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# **CMP Pits and D-Area Watershed Infiltrometer Testing**

Austin Coleman

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September 2025

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## Executive Summary

Savannah River National Laboratory (SRNL) conducted saturated hydraulic conductivity field testing at the Chemical, Metals, and Pesticide Pits (CMP Pits) and the D-Area watershed to develop infiltration rates for use in future updates to the CMP Pits groundwater flow model. Approximately 18 testing locations were selected at each site based on the soil series that were identified in the *Soil Survey of Savannah River Plant Area, Parts of Aiken, Barnwell, and Allendale Counties, South Carolina*.

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## List of Abbreviations

|      |                                    |
|------|------------------------------------|
| SRNL | Savannah River National Laboratory |
| SRS  | Savannah River Site                |
| DOE  | Department of Energy               |
| ACP  | Area Completion Projects           |
| Ksat | Saturated Hydraulic Conductivity   |
| cm/s | Centimeters Per Second             |
| CMP  | Chemical, Metals, and Pesticide    |

## 1.0 Introduction

The Savannah River Site (SRS) is a United States Department of Energy (DOE) facility originally established with the mission to produce nuclear material for national defense. Over the course of site construction and operations, large amounts of solid and liquid waste have been generated, and some of the contaminants associated with this waste have made their way into vadose zones and groundwater.

In contaminated waste mitigation systems, the soil surface and vadose zones constitute major pathways for infiltrating water and surface or subsurface contaminants. The movement of surface water, rainwater, and contaminants to a groundwater system is largely controlled by the hydraulic characteristics of the overlying zones. Therefore, information on the localized hydraulic characteristics of soil is necessary to inform comprehensive groundwater investigations. Saturated hydraulic conductivity ( $K_{sat}$ ) is usually calculated over large scales and tend to omit subtle differences in soil classifications on smaller scales. Saturated hydraulic conductivity is recognized as a critical parameter in controlling infiltration and informing hydrological models, therefore, identifying subtle differences may improve model outputs having regulatory implications.

Area Completion Projects (ACP) requested the Savannah River National Laboratory (SRNL) conduct saturated hydraulic conductivity tests at the Chemical, Metals, and Pesticide (CMP) Pits and the D-Area Watershed using the Saturo Infiltrometer. The objective of this activity is to identify saturated hydraulic conductivity rates over the model domain of the CMP Pits and the D-Area Watershed using the different soil classifications identified by the *Soil Survey of Savannah River Plant Area, Parts of Aiken, Barnwell, and Allendale Counties, South Carolina*.

## 2.0 Methods

### 2.1 Theory

Ponded infiltration from a single ring to uniformly saturated soil can be estimated by the following expression (Reynolds & Elrick, 1990):

$$Q_s = \frac{r}{G} (K_{fs}H + \varphi_m) + \pi r^2 K_{fs}$$

where  $Q_s$  is steady flow rate,  $r$  is the infiltrometer ring radius,  $G$  is an empirically determined, dimensionless shape factor,  $K_{fs}$  is field-saturated hydraulic conductivity,  $H$  is the steady depth of ponding inside the ring, and  $\varphi_m$  is matrix flux potential which varies for given soils based on initial water content. The effective dimensionless shape factor  $G_e$  is provided by Reynolds and Elrick (1990) and is estimated using the below expression:

$$G_e = 0.316 \frac{d}{r} + 0.184$$

where  $d$  is the infiltrometer ring insertion depth.  $K_{fs}$ ,  $\varphi_m$ , and  $\alpha^*$  are all provided by (Reynolds & Elrick, 1990) :

$$K_{fs} = \frac{G_e (Q_{s2} - Q_{s1})}{r (H_2 - H_1)}$$

where  $H_1$  and  $H_2$  are steady ponding depths and  $Q_{s1}$  and  $Q_{s2}$  are steady flow rates.  $\varphi_m$  and  $\alpha^*$  are given by:

$$\varphi_m = \frac{G_e}{r} \left( \frac{H_2 Q_{s1} - H_1 Q_{s2}}{H_2 - H_1} - \pi r G_e \frac{Q_{s2} - Q_{s1}}{H_2 - H_1} \right)$$

$$\alpha^* = \frac{K_{fs}}{\varphi_m}$$

$\alpha^*$  illustrates the influence of gravity and capillary forces during infiltration (Reynolds & Elrick, 1990).

## 2.2 Saturo Infiltrometer Testing

SRNL utilized the Saturo Infiltrometer device to calculate the saturated hydraulic conductivity of the surface soils. The Saturo uses a multipressure head analysis approach to simplify the corrections for three-dimensional flow from a single ring infiltrometer and provides Ksat estimates onsite without any data post-processing (*Saturo Manual*). The Saturo uses the two-pond method developed by (Reynolds & Elrick, 1990) and has a hydraulic conductivity range of  $1.05 \times 10^{-5}$  to  $3.19 \times 10^{-2}$  cm/s. The Saturo manual (Section 2.2.1) provides internal settings for soak times and pressure head configurations based on soil type. Using the soil descriptions provided, SRNL selected the Saturo setting for wet loamy sand. As needed, surface litter was removed to minimal extent to reduce error, and care was taken to not disturb the test site extensively. The Saturo ring was driven into the ground until it was flush with the ground surface. Water to supply the test was obtained from the nonpotable water supply in B-area.

The infiltrometer pump is factory calibrated to within  $\pm 5\%$  of the reading prior to shipment and METER Group recommends the pump calibration be verified every 6-12 months. Calibration checks were run routinely to ensure pump and/or tubing wear had not caused a drift in measurements. Since the infiltrometer offers either a mass or volume method for calibration, a volume calibration check was performed following the procedure in Section 4.1 of the Saturo Manual.

Testing occurred from June 30 through August 12, 2025. Three locations were selected to represent each soil series, and three saturated hydraulic conductivity tests were performed at each location to provide mean and median values associated with each soil type. Each test ran two pressure cycles for a total of 75 minutes. The Saturo begins with a soaking cycle to saturate the surface soil and pond the water to the sensor head. At each pressure cycle, once the steady state conditions are achieved, saturated hydraulic conductivity rates are measured and calculated by the software using an equation provided by Reynolds & Elrick (1990). Some values would display as negative numbers after a test run-these values were omitted from analysis. In some cases, saturated hydraulic conductivity rates were greater than the Saturo's measurement range and the infiltrometer displayed a water level warning or water level error. For locations where this occurred, the hydraulic conductivity was set to  $3.19E^{-2}$  cm/s for that location (maximum conductivity value measurable by Saturo Infiltrator). If the tests continued to fail, pressure parameters were either modified to lower settings in accordance with technical support's guidance or testing was switched from the 5cm ring to the 10cm ring. After a test, the equipment was moved 5-10 meters away to begin the next test.



**Figure 1: A typical Saturo Infiltrator setup in the field.**

## 2.3 CMP Pits Sample Locations

Below is a list of the soil series of interest at CMP Pits. Figure 2 provides a map of CMP Pits, soil series distribution, and distribution of samples across the study site. Coordinates for each testing location provided in Appendix A (A.1).

- Blanton Series: consists of somewhat excessively drained, moderately permeable soils that formed in sandy and loamy sediments of the Coastal Plain and Sand Hills. These soils are classified as loamy, thermic Grossarenic Paleudults. Soil horizon of interest: Ap: 0 to 18 centimeters: dark grayish brown (10YR 4/2) sand; weak fine granular structure, very friable; many roots; very strong acid; abrupt wavy boundary.
- Fuquay Series: consists of well drained, slowly permeable soils that formed in loamy marine sediment on the Upper Coastal Plain and the Sand Hills. Fuquay soils are classified as loamy, siliceous, thermic Arenic Plinthic Paleudults. Soil horizon of interest: Ap: 0 to 20 centimeters; grayish brown (10YR 5/2) sand; single grained; loose; many fine roots; moderately acid; abrupt smooth boundary.
- Udorthents: Consist of mostly well drained soils that formed in heterogeneous materials, which are the spoil or refuse from excavations and major construction operations. The soil material has been removed, mixed, and moved. Udorthents are divided into two groups. One is firm material, which consists largely of borrow pits and areas that are compacted by traffic, and other is friable layers of soil material, often in the form of overburden.
- Vaucluse Series: Consists of well drained, slowly permeable, and moderately slowly permeable soils that formed in thick beds of unconsolidated sand and clay of the Sand Hills. Vaucluse soils are classified as fine-loamy siliceous, thermic Typic Hapludults. Soil horizon of interest A: 0 to 13 centimeters; brown (10YR 5/3) sand loam; weak medium granular structure; very friable; many fine roots; about 10 percent pebbles 10 to 50 millimeters in diameter; extremely acid; clear wavy boundary.
- Ailey Series: Consists of well drained, slowly permeable soils that formed in thick beds of unconsolidated sandy and clayey material in the Sand Hills. Ailey Soils are classified as loamy, siliceous, thermic Arenic Hapludults. Soil horizon of interest: A: 0 to 15 centimeters; brown (10YR 5/5) sand; moderate medium granular structure; very friable; many fine and medium roots; strongly acid; clear wavy boundary.
- Pickney Series: Consists of very poorly drained, rapidly permeable soils that formed in stream sediments. These soils are on the flood plain along major streams, typically on areas where the stream has no well-defined channel. Pickney soils are classified as sandy, siliceous, thermic Cumulic Humaquepts. Soil horizon of interest: 0 to 13

centimeters; black sand; weak fine granular structure; very friable; many medium and coarse roots; extremely acid; gradual wavy boundary.

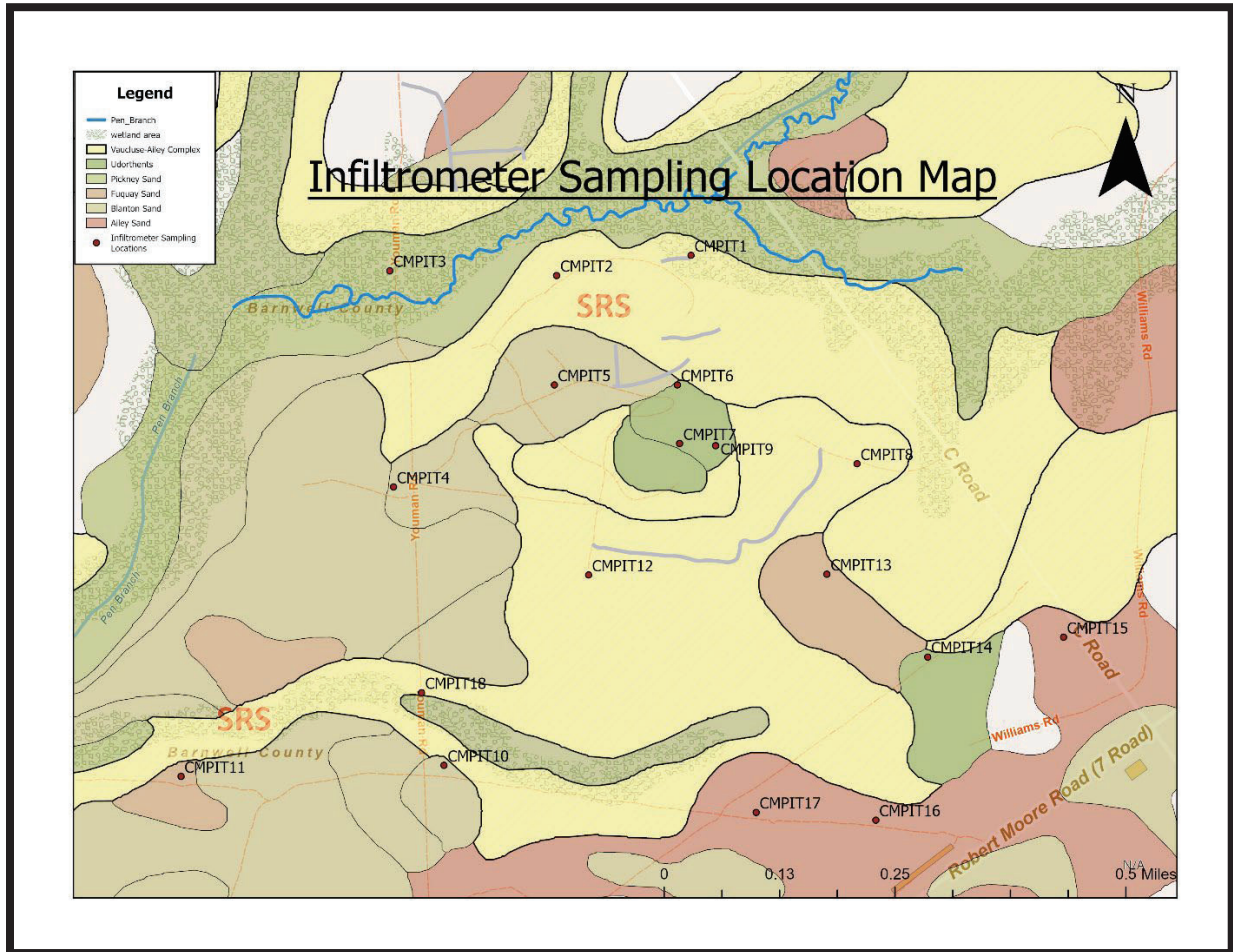


Figure 2: Infiltrometer testing locations by soil series at the CMP Pits.

## 2.4 D-Area Sample Locations

Below is a list of the soil series of interest at D-Area. Figure 3 is a map of D-Area, soil series distribution, and distribution of samples across the study site. Coordinates for each testing location provided in Appendix A (A.2).

- Rembert Series: consists of poorly drained, slowly permeable soils that formed in clayey marine deposits. Rembert soils are classified as clayey, kaolinitic, thermic Typic Ochraquults. Soil horizon of interest: A: 0 to 3 centimeters; very dark gray (10YR 3/1) sandy loam, moderate medium granular structure; very friable; many fine and medium roots; extremely acid; abrupt smooth boundary.

- Ocilla Series: consists of somewhat poorly drained, moderately permeable soils that formed in the marine river deposits on the Coastal Plain. Ocilla soils are classified as loamy, siliceous, thermic Aquic Arenic Paleudults.
- Smithboro Series – consists of somewhat poorly drained, slowly permeable soils that formed in marine and stream sediments on the Sand Hills, Coastal Plain, and Piedmont. Smithboro soils are classified as clayey, kaolinitic, thermic Aeric Paleudults. Soil horizon of interest: Ap: 0 to 10 centimeters dark gray (10YR 4/1) loam; moderate medium granular structure; very friable; common fine and medium roots; very strong acid; clear smooth boundary.
- Chastain Series: consists of poorly drained, slowly permeable soils that formed in clayey sediment on flood plains of the larger streams, mostly near the Savannah River. Chastain soils are classified as fine, mixed, acid, thermic Typic Fluvaquents. Soil horizon of interest: A: 0 to 5 centimeters; dark greenish brown (10YR 4/2) clay. Moderate medium granular structure; friable; many fine to coarse roots extremely acid; abrupt smooth boundary.
- Fluvaquents: consists of poorly drained, moderately permeable soils that formed along the flood plain of small streams and drainageways in sandy sediments of the Coastal Plain and Sand Hills. Soil Horizon of interest: A: 0 to 10 centimeters; dark gray (10YR 7/2) loamy sand; weak fine granular structure; very friable; many fine, medium, and coarse roots; very strong acid; clear wavy boundary.
- Udorthents: Consist of mostly well drained soils that formed in heterogeneous materials, which are the spoil or refuse from excavations and major construction operations. The soil material has been removed, mixed, and moved. It occurs in such irregular patterns on the landscape that classification below the Great Group is not practical. Udorthents are divided into two groups. One is firm material, which consists largely of borrow pits and areas that are compacted by traffic, and other is friable payers of soil material, often in the form of overburden.
- Blanton Series: consists of somewhat excessively drained, moderately permeable soils that formed in sandy and loamy sediments of the Coastal Plain and Sand Hills. These soils are classified as loamy, thermic Grossarenic Paleudults. Soil horizon of interest: Ap: 0 to 18 centimeters: dark grayish brown (10YR 4/2) sand; weak fine granular structure, very friable; many roots; very strong acid; abrupt wavy boundary.



about 20 infiltration measurements for a swale less than 350m long in an effort to balance accuracy in mean values with realistic sampling effort.

Due to technical issues with the Saturo, not all D-Area locations were able to be sampled. The remaining locations will be tested, and data will be reported in FY26 as a revision 1 of this document.

### 3.2 CMP Pits

Table 1 shows the raw data as measured with the Saturo Infiltrometer for test replicates 1-3. Median values as well as average infiltrometer rates per location have been calculated from the raw data excluding any values outside of the range of the infiltrometer.

**Table 1. Saturated Hydraulic Conductivity (Ksat) rates for each test at CMP Pits locations.**

| Location | Soil Series    | Test 1 Rate (cm/s) | Test 2 Rate (cm/s) | Test 3 Rate (cm/s) | Rate Median (cm/s) | Rate Average (cm/s) |
|----------|----------------|--------------------|--------------------|--------------------|--------------------|---------------------|
| CMPIT2   | Vaucluse-Ailey | *-5.53E-01         | 3.19E-02           | 1.32E-02           | 1.32E-02           | 2.26E-02            |
| CMPIT8   | Vaucluse-Ailey | 1.02E-02           | 7.91E-02           | 7.59E-03           | 1.02E-02           | 3.23E-02            |
| CMPIT12  | Vaucluse-Ailey | 6.97E-03           | 1.70E-02           | 1.92E-04           | 6.97E-03           | 8.06E-03            |
| CMPIT15  | Ailey          | 2.48E-03           | 2.59E-03           | 4.52E-03           | 2.59E-03           | 3.20E-03            |
| CMPIT16  | Ailey          | *-1.04E+00         | 6.82E-03           | 1.01E-02           | 6.82E-03           | 8.48E-03            |
| CMPIT17  | Ailey          | 3.19E-02           | 3.19E-02           | 3.19E-02           | 3.19E-02           | 3.19E-02            |
| CMPIT6   | Udorthents     | 7.51E-03           | 1.11E-02           | 5.30E-03           | 7.51E-03           | 7.95E-03            |
| CMPIT7   | Udorthents     | 7.68E-03           | 2.43E-03           | 3.36E-03           | 3.36E-03           | 4.49E-03            |
| CMPIT9   | Udorthents     | 2.62E-03           | 5.85E-03           | 1.41E-02           | 5.85E-03           | 7.52E-03            |
| CMPIT11  | Fuquay         | 3.19E-02           | 5.25E-03           | 3.19E-02           | 3.19E-02           | 2.30E-02            |
| CMPIT13  | Fuquay         | 3.19E-02           | 3.19E-02           | 3.19E-02           | 3.19E-02           | 3.19E-02            |
| CMPIT14  | Fuquay         | 3.19E-02           | 3.19E-02           | 3.19E-02           | 3.19E-02           | 3.19E-02            |
| CMPIT1   | Pickney        | 3.14E-03           | 1.77E-04           | 2.38E-04           | 2.38E-04           | 1.18E-03            |
| CMPIT3   | Pickney        | 1.20E-02           | *-4.98E-03         | 6.83E-03           | 6.83E-03           | 4.63E-03            |
| CMPIT18  | Pickney        | 6.39E-03           | 2.00E-03           | 1.97E-02           | 6.39E-03           | 9.36E-03            |
| CMPIT4   | Blanton        | 3.19E-02           | 3.19E-02           | 3.19E-02           | 3.19E-02           | 3.19E-02            |
| CMPIT5   | Blanton        | 3.19E-02           | 1.42E-02           | 3.19E-02           | 3.19E-02           | 2.60E-02            |
| CMPIT10  | Blanton        | 1.72E-02           | 1.73E-02           | 9.31E-02           | 1.73E-02           | 4.25E-02            |

\* Values not used in average and median calculation

Figure 4 displays the cumulative median and average for each soil series (n=9) found at the CMP Pits. Two soil series (Fuquay and Blanton) displayed average saturated hydraulic conductivity rates at or higher than the measurable range of the Saturo. The red line on Figure 4 indicates the maximum saturated hydraulic conductivity rate for the Saturo. The average and median saturated hydraulic conductivity rate across all soil series for CMP Pits were 1.78E-

02cm/s and 8.86E-03cm/s, respectively. The average saturated hydraulic conductivity rate on the cap, soil series Udorthents, had low saturated hydraulic conductivity relative to other soil series surrounding the cap. Fuquay and Blanton soils resulted in the highest saturated hydraulic conductivity rates and often showed rates higher than the Saturo accurately measures.

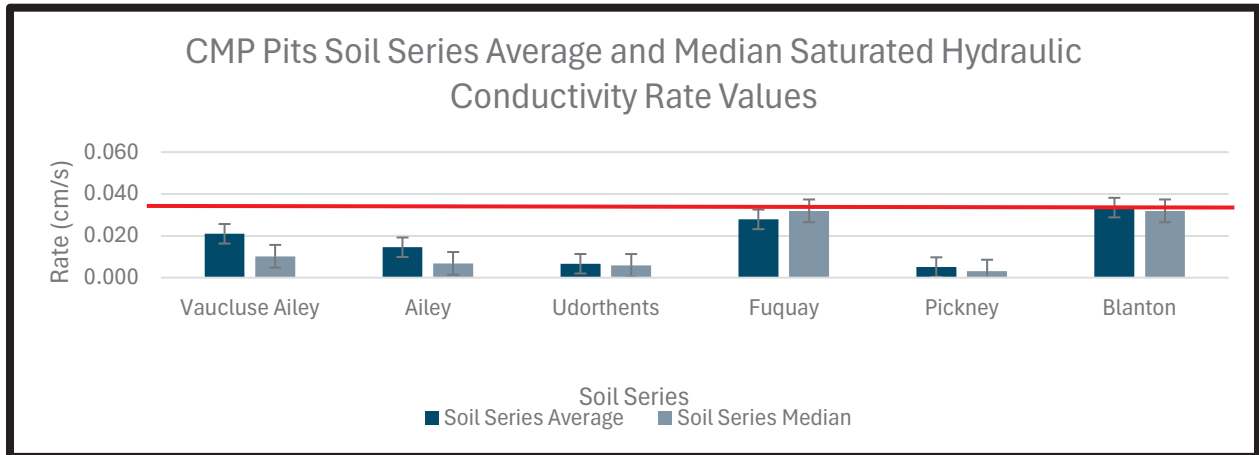


Figure 4. Average and median saturated hydraulic conductivity rates for each soil series in the CMP Pits location. The red line represents the maximum rate that can be measured by the Saturo Infiltrometer.

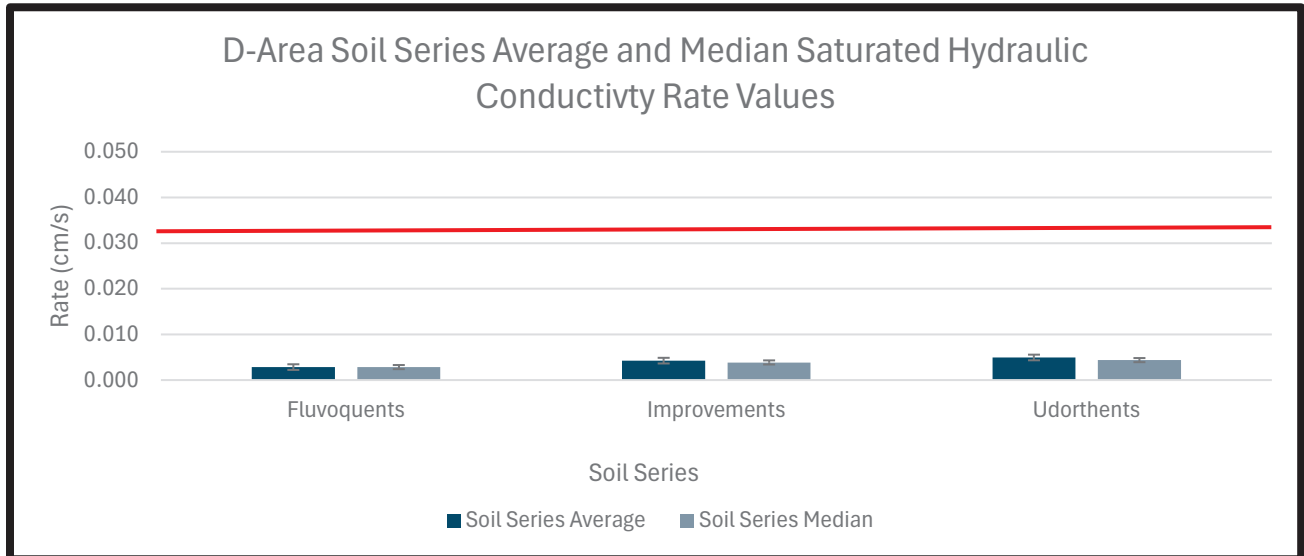
### 3.3 D-Area

Table 2 shows the raw data as measured with the Saturo Infiltrometer for test replicates 1-3. Median values as well as average infiltrometer rates per location have been calculated from the raw data withholding the values outside the range of the infiltrometer. Only two tests were run at DIT1; however, Test 3 and remainder of D-Area will be performed in FY26.

Table 2. Saturated Hydraulic Conductivity (Ksat) rates for each test at D-Area locations.

| Location | Soil Series  | Test 1 Rate (cm/s) | Test 2 Rate (cm/s) | Test 3 Rate (cm/s) | Rate Median (cm/s) | Rate Average (cm/s) |
|----------|--------------|--------------------|--------------------|--------------------|--------------------|---------------------|
| DIT15    | Improvements | 8.91E-03           | 5.03E-03           | 7.03E-03           | 7.03E-03           | 6.99E-03            |
| DIT2     | Improvements | 1.04E-03           | 2.69E-03           | 8.34E-04           | 1.04E-03           | 1.52E-03            |
| DIT13    | Udorthents   | 4.83E-03           | 3.19E-03           | 3.40E-03           | 3.40E-03           | 3.81E-03            |
| DIT18    | Udorthents   | 7.71E-03           | 3.91E-03           | 6.65E-03           | 6.65E-03           | 6.09E-03            |
| DIT1     | Fluvaquents  | 3.80E-03           | 1.89E-03           | N/A                | 2.84E-03           | 2.84E-03            |

Figure 5 displays the cumulative median and cumulative average for each soil series found in D-Area. Sample sizes varied for the soil sizes completed. Two locations were completed for the Udorthents (n=6) and Improvements (n=6) soil series and one location completed for the Fluvaquents (n=2). The red line on Figure 5 indicates the maximum saturated hydraulic conductivity rate for the Saturo. The average and median saturated hydraulic conductivity rate across all soil series for D-Area was  $4.35E-03\text{cm/s}$  and  $3.86E-03\text{cm/s}$ , respectively. For the data collected to date, saturated hydraulic conductivity rates across soil series are comparable to one another.



**Figure 5. Average and median saturated hydraulic conductivity rates for each soil series in the D-Area location. The red line represents the maximum rate that can be measured by the Saturo Infiltrometer.**

#### 4.0 Recommendations, Path Forward or Future Work

To further reduce uncertainty in the saturated hydraulic conductivity measurements, a couple of approaches could be considered. SRNL proposes a fine-scale and/or seasonal grid-based sampling approach to the areas of concern. This approach could allow model estimates to be made that further reduce uncertainty in the mean estimates. Pairing the grid-based approach with imaging data (GPR/ERT) could help better explain any variations in saturated hydraulic conductivity rates.

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## 6.0 Appendix A

### A.1 CMP Site Coordinates

| Location | Northing (WGS84) | Easting (WGS84) | Northing (NAD27) | Easting (NAD27) |
|----------|------------------|-----------------|------------------|-----------------|
| CMPIT2   | 33.23060         | -81.62770       | 441498.462346    | 3676819.14534   |
| CMPIT8   | 33.22767         | -81.62206       | 442022.033690    | 3676491.16102   |
| CMPIT12  | 33.22590         | -81.62721       | 441554.000000    | 3676297.00000   |
| CMPIT15  | 33.22496         | -81.61818       | 442381.786124    | 3676188.56506   |
| CMPIT16  | 33.22207         | -81.62167       | 442054.680487    | 3675870.08754   |
| CMPIT17  | 33.22218         | -81.62391       | 441846.021936    | 3675883.52676   |
| CMPIT6   | 33.22889         | -81.62543       | 441708.834216    | 3676628.29365   |
| CMPIT7   | 33.22797         | -81.62538       | 441712.882734    | 3676526.26770   |
| CMPIT9   | 33.22794         | -81.62471       | 441775.291706    | 3676522.56826   |
| CMPIT11  | 33.22269         | -81.63467       | 440843.710084    | 3675946.10623   |
| CMPIT13  | 33.22593         | -81.62261       | 441969.636853    | 3676298.55694   |
| CMPIT14  | 33.22464         | -81.62072       | 442144.896864    | 3676154.49041   |
| CMPIT1   | 33.23093         | -81.62519       | 441732.549481    | 3676854.32950   |
| CMPIT3   | 33.23066         | -81.63082       | 441207.797645    | 3676827.54810   |
| CMPIT18  | 33.22403         | -81.63018       | 441262.997578    | 3676092.13682   |
| CMPIT4   | 33.22726         | -81.63073       | 441213.908559    | 3676450.54790   |
| CMPIT5   | 33.22888         | -81.62773       | 441494.521777    | 3676628.47002   |
| CMPIT10  | 33.22289         | -81.62975       | 441302.304240    | 3675965.50644   |

### A.2 D-Area Site Coordinates

| Location | Northing (WGS84) | Easting (WGS84) | Northing (NAD27) | Easting (NAD27) |
|----------|------------------|-----------------|------------------|-----------------|
| D-IT-13  | 33.20727         | -81.73024       | 431926.229894    | 3674294.66637   |
| D-IT-15  | 33.20749         | -81.73349       | 431623.500407    | 3674321.17741   |
| D-IT-2   | 33.20803         | -81.73381       | 431594.096524    | 3674381.25551   |
| D-IT-18  | 33.20500         | -81.73270       | 431695.194237    | 3674044.59938   |
| D-IT-1   | 33.20037         | -81.74422       | 430617.847275    | 3673538.86132   |

### A.3 Example Sample Calculations

Equation 4 from the Saturo manual was used to perform a sample calculation.

Equation 4 from Saturo Manual:

$$K_{fs} = \Delta \frac{(i_1 - i_2)}{D_1 - D_2}$$

where:

$i_1$  is infiltration rate at the high-pressure head, cm/sec

$i_2$  is infiltration rate at the low-pressure head, cm/sec

$D_1$  is the measured high-pressure head, cm

$D_2$  is the measured low-pressure head, cm

and:

$$\Delta = 0.993 * d + 0.578 * b$$

where:

$d$  is the insertion depth of the infiltrometer ring, 10 cm

$b$  is the radius of the infiltrometer ring, 7.6 cm

Raw data for calculations were taken from CMPIT15-3. There were two pressure cycles with pressure heads of 5 and 10 cm H<sub>2</sub>O. The duration of each cycle was 30 minutes, 15 minutes at 5 cm H<sub>2</sub>O and 15 minutes at 10 cm H<sub>2</sub>O. The insertion depth of the infiltrometer ring was 10 cm. Saturo outputs a raw data file consisting of time, pressure head, flux, and volume with measurements taken on 1-minute intervals. For the sample calculations, the median values for pressure head and volume for the second pressure cycle were used to calculate the field saturated hydraulic conductivity,  $K_{fs}$ .

| <b>Median Pressure (cm)</b> | <b>Median Volume (mL/s)</b> |
|-----------------------------|-----------------------------|
| 10.0                        | 2.28                        |
| 5.3                         | 1.99                        |

Sample Calculations:

$$i_1 = \frac{2.28 \frac{cm^3}{sec}}{182.1 cm^2}$$

$$i_1 = 0.0125 cm/sec$$

$$i_2 = \frac{1.99 \frac{cm^3}{sec}}{182.1 cm^2}$$

$$i_1 = 0.0109 cm/sec$$

$$\Delta = 0.993 * 10 cm + 0.578 * 7.6 cm$$

$$\Delta = 14.3 cm$$

$$K_{fs} = \frac{14.3 cm (0.0125 cm - 0.0109 cm)}{10.0 cm - 5.3 cm}$$

$$K_{fs} = 4.8 \times 10^{-03} cm/sec$$

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