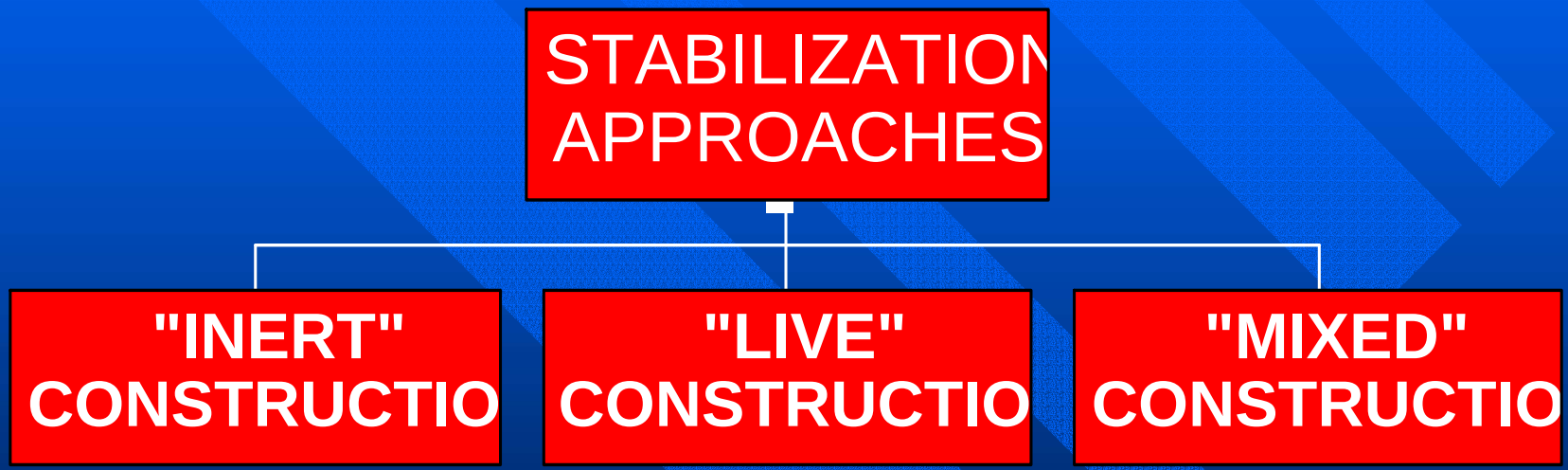
Bio-Stabilization of of Slopes & Streambanks

- ***Donald H. Gray***
- The University of Michigan

Approaches to Slope Protection and Erosion Control

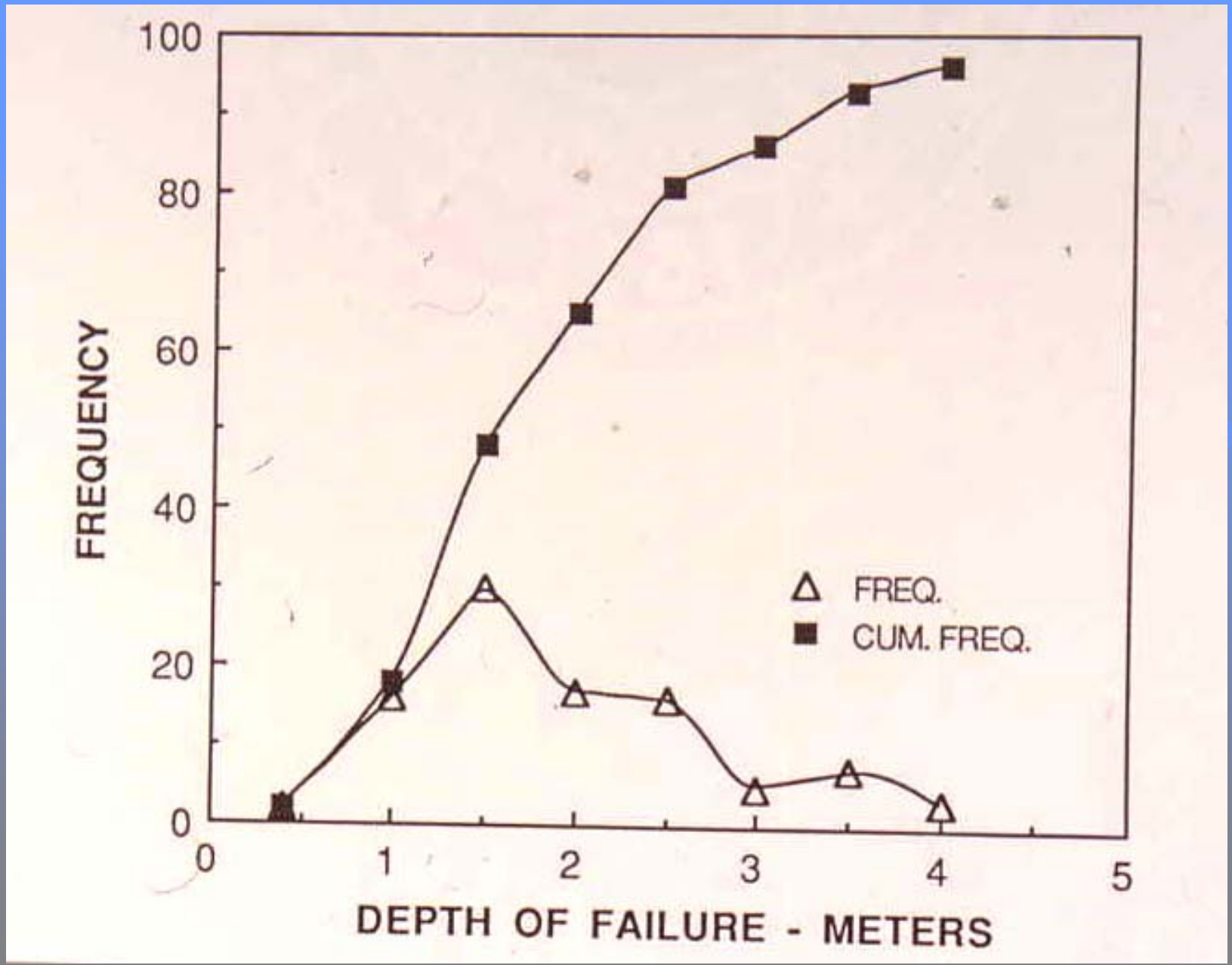


"Inert" Construction

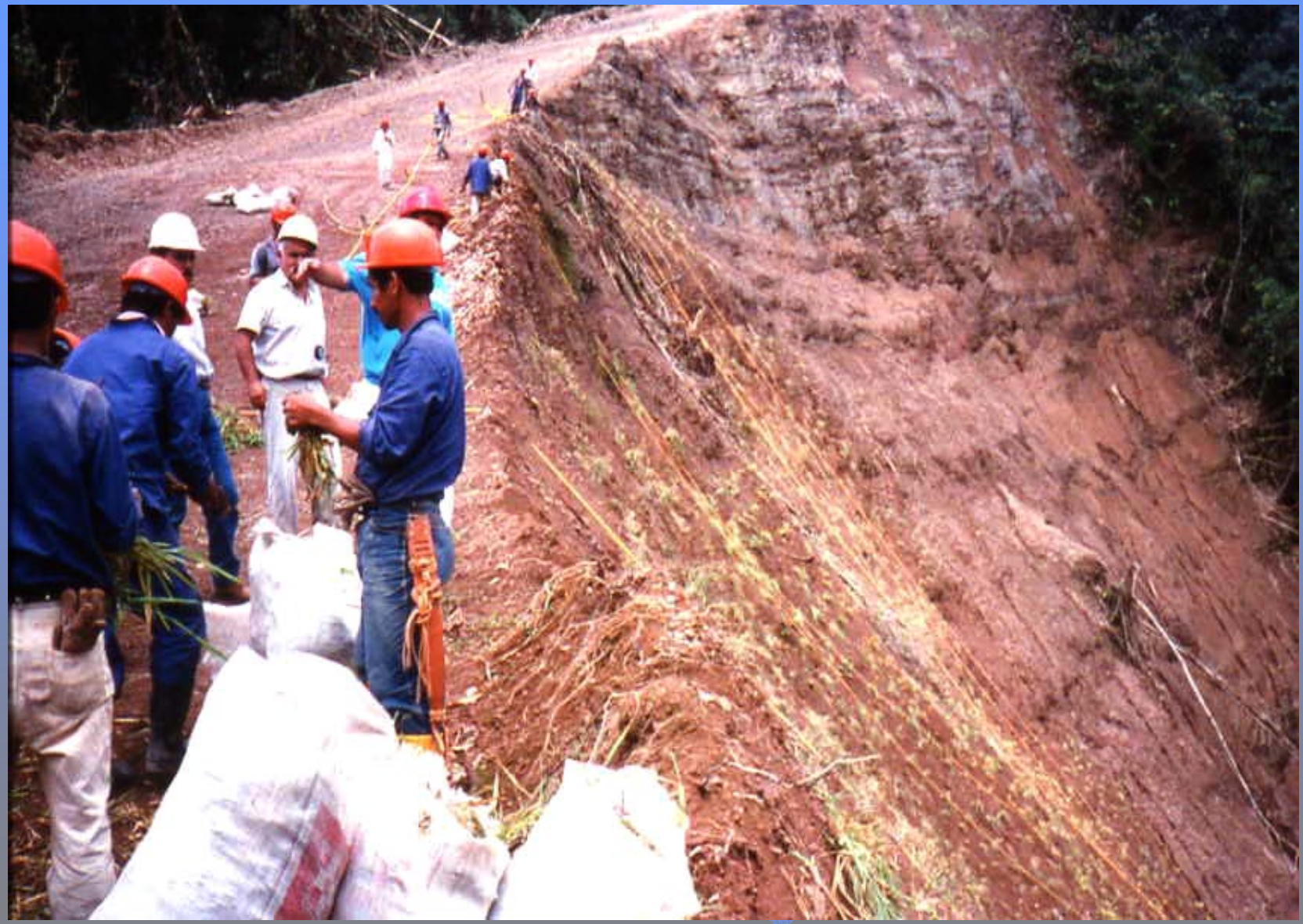
- Retaining Structures
  - -- Gravity walls
  - -- Articulated block walls
  - -- Reinforced earth walls
- Revetment Systems
  - -- Rip rap *(rock, rubble)*
  - -- Gabion mattresses
  - -- Concrete facings *(gunnite)*
- Ground Covers
  - -- Chemicals (asphalt, emulsion)
  - -- Blankets, mats, & netting
  - -- Cellular confinements systems

"Live" Construction

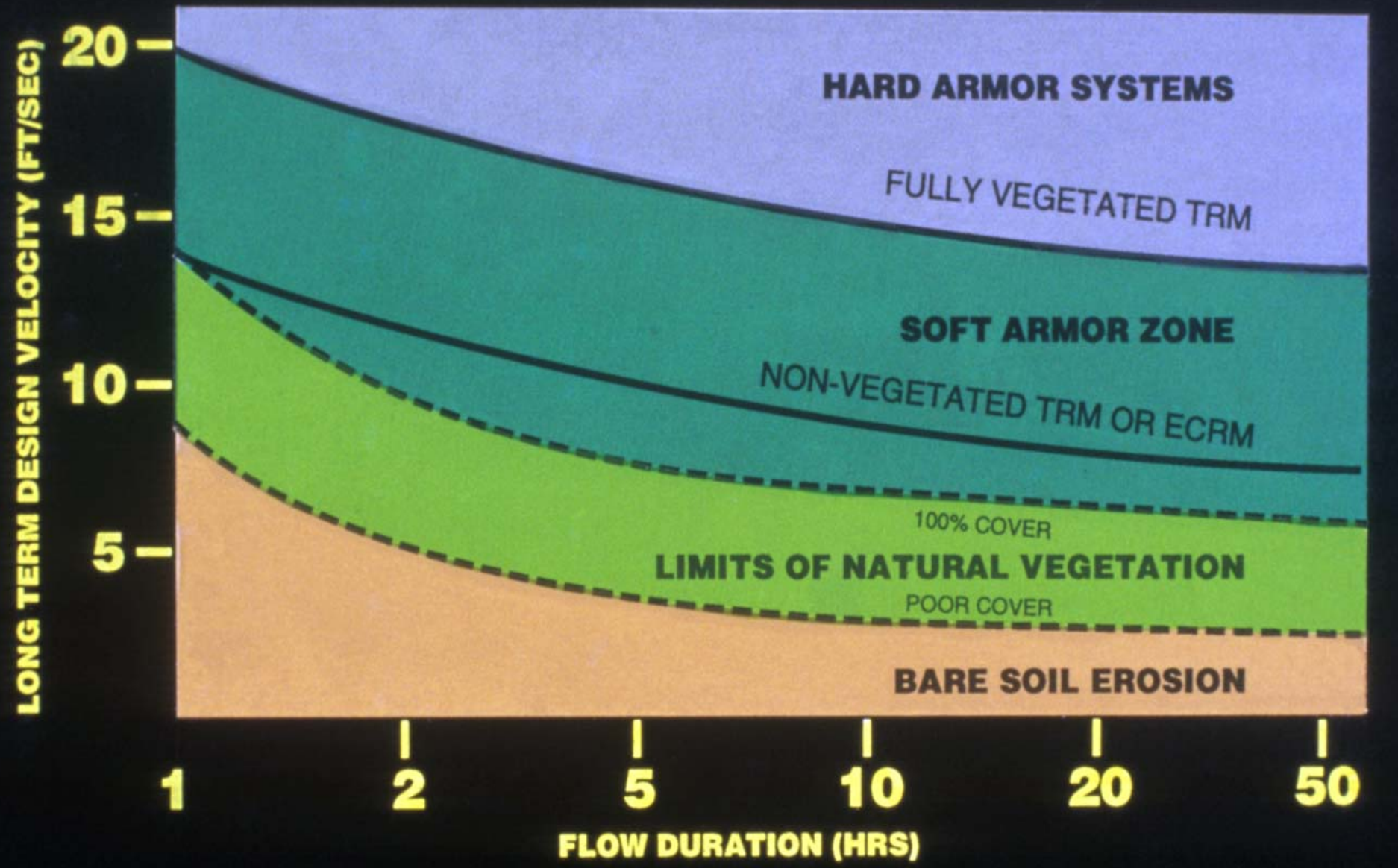
- Seeding *(grasses & forbs)*
  - -- Hydroseeding
  - -- Spot
  - -- Drill
- Transplanting *(shrubs)*
  - -- Bare root
  - -- Container
- Sodding *(turf)*


100
80
60
40
20
0
FREQUENCY
0
1
2
3
4
5
DEPTH OF FAILURE - METERS
FREQ.
CUM. FREQ.

Limitations of Conventional Plantings and Vegetative Treatments



RECOMMENDED LIMITING DESIGN VELOCITIES FOR SYNTHETIC MATTINGS VERSUS NON-REINFORCED VEGETATION



"Mixed" Construction

- **Biotechnical Stabilization**
- **Soil Bioengineering Stabilization**

Biotechnical Stabilization

- The integrated or combined use of living vegetation and inert structural elements to protect slopes against erosion and shallow mass wasting

Plant/Structure Associations

- Toe-Wall with Slope Face Plantings
- Tiered Wall with Bench Plantings
- Revetment w/ Slope Face Plantings

Vegetated Retaining Structures

- Planted Crib Walls
- Vegetated Gabion Walls
- Planted Block Walls
- Vegetated Rock Breast Walls
- Vegetated MechStabEarth

Vegetated Revetments "Hard Armor"

- Vegetated Riprap *(Joint Planting)*
- Live Staked Gabion Mattresses
- Vegetated Articulated Blocks
- Vegetated Cellular Grids

Biotechnical Groundcovers

- Erosion Control Blankets *(ECBs)*
- Turf Reinforcement Mats *(TRMs)*
- Geocellular Confinement Systems *(GCSs)*
- Articulated Concrete Block Systems*(ACBs)*

Soil Bioengineering Stabilization

- The imbedment and arrangement of live plants and cuttingsin the ground in various arrays….where they serve as reinforcements, hydraulic drains, wicks, and barriers to earth movement.

Soil Bioengineering Stabilization

- Live staking
- Fascines *(wattles)*
- Fascines w/ subdrains
- Brushlayering
- Branch packing
- Live crib walls
- Live slope gratings
- Brush mattresses

Environmentally Sensitive Channel and Bank Protection Techniques

1.0	River Training	Level
1.1.1.1	Vegetated earthen spurs,	3
1.1.1.2	Spur dikes or bank barbs,	1
1.1.1.3	Vanes,	1
1.1.1.4	Bendway weirs,	1
1.1.1.4	Large woody debris structures,	3
1.1.2.1	Weirs or check dams,	1
1.2.1.1	Longitudinal dikes with toe spurs,	2
1.2.1.2	Longitudinal peaked stone toe,	1
1.2.2.1	Coir rolls,	1
1.2.3.1	Vegetated gabion basket,	3
1.2.3.2	Live cribwalls,	2
1.2.3.3	Vegetated mechanically stabilized earth,	2
1.2.4	Live siltation,	1
1.2.5	Live brushlayering,	1
1.3.1	Willow posts and poles,	1
1.3.3	Trench fill revetment,	1
1.3.4	Fence fields,	3
1.4.1	Vegetated floodways,	2
1.4.2	Meander restoration,	2

Environmentally Sensitive Channel and Bank Protection Techniques

2.0	**Bank Armor and Protection**	
2.1.1	Vegetation alone,	1
2.1.2	Live staking,	1
2.1.3	Live fascines,	1
2.1.4	Turf reinforcement mats,	2
2.1.5	Erosion control blankets,	2
2.1.6	Geocellular containment systems,	2
2.2.1.1	Rootwad revetments,	2
2.2.1.2	Live brush mattresses,	1
2.2.2.1	Vegetated articulated concrete blocks,	1
2.2.2.3	Vegetated/modified riprap,	1
2.2.2.4	Soil & grass covered riprap,	1
2.2.2.5	Vegetated gabion mattress,	3
2.2.2.6	Cobble or gravel armor,	2

Environmentally Sensitive Channel and Bank Protection Techniques

3.0	**Riparian Buffer & Stream Corridor Opportunities**	
3.1.1	Vegetated buffer strip,	2
3.1.2	Live gully repair,	3
3.2.1	Vanes with J hooks,	1
3.2.2	Cross vanes,	1
3.2.3	Boulder clusters,	2
3.2.4	Newbury rock riffles,	2
4.0	**Slope Stabilization**	
4.1.1	Diversion dike,	1
4.1.2	Slope drain,	1
4.1.3	Live pole drain,	3
4.1.4	Chimney drain,	2
4.1.5	Trench drain,	2
4.1.6	Drop inlet,	1
4.1.7	Fascines with a subsurface interceptor drain,	2
4.2.1	Flattening,	1
4.3.1	Stone-fill trenches,	2

Recommended References

- Gray, D.H. and Sotir, R. (1996). Biotechnical and Soil Bioengineering Slope Stabilization, John Wiley, New York.
- Gray, D.H. and Leiser, A.T. (1982). Biotechnical Slope Protection and Erosion Control, VanNostrand Reinhold, New York
- Coppin, N.J. and Richards, I. (1990). Use of Vegetation in Civil Engineering, Butterworths, Kent, England.
- Schiechtl, H.M. and Stern, R. (1992). Ground Bioengineering Techniques. Blackwell Science, Oxford, England
- USDA Natl. Resources Conservation Svc. (1992). Chapter 18: Soil bioengineering for upland slope protection and erosion reduction. Part 650, 210-EFH, *Engr. Field Handbook*, 53 pp.


EROSION DRAW 1.0
NEW! with Actual Photos
Bio Draw 1.0
Bio Draw
1.0
COIR ROLL W/
BRUSHLAYERING
LIVE SILTATION

Opportunities, and Challenges in Bio-Stabilization

- Combining various treatments, e.g., use of soil bioengineering (fascines) to improve performance of ECBs and TRMs
- Determining allowable tractive stress and roughness characteristics of soil bioengineering streambank treatments
- Selection of appropriate cuttings best adapted for local and regional conditions. Use of nursery stock and cultivars vs. plant material gathered in wild.
- Use of micro-organisms (bacteria and fungae) for biostabilization of soils.

Biotechnical Stabilization

- The integrated or combined use of living vegetation and inert structural elements to protect slopes against erosion and shallow mass wasting

Plant/Structure Associations

- Toe-Wall with Slope Face Plantings
- Tiered Wall with Bench Plantings
- Revetment with Slope Face Plantings

Coastal and River Bluff Stabilization

REQUIREMENTS FOR SUCCESSFUL BANK & BLUFF STABILIZATION:

1. Toe Defense

2. Face Treatment

Toe-Walls w/ Slope Plantings

Manistee Shipping Channel - BEFORE

Manistee Shipping Channel - AFTER

Manistee Shipping Channel - AFTER

Revetments w/ Slope Plantings

Bluff Stabilization- Lake Michigan

REQUIRED ARMOR STONE WEIGHT
QUARRY STONE REVETMENT

$$W = \frac{w_r H^3}{K_d (s_R - 1)^3 \cot \theta}$$

Where:

W = weight of individual armor stones, lbs

w_r = unit weight (sat'd. surf. dry) of rock, pcf

H = design wave heigh t, ft

s_R = specific gravity of armor stone

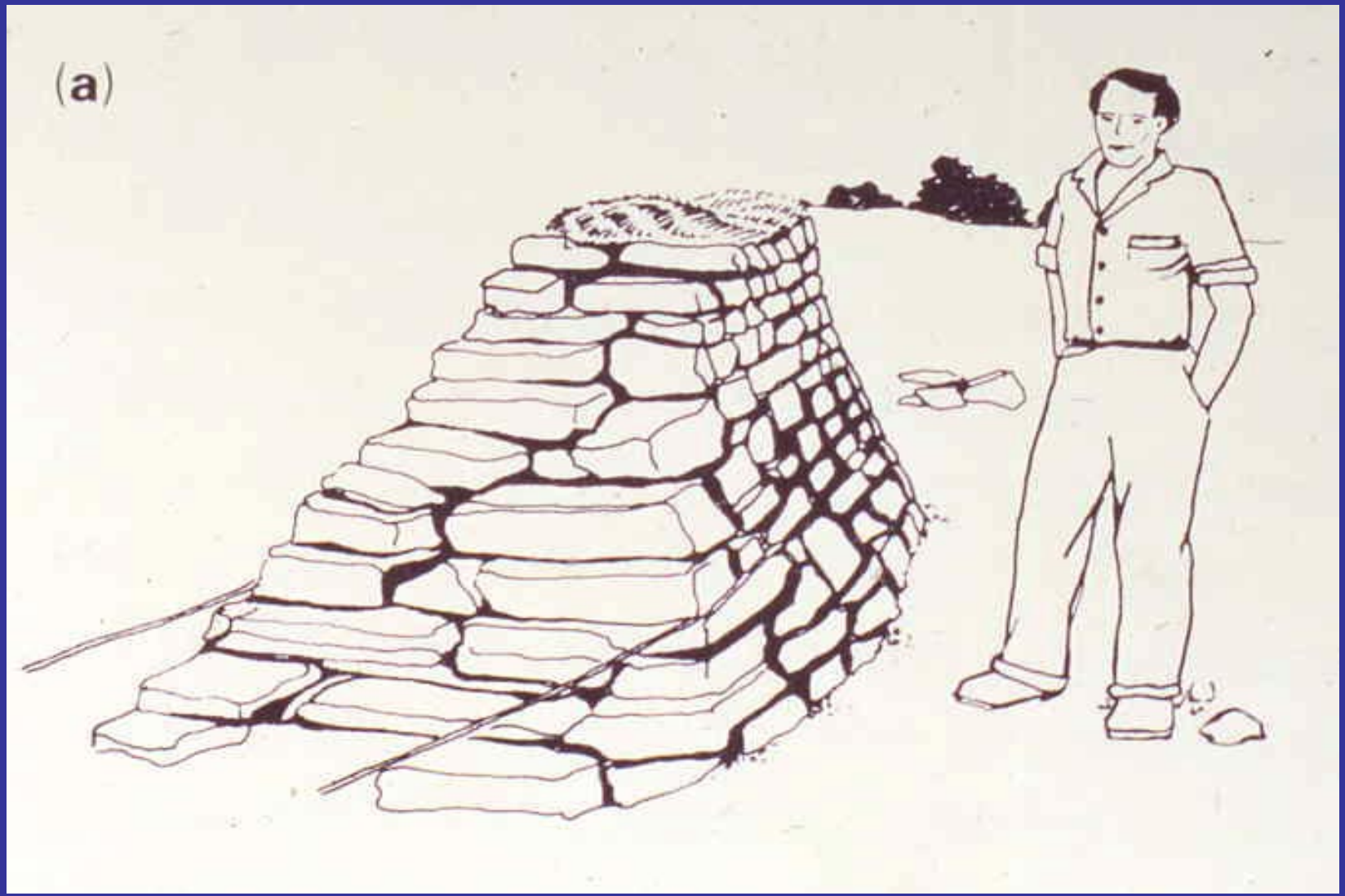
$\cot \theta$ = slope of bank (H:V ratio)

K_d = stability or roughness coeff icient

Vegetated Retaining Structures

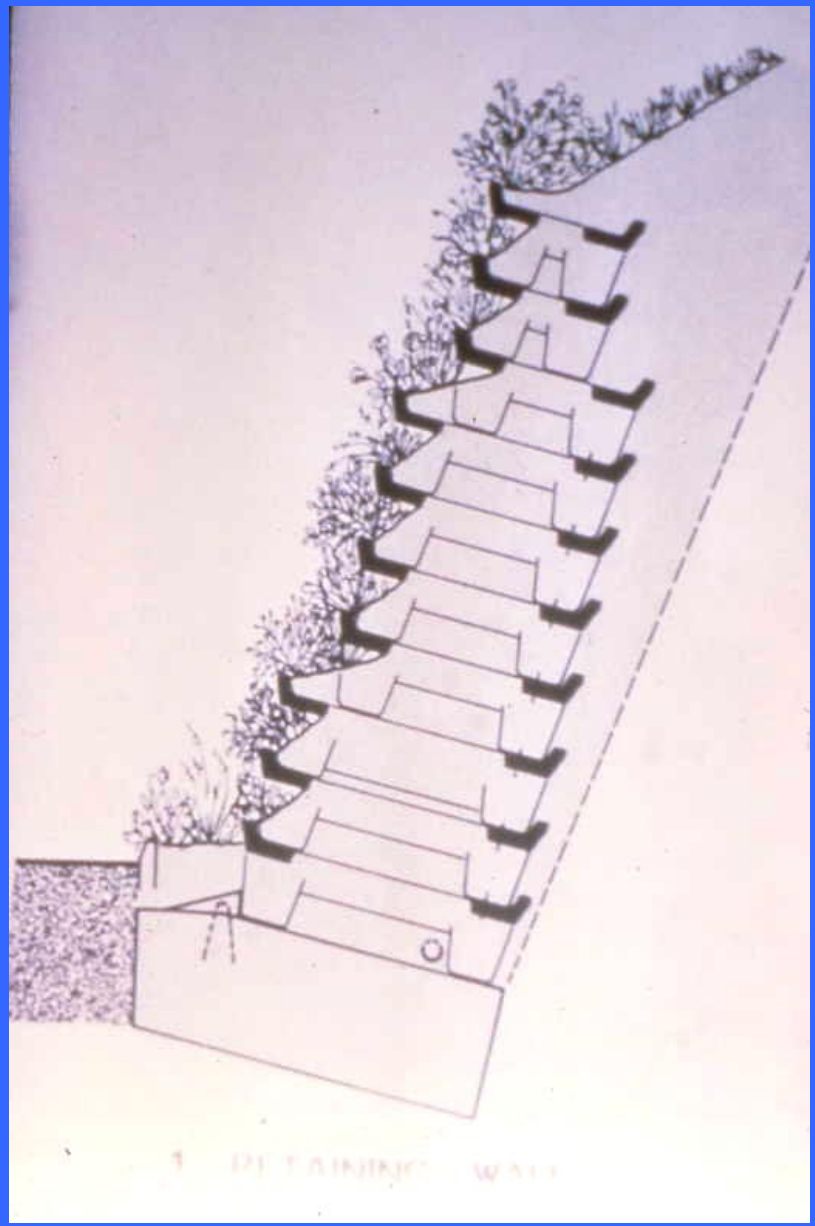
- Stone Hedgerow Walls
- Planted Crib Walls
- Vegetated Gabion Walls
- Planted Block Walls
- Vegetated Rock Breast Walls
- Vegetated Geogrid Walls

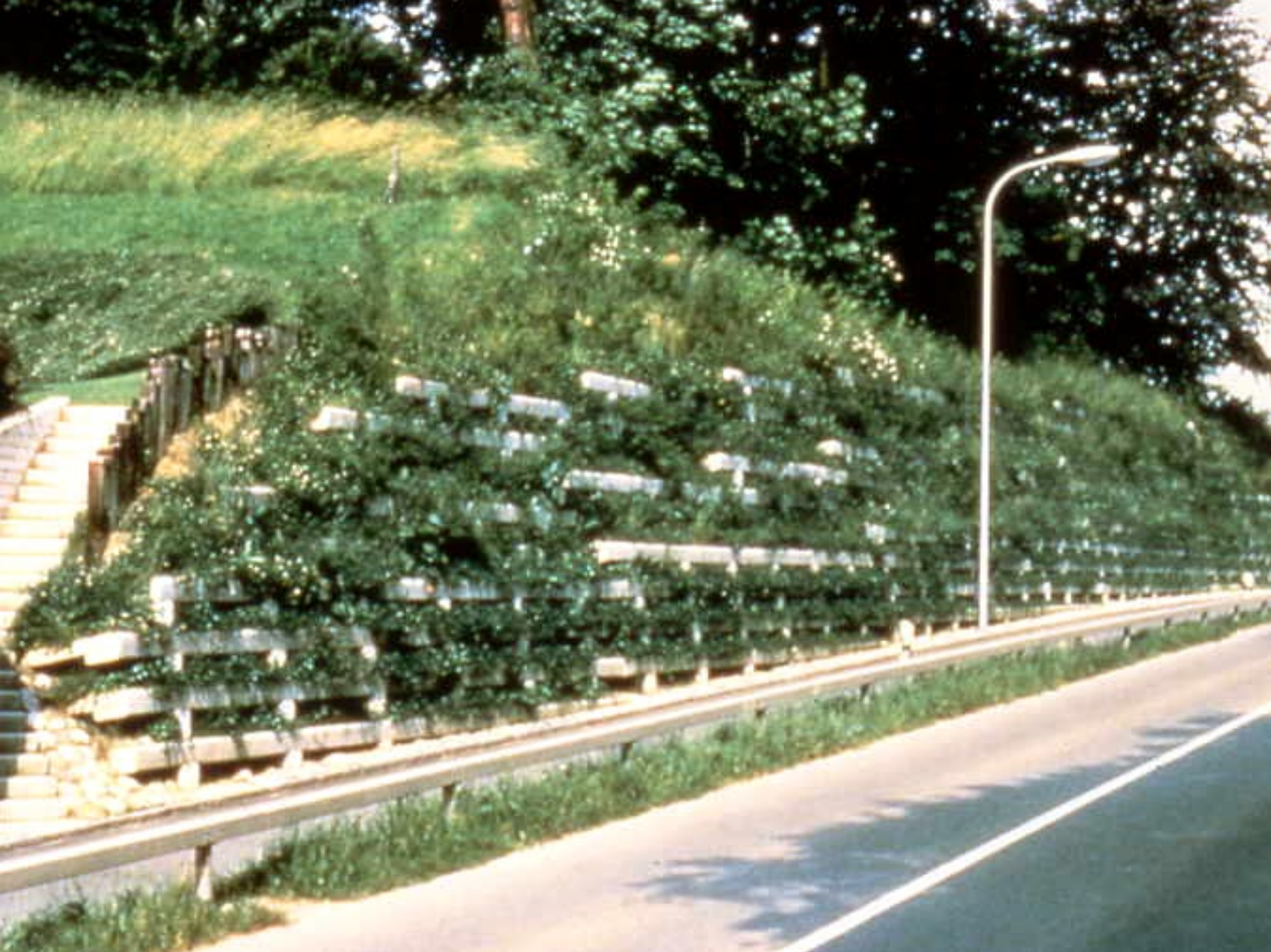
Hedgerow Walls



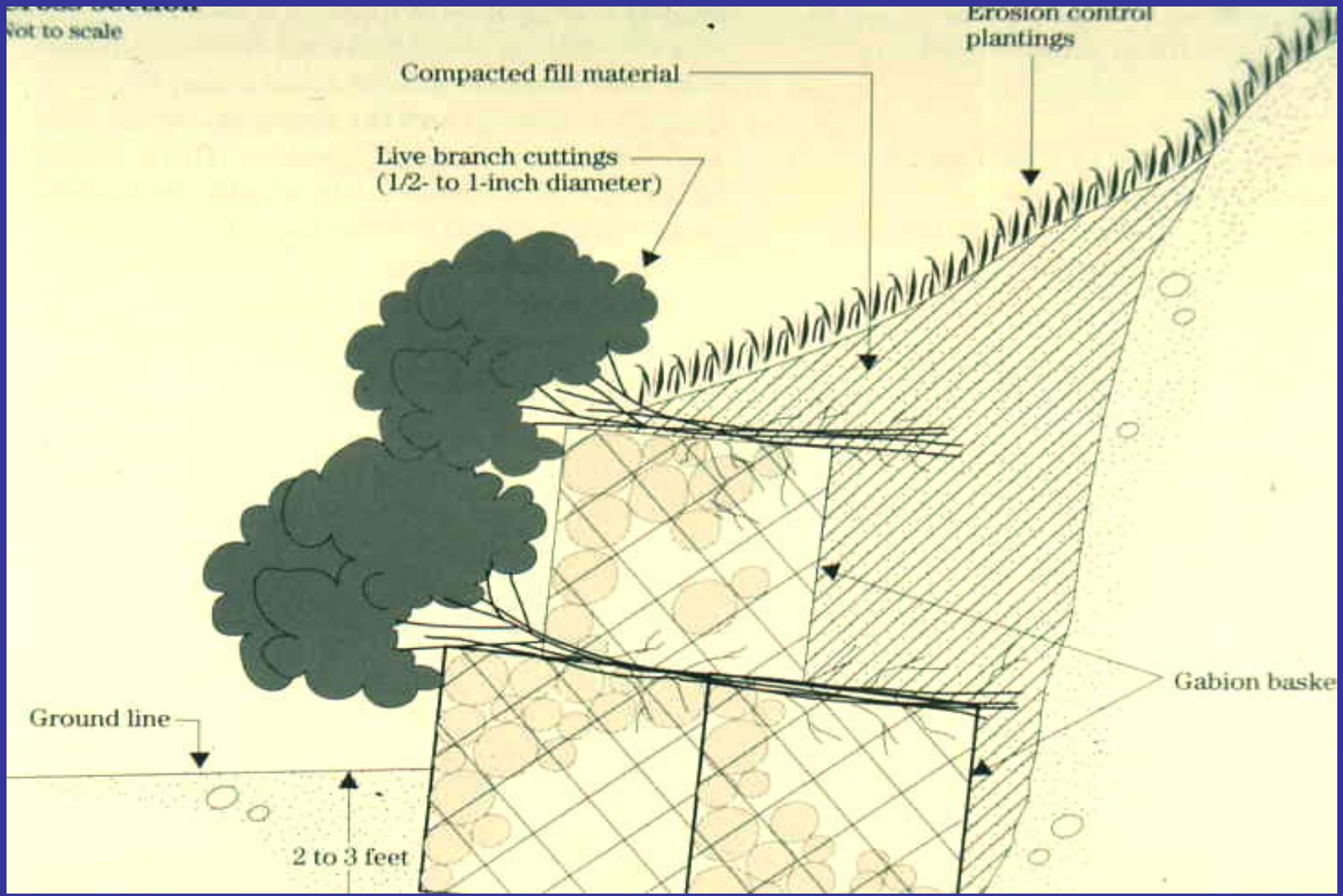
Planted Crib Walls

Evergreen Planted Wall System





Vegetated Gabions

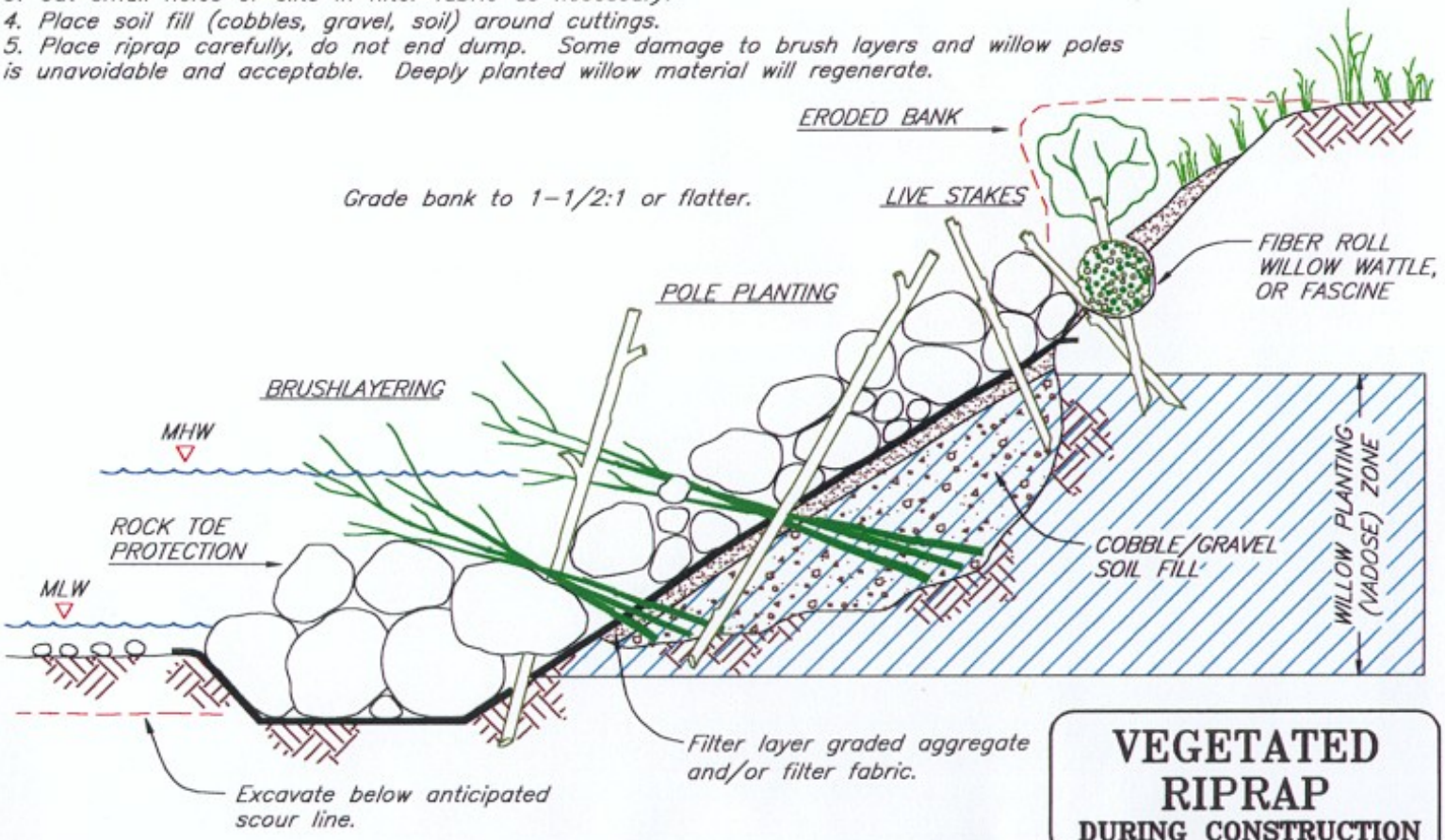


Vegetated Revetments "Hard Armor"

- Vegetated Riprap (joint planting)
- Live Staked Gabion Mattresses
- Vegetated Articulated Blocks (ABS)

Joint Planting (vegetated riprap)

NOTES:
1. Willow pole planting and brushlayering shall be installed during bank grading and riprap placement to ensure good contact with 'native ground' and soil fill.
2. Willow poles and brush layers shall extend down into expected soil moisture zones (vadose).
3. Cut small holes or slits in filter fabric as necessary.
4. Place soil fill (cobbles, gravel, soil) around cuttings.
5. Place riprap carefully, do not end dump. Some damage to brush layers and willow poles is unavoidable and acceptable. Deeply planted willow material will regenerate.

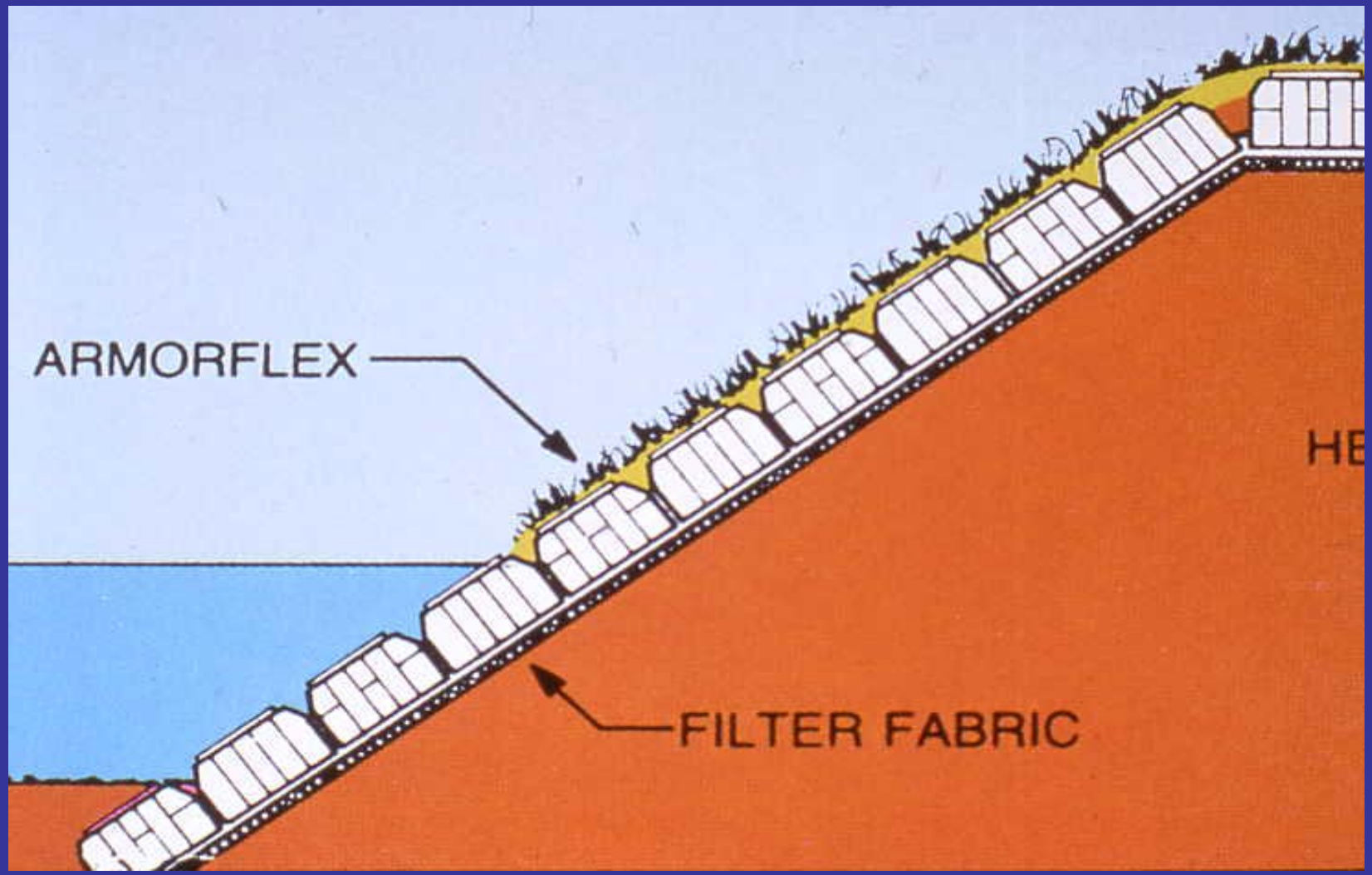


VEGETATED RIPRAP
DURING CONSTRUCTION

VGRIPRAP

Vegetated Gabion Mattress

Vegetated Concrete Blocks



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Soil Bioengineering Stabilization

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- Fascines *(wattles)*
- Fascines w/ subdrains
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- Live slope gratings
- Brush mattresses

Harvesting of Live Cuttings

- *Harvesting*
- *Handling*
- *Transportation*
- *Storage*


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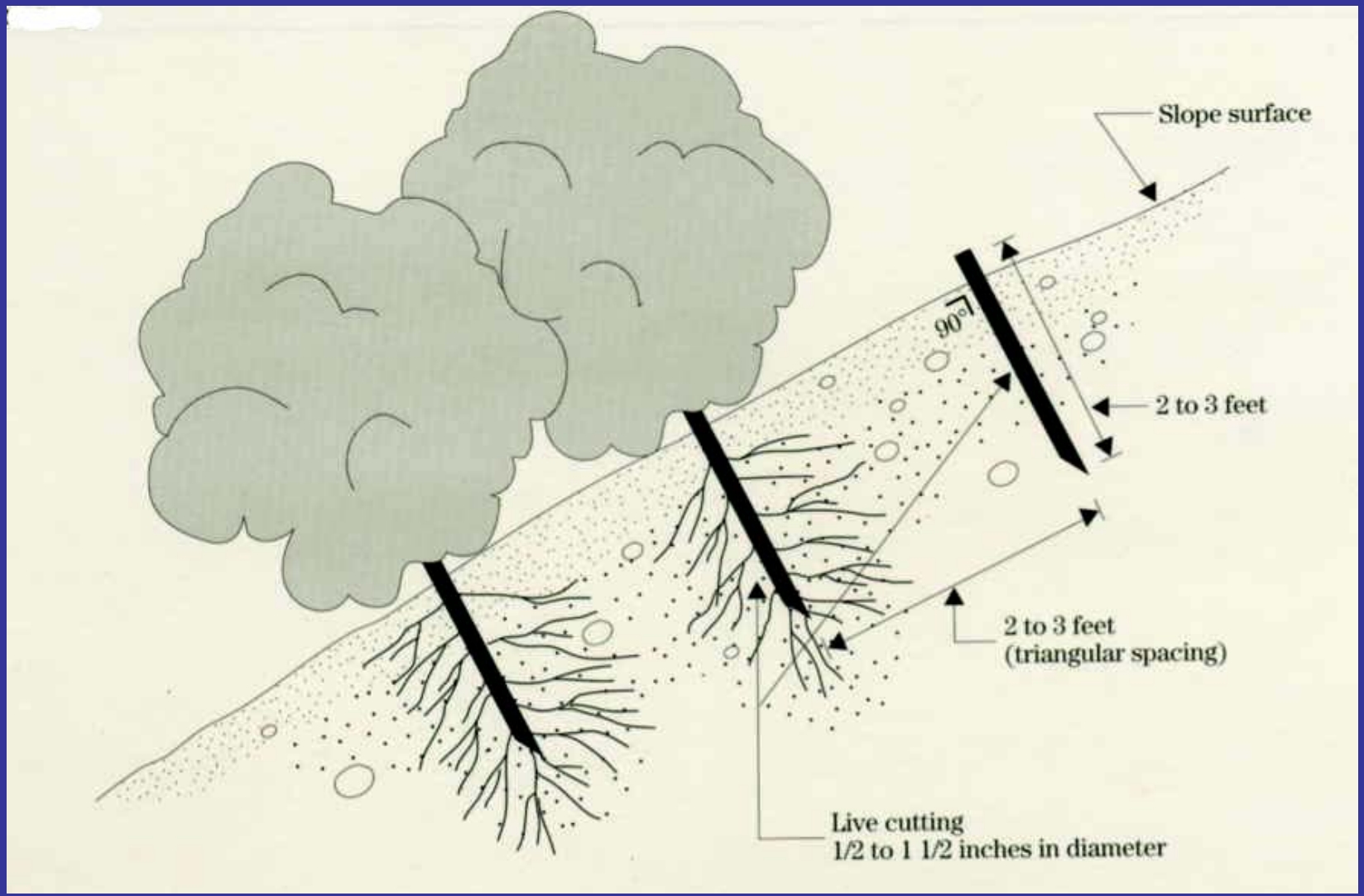
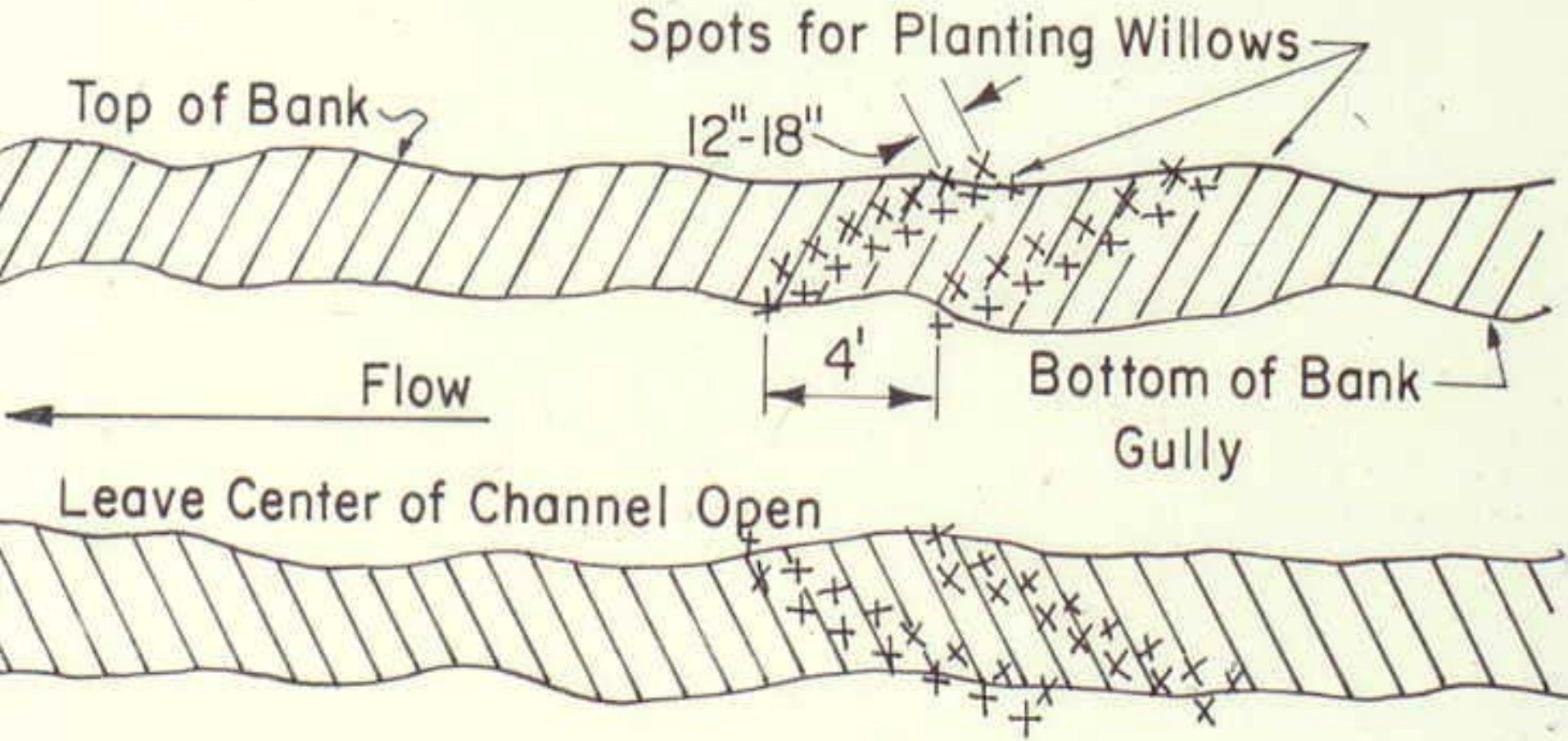
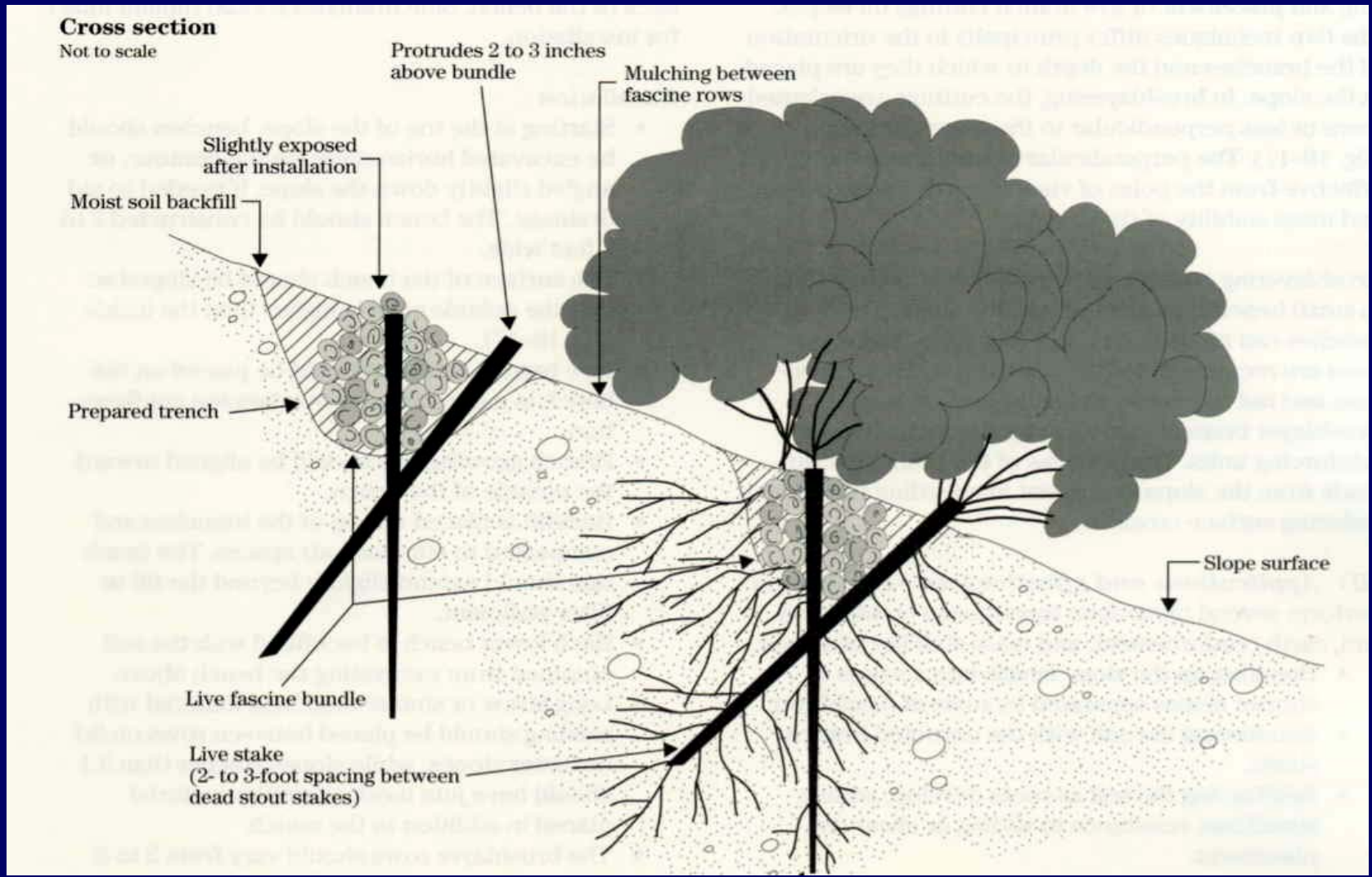
Live Staking




Spots for Planting Willows
Top of Bank
12"-18"
4'
Flow
Bottom of Bank
Gully
Leave Center of Channel Open

Live Fascines



UNITED STATES
DEPARTMENT OF AGRICULTURE
CIRCULAR No. 380

Washington, D. C. March 1936

EROSION CONTROL ON MOUNTAIN ROADS

By

CHARLES J. KRAEBEL

Senior Silviculturist
California Forest and Range Experiment Station
Forest Service

SOIL LOSS: EROSION CONTROL PLOTS* ANGELES CREST HIGHWAY, SO. CALIF.

Untreated.....750 cu. ft.(>1000 yds^3 soil/ac)

Sewn to Grain..... 50 cu. ft

Wattled & Sewn.... 15 cu. ft

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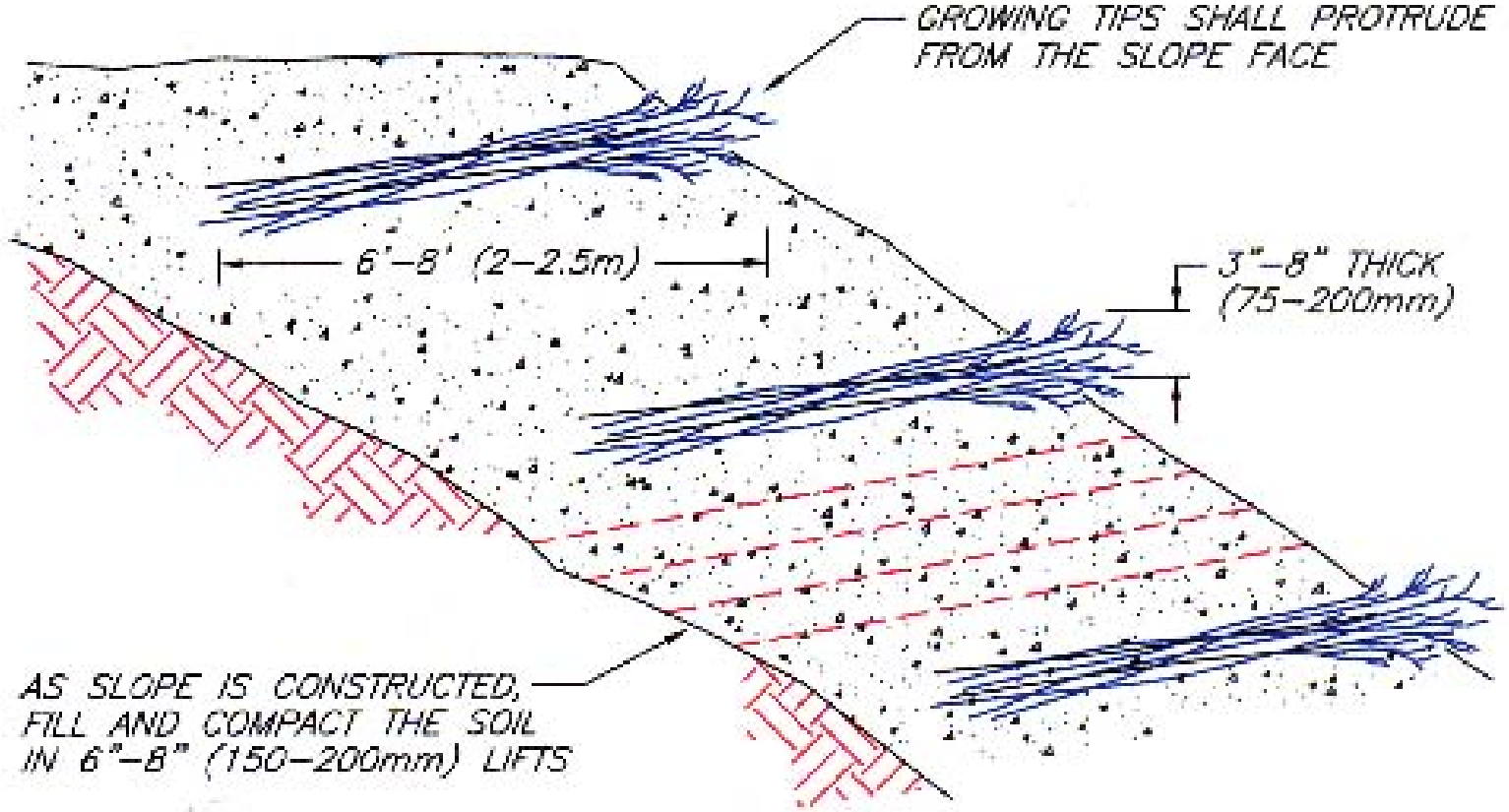
*20-foot wide plots on fill slope



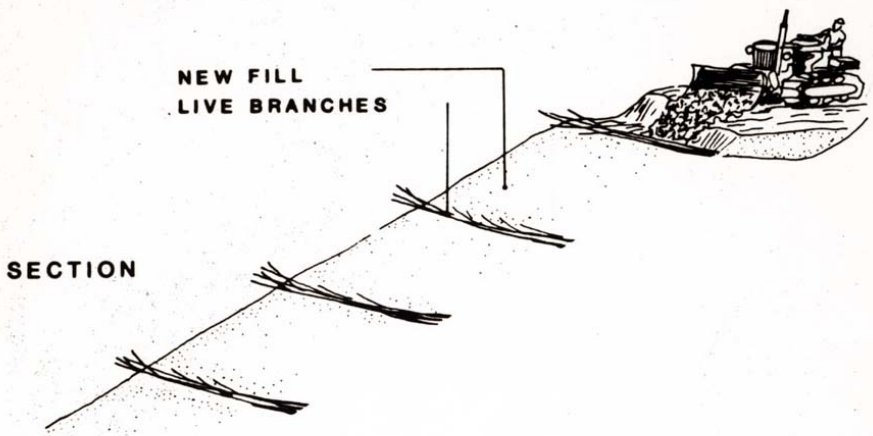
TYPICAL BRUSHLAYERING WITH SLOPE CONSTRUCTION

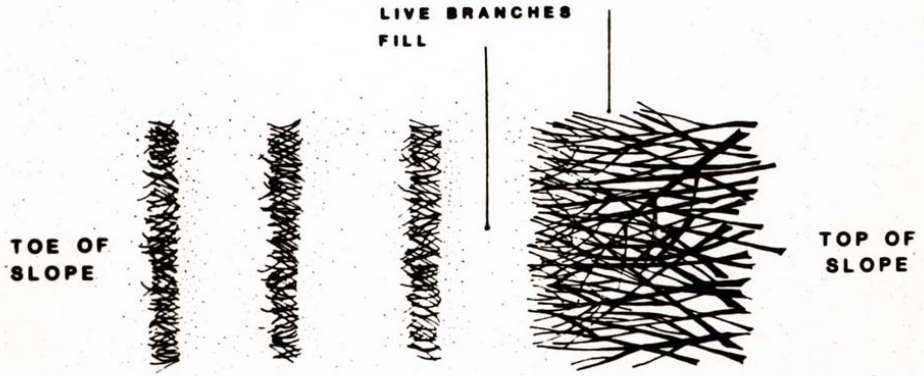
BRUSHLAYERING

Stabilizing Effect of Brushlayer Inclusions on Steepened Slopes

- Primary reinforcement from imbedded stems
- Secondary reinforcement from adventitious rooting along length of buried stems
- Surficial erosion control from exposed foliage tips
- Moisture depletion by evapo-transpiration (wicking action) from live vegetation
- Favorable modification of ground water flow regime by brushlayers acting as horizontal drains

BRUSHLAYER INSTALLATION

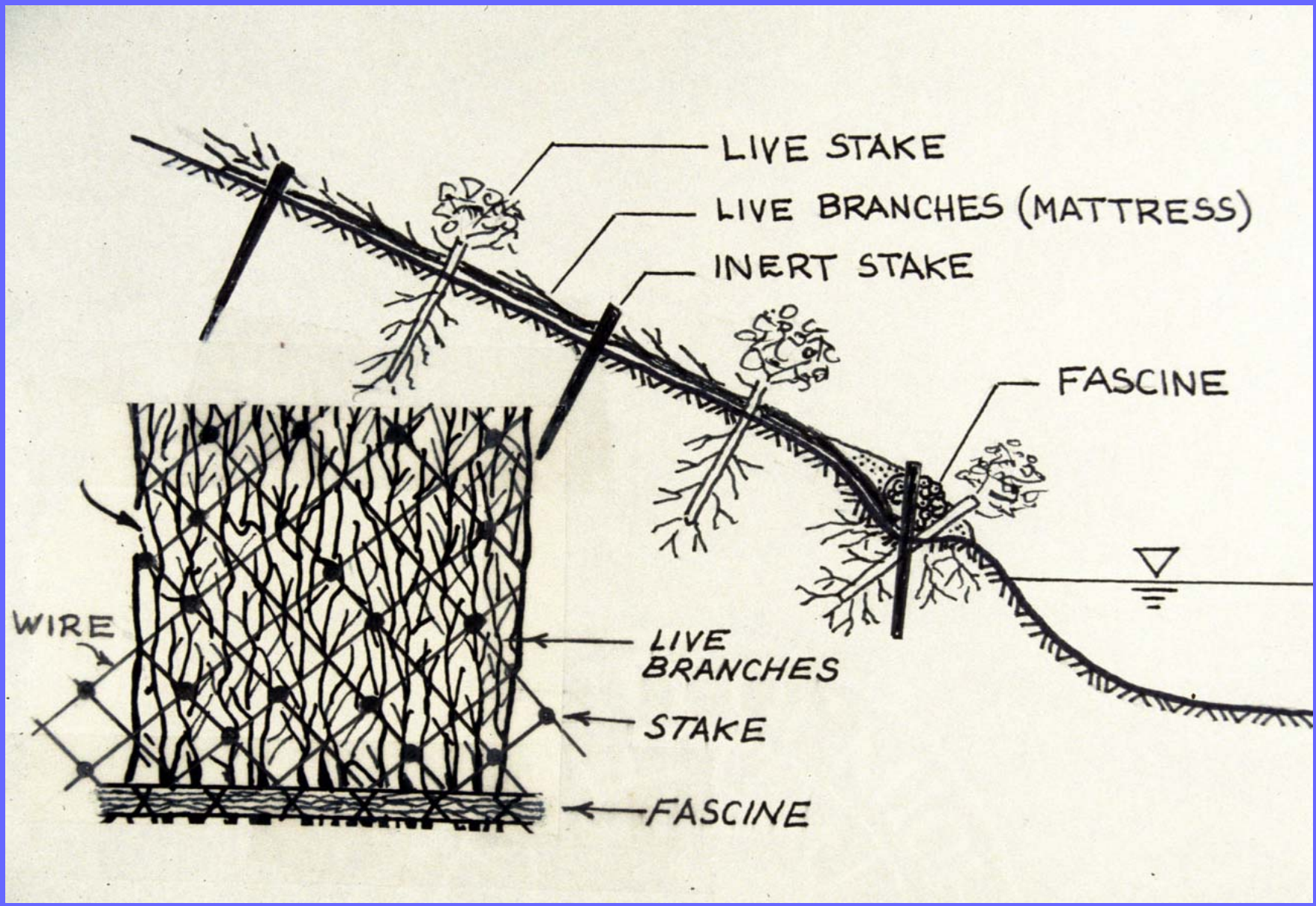




PLAN VIEW

NTS

Brush Mats

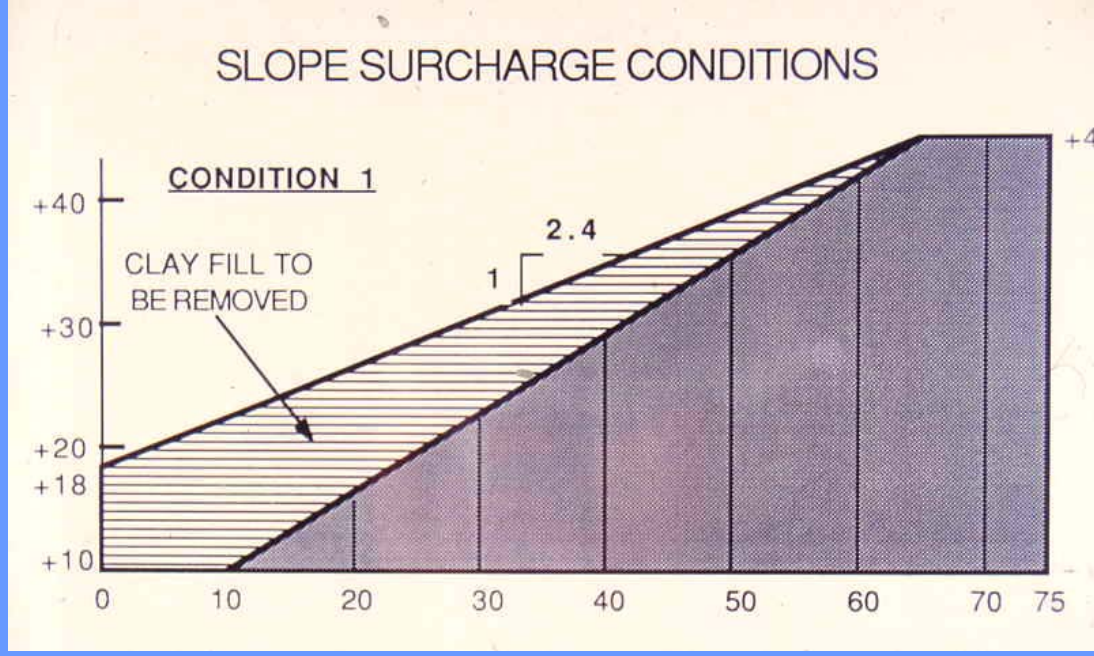

LIVE STAKE
LIVE BRANCHES (MATTRESS)
INERT STAKE
FASCINE
WIRE
LIVE BRANCHES
STAKE
FASCINE

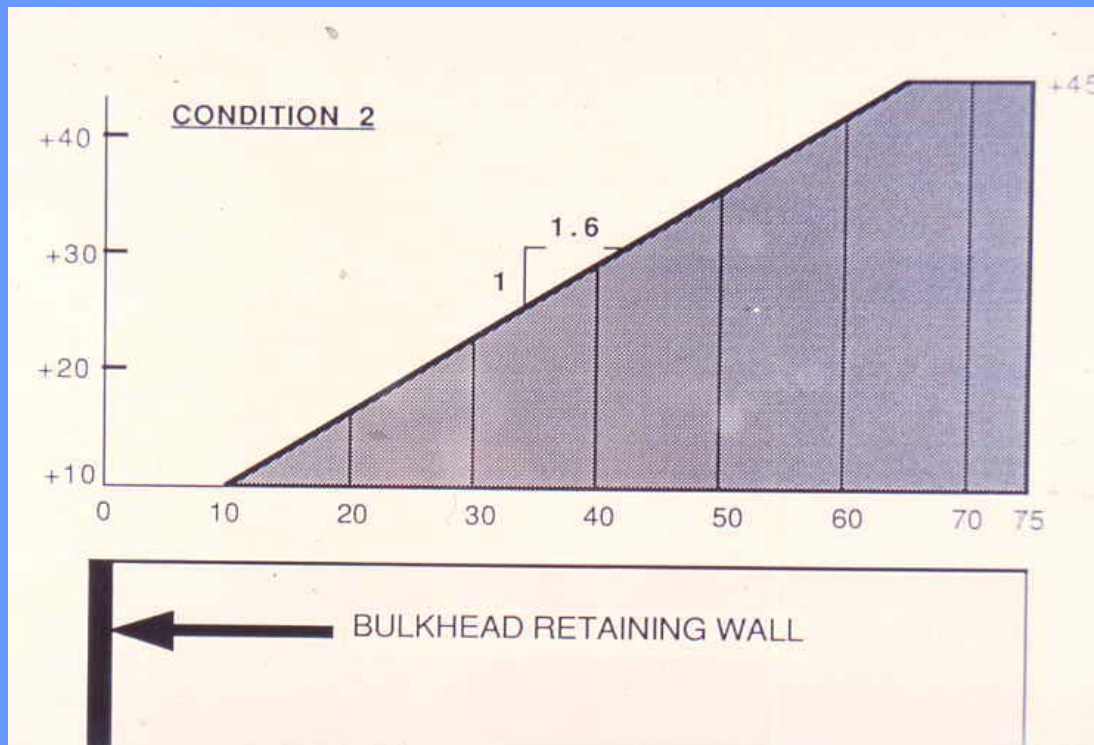

1 29 '00

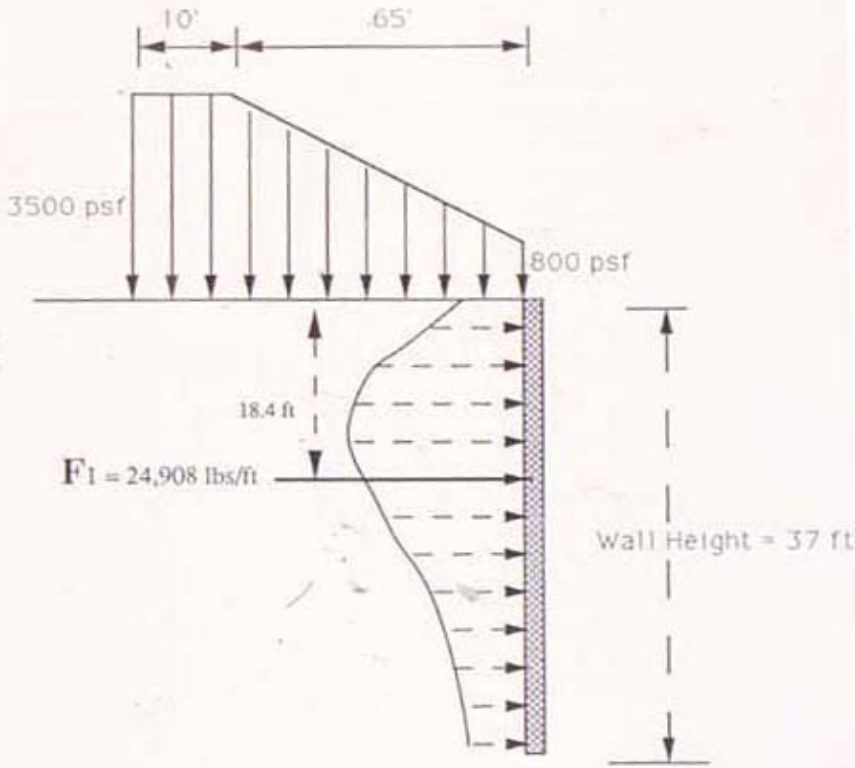

HUMBOLDT'S

Buffalo Bayou Bank Stabilization

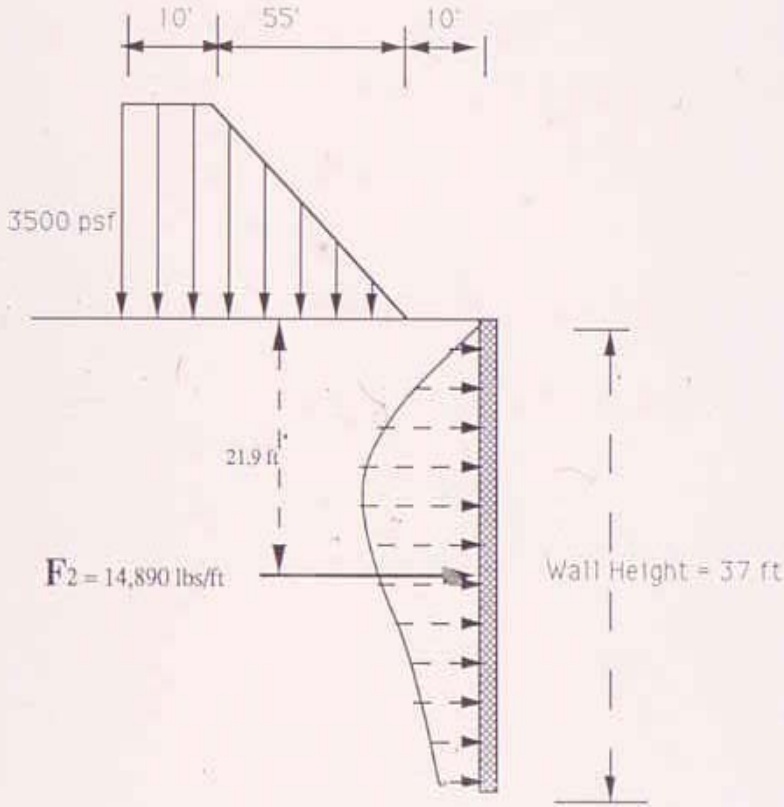
Backfill Surcharge Conditions "Before" and "After" Removal of Clay Fill





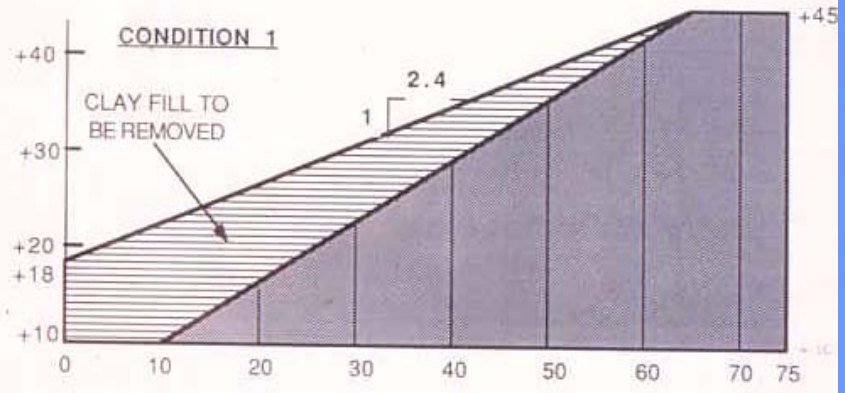


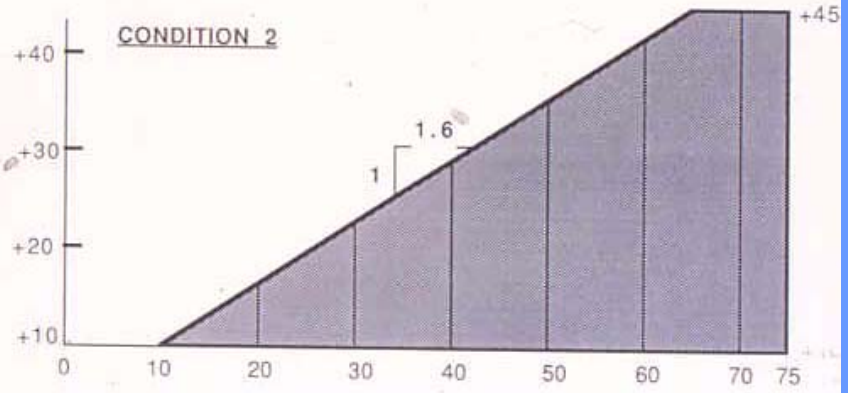
9 - Horizontal Stress Induced by Surcharge at The Initial Conditic

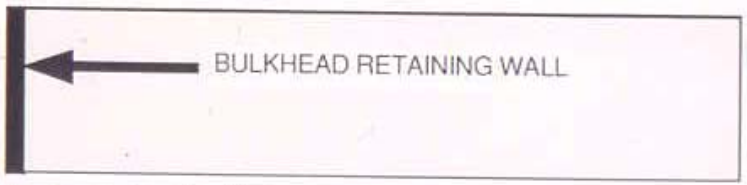


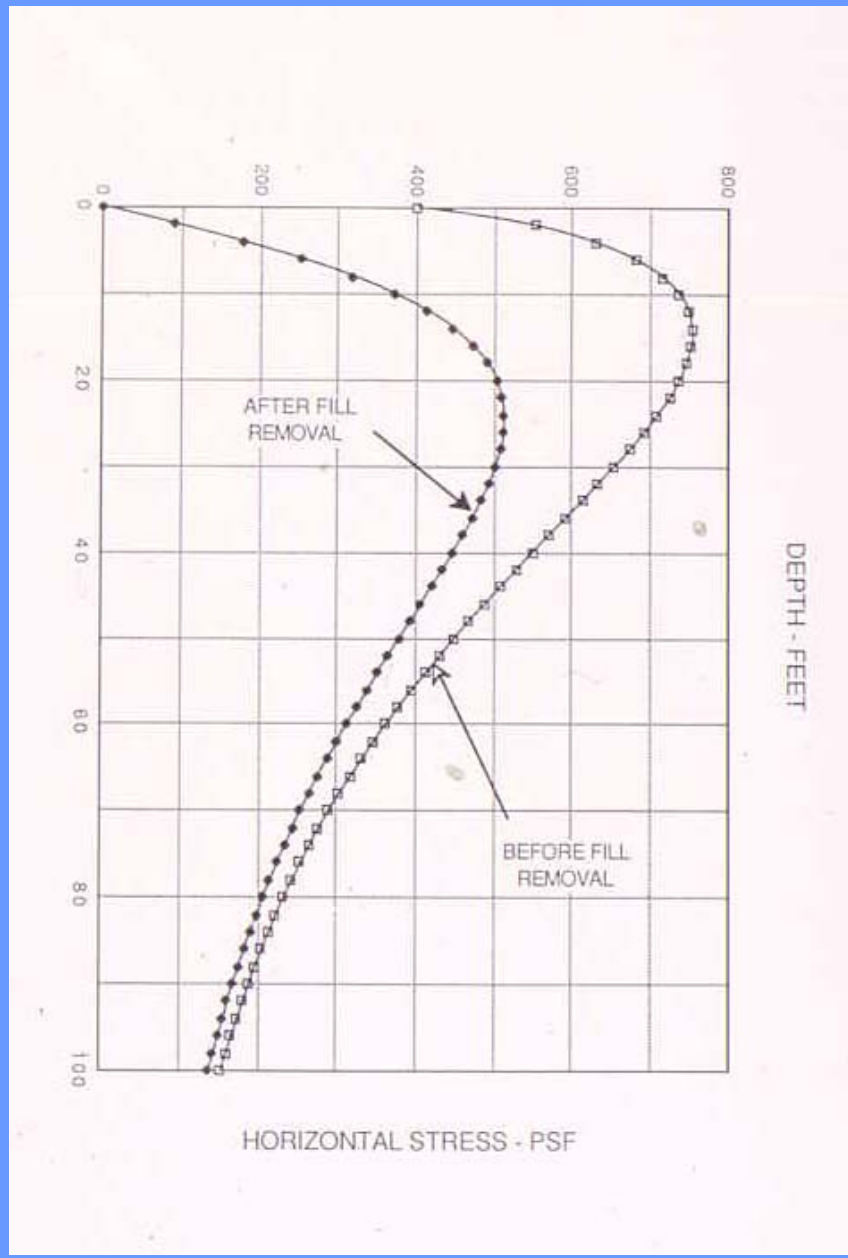
0 - Horizontal Stress Induced by Surcharge at The Final Condition

SLOPE SURCHARGE CONDITIONS



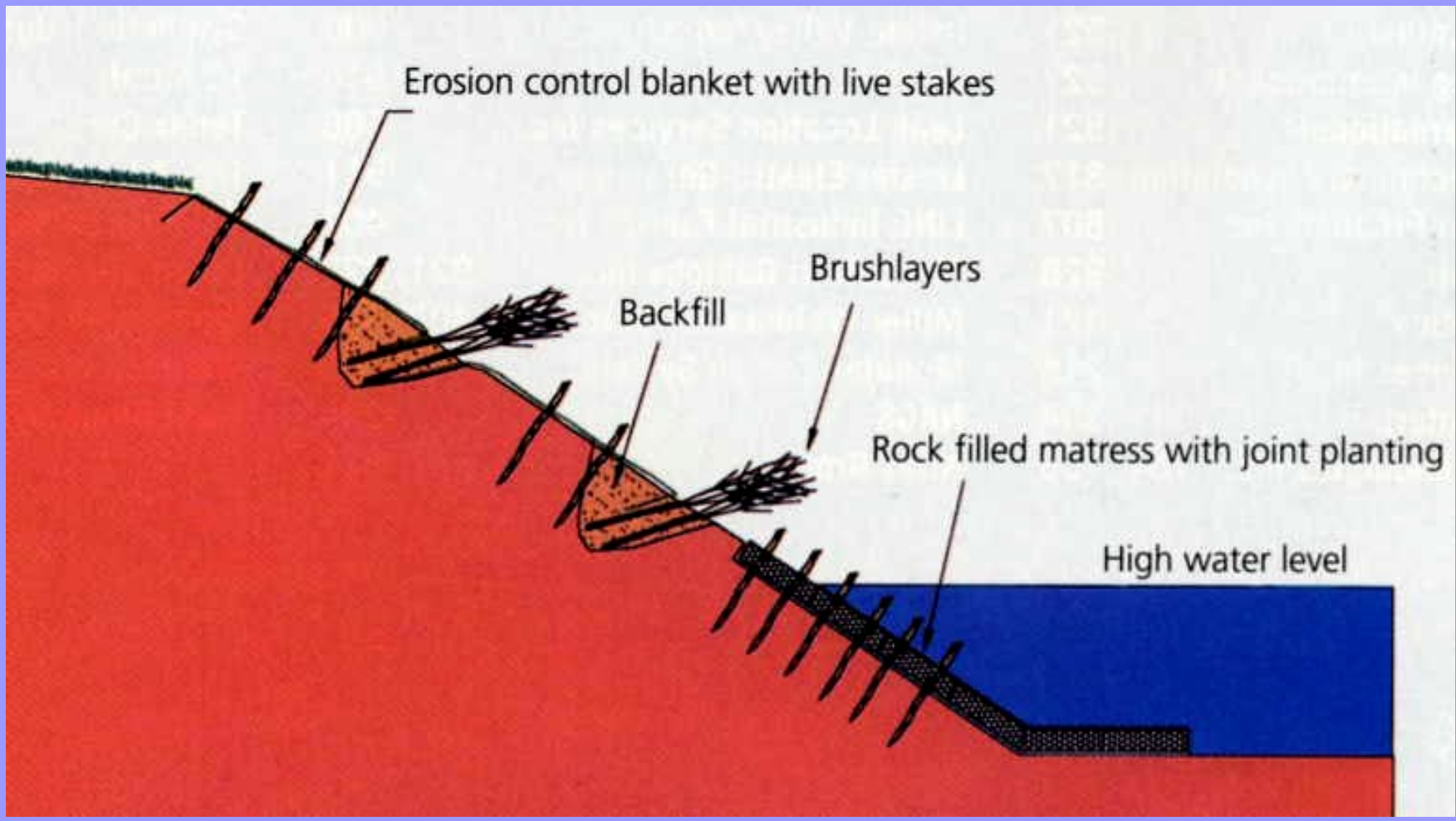




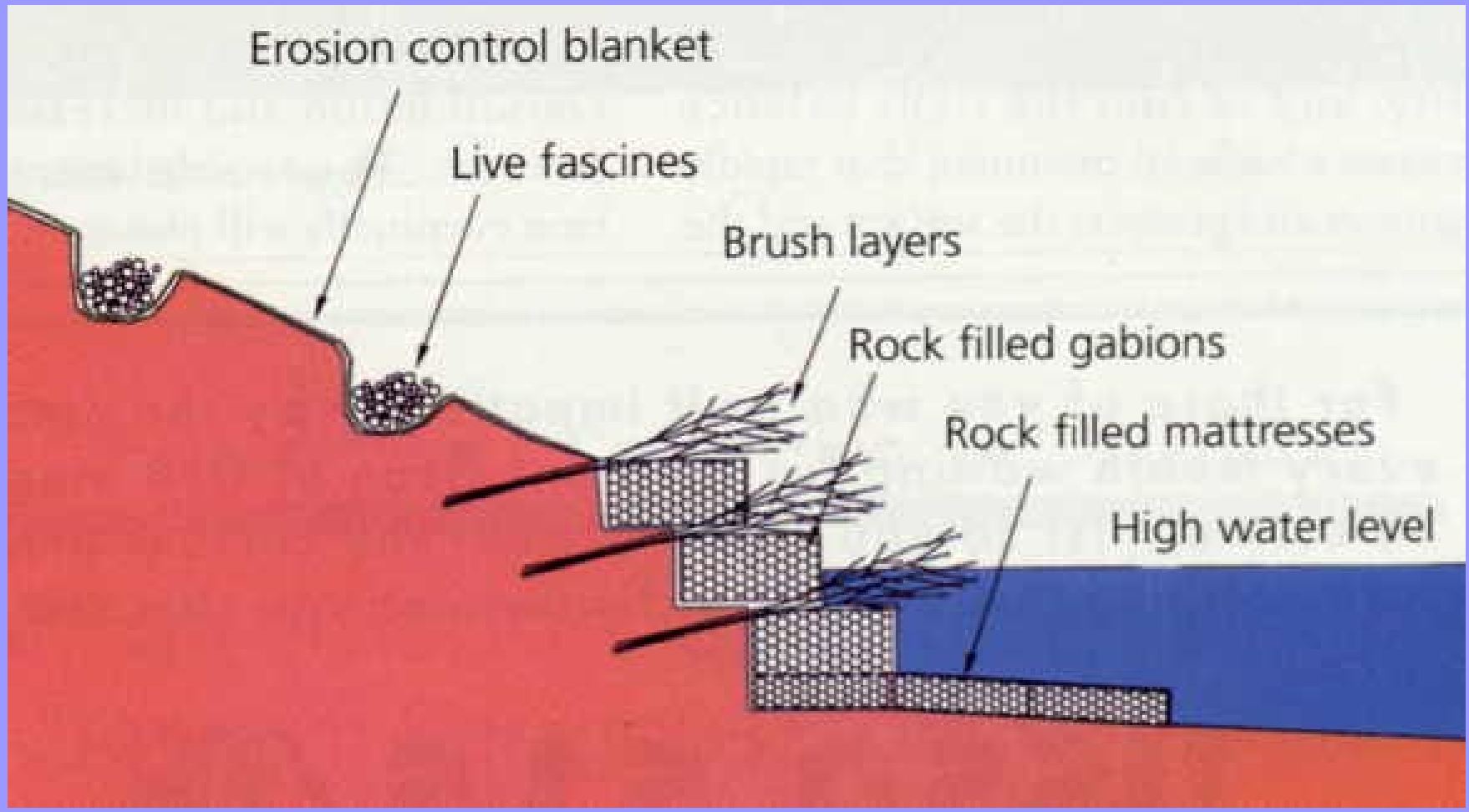


Buffalo Bayou Bank Stabilization

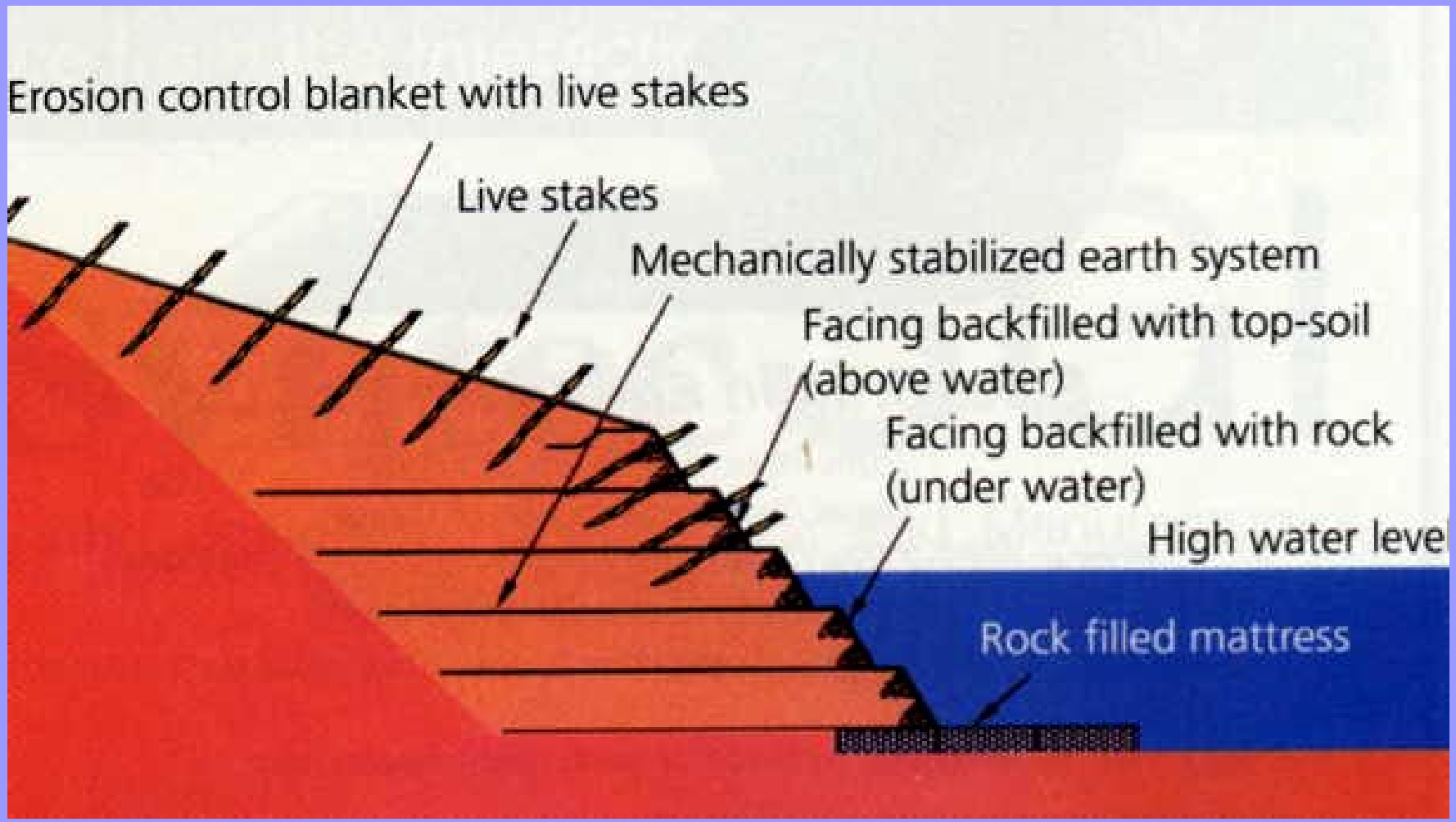
Combined Treatments



Joint planted rock mattress at toe and erosion control blanket (ECB) at mid bank supplemented by brushlayering and live staking



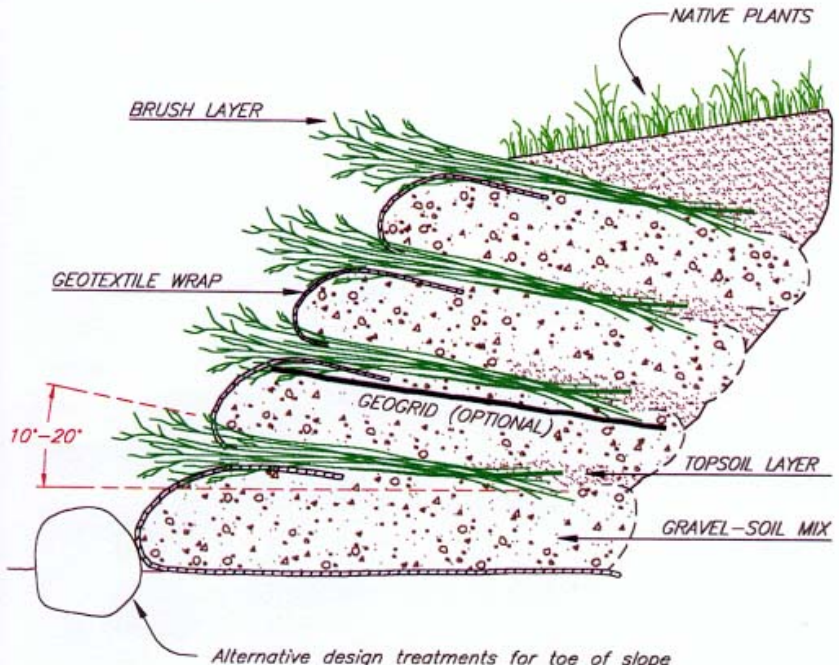
Vegetated rock gabions/gabion mattress apron at toe with erosion control blanket (ECB) and live fascines at mid bank & upper bank



Rock apron and vegetated MSE and rock toe supplemented by erosion control blanket(ECB) with live stakes on upper bank

Vegetated MSE and Rock Toe

Zayante Creek Bank Protection

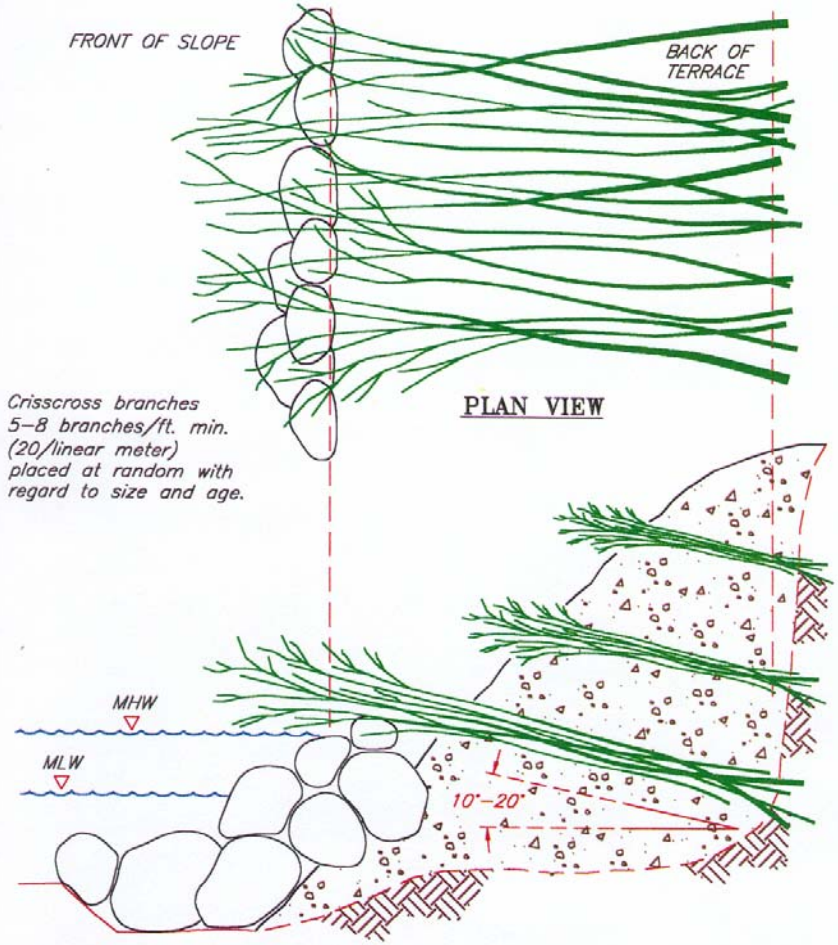


NOTES:

1. Brush layers, geofabrics and geogrids are tensile inclusions, which modify shear stress.
2. Additionally, once established the root systems bind the entire system together as a coherent mass.
3. Live brush layers act as horizontal drains and improve slope stability by redirecting the flow direction.
4. Cut branches 3' to 12' long from appropriate salix, cornus or populus species.
5. Branches up to 12' long can be used on fillslope installations. Branches for cutslope installation can be 2' to 10' long depending on the bench excavation.
6. Natural geofabrics (coir netting) or geogrids can be wrapped around soil layers to provide additional soil reinforcement.

BRUSHLAYERING WITH GEOTEXTILE SOIL WRAP

FILE: SOILWRAP



NOTES:

1. Tilt branches down into the slope 10°–20° min.
2. Brushlayering may be constructed with non–compacted or compacted backfill without damage to the brush layer.
3. Branches irrespective of length, should protrude 8–18in. (0.20–0.50 meters) beyond the face of the slope.

BRUSHLAYERING WITH ROCK TOE PROTECTION

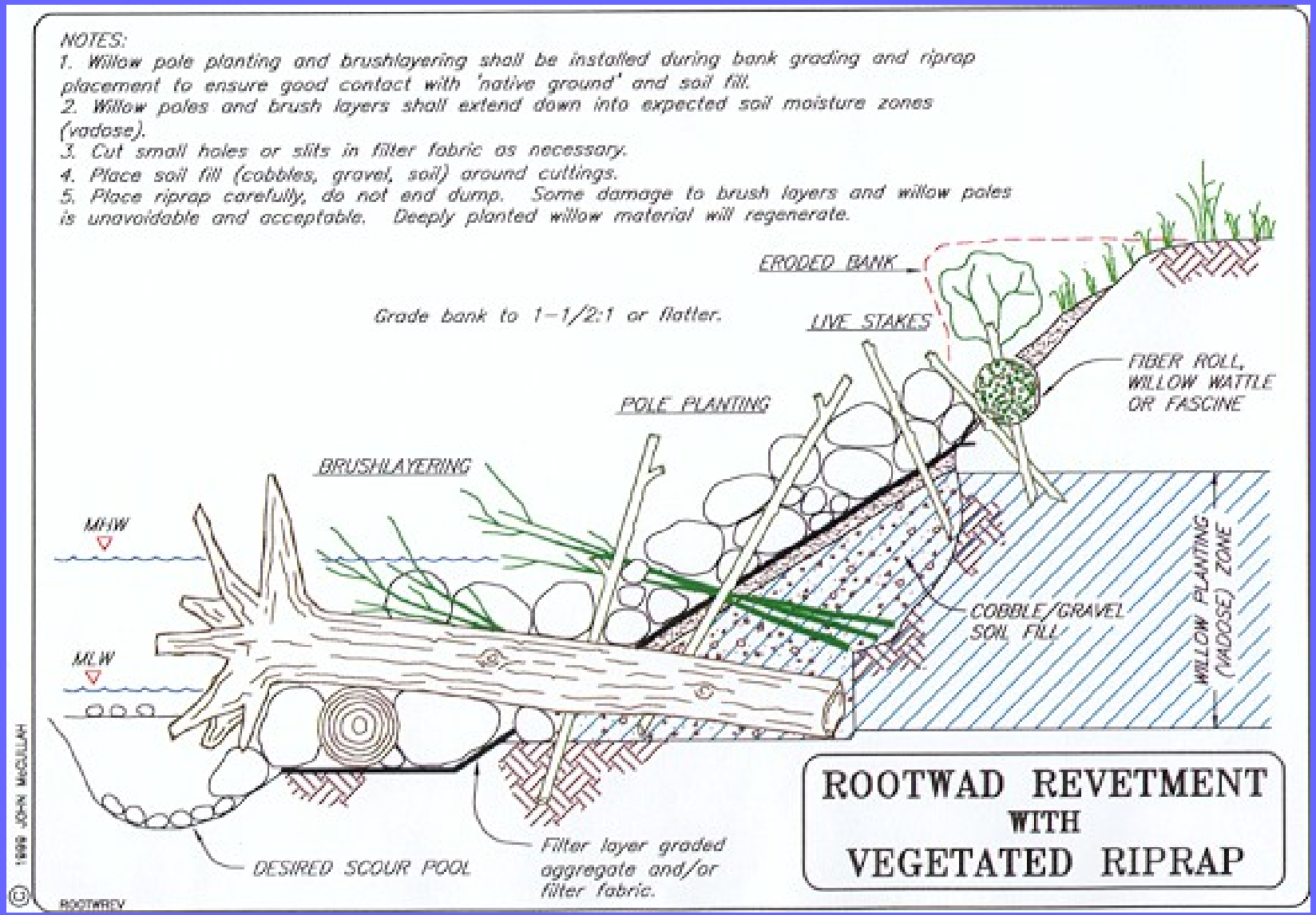
FILE: BRLAY–RT

Vegetated Rock Toe and Gabion Wall

Branciforte Creek Bank Protection

Vegetated Boulder and Rootwad Revetment with Rock Vane

San Vincente Creek Bank Protection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3. Cut small holes or slits in filter fabric as necessary.
4. Place soil fill (cobbles, gravel, soil) around cuttings.
5. Place riprap carefully, do not end dump. Some damage to brush layers and willow poles is unavoidable and acceptable. Deeply planted willow material will regenerate.
ERODED BANK
Grade bank to 1-1/2:1 or flatter.
LIVE STAKES
FIBER ROLL, WILLOW WATTLE OR FASCINE
POLE PLANTING
BRUSHLAYERING
MHW
MLW
COBBLE/GRAVEL SOIL FILL
WILLOW PLANTING (VADOSE) ZONE
DESIRED SCOUR POOL
Filter layer graded aggregate and/or filter fabric.
ROOTWAD REVETMENT
WITH
VEGETATED RIPRAP
© 1998 JOHN McCULLAH
ROOTWRFV