Colorado has a very diverse terrain; diverse soils
53 Peaks > 14,000’
Highest: Mt. Elbert, 14,439’

2.5 miles higher than Minneapolis
Mountains average ~200” snow/yr.
Run-off is a source of water to 18 states

Snowpack Produces 14 - 16 Million Acre Feet/yr.
Flow from the 7 river basins
Varied Terrain
Eastern Plains

Lowest Elevation in Colorado = 3,315’
Great Sand Dunes National Park
Outwash areas; “Platey Structure”
Soils with a high rock content
Memorial Rock; 2019
Fractured Bedrock
Decomposed Granite
Sandstone
And yet, there are no “unbuildable” sites in Colorado due strictly to soils (as long as you meet local minimum parcel size requirements and setbacks)
Onsite, at 10,000 feet
Onsite, at 13,000 feet

“Go” where few have gone before!
Sites with a high content of rock are a real concern.
So how do we address rocky sites?

Not like this!
ON-SITE WASTEWATER TREATMENT SYSTEM REGULATION

REGULATION #43, 5 CCR 1002-43
Regulation #43, On-site Wastewater Treatment System Regulation

“Effective Date: June 30, 2013”

Changed the focus from,
“Sewage Disposal”
to
“Wastewater Treatment”

And from,
“Flush and Forget”
to
“System Performance and Maintenance”
2013 Regulations for Soil Type “0”

- Soil type 1 (sand) that contains >35% rock
- Soil type 2-5 with > 50% rock

Design requirements:

- 3’ deep unlined sand filter for all type “0” soils
- Minimal credit given for pretreatment, or the treatment provided by the sand filter
Questions/Comments received

• “Why don’t we get a sizing reduction for installation of the sand filter?”

• “What you call rock, looks like course sand to me”

• “Even though it’s rocky, the site actually percs at around 30 min./inch. What’s the problem?”

• “When we excavate the soil, it breaks up into a very permeable material; and it looks the same as the sand that we’re importing”
Research

“The suitability of a soil... is based on the total volume and size of the gravel present, and the soil texture.”

“If the volume of the gravel is more than 30% of the total sample, an additional evaluation of the soil is required ...” What is the permeability of the fine earth, and what is the volume of larger rock particles?
Research

**SUITABLE:**
In Class II* or III* soils, only: soil contains less than 30% gravel; 
Or, soil contains more than 30% gravel and 80% of the gravel is smaller than 5.0 mm.

**UNSUITABLE:**
All other Class II* or III* soils that contain more gravel than is described as suitable.

* Class II and III: Sandy Loam to Clay Loam soils
Reduction in treatment capacity due to rock fragments

- For treatment of domestic STE, it is reasonable to limit the volume occupied by stones (>2-mm diameter) to < 35% of the bulk volume

- For profiles with 35 to 60% by volume, it is advised to use a buried sand filter design or provide a higher degree of treatment prior to discharge to the soil

*Decentralized Water Reclamation Engineering; Siegrist, 2017*
“More than 125 publications, which include peer reviewed journal articles, conference proceedings, text books, master thesis, and government reports were collected and reviewed.”
“The rapid flow of effluent through macropores decreases treatment because of reduced soil surface and retention time”

“Inadequate treatment in the unsaturated zone might allow wastewater contaminants to enter the groundwater if no mitigating measures are taken.”

“Sites with 35% - 50% Rock: Saturated Conductivity, not the rock content, predicts OWTS performance.”
Sites with 60% - 65% Rock: Hydraulic conductivities are not similar and are influenced by inter-gravel constituents not gravel content.

Sites with >65% Rock: Influenced more by the gravel content.

However, to some extent the movement of wastewater with a high content of rock is not well understood.
How does Colorado define rock?

- A particle that is larger than 2mm; #10 sieve (Using USDA soil classification)
Particle Sizes Comparison

![Comparison of Particle Size Classes in Different Systems](image)

<table>
<thead>
<tr>
<th>USDA</th>
<th>FINE EARTH</th>
<th>ROCK FRAGMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clay</td>
<td>Silt</td>
</tr>
<tr>
<td>millimeters:</td>
<td>0.0002</td>
<td>.002 mm</td>
</tr>
<tr>
<td>U.S. Standard Sieve No. (opening):</td>
<td>300</td>
<td>140</td>
</tr>
</tbody>
</table>
Type “R” Soils

SOIL WITH HIGH ROCK CONTENT
(2017 Reg. update)
How does Colorado define a Type R Soil?

4 categories were established

- R-0
- R-1
  - Option 1
  - Option 2
- R-2
Soil Type R-0

- R-0 same as Soil Type 0 in 2013 version of Regulation #43
- The “fine earth” portion is a Soil Type 1
  - Sand, Loamy Sand
- Contains More than 35% Rock
  - Rock, defined as being larger than 2 mm
  - Retained on a #10 Sieve
Soil Type R-1

Option 1
- Soil Types: 2-5 from Table 10-1
  - Sandy Loam - Clay
- Contains ≥35% up to 65% rock
- Of the rock fraction, more than 50% must be less than 20mm (3/4”)

Option 2
- Soil Types 2 and 2A from Table 10-1 (Very specific; Sandy Loam, Loam)
- Same amounts of rock as Option 1
- Allows for a “Rip-and-Replace” installation
  - Gradation of the material is strongly suggested
Soil Type R-2

- Soil Type 2 - 5
  - Sandy Loam - Clay

- Contains more than 65% rock (larger than 2mm)

  OR

- The majority of the rock (≥ 50%) is larger than 20mm (3/4”)
### Table 10-1A  Design Criteria for Soils with High Rock Content (Type “R” Soils) 1,2,3,4

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Percentage and Size of Rock 2</th>
<th>Maximum LTAR (Gal./sq.ft./day)</th>
<th>Type of Distribution Required</th>
<th>Treatment Level 1 5</th>
<th>Treatment Level 2</th>
<th>Treatment Level 2N</th>
<th>Treatment Level 3</th>
<th>Treatment Level 3N</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-0</td>
<td>Soil Type 7 1 with more than 35% Rock (&gt;2mm)</td>
<td>Unlined Sand Filter: 1.0 for “Preferred Sand Media”; 0.8 for “Secondary Sand Media”</td>
<td>Pressure Distribution 6</td>
<td>Minimum 3-foot deep Unlined Sand Filter</td>
<td>Minimum 3-foot deep Unlined Sand Filter</td>
<td>Minimum 2.5-foot deep Unlined Sand Filter</td>
<td>Minimum 2.5-foot deep Unlined Sand Filter</td>
<td>Minimum 2-foot deep Unlined Sand Filter</td>
</tr>
<tr>
<td>R-1; Option 1</td>
<td>Soil Type 7 2 - 5, &gt;35 - 65% Rock (&gt;2mm); with ≥50% of the Rock &lt;20 mm (3/4 inch)</td>
<td>Use TL1 LTAR from Table 10-1 for the soil type corresponding to the soil matrix, with a maximum LTAR of 0.8</td>
<td>Pressure Distribution 6</td>
<td>Minimum 2-foot deep Unlined Sand Filter</td>
<td>Minimum 1-foot deep Unlined Sand Filter</td>
<td>Minimum 1-foot deep Unlined Sand Filter</td>
<td>Sand media not required</td>
<td>Sand media not required</td>
</tr>
<tr>
<td>R-1; Option 2</td>
<td>Soil Type 7 2 and 2A, &gt;35 - 65% Rock (&gt;2mm); with ≥50% of the Rock &lt;20 mm (3/4 inch)</td>
<td>The allowable LTAR’s are defined in each individual treatment level column in this Table</td>
<td>Pressure Distribution 6</td>
<td>Remove, mix, replace 4 feet of existing material; with a maximum LTAR of 0.6</td>
<td>Remove, mix, replace 2 feet of existing material; with a maximum LTAR of 0.7</td>
<td>Remove, mix, replace 2 feet of existing material; with a maximum LTAR of 0.7</td>
<td>Remove, mix, replace 2 feet of existing material; with a maximum LTAR of 0.8</td>
<td>Remove, mix, replace 2 feet of existing material; with a maximum LTAR of 0.8</td>
</tr>
<tr>
<td>R-2</td>
<td>Soil Type 7 2 - 5, &gt;65 Rock (&gt;2mm), OR ≥50% of Rock &gt;20 mm (3/4 inch)</td>
<td>Use TL1 LTAR from Table 10-1 for the soil type corresponding to the soil matrix, with a maximum LTAR of 0.8</td>
<td>Timed, Pressure Distribution 6</td>
<td>Minimum 3-foot deep Unlined Sand Filter</td>
<td>Minimum 3-foot deep Unlined Sand Filter</td>
<td>Minimum 2.5-foot deep Unlined Sand Filter</td>
<td>Minimum 2.5-foot deep Unlined Sand Filter</td>
<td>Minimum 2-foot deep Unlined Sand Filter</td>
</tr>
</tbody>
</table>
1. General guidance for Table 10-1A: The intent of the soil type R-0 is to define a material that consists of a high percentage of rock, or rock fragments, and has a percolation rate of less than 5 mpi. Soil types R-1 and R-2 consist of a high percentage of rock or rock fragments, but have a percolation rate of greater than 5 mpi. Soil types R-0 and R-2 are considered to be a “limiting layer”.

2. No sizing adjustments are allowed for systems placed in type “R” soils. The maximum LTAR’s are provided in this table.

3. The design of type “R” soil treatment systems must conform to sections 43.11.C.2 and 3.

4. All systems installed in a type “R” soil must be designed by a professional engineer.

5. The percentage of rock may be determined by a gradation conducted per ASTM standards, or an appropriate field evaluation by volume.

6. Type “R” soil treatment systems that are designed per the criteria noted in the Treatment Level 1 column of this table do not require O/M oversight by the LPHA.

7. The “Percentage and Size of Rock” column references the soil types noted in Table 10-1.

8. Design of the pressure distribution system for type “R” soils shall comply with the requirements of sections 43.11.C.2.b, c, e, f, g, h and i.
So what type of sand do we need?
Ideal Treatment Sand Media:

- An ideal sand media has both large surface area to permit wastewater to have maximum contact with the zoogloal film on the particles where most of the treatment is accomplished, and sufficient pore space to allow aeration and unsaturated flow (Ball, 1997). Because sand media treatment is aerobic in nature, the exclusion of fines from the filter media is extremely important to maintain open passages for air.

Source: State of Washington Dept. of Health, “Sand/Media Specifications"
Is the ASTM C33 specification appropriate for OWTS?

- Concrete sands are designed to minimize voids, and usually have a high Uniformity Coefficiency (4 - 6) to pack and offer strength and stability.

- Developed for the manufacturing of concrete, sands meeting the ASTM C-33 specification have a fairly broad and even size distribution (Ball, 1997). This size distribution allows the smaller sand particles to fill the spaces between large particles, resulting in smaller and more convoluted pores spaces. When used for filter media, this condition encourages clogging of remaining void spaces with suspended solids and biological growth (Boller and Kavanaugh, 1995; Darby et al. 1996).

Source: State of Washington Dept. of Health, “Sand/Media Specifications”
Specifications for imported treatment sand

- Single Pass Sand Filters; Converse, Jan. 1999
  - D10, 0.3 – 0.5 mm
  - Uniformity Coefficient, <4

- Intermittent Sand Filters; State of Washington, 2012
  - D10, >3 mm
  - Uniformity Coefficient, <4
  - Fines (#200 sieve), <3%
Research of “Available” Sand

- Obtained sand gradations from pits across the state to review sand media specifications and availability.

- The results from our survey indicated the following:
  - 32 Gradations submitted for review
    - <20% met the 2013 specification for imported sand media
    - 47% are older than 1 year
    - 44% meet effective size req’s. of Reg. 43 (0.25 – 0.6 mm)
    - 100% fall between an effective size of 0.15 – 0.6 mm
      - Range: 0.16 – 0.34 mm
Research of “Available” Sand

➢ Results, (con’t.):
  o 28% meet uniformity coefficient req’s. of Reg. 43 (<4)
  o 90% fall below a uniformity coefficient of <7
  o 40% meet 2013 req. of <1% fines
  o 100% meet <3% fines

➢ Created options for “Preferred Sand” and “Secondary Sand”
Requirements for imported treatment sand

➢ 2013 Reg., Soil Type “0” (industry standard material)
  o Effective size (ES): 0.25 – 0.60 (D10; sieve where only 10% pass)
  o Uniformity Coefficient (UC): < 4.0 (D60 / D10)
  o Or, C-33 concrete sand with ≤ 1% fines (200 sieve)

➢ Current Reg.: “Preferred Sand Media” (Good stuff!)
  o Same ES/UC as 2013 req’s.; with allowance for up to 3% fines

➢ Current Reg.: “Secondary Sand Media” (More readily available)
  o Effective size: 0.15 – 0.60 (D10; 10% passing, on gradation)
  o Uniformity Coefficient: < 7.0 (D60 / D10)
  o Up to 3% fines

➢ 87% of the pits sampled meet the standards for Secondary Sand
Requirements for imported treatment sand

o 2013, only one requirement for all imported sand; Rarely available

o 2017 Regs provide for the use of more locally available materials

o Revisions now provide two options:
  ▪ “Preferred” sand
    o Similar specifications within previous requirement
    o Same application rate; 1.0 gal./sq.ft./day
  ▪ “Secondary” sand
    o Provides for a wider range of media size; thus,
    o Lower LTAR; 0.8 gal./sq.ft./day; Less void space
Sand type is determined by a gradation; Ultimately defining:

- Uniformity Coefficient

- Effective size
Uniformity Coefficient: Size uniformity between particles

**Low Uc**
- P.E.: Poorly, narrowly graded sand or
- Well Sorted (Geologist)

Large pore space allows rapid oxygen diffusion and unsaturated flow around the sand particles.

**High Uc**
- widely graded sand or well graded (P.E.)
- Poorly Sorted (Geologist)

Inclusion of small particles filling interspaces between large particles encourages clogging.

Determined by: D60 / D10 calculation
Just think of marbles
What is the Effective Size?

The effective size of a given sample of sand is the particle size (in millimeters) where 10% of the particles in that sample are smaller, while 90% are larger.

Usually this is denoted as the D10.
Effective Size

D10 = 0.38

Uniformity Coefficient

D60/D10
1.5 / 0.38 = 3.95
Left Side of Curve
Failed preferred; Passed Secondary

Right Side of Curve
Passed preferred sand

C33 Sand; Range
Gradation Submittal Required

A gradation, dated no more than 30 days prior to installation, must be submitted to the permitting agency.
But at the end of the day...

You can’t make everyone happy
Maroon Bells
Thank You

Questions?

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