

# ***Evapotranspiration Cap Design & Construction***

**Borrow Soil Considerations**

**Patrick McGuire, Ph.D.  
Soil Scientist/Hydrologist**

**Earth Tech**

*March 9, 2004*



## ***Acknowledgements***

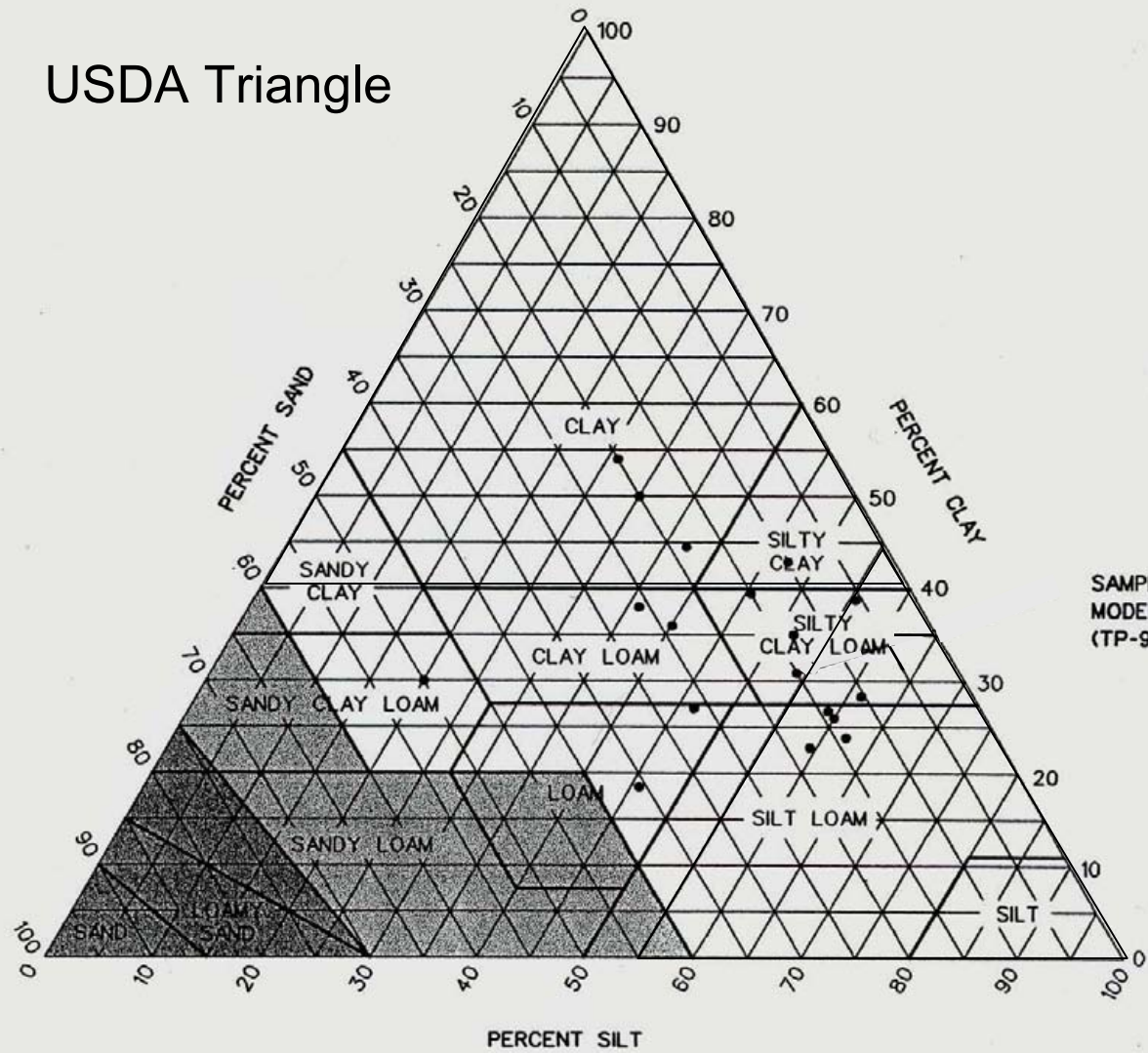
**DECAM – Fort Carson**

**US Army Corps of Engineers – Omaha District  
Earth Tech – Sheboygan, WI & Englewood, CO**

## ***Borrow Selection Process Overview***

- **Preliminary Soils Evaluations**
- **Soils Information**
- **Characterization of Borrow Soils**
- **Model Simulations and Final Design**
- **Construction Considerations**

# USDA Triangle



SAMPL  
MODEL  
(TP-9)



Model results indicate material from this type of soil may not be acceptable for use as an ET cap. Additional modeling will be required prior to using the soil in order to document the performance of an ET cap constructed from this soil.



Model results indicate material from this type of soil is not acceptable for use as an ET cap.



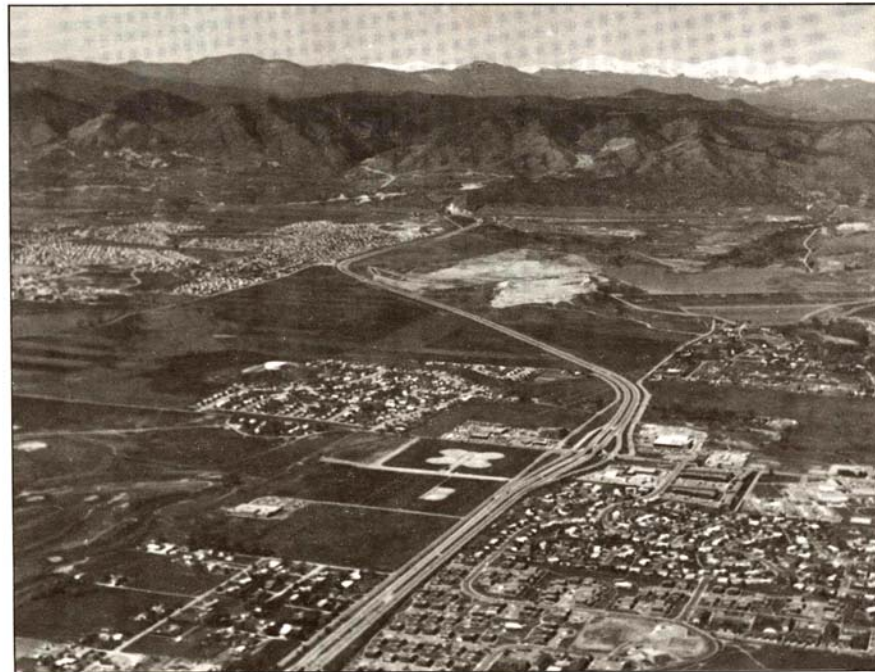
United States  
Department of  
Agriculture

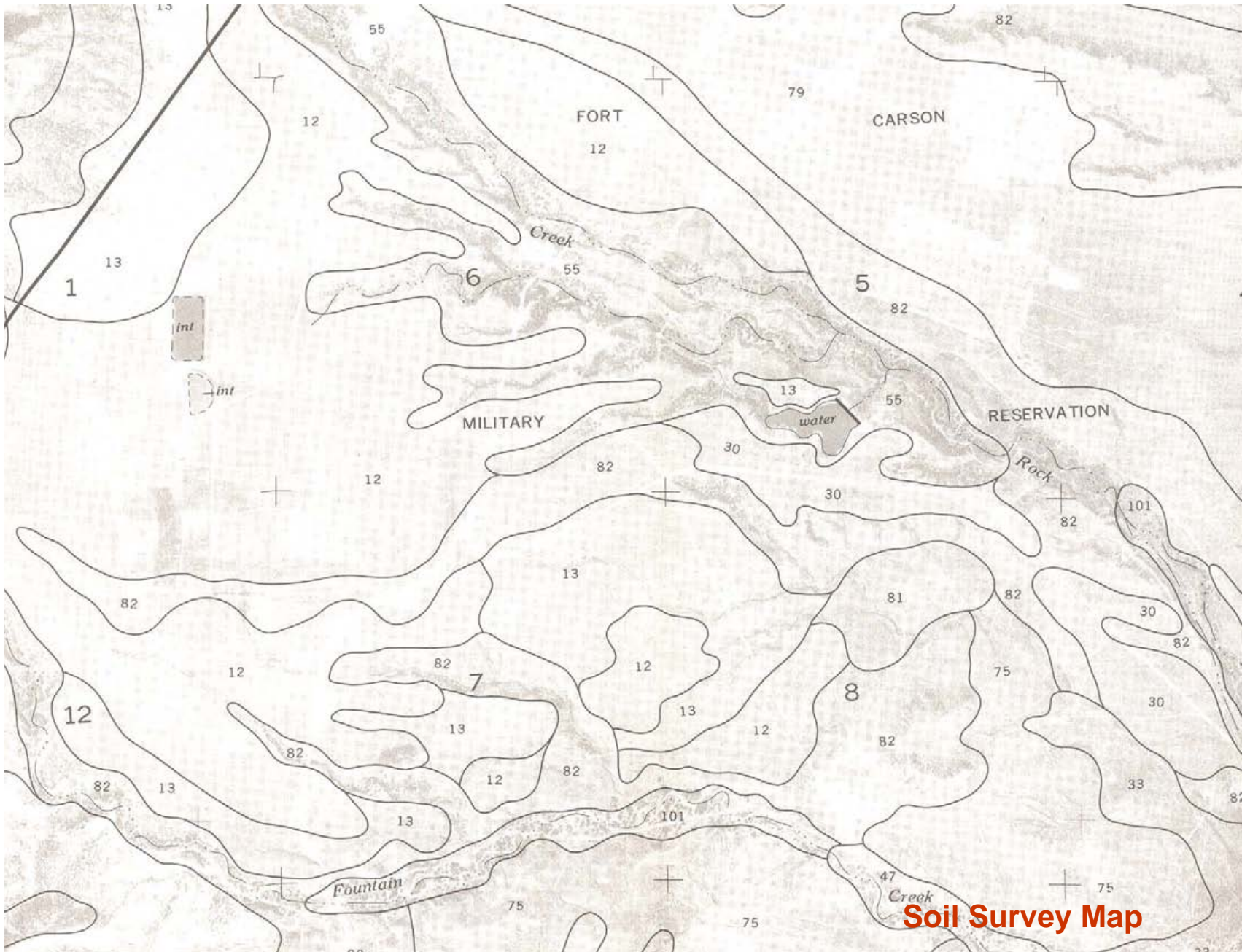
Soil  
Conservation  
Service

In Cooperation with  
Jefferson County  
and the Colorado  
Agricultural  
Experiment Station

# Soil Survey of Golden Area, Colorado

Parts of Denver,  
Douglas, Jefferson,  
and Park Counties





# Fort Collins Series

A1- 0-6 inches; brown (10YR 5/3) loam, moderate fine granular structure

B1- 6-9 inches; brown (10YR 5/3) loam; weak medium subangular blocky structure

B2t - 9-16 inches; brown (10YR 5/3) clay loam; moderate medium prismatic structure

B3ca – 16to 21 inches; brown (10YR 5/3) light clay loam; weak coarse prismatic structure

C1ca – 21 to 29 inches; pale brown (10YR 6/3) loam, coarse prismatic structure parting

C2ca – 29 to 60 inches; pale brown (10YR 6/3) loam; massive

## Range Productivity and Composition

Soil name and map symbol	Range site name	Potential production		Common plant name	Composition
		Kind of year	Dry weight		
Fort Collins: 30, 31	Loamy plains	Favorable	1,500	Blue grama	40
		Normal	1,100	Western wheatgrass	20
		Unfavorable	800	Buffalograss	10
				Sedge	5
				Needleandthread	5

## Construction Materials

Soil name and map symbol	Roadfill	Sand	Gravel	Topsoil
Fort Collins: 30, 31	Fair: low strength, frost action.	Unsuited	Unsuited	Good.

# ***Sampling Strategy Dependent On Borrow Source***

- **Depth**

  - surface soil**

  - subsurface unconsolidated deposits**

- **Origin & Variability**

  - stockpile**

  - loess surface soil**

  - fluvial deposit**



# ***Sampling Strategy***

## ***Fort Carson-Alluvial/Loess Soil***

- **Developed, Distinct, & Relatively Uniform Soil Horizons**
- **Soil Horizons Described**
  - excavated pits**
  - quarry or road cuts**
- **Discrete Samples Collected Following Field Data Evaluation**

## ***Sampling Strategy-Fluvial Unconsolidated Deposits***

- **Highly Variable Sand, Silt, and Clay Layers**
- **Random Sampling Locations Based On Grid System**
- **Composite Soil Samples**
- **Considerable Field Management**

# ***Borrow Characterization Field Description***

## **Soil Profile Descriptions - Borrow Area, July 1999**

Soil <sup>1</sup> Profile	Plant Cover (%)	Slope <sup>2</sup>	Soil Horizon <sup>3</sup>	Depth Interval (Inches)	Matrix Color <sup>4</sup>	Texture <sup>3</sup>	Structure (Grade Type) <sup>3</sup>
SP-1 SE	60 - 80	0	A	0 - 12	Dark Brown (10 YR 3/3)	Clay (L)	Mod-sangblk
			B	12 - 31	Dark Yellowish Brown (10 YR 3/4)	Clay Loam (L)	Strong-angblk
			C <sub>1K</sub>	31 - 83	Olive Brown (2.5 Y 4/3)	Clay Loam (L)	Mod-prism
			C <sub>2</sub>	83-125	Light Olive Brown (2.5Y 5/3)	Clay Loam (L)	Weak-sangblk





**Table 2 - FORT CARSON LANDFILL 5 EVAPOTRANSPIRATION CAP  
BORROW AREA PHYSICAL/HYDRAULIC SOIL ANALYSIS RESULTS**

Location	Sample		Parameters				
	Depth m (in.)	Soil Horizon <sup>1</sup>	Particle Size <sup>1</sup> (%)sand/silt/clay	USDA Soil Texture <sup>1</sup>	Bulk Density g cm <sup>-3</sup> (pcf)	Volumetric Moisture Content cm <sup>3</sup> cm <sup>-3</sup>	Hydraulic Conductivity cm s <sup>-1</sup>
Soil Profile 1	0.13 (5)	A	32/27/41	Clay	1.27 (79)	0.21	2.5x10 <sup>-6</sup>
Soil Profile 1	0.58 (23)	B	30/31/39	Clay Loam	1.25 (78)	0.12	4.0x10 <sup>-7</sup>
Soil Profile 1	1.4 (55)	C1	28/39/33	Clay Loam	1.18 (73)	0.11	6.9x10 <sup>-3</sup>
Soil Profile 2	0.13 (5)	A	34/33/33	Clay Loam	1.16 (72)	0.10	4.6x10 <sup>-4</sup>
Soil Profile 2	0.43 (17)	B	29/30/41	Clay	1.25 (78)	0.10	5.6x10 <sup>-6</sup>
Soil Profile 2	1.55 (61)	C1	30/38/32	Clay Loam	1.17 (73)	0.12	1.4x10 <sup>-5</sup>
Soil Profile 3	0.13 (5)	A	37/21/42	Clay	1.25 (78)	0.22	2.1x10 <sup>-3</sup>
Soil Profile 3	0.48 (19)	B	40/27/33	Clay Loam	1.14 (71)	0.16	1.6x10 <sup>-4</sup>
Soil Profile 3	1.2 (48)	C1	46/23/31	Sandy Clay Loam	1.13 (70)	0.23	5.6x10 <sup>-5</sup>
Soil Profile 3	2.31 (91)	C2	37/33/30	Clay Loam	1.15 (72)	0.21	1.0x10 <sup>-4</sup>
Soil Profile 5	0.18(7)	B	42/21/37	Clay Loam	1.10 (69)	0.24	2.0x10 <sup>-6</sup>
Soil Profile 5	0.86 (34)	C1	36/34/30	Clay Loam	1.18 (73)	0.25	1.4x10 <sup>-4</sup>
Soil Profile 8	0	A	39/37/24	Loam	1.10 (69)	0.22	1.3x10 <sup>-2</sup>
Soil Profile 8	0.30 (12)	B	29/36/35	Clay Loam	1.18 (73)	0.14	1.1x10 <sup>-5</sup>
Soil Profile 10	1.7 (69)	C2	49/21/30	Sandy Clay Loam	--	--	3.5x10 <sup>-3</sup>

NOTE:

<sup>1</sup> U.S. Department of Agriculture Soil Survey and Classification Terminology.











## LYSIMETER WATER STORAGE TEST RESULTS

### Process

- Lysimeter packed with clay loam to  $1.3 \text{ g cm}^{-3}$
- Lysimeter dosed with 225 gal over 8 days
- 45 gal of drainage
- Final measurements obtained 14 days following no reported drainage

### Results

<u>Depth Interval</u> in	<u>Volumetric Soil Water Content<sup>1</sup></u> $\text{in}^3 \text{ in}^{-3}$	<u>Water Storage</u> in
0 - 12	0.33	3.96
12 - 18	0.34	2.04
18 - 24	0.35	2.10
24 - 30	0.36	2.16
30 - 36	0.38	2.28
36 - 42	0.39	2.34
42 - 48	0.39	2.34

Total = 17.2 in

Total water storage capacity assuming soil water content of  $0.34 \text{ in}^3 \text{ in}^{-3} = 16 \text{ in}$

**FORT CARSON EVAPOTRANSPIRATION CAP  
BORROW AREA SOIL ANALYSIS  
SOIL FERTILITY AND SALINITY PARAMETER ANALYSIS RESULTS**

Location <sup>1</sup>	Sample		Chemical Parameters <sup>3</sup>							
	Depth (inches)	Soil Horizon <sup>2</sup>	pH	EC (mmhos/cm)	Soluble Salts				SAR	OM (%)
					(meq/l)					
Soil Profile 1	5-7	A	6.3	0.5	2.0	1.1	1.7	0.5	1.3	1.7
Soil Profile 1	23-23	B	7.9	0.5	2.0	1.2	3.0	0.4	2.4	1.0
Soil Profile 2	111-113	C2	8.2	1.7	5.6	2.2	11.1	0.2	5.6	0.6
Soil Profile 2	144-146	C3	8.1	2.1	14.0	4.1	13.8	0.2	4.6	0.5

**Normal Soils**

ph < 8.5

SAR < 13

EC < 4

# ***Fort Carson Evapotranspiration Cap Design-Water Balance Simulations***

## **UNSAT-H Model-Four Year Simulation**

- **Wet Year (21 in)**
- **Literature Based Native Grass Data**
  - Bare Area = 50 %**
  - Leaf Area Index = 0.5 to 1.5**
  - 6.5 month growing season**
  - root depth to 48 in**
- **Soil hydraulic characteristics of borrow soil types**

## ***Construction Considerations***

- **Test Pads**
- **Excessive Compaction**
- **Soil Erosion**

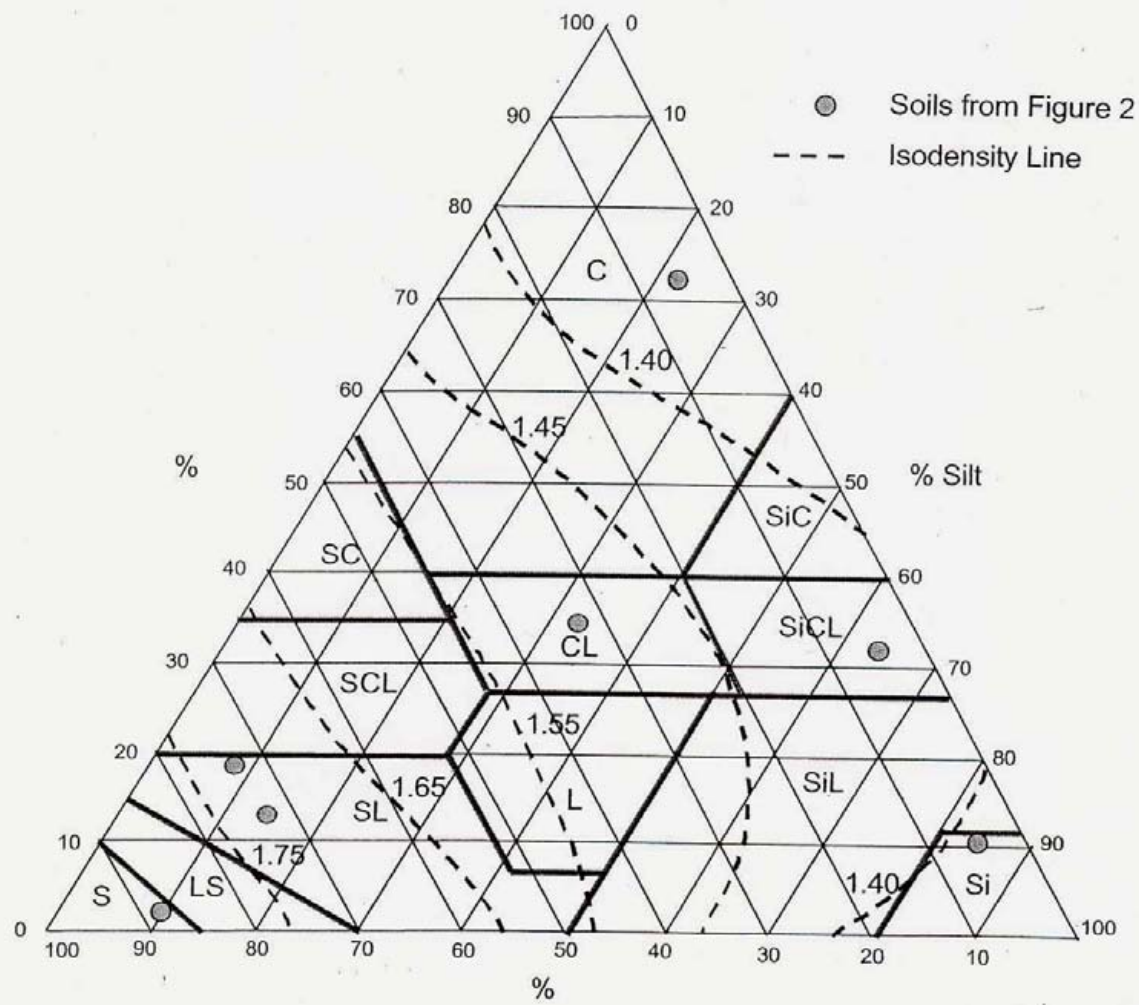


Figure 4. Growth-limiting bulk density textural triangle (Modified from Daddow and Warrington (1983))



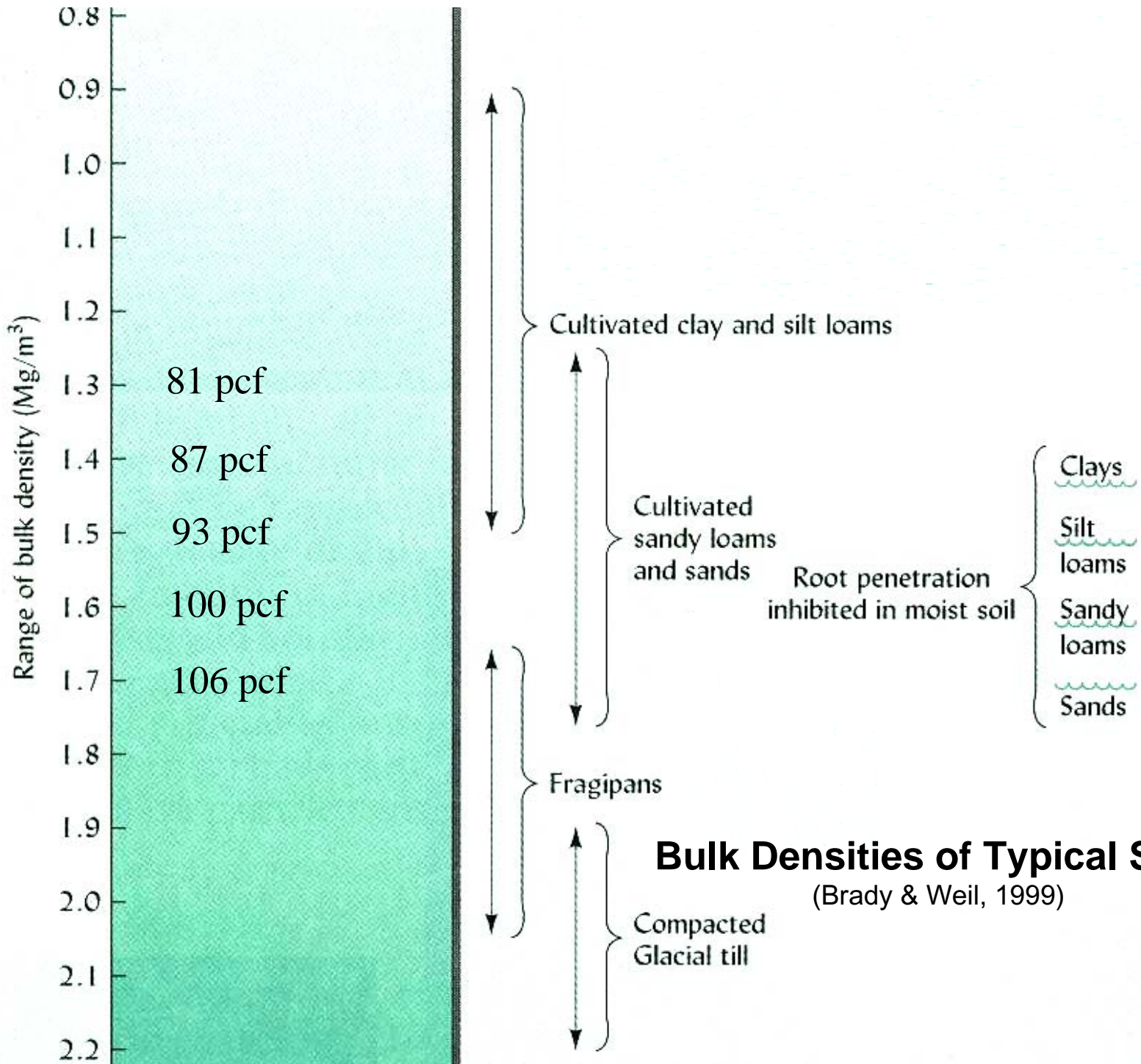
**Fort Carson Evapotranspiration  
Cap Construction Using 1-foot lifts**





**Table 5 -FORT CARSON-LANDFILL 5  
POST-CONSTRUCTION SOIL ANALYSIS RESULTS**

Monitoring Location <sup>1</sup>	Depth m (in.)	USDA Soil Texture <sup>2</sup>	Bulk Density <sup>3</sup> Cylinder	Hydraulic Conductivity (cm s <sup>-1</sup> ) <sup>4</sup>
CL1	0.30 (12)	Clay	1.35 (84)	2.7x10 <sup>-4</sup>
	0.61 (24)	--	1.06 (66)	--
	0.91(36)	Clay	1.22 (76)	6.4x10 <sup>-4</sup>
	1.2 (48)	--	1.16 (72)	--
CL2	0.30 (12)	Clay	1.65 (103)	4.6x10 <sup>-5</sup>
	0.61 (24)	--	1.46 (91)	--
	0.91(36)	Clay	1.40 (87)	1.0x10 <sup>-3</sup>
	1.2 (48)	--	1.47 (92)	--
CL3	0.30 (12)	Clay	1.63 (101)	6.0x10 <sup>-3</sup>
	0.61 (24)	--	1.58 (98)	--
	0.91(36)	Clay	1.50 (93)	3.6x10 <sup>-4</sup>
	1.2 (48)	--	1.45 (90)	--
PS1	0.30 (12)	Clay Loam	--	--
	0.61 (24)	Clay Loam	1.53 (95)	--
	0.91(36)	Clay Loam	--	--
	1.2 (48)	Clay Loam	1.68 (105)	--
PS2	0.30 (12)	--	--	--
	0.61 (24)	Clay Loam	1.49 (93)	1.7x10 <sup>-4</sup>
	0.91(36)	--	--	--
	1.2 (48)	--	1.47 (92)	--
PS4	0.30 (12)	Clay Loam	1.42 (88)	--
	0.61 (24)	Clay Loam	1.43 (89)	--
	0.91(36)	Clay Loam	--	--
	1.2 (48)	Clay Loam	--	--
PS5	0.30 (12)	Clay	1.29 (80)	2.4x10 <sup>-4</sup>
	0.61 (24)	--	--	--
	0.91(36)	Clay Loam	1.49 (93)	2.4x10 <sup>-3</sup>
	1.2 (48)	--	--	--



## Bulk Densities of Typical Soils

(Brady & Weil, 1999)

## ***Fort Carson Landfill Erosion Control***

- **Erosion Control Reinforced Mat**  
side slopes (4:1)  
down slope channels
- **Riprap**





