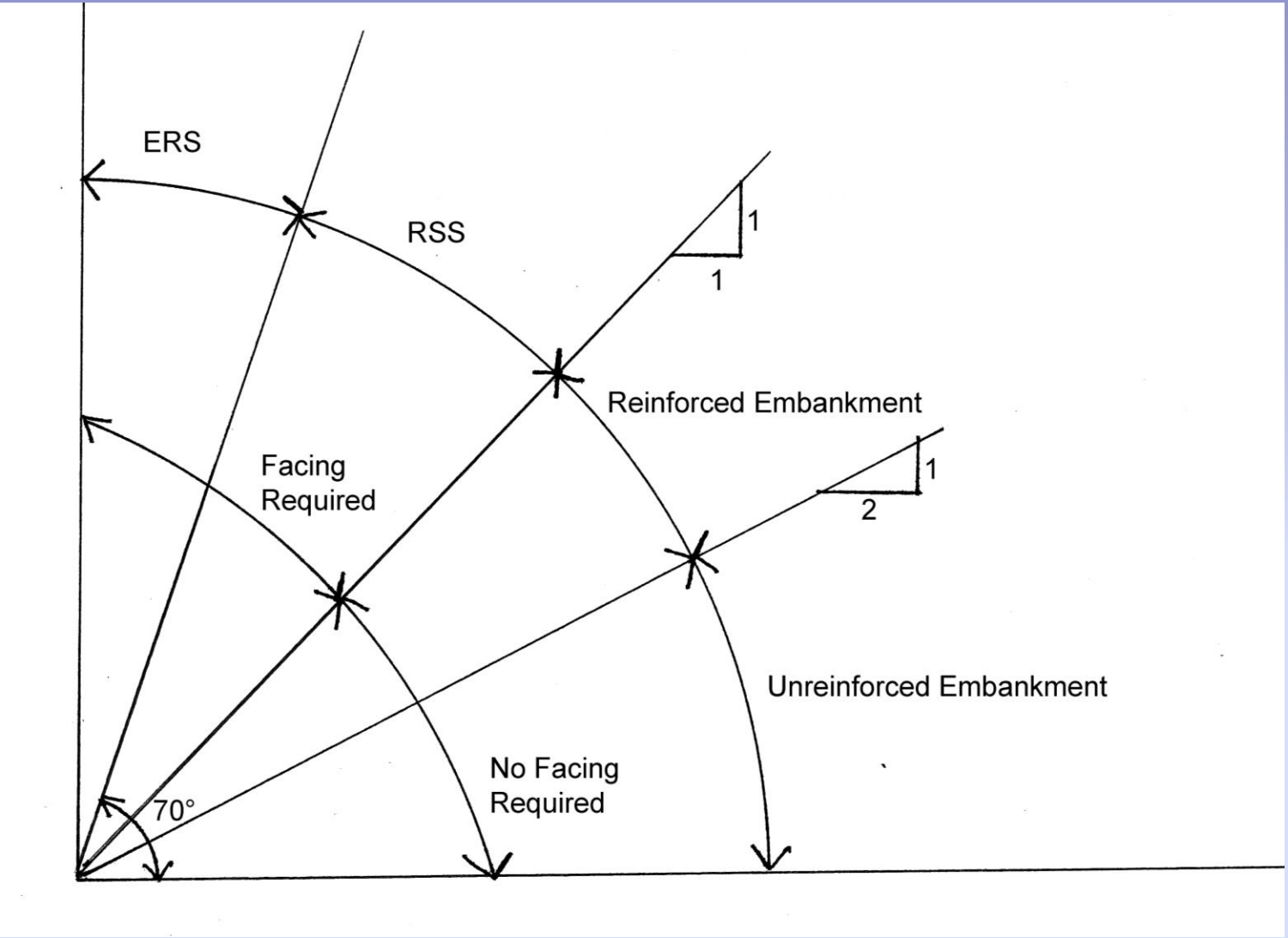
- Version 2.0
  - ERSs in Bridge Embankments
    - Seismic Slope Stability Analysis required
      - Previous criteria not met
      - ERS is part of a larger slope
  - ERSs in Roadway Embankment
    - No Seismic Slope Stability analysis required
      - PGA ≤ 0.4g
      - H ≤ 10 feet
      - Regardless of presence or absence of SSL
      - SSL not present follow Bridge Embankment criteria for no analysis
    - Seismic Slope Stability Analysis required
      - Previous criteria not met
      - ERS is part of a larger slope
      - ERS supports another structure that could be affected by instability

Chapters 15 & 16

- No significant changes between versions 1.1 and 2.0

Chapter 17

- Version 1.1
  - Modified Bishop required
    - Static only
    - Circular only
- Version 2.0
  - Spencer method will be required
    - Static and Dynamic
    - Circular and Non-circular
  - Embankment design discussed more
    - Reinforced Soil Slopes moved to this Chapter


ERS
RSS
1
1
Reinforced Embankment
Facing
Required
1
2
Unreinforced Embankment
No Facing
Required
70°

Chapter 18

- Version 1.1
  - Reinforced Soil Slopes included
- Version 2.0
  - Moved Reinforced Soil Slopes to Chapter 17

Chapter 19

- Version 1.1
  - Column Supported Embankment
    - Designed using Beam Approach (Modified Collin Method)
- Version 2.0
  - Added Ground Improvement Technology Selection Matrix
  - Column Supported Embankment
    - Designed using Load and Displacement Compatibility Method

Geotechnology \ ISF		Speed of Construction	Minimize Construction Disturbance	Longevity of Constructed Works	Cost of Construction	Constructability	ROW Requirements or Restrictions	Aesthetics	Environmental Concerns	Degree of Establishment	Familiarity with Geotechnology	Design Procedure	Contracting	Life-cycle Cost	Project Constraint – Construction Season	Additional Project Constraint (if required)	Project Risk – Delay Due to Settlement Time	Project Risk – Quality Assurance	Addition Project Risk (if required)	**Total Weighted Rating (WR_T)**
	IR	3	2	2	2	1	0	2	2	3	1	2	2	1	0	0	2	3	0	
Geotechnology A[1]	SF	4	1	3	3	1	4	4	3	4	2	4	2	2	1	1	4	3	2	
	WR	**12**	**2**	**6**	**9**	**1**	**0**	**8**	**6**	**12**	**2**	**8**	**4**	**2**	**0**	**0**	**8**	**9**	**0**	**89**
Geotechnology B[1]	SF	3	1	3	1	4	1	4	4	1	3	3	2	3	1	1	3	1	4	
	WR	**9**	**2**	**6**	**3**	**4**	**0**	**8**	**8**	**3**	**3**	**6**	**4**	**3**	**0**	**0**	**6**	**3**	**0**	**57**
Geotechnology C[1]	SF	4	1	1	1	1	4	2	4	3	4	2	3	1	1	1	4	1	2	
	WR	**12**	**2**	**2**	**3**	**1**	**0**	**4**	**8**	**9**	**4**	**4**	**6**	**1**	**0**	**0**	**8**	**3**	**0**	**67**

[1]SF for each geotechnology are based on project requirements and site constraints. Each SF should be rated between 1, least suitable, and 4, most suitable.

Chapters 20 to 26

- No significant changes between versions 1.1 and 2.0

Appendices

- Version 1.1
  - A – Geotechnical Forms
  - B – Slope Stability Design Charts
  - C – MSE Walls
  - D – Reinforced Soil Slopes
  - E – Geotechnical Template Plans
  - F – Project Specific Specifications List
  - G – Software List
- Version 2.0
  - A – Geotechnical Forms
  - B – Deleted
  - C – MSE Walls
  - D – Reinforced Soil Slopes
  - E Geotechnical Template Plans
  - Project Specific Specifications List
  - G – Software List

- Version 2.0
  - H – Shear Wave Velocity Profiles
  - I – Shear Strength Ratio Triggering Methods
  - J – Flow Charts
  - K – Performance Objective Development

What's Next?

- Currently Chapters 19 and 20 are in review by ACEC and others
- Chapters 21 through 26 should be out for review by ACEC in March
- Version 2.0 of GDM anticipated to be issued May 2017

- Thank You!
- Questions?

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