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MSE Wall Engineering
A New Look at Contracting, Design, and Construction

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Why Do We Need Change?

- Whitman (1984) states that appropriate structural designs should have a failure rate in the range of 1 in 1,000 to 1 in 10,000.

- Soong and Koerner (1999) reported MSE wall failures at a rate of approximately 1 in 1,000 (26 failures reported for approximately 35,000 walls).

Why Do We Need Change?

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Why Do We Need Change?

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Why Do We Need Change?

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Why Do We Need Change?

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Why Do We Need Change?

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Why Do We Need Change?

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Where Do You Want to Put Your Risk?

- Cost to construct
  - MSE Wall typical cost - $30 to $65 per sf
- Cost of failure
  - MSE Wall stabilization - $60 to $130 per sf
  - MSE Wall replacement - $300 to $650 per sf

What Change is Needed?

- Better communication between designers
- Better identification of conflicts
- Better documentation during construction
- Accountability by all parties

Results in Better MSE Walls

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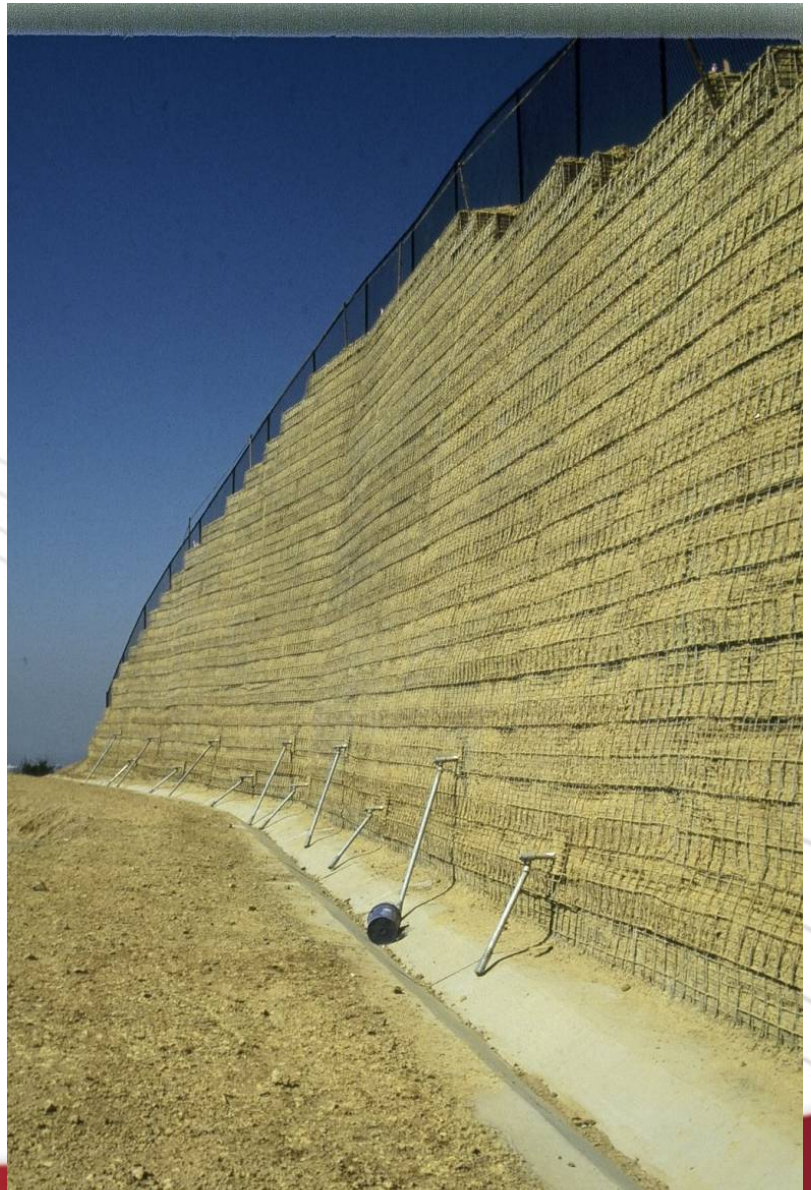
Results in Better MSE Walls



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Results in Better MSE Walls

Results in Better MSE Walls

Traditional Design Information

- Civil
- Utility
- Drainage
- Structural
- Geotechnical
  - Recommendations based on 30% plans
  - Simplified MSE Wall parameters (if provided at all)

"Who is looking out for the MSE Wall?"

Traditional Geotechnical Report Information

TABLE 3: MSE WALL ALLOWABLE BEARING RESISTANCE

MSE Wall	Maximum Wall Height (feet)	Wall Section	Allowable Bearing Resistance (psf)	Maximum Allowable Wall Height	
				70% Anchors	100% Anchors
A	11	Entire Wall	4,300	11	NA
B	11	Wall Sections Less Than 18 Feet High	3,000	15	18
B	21*	Entire MSE Wall Portion*	4,000*	21*	NA
C	25	Entire Wall	4,300	23	25
D	22	Entire Wall	4,000	22	NA
E	20	Entire Wall	4,300	20	NA
F	28	Entire Wall	4,300	23	28
I	6	Entire Wall	4,000	6	NA

*Treatment of the wall foundation subgrade as discussed in Section 6.6.2 will be required to develop the allowable bearing resistance.

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Traditional Geotechnical Report Information

TABLE 5: LATERAL EARTH PRESSURES – MSE AND CIP RETAINING WALLS

Wall Backfill	Equivalent Fluid Pressure for Backfill Slopes of:		
	3H:1V	6H:1V	Level Backfill
MSE Wall Reinforced Volume Granular Backfill	44 pcf	39 pcf	35 pcf
Type C Backfill	53 pcf	45 pcf	40 pcf

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Traditional Geotechnical Report Information

6.2 RETAINING WALL DESIGN CRITERIA

The bearing resistance values and maximum allowable wall heights presented in the following report sections are based on the criteria listed below.

1. The walls will be embedded at least 2 feet below final grade next to the wall.
2. The walls will have a two-foot-wide mow strip at the toe of the walls. The ground surface beyond the mow strip will slope down at a maximum slope of 4 horizontal to 1 vertical (4H:1V) for a horizontal distance of 20 feet or less and will then be flat and level.
3. The MSE and CIP walls will be well drained.
4. The MSE walls will have a minimum anchor length of 8 feet and all the wall anchors will have the same length within a vertical section of wall. In addition, the minimum MSE wall anchor length will not be less than 70 percent of the wall height.
5. The walls will have a safety factor of at least 2.0 for bearing resistance.
6. The wall foundation subgrades will be prepared in accordance with the recommendations presented in this report.
7. Design soil strengths for computing the bearing resistance values were selected based on triaxial test results and TCP test results.
8. The maximum allowable wall heights that would not apply a bearing pressure that would exceed the allowable soil bearing resistance were computed based on a lateral earth pressure of 40 pcf, backfill soil unit weight of 125 pcf, and a distributed surcharge load of 240 psf.
9. The wall height is the vertical distance from the base of the wall at the top of the leveling pad to the top of the retained fill.

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Traditional Geotechnical Report Information

6.5 SLIDING RESISTANCE

An ultimate coefficient of sliding resistance of 0.40 is recommended for design of the MSE and CIP walls. The retaining walls should have a safety factor of at least 1.5 with respect to sliding.

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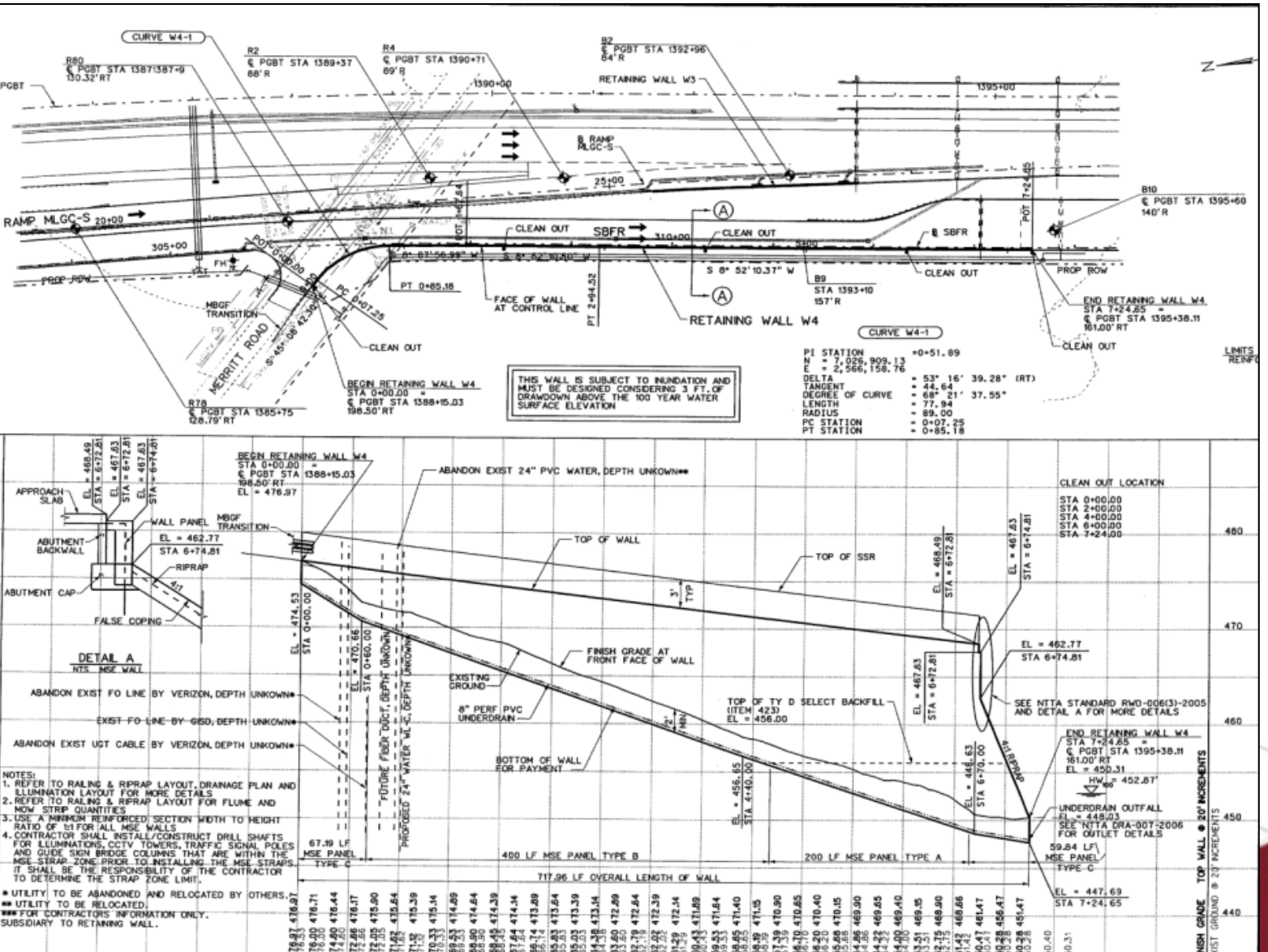
Traditional Design

- Project Plans
  - Civil
  - Utilities
  - Drainage
  - Structural
  - Standard Design Sheets

  - Geotechnical Report “For Information Only”

“Who is looking out for the MSE Wall?”

Traditional Civil Plan Sheet



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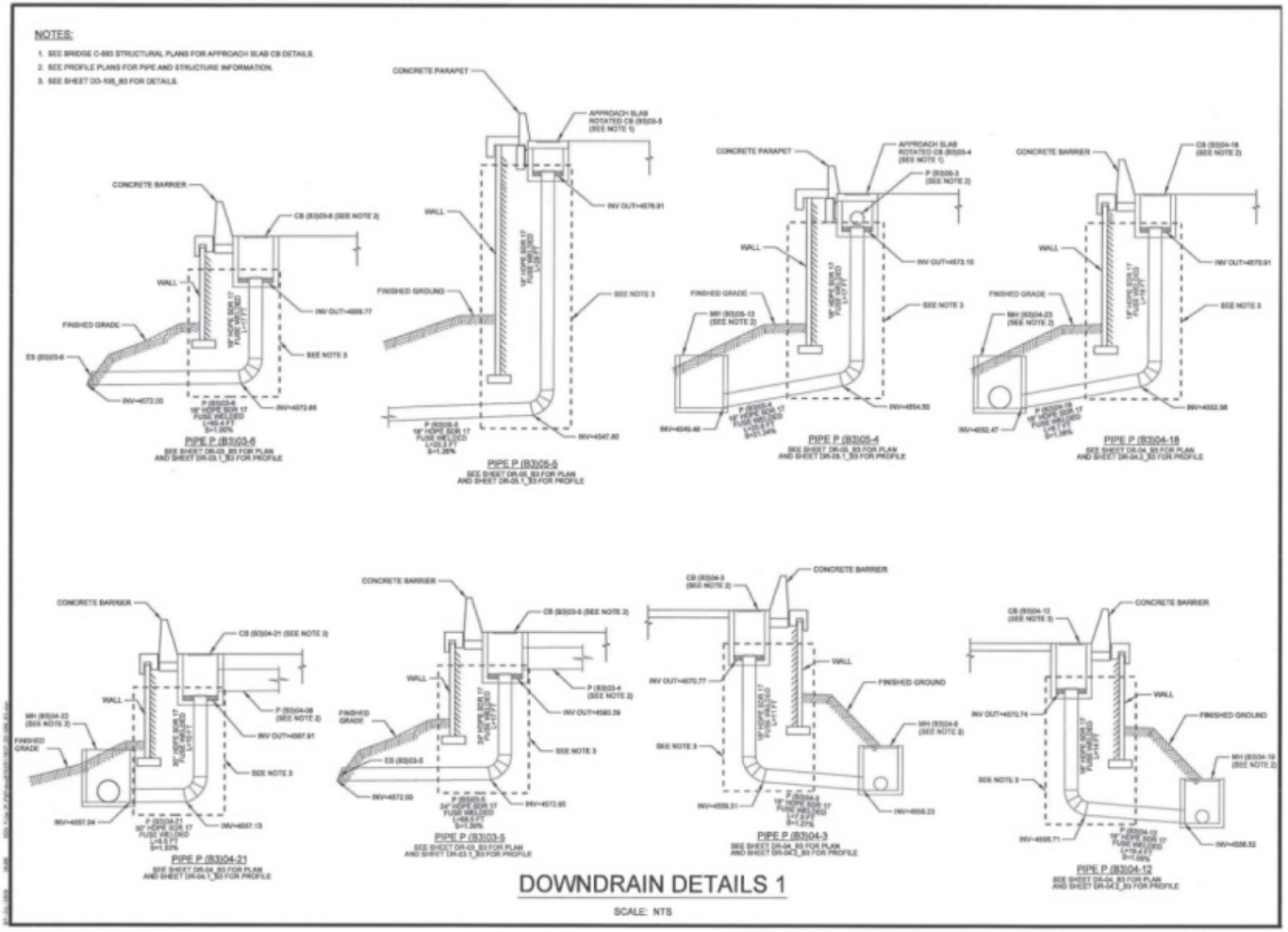
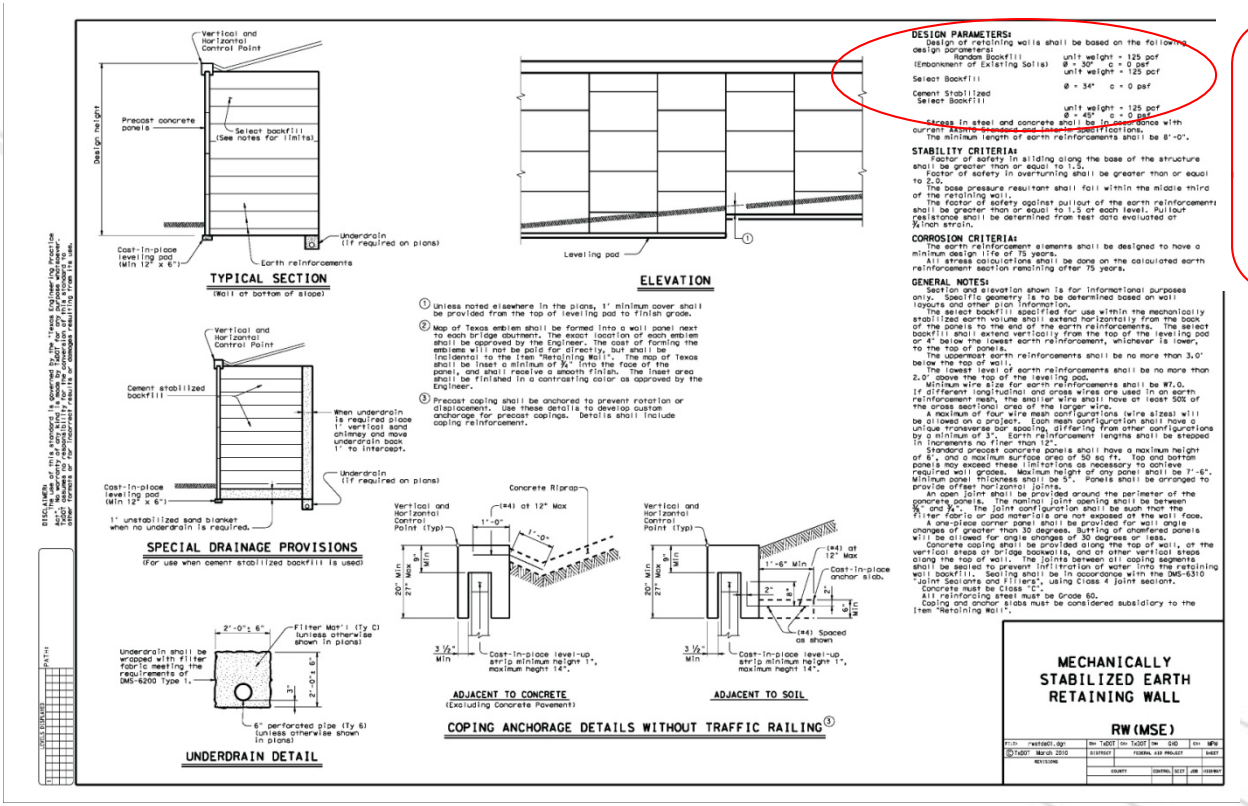
Traditional Drainage Plan Sheet



MSE Wall Standard Detail



DESIGN PARAMETERS:

Design of retaining walls shall be based on the following design parameters:

Random Backfill (Embankment of Existing Soils)	unit weight = 125 pcf Ø = 30° c = 0 psf
Select Backfill	unit weight = 125 pcf Ø = 34° c = 0 psf
Cement Stabilized Select Backfill	unit weight = 125 pcf Ø = 45° c = 0 psf

DISCLAIMER: The use of this standard is governed by the "*State* Engineering Practice Act". No Warranty of any kind is made by the *DOT* for any purpose whatsoever. The DOT assumes no responsibility for the conversion of this standard to other formats or for incorrect results or damages resulting from its use.

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Traditional MSE Wall Design

- Construction Contract Design and Coordination
  - G/C designs MSE Wall (Shop Drawings)
  - CM reviews shop drawings
  - CM coordinates with Contractor to resolve field issues

"Who is looking out for the MSE Wall?"

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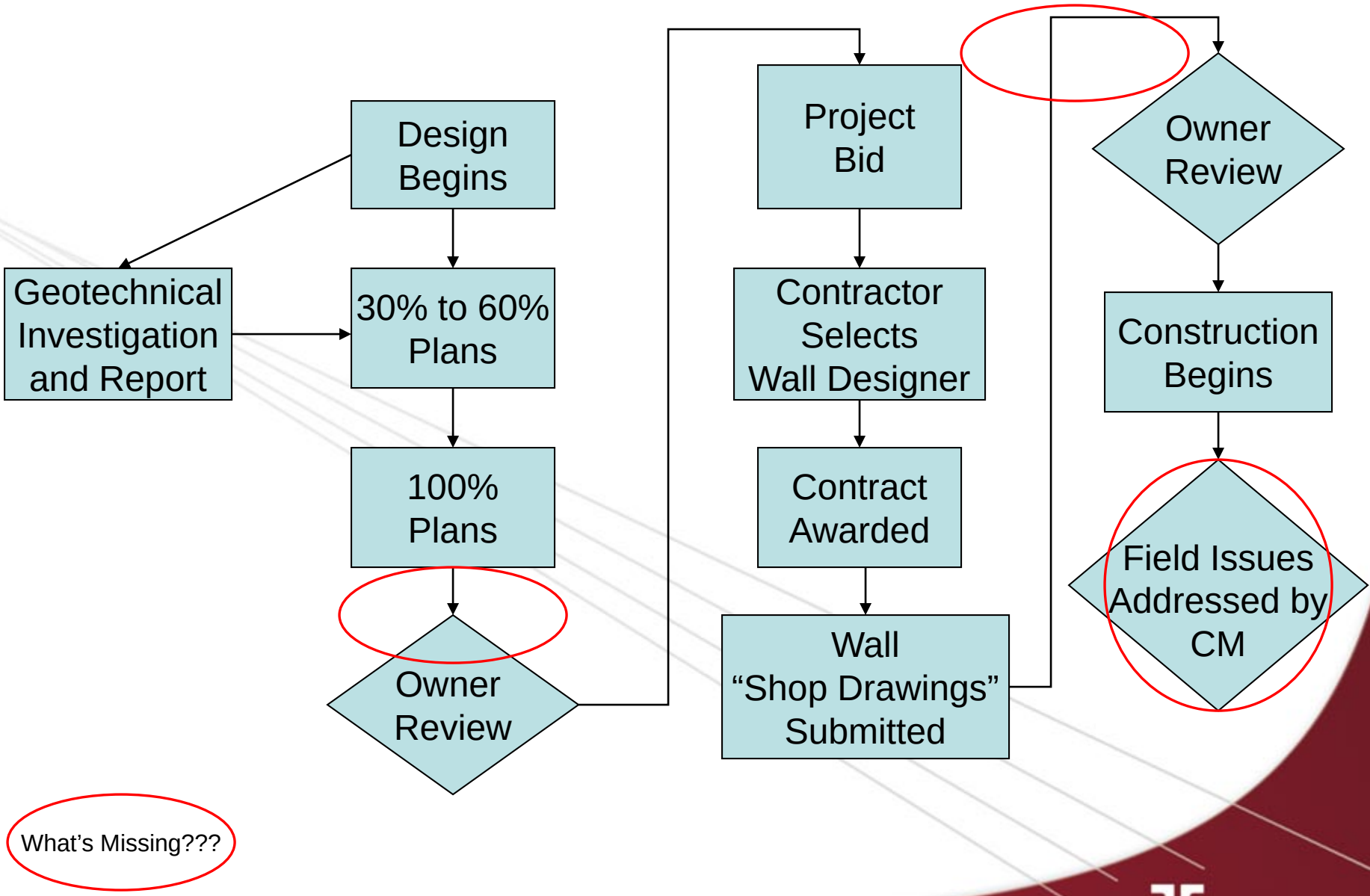
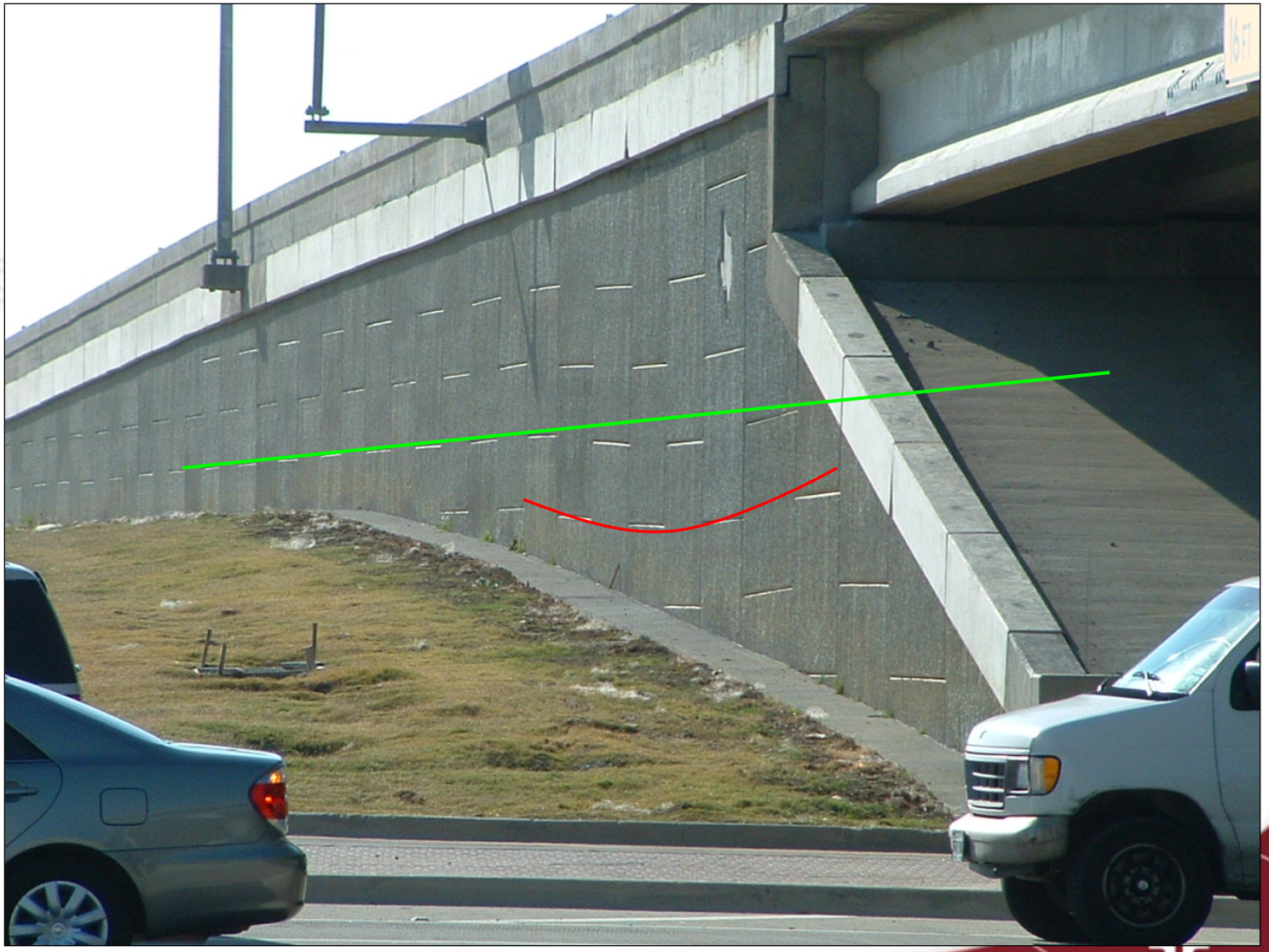

Design Begins
Geotechnical Investigation and Report
30% to 60% Plans
100% Plans
Owner Review
Project Bid
Contractor Selects Wall Designer
Contract Awarded
Wall "Shop Drawings" Submitted
Owner Review
Construction Begins
Field Issues Addressed by CM
What's Missing???

Design Review

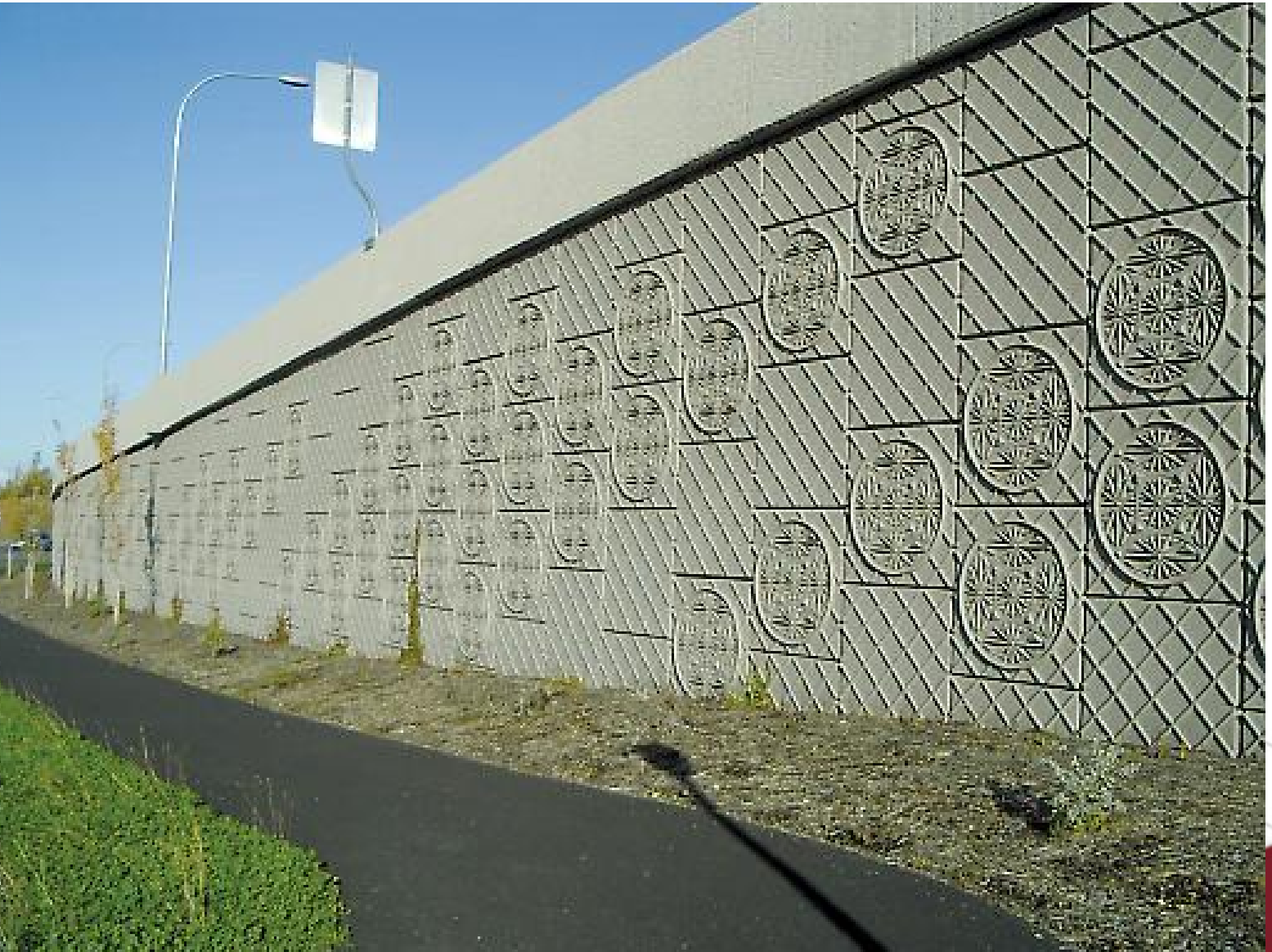
- Civil
- Utility
- Drainage
- Structural
- Geotechnical

"Who is looking out for the MSE Wall?"

Traditional Results



Traditional Results



Traditional Results

Traditional Results

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Traditional Results

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Traditional Results

Traditional Results

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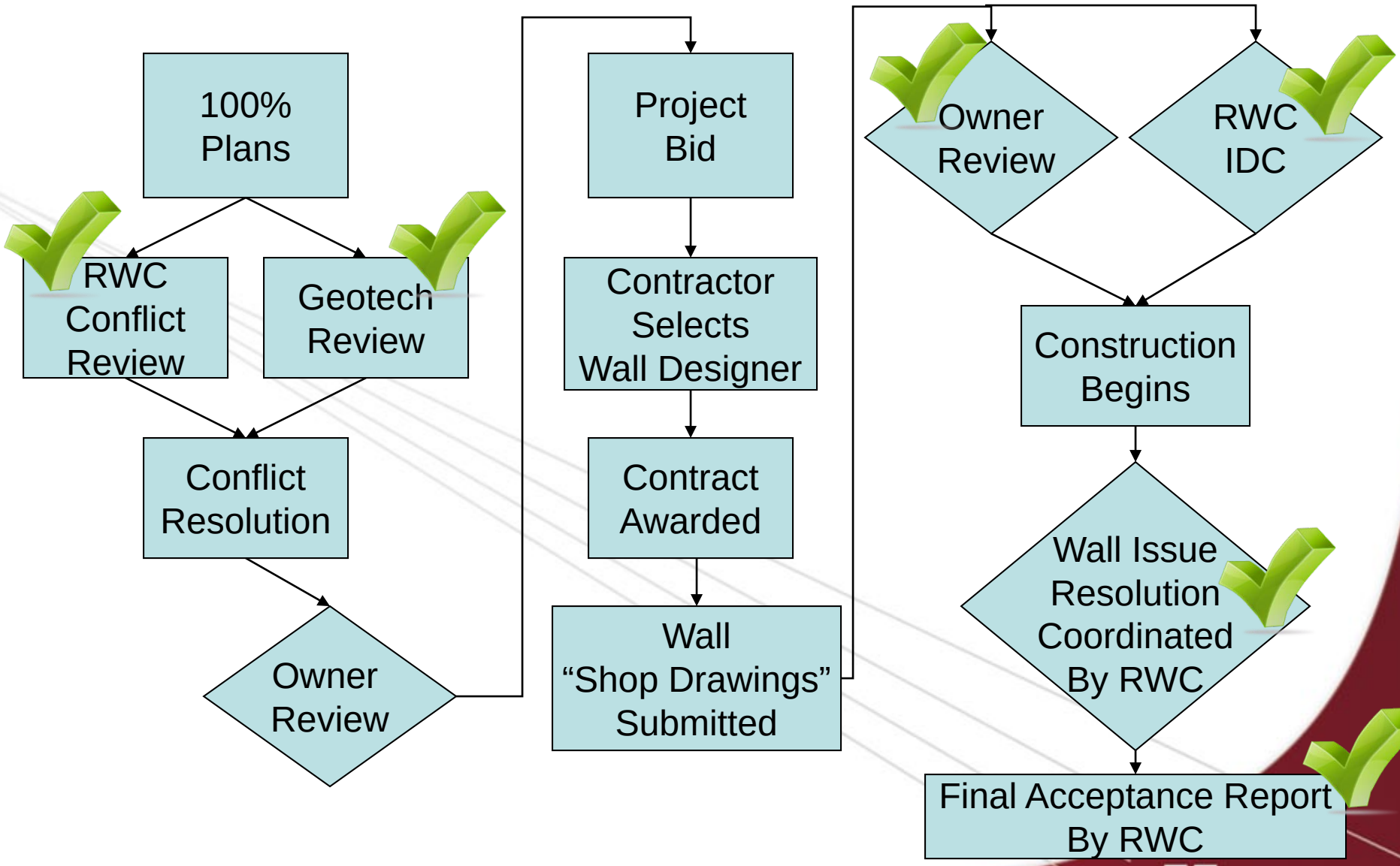
Traditional Results

Retaining Wall Coordinator

- Single point of contact
- In charge of coordinating all facets of MSE wall design between disciplines (Design and Construction)
- Works out conflicts between disciplines
- Verify construction documentation


100% Plans
RWC Conflict Review
Geotech Review
Conflict Resolution
Owner Review
Project Bid
Contractor Selects Wall Designer
Contract Awarded
Wall "Shop Drawings" Submitted
Owner Review
RWC IDC
Construction Begins
Wall Issue Resolution Coordinated By RWC
Final Acceptance Report By RWC

RWC Design Duties

- Geotechnical Investigation
  - MSE wall specific strength parameters

Wall ID	WALL STATION RANGE	SELECT FILL SOIL		RETAINED SOIL			FOUNDATION SOIL								
							Effective Stress Parameters for Calculating Sliding FS and Allow. Bearing Pressure			Total Stress Parameters for Calculating Sliding FS			Total Stress Parameters for Calculating Allow. Bearing Pressure		
		U. WEIGHT - PCF	FRICTION ANGLE, ϕ	SOIL TYPE	U. WEIGHT - PCF	EFFECTIVE STRESS FRICTION ANGLE, ϕ	SOIL TYPE	U. WEIGHT - PCF	FRICTION ANGLE, ϕ	COHESION, (C) - PSF	U. WEIGHT - PCF	FRICTION ANGLE, ϕ	COHESION, (C) - PSF	U. WEIGHT - PCF	FRICTION ANGLE, ϕ	COHESION, (C) - PSF
E1	0+00 to 8+52	130	34	non-select	125	25	undisturbed clay	125	25	0	125	0	2000	125	0	1709
E2	0+00 to 17+79	130	34	combination of non-select and Type A emb.	125	30	undisturbed clay	125	25	0	125	0	1728	125	0	1938
E3	0+00 to 7+35	130	34	non-select	125	25	undisturbed clay	125	25	0	125	0	1250	125	0	1250
E5	0+00 to 3+76	130	34	non-select	125	25	undisturbed clay	125	25	0	125	0	1385	125	0	1385
E6	0+00 to 7+00	130	34	non-select	125	25	undisturbed clay	125	25	0	125	0	865	125	0	1953
E7	0+00 to 4+60	130	34	combination of non-select and Type A emb.	125	30	undisturbed clay	125	25	0	125	0	865	125	0	1953
	4+60 to 6+10						combination of undisturbed clay and 5' of Type A emb.	63	30	0	N/A			125	0	2316
	6+10 to 10+40						combination of undisturbed clay and 5'-16' of Type A emb.	63	30	0	N/A			125	0	3250
	10+40 to 12+60						undisturbed clay	125	25	0	125	0	865	125	0	1953
	12+60 to 16+90						combination of undisturbed clay and 0'-11' of Type A emb.	63	30	0	N/A			125	0	3250
	16+90 to 25+65						undisturbed clay	125	25	0	125	0	1500	125	0	2000

RWC Design Duties

- Project Plans
  - Clearly identify anticipated materials
  - Standard Sheets modified to include site specific parameters

RWC Design Duties

- Review Plans and Specifications
  - Verify the geotechnical parameters
  - Verify that the geotechnical engineer has performed slope stability analyses for the final design
  - Identify conflicts that impact wall design and performance
  - Verify conflicts have been resolved

RWC Verifies Design Checklist

		Reference (See Note 3)	Yes	No	NA	Comments/ Action Required
I.	GENERAL INFORMATION					
1.	Is the wall vendor pre-approved? (visit _____for a list of pre-approved wall systems)	APL	☐	☐	☐	
2.	Is the wall within the limitations of the pre-approved product? (e.g., wall height, external loading, environmental constraints, seismic loading and other project specific constraints; visit for limitations)	APL	☐	☐	☐	
3.	Has the Contractor used the correct design survey data (e.g., existing ground elevations and horizontal offsets) for wall design?	Project/vendor drawings	☐	☐	☐	
4.	Has the Contractor correctly reflected the location of utilities in the area of the wall(s)?	Project/vendor Drawings	☐	☐	☐	
5.	Is the wall profile (top and bottom elevations) including start and end stations correct?	Project/vendor Drawings	☐	☐	☐	
6.	Is the wall design life specified?	Spec/ Section 2.8	☐	☐	☐	
7.	Have the following items been specified by the vendor and are they in conformance with the project requirements?					
	a. Material requirements					
	i. Soil Properties (strength, gradation, PI, soundness, electrochemical)	Spec	☐	☐	☐	
	ii. Soil Reinforcement (ultimate and yield tensile strengths, reduction factors for geosynthetics)	Spec	☐	☐	☐	
	iii. Concrete (strength and other properties)	Spec/Project Drawings	☐	☐	☐	
	iv. Concrete reinforcement (type, number and strength)	Spec/Project Drawings	☐	☐	☐	
	v. Leveling Pad (strength)	Spec/Project Drawings	☐	☐	☐	
	vi. Steel facing elements for wire mesh systems (ultimate and yield tensile strengths)	Spec	☐	☐	☐	
	b. Construction procedures including sequence	APL	☐	☐	☐	
	c. Soil compaction procedures and restrictions for reinforced fill, retained fill and foundation preparation	APL/spec/ PGR	☐	☐	☐	
	d. Facing alignment tolerances	Spec	☐	☐	☐	

- Wall Elevations
- Leveling Pad
- Facing Units
- Utilities
- Drainage
- Wall Details
- Soil Reinforcement
- External Stability
- Internal Stability

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RWC Preconstruction Duties

- Independent Design Check of Shop Drawings
  - Review calculations
  - Review plans and specifications
  - Review material submittals

Drawing Review Checklist

Table 11-2. Checklist for Drawing Review. (after FHWA NHI-08-094/095)

YES	NO	NA	
			1.0 DOCUMENTS
			1.1 Have you thoroughly reviewed the design drawings?
			1.2 Is there a set of all project drawings in the field trailer?
			1.3 Has the contractor submitted shop drawings?
			1.4 Have the shop drawings been approved by the designer and/or construction division manager?
			2.0 LAYOUT
			2.1 Have you located the horizontal and vertical control points?
			2.2 Do you know where the MSEW/RSS begins and ends?
			2.3 Have you identified any locations of existing utilities, signs, piles, lights that affect the proposed construction?
			2.4 Have you identified the elevations/ grade at top and at bottom of MSEWs/RSSs?
			2.5 Have you identified the existing and finished grades?
			2.6 Do you know where the construction limits are?
			2.7 Have you identified how the site will be accessed and any provisions for material storage?
			2.8 Is phased construction involved?
			3.0 FOUNDATION PREPARATION
			3.1 Are any special foundation treatments required?
			3.2 Is the foundation stepped?
			3.3 Is concrete leveling pad and the required elevation(s) shown on the drawings?
			3.4 Is shoring required?
			4.0 DRAINAGE
			4.1 Have you located the details for drainage?
			4.2 When must the drainage provisions be installed?
			4.3 Where does the drainage system outlet and does it allow for positive drainage?
			4.4 Are geotextile filters required?
			4.5 Is a drainage barrier (geomembrane) required for this project?
			5.0 FACING
			5.1 Have you identified the facing type, shape, size, and architectural finishing?
			5.2 Are there different types, colors, or sized facing units on the job?
			5.3 How do the facing units fit together?

Specification Compliance Checklist

Table 11-3. Checklist for Specification Compliance. (after FHWA NHI-08-094/095)

YES	NO	NA	
			1.0 DOCUMENTS
			1.1 Have you thoroughly reviewed the specifications?
			1.2 Is there a set of specifications in the field trailer?
			1.3 Are standard specifications or special provisions required in addition to the project specifications? Do you have a copy?
			2.0 PRE-CONSTRUCTION QUALIFYING OF MATERIAL SOURCES / SUPPLIERS
			2.1 Has the Contractor submitted pre-construction qualification test results (showing that it meets the gradation, density, electrochemical, and other soil-property requirements) for:
			2.1.1 Reinforced soil
			2.1.2 Retained soil
			2.1.3 Facing soil (if applicable)
			2.1.4 Drainage aggregate
			2.1.4 Graded granular filters (if applicable)
			2.2 Has the Contractor or Manufacturer submitted pre-construction qualification test results and/or Certificate of Compliance demonstrating that the facing materials comply with the applicable sections of the specifications including:
			2.2.1 Facing unit and connections
			2.2.2 Horizontal facing joint bearing pads
			2.2.3 Geotextile filter for facing joint
			2.3 Has the Contractor or Manufacturer submitted pre-construction qualification test results and/or Certificate of Compliance demonstrating that the reinforcing materials comply with the applicable sections of the specifications?
			2.4 Has the Contractor or Manufacturer submitted pre-construction qualification test results and/or Certificate of Compliance demonstrating that the drainage materials comply with the applicable sections of the specifications including:
			2.2.1 Geotextile filters (e.g., Type, AOS, permittivity, strength)
			2.2.2 Prefabricated Drains (i.e., geotextile filter and core)
			2.2.3 Drainage Pipe (material, type, ASTM designation and schedule
			2.4 Has approval of the soil sources been officially granted for:
			2.4.1 Reinforced soil
			2.4.2 Retained soil

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RWC Preconstruction Duties

- Communicate critical wall system elements
- Provide project specific training to personnel involved with wall construction
- Communicate expectations

Field Inspection Checklist

Table 11-1. Outline of MSE/RSS Field Inspection Checklist Requirements.

- □ **1. Read the specifications and become familiar with:**
  - material requirements
  - construction procedures
  - soil compaction procedures
  - alignment tolerances
  - acceptance/rejection criteria
- □ **2. Review the construction plans and become familiar with:**
  - construction sequence
  - corrosion protection requirements
  - special placement to reduce damage
  - soil compaction restrictions
  - details for drainage requirements
  - details for utility construction
  - construction of slope face
  - contractor's documents
- □ **3. Review material requirements and approval submittals.**
  Review construction sequence for the reinforcement system.
- □ **4. Check site conditions and foundation requirements. Observe:**
  - preparation of foundations
  - leveling pad construction (check level and alignment)
  - site accessibility
  - limits of excavation
  - construction dewatering
  - drainage features; seeps, adjacent streams, lakes, etc.
- □ **5. On site, check reinforcements and prefabricated units. Perform inspection of prefabricated elements (i.e. casting yard) as required. Reject precast facing elements if:**
  - compressive strength < specification requirements
  - molding defects (e.g., bent molds)
  - honey-combing
  - severe cracking, chipping or spalling
  - color of finish variation
  - tolerance control
  - misaligned connections
- □ **6. Check reinforcement labels to verify whether they match certification documents.**
- □ **7. Observe materials in batch of reinforcements to make sure they are the same. Observe reinforcements for flaws and nonuniformity.**
- □ **8. Obtain test samples according to specification requirements from randomly selected reinforcements.**
- □ **9. Observe construction to see that the contractor complies with specification requirements for installation.**
- □ **10. If possible, check reinforcements after aggregate or riprap placement for possible damage. This can be done either by constructing a trial installation, or by removing a small section of aggregate or riprap and observing the reinforcement after placement and compaction of the aggregate, at the beginning of the project. If damage has occurred, contact the design engineer.**
- □ **11. Check all reinforcement and prefabricated facing units against the initial approved shipment and collect additional test samples.**
- □ **12. Monitor facing alignment:**
  - adjacent facing panel joints
  - precast face panels
  - modular block walls
  - wrapped face walls
  - line and grade

RWC Construction Duties

- Verifies that the specified materials are being provided
- Verifies that the field testing is being performed in accordance with and meets the project specifications
- Verifies that the various disciplines have reviewed the as-built drawings and daily reports as necessary

RWC Construction Duties

- Provides support regarding field changes
- Assures appropriate parties are involved in field change process
- Provide project specific training of field QA/QC personnel with respect to walls

RWC Construction Duties

- Project Documentation
  - Review QA/QC documentation for compliance
  - Maintain weekly wall progress reports
  - Prepare final wall acceptance reports

Challenges

- Coordination with multiple entities

Challenges (continued)

- Design interpretations

Challenges (continued)

- Controlling surface water runoff

Challenges (continued)

- Backfilling against the wall facing

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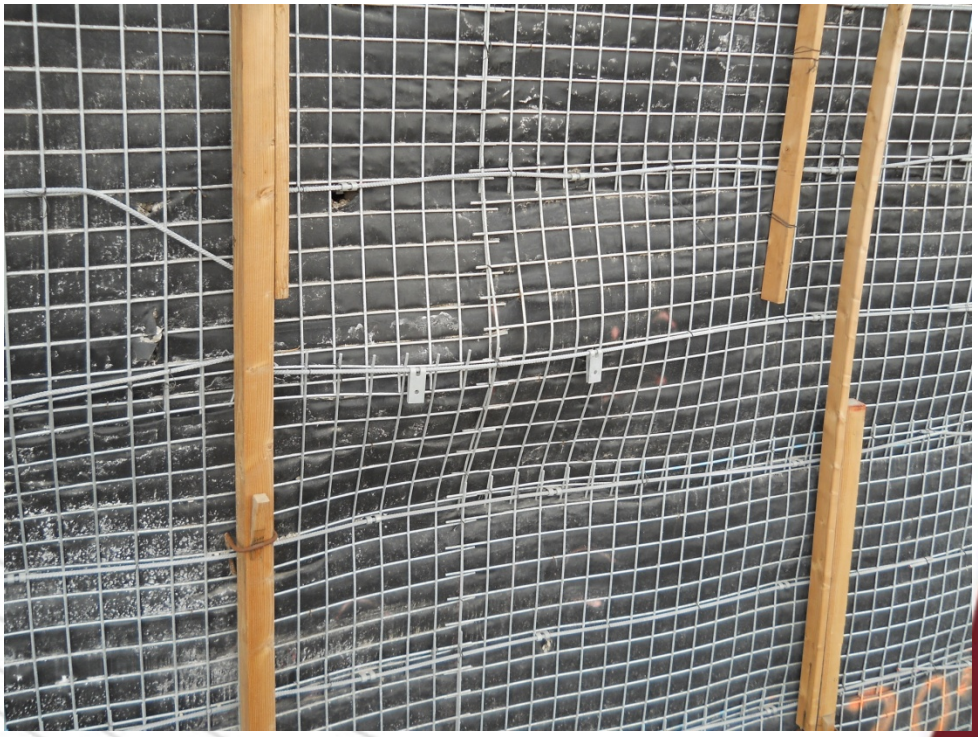
Challenges (continued)

- Strapping installation



Final Acceptance Report

- Compile all project specific data for each wall
  - As-built drawings
  - Field inspection reports
  - QA/QC field and laboratory data
  - Manufacturers submittals
  - A statement that the wall was built in conformance with plans and specifications

RWC Results

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RWC Results

RWC Results

RWC Results

Where Do You Want to Put Your Risk?

- MSE Wall Typical Cost - $30 to $65 per SF
- Cost of failure
  - MSE Wall Stabilization - $60 to $130 per sf
  - MSE Wall Replacement - $300 to $650 per sf
- Cost of Retaining Wall Engineer
  - MSE Wall Construction Cost with RWC - $5.00 to $10.00 sf

Questions