Field Analysis of Soils and Sediments

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Why Are We Here?

In geotechnical engineering, more than in any other field of civil engineering, success depends on practical experience … Since personal experience is necessarily somewhat limited, the engineer is compelled to rely at least to some extent on the [written] records of the experiences of others. If these records contain adequate descriptions of the soil conditions, they constitute a storehouse of valuable information. Otherwise, they may be misleading.

- Karl Terzaghi

Characteristics Used to Describe Soils

Important Characteristics

- Contacts
- Structure
- Cementation
- Color
- Odor
- Moisture content
- Consistency
- Plasticity
- Grain size
- Grain sorting
- Grain angularity
- Grain shape
- Grain composition
- Grain hardness

Estimating Particle Size

Term	*Size Range*	*Example*
Cobble	3" to 12"	Grapefruit
Coarse gravel	¾" to 3"	Plums
Fine gravel	#4 sieve to ¾"	Grapes
Coarse sand	#10 to #4 sieve	Peppercorns
Medium sand	#40 to #10 sieve	Sugar or salt
Fine sand	#200 to #40 sieve	Ground pepper
Fines	< #200 sieve	Flour

Cobble (grapefruit)

Coarse gravel

Fine gravel

Coarse sand

Medium sand

Fine sand

Fines

Well graded sand

Gap-graded sand

Types of Cementation

Type	Indicator
Calcium Carbonate	Reaction with dilute HCl
Iron Oxides	Red or orange color
Clays	Hard when dry, slakes with wet
Silica	Hard, dense, no reaction to liquids
Other cements	Identification requires lab work

Silica and iron cement

Cementation with $CaCO_3$

Description	Reaction to Dilute HCl
None	No reaction
Weak	Weak to moderate fizzing, bubbles form slowly
Strong	Violent fizzing, bubbles form immediately

Fizzzzzz test

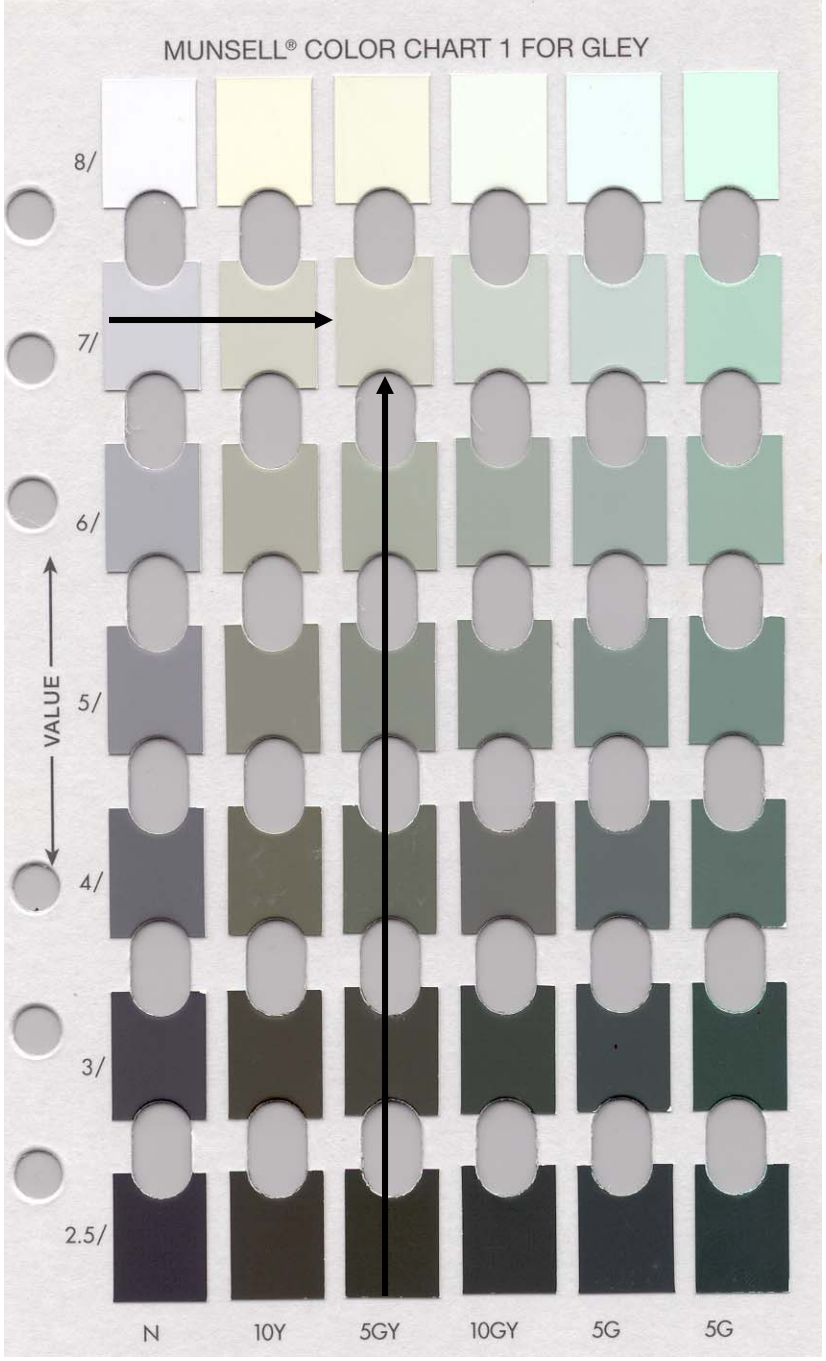
Degree of Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or slight finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure
	None of the above

Color

Hue	Gley	Red	Yellow-Red	Yellow
Value (8 – 2.5)	Greenish or bluish gray to black	Pink to dark red	Pink or yellow to dark red	Pale yellow to olive or olive brown
Chroma (1 – 8)	Greenish to bluish	Reddish gray or white to red	White or gray to dark brown	Gray to olive yellow or brown

Colors are assigned using Munsell Color Chart



Munsell Color Charts

Gley 7/5GY

Odor

Description	Example
(none)	No odor noticeable
Earthy	Moldy or musty odor
Chemical	Includes oily odor
Organic	Odor from manure or decay

Moisture content

Description	Criteria
Dry	No moisture present, dusty, dry to the touch
Moist	Some moisture present, damp, no visible water
Very Moist	Moisture present, but not saturated
Wet	Saturated, visible free water

Consistency

Description	Example
Very Soft	Thumb will easily penetrate soil past first knuckle
Soft	Thumb will penetrate soil up to the first knuckle
Firm	Thumb will indent soil about ¼”
Stiff	Thumb will not indent soil but thumbnail will
Hard	Thumbnail barely indents soil

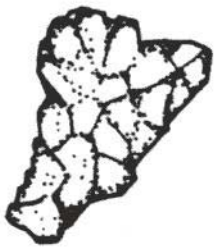
Plasticity

Term	Field Test
Non-Plastic	Can’t be rolled to 1/8” thread
Slightly Plastic	Can be rolled to 1/8” thread with care
Medium Plastic	Easily rolled to 1/8” thread
Highly Plastic	Will roll into a thinner thread

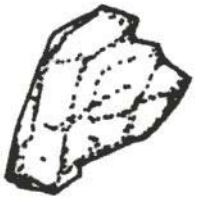
Grain angularity

Description	Criteria
Angular	Sharp edges and relatively plane sides with unpolished surfaces
Subangular	Rounded edges and relatively plane sides with unpolished surfaces
Subrounded	Well rounded corners and edges but an irregular or non-spherical shape
Rounded	Smoothly curved sides with no visible corners or edges

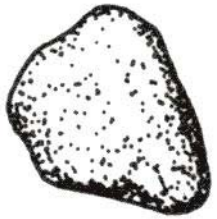
Grain angularity



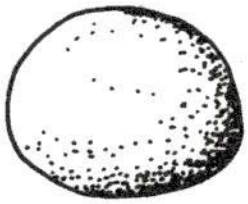
Very Angular



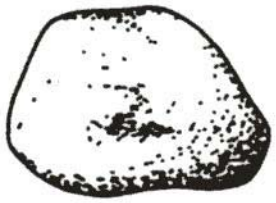
Angular



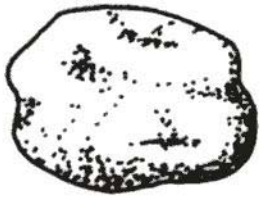
Subangular



Well-Rounded



Rounded



Subrounded

Grain shape

Description	Criteria
Flat	Width > 3 × Thickness
Elongated	Length > 3 × Width
Flat & Elongated	Length > 3 × Width > 3 × Thickness
	none of the above

Grain hardness

- Describe what happens when coarse sand and larger particles are hit by a hammer
  - “Gravel particles fracture with hammer blow”
  - “Coarse sand particles crumble with hammer blow”
  - “Coarse gravel particles crack with hammer blow”
- If the particles do not crack, fracture, or crumble under a hammer blow, describe them as “hard”

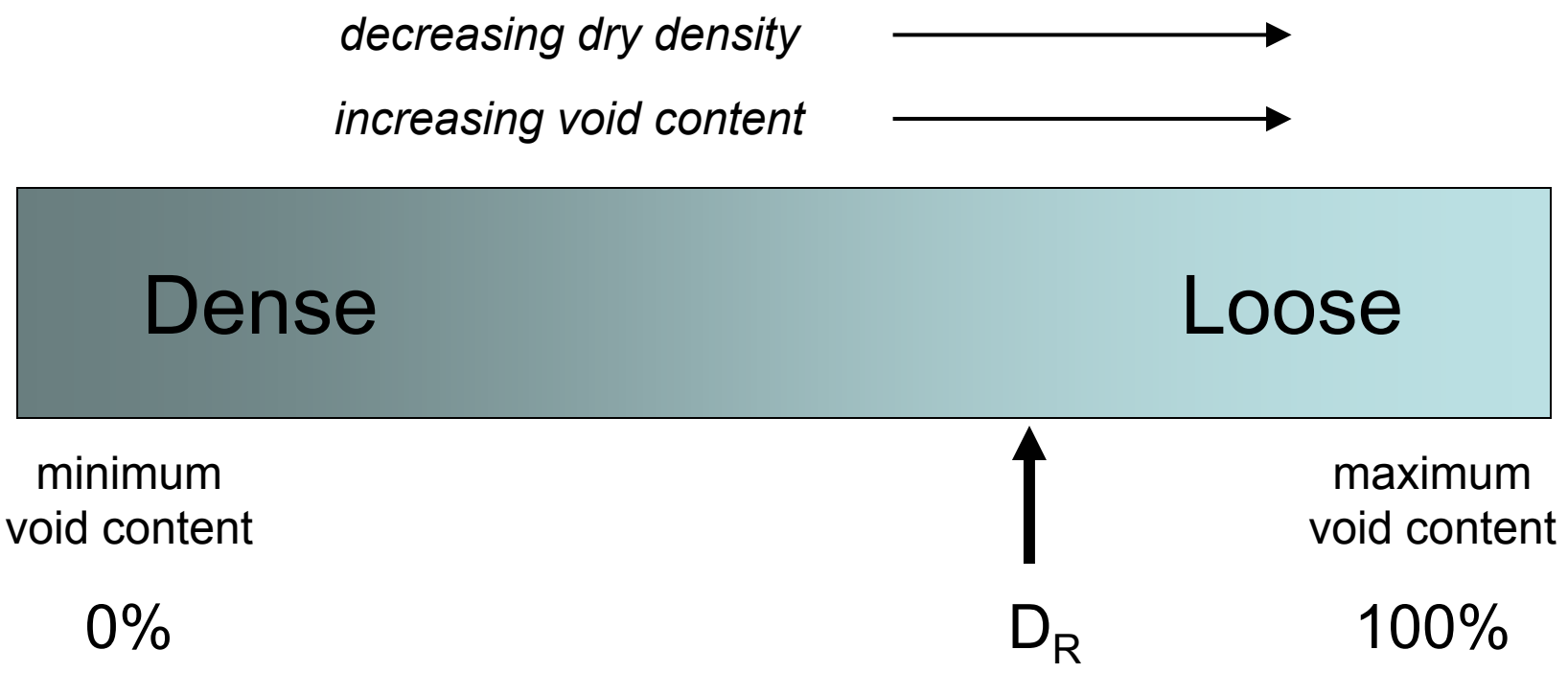
The Unified Soil Classification System

USCS Basics

- The behavior of coarse-grained soil is largely determined by two properties:
  - grain size
  - grain sorting

  and one state variable:
  - relative density

Relative Density



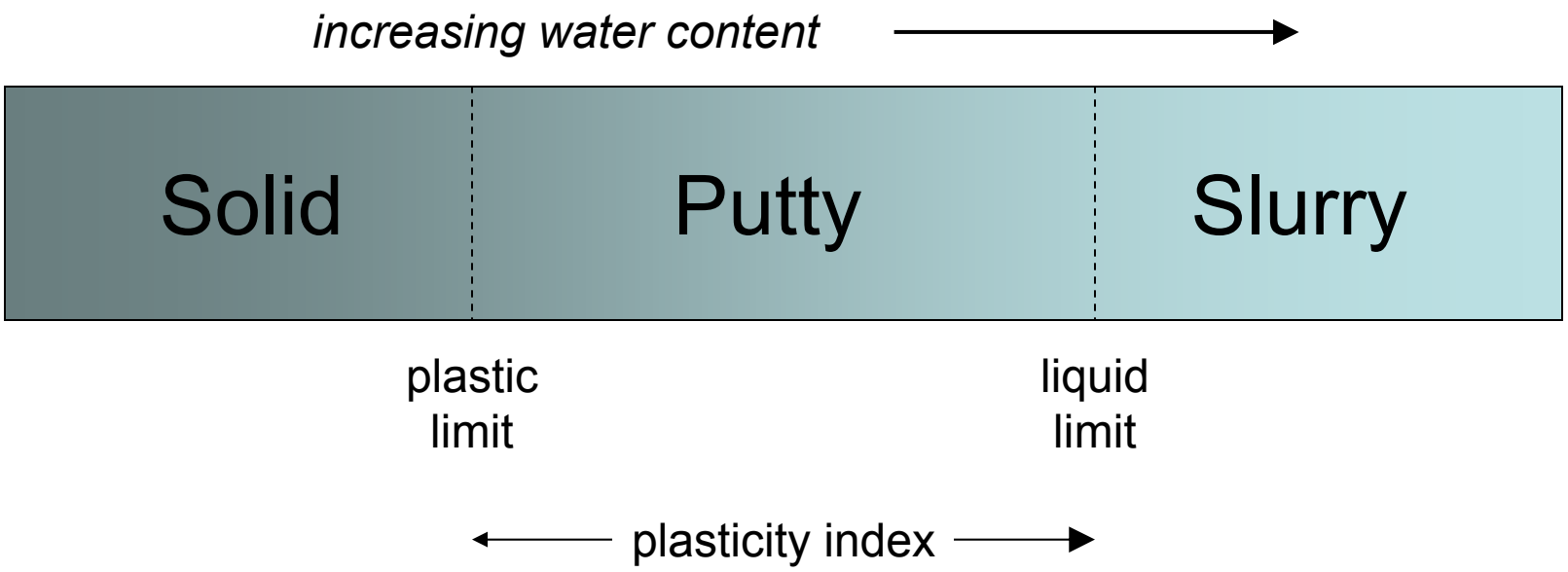
$$\text{void content} = \frac{\text{volume of void spaces}}{\text{volume of soil particles}}$$

USCS Basics

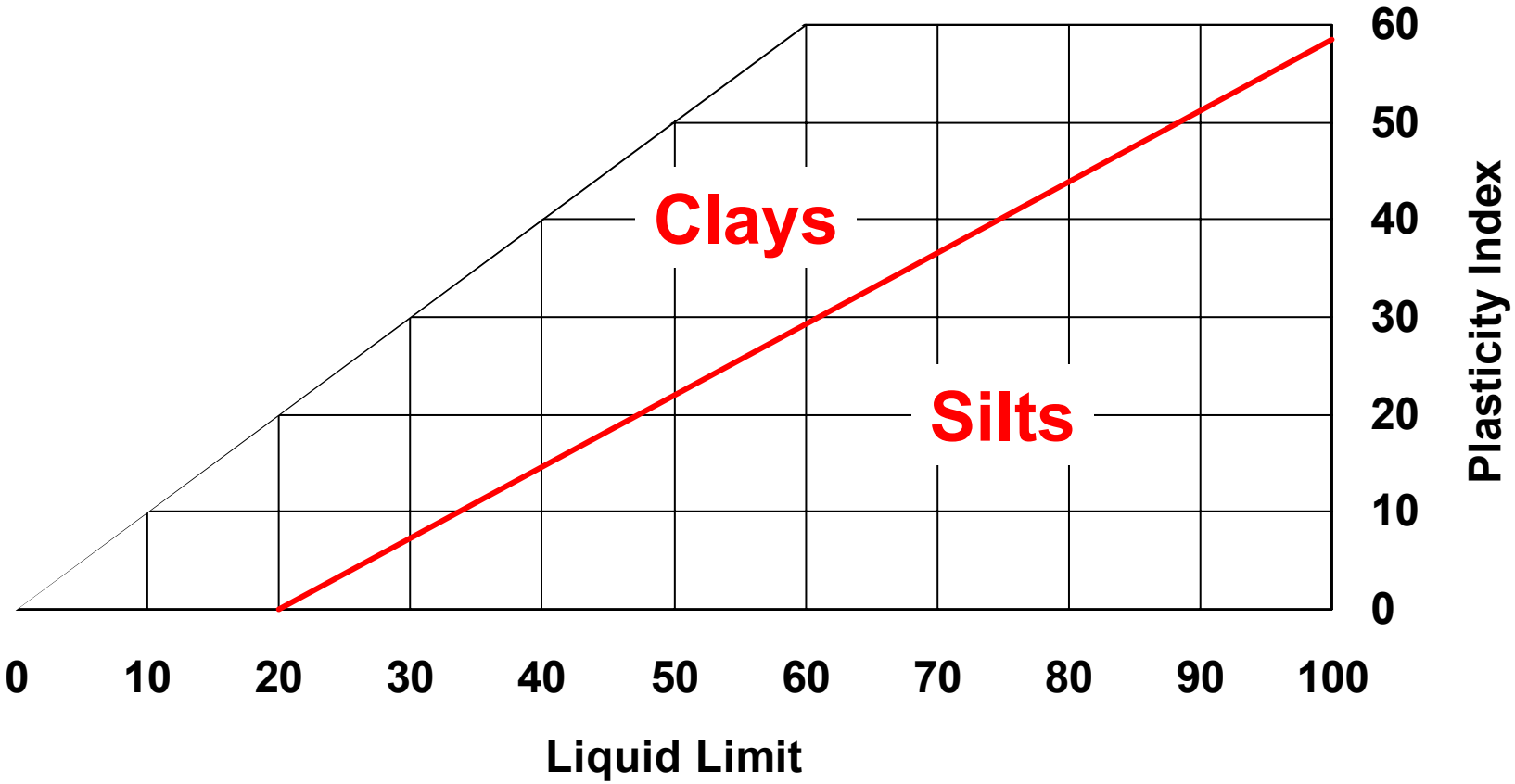
- The behavior of fine-grained soil is largely determined by two properties:
  - liquid limit
  - plastic limit

  and one state variable:
  - liquidity index

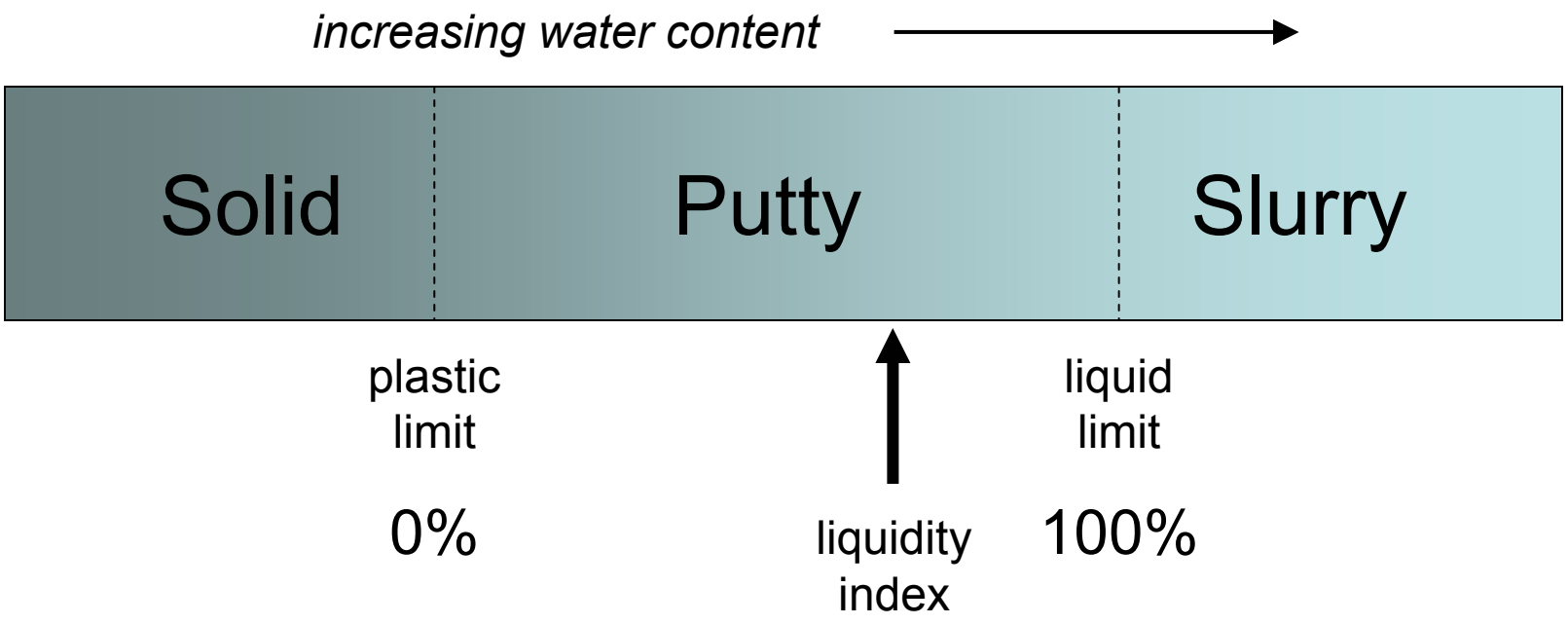
Atterberg Limits



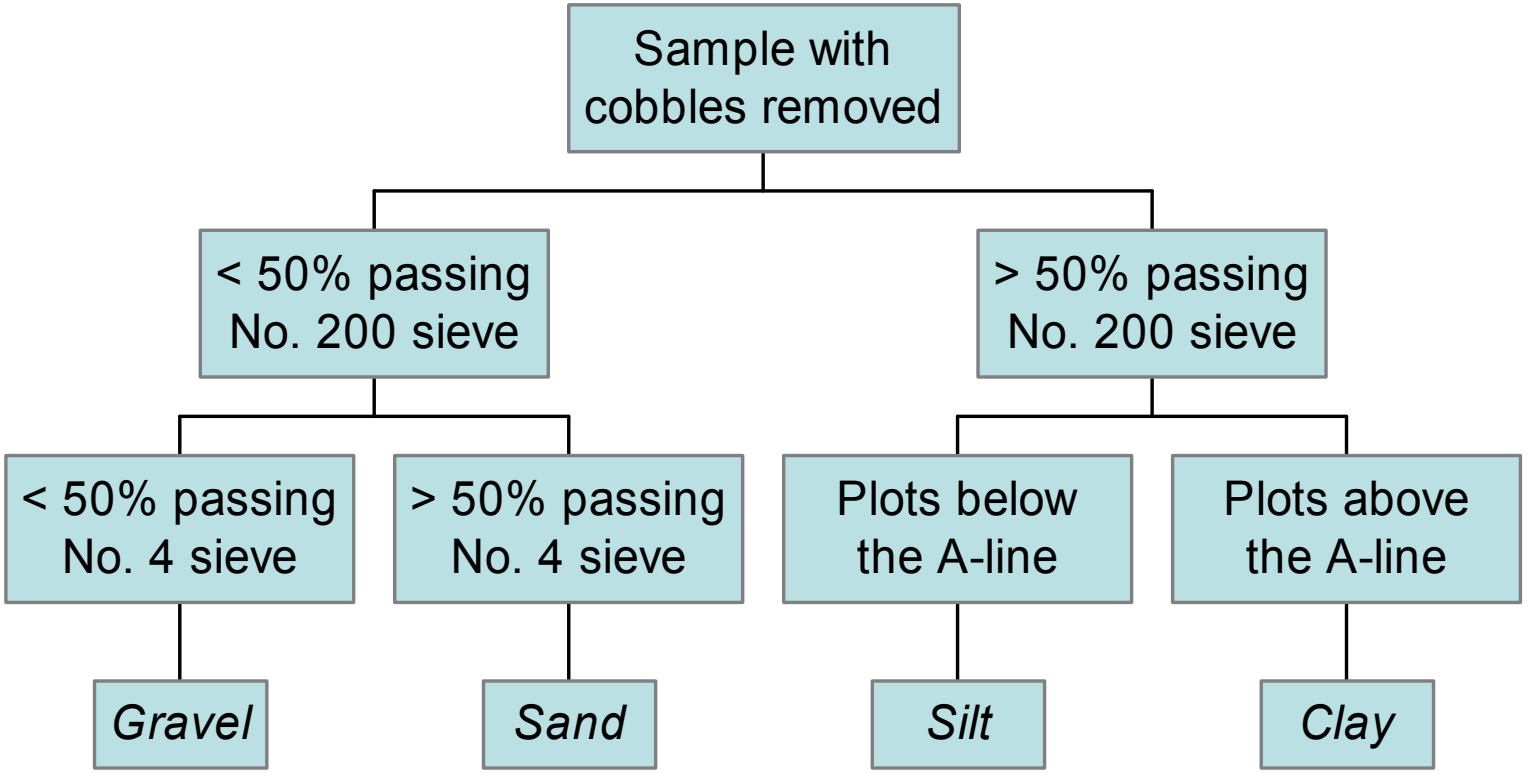
The A-line


Clays
Silts
0
10
20
30
40
50
60
70
80
90
100
Liquid Limit
0
10
20
30
40
50
60
Plasticity Index

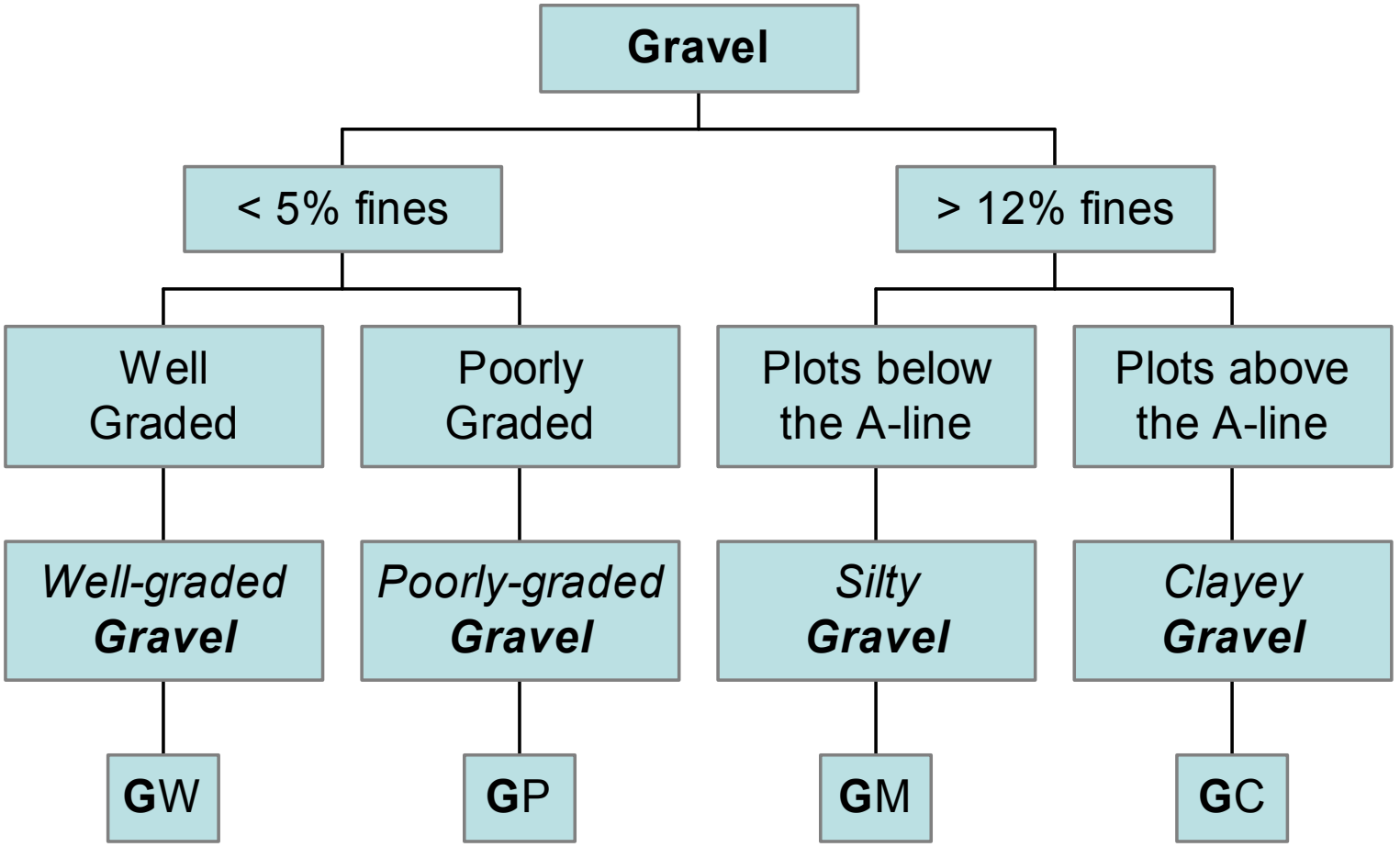
Liquidity Index



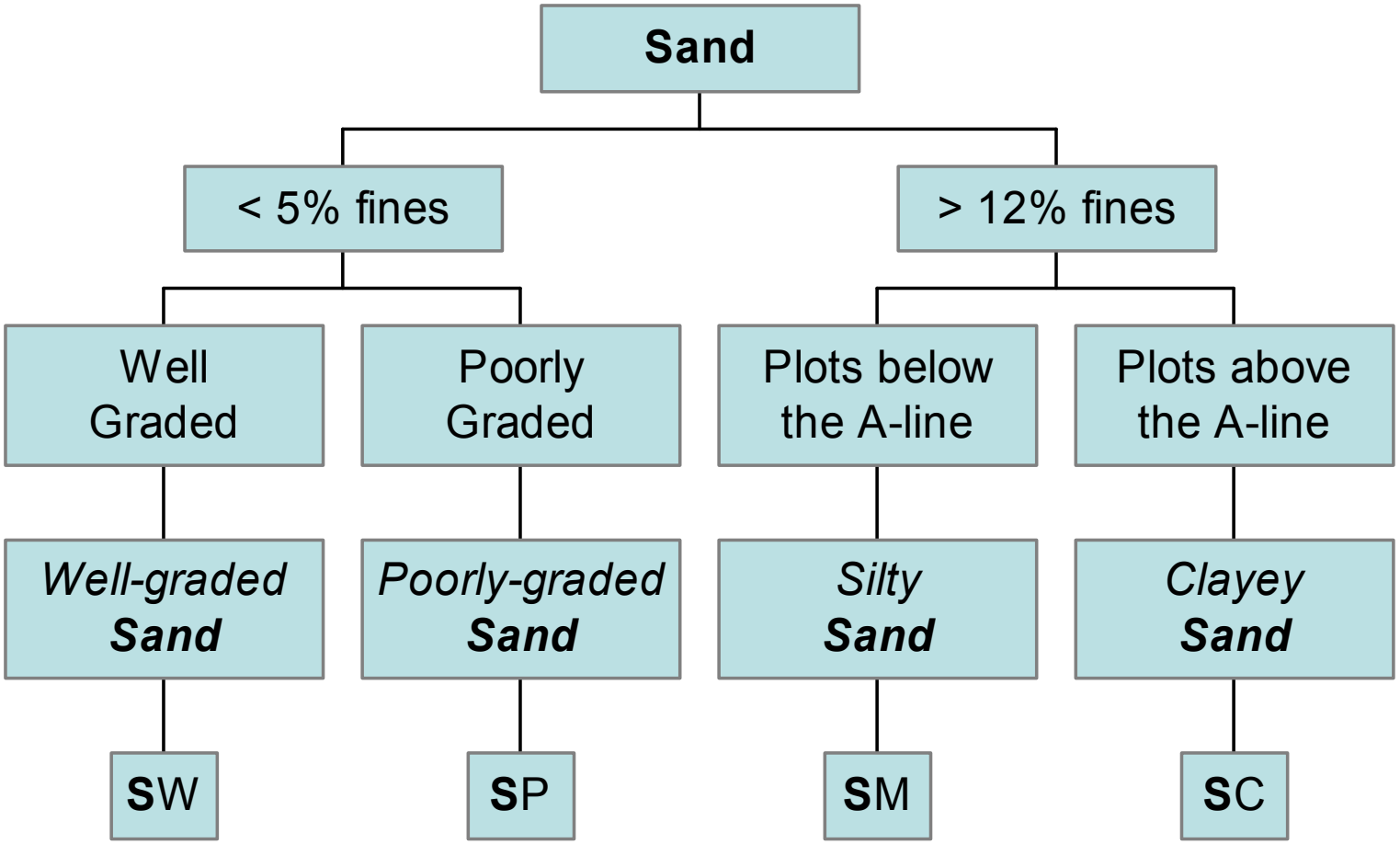
USCS Decision Tree



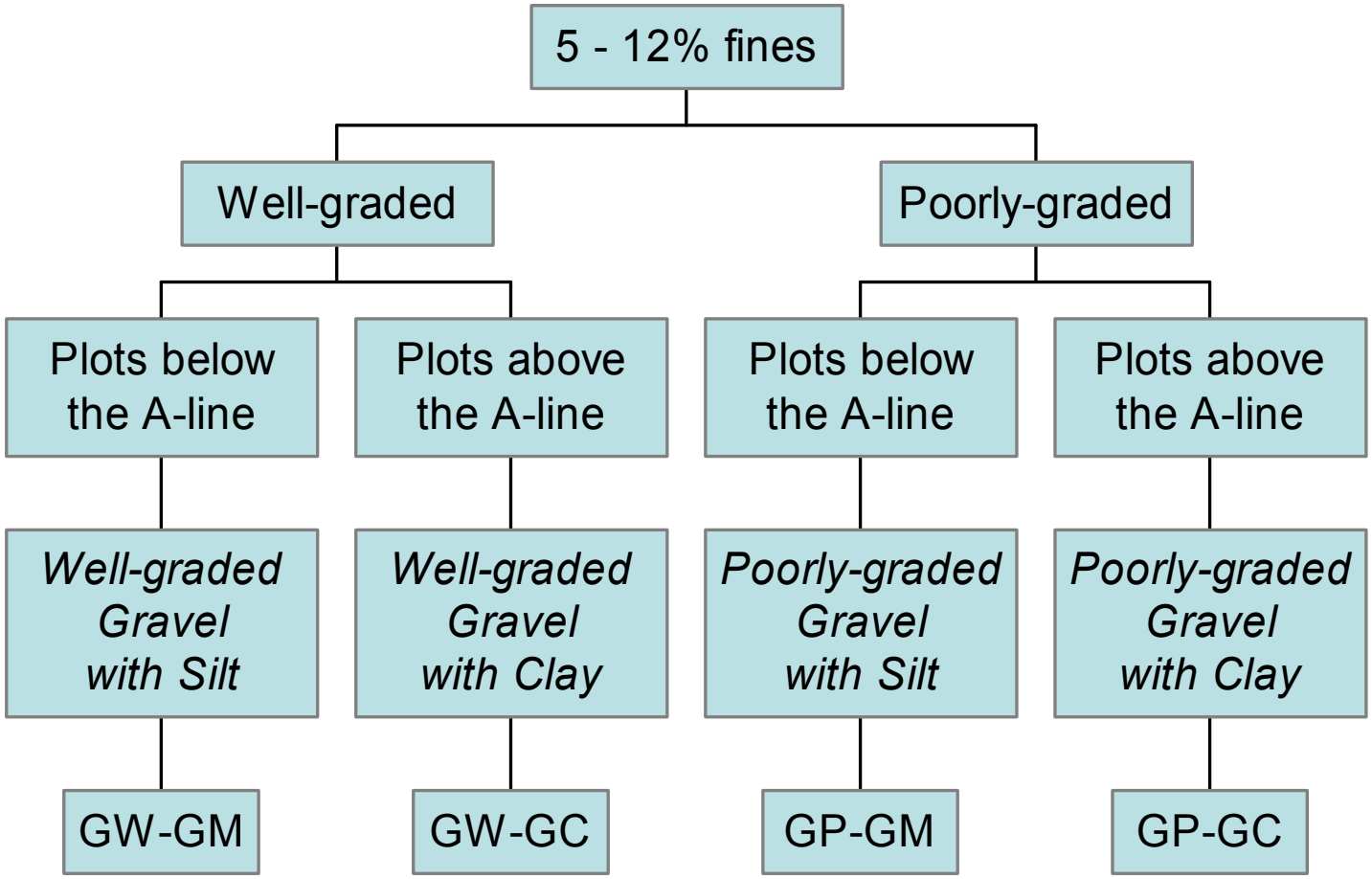
USCS (Gravel)


Gravel
< 5% fines
> 12% fines
Well Graded
Poorly Graded
Plots below the A-line
Plots above the A-line
Well-graded ***Gravel***
Poorly-graded ***Gravel***
Silty ***Gravel***
Clayey ***Gravel***
GW
GP
GM
GC

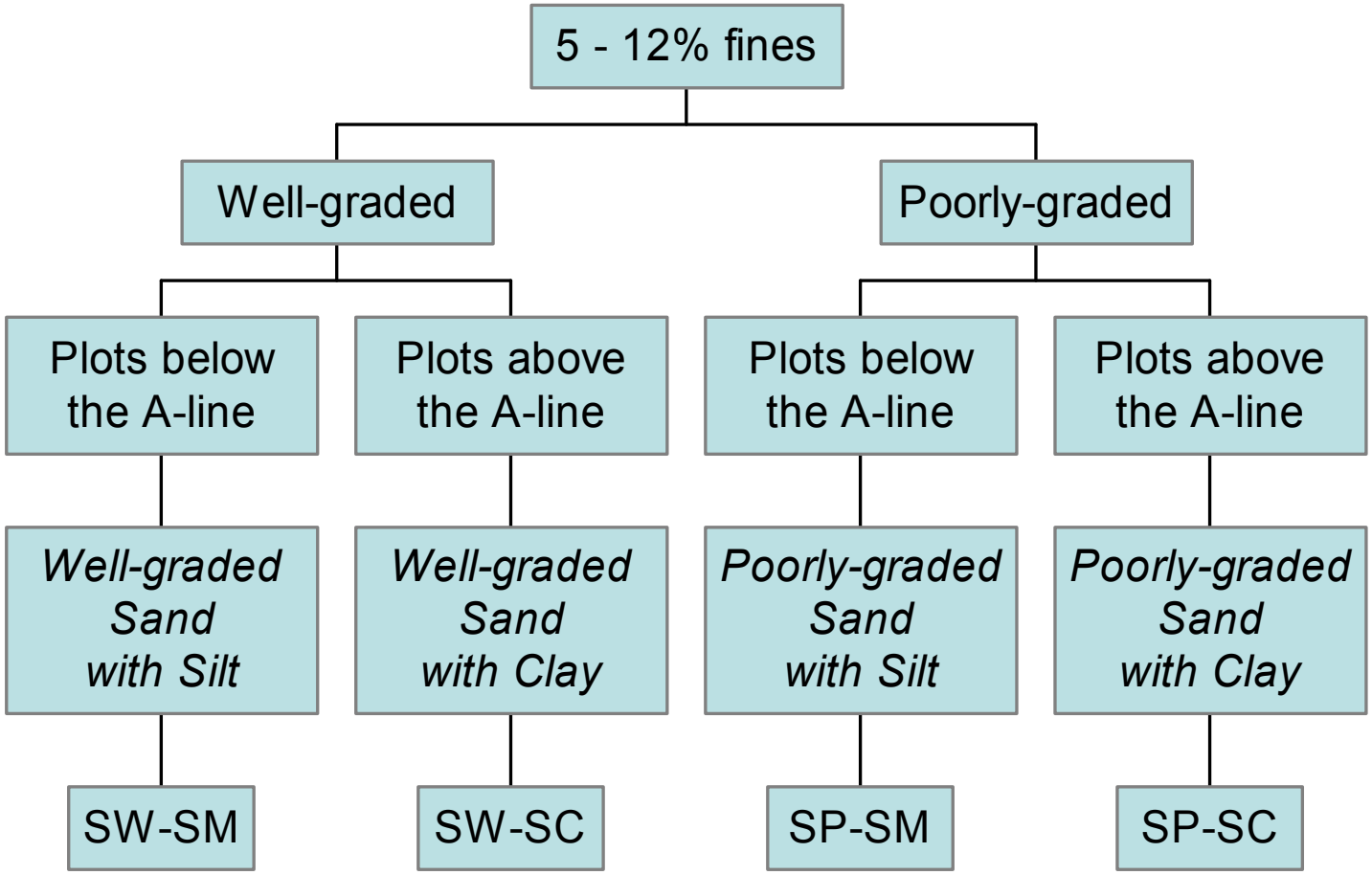
USCS (Sand)


Sand
< 5% fines
> 12% fines
Well Graded
Poorly Graded
Plots below the A-line
Plots above the A-line
Well-graded ***Sand***
Poorly-graded ***Sand***
Silty ***Sand***
Clayey ***Sand***
SW
SP
SM
SC

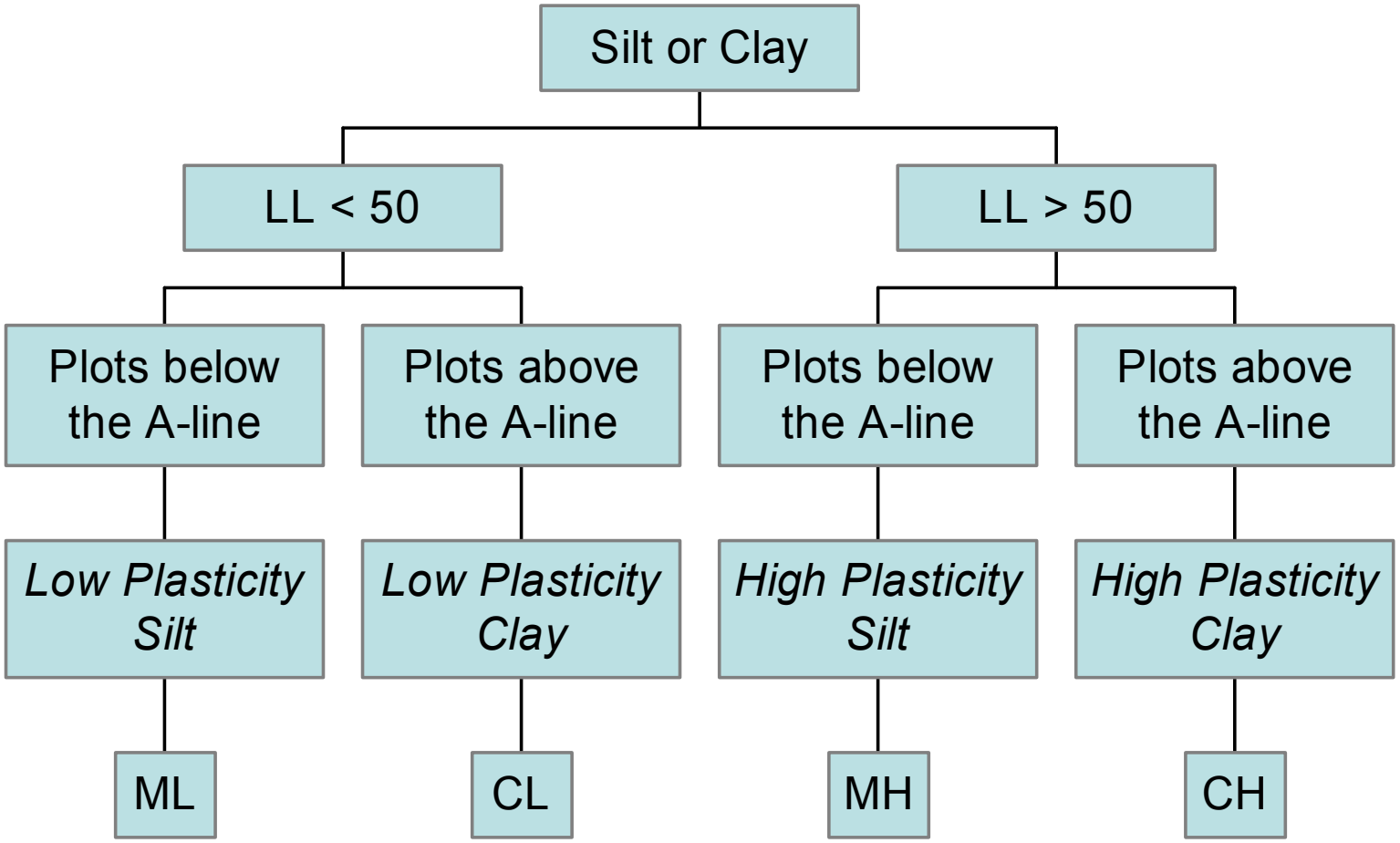
USCS (Gravel with Fines)



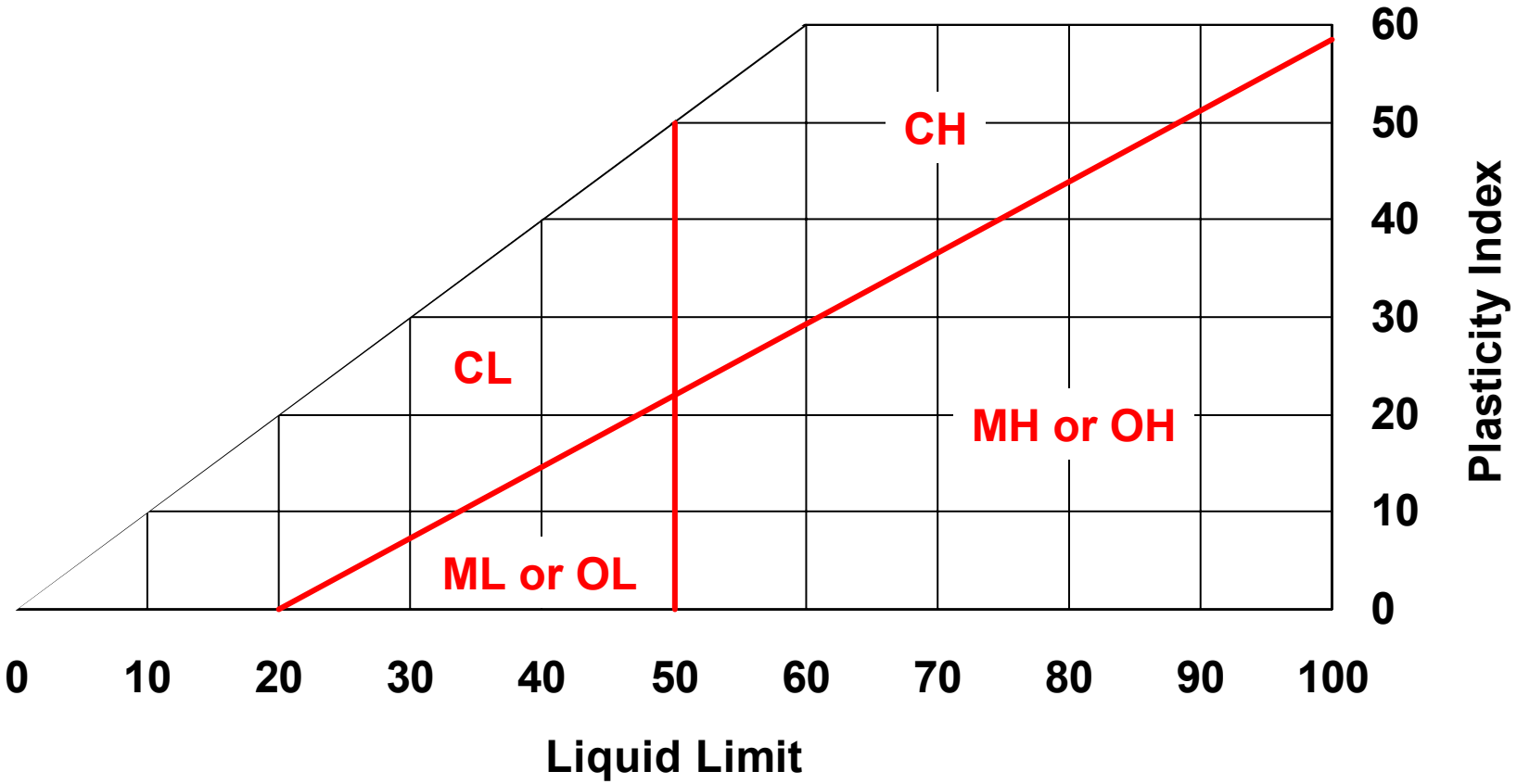
USCS (Sand with Fines)



USCS (Silt and Clay)



Silt and Clay



Soil Property Estimates

USCS Symbol	Permeability when compacted	Shear Strength when compacted and saturated	Compressibility when compacted and saturated	Workability as a construction material
GW	pervious	excellent	negligible	excellent
GP	very pervious	good	negligible	good
GM	semi-pervious	good	negligible	good
GC	impervious	good to fair	very low	good
SW	pervious	excellent	negligible	excellent
SP	pervious	good	very low	fair
SM	semi-pervious	good	low	fair
SC	impervious	good to fair	low	good

Soil Property Estimates

USCS Symbol	Permeability when compacted	Shear Strength when compacted and saturated	Compressibility when compacted and saturated	Workability as a construction material
ML	semi-pervious	fair	medium	fair
CL	impervious	fair	medium	good to fair
OL	semi-pervious	poor	medium	fair
MH	semi-pervious	fair to good	high	poor
CH	impervious	poor	high	poor
OH	impervious	poor	high	poor
PT	—	—	—	—

Source: U.S. Department of the Interior Bureau of Reclamation *Soil Manual* (1963)

Classifying Soils in the Field

Field Kit

Pocket knife or small spatula

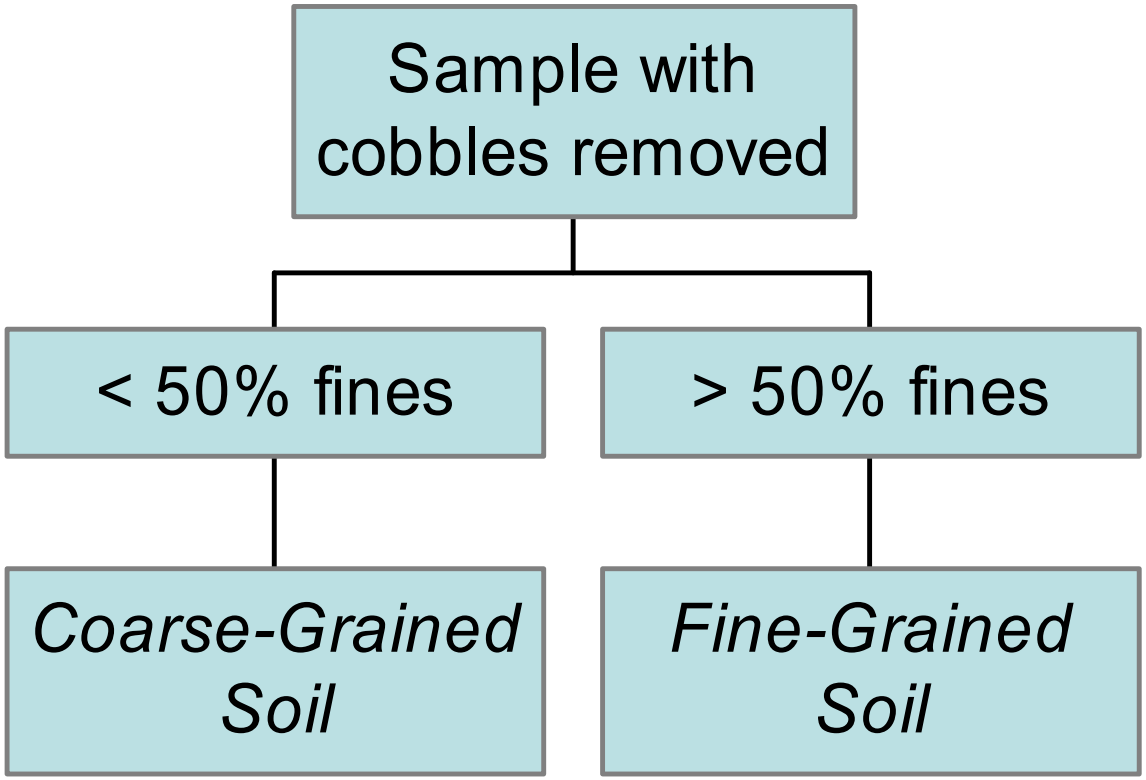
Jar with tight-fitting lid

Small hand lens

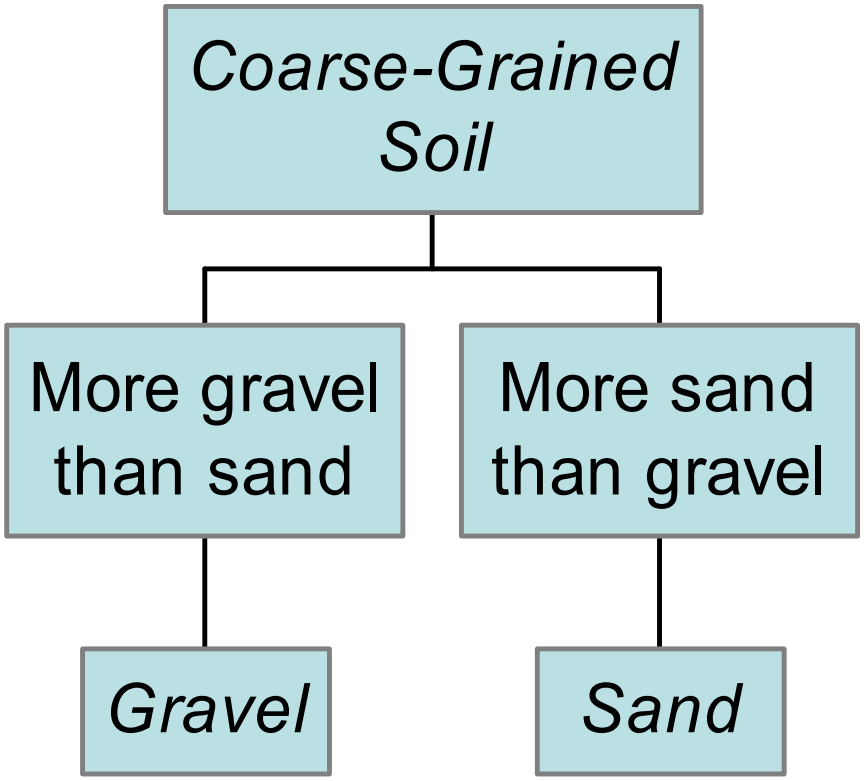
Water

Small bottle containing dilute HCl
(1 part HCl added to 3 parts distilled water)

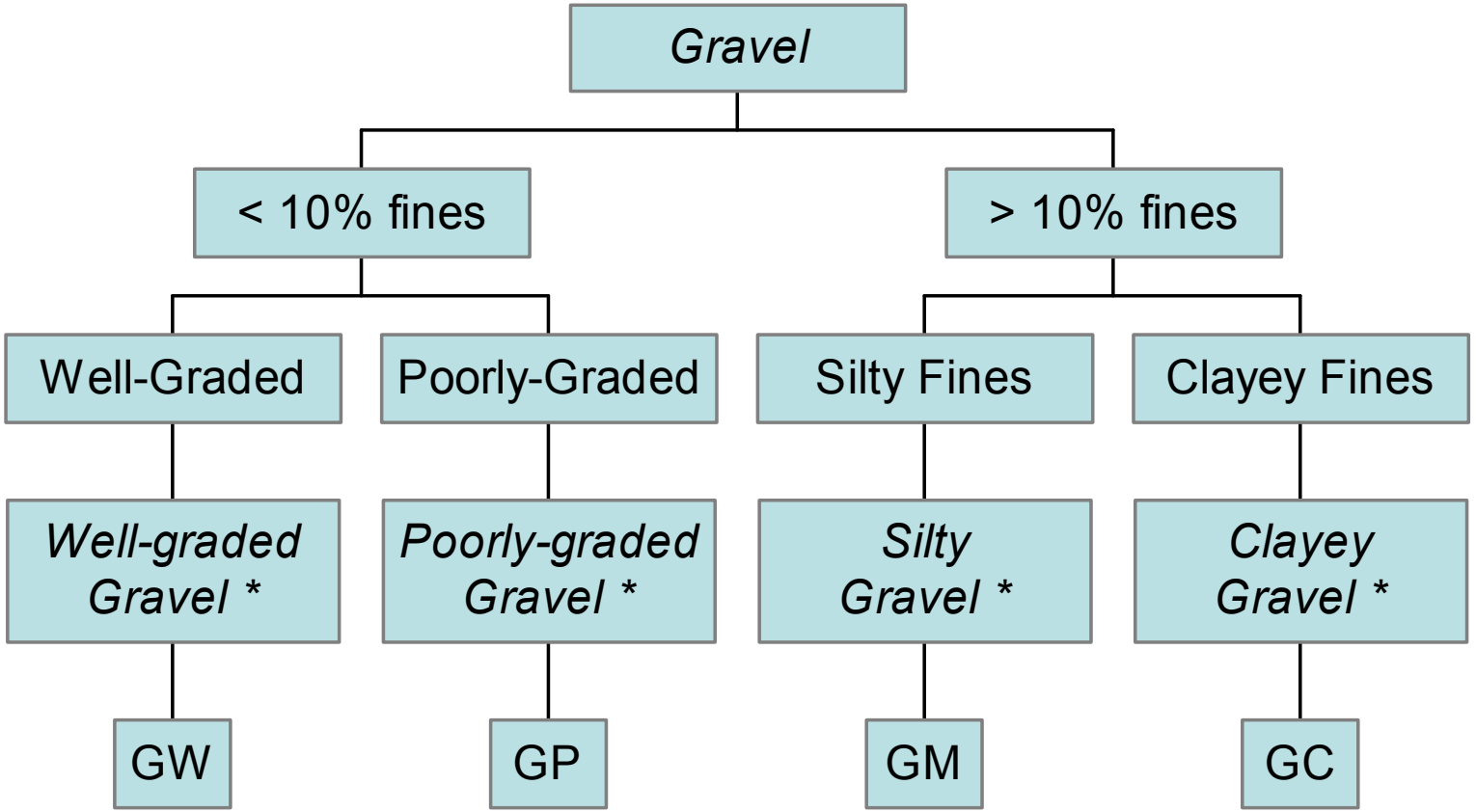
USCS Field Method



USCS Field Method (Coarse)

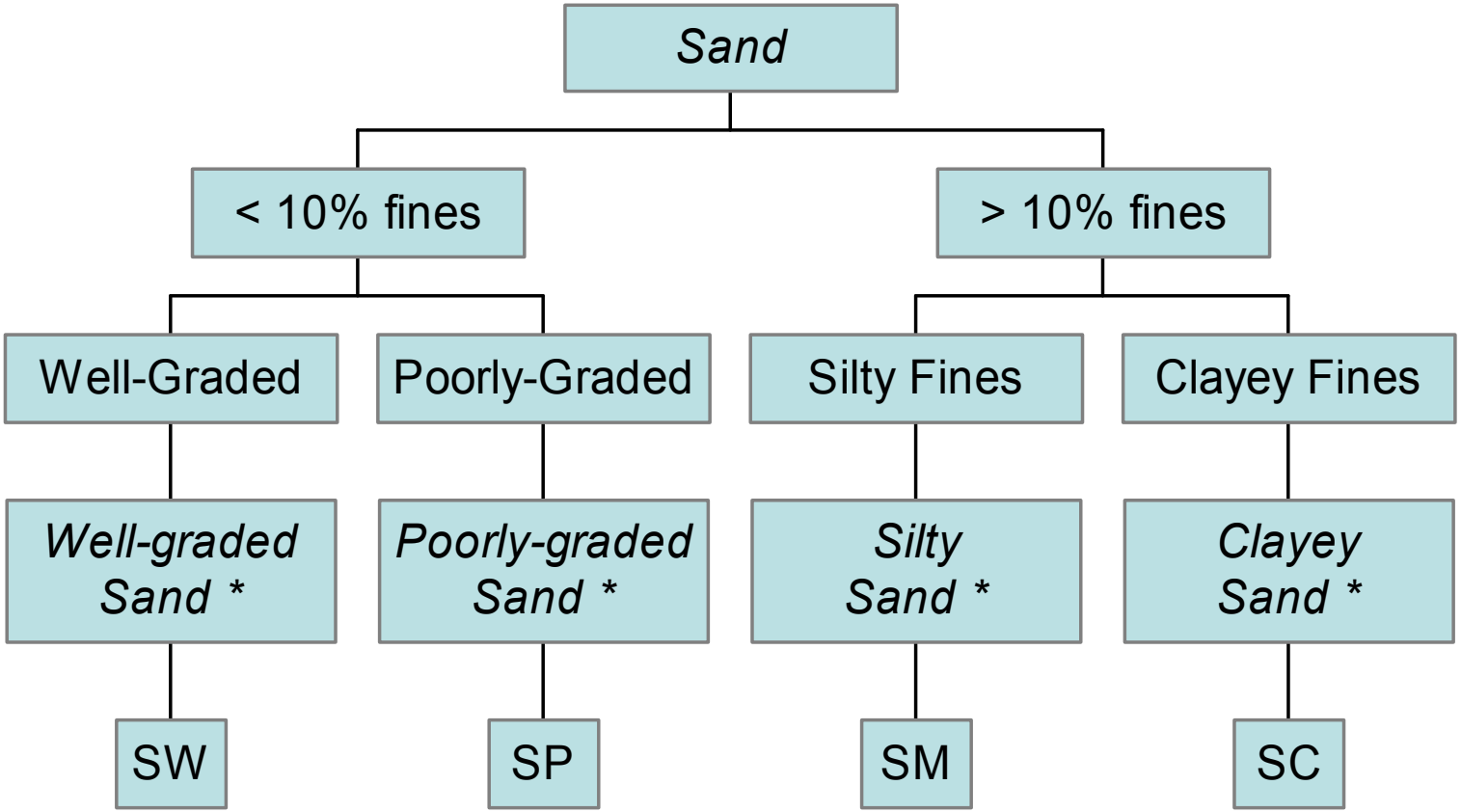


USCS Field Method (Gravel)



*If there is more than 15% sand present, append the phrase “with sand”

USCS Field Method (Sand)



*If there is more than 15% gravel present, append the phrase “with gravel”

Estimating Particle Size

Term	*Size Range*	*Example*
Cobble	3" to 12"	Grapefruit
Coarse gravel	¾" to 3"	Plums
Fine gravel	#4 sieve to ¾"	Grapes
Coarse sand	#10 to #4 sieve	Peppercorns
Medium sand	#40 to #10 sieve	Sugar or salt
Fine sand	#200 to #40 sieve	Ground pepper
Fines	< #200 sieve	Flour

Estimating Particle Size

- Rub a small quantity of the soil between the palms of your hands
- Try to shake the material off by rubbing and patting your hands together
- Sand grains will fall off, leaving your palms clean
- Silt and clay will stick in the fine creases, leaving a “dirty” appearance

Distinguishing Silts and Clays

Symbol	*Dry Strength*	*Dilatancy*	*Toughness Plasticity*
ML	none to low	slow to rapid	low or none
CL	medium to high	none to slow	medium
MH	low to medium	none to slow	low to medium
CH	high to very high	none	high

Dry Strength

Description	Example
None	Specimen crumbles just by handling
Low	Specimen crumbles with some finger pressure
Medium	Specimen crumbles with considerable finger pressure
High	Specimen cannot be broken with finger pressure
Very High	Specimen cannot be broken between the thumb and a hard surface

Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface during shaking and disappears slowly upon squeezing
Rapid	Water appears quickly on the surface during shaking and disappears quickly upon squeezing

Roll sample into ½-inch ball

Flatten into a patty

Tap hand and look for water rising to the surface

Plasticity

Term	Field Test
Non-Plastic	Can’t be rolled to 1/8” thread at any moisture content
Slightly Plastic	Can barely be rolled to 1/8” thread with great care
Medium Plastic	Easily rolled to 1/8” thread but breaks apart with continued handling
Highly Plastic	Will roll into a thread thinner than 1/8” and can be remolded and rolled again and again

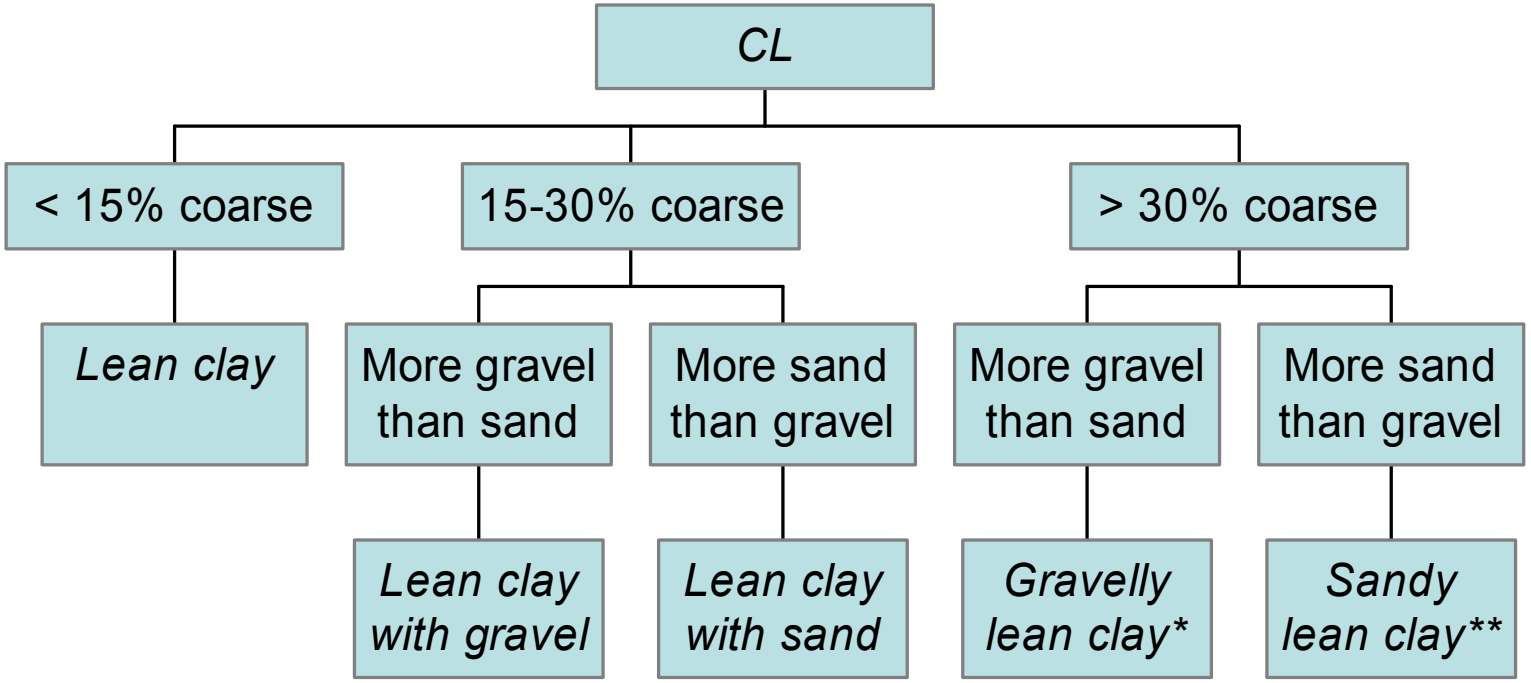
Roll sample into ½-inch ball

Try to roll it into an 1/8" thread

Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit; thread is weak and soft
Medium	Medium pressure is required to roll the thread near the plastic limit; thread is moderately stiff
High	Considerable pressure is required to roll the thread near the plastic limit; thread is very stiff

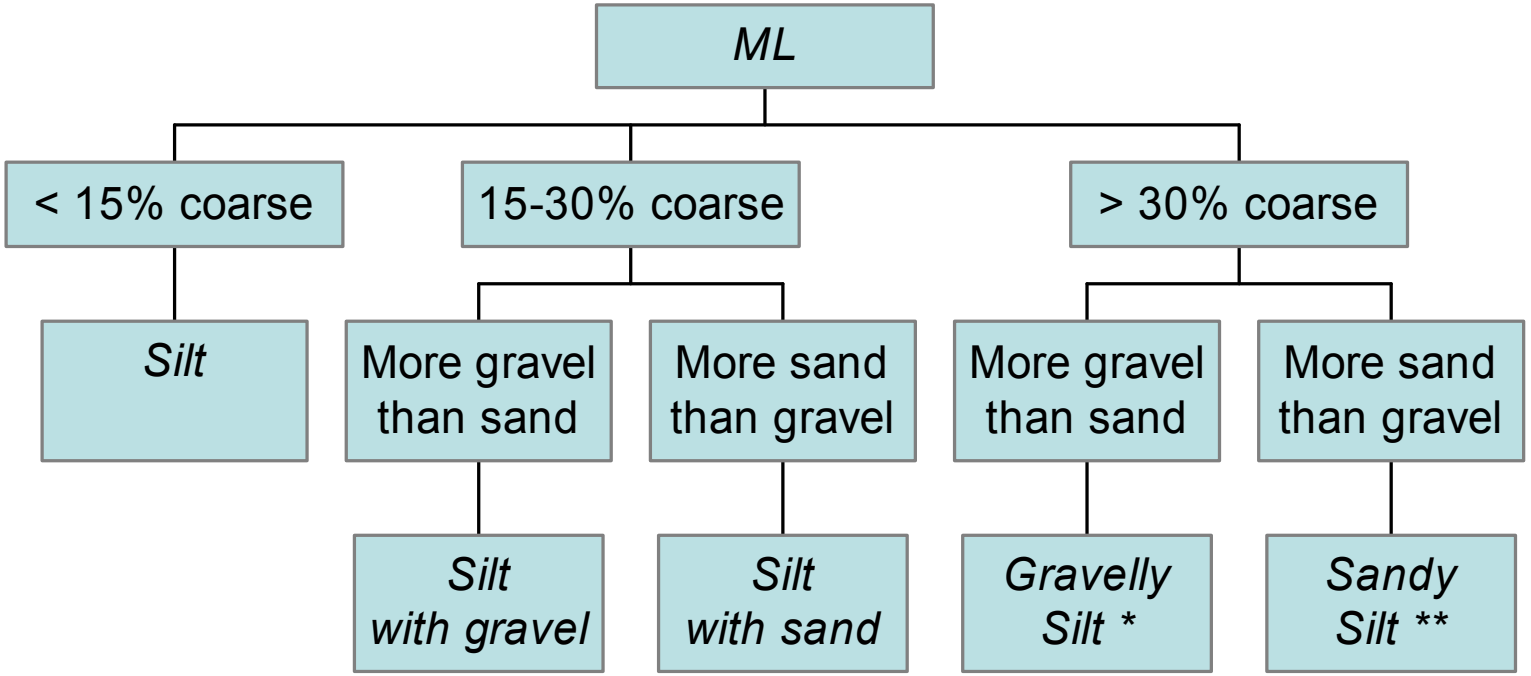
USCS Field Method (CL)



* If there is more than 15% sand present, append the phrase “with sand”

** If there is more than 15% gravel present, append the phrase “with gravel”

USCS Field Method (ML)



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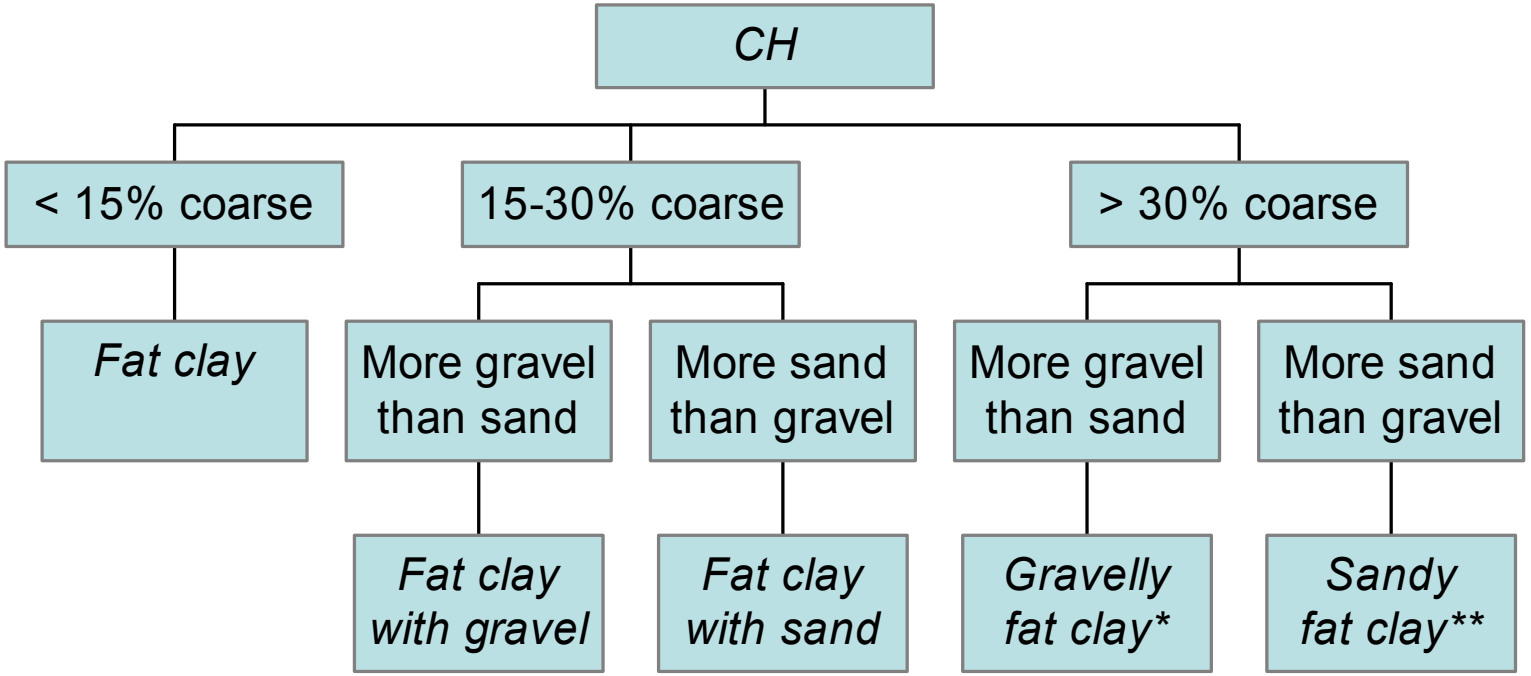
USCS Field Method (CH)



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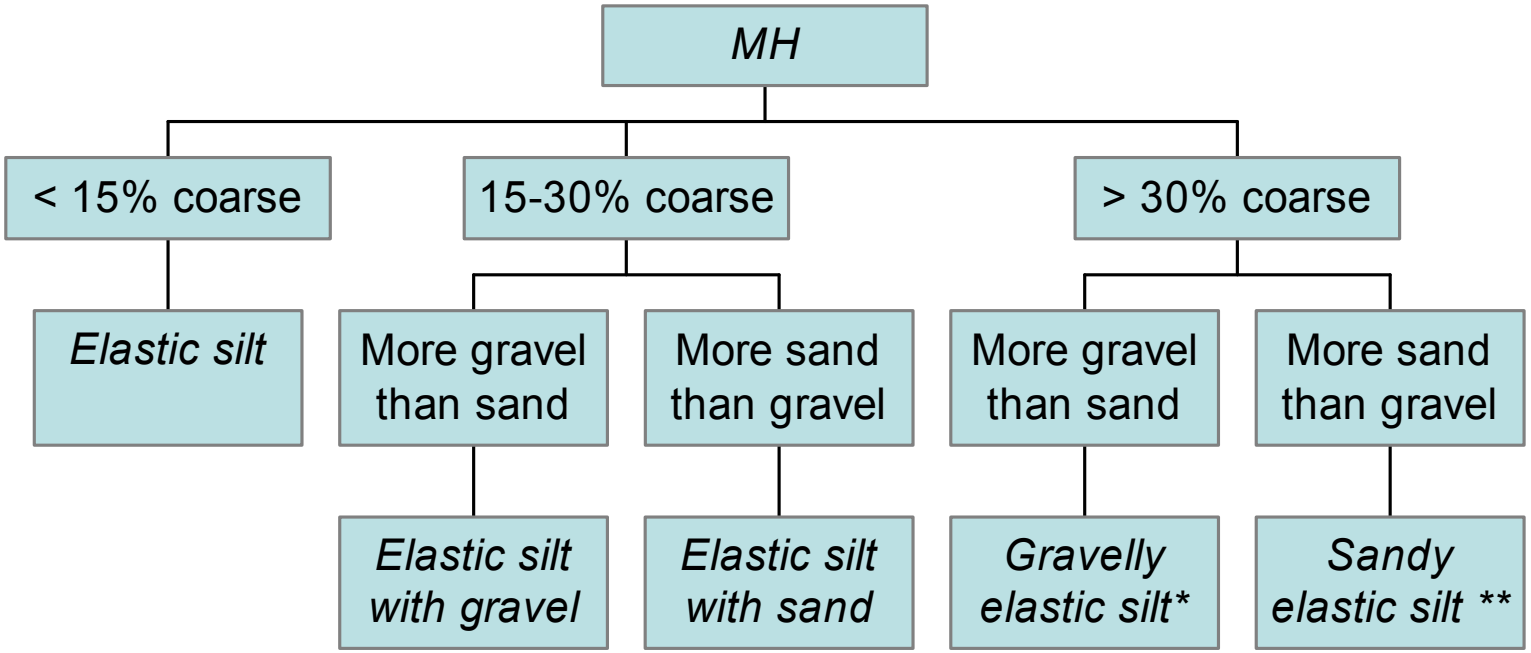
USCS Field Method (MH)



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** If there is more than 15% gravel present, append the phrase “with gravel”

Estimating Size Fractions

Jar method

Wash test

Jar Method

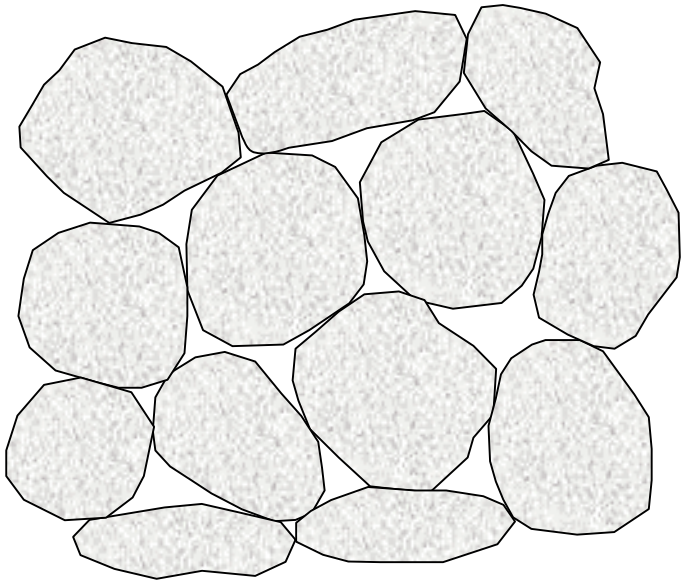
- Place soil in jar or test tube and note the height of the soil column
- Add water and shake vigorously to place the soil particles in suspension
- Let the mixture settle
- Sand particles will settle in 20-30 seconds
- Note the height of the settled soil column to estimate the percentage of sand

Jar with graduations is best

Dry sediment volume

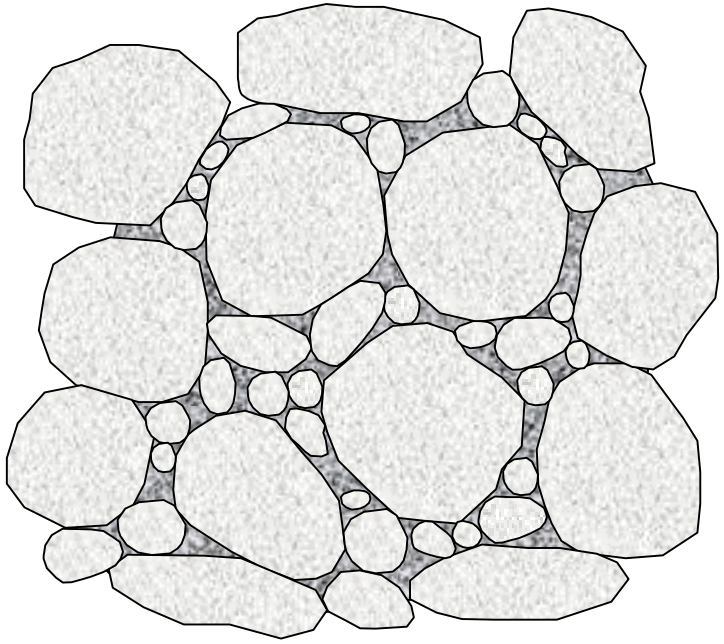
Settled sand volume

Void Content



The void content of well sorted soils and sediments may be as high as 35% to 40%

Void Content



The void content of poorly sorted soils and sediments may be as low as 25% to 30%

Wash Test

- Select and moisten enough sands and fines to form a 1" cube of soil
- Cut the cube in half, set one half aside and place the other half in a small dish
- Wash and decant the fines from the dish until the wash water is clear
- Compare the two samples to estimate the percentages of sand and fines

Wash Test

Unwashed Sample

Washed Sample

Sample Descriptions

Example 1

Well-Graded Gravel with Sand (GW) – About 75% fine to coarse, hard, subangular gravel, quartz and chert; about 25% fine to coarse, hard, subangular sand, quartz; trace of fines; maximum size, 75 mm; brown (7.5YR 5/3); dry; no reaction with HCl.

Example 2

Silty Sand with Gravel (SM) – About 60% fine sand; about 25% silty fines with low plasticity, low toughness, low dry strength, rapid dilatancy; about 15% fine, hard, subrounded gravel, some particles fracture with hammer blow, quartz and chert; maximum size: 25 mm; no HCl reaction.

In-Place Conditions – Firm, stratified, contains lenses of silt 25 to 50 mm thick, moist, brown to gray (10YR 5/3 to 10YR 5/1).

Example 3

Silty Sand with Organic Fines (SM) – About 75% fine to coarse, hard, subangular reddish-brown (2.5YR 5/4) sand, quartz with iron-oxide coatings; about 25% organic and silty dark brown (7.5YR 3/3) nonplastic fines with no dry strength and slow dilatancy; wet; maximum size: coarse sand; weak reaction with HCl.

Example 4

Poorly Graded Gravel with Sand (GP) – About 75% fine to coarse, hard, subrounded to subangular gravel, chert and limestone; about 15% fine, hard, subrounded to subangular sand; about 10% silty nonplastic fines; moist, brown (7.5 YR 5/3); no reaction with HCl; original field sample had about 5% (by volume) hard, subrounded cobbles, chert and limestone, with a maximum dimension of 6 in. (150 mm).

Example 5

Organic Soil (OL/OH) – About 100% fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown (10YR 3/3), organic odor; weak reaction with HCl.