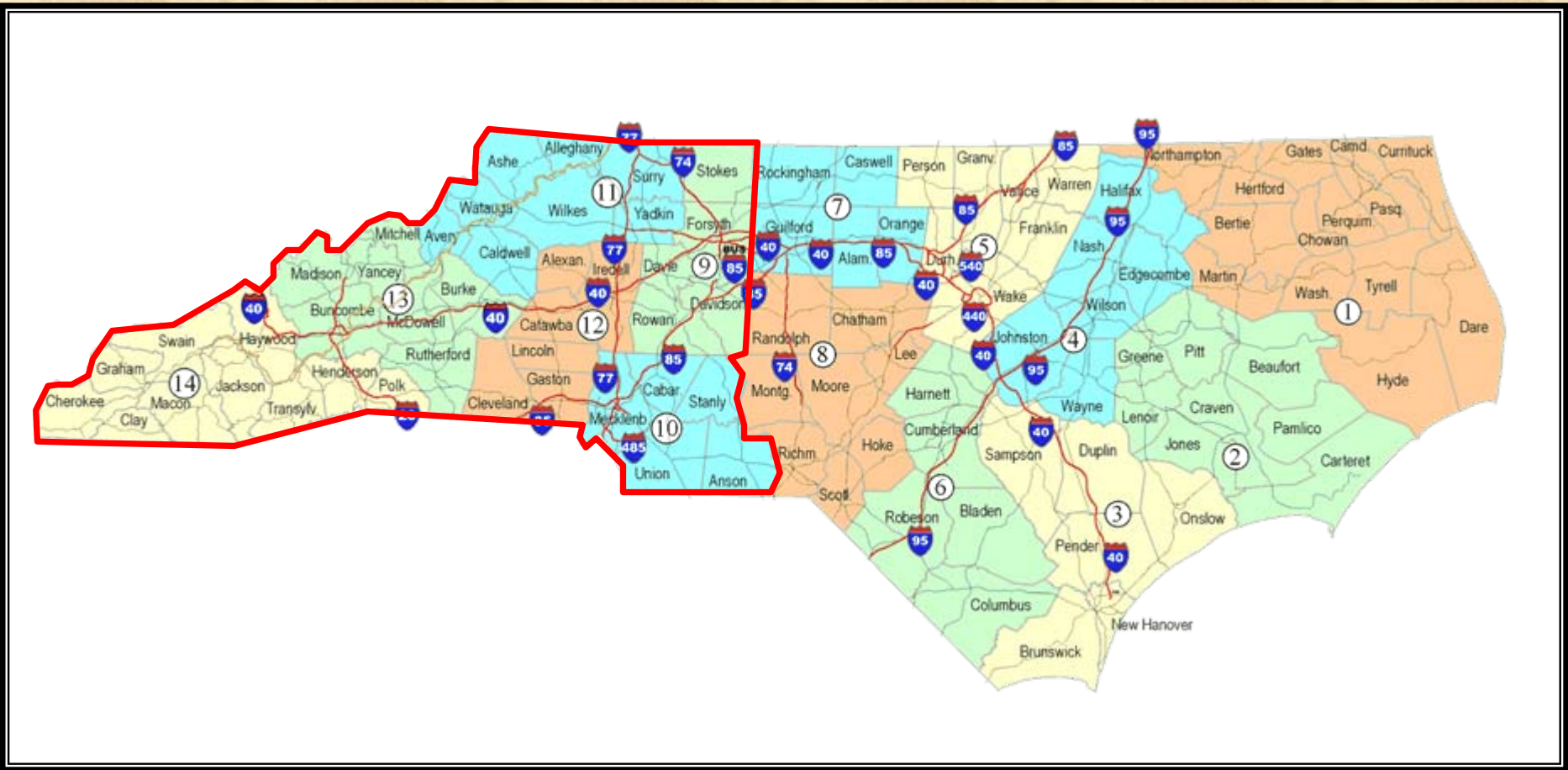




STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION GEOTECHNICAL ENGINEERING UNIT



**Proofrolling and Failing Subgrades -
What do I do next?**



GEOTECHNICAL ENGINEERING UNIT

- Western Regional Office (Div. 8 -14)
 - Harrisburg, NC
 - Western Regional Operations Group
 - Dean Hardister, PE
- Central Office
 - Raleigh, NC
 - Geopavement Section
 - Tom Hearne, PE – Geopavement Supervisor (Harrisburg)
 - Kevin Sebold – Senior Geopavement Engineer (Raleigh)

PROOFROLLING

- By the Book – Section 260
 - Coverage of subgrade to 2 feet outside pavement
 - Gross weight of 48 to 50 tons
 - 4 pneumatic rubber tires
 - Tire inflation pressure of 68 to 72 psi
- NOT By the Book
 - Using rubber-tired construction equipment
 - GOOD – pans, backhoes, motorgraders, dump trucks
 - NOT SO MUCH – grade-alls, manlifts, telehandlers





PROOFROLLING

- Why Should a Subgrade Be Proofrolled?
 - Rapid determination of subgrade strength
 - Rapid determination of subgrade stability

PASSING DENSITY \neq PASSING PROOFROLL

PROOFROLLING

- Types of Failure

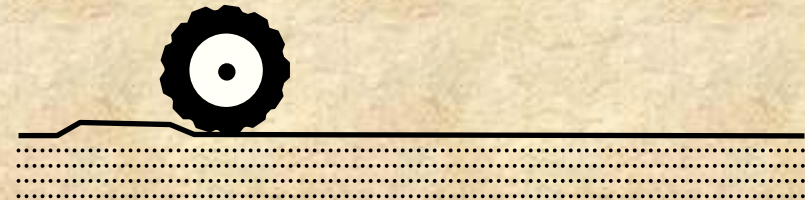
- PUMPING



- RUTTING



- SURFACE SHEARING

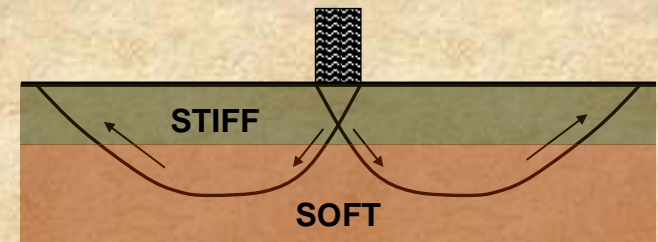
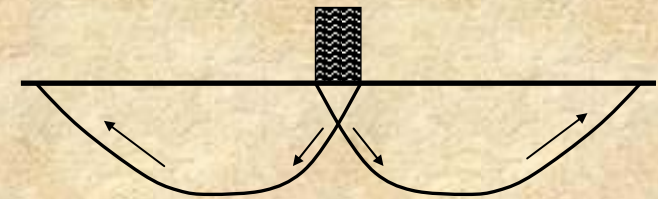


SUBGRADE FAILURE

- What's going on?
 - Bearing capacity

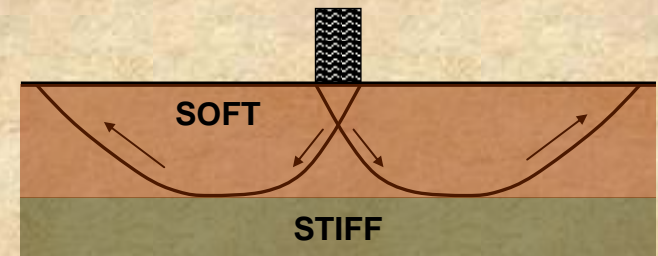
- PUMPING

- Stiff Layer over Softer Layer



- RUTTING

- Soft Layer over Stiffer Layer



SUBGRADE FAILURE

- What's the culprit?
 - Public Enemy #1

WATER!



SUBGRADE FAILURE

- What's the culprit?
 - Water: When to suspect?
 - Standing water/bridge plug
 - Weeping cut slopes
 - Ditches not fully constructed
 - Standing water in ditches
 - Subgrade always appears moist
 - Water: How to know?
 - Install piezometers
 - Dig test pits





SUBGRADE FAILURE

- What's the culprit?
 - Silty or Micaceous Soils: When to Suspect?
 - SURFACE SHEARING
 - Weak Soils: When to Suspect?
 - RUTTING
 - PUMPING
- OK, proofrolling didn't go so well! Now what?



WHAT'S THE POINT?

- Objectives
 - Proper subgrade moisture
 - Short-Term & Long-Term
 - Proper subgrade stability
 - Compaction of overlying pavement layers
 - Proper subgrade strength
 - Layered system – depth of soft zones matters
 - Dynamic Cone Penetrometer (DCP) Index
 - California Bearing Ratio (CBR)



REMEDIATION ARSENAL

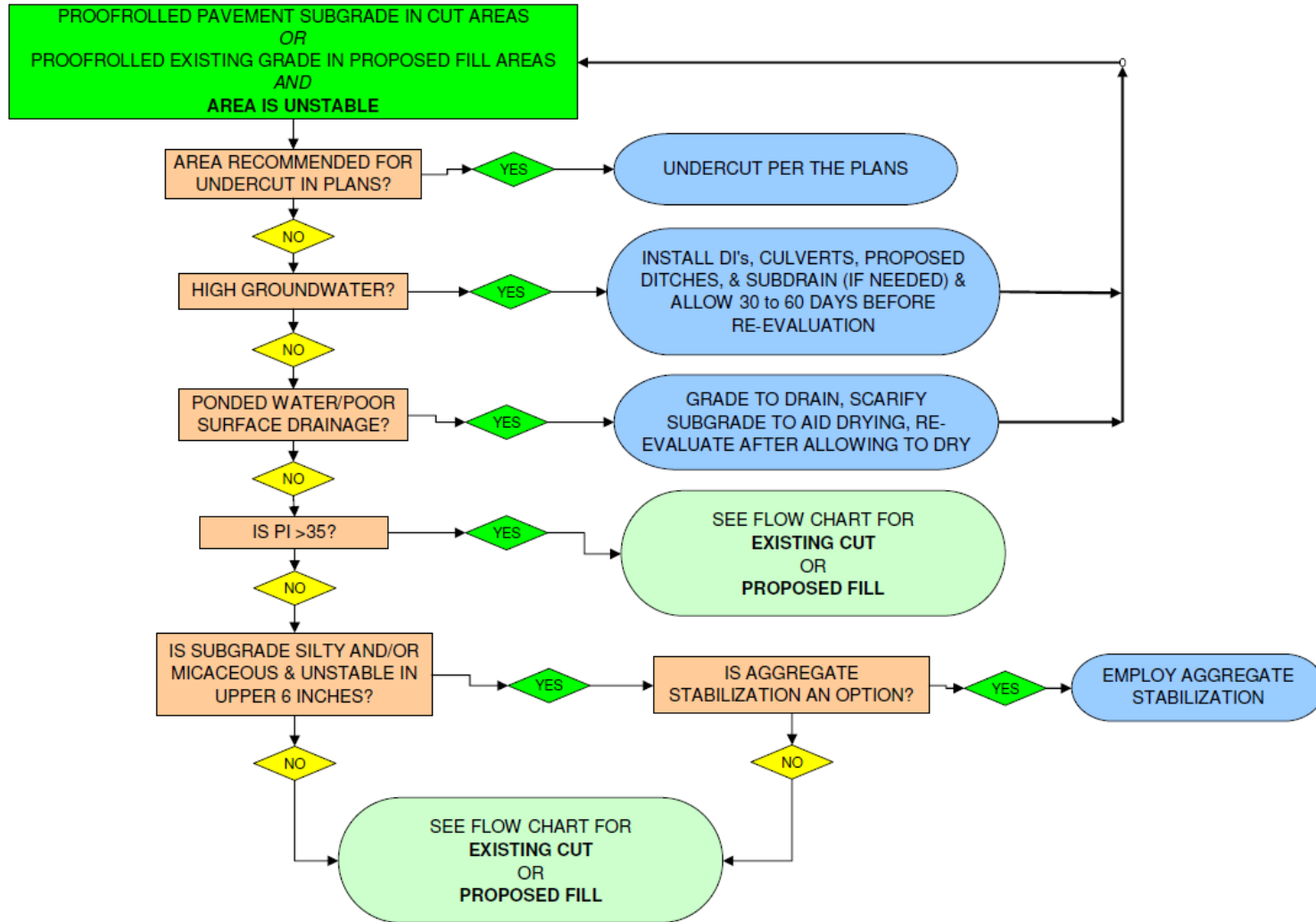
- Objectives
 - Proper subgrade moisture
 - Ditches – Get them in early
 - Grade surface to drain; use weeps
 - Subdrains; use extra pipe bedding
 - Proper subgrade stability
 - Aggregate Stabilization – Section 510
 - Chemical Stabilization – Occasionally; Upper 12”
 - Proper subgrade strength
 - Select Class II, Class III, Class IV – 92% T-180
 - Soil Stabilization Fabric – Type 4
 - HS Engineering Fabrics & Geogrids – Requires SA
 - Other Contract Items – Rip Rap, Recycled Concrete

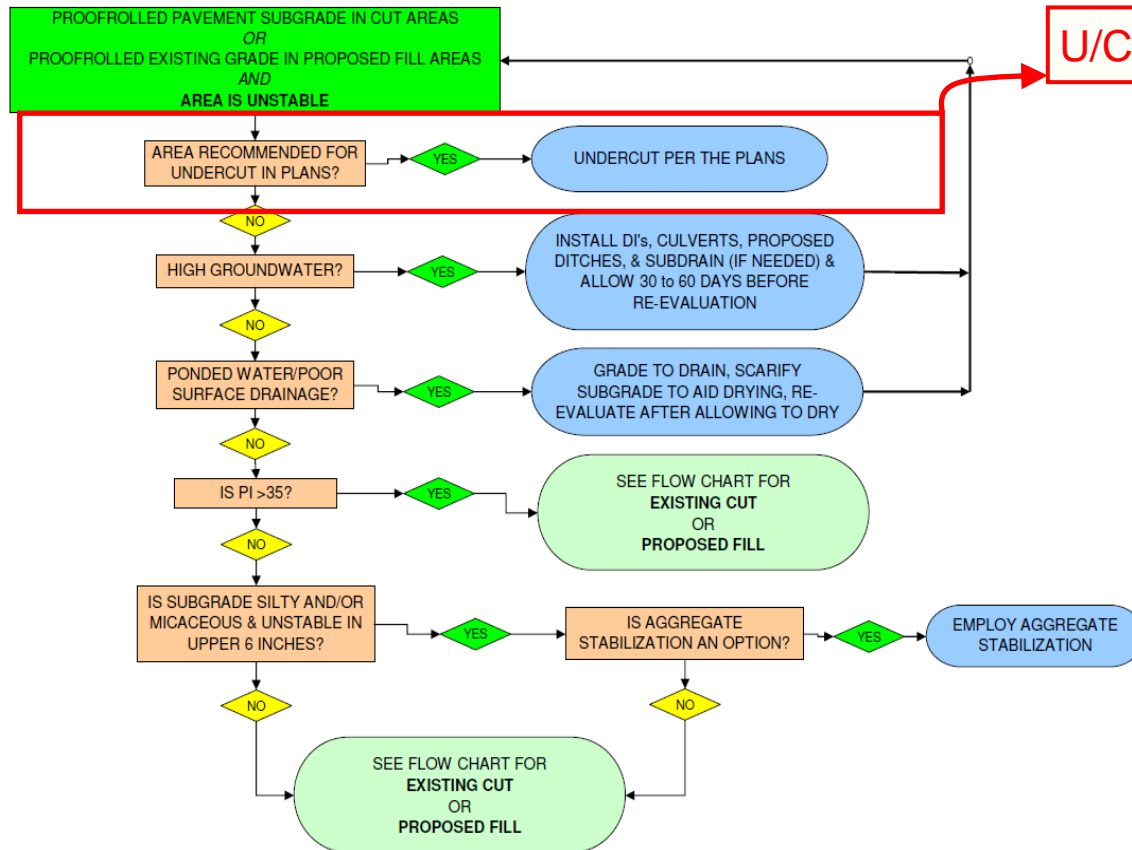


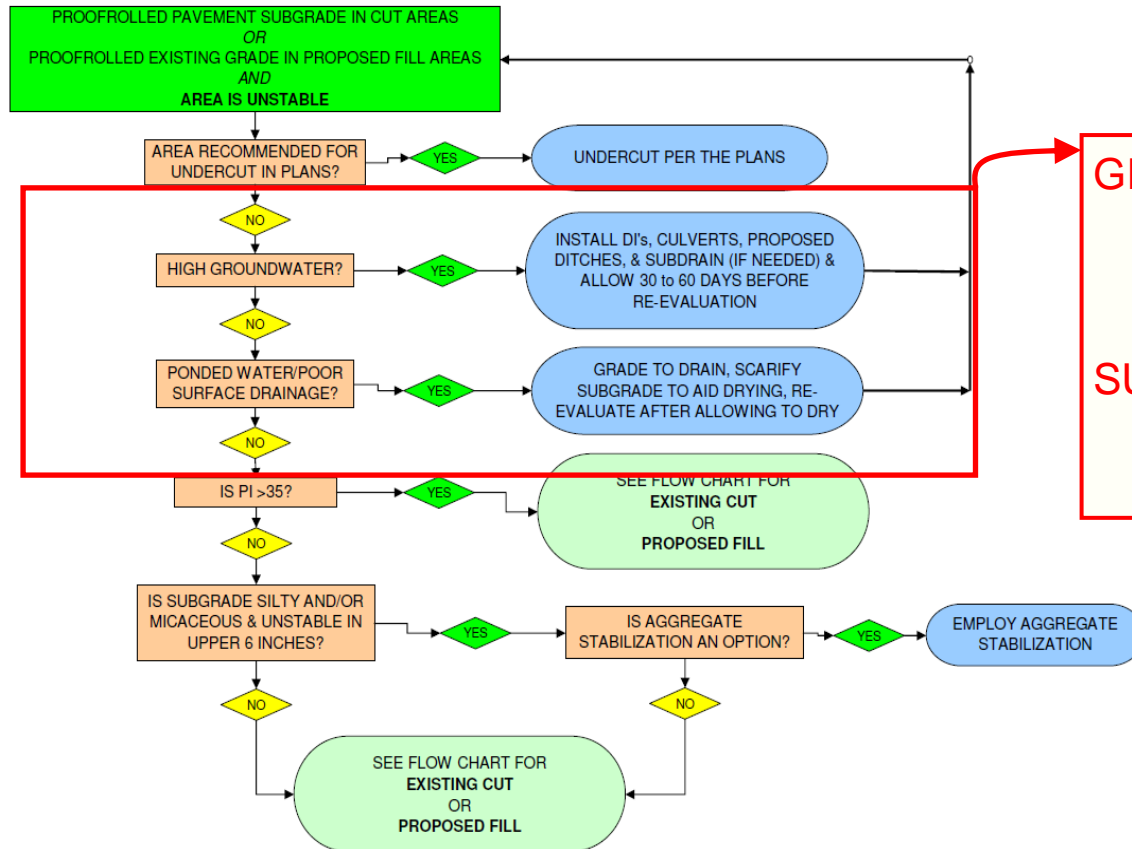
- Putting It All Together
 - Review the Objectives
 - Get it Dry and Keep it Dry
 - Make it Stable and Strong for Next Layers

 - Flow Charts to Walk Thru the Decision Process
 - Proofrolling Flow Chart
 - DCP Flow Chart
 - Cut Areas
 - Embankment Areas

PROOFROLLING FLOW CHART





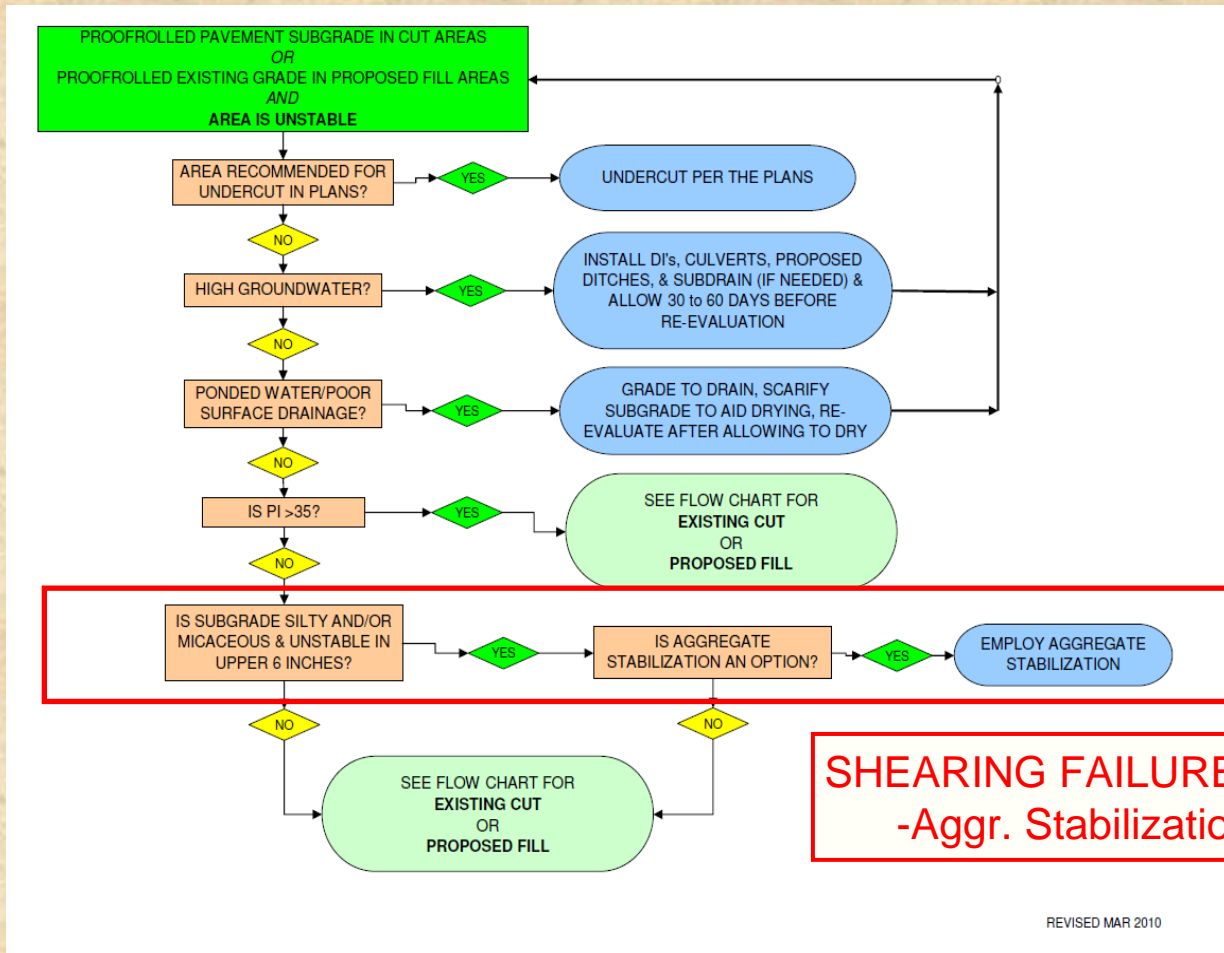


GROUNDWATER?

- Install DI's
- Install Ditches
- Install Subdrain

SURFACE WATER?

- Grade to Drain
- Scarify/Dry





- **IF SUBGRADE FAILURE IS WITHIN UPPER 12 INCHES AND SUBGRADE STABILIZATION IS IN THE CONTRACT, IT MAY BE POSSIBLE TO CONSTRUCT EXTRA-DEPTH STABILIZATION.**
- **CONTACT GEOPAVEMENT SECTION.**

SUBGRADE FAILURE - PART DEUX



- I followed your flow chart, re-proofrolled the subgrade, and there are still unstable areas in the subgrade.

OR

- We don't have a water problem and we don't have micaceous soils in Div. 14.

NOW WHAT?!?!





- **Putting It All Together**

- Review the Objectives

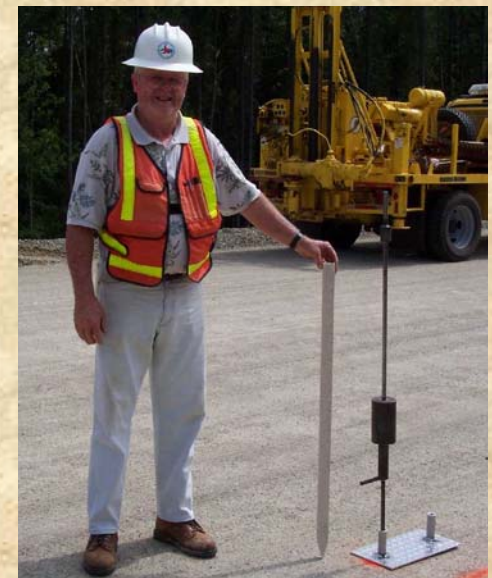
- Get it Dry and Keep it Dry
 - Make it Stable and Strong for Next Layers

- Flow Charts to Walk Thru the Decision Process

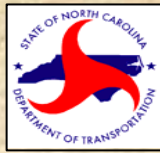
- Proofrolling Flow Chart
 - DCP Flow Charts
 - Cut Areas
 - Embankment Areas

DCP FLOW CHARTS

- What you need to know:
 - Is proofrolled subgrade in an existing cut or proposed fill?
- What you need to have:
 - Pavement DCP
 - Grade stake marked in 1-inch increments
 - Hammer to drive stake



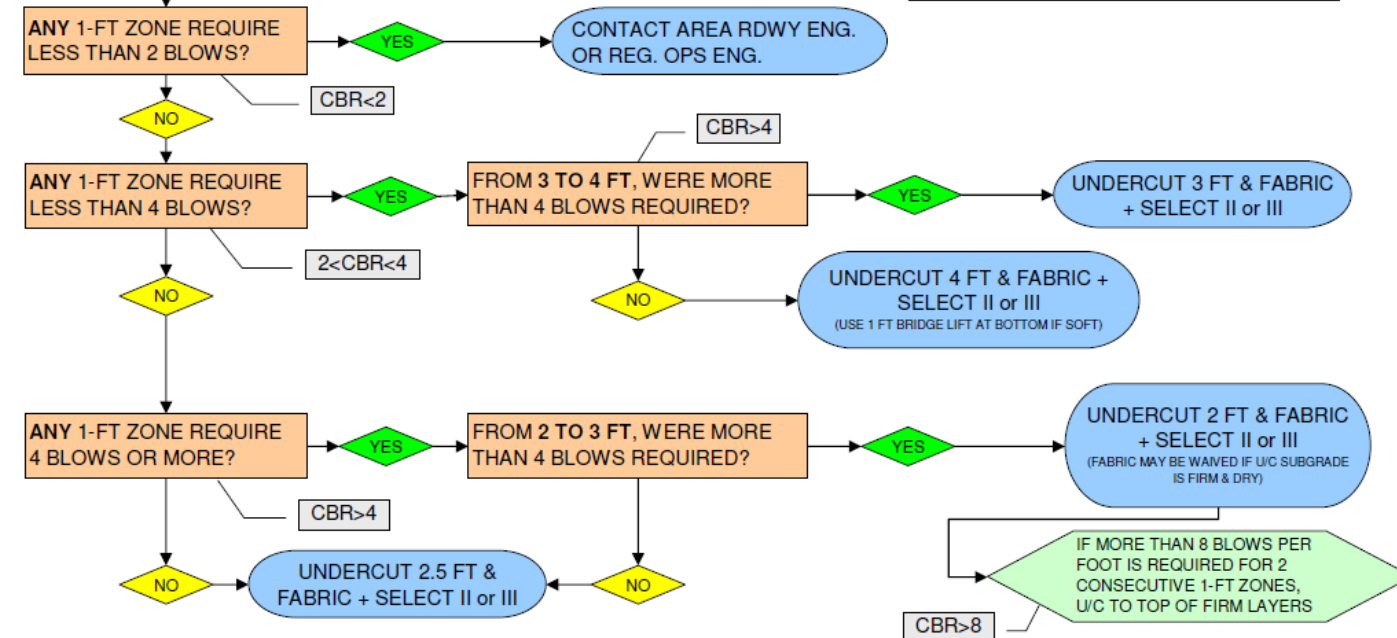
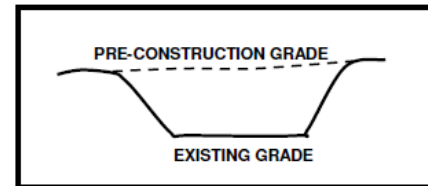
DCP FLOW CHART – CUT



EXISTING CUT DCP FLOW CHART for SUBGRADE STABILIZATION FABRIC & SELECT GRANULAR FILL

SELECT II & III REFERS TO SELECT MATERIAL CLASS II & CLASS III (SECTION 1016)
 IF SELECT MATERIAL CLASS II TYPE 2 IS USED, RESTRICT USAGE TO A-2-4 (SANDY GRANULAR SOIL)
 IF CLASS IV SELECT IS USED, REDUCE UNDERCUT DEPTHS BY 0.5 FOOT (6 INCHES)

- PERFORM DCP IN UNSTABLE AREAS TO A DEPTH OF 4 FEET
 - RECORD THE NUMBER OF BLOWS REQUIRED TO PENETRATE EACH 1 FOOT ZONE FOR 0-1', 1-2', 2-3', & 3-4'

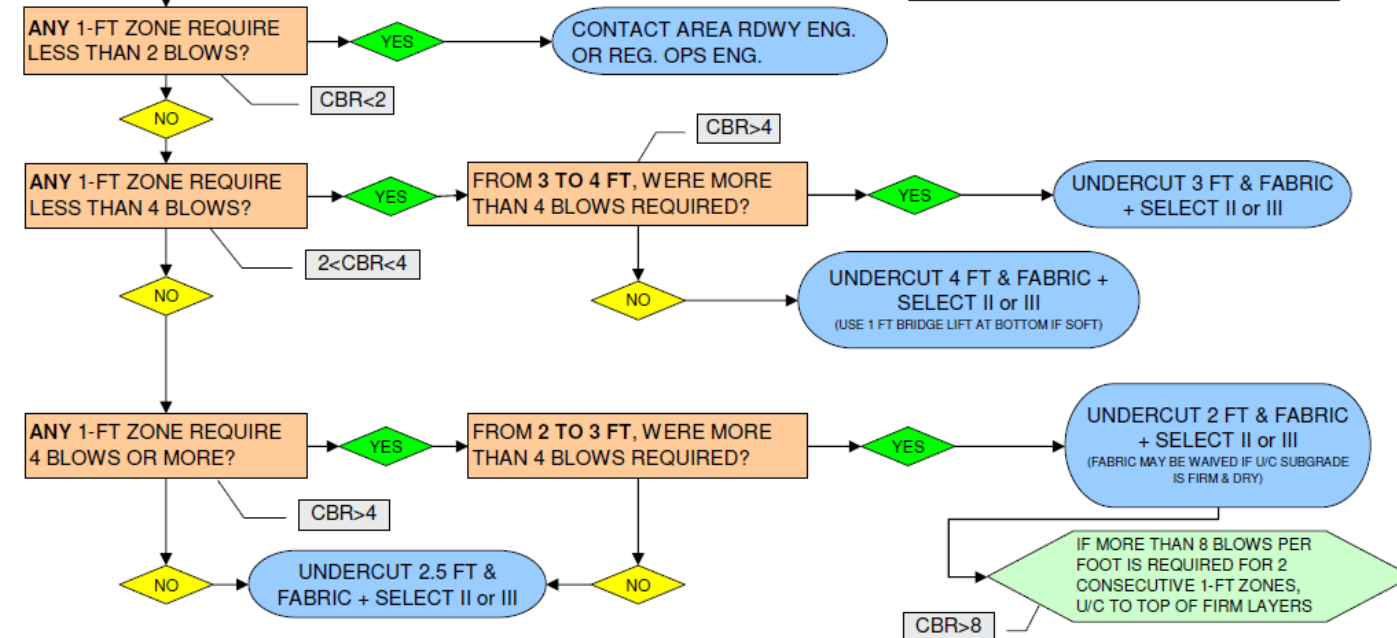
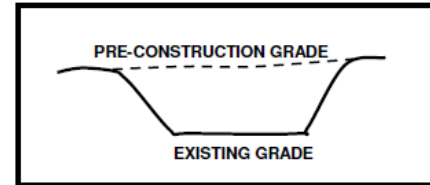


NEED TO EVALUATE GROUNDWATER CONDITIONS - NO WATER IS TO BE WITHIN 6 FT OF FINAL SUBGRADE -
 IF GROUNDWATER IS PRESENT IN OR COULD RISE INTO U/C AREA, NEED TO INSTALL SUBDRAINS

EXISTING CUT DCP FLOW CHART for SUBGRADE STABILIZATION FABRIC & SELECT GRANULAR FILL

SELECT II & III REFERS TO SELECT MATERIAL CLASS II & CLASS III (SECTION 1016)
 IF SELECT MATERIAL CLASS II TYPE 2 IS USED, RESTRICT USAGE TO A-2-4 (SANDY GRANULAR SOIL)
 IF CLASS IV SELECT IS USED, REDUCE UNDERCUT DEPTHS BY 0.5 FOOT (6 INCHES)

- PERFORM DCP IN UNSTABLE AREAS TO A DEPTH OF 4 FEET
 - RECORD THE NUMBER OF BLOWS REQUIRED TO PENETRATE EACH 1 FOOT ZONE FOR 0-1', 1-2', 2-3', & 3-4'



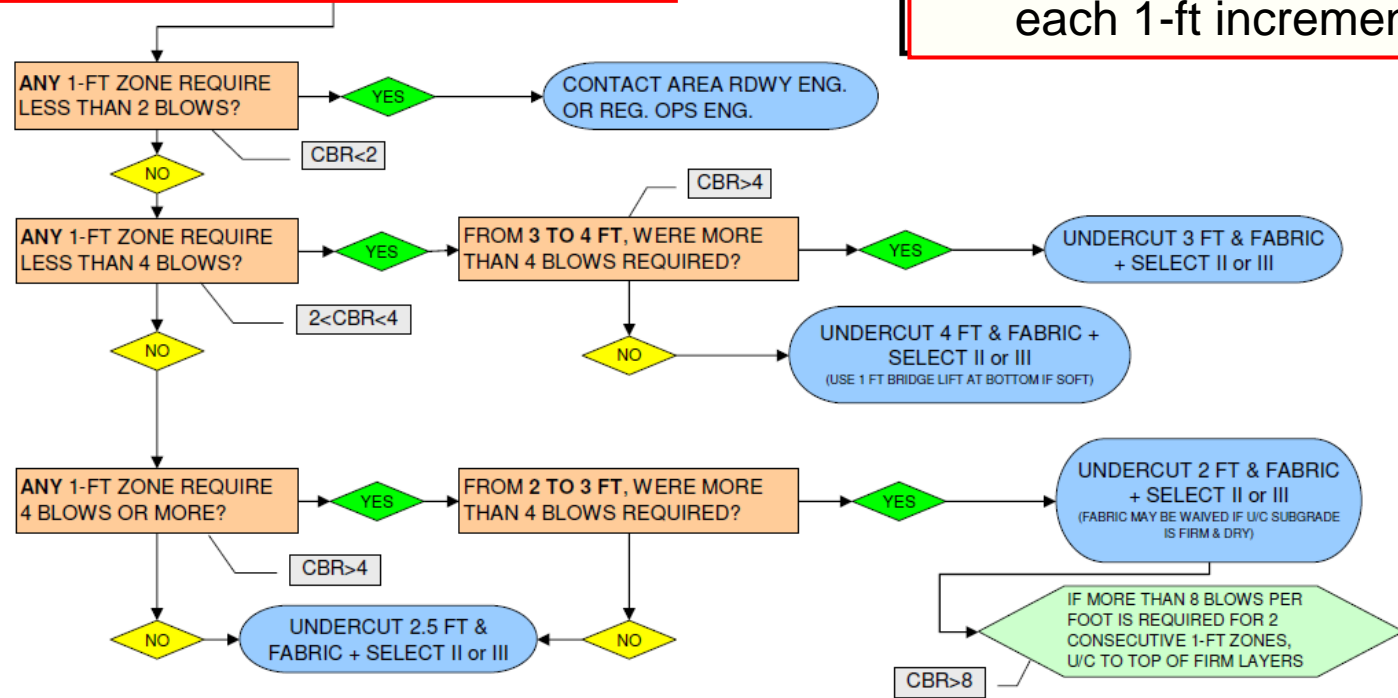
NEED TO EVALUATE GROUNDWATER CONDITIONS - NO WATER IS TO BE WITHIN 6 FT OF FINAL SUBGRADE - IF GROUNDWATER IS PRESENT IN OR COULD RISE INTO U/C AREA, NEED TO INSTALL SUBDRAINS

EXISTING CUT DCP FLOW CHART for SUBGRADE STABILIZATION FABRIC & SELECT GRANULAR FILL

SELECT II & III REFERS TO SELECT MATERIAL CLASS II & CLASS III (SECTION 1016)
 IF SELECT MATERIAL CLASS II TYPE 2 IS USED, RESTRICT USAGE TO A
 IF CLASS IV SELECT IS USED, REDUCE UNDERCUT DEPTHS BY

- PERFORM DCP IN UNSTABLE AREAS TO A DEPTH OF 4 FEET
 - RECORD THE NUMBER OF BLOWS REQUIRED TO PENETRATE EACH 1 FOOT ZONE FOR 0-1', 1-2', 2-3', & 3-4'

- Install stake
 - Drive DCP
 - Record blows for each 1-ft increment



NEED TO EVALUATE GROUNDWATER CONDITIONS - NO WATER IS TO BE WITHIN 6 FT OF FINAL SUBGRADE -
 IF GROUNDWATER IS PRESENT IN OR COULD RISE INTO U/C AREA, NEED TO INSTALL SUBDRAINS

EXISTING CUT DCP FLOW CHART for SUBGRADE STABILIZATION FABRIC & SELECT GRANULAR FILL

SELECT II & III REFERS TO SELECT MATERIAL CLASS II & CLASS III (SECTION 202.03) IF SELECT MATERIAL CLASS II TYPE 2 IS USED, RESTRICT USAGE TO A-2-4 (SANDY SILT) IF CLASS IV SELECT IS USED, REDUCE UNDERCUT DEPTHS BY 0.5 FOOT (SECTION 202.03)

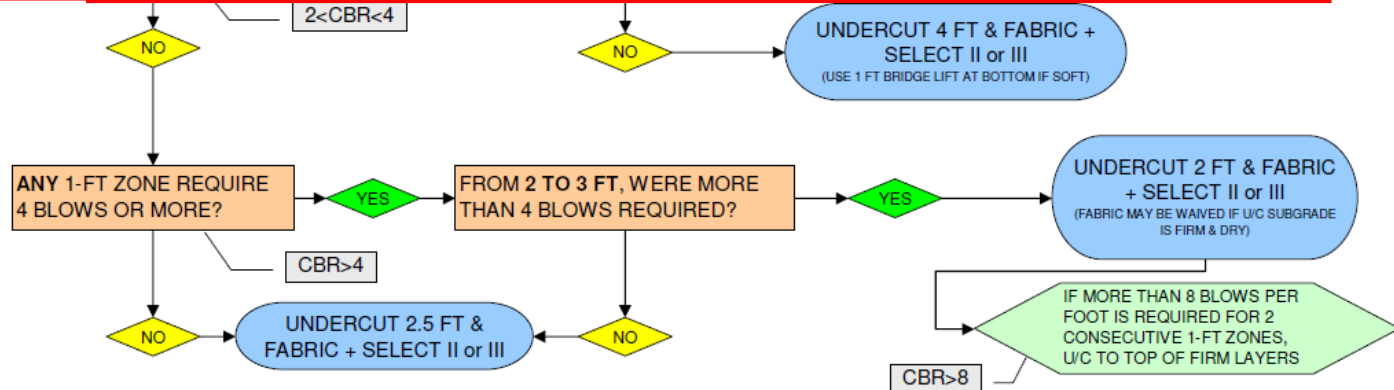
EXAMPLE:

0-1'	10 blows
1-2'	3 blows
2-3'	6 blows
3-4'	5 blows

- PERFORM DCP IN UNSTABLE AREAS TO A DEPTH OF 4 FEET
- RECORD THE NUMBER OF BLOWS REQUIRED TO PENETRATE EACH 1 FOOT ZONE FOR 0-1', 1-2', 2-3', & 3-4'

ANY 1-FT ZONE REQUIRE LESS THAN 4 BLOWS? YES → CONTACT AREA RDWY ENG.

ANY 1-FT ZONE REQUIRE LESS THAN 4 BLOWS? UNDERCUT DEPTHS SHOWN ARE FOR SELECT CLASS II or CLASS III. CLASS IV MAY BE USED. IF CLASS IV IS USED, REDUCE UNDERCUT BY 0.5 FT.

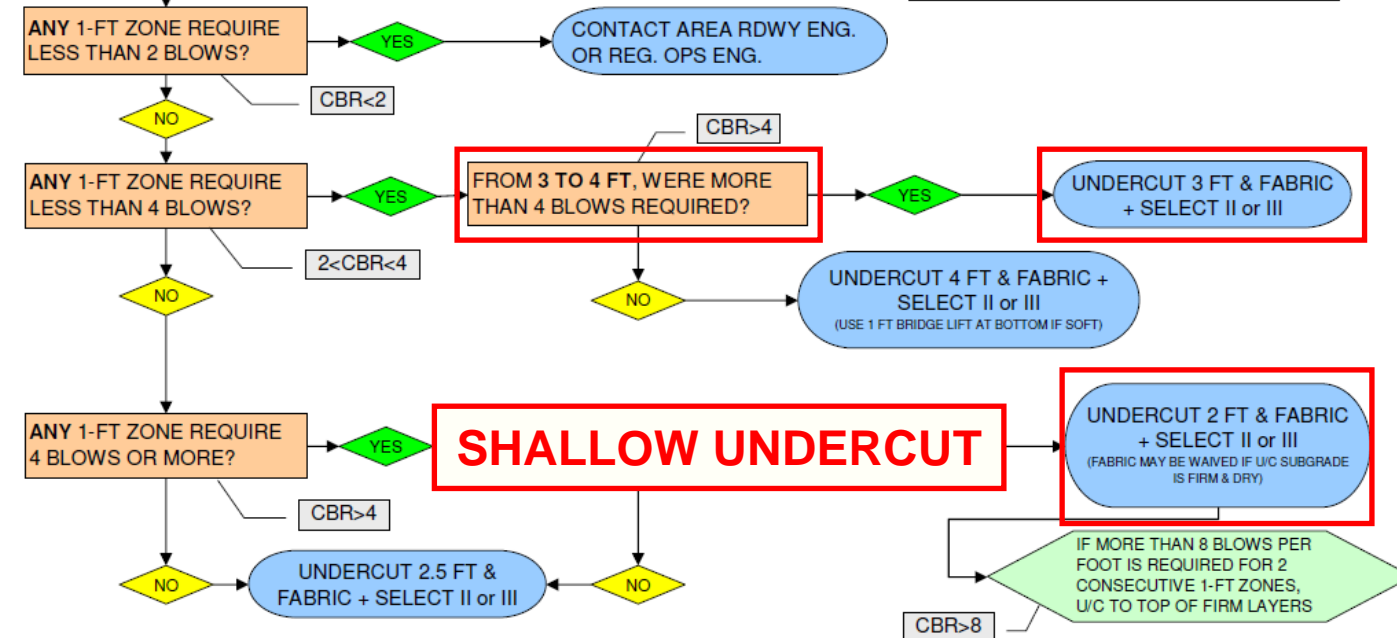
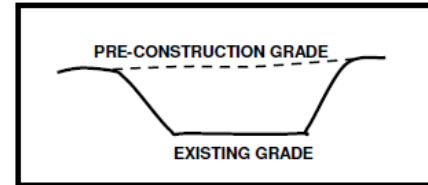


NEED TO EVALUATE GROUNDWATER CONDITIONS - NO WATER IS TO BE WITHIN 6 FT OF FINAL SUBGRADE - IF GROUNDWATER IS PRESENT IN OR COULD RISE INTO U/C AREA, NEED TO INSTALL SUBDRAINS

EXISTING CUT DCP FLOW CHART for SUBGRADE STABILIZATION FABRIC & SELECT GRANULAR FILL

SELECT II & III REFERS TO SELECT MATERIAL CLASS II & CLASS III (SECTION 1016)
 IF SELECT MATERIAL CLASS II TYPE 2 IS USED, RESTRICT USAGE TO A-2-4 (SANDY GRANULAR SOIL)
 IF CLASS IV SELECT IS USED, REDUCE UNDERCUT DEPTHS BY 0.5 FOOT (6 INCHES)

- PERFORM DCP IN UNSTABLE AREAS TO A DEPTH OF 4 FEET
 - RECORD THE NUMBER OF BLOWS REQUIRED TO PENETRATE EACH 1 FOOT ZONE FOR 0-1', 1-2', 2-3', & 3-4'



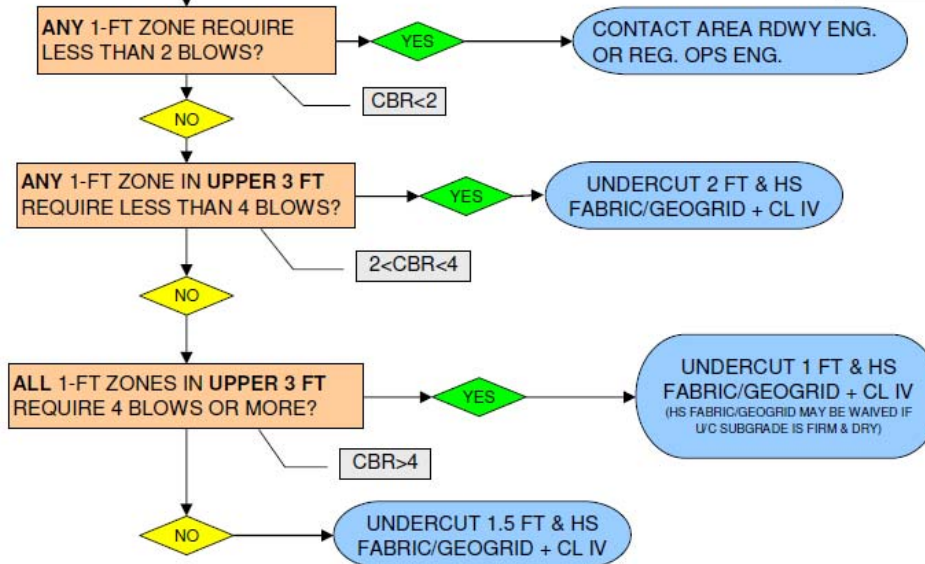
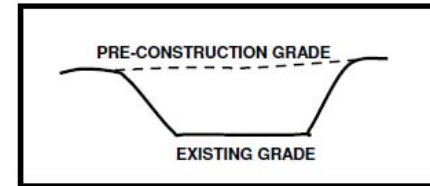
NEED TO EVALUATE GROUNDWATER CONDITIONS - NO WATER IS TO BE WITHIN 6 FT OF FINAL SUBGRADE -
 IF GROUNDWATER IS PRESENT IN OR COULD RISE INTO U/C AREA, NEED TO INSTALL SUBDRAINS

DCP FLOW CHART – CUT



EXISTING CUT DCP FLOW CHART for HIGH-STRENGTH FABRIC/GEOGRID & CLASS IV

PERFORM DCP IN UNSTABLE AREAS TO A DEPTH OF 4 FEET
 RECORD THE NUMBER OF BLOWS REQUIRED TO PENETRATE
 EACH 1 FOOT ZONE FOR 0-1', 1-2', 2-3', & 3-4'

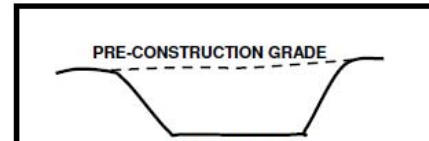


NEED TO EVALUATE GROUNDWATER CONDITIONS - NO WATER IS TO BE WITHIN 6 FT OF FINAL SUBGRADE -
 IF GROUNDWATER IS PRESENT IN OR COULD RISE INTO U/C AREA, NEED TO INSTALL SUBDRAINS

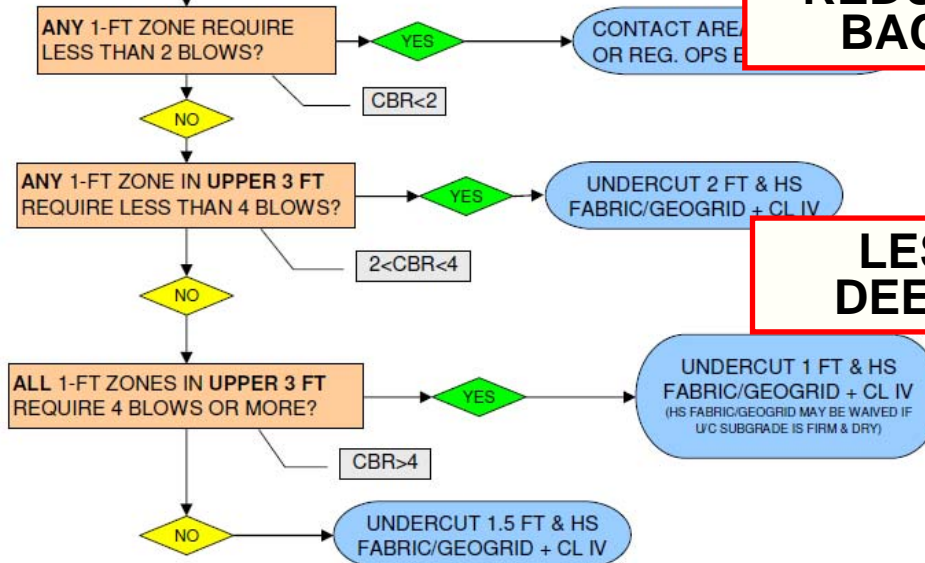
EXISTING CUT DCP FLOW CHART for HIGH-STRENGTH FABRIC/GEOGRID & CLASS IV

PERFORM DCP IN UNSTABLE AREAS TO A DEPTH OF 4 FEET
RECORD THE NUMBER OF BLOWS REQUIRED TO PENETRATE

LEVERAGES STRENGTH OF FABRIC/GEOGRID



REDUCES UNDERCUT & BACKFILL VOLUMES



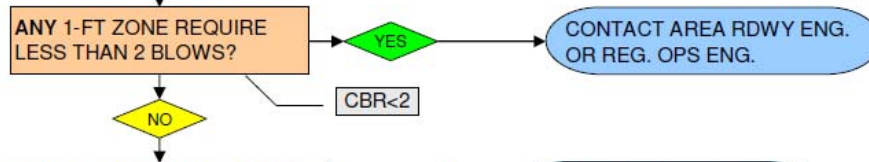
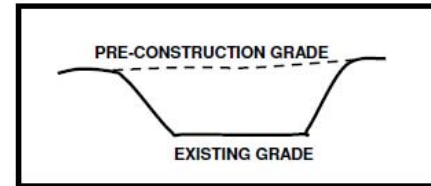
LESS SENSITIVE TO DEEPER SOFT ZONES

NEED TO EVALUATE GROUNDWATER CONDITIONS - NO WATER IS TO BE WITHIN 6 FT OF FINAL SUBGRADE -
IF U/C AREA, NEED TO INSTALL SUBDRAINS

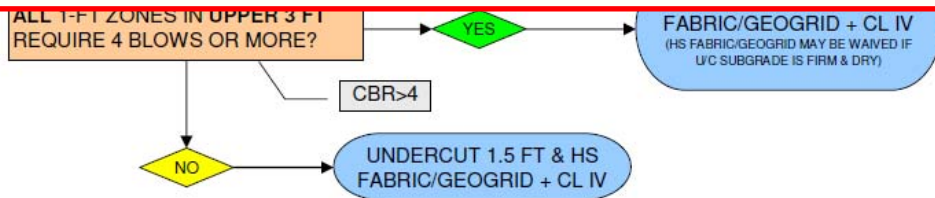
**BEST ECONOMY IN
SOFT or VERY SOFT SOILS**

EXISTING CUT DCP FLOW CHART for HIGH-STRENGTH FABRIC/GEOGRID & CLASS IV

PERFORM DCP IN UNSTABLE AREAS TO A DEPTH OF 4 FEET
 RECORD THE NUMBER OF BLOWS REQUIRED TO PENETRATE
 EACH 1 FOOT ZONE FOR 0-1', 1-2', 2-3', & 3-4'



- SAVES 1/2 FOOT IN MARGINAL SOILS
- SAVES 1 to 2 FEET IN WEAK SOILS

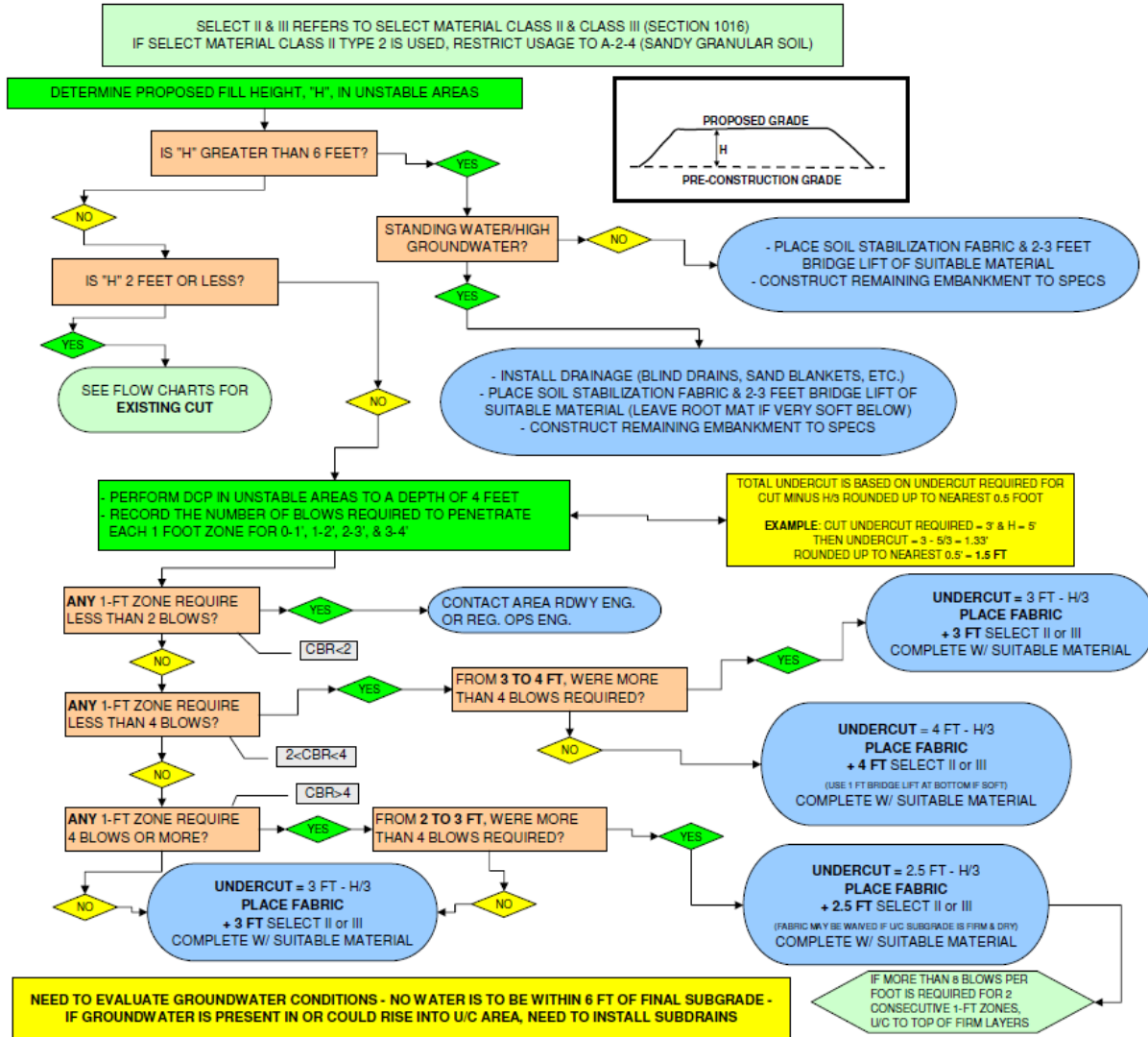


NEED TO EVALUATE GROUNDWATER CONDITIONS - NO WATER IS TO BE WITHIN 6 FT OF FINAL SUBGRADE - IF GROUNDWATER IS PRESENT IN OR COULD RISE INTO U/C AREA, NEED TO INSTALL SUBDRAINS

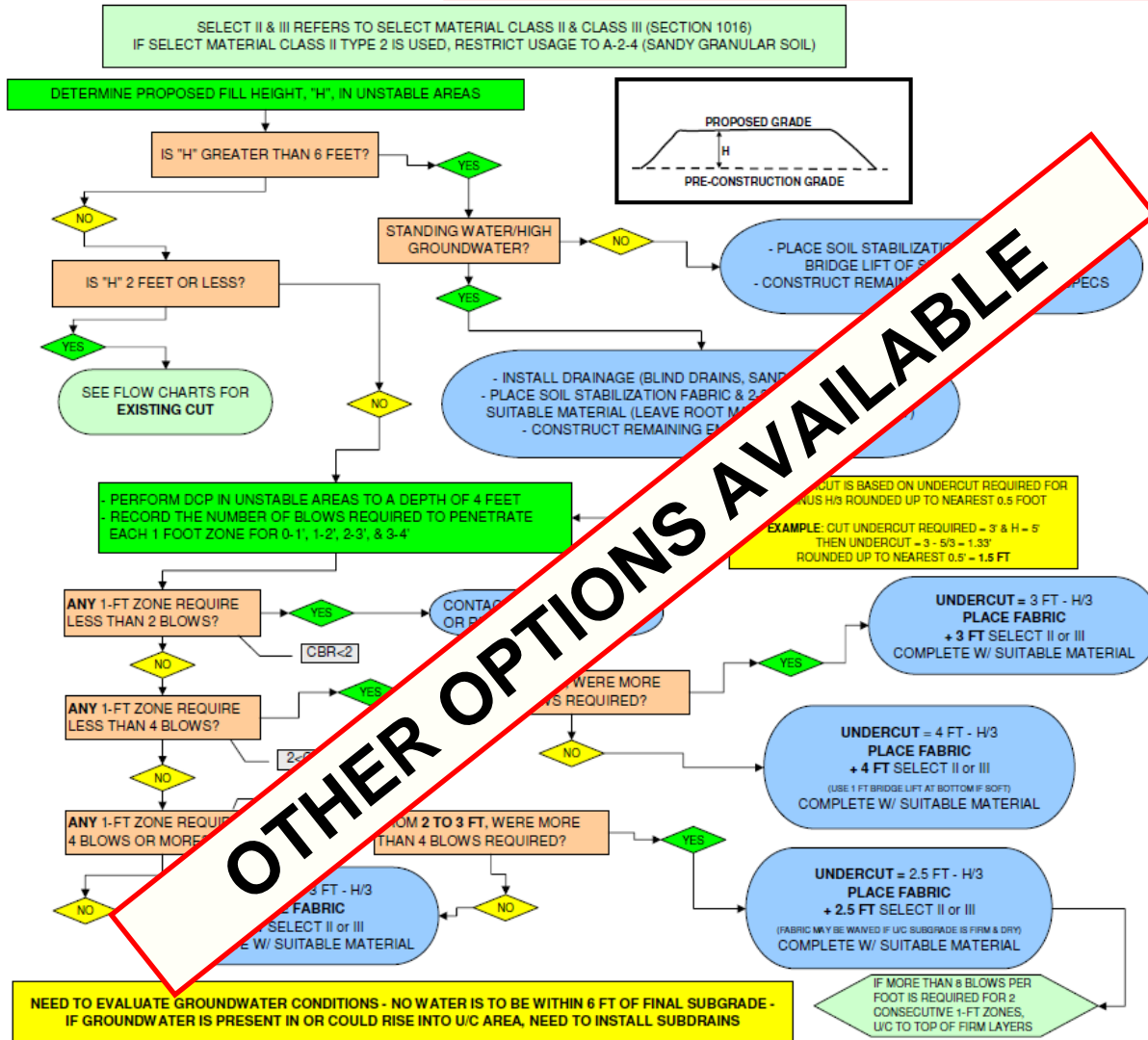
DCP FLOW CHART – FILL



PROPOSED FILL DCP FLOW CHART for SUBGRADE STABILIZATION FABRIC & SELECT GRANULAR FILL

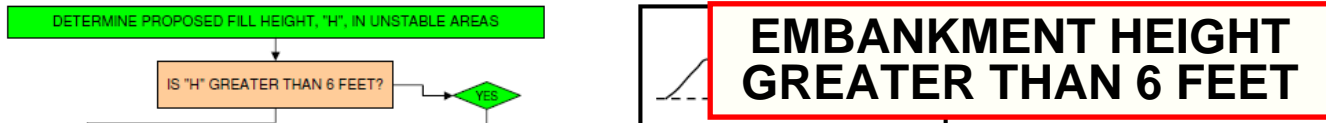


PROPOSED FILL DCP FLOW CHART for SUBGRADE STABILIZATION FABRIC & SELECT GRANULAR FILL

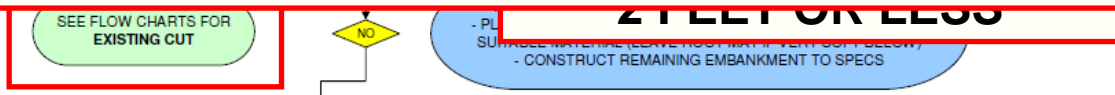


PROPOSED FILL DCP FLOW CHART for SUBGRADE STABILIZATION FABRIC & SELECT GRANULAR FILL

SELECT II & III REFERS TO SELECT MATERIAL CLASS II & CLASS III (SECTION 1016)
 IF SELECT MATERIAL CLASS II TYPE 2 IS USED, RESTRICT USAGE TO A-2-4 (SANDY GRANULAR SOIL)



- UNDERCUT FOR CUT AREAS USED AS BASIS
- REDUCES TOTAL UNDERCUT ACCOUNTING FOR ADDITIONAL EMBANKMENT TO BE CONSTRUCTED

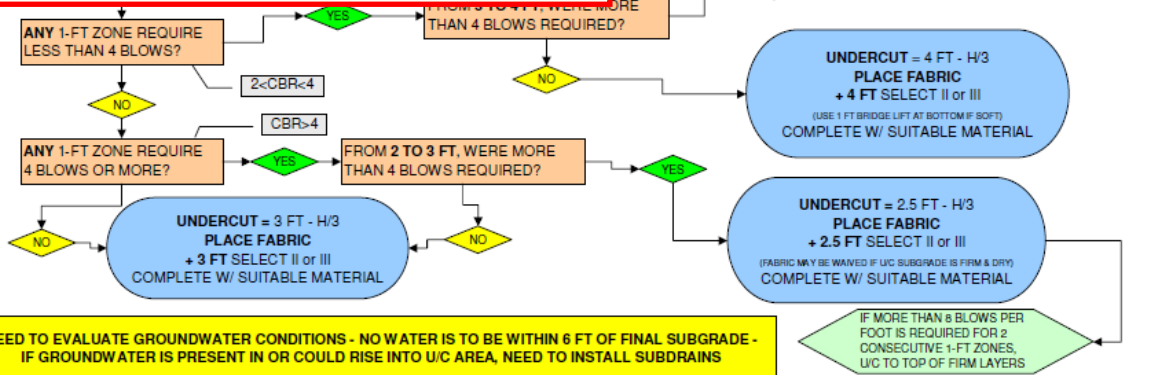


PERFORM DCP IN UNSTABLE AREAS TO A DEPTH OF 4 FEET
 RECORD THE NUMBER OF BLOWS REQUIRED TO PENETRATE EACH 1 FOOT ZONE FOR 0-1', 1-2', 2-3', & 3-4'

TOTAL UNDERCUT IS BASED ON UNDERCUT REQUIRED FOR CUT MINUS H/3 ROUNDED UP TO NEAREST 0.5 FOOT

EXAMPLE: CUT UNDERCUT REQUIRED = 3' & H = 5'
 THEN UNDERCUT = 3 - 5/3 = 1.33'
 ROUNDED UP TO NEAREST 0.5' = 1.5 FT

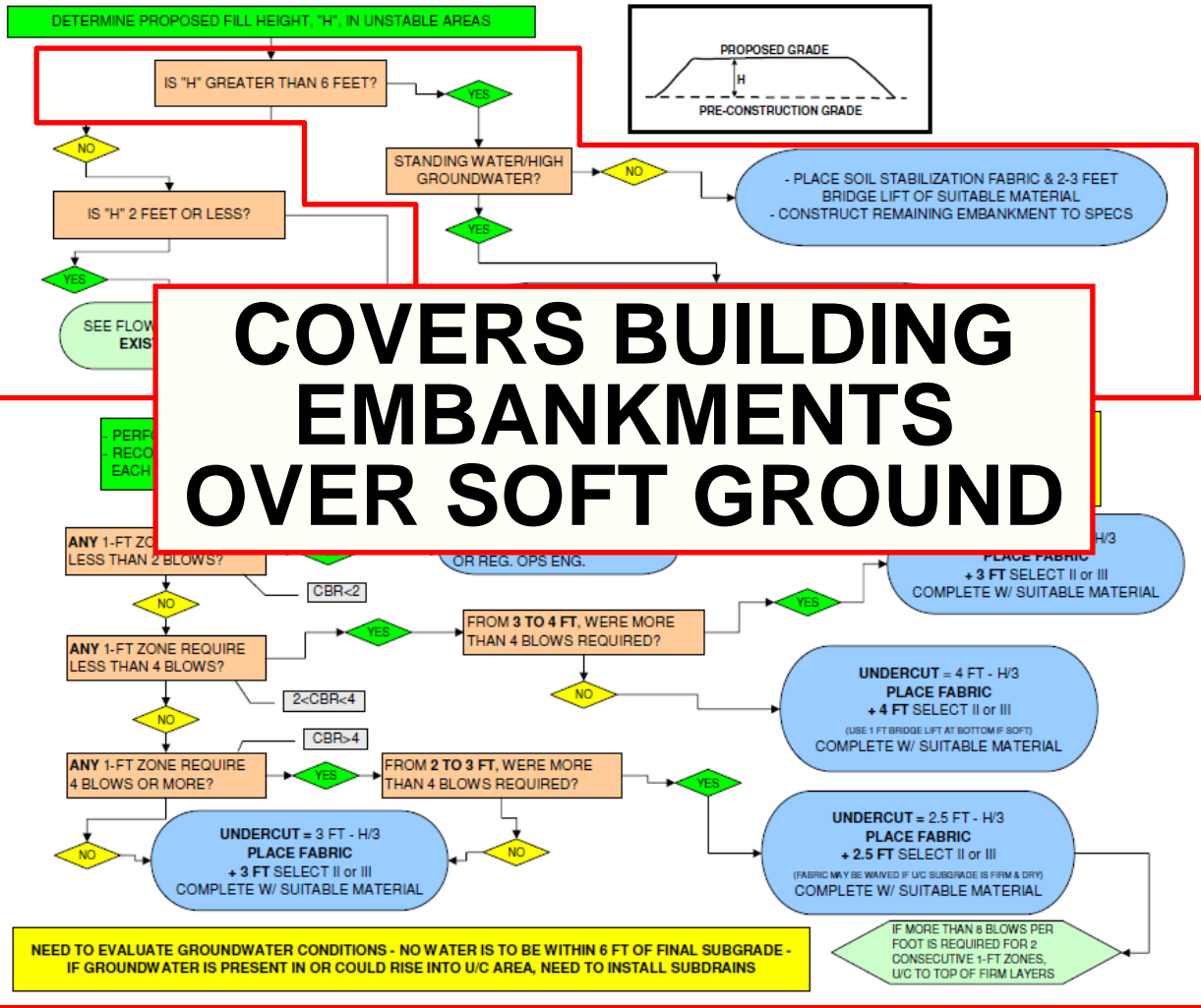
USE CUT FLOW CHARTS



NEED TO EVALUATE GROUNDWATER CONDITIONS - NO WATER IS TO BE WITHIN 6 FT OF FINAL SUBGRADE - IF GROUNDWATER IS PRESENT IN OR COULD RISE INTO U/C AREA, NEED TO INSTALL SUBDRAINS

PROPOSED FILL DCP FLOW CHART for SUBGRADE STABILIZATION FABRIC & SELECT GRANULAR FILL

SELECT II & III REFERS TO SELECT MATERIAL CLASS II & CLASS III (SECTION 1016)
 IF SELECT MATERIAL CLASS II TYPE 2 IS USED, RESTRICT USAGE TO A-2-4 (SANDY GRANULAR SOIL)





BACKFILLING

- Place Fabric or Geogrid
 - Flat; No wrinkles or folds
 - Slight tension; anchor with backfill NOT pins
 - Overlaps vary depending on soil strength
 - Greater than 4 BPF = 12 inches
 - Between 2 & 4 BPF = 24 inches
 - Less than 2 BPF = Contact ARCE or GEU Ops
- Place Backfill
 - End dump on fabric/geogrid; no traffic
 - Compact Select 92% T-180; Other per Specs



COST COMPARISON – 30' x 100'

Undercut = \$9.30/CY Select = \$24.25/CY Class IV = \$23.25/TN
SS Fabric = \$1.90/SY HS Fabric/Geogrid = \$4.00/SY

SOFT SOILS – 2 to 4 BPF

• SS Fabric – 4 ft UC

– U/C = 445 CY = \$ 4,133
– SELECT = 445 CY = \$10,778
– FABRIC = 333 SY = \$ 633
TOTAL = \$15,544

• HS Fabric/Geogrid – 2 ft UC

– U/C = 222 CY = \$ 2,067
– CL IV = 450 TN = \$10,508
– GRID = 333 SY = \$ 1,333
TOTAL = \$13,908

FIRM SOILS – > 4 BPF

• SS Fabric – 2 ft UC

– U/C = 222 CY = \$ 2,067
– SELECT = 222 CY = \$ 5,389
– FABRIC = 333 SY = \$ 633
TOTAL = \$ 8,089

• HS Fabric/Geogrid – 1 ft UC

– U/C = 111 CY = \$ 1,033
– CL IV = 225 TN = \$ 5,254
– GRID = 333 SY = \$ 1,333
TOTAL = \$ 7,620



**HS FABRIC or GEOGRID IS
NOT ALWAYS CHEAPEST ...
CONTRACT PRICES RULE !!!**



Where can I obtain the information
from this presentation?



QUESTIONS?



THANKS!