# Assessment of Existing and Potential Volume Reduction for Post Construction Stormwater Management

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<tr><td colspan="3">16. Abstract<br>**The Assessment of Existing and Potential Volume Reduction for Post Construction Stormwater Management research project focuses on developing additional options for post construction BMPs available to ODOT projects. Real-time flow monitoring equipment was installed along ODOT roadways to measure stormwater runoff across the state of Ohio. This resulted in the largest data collection effort of its kind in the state of Ohio. Through extensive performance evaluation and cost-benefit analysis, a new BMP, the Amended Vegetated Filter Strip (AVFS), has been developed for inclusion in ODOT's Locations and Design Manual, which provides design guidance for all ODOT construction projects.**</td></tr>
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# Problem Statement

The Ohio Environmental Protection Agency (OEPA) regulations require the implementation of stormwater Best Management Practices (BMPs) into the design of many construction projects for post-construction runoff control. The Ohio Department of Transportation (ODOT) Location and Design Manual, Volume 2, outlines several BMPs that have been approved by the OEPA for use on publicly-funded transportation projects. Currently, ODOT can only take credit for BMPs that have been approved for use by the OEPA.

The post-construction BMP requirements vary depending on the size and type of construction project. For larger projects that add significant impervious area outside of existing right-of-way, the most likely BMPs that meet the OEPA treatment requirements are detention basins and bioretention cells. While these BMPs can be effective at meeting permit requirements, they tend to have a large footprint which creates the need to acquire additional right-of-way area. These BMPs can also pose a safety hazard from standing water. For certain construction projects, the footprint and safety concerns can limit their feasibility.

Many ODOT roadway projects have common features (e.g. grassed medians and grassed shoulders) that likely contribute to overall volume reduction—through infiltration and evapotranspiration. Runoff that infiltrates into the ground is considered "treated" per the requirements of the OEPA Construction General National Pollutant Discharge Elimination System (NPDES) Permit; however, BMPs that utilize infiltration to treat runoff must be located on Hydrologic Soil Group (HSG) A or B soil types to be approved. Most soils that ODOT projects encounter are less conductive HSG C or D soil types. However, modifications to the grassed medians and shoulders (such as soil amendments) may increase the infiltration capacity of these areas.

The Assessment of Existing and Potential Volume Reduction for Post Construction Stormwater Management research project focuses on developing an approved stormwater volume reduction BMP utilizing common features on roadway projects (i.e. grassed shoulders and medians) that are within the right-of-way. The intent of these BMPs is to reduce post-construction stormwater runoff by means of infiltration and evapotranspiration, in order to meet stormwater quantity management requirements per the OEPA's Construction General Permit. This will benefit ODOT, regulatory agencies, design engineers, contractors/developers, and the general public, by providing a space-efficient, cost-effective, and easy to implement alternative to traditional stormwater volume BMPs.

# Research Background

The goal of this research is to develop additional options for post-construction stormwater BMPs available to ODOT projects. This will better enable ODOT to meet regulatory requirements for construction projects as efficiently as possible. The research was conducted in three distinct phases.

## PHASE 1

In this phase, the research team developed sampling and soil amendment plans. The work plan for this phase included the following tasks:

1. Identification of sites within ODOT right-of-way that are appropriate for flow monitoring.
2. Development of a drainage area map with contours for each of site.
3. Development of site-specific plans to implement soil amendments at each monitoring sites. These soil amendment plans included: material types, depths, incorporation methods, re-establishment of grass over the amended soil, erosion and sediment control measures, and maintenance of traffic. These plans were developed with ODOT standard equipment, construction specifications, and project scale in mind. For example, manual activities, like hand broadcasting of seed, were not included. The soil amendments were optimized to improve infiltration while considering roadway safety.
4. Development of site-specific sampling plans to monitor flow volume exiting the identified sites in order to estimate volume reduction that is occurring as a result of the soil amendments. Monitoring at the sites included flow monitoring of existing conditions, followed by implementation of soil amendments and time for grass growth, then flow monitoring for the amended condition. Monitoring parameters included continuous precipitation and continuous flow rates at the downstream end of the monitored area. Readings for precipitation intensity and flow rate were taken at short enough intervals to estimate the volume generated from short and long duration storms. Water quality parameters (e.g. TSS) were not monitored. The sampling plans took into consideration the time to implement soil amendments, as well as the time for re-establishment of grass following implementation of soil amendments. The sampling plans also included safety consideration for researchers working within ODOT right-of-way (e.g. flashers on vehicles, safety vests, hard hats, etc.)
5. Development of a description of all proposed work for each site, including figures, for submittal to ODOT district offices for review and comment.
6. Development of a Phase 1 Interim Report, containing the soil amendment plans and the sampling plans, to ODOT.

## PHASE 2

In this phase, the research team monitored/documented existing site flow conditions. The work plan for this phase included the following tasks:

1. Installed flow monitoring equipment at the selected sites across Ohio per the approved sampling plans.
2. Performed flow monitoring at the selected sites to estimate the following:
    a. Average annual flow volume reduction compared to theoretical runoff coefficient calculations.
    b. Flow volume reduction on an event basis compared to theoretical runoff coefficient calculations.
    c. Weather factors (temperature, season, precipitation intensity, etc.) affecting volume reduction.
3. Documented the existing conditions monitoring results in an interim report to ODOT.

4. Recommended modifications to the soil amendment plans if interpretation of the results from the flow monitoring leads to possible plan improvements.
5. Developed construction plans, consistent with ODOT typical construction plans, for each of the amendment sites, including construction details and notes.
6. Provided a Phase 2 Interim Report, outlining the details from steps 1 through 5 to ODOT.

## PHASE 3

In this phase, the research team implemented the approved soil amendment designs and monitored/documented the impacts on site flow conditions. The work plan for this phase included the following tasks:

1. Installed/constructed the approved soil amendments at the monitoring sites.
2. After re-establishment of grass, continued monitoring the amended sites to estimate the following:
    a. Average annual flow reduction compared to theoretical calculations and existing conditions measurements.
    b. Flow volume reduction on an event basis compared to theoretical calculations and existing conditions measurements.
    c. Weather factors (temperature, season, precipitation intensity, etc.) affecting volume reduction.
3. Prepared a report documenting the estimated flow volume reduction from existing and amended sites.
4. Recommended language for ODOT's Location and Design Manual, Volume 2 associated with post-construction BMPs in order to demonstrate how a designer may take credit for incorporation of these features into a project. Presented this language to ODOT. Included construction lessons learned during construction of the pilot-scale soil amendments.
5. Prepared typical notes and design details to show the minimum requirements for each feature to be considered as a volume reduction practice in-lieu of currently approved post construction BMPs.
6. Made recommendations for future volume reduction studies that may benefit ODOT in terms of meeting post-construction treatment requirements.

The literature review for this research project included the following sources. A complete literature review is included in Appendix A.

1. Design Guide for Roadside Infiltration Strips in Western Oregon. June 2016.
   Chad Higgins
2. Enhancements and Application of the Minnesota Dry Swale Calculator.
   April 2016. John S. Gulliver
3. Pennsylvania Stormwater Best Management Practices Manual. Pennsylvania Department of Environmental Protection. December 2006.
4. The Performance of Grassed Swales as Infiltration and Pollution Prevention Practices, A Literature Review. November 2010. P. Weiss, J. Gulliver, and A. Erickson
5. Soil Compost Amendment. Virginia DEQ Stormwater Design Specification No.4. March 2011.
6. Using Vegetated Compost Blankets to Achieve Highway Runoff Volume and Pollutant Reduction, NCHRP 14-39 (RPF closed 11/15/2016).

# Research Approach

## 1.0 SITE IDENTIFICATION

The first step of the Assessment of Existing and Potential Volume Reduction for Post Construction Stormwater Management research project was to identify sites, located within ODOT right-of-way, that are appropriate for soil amendment and flow monitoring. The original intent of the research project was to select 10 sites for analysis; however, after discussions with ODOT, the research team decided to add two additional monitoring locations to serve as control sites (for a total of 12 sites).

The control sites were used to provide more accurate monitoring results and data analysis. They were not subjected to soil amendment but served as controls to compare rainfall and runoffs from one year to the next. This helped the research team identify the impact of varying rainfall pattern and climate between pre-amendment and post-amendment monitoring and establish a baseline for runoff comparison.

### 1.1 Site Selection Criteria

Coordination between ODOT and the research team led to the development of the following site selection criteria. More detailed discussion of these selection criteria is located in Appendix B.

1. Sites will be a typical grassed shoulder, similar to ODOT's current vegetated filter strip BMPs that drains to a vegetated ditch.
2. Sites will have safe access to install and maintain flow monitoring equipment at a single location in the vegetated ditch, downstream of the grassed shoulder.
3. Sites will have appropriate width and length of a potential vegetated filter strip to incorporate the soil amendments with the purpose of increasing infiltration along the grassed shoulder.
4. Sites will have a target side slope of 3:1 or shallower, and a longitudinal slope of 1-3%.
5. Sites will have less than 5 acres draining to the single-flow monitoring point in the vegetated ditch.
6. Sites will be evenly distributed among the various Ohio rainfall intensity zones and be within a reasonable travel distance for the research team and maintenance personnel.
7. Sites will be free of existing utilities that may interfere with installation of monitoring equipment or construction of soil amendments.
8. Sites will not have future scheduled construction projects which could disturb the monitoring areas during the research period.
9. Sites will be approved by ODOT District maintenance staff.

### 1.2 Site Selection Process

The site selection process was comprised of a desktop exercise to identify potential sites and field visits to confirm site criteria and suitability. The desktop exercise was performed using Google Earth and GIS data analysis. GIS data was obtained through the ODOT Transportation Information Mapping System (TIMS), the Ohio Geographically Referenced Information Program (OGRIP), and the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) Geospatial Data Gateway. Field visits were conducted with participants from ODOT and the research team.

### 1.3 Selected Sites

After careful consideration and analysis, 12 sites were selected for this research effort. See Figure 1 for the location of the selected monitoring sites. Amendment sites are numbered one through ten, and control sites are denoted by "C".

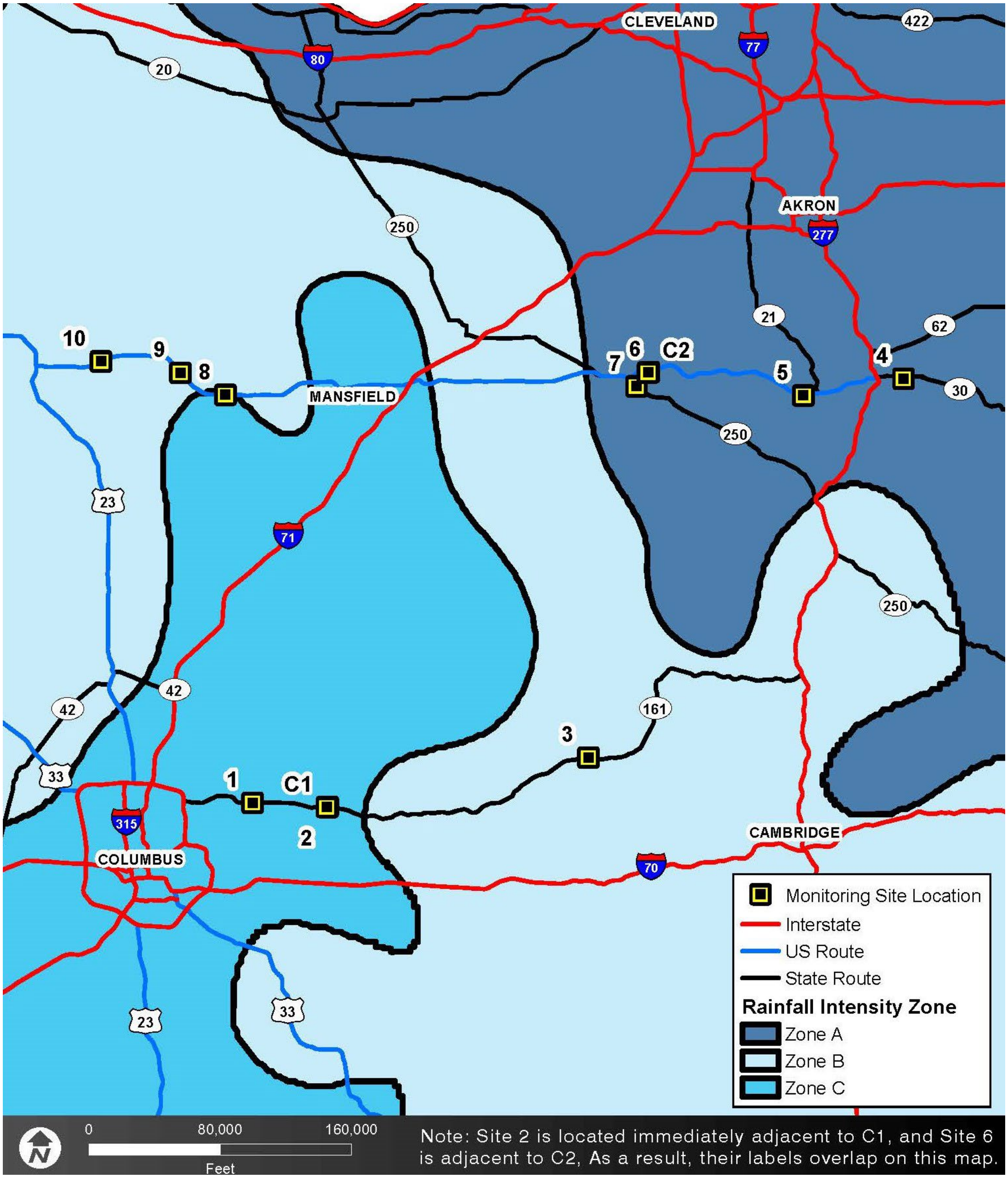


**Figure 1: Monitoring Site Locations**

# 2.0 FLOW MONITORING PLAN

Once monitoring sites were identified, the research team developed a plan to measure rainfall and associated runoff. The monitoring plan consisted of equipment installation, data collection, and equipment operation and maintenance, as summarized below. Additional details regarding the flow monitoring plan can be found in the USGS report 'Assessment of Runoff Volume Reduction Associated with Installation of Soil Amendments in Portions of Highway Median Strip Catchments in Ohio, 2018–2020, located in Appendix C.

## 2.1 Equipment

The typical equipment at each monitoring site consisted of a tipping bucket rain gauge, H-flume with pressure transducer, and outdoor digital camera. The sensors were controlled by a data logger that stored data and transit data via a cellular modem. An environmental enclosure housed all electronics including the battery and solar regulator.

### *2.1.1 Rain gages*

Rain was measured with tipping bucket rain gages with each tip equal to 0.01 of an inch of rain. Precipitation and flow data was not collected during winter months, as snow, ice, and frozen ground could skew the data. As a result, there was no need for heated rain gages.

### *2.1.2 H-Flumes*

Stormwater runoff from the monitoring site was measured using h-flumes with detached stilling wells equipped with pressure transducers for measuring water-levels with an accuracy of 0.01 ft. H-flumes have a defined range of flows that can be accurately measured. When determining the flume size for each site, it was important to establish a balance between capturing the largest possible storm events and capturing the statistically more probable, smaller events. While the larger flumes measured greater flows, they also had a higher minimum flow threshold and were not as accurate when measuring low flows. Flume sizing was based largely on the drainage area, slope, and land cover of the proposed monitoring locations, coupled with the knowledge and experience of the research team.

Three sites were equipped with 0.50-ft flumes and nine of the runoff gages were equipped with 0.75-ft flumes. The 0.50-ft flumes have a maximum capacity of 0.331 cubic feet per second (cfs) and the 0.75-ft flumes have a maximum capacity of 0.957 cfs. The minimum rated flows for 0.50-ft and 0.75-ft flumes were 0.0004 cfs and 0.006 cfs, respectively. The flow was assumed to be zero any time the measured gage height (stage) was 0.01 ft. or less.

Shortly after installation, two of the sites were refitted with larger H-flumes. One 0.75-ft H-flume was replaced with a 1.00-ft H-flume with a maximum measurable flow rate of 1.92 cfs. One 0.50-ft H-flume was replaced with a 0.75-ft flume.

### *2.1.3 Outdoor Digital Cameras*

Each site was equipped with an outdoor camera to provide independent checks on the water levels as well as to provide information on current conditions at the site. The camera was capable of remote panning to look at the flume exit as well as the approach area and had infrared capability for imaging during low light levels.

### *2.1.4 Power supply*

Power for the station was provided by a combination of battery and solar panel. The battery was a 12 volt, 110 amp-hour battery. Based upon the power requirements for the pressure transducer, rain gage, modem, outdoor camera, and data logger, the battery was recharged by using a 90-watt solar panel.

### 2.1.5 Other Equipment

Additional equipment at each site consisted of a data logger to store the information, a cellular modem to transmit the information, a battery for powering the instrumentation, a solar panel to charge the battery, and a solar regulator to ensure the battery does not over-charge.

Wing walls were installed at each site to ensure that all runoff is directed through the flume. The wing walls were constructed to the same height as the top of the flume, and extended laterally until the tops of wing walls intersected with the ground at an elevation near the top of the flume. Crest stage pipes were also installed to provide accurate peak water levels (stage); in the event the flume were to overtop during large runoff events. Knowledge of the peak stage enabled the use of the simplified weir equation to calculate flow rates.

## 2.2 Equipment installation

The H-flumes were installed directly to the drainage basin concrete approach pad at each site. Holes corresponding to the holes in the feet of each H-flume were drilled into the approach pad. Concrete expansion anchors were inserted into the holes for attaching and leveling the H-flumes. Wing walls were attached to the H-flume approach section and anchored using fence posts. A detached stilling well was connected to the H-flume with PVC piping. The outdoor camera was installed near the approach section. A 2-inch pipe was driven into the ground to serve as a mast onto which the environmental enclosure, rain gage, solar panel, and modem antennae were attached. The mast was installed at a location close to the H-flume that provided an adequate level of safety for servicing personnel as well as traffic.

The monitoring equipment was installed during March of 2018 with the final installation completed on March 31, 2018. A few of the gages had some operational malfunctions due to instrumentation failures or insufficient wiring installations, but all gages were fully functioning by April 10, 2018. Figure 2 shows a typical site, with installed monitoring equipment.

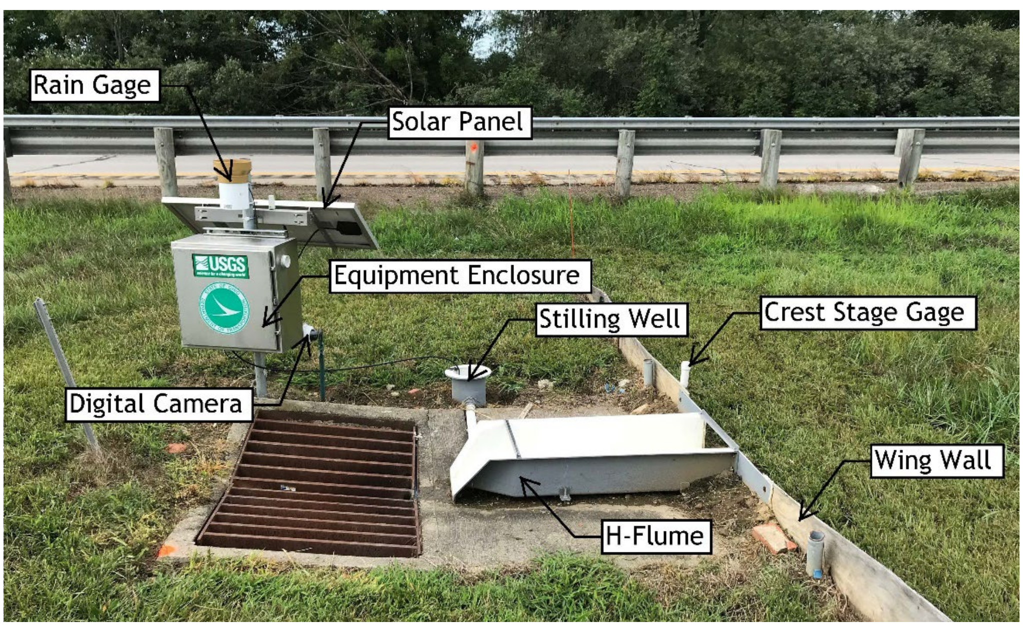


**Figure 2: Installed Monitoring Equipment**

## 2.3 Data collection

The data collected at each site included precipitation data and H-flume stage as well as digital photographs. The stage was converted to discharge through the use of H-flume manufacturer rating tables. Data (rainfall, stage) was recorded every 1 minute. Digital images were recorded daily during normal operation and more frequent during runoff events. The frequency of image collection was determined based on storage capability of the logger and need for quality assurance images.

Data was collected from March 2018 to December 2018 to monitor the existing conditions runoff. Afterwards, the soil was amended, and the grass was allowed to reestablish itself. A second monitoring period from May 2019 to September 2020 monitored the post-amendment runoff conditions. Monitoring equipment remained in place for the whole post-amendment monitoring period; however, usable data was minimal during the winter months. Data was retrieved hourly and processed by USGS into the National Water Information System (NWIS).

Data was retrieved hourly and processed by USGS. After processing, the data was immediately displayed on the USGS National Water Information System: Web Interface (NWISWeb) (http://waterdata.usgs.gov) where it could be viewed or downloaded by any interested party. This data will remain publicly available in perpetuity, and is accessible via searching by Flume Number or Rain Gage Number (shown in Table 2).

The time lag between processing of data and display on NWISWeb typically was less than 2-3 minutes; however, the lag between recording of a measurement in the field and display on NWISWeb could be as long as an hour (the lag being dependent on the time interval between data retrievals). Each monitoring site was identified by a unique site number and location, shown in Table 2.

**Table 2: NWISWeb Site Identification**

| Site | Flume Number | Rain Gage Number | Location |
|---|---|---|---|
| 1 | 400448082452500 | 400448082452501 | SR 161 nr Beech Road nr New Albany OH |
| 2 | 400423082353500 | 400423082353501 | SR 37 E of Moots Run nr Alexandria OH |
| 3 | 400918082012700 | 400918082012701 | SR 16 nr SR 60 nr Dresden OH |
| 4 | 404702081193500 | 404702081193501 | SR 30 nr Trump Avenue nr Canton OH |
| 5 | 404527081325100 | 404527081325101 | SR 30 nr 17th Street SW nr Canton OH |
| 6 | 404755081531300 | 404755081531301 | SR 30 E of Apple Creek nr Wooster OH |
| 7 | 404631081545100 | 404631081545101 | SR 83 near Selby Road nr Wooster OH |
| 8 | 404543082490800 | 404543082490801 | SR 30 nr Biddle Road nr Gallion OH |
| 9 | 404755082550600 | 404755082550601 | SR 30 nr Twp Rd 13 nr Bucyrus OH |
| 10 | 404901083053600 | 404901083053601 | SR 30 nr Twp Rd 1 nr Bucyrus OH |
| C1 | 400423082354100 | 400423082353501 | SR 37 W of Moots Run nr Alexandria OH |
| C2 | 404755081531900 | 404755081531301 | SR 30 W of Apple Creek nr Wooster OH |

## 2.4 Operation and maintenance

The sites were visited by USGS personnel at least every 4 weeks to collect back-up data files, perform routine maintenance, cleaning, and calibration. Timed manual volumetric checks of flow rates were performed when possible to validate the H-flume ratings. Checks on the accuracy of stages measured by the pressure transducers were made by comparing manual determinations of stage (digital images or crest stage marks) against concurrent values of stage measured with the pressure transducers.

The research team continually monitored all equipment during the course of the data collection period to ensure satisfactory performance.

# 3.0 EXISTING CONDITIONS MONITORING

Existing conditions monitoring was performed from April 2018 to December 2018. Data collected at all 12 monitoring sites is summarized below. Additional details regarding the existing conditions monitoring results can be found in the USGS report ‘Assessment of Runoff Volume Reduction Associated with Installation of Soil Amendments in Portions of Highway Median Strip Catchments in Ohio, 2018–2020, located in Appendix C.

## 3.1 Existing Conditions Results

A rainfall-runoff event was defined to begin at the time of the first measured rainfall and end when rainfall and runoff (if any) ceased and remained ceased for at least 3 hours. The number of events measured at each monitoring site during the existing conditions period ranged from 119 to 186 and averaged 141. The amount of rainfall measured during a single event in the existing conditions period ranged from 0.01 to 4.25-inches, with a median rainfall amount of 0.10-inches. On average, about one third (34%) of the existing conditions rainfall events resulted in measurable runoff.

In order to quantify rainfall to runoff percentages, the amount of rainfall (recorded in 0.01-inch increments) was multiplied by the drainage area of each site to obtain a total volume of rain in cubic feet. The rainfall was assumed to be uniform over the drainage area for each site.

The instantaneous flow rates within the H-flumes were measured/recorded every minute, in cubic feet per second. Therefore, the runoff volume (cubic feet) was computed by multiplying each instantaneous flow rate value by 60 and summing the 1-minute volumes. The runoff percent was calculated by dividing the rainfall volume by the runoff volume. A summary of the existing conditions monitoring results are presented in Table 3. All data is available on the USGS National Water Information System: Web Interface (NWISWeb) (http://waterdata.usgs.gov).

**Table 3: Existing Conditions Monitoring Results**

| Site | Drainage Areas (acres) | Number of Rain Events | Number of Rain Events with Runoff | Percent of Rain Events with Runoff | Total Rainfall (in) | Total Rainfall Volume ($ft^3$) | Total Runoff Volume ($ft^3$) | Runoff Percent |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.05 | 129 | 55 | 42.60% | 46.60 | 346,551 | 162,304 | 46.80% |
| 2 | 1.03 | 136 | 54 | 39.70% | 48.90 | 182,720 | 87,036 | 47.60% |
| 3 | 0.51 | 119 | 50 | 42.00% | 39.40 | 72,867 | 27,278 | 37.40% |
| 4 | 1.64 | 174 | 64 | 36.80% | 49.70 | 295,576 | 64,136 | 21.70% |
| 5 | 1.88 | 135 | 49 | 36.30% | 39.00 | 266,015 | 80,940 | 30.40% |
| 6 | 0.97 | 186 | 42 | 22.60% | 43.50 | 153,238 | 13,746 | 9.00% |
| 7 | 1.89 | 132 | 61 | 46.20% | 39.70 | 272,027 | 129,373 | 47.60% |
| 8 | 0.82 | 144 | 24 | 16.70% | 35.30 | 105,134 | 8,622 | 8.20% |
| 9 | 0.83 | 133 | 39 | 29.30% | 33.00 | 99,486 | 17,899 | 18.00% |
| 10 | 1.47 | 132 | 61 | 46.20% | 32.90 | 175,558 | 41,824 | 23.80% |
| C1 | 2.42 | 130 | 46 | 35.40% | 45.00 | 395,571 | 110,692 | 28.00% |
| C2 | 0.78 | 146 | 30 | 20.50% | 36.20 | 102,412 | 5,209 | 5.10% |

### 3.1.1 Notable Finding

The research team observed some unexpected runoff characteristics at Site 7. Measureable flow was recorded in the H-flume well after precipitation had ended. It took longer for measurable flow to cease following precipitation at Site 7, than at any other monitoring site. The research team inspected all monitoring equipment at the site and determined that the results were accurate, and not caused by equipment malfunction. This abnormality was observed only at Site 7, and occurred throughout existing conditions monitoring, leading the research team to conclude that it was most likely caused by groundwater influence, due to high water table. As a result, Site 7 experienced the highest runoff percent and highest percent of rain events resulting in runoff of any site.

# 4.0 SOIL AMENDMENT PLANS

## 4.1 Amendment Materials Reviewed

Soil amendment, for the purpose of this document, is the process of improving the soil porosity, texture, and capacity to hold moisture in order to improve the soils long-term capacity for infiltration and exfiltration. Soil amendments can also improve plant growth and increase surface roughness, which improves the soils ability to retain water and resist erosion. In general, soil amendments allow soils to retain more water and then slowly release the moisture.

Amendment materials researched included natural and manufactured materials. To manage costs and constructability, materials that are readily available in Ohio, materials that Ohio highway contractors typically deal with, and materials that are not cost prohibitive are desired. The following materials were reviewed for this research. Detailed discussion of these materials is located in Appendix D.

1. Compost: an organic soil amendment, derived from organic waste materials, such as yard clippings and wood wastes.
2. Sand: a granular material composed of finely divided rock and mineral particles
3. Gravel: a loose aggregation of small water-worn or pounded stones
4. Gypsum: a soft white or gray mineral consisting of hydrated calcium sulfate.
5. Expanded Shale: formed when shale is crushed and fired in a rotary kiln. This process causes tiny air spaces in the shale to expand.
6. Biochar: charcoal that is produced by pyrolysis of biomass in the absence of oxygen.
7. Crumb rubber: recycled rubber produced from automotive and truck scrap tires.
8. Peat moss: a large absorbent moss that grows in dense masses on boggy ground, where the lower parts decay slowly to form peat deposits.
9. Zeolite: minerals that contain mainly aluminum and silicon compounds

## 4.2 Soil Amendment Design

Based on a variety of factors discussed in Appendix D, including infiltration/exfiltration benefits, vegetation benefits, material cost/availability, constructability, previous research efforts, etc., the research team selected the following materials for further evaluation and inclusion in the amended soil design.

1. Compost: adding compost will increase the soils ability to infiltrate and exfiltrate water and greatly increase its ability to maintain a thicker and more vigorous stand of grass than the existing soils. Compost alone is commonly used throughout the U.S. as a soil amendment.
2. Sand: sand is added to increase soil texture and porosity which will increase the soils ability to infiltrate and exfiltrate water. Incorporating sand as a sole amendment has rarely been used.

Ohio C and D soils are low in organic content which reduces their ability to maintain vigorous stands of grass. Adding sand alone further decreases the organic content of the soils and can increase its erodibility.

3. Expanded Shale: expanded shale is included for the same reason as sand, to increase the soils ability to infiltrate and exfiltrate water. Benefits of expanded shale over sand is: expanded shale is more porous and has a greater ability to absorb water than sand. However, the expanded shale comes at a higher average cost than sand.

While establishing the composition of the proposed soil amendments, the research team considered various quantities/combinations of materials, depth of amendment, and installation/incorporation procedure. Emphasis was placed on creating a soil amendment mix that reduced stormwater runoff volume, while also maximizing constructability, maintaining vehicle safety (such as a vehicle tire catching in loose soil), and overall cost-performance benefit.

The research team determined that the ideal soil amendment composition should combine the organic/nutrient benefits of compost with the soil texture/porosity benefits of sand and expanded shale. Organic soil amendments absorb water and store water until the water is infiltrated, evaporated, or absorbed by plants. Compost amendments increase water holding and retention, improve infiltration and exfiltration, and increase nutrient availability in the existing soil. Sand and expanded shale will increase soil texture and infiltration rates by creating larger pore spaces within otherwise poorly drained and aerated clayey or compacted soils. It was determined that two mix designs would be tested. One with compost and sand, the other with compost and expanded shale to allow comparison between the materials.

When evaluating amendment depth, the research team considered a maximum depth of 12-inches, however, amending the existing soil to that depth would need to occur in layers, which affects timing, costs, and material stockpiling/removal. Therefore, the amendments were limited to an incorporation depth of 6 inches or less. It was determined that two amendment depths would be tested. One at 4-inches and one at 6-inches, to allow performance comparison between the depths.

The combination of two varied material mixes and two varied depths resulted in four unique amendment designs. Table 4 summarizes the percentages of materials and amendment depths to be tested.

**Table 4: Final Recommended Soil Amendment Design**

| Mix Design | Incorporation Depth (in.) | Native Soil (%) | Compost (%) | Sand (%) | Expanded Shale (%) |
|---|---|---|---|---|---|
| A | 4 | 50 | 31 | 19 | 0 |
| B | 4 | 50 | 31 | 0 | 19 |
| C | 6 | 54 | 29 | 17 | 0 |
| D | 6 | 54 | 29 | 0 | 17 |

The target inclusion rate of compost was chosen in an attempt maximize the soils ability to maintain a vigorous stand of grass while keeping its ability to withstand traffic loads with limited-to-no rutting. The inclusion rate of sand/expanded shale was chosen so that a silty clay would become a clay loam after its incorporation into the existing soil. Detailed material specifications and soil amendment construction procedure is located in Appendix D.

## 4.3 Amendment Locations

The installation locations for the various soil amendment designs were selected in order to create an even distribution of amendment material mixes and depths.

1. Among sites of varying amendment areas.
2. Across the different rainfall zones.

When possible, different combinations of amendment mixes and depths were located near one another in order to provide opportunities for data comparison under similar rainfall conditions. The location of each amendment mix to be installed is shown in Figure 3.

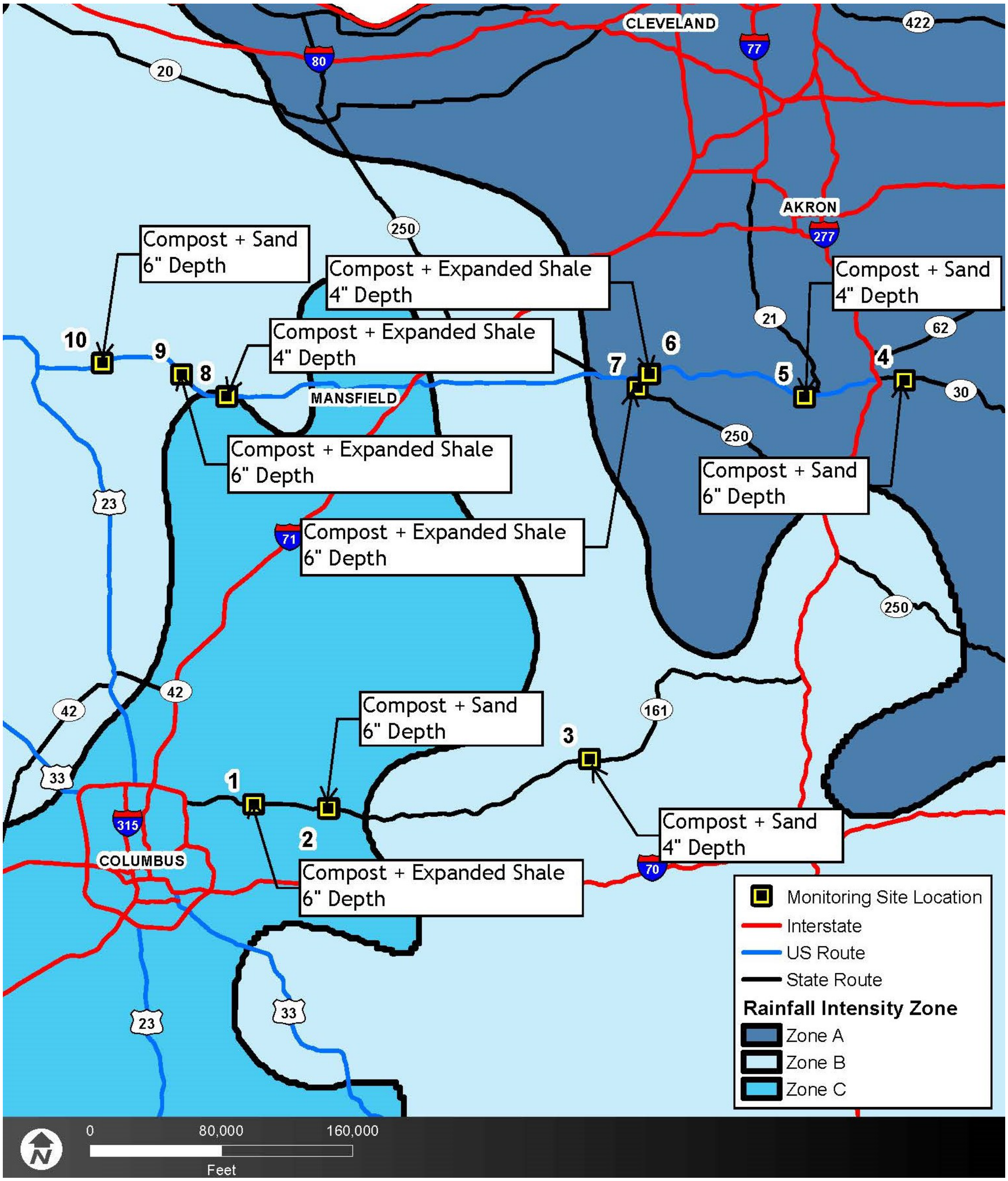


**Figure 3: Soil Amendment Locations**

# 5.0 SOIL AMENDMENT INSTALLATION

## 5.1 Plans and Specifications

Construction plans were prepared for the proposed soil amendment installation. These plans contained all pertinent information for successful installation of the soil amendment designs, including: site location, limits of construction, maintenance of traffic, material specifications, soil amendment details, and means of construction. Some minor field modifications were made during construction, as recorded on red-lined construction drawings, which are located in Appendix E.

## 5.2 ODOT District Coordination and Maintenance of Traffic

The research team coordinated construction with the local County/City maintenance crews, and oversaw maintenance of traffic during construction. All local maintenance crews were notified prior to beginning construction in order to avoid any maintenance/construction conflicts. The ODOT county maintenance crews also provided maintenance of traffic for sites 1, 2, 3, 5, 6, and 7. The City of Canton Street Department performed maintenance of traffic for site 4. The contractor responsible for installing the soil amendments, BUDS Inc., provided maintenance of traffic for sites 8, 9, and 10.

## 5.3 Construction Schedule

The construction and installation of the proposed soil amendments began in April 1, 2019. Construction and site stabilization was completed by May 23, 2019 so there was time for vegetation to reestablish prior to post-amendment flow monitoring to begin. Soil amendments were not installed at the 2 control sites. The construction schedule for each site is shown in Table 5.

**Table 5: Soil Amendment Construction Dates**

| Site | Amendment Mix | Construction Start Date | Construction End Date |
|---|---|---|---|
| 1 | 6” Compost + Expanded Shale | 04/10/2019 | 04/19/2019 |
| 2 | 6” Compost + Sand | 04/04/2019 | 04/10/2019 |
| 3 | 4” Compost + Sand | 04/01/2019 | 04/02/2019 |
| 4 | 6” Compost + Sand | 05/20/2019 | 05/23/2019 |
| 5 | 4” Compost + Sand | 05/13/2019 | 05/21/2019 |
| 6 | 4” Compost + Expanded Shale | 05/08/2019 | 05/13/2019 |
| 7 | 6” Compost + Expanded Shale | 05/01/2019 | 05/07/2019 |
| 8 | 4” Compost + Expanded Shale | 04/25/2019 | 04/30/2019 |
| 9 | 6” Compost + Expanded Shale | 04/24/2019 | 04/25/2019 |
| 10 | 6” Compost + Sand | 04/22/2019 | 04/24/2019 |
| C1 | None | N/A | N/A |
| C2 | None | N/A | N/A |

## 5.4 Vegetation Establishment

The final step in the construction of the soil amendments was to re-establish a full stand of vegetation in order to return the cover condition to pre-construction conditions. Full establishment of vegetation is important in order to provide an accurate comparison of existing conditions to post-amendment runoff volume. Therefore, it was critical that the sites reach full vegetation/stabilization as quickly as possible. However, the research team found that several sites were experiencing issues with the grass/vegetation reaching full establishment.

The team employed mitigation actions, including spot treatment of localized bare patches with seeding, hand broadcast, and hydro-seeding for those with significant issues, in an attempt to improve the vegetated condition of the amended sites. These mitigation efforts were moderately effective, but many sites did not appear to reach the same density or quality of vegetation as the pre-amendment condition.

### 5.4.1 Factors Impacting Vegetation

During construction, the contractor obtained compost from Ohio EPA Class 4 composting facilities, as required by the compost specification, but no material testing data was provided to ensure that it met the other chemical/physical properties specified in the construction drawings. Near the completion of construction, inspectors observed that the compost appeared to differ from what was specified. Material samples from each compost supplier were sent to a laboratory for analysis, and the results confirmed that the compost did not meet every parameter of the specification. Table 6 summarizes the laboratory tests of the two compost sources used for construction, compared to the specification.

**Table 6: Compost Testing Results**

| Compost Specification Requirement | Sample 1 (Kurtz Bros., Inc.) | Sample 2 (Earth 'n Wood Products, Inc.) |
|---|---|---|
| Originate from OEPA Class IV Composting Facility | YES | YES |
| Meet ODOT 659.06 (nitrogen content 1.4% or greater) | 1.15% | 0.47% |
| 100% material pass 1/2 inch screen | 100% | 100% |
| 98% material pass 3/4 inch screen | 82.5% | 93.2% |
| pH between 5.5 and 8.5 | 8.1 | 8.2 |
| Inert material less than 1% | 0 | 0 |
| Organic content between 35% and 65% | 37.77 | 29.60 |
| Stability = 7 and/or Maturity greater than 80% | 5* | 5* |
| Moisture content between 30% and 60% | 59.15 | 42.62 |
| No visible free water or dust | YES | YES |

*Solvita Maturity Index calculation was used by the laboratory.

Although the compost from the two suppliers are similar, neither appear to be at the maturity level specified nor do they both meet the parameters for nitrogen content or sieve size. These factors may have contributed to the vegetation establishment issues.

The research team also conducted soil analyses at the amended soil sites to analyze potential parameters relating to vegetative growth success. The analysis included field collection of soil samples, visual soil profile observations, and laboratory testing. This analysis found that the various soil amendment components (native soil, compost, sand/expanded shale) were stratified in many areas and not homogenously mixed. The lack of proper incorporation of the soil amendment into the existing soil may have also contributed to the vegetation establishment issues.

Based on the findings of the soil analysis, the research team modified the compost specification and construction procedure to improve vegetation establishment. The team also added a requirement for contractors to submit compost laboratory test results prior to construction. These modified compost specification and construction procedures were not incorporated into the soil amendments at the monitoring sites but will be recommended for future applications of the soil amendment BMP. See Section 10.0 of this report for the research team's final recommendations for material specifications and construction procedures.

The complete soil analysis report, located in Appendix F, provides a detailed summary of the data collection, analysis, and conclusions/recommendations from the testing.

## 7.0 POST-AMENDMENT FLOW MONITORING

Post-amendment conditions monitoring was performed from May 2019 to September 2020. Data collected at all 12 monitoring sites is summarized below. The project team originally scheduled post-amendment flow monitoring to conclude by winter of 2019. Due to delays in vegetation establishment, the research team decided to extend post-amendment monitoring an additional year. Extending the monitoring to the end of 2020 allowed for more post-amendment monitoring, better evaluation of vegetation establishment, and increased confidence in the monitoring results.

Data collected at all 12 monitoring sites is summarized below. The procedures and methodologies from the existing conditions monitoring remained the same during post-amendment monitoring. Additional details regarding the post-amendment conditions monitoring results can be found in the USGS report 'Assessment of Runoff Volume Reduction Associated with Installation of Soil Amendments in Portions of Highway Median Strip Catchments in Ohio, 2018–2020', located in Appendix C.

### 7.1 Post-Amendment Conditions Results

The number of rain events measured at each study site during the post-amendment period ranged from 166 to 266 and averaged 209. The amount of rainfall measured during an event in the post-BMP period ranged from 0.01 to 4.18 inches, with a median rainfall amount of 0.11 inches. About one third (37%) of the post-amendment period events had measurable runoff and nearly one quarter (28%) of the post-amendment events at CNT sites had measurable runoff. A summary of the post-amendment conditions monitoring results are presented in Table 7. All data is available on the USGS National Water Information System: Web Interface (NWISWeb) (http://waterdata.usgs.gov).

**Table 7: Post-Amendment Conditions Monitoring Results**

| Site | Drainage Areas (acres) | Number of Rain Events | Number of Rain Events with Runoff | Percent of Rain Events with Runoff | Total Rainfall (in) | Total Rainfall Volume ($ft^3$) | Total Runoff Volume ($ft^3$) | Runoff Percent |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.05 | 195 | 77 | 39.50% | 59.50 | 442,620 | 143,100 | 32.30% |
| 2 | 1.03 | 172 | 69 | 40.10% | 61.70 | 230,728 | 83,197 | 36.10% |
| 3 | 0.51 | 229 | 79 | 34.50% | 66.70 | 123,519 | 24,206 | 19.60% |
| 4 | 1.64 | 214 | 57 | 26.60% | 55.60 | 330,700 | 61,869 | 18.70% |
| 5 | 1.88 | 180 | 73 | 40.60% | 57.10 | 389,741 | 143,568 | 36.80% |
| 6 | 0.97 | 231 | 62 | 26.80% | 58.00 | 204,224 | 13,255 | 6.50% |
| 7 | 1.89 | 166 | 81 | 48.80% | 55.60 | 381,661 | 173,975 | 45.60% |
| 8 | 0.82 | 227 | 54 | 23.80% | 64.80 | 192,765 | 25,340 | 13.10% |
| 9 | 0.83 | 217 | 108 | 49.80% | 54.60 | 164,625 | 35,649 | 21.70% |
| 10 | 1.47 | 187 | 98 | 52.40% | 52.90 | 282,440 | 84,972 | 30.10% |
| C1 | 2.42 | 223 | 87 | 39.00% | 63.60 | 558,071 | 148,607 | 26.60% |
| C2 | 0.78 | 266 | 48 | 18.00% | 64.30 | 182,837 | 5,449 | 3.00% |

# Research Findings and Conclusions

The USGS prepared a detailed analysis report that thoroughly breaks down the existing conditions and post-amendment monitoring data. This report presents a comprehensive evaluation of variables and factors that may impact the monitoring results. Below is a brief summary of the research findings and conclusions. The detailed monitoring results analysis can be found in the USGS report 'Assessment of Runoff Volume Reduction Associated with Installation of Soil Amendments in Portions of Highway Median Strip Catchments in Ohio, 2018–2020, referenced in Appendix C.

## 8.0 RAINFALL CHARACTERISTICS

Rainfall depth, intensity, durations, etc., have a direct effect on stormwater runoff. Therefore, it was important for the research team to have a thorough understanding of the rainfall observed during the monitoring period. The rainfall data collected during the existing conditions and the post-amendment monitoring periods were compared to determine if there were any appreciable differences from one period to the next, that may affect the runoff data.

The distribution of rainfall amounts associated with events was similar in the existing condition and post-amendment monitoring periods. The distribution of rainfall events observed over the course of the research project is shown in the boxplot, in Figure 4. This plot shows that rainfall events of similar magnitude occurred at a similar frequency during both the existing conditions monitoring period and the post-amendment monitoring period. Because the duration of the post-amendment monitoring period was greater than the existing condition monitoring period, there are more data points (rainfall events) in the post-amendment period.

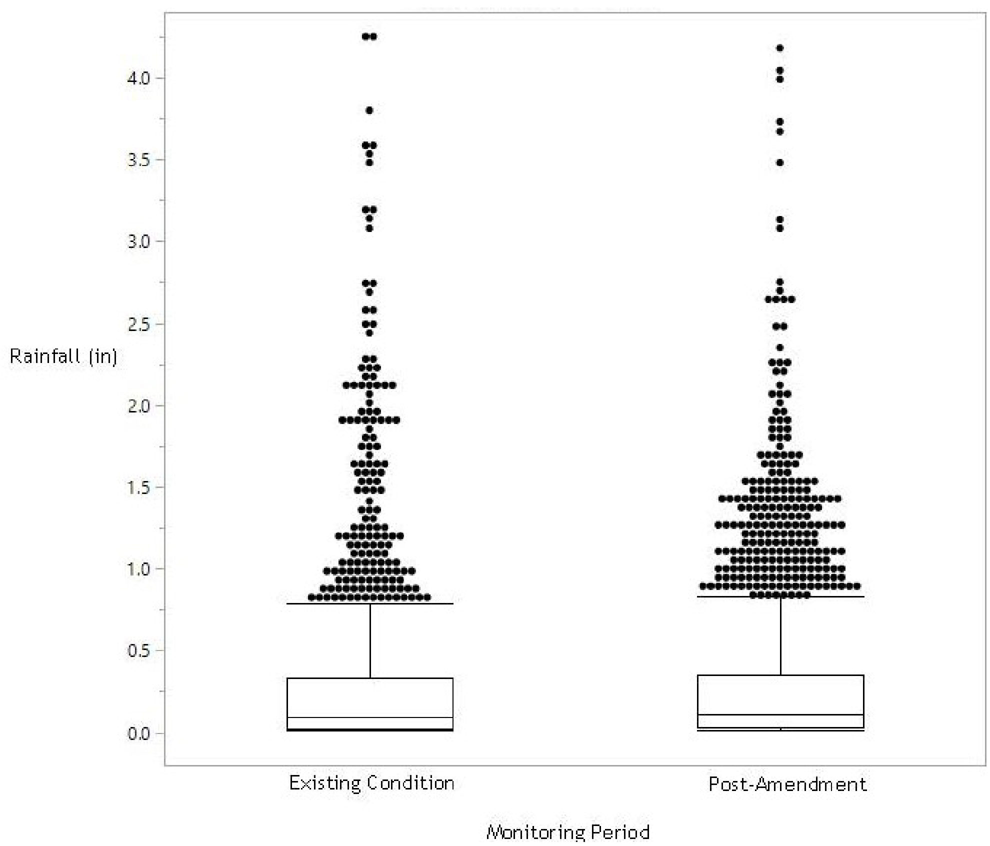


**Figure 4: Rainfall Distribution Plot**

# 9.0 RUNOFF CHARACTERISTICS

## 9.1 Runoff Percent Comparison

Runoff percent was calculated as the total volume of runoff during an event expressed as a percentage of the total volume of rainfall falling over the catchment area, assuming a spatially uniform distribution of rainfall. This runoff percent was computed for each rainfall event, and the values from the existing condition monitoring period were compared to the values from the post-amendment monitoring period.

There were appreciable differences between sites in the distribution of runoff percentages, both during the existing condition and post-amendment periods. Table 8 shows the aggregated runoff percent, for each site, for the entirety of existing and amended condition monitoring periods. Some sites experienced a decrease in total runoff percent, while others experienced an increase in runoff percent, after the amendments were installed.

**Table 8: Runoff Percent Comparison**

| Site | Soil Amendment Material | Amendment Depth (in) | Existing Condition Runoff Percent | Amended Condition Runoff Percent | Change in Runoff Percent |
|---|---|---|---|---|---|
| 1 | Compost + Expanded Shale | 6” | 46.80% | 32.30% | -14.50% |
| 2 | Compost + Sand | 6” | 47.60% | 36.10% | -11.60% |
| 3 | Compost + Sand | 4” | 37.40% | 19.60% | -17.80% |
| 4 | Compost + Sand | 6” | 21.70% | 18.70% | -3.00% |
| 5 | Compost + Sand | 4” | 30.40% | 36.80% | +6.40% |
| 6 | Compost + Expanded Shale | 4” | 9.00% | 6.50% | -2.50% |
| 7 | Compost + Expanded Shale | 6” | 47.60% | 45.60% | -2.00% |
| 8 | Compost + Expanded Shale | 4” | 8.20% | 13.10% | +4.90% |
| 9 | Compost + Expanded Shale | 6” | 18.00% | 21.70% | +3.70% |
| 10 | Compost + Sand | 6” | 23.80% | 30.10% | +6.30% |
| C1 | None | N/A | 28.00% | 26.60% | -1.40% |
| C2 | None | N/A | 5.10% | 3.00% | -2.10% |

During the existing conditions monitoring period, the average runoff percent for all sites was approximately 27%. During the post-amendment monitoring period, the average runoff percent for all sites was approximately 24%. When not including control sites, the average runoff percent was 29% during the existing conditions period, and 26% during the post-amendment period.

### *9.1.1 Groundwater Influence*

As discussed in Existing Conditions Results, Section 3.1.1 of this report, there were suspected groundwater influences affecting the flow monitoring results at Site 7. These groundwater influences persisted through the post-amendment monitoring period as well. As a result, Site 7 had the highest runoff percent of any monitoring site, making it somewhat of an outlier.

When Site 7 is removed from the monitoring data, the average runoff percent was 25% during the existing conditions period, and 22% during the post-amendment period. When not including control sites, the average runoff percent was 27% during the existing conditions period, and 24% during the post-amendment period.

## 9.2 Event Runoff Percent Comparison

Event runoff percent differs from volumetric runoff percent in that it does not look at the percent of stormwater runoff in volumetric terms, but rather, the percent of rainfall events that resulted in runoff, regardless of the measured quantity of runoff. A rainfall-runoff event was defined to begin at the time of the first measured rainfall and end when rainfall and runoff (if any) ceased and remained ceased for at least 3 hours.

Table 9 shows a summary of the event runoff percent, for each site, for the entirety of existing and amended condition monitoring periods. About 34% of the existing condition rain events resulted in measurable runoff whereas about 37% of the post-amendment period events had measurable runoff. Only about 28% of the events at control sites had measurable runoff during the existing conditions period and during the post-amendment monitoring period. Some sites experienced a decrease in event runoff percent, while other experienced an increase in event runoff percent, after the amendments were installed. However, in aggregate, the percentage of events with runoff increased slightly from the existing condition to the post-amendment period at amended sites and remained about the same at control sites.

**Table 9: Event Runoff Percent Comparison**

| Site | Soil Amendment Material | Amendment Depth (in) | Existing Condition Percent of Rain Events with Runoff | Amended Condition Percent of Rain Events with Runoff | Change in Percent of Rain Events with Runoff |
|---|---|---|---|---|---|
| 1 | Compost + Expanded Shale | 6” | 42.60% | 39.50% | -3.10% |
| 2 | Compost + Sand | 6” | 39.70% | 40.10% | +0.40% |
| 3 | Compost + Sand | 4” | 42.00% | 34.50% | -7.50% |
| 4 | Compost + Sand | 6” | 36.80% | 26.60% | -10.10% |
| 5 | Compost + Sand | 4” | 36.30% | 40.60% | +4.30% |
| 6 | Compost + Expanded Shale | 4” | 22.60% | 26.80% | +4.30% |
| 7 | Compost + Expanded Shale | 6” | 46.20% | 48.80% | +2.60% |
| 8 | Compost + Expanded Shale | 4” | 16.70% | 23.80% | +7.10% |
| 9 | Compost + Expanded Shale | 6” | 29.30% | 49.80% | +20.40% |
| 10 | Compost + Sand | 6” | 46.20% | 52.40% | +6.20% |
| C1 | None | N/A | 35.40% | 39.00% | +3.60% |
| C2 | None | N/A | 20.50% | 18.00% | -2.50% |

## 9.3 Statistical Analysis

As part of the comprehensive data analysis, the USGS looked at the statistical significance of each variable that may be contributing to stormwater runoff. The intent of this analysis was to determine which variables had the greatest correlation with measured runoff. The analysis considered the following variables.

1. Rainfall totals
2. Antecedent condition (7-day total rainfall preceding a runoff event)
3. A cross-product term the rainfall total and the 7-day total rainfall preceding a runoff event
4. Amendment type (compost + sand or compost + expanded shale)
5. Amendment thickness (4-inch or 6-inch)
6. Drainage area

7. Longitudinal channel slope
8. Percentage of the drainage area that is paved
9. Intercept term (the intercept is the value of the dependent variable when the sum of weighted contributions of the explanatory variables to the value of the dependent variable is zero.).

The statistical analysis showed that amendment material (compost + sand vs. compost + expanded shale) and amendment depth (4-inches vs. 6-inches) did not have as strong of a correlation with measured runoff as other variables did (such as total rainfall and drainage area). A detailed breakdown of these variables and their correlation to stormwater runoff is provided in the USGS report located in Appendix C.

Another objective of this analysis was to verify whether any runoff difference between the existing conditions monitoring period and the post-amendment monitoring period was substantial enough to be considered statistically significant. In simple terms, statistical significance means that the measured runoff variation between the monitoring periods is caused by something other than chance or coincidence. However, it is important to note that statistical significance of an explanatory factor does not necessarily indicate direct causation

When all rainfall events were analyzed, three sites were found to be statistically significant (BMP02, BMP03, and BMP04). The analysis indicated that proportionally, more events had lower runoff percentages during the post-amendment period than during the existing condition period, at these three sites. However, when only rainfall events that generated measurable runoff were analyzed, sites BMP01, BMP02, and BMP03 were found to be statistically significant. The statistical analysis of runoff percentage for the other six amended sites and the control sites did not differ enough between the existing condition and post-amendment period to be considered statistically different.

The research team did not find a strong statistical correlation between stormwater runoff volume and amendment material (compost + sand vs compost + expanded shale). This is to say that there was little statistical difference between the post-amendment runoff results at the sites with compost and sand amendments vs. sites with compost and expanded shale amendments. The same statistical relationship was present when analyzing the depth of soil amendment (4-inch or 6-inch). There was little statistical difference between the post-amendment runoff results at the sites with 4-inch amendments vs. sites with 6-inch amendments.

## 9.4 Cost Benefit Analysis

In terms of material cost, expanded shale is approximately 67% more expensive than sand, per cubic yard ($75 per CY vs. $45 per CY). The additional material, excavation, and installation costs required to construct the 6-inch soil amendment is approximately 33% more expensive, per acre, compared to the 4-inch soil amendment.

Based on the monitoring results and statistical analysis, the additional cost associated with expanded shale material compared to sand is not warranted, as it does not provide any statistically significant volume reduction benefit. Similarly, the additional cost to install/incorporate the soil amendment to a depth of 6-inch, compared to 4-inches, was also not found to be cost-beneficial. Therefore, the 4-inch compost and sand amendment was the most cost-effective soil amendment alternative without sacrificing volume reduction efficacy.

The research team developed a high level cost estimate for construction/installation of the 4-inch compost and sand, soil amendment BMP, as detailed in Table 10.

**Table 10: Cost to Amend 1 Acre of Soil**

| Item | Unit Cost | Unit | Quantity (per acre) | Total Cost (per acre) |
|---|---|---|---|---|
| Compost | $25.00 | CY | 235 | $5,875 |
| Sand | $45.00 | CY | 101 | $4,545 |
| Excavation | $18.00 | CY | 269 | $4,842 |
| Incorporation (soil ripping/rototilling/compaction) | $2.00 | SY | 4,840 | $9,680 |
| Seeding | $1.00 | SY | 4,840 | $4,840 |
| Erosion Control Mat | $2.00 | SY | 4,840 | $9,680 |
| Total Cost Per Acre | | | | $39,462 |

The construction cost for the BMP is estimated to be $39,462 per acre of amended area, which equates to approximately $0.91 per square foot. These costs may vary depending on the size/scope of the project and quantities of amendment material needed. As a result, this estimate represents a very conservative, high-end cost for the soil amendment BMP. However, if the soil amendment BMP were included in a large construction project, the costs for some of the items would be greatly reduced or eliminated, in relation to the total construction activity.

For example, the excavation quantity necessary for the soil amendment BMP would likely be minimal compared to the overall project excavation quantity. Similarly, the side slopes of a roadway project will require seeding and erosion protection regardless of whether the soil amendment BMP is constructed there or not. As a result, the costs for these items can be assumed to be negligible for a typical large roadway project. If the costs for excavation, seeding, and erosion control mat are removed from the cost estimate, the resultant total cost to construct the soil amendment BMP is $20,100 per amended acre ($0.46 per square foot).

In addition to performing cost-benefit analysis to determine the most cost-efficient soil amendment BMP design, the research team also analyzed the cost-benefit of the soil amendment BMP compared to traditional stormwater volume BMPs. For this analysis the research team compared the 4-inch compost and sand soil amendment to various ODOT post-construction water quantity BMPs. Table 11 contains high level BMP cost estimates, based on research conducted by ODOT in 2015. These cost estimates represent the capital cost to construct the designated BMP in order to treat 1-acre of tributary ODOT right-of-way.

**Table 11: ODOT BMP Capital Costs**

| BMP Type | Capital Cost per Acre Treated |
|---|---|
| Bioretention Cell | $25,000 |
| Detention Basin | $25,000 |
| Infiltration Basin | $25,000 |
| Infiltration Trench | $25,000 |
| Retention Basin | $25,000 |
| Constructed Wetland | $40,000 |
| Underground Detention | $40,000 |

Based on the design criteria of the amended soil BMP, detailed in Section 11.0 of this report, treating 1-acre of tributary ODOT right-of-way, requires 0.625 acres (27,225 square feet) of amended soil area. Using the conservative cost estimate of $0.91 per square foot, calculated above, the cost to construct the amended soil BMP to treat 1-acre of tributary ODOT right-of-way, is approximately $24,775. However, using the alternative cost estimate of $0.46 per square foot, which assumes significant cost savings based on large scale roadway construction projects, the cost to construct the amended soil BMP to treat 1-acre of tributary ODOT right-of-way, is approximately $12,524.

Therefore, assuming the worst case scenario, the cost to treat 1-acre of tributary ODOT right-of-way using the soil amendment BMP is less than or equal to the cost of the cheapest stormwater quantity BMPs. But for the typical large roadway construction project, the soil amendment BMP can be expected to be approximately half the cost of any other ODOT stormwater quantity BMP.

These costs do not account for any potential right-of-way acquisition, which typically results in a significant increase to the cost to construct a traditional ODOT stormwater quantity BMP. While the amended soil BMP will require a larger footprint than other stormwater quantity BMP, that amended area will likely always be within the project right-of-way limits, eliminating the need for additional right-of-way acquisition.

## 9.5 Conclusion

The measured volume of stormwater runoff at the monitoring sites was generally lower than the research team expected. This was true for the existing conditions monitoring period and the post-amendment monitoring period. During the existing conditions monitoring period, the average runoff percent (total runoff volume divided by total rainfall volume) was approximately 29% (not including control sites). During the post-amendment monitoring period, the average runoff percent was approximately 26% (not including control sites).

When Site 7 is treated as an outlier, and removed from consideration due to the apparent groundwater impacts (as discussed in Sections 3.1.1 and 9.1.1 of this report), the average runoff percent in the post-amendment period is reduced from 26% to less than 24%. In this same scenario, the maximum runoff percent recorded at any monitoring site during the post-amendment period is 36.80%.

While the volume reduction from the existing condition to the amended condition was not as significant as the research team anticipated, the actual measured runoff percent generated from any given rainfall event was relatively low. This is an encouraging finding and is an overall positive outcome of the research. Even without the soil amendment significantly reducing the stormwater runoff volume, it does provide a benefit, by fortifying stormwater runoff performance. The installation of the amended soils increases the likelihood that the resultant runoff percent will be within an acceptable range, by providing consistent soil media within the top layer of soil.

The soils that ODOT projects commonly encounter are low quality; often times consisting of construction fill and low hydrologically conductive HSG C or D soils. These soils generally have poor nutrient levels and are low in organic content. The addition of compost, through soil amendment, will increase the organic content, nutrient levels, and overall quality of the native soil.

The typical scope and scale of an ODOT roadway project is well suited for construction of the soil amendment BMP. There are a number of cost-sharing activities that result in the BMP requiring very little additional effort than what would ordinarily be required for the roadway project alone. And unlike traditional ODOT stormwater BMPs, like detention basins and retention basins, the amended soil BMP is not expected to require additional right-of-way acquisition, making it an even more attractive option from a cost standpoint.

Based on stormwater runoff performance, soil quality benefits, and overall cost-benefit analysis, the research team determined the 4-inch compost and sand soil amendment (with some modification, as described in the Recommendations for Implementation Section) to be the most efficient for incorporation into the ODOT Locations and Design Manual, as a post-construction stormwater volume reducing BMP. The Amended Vegetated Filter Strip (AVFS) BMP should be implemented in a strip, parallel with the roadway, so that it can receive sheet flow directly from the paved roadway areas.

## Recommendations for Implementation

The research team determined that the 4-inch sand and compost amendment was the most efficient stormwater volume reducing soil amendment alternative. However, to ensure the amendment material (sand and compost) is thoroughly integrated into the native soil, a 6-inch incorporation depth is recommended. Therefore, the quantity of soil amendment material used in the 4-inch soil amendment, combined with an incorporation depth of 6-inches is being proposed for the Amended Vegetated Filter Strip (AVFS) BMP.

This equates to the addition/incorporation of 82 LB/SY (0.75-inches) of sand and 43 LB/SY (1.25-inches) of compost, into the existing soil, per the methods and procedures explained below. The resultant amendment material composition, by volume, is: 13% Sand, 21% Compost, and 67% Native Soil. Standard construction notes and details for the recommended AVF BMP are located in Appendix G.

# 10.0 CONSTRUCTION AND MATERIAL SPECIFICATIONS

## 10.1 Material Specifications

The Amended Vegetated Filter Strip materials should meet the following specifications.

1. **Sand**: Meet ODOT CMS 703.02 – Fine Aggregate.
2. **Soil Amendment Compost:**
    a. Soil amendment compost shall originate from an Ohio EPA Class IV Composting facility.
    b. 100% of material must pass the ½-inch screen, with 75% passing 1/4-inch screen.
    c. 5.5 < pH < 8.5
    d. Inert Material < 1%
    e. 35% < Organic Content < 65% (dry weight basis determined by Loss on Ignition)
    f. 20% < C:N ratio of < 25%
    g. Maturity > 80% (Solvita Index Value between 7 and 8). Parent material is no longer visible. Compost should be stable with regard to oxygen consumption and carbon dioxide generation.
    h. < 1,000 MPN/GTS Fecal Coliform and < 3 MPN/GTS Salmonella spp.
    i. 30% < Moisture Content < 60% wet basis
    j. Soil amendment compost samples should be taken from the material stockpiled by the supplier within 15 calendar days prior to initial application. Submit laboratory results to the Engineer for approval. Soil amendment compost that does not meet the specification shall not be used.

## 10.2 Construction Procedure

The Amended Vegetated Filter Strip construction/installation process should abide by the following steps.

1. **Soil Ripping**: Use a solid-shank ripper with teeth, traversing the area with 2 passes in each direction to a depth of 12 inches. Each pass is considered the width of the ripper, with teeth spaced no more than 12 inches apart. This may be accomplished with implements mounted to a tractor or dozer or use of a grader with appropriate implements (scarifier teeth), but must meet the 12-inch depth. If teeth are spaced greater than 12 inches, additional passes are required to meet a furrow spacing of 6 inches. Only perform ripping during dry conditions when soils are friable.

2. **Excavation:** Remove excess soil (approximately 2-inches), so that after the amendments have been incorporated into the existing soil, the existing ground surface profile will not appreciably change. This may not always be necessary depending on the site conditions and overall project construction sequence. However, it will likely be required for mitigation sites, where the soils are being amended, but the existing grade is being maintained.
3. **Amendment Placement and Incorporation:** Spread amendments over the ground surface in a uniform thickness to the specified amendment depth. Incorporate amendments with a rototiller or similar equipment into the soil to a depth of 6 inches. Continue tilling until all soil clods are reduced to a maximum size of 1-inch (25 mm) and the mixture is uniform. Incorporation should only be performed during dry conditions when soils are friable. Six passes (pass is the width of the machine) with a rototiller or similar is anticipated to meet the uniformity requirement.
4. **Fine Grading and Limited Compaction:** Perform fine grading to achieve the slope geometry and elevations specified in the plans. To achieve an approximate compaction of 85 to 90% maximum density, one pass with a rubber-tired or smooth drum roller is anticipated.
5. **Soil Amendment Compost Blanket:** Evenly spread a 0.5-inch thick layer of soil amendment compost over the ground surface.
6. **Seeding and Watering:** ODOT Class I – Lawn Mixture (ODOT Item 659.09) installed per Item 659. Rake seed into soil amendment compost. Contractor is responsible for establishing a minimum of 70% permanent vegetation coverage within the project schedule. Watering may be necessary.
7. **Fertilizer:** Apply the following fertilizer and rates. Follow ODOT Item 659.04 specification for application of fertilizer.
   - 1.0 lb./1,000 $ft^2$ potassium
   - 2.5 lb./1,000 $ft^2$ potash
   - 1.0 lb./1,000 $ft^2$ magnesium
8. **Erosion Control Matting:** ODOT CMS Item 712 – Type A Temporary Erosion Control Mat. Install per ODOT Item 671. Do not run machinery/equipment over the amended soils during installation of the erosion control mat.

## 11.0 DESIGN CRITERIA AND TREATMENT CREDIT

In collaboration with ODOT, the research team established the following design criteria and stormwater treatment credit methodology for the Amended Vegetated Filter Strip BMP. These criteria are based on current ODOT design standards and stormwater treatment requirements; and are proposed to be incorporated into the ODOT Location and Design Manual, Volume 2. Appendix H contains example scenarios that demonstrate how the stormwater treatment credit for the soil amendment BMP is calculated.

1. The AVFS BMP consists of the grassed portion of the graded shoulder, where the soils have been amended per the construction procedures and specification outlined in Section 10.0.
2. The AVFS can begin a minimum of 2-feet from the edge of the paved shoulder, or at any point further down the slope. AVFS must end a minimum of 2-feet above the toe of slope or ditch bottom.
3. The AVFS must be void of erosive gullies or rills.
4. All runoff must be sheet flow, with no concentrated flows to the AVFS.
5. Areas such as pavement, graded shoulder, or any grass slope that drain to the AVFS, and the AVFS area itself, receive treatment credit at the following rates:
   a. 60% credit for pavement area, graded shoulder area, or any grass slope area that sheet flows to AVFS.

b. 100% credit for the area of AVFS.

6. The tributary width draining to the AVFS can be larger than the AVFS width; however, the maximum tributary area width given credit is equal to the width of amended vegetated filter strip.
7. The minimum width of the AVFS is 4 feet.
8. The maximum slope of the AVFS or any area draining to the AVFS is 3:1.
9. All pervious area draining to the AVFS and the AVFS itself must maintain a minimum of 70% grass coverage.
10. Do not include any ditch bottom areas in the AVFS area since flow is concentrated at the ditch bottom.

# 12.0 MAINTENANCE

Minimal maintenance should be necessary to ensure continued functioning of Amended Vegetated Filter Strips. Maintenance requirements consist of the following:

1. Routine mowing. Grass within the filter strip should be maintained at the same rate as standard ODOT roadway side slopes. Grass must be kept healthy and free from brush or woody vegetation.
2. Inspect for rills and gullies. If rills and gullies occur, they must be repaired and stabilized with soil and seed or sod. Measures must be taken to eliminate any concentrated flow causing erosive rills and gullies.

# 13.0 POTENTIAL OBSTACLES FOR IMPLEMENTATION

Following installation of the soil amendments, the research team noted issues with establishment of permanent vegetation. Based on extensive analysis and soil sampling (detailed in Section 5.4 and Appendix F), the vegetation establishment issue is believed to be attributable to the construction procedures at the time of implementation, as well as amendment materials not meeting the required specifications.

The final recommendations of this report have taken these lessons learned into consideration, and the recommended construction procedures and material specifications have been revised. The compost specification was revised to better ensure that desired chemical and physical properties are met. The specification was also revised to require laboratory test results of the compost be submitted prior to beginning construction. The construction procedures were modified to triple the number of recommended passes with a rototiller, in order to ensure more uniform, homogenous mixing of the amendment materials. As a result of these revised material specifications and construction procedures, the vegetation issue is not anticipated to be a concern for future implementation of the Amended Vegetated Filter Strip BMP, however, vegetation growth should be monitored to ensure proper establishment.

# 14.0 EXPECTED BENEFITS

The Amended Vegetated Filter Strip BMP will benefit ODOT, regulatory agencies, design engineers, contractors, developers, and the general public, by providing a space-efficient, cost-effective, and easy to implement alternative to traditional stormwater volume reduction BMPs. The Amended Vegetated Filter Strip BMP will also reduce standing water adjacent to the roadway, eliminating a common safety hazard associated with typical stormwater detaining BMPs (e.g. detention basins).

The Amended Vegetated Filter Strip BMP will better allow for post-construction stormwater quantity requirements to be met, without the need for excessive right-of-way acquisition that may be required for detention basins and bioretention cells. This is beneficial for linear transportation projects, which do not have wide right-of-ways. It could present a significant cost savings to projects, as right-of-way is typically expensive to acquire.

The Amended Vegetated Filter Strip BMP is also uniquely suited to linear roadway projects due to limitations in stormwater conveyance. There are a variety of project constraints that can make it difficult to capture and convey stormwater to a centralized stormwater BMP (project budget, existing topography, etc.). The ability for stormwater runoff to sheet flow from the roadway directly to the BMP is a significant benefit of the soil amendment BMP.

Compared to traditional stormwater quantity BMPs, the AVFS will be relatively easy to design and construct. It does not require any type of stormwater conveyance system, outlet structure, or complex grading plans, nor does it require any specialty installation equipment. The amendment materials are affordable and readily available in Ohio. Maintenance requirements will also be significantly less than traditional stormwater quantity BMPs. There is no special requirement to clean out accumulated sediment or maintain an outlet structure.

Lastly, incorporation of the AVFS as a standard BMP will allow transportation post-construction BMPs to focus more on “Green Infrastructure” which has been an expressed goal of Ohio EPA. By promoting infiltration near the location of runoff production, the BMP mitigates potential impact from pollution and increases in flows better that other already used post-construction BMPs.

This research project resulted in the largest data collection effort of its kind in the state of Ohio. In addition to the development of the Amended Vegetated Filter Strip BMP, the data collected during this project is a benefit in and of itself. The regulatory and engineering communities will both benefit greatly from the rainfall data, runoff flow monitoring data, and extensive data analysis performed by the research team.

# 15.0 RECOMMENDATIONS FOR FUTURE RESEARCH

Given the vegetation issues experienced during this project, the research team recommends that additional research be conducted on various seeding and mulching practices. This would include analysis and comparison of proprietary rolled erosion control products, generic straw/mulch blankets, and hydroseeding. It is important to know how these methods hold up to typical ODOT site conditions, whether they can adequately protect the bare earth from erosive forces, and how well they allow permanent grass to grow. These products/practices could be performance tested under varying flow rates and slopes to simulate typical ODOT ditches and roadway slopes.

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# Appendix A: Literature Review

Below is the summary of literature review based on recent research and reports conducted for determining the post construction stormwater volume and quantity control benefits from practices across the country.

**Design Guide for Roadside Infiltration Strips in Western Oregon. June 2016. Chad Higgins**
This report from the Department of Biological and Ecological Engineering at Oregon State University examines the performance of roadside vegetated filter strips. Data was gathered through a 2-year research effort, where vegetated filter strip performance was measured and recorded. Using dimensional analysis of the results, a design equation was produced to model performance of vegetated filter strips and simplify the design process.

**Enhancements and Application of the Minnesota Dry Swale Calculator. April 2016. John S. Gulliver**
This research from the Minnesota Department of Transportation Research Services Library analyzes the infiltration performance of roadside swales. The study examines numerous parameters, including: infiltration capacity of the soil, initial soil moisture content, ratio of impervious drainage area-swale area, length, and width of the vegetated area, slope, type of flow down the side slope of the swale (spread or concentrated flow), and total depth and intensity of precipitation. These parameters were analyzed to determine their impacts on volume reduction performance of roadside swales by infiltration.

**Pennsylvania Stormwater Best Management Practices Manual. Pennsylvania Department of Environmental Protection. December 2006.**
Section 6.7.3: Soil Amendment & Restoration discusses improving disturbed soils and low organic soils by restoring soil porosity and/or adding a soil amendment, such as compost, for the purpose of reestablishing the soil's long term capacity for infiltration and pollution removal.

**The Performance of Grassed Swales as Infiltration and Pollution Prevention Practices, A Literature Review. November 2010. P. Weiss, J. Gulliver, and A. Erickson**
This review discusses Low Impact Development (LID) practices, such as vegetated filter strips and grassed swales, to reduce stormwater runoff quantity and improve stormwater runoff quality. Swale performance is analyzed to determine infiltration capacity, suspended solids removal, resuspension of suspended solids, and removal of other contaminants and dissolved nutrients. Various types of natural soils, composts and soil additives are also analyzed to compare performance.

**Soil Compost Amendment. Virginia DEQ Stormwater Design Specification No.4. March 2011.**
This section from the Virginia DEQ Stormwater Design Specification discusses the practice of soil restoration and soil amendment. It discusses soil performance, physical feasibility, design applications, and design criteria.

**Using Vegetated Compost Blankets to Achieve Highway Runoff Volume and Pollutant Reduction, NCHRP 14-39 (RPF closed 11/15/2016).**
NCHRP 14-39 is a pending three-phase research project to identify the hydrologic and water quality benefits of vegetated compost blankets (VCBs), as well as evaluate their effectiveness, when applied along roadway embankments in place of traditional vegetated filter strips. Pollutant removal capacity, the ability to detain and retain runoff, and the effect of climate, soils, compost composition, compost blanket thickness, and other parameters will be evaluated to judge performance.

# Appendix B: Site Selection Criteria

## B.1 SAFETY

Safety was of the highest priority in determining the monitoring locations. Maximizing safety in regard to monitoring equipment installation, soil amendment installation, maintenance crews, and vehicular traffic were all taken into account. Preferred sites have areas to install the monitoring equipment where it will be protected by a physical barrier, such as guardrail, concrete barrier, or bridge approach. This will not only provide protection for the flow monitoring equipment and minimize the chance of vehicular collision with the equipment, but also protect maintenance crews who will be servicing the equipment. Sites where physical barriers are not present must be adequately wide that there is enough clear space to the roadway that all parties feel safe.

## B.2 RAINFALL INTENSITY DISTRIBUTION

The selected monitoring sites were evenly distributed among the various Ohio rainfall intensity zones, with the exception of Zone D. Zone D covers a small area and is not representative of the majority of the state, so it was excluded. Even distribution among the rainfall intensity zones is intended to insure that the proposed amended filter strip BMP will be functional and effective throughout the state, and under a wide variety of environmental settings and rainfall conditions. Distributing the monitoring locations will also help ensure that measurable rainfalls are recorded at all sites and minimizes the potential for localized rainfalls to skew the monitoring results. Figure B1, shows the Rainfall Intensity Zones for the state of Ohio, as illustrated in Figure 1101-3 of the ODOT Location and Design Manual, Volume 2.

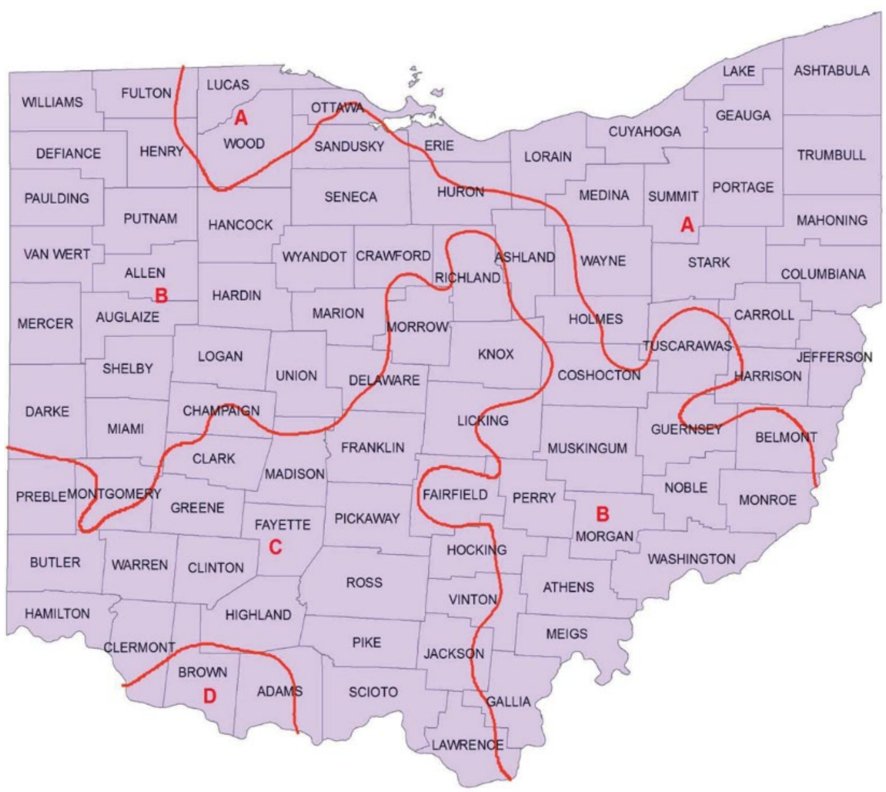


**Figure B5: ODOT Rainfall Intensity Zone Map Throughout Ohio**

## B.3 SLOPE

The vegetated filter strips both longitudinal and side slopes are important factors for proper flow monitoring and for determining the effectiveness of soil amendment as a volume reduction BMP.

Research sources indicate that filter strips are not successful on lateral slopes greater than 30%, with most design manuals citing less than 20% slopes. A target side slope of 3:1 or shallower was established to ensure that the stormwater runoff from the roadway will sheet flow over the amended area at an appropriate rate. This prescribed side slope will minimize slope-stability issues and erosion and sediment loss during or after soil-amendment installation, and allow for improved re-establishment of vegetation.

The ODOT L&D manual recommends a relative minimum longitudinal slope of 0.50% for roadway drainage ditches, with an absolute recommended minimum longitudinal slope of 0.25%. Through field observations, the research team determined that a longitudinal slope of 1-3% provides the best flow characteristics and is most likely to provide accurate monitoring results. Selected monitoring sites were preferred to have longitudinal slopes of 1-3%.

## B.4 DRAINAGE AREA

For the purposes of this research effort, monitoring sites with drainage areas of 5 acres or less were required. Sites with drainage areas of 1 acre or less were most desirable. This acreage requirement is consistent with the general recommended drainage area for vegetated filter strip BMPs.

In addition to the overall size of the drainage area, the breakdown of each drainage area and the percent impervious vs. percent amended was very important. It was determined that at least 30% of the total drainage area of each monitoring site should be amendable. This amendable area is the portion of pervious, grassed slope, in which the soil amendment mix is to be installed. Table B1, shows the area breakdown of each selected monitoring site. Amendment sites are numbered one through 10, and control sites are denoted by "C".

**Table B12: Monitoring Site Area Breakdown**

| Site | Total Drainage Area (Ac) | Amendable Area (Ac) | Impervious Area (Ac) | Percent Amendable (%) | Percent Impervious (%) |
|---|---|---|---|---|---|
| 1 | 2.05 | 1.07 | 0.66 | 52% | 32% |
| 2 | 1.03 | 0.56 | 0.33 | 54% | 33% |
| 3 | 0.51 | 0.25 | 0.13 | 49% | 25% |
| 4 | 1.64 | 0.72 | 0.59 | 44% | 36% |
| 5 | 1.88 | 0.93 | 0.69 | 49% | 37% |
| 6 | 0.97 | 0.53 | 0.30 | 55% | 31% |
| 7 | 1.89 | 0.93 | 0.85 | 49% | 45% |
| 8 | 0.82 | 0.40 | 0.32 | 49% | 39% |
| 9 | 0.83 | 0.26 | 0.29 | 31% | 35% |
| 10 | 1.47 | 0.35 | 0.59 | 24% | 40% |
| C1 | 2.42 | N/A | 0.85 | 0% | 35% |
| C2 | 0.78 | N/A | 0.31 | 0% | 40% |

## B.5 EXISTING UTILITIES/UNDERDRAINS

In selecting monitoring sites and amendment areas, existing utilities were investigated to ensure there would be no conflicts or interference with the installation of the soil amendment or the monitoring equipment. The location of existing utilities was requested from the Ohio Utilities Protection Service

(OUPS). OUPS requests were performed for each proposed amendment site. Record drawings for the roadways were also provided by ODOT in order to verify existing utility locations.

ODOT record drawings were used to identify the location of roadway underdrains. Based on the experience of the research team, it was determined that the presence of underdrains would not have an impact on the accuracy of the monitoring results. While underdrains will not have an impact on results, it was important to note their location in order to insure they will not be damaged or disturbed during the installation of the proposed soil amendments.

## B.6 SURVEY

Each proposed amendment location was surveyed to:

- Verify drainage areas
- Identify the location of existing visible utilities
- Locate at-grade and above grade features (catch basin, guardrail, edge of pavement, etc.)

The topographic survey revealed the preliminary drainage areas, calculated through GIS analysis, to be acceptably accurate. Therefore, the preliminary drainage areas were used for site selection and flume sizing. Survey information was used to develop construction plans for amendment installation. The exact drainage areas calculated through survey was also be critical during flow monitoring and data analysis.

## B.7 CURRENT/FUTURE CONSTRUCTION PROJECTS

In order to obtain the most accurate and useful flow monitoring results, the amendment site conditions must be kept as consistent as possible between pre-amendment and post-amendment monitoring. The only acceptable disturbance should be the designated soil amendment installation. Therefore, in order to minimize unwanted disturbance, each site was analyzed to determine if there are/will be any construction activities in the vicinity during the research project duration. No sites were selected in which active construction was scheduled to occur and which could disturb the monitoring areas during the monitoring period. Current and proposed construction projects were obtained through ODOT's TIMS database, as well as requests made to the ODOT regional districts.

## B.8 ODOT DISTRICT COORDINATION

Coordination and communication between the research team and ODOT Districts is essential to the research project's success. Individual meetings were held with each local District to discuss the research project's goals, objectives, and expectations. District staffs were briefed on the anticipated flow monitoring equipment, duration of flow monitoring, and maintenance requirements for monitoring sites. All proposed monitoring sites were approved by the regional districts and verified to have no scheduled construction or maintenance conflicts.

# Appendix C: USGS Flow Monitoring Report

**Assessment of Runoff Volume Reduction Associated with Soil Amendments Added to Portions of Highway Median-Strip Catchments in Ohio, 2018-2020**

This report is available online at: **https://pubs.er.usgs.gov/publication/sir20215114**

First posted October 27, 2021

For additional information, contact:

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# Appendix D: Soil Amendment Plan Development

## D.1 STORMWATER RUNOFF FACTORS

The volume of stormwater runoff is primarily controlled by the amount of precipitation received and the infiltration capacity of the underlying soil. There is a positive correlation between runoff intensity and rainfall intensity, slope, and initial soil water content. There is a negative relationship between the stormwater runoff rate and amount of vegetative cover. Thus, key components affecting stormwater runoff include:

### D.1.1 Soils

Stormwater infiltration is controlled by percolation (entry of water through the soil/grass surface); movement through the vadose (unsaturated) zone; and pore-space availability. Soil parameters that can affect stormwater runoff/infiltration include:

1. Porosity: the small voids between particles of soil.
2. Hydraulic conductivity: a measure of how easily water can pass through soil or rock: high values indicate permeable material through which water can pass easily; low values indicate that the material is less permeable
3. Grain size: the diameter of individual grains of sediment, or the lithified particles in clastic rocks
4. Soil moisture: the water content of the soil.

Soils in grassed roadway median areas of Ohio are mostly in the U.S. Soil Conservation Service (SCS) hydrologic soil group classification of C or D. These soils are generally defined as:

C = Moderately high runoff potential, with low infiltration rates. Consists mainly of soils with a layer that impedes downward water movement. Soils are finer grained with low rate of water transmission (0.05 to 0.15 in/hr.).

D = High runoff potential, with low infiltration rates. Consists mainly of clay soils with high-swelling potential. Water transmission rate of 0 to 0.05 in/hr.

### D.1.2 Rainfall

Rainfall parameters include:

1. Intensity: the rate at which precipitation falls.
2. Duration: the time period over which precipitation falls.

### D.1.3 Site Condition

Stormwater runoff can be affected by:

1. The size of the contributing drainage area.
2. Slope: mild slopes are preferred to reduce the potential for concentrated flows and reduce the likelihood of erosion. A slight slope is needed to reduce the potential for ponding.
3. Depth to water table: a shallower groundwater table reduces the potential for infiltration. An unsaturated zone of at least 4 to 5 feet is desired. Soil moisture content also affects infiltration, with a lower infiltration resulting when soil moisture is higher.
4. Depth to bedrock. A depth of at least 4 feet is desired.
5. Presence of wetlands, seeps, and floodplains.
6. Vegetation density.

## D.2 MATERIAL SPECIFICATIONS

The research team conducted a thorough literature review of various materials that could be used for soil amendment. This literature review included physical/chemical properties, known applications and benefits, material availability, etc. This literature review was used to select which materials would be installed at the soil amendment monitoring sites. The soil amendments installed during at the monitoring sites during this research, and the final material recommendations of this research project may differ from the what is discussed in this appendix.

### D.2.1 Compost

Compost is an organic soil amendment, derived from organic waste materials, such as yard clippings and wood wastes. Organic soil amendments absorb water and store water until the water is infiltrated, evaporated, or absorbed by plants. Compost amendments increase water holding and retention, improve infiltration and exfiltration, and increase nutrient availability in the soil. Studies have shown water-holding capacity of soil to double with a 2:1 (compost:soil) amendment and infiltration rates increasing by 1.5 to 10.5 times after amending soils with compost.

One of the most important benefits of compost as a soil amendment is its ability to enhance the growth of vegetation. Given the low organic content of the existing soils, the addition of compost should greatly increase the existing soils ability to maintain a vigorous stand of grass. Increasing the quantity/thickness of the grass will increase water infiltration and exfiltration. Typical compost amendment inclusion rates appear to range between 25% and 33%, with depths of incorporation ranging between 3 and 24 inches.

Facilities providing compost are available throughout Ohio. Facilities that are economical and are anticipated to maintain availability of compost near the project area include, but are not limited to:

- Kurtz Bros. of central Ohio
- Earth'n Wood Products Inc. of North Canton, Ohio
- Miller's Landscaping Materials of Navarre, Ohio

Most sources cited specifying the use of compost products that are certified by the U.S. Composting Council's Seal of Testing (STA) Program (www.compostingcouncil.org). Further investigation determined that compost products containing this certification were not readily available for central Ohio and therefore considered infeasible. ODOT CMS 659.06 Compost specification lists either OEPA rated Class IV compost, biosolids compost, or an approved equal. An OEPA Class IV Composting Facility is a facility that produces compost using only yard wastes as feedstock.

Stability as it relates to compost indicates the level of microbial activity. Unstable compost can create objectionable odors. Compost should be stable with regard to oxygen consumption and carbon dioxide generation, with no visible free water or dust produced when handling the material. Compost should also be sufficiently mature to ensure maximum nutrient availability in the soil. Metrics for maturity include carbon:nitrogen ratio, germination rates, and oxygen consumption.

### D.2.2 Sand

The incorporation of sand within soil amendments has been shown to increase soil texture and infiltration rates by creating larger pore spaces within otherwise poorly drained and aerated clayey or compacted soils. Sand is often used in gardening as an amendment, often referred to as "builders sand." Facilities providing sand are available throughout Ohio.

Incorporating sand as a sole amendment has rarely been used. Ohio C and D soils are low in organic content, which reduces their ability to maintain vigorous stands of grass. Adding sand alone further decreases the organic content of the soils and can increase its erodibility.

### D.2.3 Gravel

Sharp-edged gravel (not rounded) has a rough texture allowing the creation of more air voids. However, increasing surface area and pore space within the soil amendment can be better achieved with the addition of other researched amendments, such as sand. Additionally, the use of gravel in bioretention facilities is typically combined with the implementation of underdrains. Thus, no further research on this amendment was performed.

### D.2.4 Gypsum

The addition of gypsum was found to be more applicable to preventing soil erosion than increasing water infiltration rates, and thus no further research on this amendment was performed.

### D.2.5 Expanded Shale

Expanded shale is shale that has been kiln fired causing it to expand, resulting in a very porous and lightweight material which is capable of retaining moisture. Expanded shale can be crushed into a desired aggregate size. Expanded shale has beneficial properties as a soil amendment including, but not limited to, increased insulation, increased soil porosity, no pH effects, increased drainage and aeration, non-toxic, 100% inert, not chemically reactive, and easy to handle. Dr. Steve George of Texas A&M studied the use and success of expanded shale within the top 6 inches of soil. The expanded shale provided an immediate improvement to the soils drainage and aeration properties.

At the time of the literature review, suppliers for expanded shale in Ohio were limited. DiGeronimo Aggregates LLC (Cleveland, Ohio) was a supplier of expanded shale (under the commercial name "Haydite"). However, DiGeronimo Aggregates stopped supplying expanded shale prior to construction. Outside of Ohio, the following suppliers were identified:

- Trinity Lightweight Expanded Shale & Clay – Brooklyn, Indiana
- Stalite Rotary Kiln Expanded Shale Lightweight Aggregate – Gold Hill, North Carolina

### D.2.6 Biochar

Recent and ongoing studies have demonstrated that using biochar as a soil amendment in highway soils can increase infiltration and decrease runoff discharges by approximately 50% to 60%. Biochar functions like compost and provides similar benefits, especially an increase in soil macropores.

Biochar is the product of heating biomass in an oxygen limited environment, often referred to as a "carbon sponge". However, if biochar is not produced optimally, potentially hazardous chemicals can be produced. Given this, the International Biochar Initiative (IBI) and the European Biochar Certificate have developed quality protocols to assure that there are no critical amounts of hazardous materials within the biochar product. Currently, there only two IBI certified manufacturers listed in the United States, located in Colorado and California. There are several non-certified manufacturers as well, however no local supplier or producer could be identified feasibly near the proposed Ohio study sites. Since biochar amended soils have already proven successful in stormwater runoff reductions and is not readily available in Ohio, biochar was not researched further for this limited variable study.

### D.2.7 Other

Crumb rubber has been applied in soil amendments as an economically and environmentally conscious alternative in promoting the physical properties of soils. Though the addition of crumb rubber has been shown to increase soil durability, there are no consistent or significant results on its ability to increase infiltration. Other organic media, such as peat moss and zeolite have also been used, but are generally less available and not as cost-effective as compost.

## D.3 MATERIAL SPECIFICATIONS

The research team conducted a thorough literature review of various materials that could be used for soil amendment. This literature review included physical/chemical properties, known applications and benefits, material availability, etc. This literature review was used to select which materials would be installed at the soil amendment monitoring sites. The final material recommendations of this research project (Section 10.0) may differ from the what is discussed in this appendix.

### D.3.1 Compost

Compost shall:

1. Originate from an Ohio EPA Class IV Composting Facility and meet the requirements of ODOT CMS 659.06.
2. 100% of material must pass the 1/2-inch screen with 98% passing ¾-inch screen
3. 5.5 < PH < 8.5
4. Inert material < 1%
5. 35% < Organic content < 65%
6. Stability ≤7 and/or Maturity > 80%
7. 30% <Moisture Content <60%, wet weight basis
8. Compost should be stable with regard to oxygen consumption and carbon dioxide generation, with no visible free water or dust produced when handling the material.

### D.3.2 Sand

ODOT CMS Specification 703.02

### D.3.3 Expanded Shale

The expanded shale material should meet ASTM C330/C330M, Standard Specification for Lightweight Aggregates for Structural Concrete and ASTM D5883, Standard Guide for Use of Rotary Kiln Produced Expanded Shale, Clay or Slate (ESCS) as a Mineral Amendment in Topsoil Used for Landscaping and Related Purposes. Expanded shale shall conform to the gradation described in Table D2.

**Table D13: Expanded shale gradation**

| Sieve Size | % Passing |
|---|---|
| 1/2" | 100 |
| 3/8" | 80-100 |
| #4 | 5-40 |
| #8 | 0-20 |
| #16 | 0-10 |
| #200 | 0-10 |

### D.3.4 Seed Mix

ODOT Class 1 – Lawn Mixture (ODOT CMS 659)

### D.3.5 Fertilizer

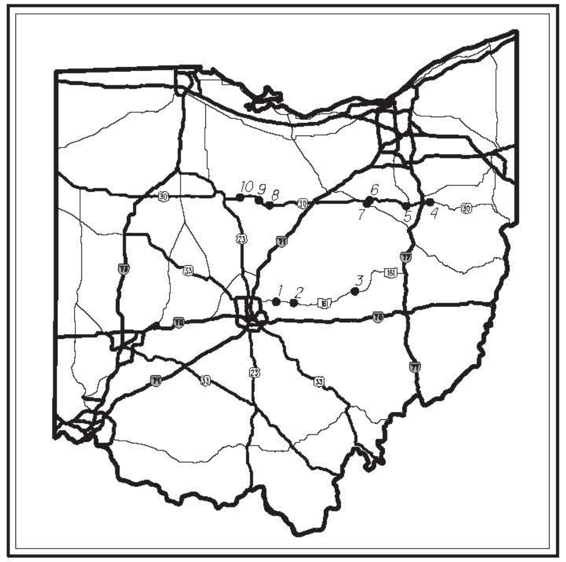
ODOT CMS Item 659.04

## D.4 CONSTRUCTION PROCEDURE

The construction procedure for implementing the soil amendments during the research project includes: ripping the subgrade, distributing the amendment, incorporating the amendments into the subsoil, light compaction, installation of a compost blanket, seed, and erosion control matting. The intent was to fully incorporate the amended soil mix into the existing soil and return the site back to existing grade. Note: this procedure was used to install the soil amendments at the monitoring sites during the research and may differ from the final soil amendment recommendations at the conclusion of this report. The procedure listed here deviated from the originally intended construction procedure for the test sites, due to minor field modification that were made during construction of the soil amendments. These field modifications were documented in the red-lined construction plans, located in Appendix E.

1. Excavate: the top layer of existing soil was excavated and removed from the site. The thickness of the layer removed was based on the final grade, so that—after the amendments have been incorporated into the existing soil—the profile will not appreciably change.
2. Soil Ripping: the soil was ripped to a depth of 12-inches. This was accomplished by making several passes with a solid-shank ripper or similar implements, mounted to a tractor, dozer, or grader. The soil was then rototilled to a depth of 6-inches to further loosen the native material. A tractor or skidsteer-mounted rototiller or similar implement was used to perform rototilling.
3. Amendment Incorporation: the amendments were spread over the ground in a uniform thickness, via a slinger, except for one site was end-dumped by trucks (which was found to be inefficient). Once the amendment material was spread, it was incorporated into the soil via two passed of rototilling.
4. *Fine Grading and Limited Compaction:* the slope geometry and general elevations remained the same as pre-amendment installation. To achieve an approximate compaction of 85% to 90% maximum density, one pass with a rubber-tired or smooth drum roller was performed.
5. *Compost Blanket and Stabilization:* A 0.5-inch thick compost blanket was spread over the surface, followed by seeding being installed. Erosion control matting was then installed to minimize the chance of erosion and to enhance the rapid creation of a thick stand of grass.
6. *Construction Timing:* The soil amendments were installed at a time of the year when vegetative growth was most likely without regular irrigation. The OEPA Rainwater and Land Development Manual specifies that permanent seeding should be done March 1 to May 31 or August 1 to September 30. If seeding occurs outside of the specified dates, additional mulch and irrigation may be required to ensure a minimum of 80% germination.
7. *Erosion Control:* Based on the type of construction and the short duration of construction (about five days) for each site, erosion control measures consisted of: inlet protection and installation of erosion control matting. The inlet protection was removed once the vegetation had established 70% coverage.
8. *Traffic Control:* Based on site locations within roadway medians, traffic control during construction consisted of closing the lane adjacent to the work being performed. Since the soils were amended on both sides of the median, single lane closures took place on both sides of the median.

# Appendix E: Soil Amendment Construction Drawings



**LOCATION MAP**

SEE GENERAL NOTES (SHEET 2) FOR DETAILED SITE LOCATION

SCALE IN MILES

0 40 80 120 160

N

INTERSTATE HIGHWAY
FEDERAL ROUTES
STATE ROUTES

# STATE OF OHIO
# DEPARTMENT OF TRANSPORTATION
# OFFICE OF HYDRAULIC ENGINEERING
# RESEARCH

# ASSESSMENT OF EXISTING AND POTENTIAL VOLUME REDUCTION FOR POST CONSTRUCTION STORMWATER MANGEMENT

# SOIL AMENDMENT INSTALLATION

**CITY OF CANTON**
**CRAWFORD COUNTY**
**LICKING COUNTY**
**MUSKINGUM COUNTY**
**STARK COUNTY**

### PROJECT DESCRIPTION

SOIL AMENDMENTS ARE TO BE INSTALLED WITHIN THE ROADWAY MEDIAN AT THE DESIGNATED LOCATIONS. THE SOIL AMENDMENTS WILL ALLOW FOR THE CONTINUATION OF THE OHIO DEPARTMENT OF TRANSPORTATION OFFICE OF HYDRAULIC ENGINEERING RESEARCH PROJECT, IN ORDER TO EVALUATE SOIL AMENDMENT AS A VOLUME REDUCING STORMWATER BMP.

### EARTH DISTURBED AREAS

PROJECT EARTH DISTURBED AREA: VARIES BY SITE
ESTIMATED CONTRACTOR EARTH DISTURBED AREA: VARIES BY SITE

### 2016 SPECIFICATIONS

THE STANDARD SPECIFICATIONS OF THE STATE OF OHIO, DEPARTMENT OF TRANSPORTATION, INCLUDING SUPPLEMENTAL SPECIFICATIONS LISTED IN THE PLANS AND CHANGES LISTED IN THE PROPOSAL SHALL GOVERN THIS IMPROVEMENT.

### INDEX OF SHEETS:


| | |
|---|---|
| TITLE SHEET | 1 |
| GENERAL NOTES AND MATERIAL SPECIFICATIONS | 2 |
| SITE 1 AMENDMENT PLAN | 3 |
| SITE 2 AMENDMENT PLAN | 4 |
| SITE 3 AMENDMENT PLAN | 5 |
| SITE 4 AMENDMENT PLAN | 6 |
| SITE 5 AMENDMENT PLAN | 7 |
| SITE 6 AMENDMENT PLAN | 8 |
| SITE 7 AMENDMENT PLAN | 9 |
| SITE 8 AMENDMENT PLAN | 10 |
| SITE 9 AMENDMENT PLAN | 11 |
| SITE 10 AMENDMENT PLAN | 12 |


**UNDERGROUND UTILITIES**

CONTACT BOTH SERVICES TWO WORKING DAYS **BEFORE YOU DIG.**

OHIO Utilities Protection SERVICE
Call Before You Dig 1-800-362-2764
(Non-members must be called directly)

OIL & GAS PRODUCERS UNDERGROUND PROTECTION SERVICE 1-800-925-0988

PLAN PREPARED BY:

ms consultants, inc.
engineers, architects & planners
2221 Schrock Road
Columbus, Ohio 43229-1547
Tel 614.898.7100 Fax 614.898.7570
www.msconsultants.com

ENGINEERS SEAL:

SIGNED:
DATE:

ENGINEERS SEAL:

SIGNED:
DATE:

| STANDARD CONSTRUCTION DRAWINGS | | | | | SUPPLEMENTAL SPECIFICATIONS | SPECIAL PROVISIONS |
|---|---|---|---|---|---|---|
| MT-95.30 7/21/17 | | | | | | |

I HEREBY APPROVE THESE PLANS AND DECLARE THAT THE MAKING OF THIS IMPROVEMENT WILL NOT REQUIRE THE CLOSING TO TRAFFIC OF THE HIGHWAY AND THAT PROVISIONS FOR THE MAINTENANCE AND SAFTY OF TRAFFIC WILL BE AS SET FORTH ON THE PLANS AND ESTIMATES.

APPROVED
DATE DISTRICT DEPUTY DIRECTOR

APPROVED
DATE DIRECTOR, DEPARTMENT OF TRANSPORTATION

FEDERAL PROJECT NO. **00000**

PID NO. **00000**

CONSTRUCTION PROJECT NO. **00000**

RAILROAD INVOLVEMENT **NONE**

**ODOT RESEARCH**

1
12

PROJECT DESCRIPTION AND LOCATION

THIS WORK CONSISTS OF SOIL EXCAVATION, AMENDMENT, AND PLACEMENT, WITHIN THE MEDIAN. WORK LIMITS WILL NOT IMPACT THE EXISTING ROADWAY OR ROADWAY FEATURES, INCLUDING: TRAVEL LANES, PAVED AND GRADED SHOULDER, GUARDRAILS, OR SIGNS.

THIS WORK WILL OCCUR AT TEN (10) SITES AT THE LOCATIONS INDICATED BELOW:

SITE 1
STATE ROUTE 161 AT BEECH ROAD
LAT: 40° 04' 47.7" N
LONG: 82° 45' 24.7" W

SITE 2
STATE ROUTE 161 NEAR MOOTS RUN
LAT: 40° 04' 23.1" N
LONG: 82° 35' 34.9" W

SITE 3
STATE ROUTE 16 AT STATE ROUTE 60
LAT: 40° 09' 17.7" N
LONG: 82° 01' 27.4" W

SITE 4
STATE ROUTE 30 NEAR TRUMP AVENUE
LAT: 40° 47' 01.7" N
LONG: 81° 19' 34.8" W

SITE 5
STATE ROUTE 30 AT 17TH STREET SW
LAT: 40° 45' 27.2" N
LONG: 81° 32' 50.7" W

SITE 6
STATE ROUTE 30 AT APPLE CREEK
LAT: 40° 47' 55.2" N
LONG: 81° 53' 13.4" W

SITE 7
STATE ROUTE 83 NEAR SHELBY ROAD
LAT: 40° 46' 30.7" N
LONG: 81° 54' 50.7" W

SITE 8
STATE ROUTE 30 AT BIDDLE ROAD
LAT: 40° 45' 43.4" N
LONG: 82° 49' 07.7" W

SITE 9
STATE ROUTE 30 AT LOWER LEESVILLE RD
LAT: 40° 47' 55.1" N
LONG: 82° 55' 06.0" W

SITE 10
STATE ROUTE 30 AT MARION MEMORIAL RD
LAT: 40° 49' 01.1" N
LONG: 83° 05' 36.1" W

MAINTENANCE OF TRAFFIC

THIS ITEM SHALL CONSIST OF MAINTENANCE OF TRAFFIC ON EXISTING ROADWAYS IN ACCORDANCE WITH THE OHIO MANUAL OF UNIFORM TRAFFIC CONTROL DEVICES FOR STREETS AND HIGHWAYS, CURRENT EDITION, LATEST REVISION, THE SPECIFICATIONS AND THE FOLLOWING:

MAINTENANCE OF TRAFFIC SHALL CONSIST OF LANE CLOSURES, IN ACCORDANCE WITH ODOT MAINTENANCE OF TRAFFIC SCD MT-95.30.

THE CONTRACTOR SHALL INFORM THE DISTRICT OFFICE (SEE SOIL AMENDMENT PLANS FOR DISTRICT CONTACT INFORMATION), FOURTY-EIGHT (48) HOURS PRIOR (EXCLUSIVE OF SATURDAY, SUNDAY, OR HOLIDAYS) TO THE BEGINNING OF WORK.

THE CONTRACTOR AND/OR OHIO DEPARTMENT OF TRANSPORTATION SHALL FURNISH, ERECT, MAINTAIN, AND SUBSEQUENTLY REMOVE ALL FLAGS, DRUMS, BARRICADES, SIGNS, SIGN SUPPORTS AND FURNISH AND MAINTAIN ALL FLAGGERS, WATCHERS, AND INCIDENTALS RELATED THERETO. LANE RESTRICTIONS OR LANE REDUCTIONS SHALL NOT BE PERMITTED AFTER NORMAL WORKING HOURS. NORMAL WORKING HOURS SHALL BE THOSE HOURS DURING WHICH THE CONTRACTOR HAS A FULL COMPLEMENT OF EMPLOYEES AND EQUIPMENT ACTIVELY REMOVING AND/OR PLACING MATERIALS.

UNDER NO CIRCUMSTANCES SHALL THE CONTRACTOR BE PERMITTED TO HAVE SUCCESSIVE WORK ZONES UNLESS THE DISTANCE BETWEEN THE DRUMS, BARRICADES, OR CONES EXCEEDS ONE (1) MILE.

UTILITIES

THE APPROXIMATE LOCATION OF KNOWN UTILITES ARE SHOWN ON THE CONSTRUCTION PLANS. CONTRACTOR IS RESPONSIBLE FOR VARIFYING UTILITY LOCATIONS VIA OUPS CALLS AND FIELD VERIFICATION.

WORK LIMITS

THE WORK LIMITS SHOWN ON THESE PLANS ARE FOR PHYSICAL CONSTRUCTION LIMITS. PROVIDE THE INSTALLATION AND OPPERATION OF ALL WORK ZONE TRAFFIC AND WORK ZONE TRAFFIC CONTROL DEVICES REQUIRED BY THESE PLANS WHETHER INSIDE OR OUTSIDE THESE WORK LIMITS.

PROTECTION OF RIGHT-OF-WAY LANDSCAPING

PRIOR TO BEGINNING WORK, THE CONTRACTOR, THE PROJECT ENGINEER, AND A REPRESENTATIVE OF THE MAINTAINING AGENCY WILL REVIEW AND RECORD ALL LANDSCAPING ITEMS WITHIN THE RIGHT OF WAY (BOTH WITHIN AND OUTSIDE THE CONSTRUCTION LIMITS) A RECORD OF THIS REVIEW WILL BE KEPT IN THE PROJECT ENGINEER'S FILES. PRIOR TO FINAL ACCEPTANCE, A FINAL REVIEW OF LANDSCAPING ITEMS WILL BE MADE.

CONSTRICT ALL ACTIVITIES, EQUIPMENT STORAGE, AND STAGING TO WITHIN THE CONSTRUCTION LIMITS.

SUBMIT A WRITTEN REQUEST TO THE PROJECT ENGINEER TO USE ANY AREA OUTSIDE THESE LIMITS. THE DOCUMENT SUBMITTED MUST CLEARLY IDENTIFY THE AREA AND EXPLAIN THE PROPOSED USE AND RESTORATION OF THE AREA. USE OF THESE AREAS FOR DISPOSAL OF WASTE MATERIAL AND CONSTRUCTION DEBRIS, EXCAVATION OF BORROW MATERIAL AND PLACEMENT OF PORTABLE PLANTS IS PROHIBITED. THE REQUEST MUST BE APPROVED, IN WRITING, BEFORE THE CONTRACTOR HAS PERMISSION TO USE THE AREA.

SOIL AMENDMENT MATERIAL SPECIFICATIONS

COMPOST

1. ORIGINATE FROM AN OHIO EPA CLASS IV COMPOSTING FACILITY AND MEET THE REQUIREMENTS OF ODOT CMS 659.06.
2. 100% OF MATERIAL MUST PASS THE 1/2-INCH SCREEN WITH 98% PASSING 3/4-INCH SCREEN
3. 5.5 < PH < 8.5
4. INERT MATERIAL < 1%
5. 35% < ORGANIC CONTENT < 65%
6. STABILITY =7 AND/OR MATURITY > 80%
7. 30% < MOISTURE CONTENT < 60%, WET WEIGHT BASIS
8. COMPOST SHOULD BE STABLE WITH REGARD TO OXYGEN CONSUMPTION AND CARBON DIOXIDE GENERATION, WITH NO VISIBLE FREE WATER OR DUST PRODUCED WHEN HANDLING THE MATERIAL.

SAND

1. ODOT CMS SPECIFICATION 703.02. - FINE AGGREGATE

EXPANDED SHALE

1. THE MATERIAL SHOULD MEET ASTM C330/C330M, STANDARD SPECIFICATION FOR LIGHTWEIGHT AGGREGATES FOR STRUCTURAL CONCRETE AND ASTM D5883, STANDARD GUIDE FOR USE OF ROTARY KILN PRODUCED EXPANDED SHALE, CLAY OR SLATE (ESCS) AS A MINERAL AMENDMENT IN TOPSOIL USED FOR LANDSCAPING AND RELATED PURPOSES.

EXPANDED SHALE MATERIAL SHALL CONFORM TO THE FOLLOWING GRADATION:

| SIEVE SIZE | % PASSING |
|---|---|
| 1/2" | 100 |
| 3/8" | 80-100 |
| #4 | 5-40 |
| #8 | 0-20 |
| #16 | 0-10 |
| #200 | 0-10 |

SEED MIX AND FERTILIZER

1. ODOT CLASS 1 - LAWN MIXTURE (ODOT ITEM 659)
2. ODOT CMS ITEM 659.04

EROSION CONTROL MATS

1. ODOT CMS ITEM 671 - TYPE A

ANTICIPATED CONSTRUCTION PROCEDURES

IN GENERAL, EACH SOIL AMENDMENT DESIGN INCLUDES: RIPPING THE SUBGRADE, DISTRIBUTING THE AMENDMENT, INCORPORATING THE AMENDMENT MATERIAL INTO THE SUBSOIL, LIGHT COMPACTION, INSTALLATION OF A COMPOST BLANKET, SEED, AND EROSION CONTROL MATTING.

1. SOIL RIPPING
A SOLID-SHANK RIPPER SHOULD BE USED, TRAVERSING THE AREA WITH MULTIPLE PASSES. THIS MAY BE ACCOMPLISHED WITH IMPLEMENTS MOUNTED TO A TRACTOR OR DOZER OR USE OF A GRADER WITH APPROPRIATE IMPLEMENTS (SCARIFIER TEETH).
2. AMENDMENT INCORPORATION
THE TOP LAYER OF EXISTING SOIL WILL BE EXCAVATED AND REMOVED FROM THE SITE. THE THICKNESS OF THE LAYER REMOVED WILL BE BASED ON THE FINAL GRADE, SO THAT AFTER THE AMENDMENTS HAVE BEEN INCORPORATED INTO THE EXISTING SOIL, THE PROFILE WILL NOT APPRECIABLY CHANGE. THE AMENDMENTS WILLTHEN BE SPREAD OVER THE GROUND IN A UNIFORM THICKNESS AND BE INCORPORATED INTO THE SOIL.
3. FINE GRADING AND LIMITED COMPACTION
THE SLOPE GEOMETRY AND GENERAL ELEVATIONS SHOULD REMAIN THE SAME AS PRE-AMENDMENT INSTALLATION. TO ACHIEVE AN APPROXIMATE COMPACTION OF 85 TO 90% MAXIMUM DENSITY, ONE PASS WITH A RUBBER-TIRED OR SMOOTH DRUM ROLLER IS ANTICIPATED.
4. COMPOST BLANKET AND STABILIZATION
A 0.5-INCH THICK COMPOST BLANKET WILL BE SPREAD OVER THE SURFACE AND THEN SEEDING WILL BE INSTALLED. EROSION CONTROL MATTING WILL THEN BE INSTALLED TO MINIMIZE THE CHANCE OF EROSION AND TO ENHANCE THE RAPID CREATION OF A THICK STAND OF GRASS.
5. CONSTRUCTION TIMING
IT IS UNDERSTOOD THAT INSTALLATION OF THE SOIL AMENDMENTS IS TO TAKE PLACE IN SPRING, 2019. WORK SHOULD ONLY BE PERFORMED DURING DRY CONDITIONS WHEN SOILS ARE FRIABLE.
6. EROSION AND SEDIMENT CONTROL
BASED ON THE TYPE OF CONSTRUCTION AND THE SHORT DURATION OF CONSTRUCTION FOR EACH SITE, EROSION CONTROL MEASURES ARE ONLY NECESSARY DURING CONSTRUCTION AND ARE ANTICIPATED TO CONSIST OF:
-INLET PROTECTION
-INSTALLATION OF EROSION CONTROL MATTING.
7. PERMANENT VEGETATION AND WATERING
CONTRACTOR IS REPONSIBLE FOR ESTABLISHING PERMANENT VEGETATION WITHIN THE PROJECT SCHEDULE. WATERING MAY BE NECESSARY TO FACILITATE VEGETATION GROWTH.
8. MAINTENANCE OF TRAFFIC
MAINTENANCE OF TRAFFIC SHALL CONSIST OF CLOSING THE LANE ADJACENT TO THE WORK BEING PERFORMED ON EACH SIDE OF THE MEDIAN, PER ODOT MAINTENANCE OF TRAFFIC SCD MT-95.30.

CALCULATED MRB CHECKED JAK

GENERAL NOTES AND MATERIAL SPECIFICATIONS

ODOT RESEARCH

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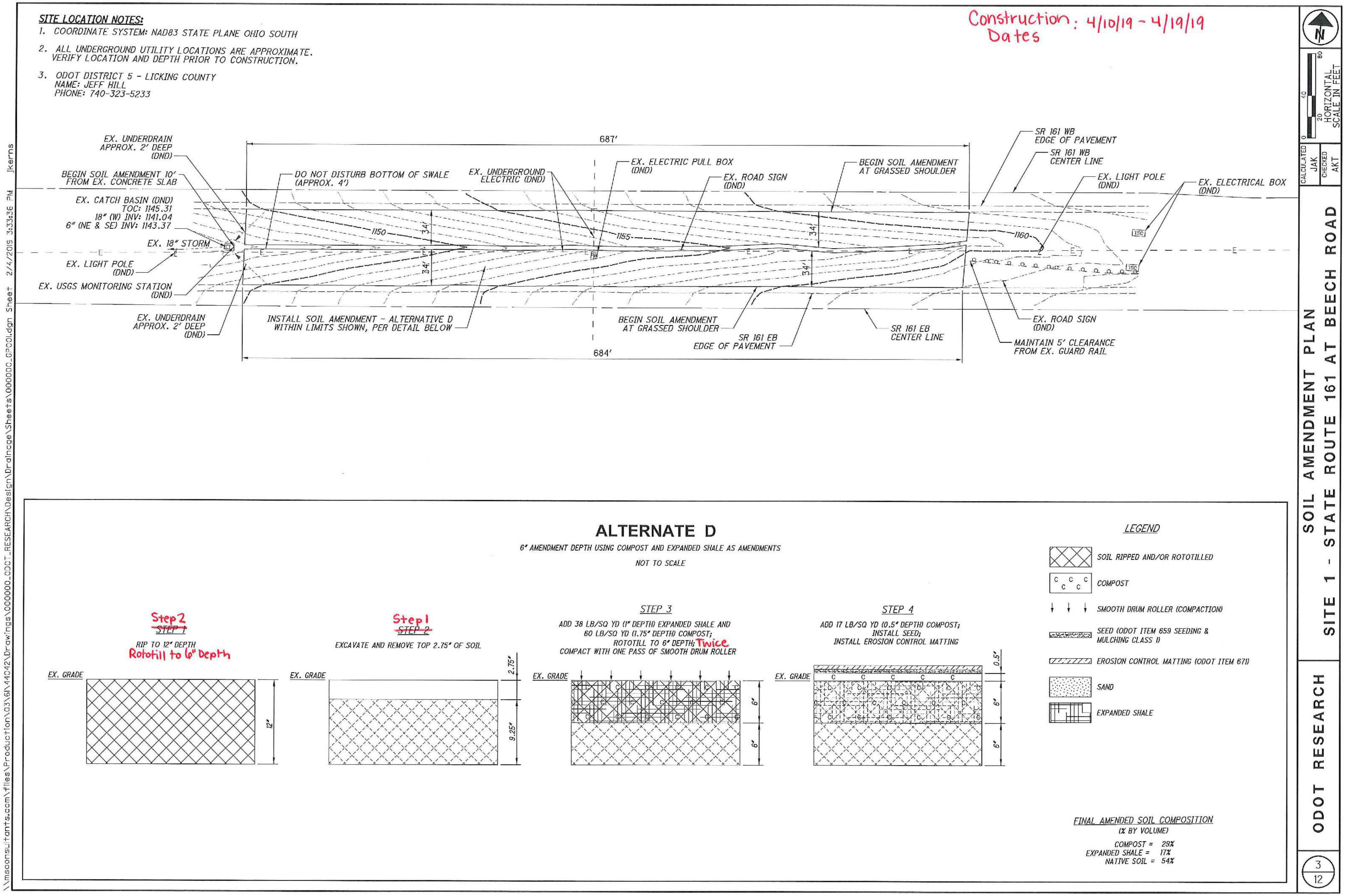
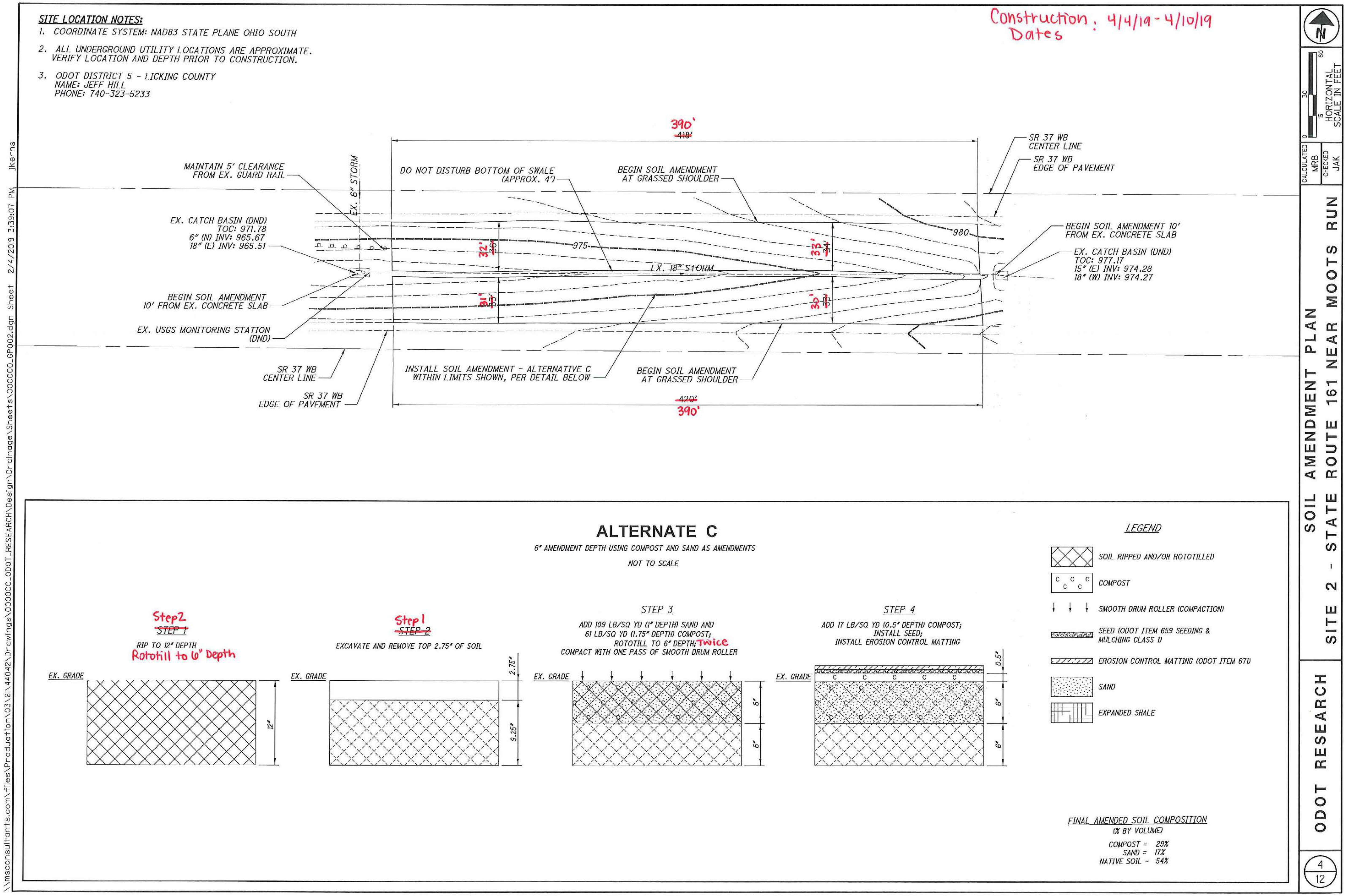

SITE LOCATION NOTES:
1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO SOUTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 5 - LICKING COUNTY
NAME: JEFF HILL
PHONE: 740-323-5233
Construction Dates: 4/10/19 - 4/19/19
EX. UNDERDRAIN APPROX. 2' DEEP (DND)
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
EX. CATCH BASIN (DND) TOC: 1145.31 18" (W) INV: 1141.04 6" (NE & SE) INV: 1143.37
EX. 18" STORM
EX. LIGHT POLE (DND)
EX. USGS MONITORING STATION (DND)
EX. UNDERDRAIN APPROX. 2' DEEP (DND)
687'
684'
DO NOT DISTURB BOTTOM OF SWALE (APPROX. 4')
EX. UNDERGROUND ELECTRIC (DND)
EX. ELECTRIC PULL BOX (DND)
EX. ROAD SIGN (DND)
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 161 WB EDGE OF PAVEMENT
SR 161 WB CENTER LINE
EX. LIGHT POLE (DND)
EX. ELECTRICAL BOX (DND)
1150
1155
1160
34'
INSTALL SOIL AMENDMENT - ALTERNATIVE D WITHIN LIMITS SHOWN, PER DETAIL BELOW
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 161 EB EDGE OF PAVEMENT
SR 161 EB CENTER LINE
EX. ROAD SIGN (DND)
MAINTAIN 5' CLEARANCE FROM EX. GUARD RAIL
ALTERNATE D
6" AMENDMENT DEPTH USING COMPOST AND EXPANDED SHALE AS AMENDMENTS
NOT TO SCALE
Step 2 ~~STEP 1~~
RIP TO 12" DEPTH
Rotofill to 6" Depth
Step 1 ~~STEP 2~~
EXCAVATE AND REMOVE TOP 2.75" OF SOIL
STEP 3
ADD 38 LB/SQ YD (1" DEPTH) EXPANDED SHALE AND 60 LB/SQ YD (1.75" DEPTH) COMPOST; ROTOTILL TO 6" DEPTH; Twice
COMPACT WITH ONE PASS OF SMOOTH DRUM ROLLER
STEP 4
ADD 17 LB/SQ YD (0.5" DEPTH) COMPOST; INSTALL SEED; INSTALL EROSION CONTROL MATTING
EX. GRADE
12"
2.75"
9.25"
6"
0.5"
LEGEND
SOIL RIPPED AND/OR ROTOTILLED
COMPOST
SMOOTH DRUM ROLLER (COMPACTION)
SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
EROSION CONTROL MATTING (ODOT ITEM 671)
SAND
EXPANDED SHALE
FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)
COMPOST = 29%
EXPANDED SHALE = 17%
NATIVE SOIL = 54%
HORIZONTAL SCALE IN FEET
CALCULATED JAK
CHECKED AKT
SOIL AMENDMENT PLAN
SITE 1 - STATE ROUTE 161 AT BEECH ROAD
ODOT RESEARCH
3
12


SITE LOCATION NOTES:
1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO SOUTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 5 - LICKING COUNTY
NAME: JEFF HILL
PHONE: 740-323-5233
Construction Dates: 4/4/19 - 4/10/19
390'
~~418'~~
MAINTAIN 5' CLEARANCE FROM EX. GUARD RAIL
EX. 6" STORM
DO NOT DISTURB BOTTOM OF SWALE (APPROX. 4')
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 37 WB CENTER LINE
SR 37 WB EDGE OF PAVEMENT
EX. CATCH BASIN (DND)
TOC: 971.78
6" (N) INV: 965.67
18" (E) INV: 965.51
975
980
EX. 18" STORM
32'
33'
31'
30'
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
EX. CATCH BASIN (DND)
TOC: 977.17
15" (E) INV: 974.28
18" (W) INV: 974.27
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
EX. USGS MONITORING STATION (DND)
SR 37 WB CENTER LINE
SR 37 WB EDGE OF PAVEMENT
INSTALL SOIL AMENDMENT - ALTERNATIVE C WITHIN LIMITS SHOWN, PER DETAIL BELOW
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
~~420'~~
390'
ALTERNATE C
6" AMENDMENT DEPTH USING COMPOST AND SAND AS AMENDMENTS
NOT TO SCALE
Step2
~~STEP 1~~
RIP TO 12" DEPTH
Rototill to 6" Depth
Step1
~~STEP 2~~
EXCAVATE AND REMOVE TOP 2.75" OF SOIL
STEP 3
ADD 109 LB/SQ YD (1" DEPTH) SAND AND 61 LB/SQ YD (1.75" DEPTH) COMPOST; ROTOTILL TO 6" DEPTH; Twice
COMPACT WITH ONE PASS OF SMOOTH DRUM ROLLER
STEP 4
ADD 17 LB/SQ YD (0.5" DEPTH) COMPOST; INSTALL SEED; INSTALL EROSION CONTROL MATTING
EX. GRADE
12"
2.75"
9.25"
6"
0.5"
LEGEND
SOIL RIPPED AND/OR ROTOTILLED
COMPOST
SMOOTH DRUM ROLLER (COMPACTION)
SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
EROSION CONTROL MATTING (ODOT ITEM 671)
SAND
EXPANDED SHALE
FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)
COMPOST = 29%
SAND = 17%
NATIVE SOIL = 54%
N
HORIZONTAL SCALE IN FEET
0 15 30 60
CALCULATED MRB
CHECKED JAK
SOIL AMENDMENT PLAN
SITE 2 - STATE ROUTE 161 NEAR MOOTS RUN
ODOT RESEARCH
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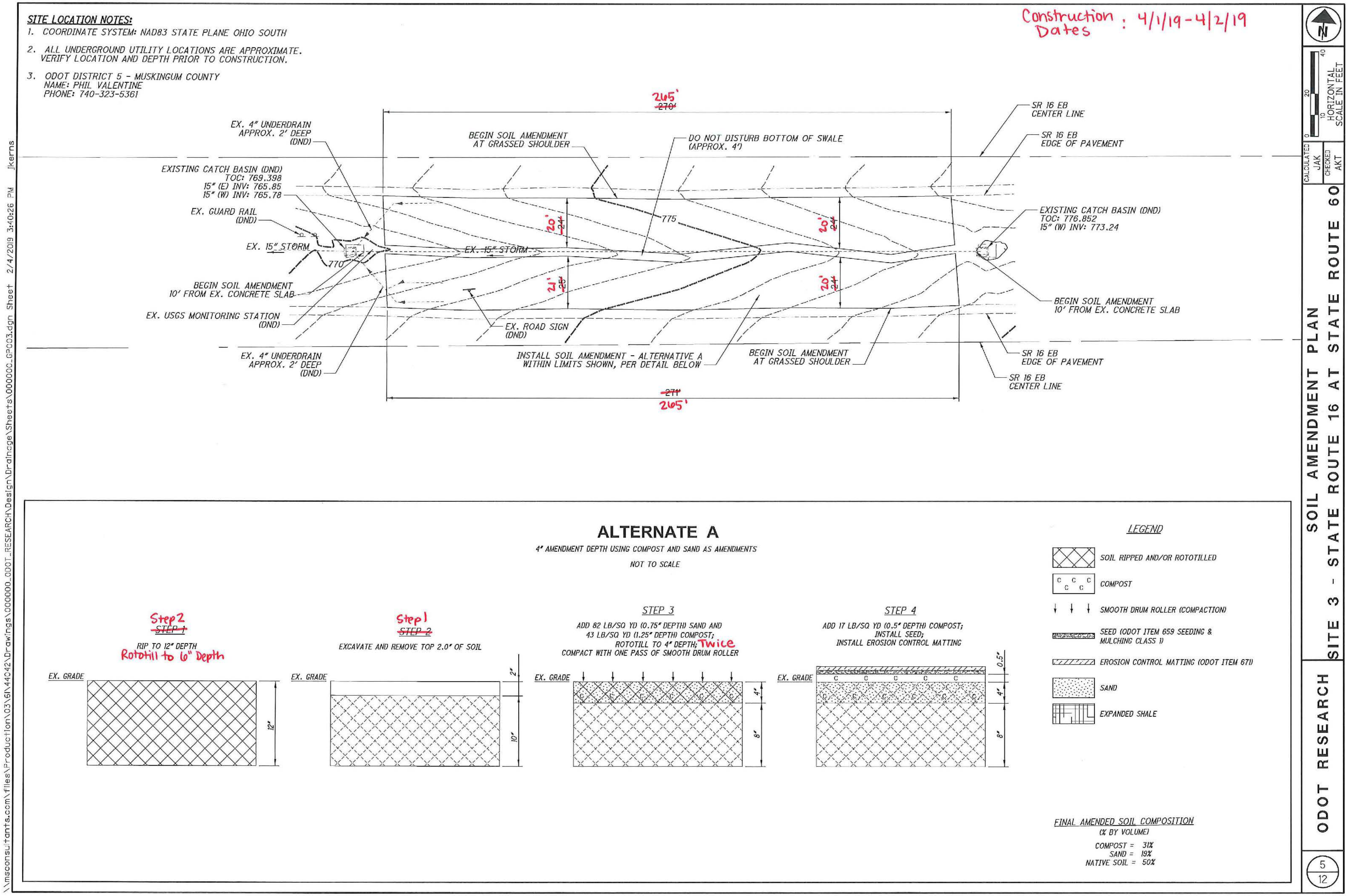
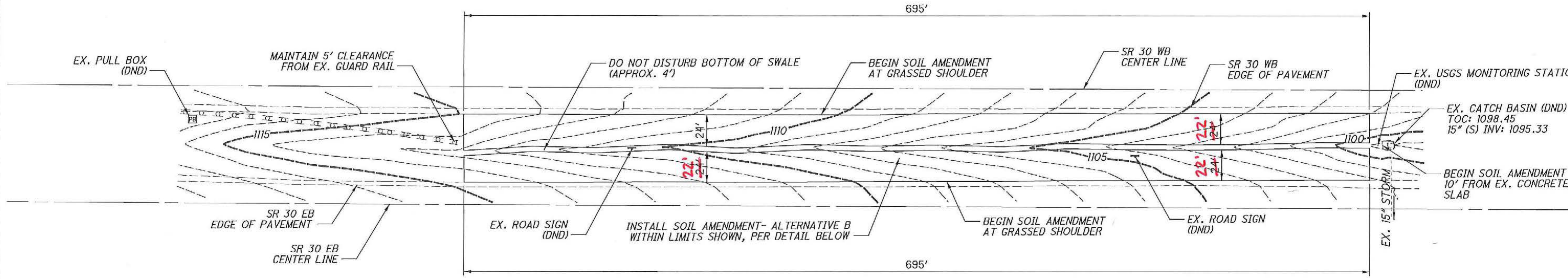

SITE LOCATION NOTES:
1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO SOUTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 5 - MUSKINGUM COUNTY
NAME: PHIL VALENTINE
PHONE: 740-323-5361
Construction Dates : 4/1/19-4/2/19
265'
~~270'~~
EX. 4" UNDERDRAIN APPROX. 2' DEEP (DND)
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
DO NOT DISTURB BOTTOM OF SWALE (APPROX. 4')
SR 16 EB CENTER LINE
SR 16 EB EDGE OF PAVEMENT
EXISTING CATCH BASIN (DND)
TOC: 769.398
15" (E) INV: 765.85
15" (W) INV: 765.78
EX. GUARD RAIL (DND)
EX. 15" STORM
775
770
20' ~~24'~~
21' ~~28'~~
EXISTING CATCH BASIN (DND)
TOC: 776.852
15" (W) INV: 773.24
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
EX. USGS MONITORING STATION (DND)
EX. ROAD SIGN (DND)
EX. 4" UNDERDRAIN APPROX. 2' DEEP (DND)
INSTALL SOIL AMENDMENT - ALTERNATIVE A WITHIN LIMITS SHOWN, PER DETAIL BELOW
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 16 EB EDGE OF PAVEMENT
SR 16 EB CENTER LINE
~~271'~~
265'
ALTERNATE A
4" AMENDMENT DEPTH USING COMPOST AND SAND AS AMENDMENTS
NOT TO SCALE
Step 2
~~STEP 1~~
RIP TO 12" DEPTH
Rototill to 6" Depth
Step 1
~~STEP 2~~
EXCAVATE AND REMOVE TOP 2.0" OF SOIL
STEP 3
ADD 82 LB/SQ YD (0.75" DEPTH) SAND AND 43 LB/SQ YD (1.25" DEPTH) COMPOST; ROTOTILL TO 4" DEPTH; Twice
COMPACT WITH ONE PASS OF SMOOTH DRUM ROLLER
STEP 4
ADD 17 LB/SQ YD (0.5" DEPTH) COMPOST; INSTALL SEED; INSTALL EROSION CONTROL MATTING
EX. GRADE
12"
2"
10"
4"
8"
0.5"
LEGEND
SOIL RIPPED AND/OR ROTOTILLED
COMPOST
SMOOTH DRUM ROLLER (COMPACTION)
SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
EROSION CONTROL MATTING (ODOT ITEM 671)
SAND
EXPANDED SHALE
FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)
COMPOST = 31%
SAND = 19%
NATIVE SOIL = 50%
HORIZONTAL SCALE IN FEET
CALCULATED JAK
CHECKED AKT
SOIL AMENDMENT PLAN
SITE 3 - STATE ROUTE 16 AT STATE ROUTE 60
ODOT RESEARCH
5
12

Construction Dates: 5/20/19 - 5/23/19

**SITE LOCATION NOTES:**

1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO NORTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 4 - STARK COUNTY
   NAME: DOUG MCELROY
   PHONE: 330-786-4927

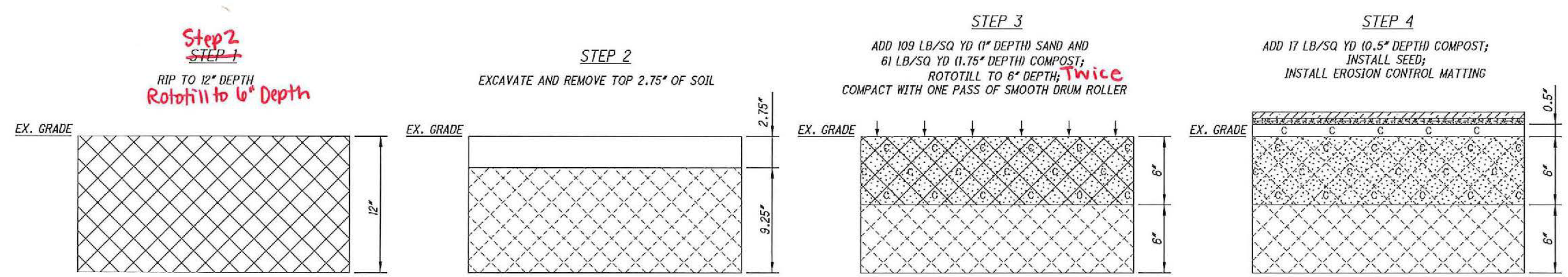
   CITY OF CANTON STREET DEPARTMENT
   NAME: STEVE TRZCINSKI
   PHONE: 330-813-1294




## ALTERNATE C

6" AMENDMENT DEPTH USING COMPOST AND SAND AS AMENDMENTS

NOT TO SCALE




**LEGEND**

- SOIL RIPPED AND/OR ROTOTILLED
- COMPOST
- SMOOTH DRUM ROLLER (COMPACTION)
- SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
- EROSION CONTROL MATTING (ODOT ITEM 671)
- SAND
- EXPANDED SHALE

FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)

COMPOST = 29%
SAND = 17%
NATIVE SOIL = 54%

HORIZONTAL SCALE IN FEET 0 20 40 80

CALCULATED MRB CHECKED JAK

SOIL AMENDMENT PLAN

SITE 4 - STATE ROUTE 30 NEAR TRUMP AVE.

ODOT RESEARCH

6/12

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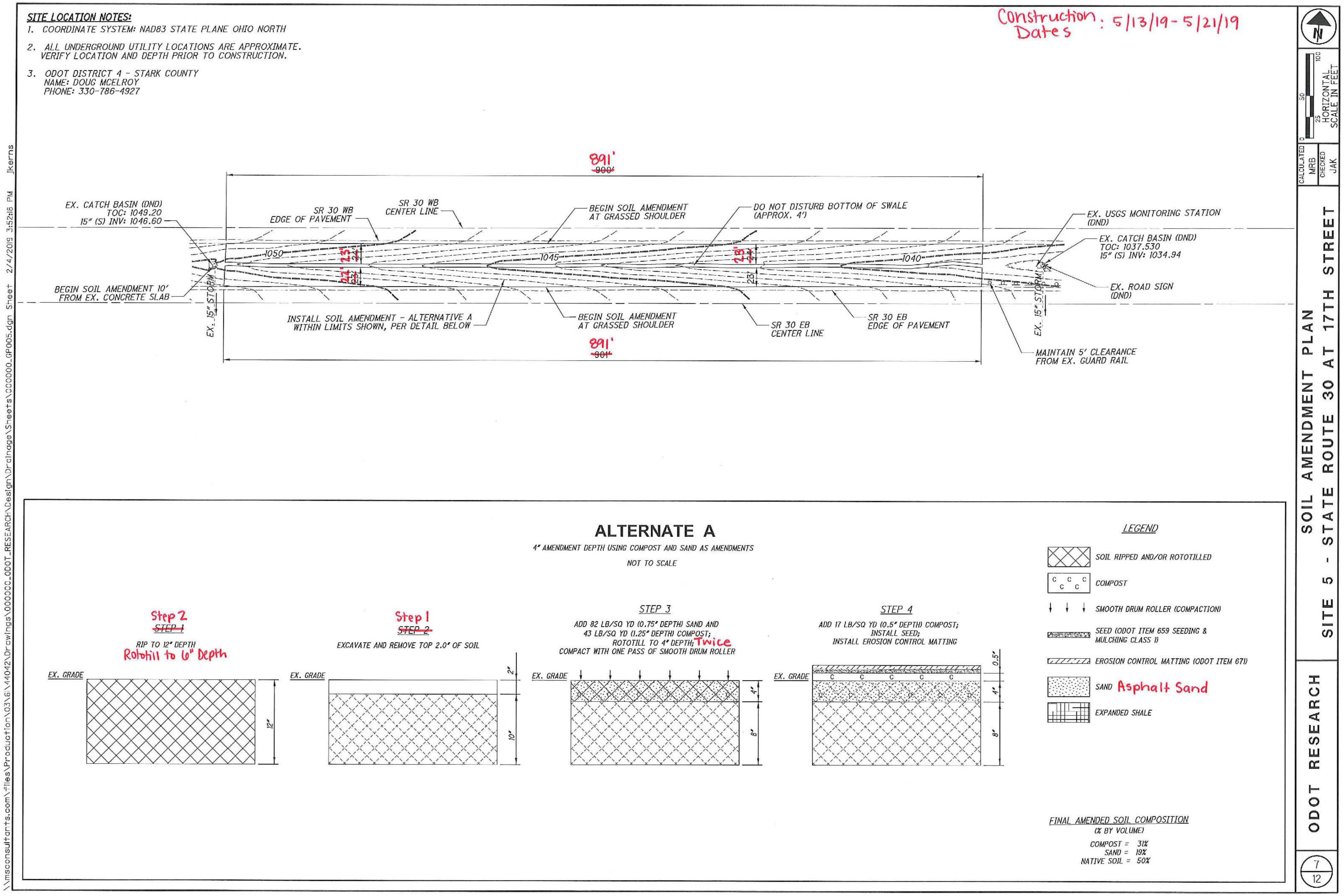
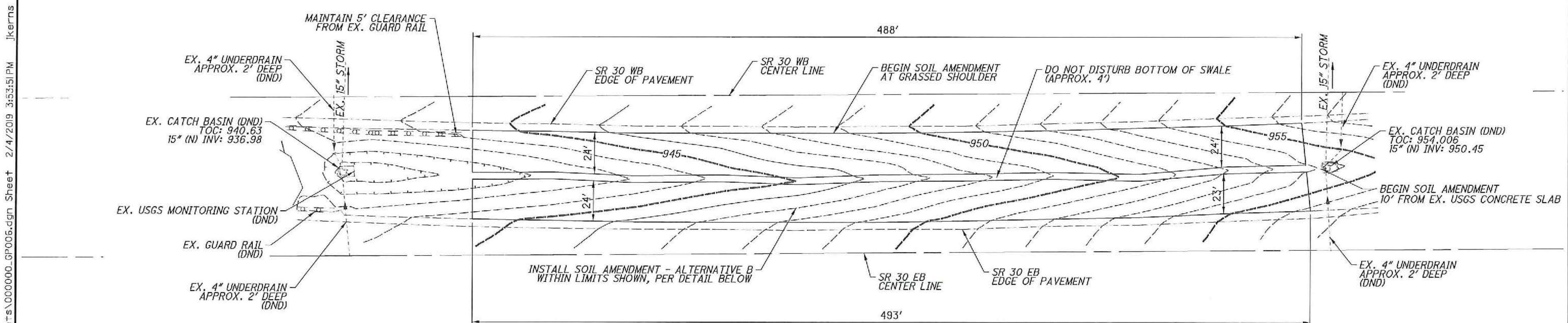

SITE LOCATION NOTES:
1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO NORTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 4 - STARK COUNTY
NAME: DOUG MCELROY
PHONE: 330-786-4927
Construction Dates: 5/13/19 - 5/21/19
891'
~~900'~~
EX. CATCH BASIN (DND)
TOC: 1049.20
15" (S) INV: 1046.60
SR 30 WB EDGE OF PAVEMENT
SR 30 WB CENTER LINE
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
DO NOT DISTURB BOTTOM OF SWALE (APPROX. 4')
EX. USGS MONITORING STATION (DND)
EX. CATCH BASIN (DND)
TOC: 1037.530
15" (S) INV: 1034.94
EX. ROAD SIGN (DND)
1050
1045
1040
23'
21'
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
EX. 15" STORM
INSTALL SOIL AMENDMENT - ALTERNATIVE A WITHIN LIMITS SHOWN, PER DETAIL BELOW
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 30 EB CENTER LINE
SR 30 EB EDGE OF PAVEMENT
891'
~~901'~~
MAINTAIN 5' CLEARANCE FROM EX. GUARD RAIL
ALTERNATE A
4" AMENDMENT DEPTH USING COMPOST AND SAND AS AMENDMENTS
NOT TO SCALE
Step 2
~~STEP 1~~
RIP TO 12" DEPTH
Rototill to 6" Depth
EX. GRADE
12"
Step 1
~~STEP 2~~
EXCAVATE AND REMOVE TOP 2.0" OF SOIL
EX. GRADE
2"
10"
STEP 3
ADD 82 LB/SQ YD (0.75" DEPTH) SAND AND 43 LB/SQ YD (1.25" DEPTH) COMPOST;
ROTOTILL TO 4" DEPTH; Twice
COMPACT WITH ONE PASS OF SMOOTH DRUM ROLLER
EX. GRADE
4"
8"
STEP 4
ADD 17 LB/SQ YD (0.5" DEPTH) COMPOST;
INSTALL SEED;
INSTALL EROSION CONTROL MATTING
EX. GRADE
0.5"
4"
8"
LEGEND
SOIL RIPPED AND/OR ROTOTILLED
COMPOST
SMOOTH DRUM ROLLER (COMPACTION)
SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
EROSION CONTROL MATTING (ODOT ITEM 671)
SAND Asphalt Sand
EXPANDED SHALE
FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)
COMPOST = 31%
SAND = 19%
NATIVE SOIL = 50%
HORIZONTAL SCALE IN FEET
0 25 50 100
CALCULATED MRB
CHECKED JAK
SOIL AMENDMENT PLAN
SITE 5 - STATE ROUTE 30 AT 17TH STREET
ODOT RESEARCH
7
12

Construction Dates: 5/8/19 - 5/13/19

**SITE LOCATION NOTES:**

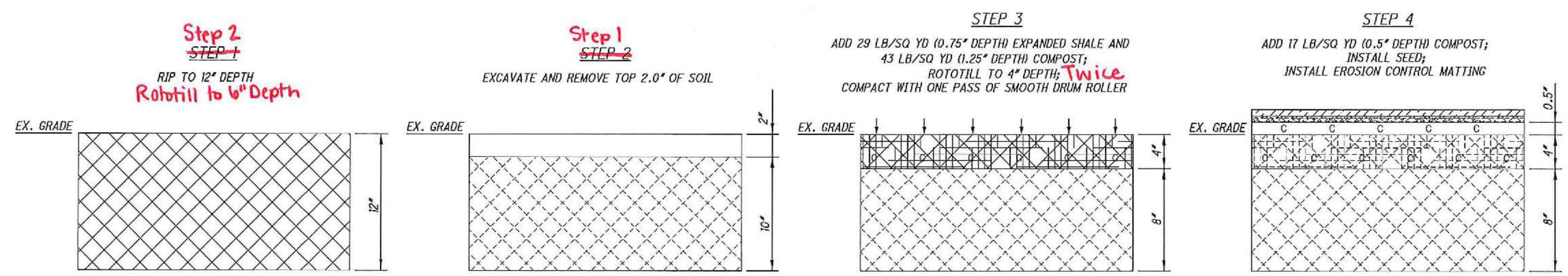
1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO NORTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 3 - WAYNE COUNTY
   NAME: JASON SUTHERLAND
   PHONE: 419-207-2801




## ALTERNATE B

4" AMENDMENT DEPTH USING COMPOST AND EXPANDED SHALE AS AMENDMENTS

NOT TO SCALE




**LEGEND**

- SOIL RIPPED AND/OR ROTOTILLED
- COMPOST
- SMOOTH DRUM ROLLER (COMPACTION)
- SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
- EROSION CONTROL MATTING (ODOT ITEM 671)
- SAND
- EXPANDED SHALE

**FINAL AMENDED SOIL COMPOSITION**
(% BY VOLUME)

COMPOST = 31%
EXPANDED SHALE = 19%
NATIVE SOIL = 50%

HORIZONTAL SCALE IN FEET: 0 15 30 60

CALCULATED MRB
CHECKED JAK

SOIL AMENDMENT PLAN
SITE 6 - STATE ROUTE 30 AT APPLE CREEK

ODOT RESEARCH

8
12

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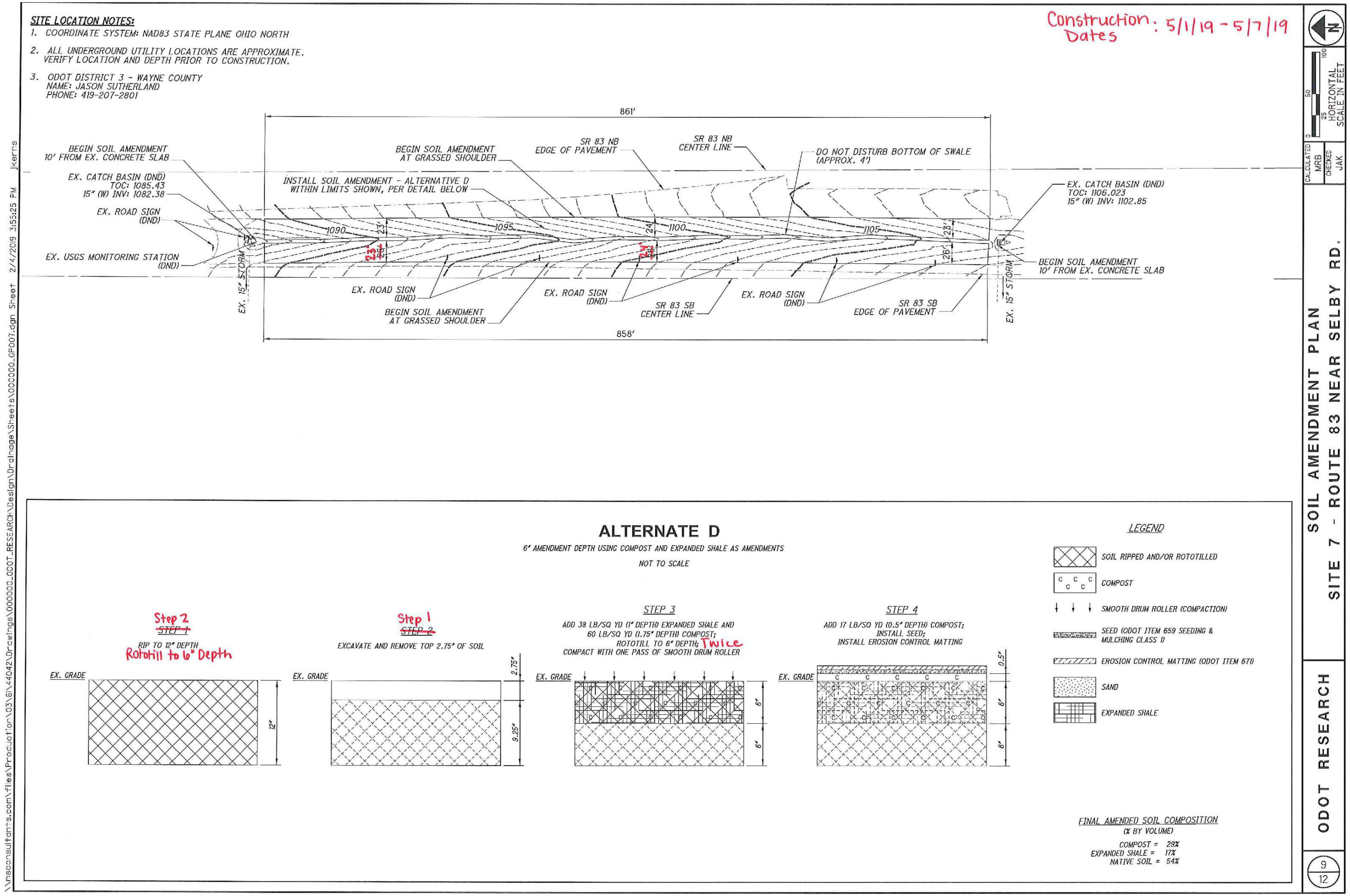
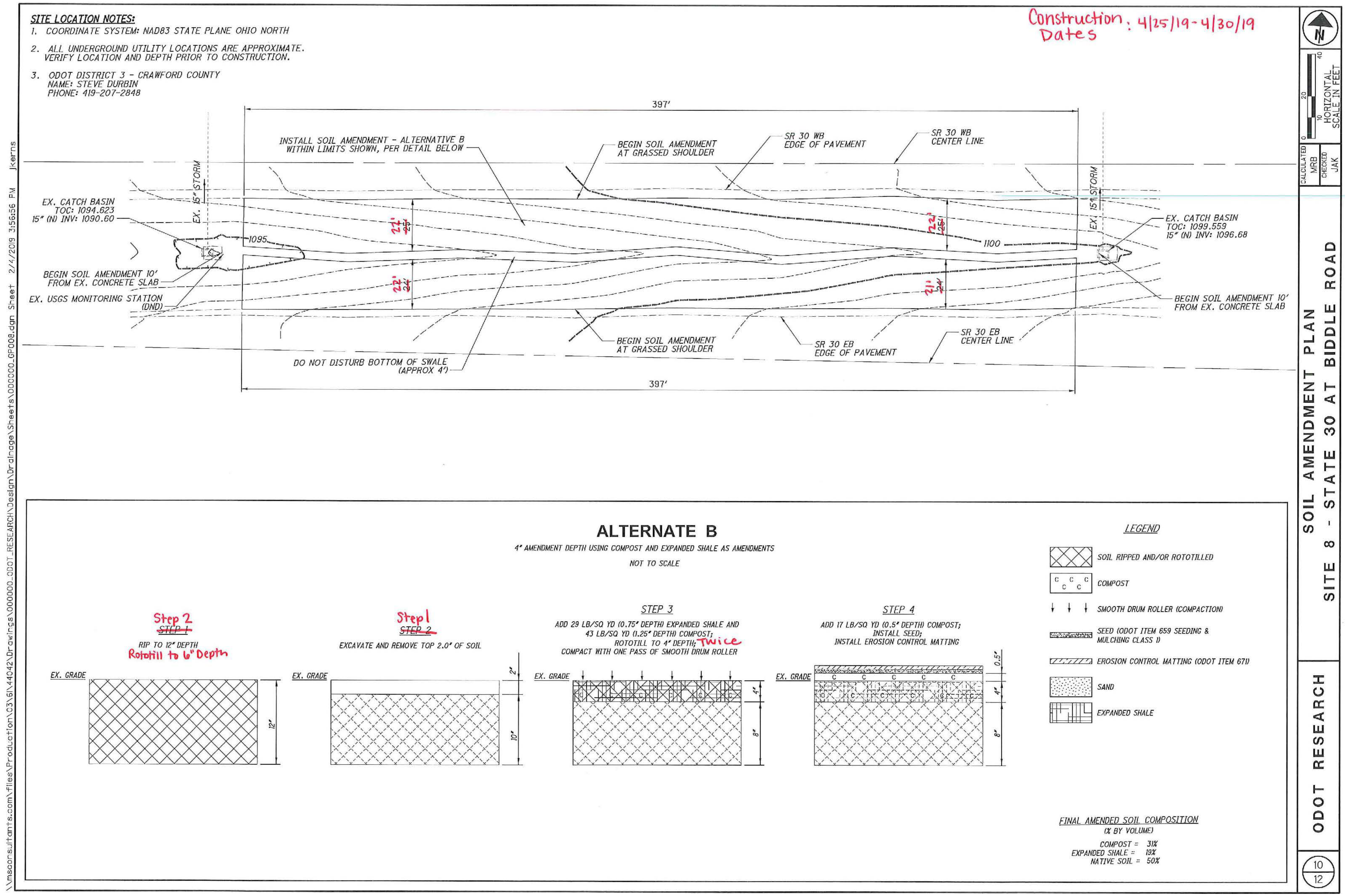
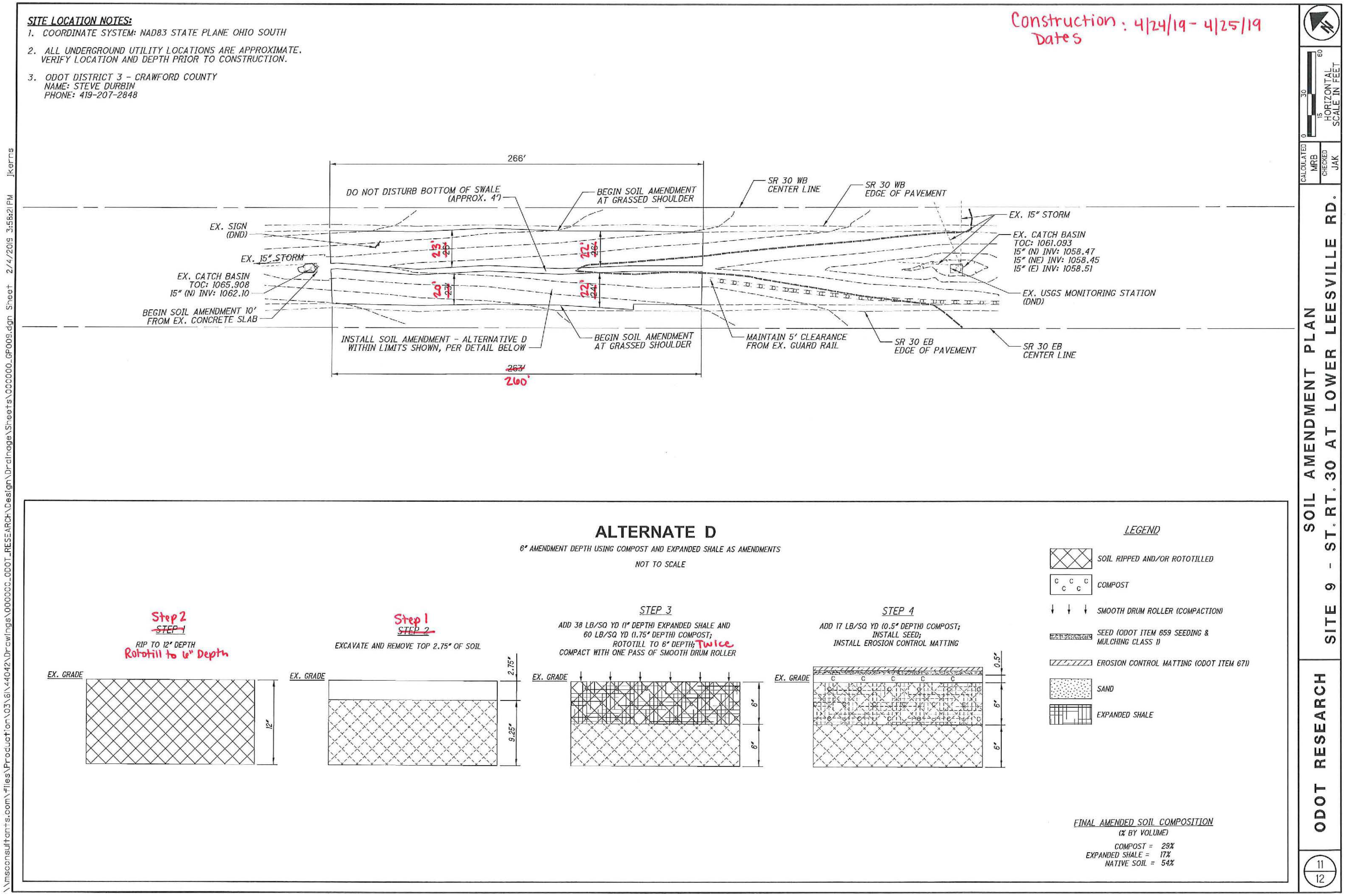
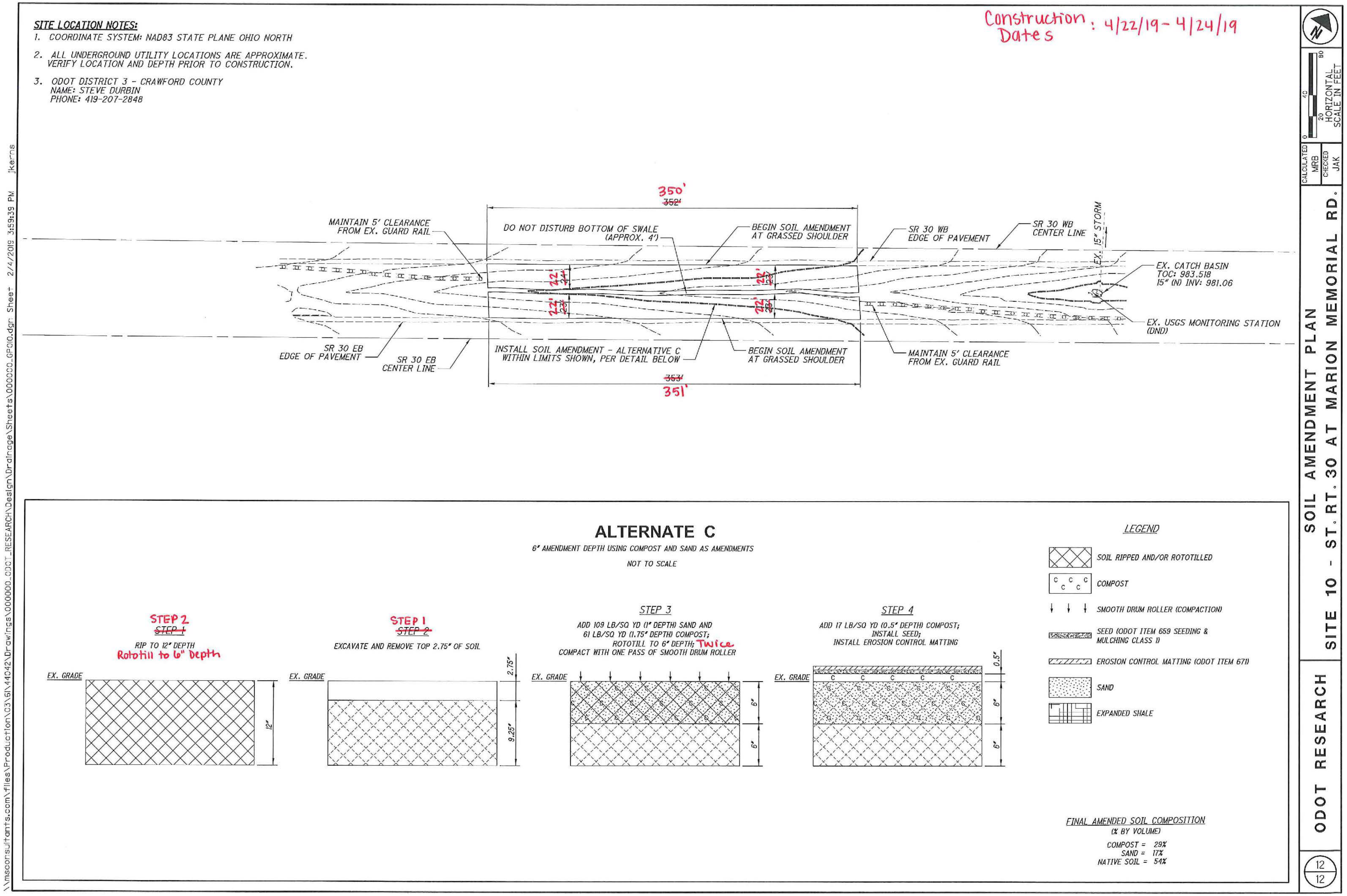

SITE LOCATION NOTES:
1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO NORTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 3 - WAYNE COUNTY
NAME: JASON SUTHERLAND
PHONE: 419-207-2801
Construction Dates: 5/1/19 - 5/7/19
861'
858'
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
EX. CATCH BASIN (DND) TOC: 1085.43 15" (W) INV: 1082.38
EX. ROAD SIGN (DND)
EX. USGS MONITORING STATION (DND)
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 83 NB EDGE OF PAVEMENT
SR 83 NB CENTER LINE
DO NOT DISTURB BOTTOM OF SWALE (APPROX. 4')
INSTALL SOIL AMENDMENT - ALTERNATIVE D WITHIN LIMITS SHOWN, PER DETAIL BELOW
EX. CATCH BASIN (DND) TOC: 1106.023 15" (W) INV: 1102.85
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
EX. ROAD SIGN (DND)
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 83 SB CENTER LINE
SR 83 SB EDGE OF PAVEMENT
EX. 15" STORM
1090
1095
1100
1105
23'
24'
26'
ALTERNATE D
6" AMENDMENT DEPTH USING COMPOST AND EXPANDED SHALE AS AMENDMENTS
NOT TO SCALE
Step 2
~~STEP 1~~
~~RIP TO 12" DEPTH~~
Rototill to 6" Depth
Step 1
~~STEP 2~~
EXCAVATE AND REMOVE TOP 2.75" OF SOIL
STEP 3
ADD 38 LB/SQ YD (1" DEPTH) EXPANDED SHALE AND 60 LB/SQ YD (1.75" DEPTH) COMPOST; ROTOTILL TO 6" DEPTH; Twice
COMPACT WITH ONE PASS OF SMOOTH DRUM ROLLER
STEP 4
ADD 17 LB/SQ YD (0.5" DEPTH) COMPOST; INSTALL SEED; INSTALL EROSION CONTROL MATTING
EX. GRADE
12"
2.75"
9.25"
6"
0.5"
LEGEND
SOIL RIPPED AND/OR ROTOTILLED
COMPOST
SMOOTH DRUM ROLLER (COMPACTION)
SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
EROSION CONTROL MATTING (ODOT ITEM 671)
SAND
EXPANDED SHALE
FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)
COMPOST = 29%
EXPANDED SHALE = 17%
NATIVE SOIL = 54%
HORIZONTAL SCALE IN FEET
CALCULATED MRB
CHECKED JAK
SOIL AMENDMENT PLAN
SITE 7 - ROUTE 83 NEAR SELBY RD.
ODOT RESEARCH
9
12


SITE LOCATION NOTES:
1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO NORTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 3 - CRAWFORD COUNTY NAME: STEVE DURBIN PHONE: 419-207-2848
Construction Dates: 4/25/19-4/30/19
397'
INSTALL SOIL AMENDMENT - ALTERNATIVE B WITHIN LIMITS SHOWN, PER DETAIL BELOW
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 30 WB EDGE OF PAVEMENT
SR 30 WB CENTER LINE
EX. CATCH BASIN TOC: 1094.623 15" (N) INV: 1090.60
EX. 15" STORM
1095
1100
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
EX. USGS MONITORING STATION (DND)
EX. CATCH BASIN TOC: 1099.559 15" (N) INV: 1096.68
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 30 EB EDGE OF PAVEMENT
SR 30 EB CENTER LINE
DO NOT DISTURB BOTTOM OF SWALE (APPROX 4')
397'
ALTERNATE B
4" AMENDMENT DEPTH USING COMPOST AND EXPANDED SHALE AS AMENDMENTS
NOT TO SCALE
Step 2
~~STEP 1~~
RIP TO 12" DEPTH
Rototill to 6" Depth
Step 1
~~STEP 2~~
EXCAVATE AND REMOVE TOP 2.0" OF SOIL
STEP 3
ADD 29 LB/SQ YD (0.75" DEPTH) EXPANDED SHALE AND 43 LB/SQ YD (0.25" DEPTH) COMPOST; ROTOTILL TO 4" DEPTH; Twice
COMPACT WITH ONE PASS OF SMOOTH DRUM ROLLER
STEP 4
ADD 17 LB/SQ YD (0.5" DEPTH) COMPOST; INSTALL SEED; INSTALL EROSION CONTROL MATTING
EX. GRADE
LEGEND
SOIL RIPPED AND/OR ROTOTILLED
COMPOST
SMOOTH DRUM ROLLER (COMPACTION)
SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS D)
EROSION CONTROL MATTING (ODOT ITEM 671)
SAND
EXPANDED SHALE
FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)
COMPOST = 31%
EXPANDED SHALE = 19%
NATIVE SOIL = 50%
HORIZONTAL SCALE IN FEET
CALCULATED MRB
CHECKED JAK
SOIL AMENDMENT PLAN
SITE 8 - STATE 30 AT BIDDLE ROAD
ODOT RESEARCH
10
12


SITE LOCATION NOTES:
1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO SOUTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 3 - CRAWFORD COUNTY
NAME: STEVE DURBIN
PHONE: 419-207-2848
Construction Dates: 4/24/19 - 4/25/19
266'
DO NOT DISTURB BOTTOM OF SWALE (APPROX. 4')
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 30 WB CENTER LINE
SR 30 WB EDGE OF PAVEMENT
EX. 15" STORM
EX. CATCH BASIN
TOC: 1061.093
15" (N) INV: 1058.47
15" (NE) INV: 1058.45
15" (E) INV: 1058.51
EX. USGS MONITORING STATION (DND)
EX. SIGN (DND)
EX. 15" STORM
EX. CATCH BASIN
TOC: 1065.908
15" (N) INV: 1062.10
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
INSTALL SOIL AMENDMENT - ALTERNATIVE D WITHIN LIMITS SHOWN, PER DETAIL BELOW
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
MAINTAIN 5' CLEARANCE FROM EX. GUARD RAIL
SR 30 EB EDGE OF PAVEMENT
SR 30 EB CENTER LINE
~~263'~~ 260'
ALTERNATE D
6" AMENDMENT DEPTH USING COMPOST AND EXPANDED SHALE AS AMENDMENTS
NOT TO SCALE
Step 2 ~~STEP 1~~
RIP TO 12" DEPTH
Rototill to 6" Depth
EX. GRADE
12"
Step 1 ~~STEP 2~~
EXCAVATE AND REMOVE TOP 2.75" OF SOIL
EX. GRADE
2.75"
9.25"
STEP 3
ADD 38 LB/SQ YD (1" DEPTH) EXPANDED SHALE AND 60 LB/SQ YD (0.75" DEPTH) COMPOST;
ROTOTILL TO 6" DEPTH; Twice
COMPACT WITH ONE PASS OF SMOOTH DRUM ROLLER
EX. GRADE
6"
6"
STEP 4
ADD 17 LB/SQ YD (0.5" DEPTH) COMPOST;
INSTALL SEED;
INSTALL EROSION CONTROL MATTING
EX. GRADE
0.5"
6"
6"
LEGEND
SOIL RIPPED AND/OR ROTOTILLED
COMPOST
SMOOTH DRUM ROLLER (COMPACTION)
SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
EROSION CONTROL MATTING (ODOT ITEM 671)
SAND
EXPANDED SHALE
FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)
COMPOST = 29%
EXPANDED SHALE = 17%
NATIVE SOIL = 54%
HORIZONTAL SCALE IN FEET
CALCULATED MRB
CHECKED JAK
SOIL AMENDMENT PLAN
SITE 9 - ST. RT. 30 AT LOWER LEESVILLE RD.
ODOT RESEARCH
11
12


SITE LOCATION NOTES:
1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO NORTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 3 - CRAWFORD COUNTY
NAME: STEVE DURBIN
PHONE: 419-207-2848
Construction Dates: 4/22/19 - 4/24/19
350'
~~352'~~
MAINTAIN 5' CLEARANCE FROM EX. GUARD RAIL
DO NOT DISTURB BOTTOM OF SWALE (APPROX. 4')
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 30 WB EDGE OF PAVEMENT
SR 30 WB CENTER LINE
EX. 15" STORM
EX. CATCH BASIN
TOC: 983.518
15" (N) INV: 981.06
EX. USGS MONITORING STATION (DND)
SR 30 EB EDGE OF PAVEMENT
SR 30 EB CENTER LINE
INSTALL SOIL AMENDMENT - ALTERNATIVE C WITHIN LIMITS SHOWN, PER DETAIL BELOW
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
MAINTAIN 5' CLEARANCE FROM EX. GUARD RAIL
~~353'~~
351'
ALTERNATE C
6" AMENDMENT DEPTH USING COMPOST AND SAND AS AMENDMENTS
NOT TO SCALE
STEP 2
~~STEP 1~~
RIP TO 12" DEPTH
Rototill to 6" Depth
STEP 1
~~STEP 2~~
EXCAVATE AND REMOVE TOP 2.75" OF SOIL
STEP 3
ADD 109 LB/SQ YD (1" DEPTH) SAND AND 61 LB/SQ YD (1.75" DEPTH) COMPOST; ROTOTILL TO 6" DEPTH; Twice
COMPACT WITH ONE PASS OF SMOOTH DRUM ROLLER
STEP 4
ADD 17 LB/SQ YD (0.5" DEPTH) COMPOST; INSTALL SEED; INSTALL EROSION CONTROL MATTING
EX. GRADE
12"
2.75"
9.25"
6"
0.5"
LEGEND
SOIL RIPPED AND/OR ROTOTILLED
COMPOST
SMOOTH DRUM ROLLER (COMPACTION)
SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
EROSION CONTROL MATTING (ODOT ITEM 671)
SAND
EXPANDED SHALE
FINAL AMENDED SOIL COMPOSITION (% BY VOLUME)
COMPOST = 29%
SAND = 17%
NATIVE SOIL = 54%
HORIZONTAL SCALE IN FEET
CALCULATED MRB
CHECKED JAK
SOIL AMENDMENT PLAN
SITE 10 - ST. RT. 30 AT MARION MEMORIAL RD.
ODOT RESEARCH
12
12

# Appendix F: Soil Analysis Report

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ENVIRONMENTAL, ENGINEERING & SCIENCE

# SOIL AMENDMENT /POOR GRASS GROWTH ANALYSIS

## ODOT Stormwater Volume Reduction Research

**Prepared for:**

**ms consultants**
2221 Schrock Road
Columbus, Ohio 43229

**Prepared by:**

**Stone Environmental Engineering and Science, Inc.**
748 Green Crest Drive
Westerville, OH 43081

July 27, 2021
C584-004-16

ENVIRONMENTAL, ENGINEERING & SCIENCE

July 27, 2021
C584-004-16

Mr. Anil Tangirala
ms consultants, inc.
2221 Schrock Road
Columbus, OH 43229
ATangirala@msconsultants.com

**Re: Soil Amendment / Poor Grass Growth Analysis**
ODOT Stormwater Volume Reduction Research

Dear Mr. Tangirala,

In accordance with our proposal, Stone Environmental Engineering and Science, Inc. (STONE) conducted soil analyses on the amended soils of the ODOT Stormwater Volume Reduction test sites to analyze potential parameters relating to vegetative growth success. The enclosed report provides a summary of the data collection, analysis, and conclusions from the testing.

Thank you for the opportunity and please let us know if you have any questions.

Sincerely,
**Stone Environmental Engineering & Science, Inc.**

Mary Sharrett, PE, LEED AP, CPESC
President

Samantha Robbins, CESSWI
Project Scientist

Submitted: 1 electronic copy (PDF) via e-mail

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# APPENDICES

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Soil Sample Location Figures
Soil Profile Figures

**Appendix B**
Photo Log

**Appendix C**
Table C - Summary Table of Laboratory Results
Laboratory Analytical Reports

# 1 OVERVIEW

It is understood that vegetative growth has not been considered successful on several of the amended soil sites as part of the stormwater volume reduction research project. At least four of the ten sites have not reached the 70% established growth as expected per Ohio Department of Transportation (ODOT) Items 659 and 832. The remainder (6 sites) have met the minimum requirements. Some potential contributors to poor vegetative growth include the compost used, homogeneity of the amended soils, lack of nutrients, soil pH, and soil texture as well as other environmental factors. The following report discusses the parameters evaluated and soil testing performed in an effort to define the cause(s) of the poor grass growth.

# 2 BACKGROUND

## 2.1 Research Data

ms consultants, inc. provided the following information to Stone Environmental Engineering & Science, Inc. (STONE) on April 20, 2021

| Site | % Veg. Coverage (04-15-2021) | Amendment Type | Hydroseeded in Summer 2019 | Pre-BMP Runoff Percentage | Post-BMP Runoff Percentage |
|---|---|---|---|---|---|
| 1 | >70% | Expanded Shale | | 46.8 | 32.3 |
| 2 | ~60% | Sand | | 47.6 | 36.1 |
| 3 | ~70% | Sand | | 37.4 | 19.6 |
| 4 | >70%* | Sand | Hydroseeded | 21.7 | 18.7 |
| 5 | ~10%* | Sand | Hydroseeded | 30.4 | 36.8 |
| 6 | >70%* | Expanded Shale | Hydroseeded | 9.0 | 6.5 |
| 7 | ~50%* | Expanded Shale | Hydroseeded | 47.6 | 45.6 |
| 8 | ~50% | Expanded Shale | | 8.2 | 13.1 |
| 9 | ~50% | Expanded Shale | | 18.0 | 21.7 |
| 10 | ~70%* | Sand | Hydroseeded | 23.8 | 30.1 |

Also provided were photographs at each amendment site taken by ODOT in April 2021 of the grass coverage/growth, comparing amended soil areas to adjacent non-amended areas. In addition to poorer coverage of grass, ODOT noted that some sites also appeared to contain more clover or weedy species as opposed to grass.

Higher post-BMP runoff percentages were found for Sites 5, 8, 9 and 10, taking into account the second round of seeding for sites 5 and 10. STONE was requested to evaluate the potential causes for poor grass growth, and review the amendment formula intended to be used by ODOT in the future for stormwater runoff reduction.

## 2.2 General

The following table summarizes some of the features of each of the 10 sites, in an effort to evaluate potential grass growth factors.

Sites 4, 5, 6, 7, and 10 were overseeded twice following construction completion. STONE personnel overseeded by hand broadcasting 100 pounds of Class 1 Lawn seed mix across these sites on June 18, 2019. These same sites were also overseeded on July 25, 2019 by application of hydroseed. The hydroseed mixture applied to the sites included Class 1 Lawn Mixture, Annual Rye, 15-30-15 Fertilizer, and Liquid Lime Plus. The sites were watered twice within two weeks after hydroseeding.

**TABLE 2.2 – OVERVIEW OF SITE DATA**
**Soil Amendment /Poor Grass Growth Analysis**

| Site | % Veg. Coverage | Amendment Type | Reseeded | Fertilizer Added | Rainfall Zone | Mapped Soil Type | Construction Timing |
|---|---|---|---|---|---|---|---|
| 1 | >70% | 6" Expanded Shale | | | C | Silt Loam | 4/10 to 4/19 |
| 2 | ~60% | 6" Sand | | | C | Silt Loam | 4/4 to 4/10 |
| 3 | ~70% | 4" Sand | | | B | Silt Loam | 4/1 to 4/2 |
| 4 | >70%* | 6" Sand | Yes | Yes | A | Silt Loam | 5/20 to 5/23 |
| **5** | **~10%*** | **4" Sand** | **Yes** | **Yes** | **A** | **Silt Loam** | **5/13 to 5/21** |
| 6 | >70%* | 4" Expanded Shale | Yes | Yes | A | Silt Loam | 5/8 to 5/13 |
| **7** | **~50%*** | **6" Expanded Shale** | **Yes** | **Yes** | **A** | **Silt Loam** | **5/1 to 5/7** |
| **8** | **~50%** | **4" Expanded Shale** | | | **C** | **Silt Loam/ Silty Clay Loam** | **4/25 to 4/30** |
| **9** | **~50%** | **6" Expanded Shale** | | | **B** | **Silt Loam/ Silty Clay Loam** | **4/24 to 4/25** |
| 10 | ~70%* | 6" Sand | **Yes** | **Yes** | B | Silt Loam/ Silty Clay Loam | 4/22 to 4/24 |

*Hydroseeded
**Bolded** are sites considered to have the poorest grass growth.

No overseeding was applied to sites 8 and 9 as their initial growth success did not indicate additional seeding would be needed, however they are listed as two of the four sites with poor vegetative cover in 2021. Sites 5 and 7 were overseeded and have been identified as two of the four sites with poor vegetative cover in 2021. Sites 4, 6, and 10 were overseeded and have been identified to have ~70% vegetative cover by ODOT in 2021.

# 3 FIELD SOIL SAMPLE COLLECTION

On June 15, and June 16, 2021 STONE collected soil samples at six sites to further analyze the potential contributing factors to the poor vegetative growth.

## 3.1 Site Selection

STONE sampled six of the ten amended sites (Sites 3, 4, 5, 7, 8, and 9) as agreed upon with the research team. The following Table 3.1 summarizes various site features.

The following items (environmental conditions as well as amendment designs) were considered as potential factors contributing to the poor grass performance:

- Amendment Formula
- Native Soils
- Location
- Time of Construction/Seeding
- Compost

- Rainfall Events
- Seed Type/Mix
- Fertilizer and Lime
- Homogenous Incorporation

**TABLE 3.1 – SITE SELECTION SUMMARY**
**Soil Amendment /Poor Grass Growth Analysis**

| Site | % Veg. Coverage | Total Drainage Area (Ac) | Amended Area (Ac) | Amendment | Depth (in) | Compost Depth (in) | ODOT Note |
|---|---|---|---|---|---|---|---|
| 1 | >70% | 2.26 | 1.07 | Expanded Shale | 1.0 | 1.75 | |
| 2 | ~60% | 1.17 | 0.56 | Sand | 1.0 | 1.75 | mostly clover |
| **3** | **~70%** | 0.57 | 0.25 | **Sand** | **0.75** | 1.25 | Sandy, loose |
| **4** | **>70%*** | 1.92 | 0.72 | **Sand** | **1.0** | 1.75 | |
| **5** | **~10%*** | **1.85** | **0.93** | **Sand** | **0.75** | 1.25 | Sandy, loose |
| 6 | >70%* | 1.2 | 0.53 | Expanded Shale | 0.75 | 1.25 | Weedy, clover, dandelions |
| **7** | **~50%*** | **2.11** | **0.93** | **Expanded Shale** | **1.0** | 1.75 | |
| **8** | **~50%** | **0.78** | **0.4** | **Expanded Shale** | **0.75** | 1.25 | Grass, with large bare spots |
| **9** | **~50%** | **0.92** | **0.26** | **6" Expanded Shale** | **1.0** | 1.75 | North side 20% coverage, south 60 to 70% coverage |
| 10 | ~70%* | 1.43 | 0.35 | 6" Sand | 1.0 | 1.75 | North side 60% coverage, south 80%, heterogeneous |

**Bold** indicates sampled Site.

## 3.2 Sample Locations

For each site, five soil samples were collected. The five samples consisted of:

- Two soil samples from "good" grass growth areas within the amended area
- Two soil samples from "poor" grass growth areas within the amended area
- One sample from the native soils in a good grass growth area outside of the amended area. This is also referred to as the "native" sample.

Samples were identified using the following format:

- Site Number (e.g., 3)
- North "N" or South "S" side of the site
- Type of area "G" for good grass and "B" for poor grass
- Sample number. Samples 1 through 4 were in the amended areas. Sample 5 was taken from the native area.

For example, the sample from Site 3 on the north side in the area of poor grass growth, which was the second sample collected, was labelled 3NB2.

It is noted that Site 7 was the only site that did not have a north and a south side but rather an east and a west side. To maintain labelling consistency, the west side samples were labelled “N” and the East side samples were labelled “S”.

Figures in Appendix A illustrate the sample collection locations.

## 3.3 Soil Sample Collection Procedure

A hand sampling kit was used for sample collection. The kit consisted of a slide hammer, anvil, rods, and sample barrel. A two-foot long PVC liner was placed in the sample barrel used to collect the samples. The barrel was driven with the slide hammer 18-inches to 24-inches in depth, or until refusal. The blow counts with the slide hammer were recorded to document the differences at six-inch intervals. The sampler was then removed from the ground, requiring the use of a jack at times, and the PVC liners were extracted and capped for visual assessment to take place at the office.

After the core samples were collected, additional material was collected by hand shovel immediately adjacent to the core sample location. The shovel (bulk) sample was approximately 6-inches by 6-inches with a depth of 8-inches. This material was collected, labelled, and sealed in plastic bags. The soil cores collected in the liners were utilized for visual profile observation, while the bulk soil samples collected in the plastic bags provided the needed quantity for laboratory analysis.

For each site a total of five samples, four samples in the amended area and one in a non-amended area was collected. The non-amended sample was collected for general comparison. Each sample location was recorded with a hand-held GPS unit (locations are illustrated on the figures in Appendix A). The sites were visually assessed to identify areas of good growth and poor growth. The good growth samples collected on Sites 5, 7 and 9 are relative to those sites. Good growth areas on these sites were challenging to identify and may be considered poor growth on other sites. Photographs of the vegetation condition at each sample location are depicted in the Photo Log in Appendix B.

Table 3.3 (following page) summarizes the samples collected and the blow counts recorded.

## 3.4 Soil Sample Selection

Five samples were collected at each site, but only three from each site were sent for lab analysis. All sites had the native soil sample from the non-amended area (e.g., XEG5) sent for analysis. The cores were then visually assessed to identify the representative “good growth” and “poor growth” sample from each site’s amended areas to send for lab analysis. For example, between two “poor growth” cores, if one showed a much higher concentration/obvious layer of sand, that sample was chosen for analysis.

## TABLE 3.3 – FIELD OBSERVATION
## Soil Amendment /Poor Grass Growth Analysis

| Sample ID | Location | 0 to 6" | 6" to 12" | 12" to 18" | Field Notes | Observed Root Depth (in) |
|---|---|---|---|---|---|---|
| 3NG1 | Amended | NA | NA | NA | 70 blow count. Refusal at 13" | 2.5 |
| 3NB2 | Amended | 10 | 57 | 68 | Very rocky. Refusal at 13" | 0 |
| 3SG3 | Amended | 4 | 33 | 54 | Refusal at 13" | 2 |
| 3SB4 | Amended | 2 | 22 | 55 | Very sandy / loose. Refusal at 15" | 0 |
| **3EG5** | Existing | NA | NA | NA | Blow count estimated at 90 at refusal | 0.5 |
| 4NG1 | Amended | 13 | 25 | 50 | Blow count to 24" depth | 5 |
| 4NB2 | Amended | 4 | 14 | 31 | | 4 |
| 4SG3 | Amended | 8 | 15 | 23 | | 2.5 |
| 4SB4 | Amended | 3 | 9 | 18 | Very sandy. 18 strikes to 18". | 1 |
| **4EG5** | Existing | 8 | 19 | 34 | Good looking.60 strikes to 24" depth | 3 |
| 5NG1 | Amended | 5 | 12 | 28 | The "goods" are still bad | 1.5 |
| 5NB2 | Amended | 3 | 10 | 25 | Loose, easy to remove. | 0 |
| 5SG3 | Amended | 5 | 13 | 25 | "Good" is still bad. | 2.5 |
| 5SB4 | Amended | 5 | 11 | 21 | | 0 |
| **5EG5** | Existing | 5 | 11 | 15 | Existing soil not good vegetation either | 2 |
| 7NG1 | Amended | 5 | 14 | 53 | Not well mixed. Not really "good growth". | 4 |
| 7NB2 | Amended | 6 | 14 | 31 | | 0 |
| 7SG3 | Amended | 5 | 10 | 24 | | 2.5 |
| 7SB4 | Amended | 4 | 16 | 33 | Not well mixed. | 2 |
| **7EG5** | Existing | 16 | 48 | 83 | Rocky pebbles. | 4 |
| 8NG1 | Amended | 6 | 13 | 17 | | 3 |
| 8NB2 | Amended | 3 | 7 | 14 | | 0 |
| 8SG3 | Amended | 4 | 9 | 17 | Lots of expanded shale. | 3 |
| 8SB4 | Amended | 3 | 7 | 14 | Loose. Heavy on compost. | 0 |
| **8EG5** | Existing | 11 | 23 | 31 | | 7 |
| 9NG1 | Amended | 7 | 17 | 26 | | 2.5 |
| 9NB2 | Amended | 5 | 23 | 44 | | -- |
| 9SG3 | Amended | 5 | 17 | 27 | | 3 |
| 9SB4 | Amended | 5 | 10 | 22 | | 0.5 |
| **9EG5** | Existing | 7 | 13 | 21 | | 4 |

NA – data not recorded
**Bold** indicates sample was selected for laboratory analyses.
Shaded indicates non-amended sample.

# 4 SOIL PROFILE OBSERVATION

Soil profile samples were brought back to the office for further visual review. After cutting open the plastic sleeves containing the core sample, visual observations, measurements, and photographs were taken. Photographs of the cores are included in the Photo Log in Appendix B. Visual observations of the core included:

- Grass root depth
- Soil profile and materials
- Unconfined strength (for cohesive soils using a hand penetrometer)

Figures illustrating the general soil profile are included in Appendix A. Root depths are summarized in Table 3.3. Root depths were measured with a tape based on obvious evidence of root structure. In general, the existing soils had deeper roots, with the better performing amendment soil samples also having deeper roots.

## 4.1 Site 3

Amendment mix was 0.75-inches of sand and 1.25-inches of compost. Weathered shale appeared to be the parent material, and was as shallow as 6 inches below the ground surface. With the exception of sample 3NB2, soils appeared to consist of the compost/mulch/soil underlain with fine sand or clayey silt with fine sand, underlain by weathered shale. Refusal was encountered during sample collection around 13 inches below the ground surface, and soil was noted as "very rocky" in 3NB2.

## 4.2 Site 4

Amendment mix was 1.0-inches of sand and 1.75-inches of compost. Of the sites sampled, this site was the best vegetated. All amended soil samples appeared to have compost and sand intermixed to a depth of 4 to 6 inches. For samples 4NG1 and 4SB4, blow counts were low (as compared to other sample locations) to a depth of 18 inches. Parent material consisted of very-stiff to hard clayey silt.

## 4.3 Site 5

Amendment mix was 0.75-inches of sand and 1.25-inches of compost. The "good" samples (5NG1, 5SG3) appeared to have a mixture of compost to a depth of about 5 inches. It is noted that the "good" samples were observed to have poor vegetative growth as compared to other sites. The two "bad" (5NB2, 5SB4) samples appeared to lack the top compost layer, and was predominantly composed of sand to a depth of about 6 inches. During sample collection, the material at 5NB2 was described as "very loose". Parent material was generally stiff to very stiff cohesive soils, however in 5NG1, fine sand was encountered to a depth of 15 inches.

## 4.4 Site 7

Amendment mix was 1.0-inches of expanded shale and 1.75-inches of compost. The "good" samples (7NG1, 7SG3) appeared to have a top layer of mulch/compost/soil underlain by cohesive soils. In the field, 7NG1 was noted as not being well mixed, and growth was still poor. 7NG3 had a thin layer of fine gravel between the rototilled soil and native soil. The two "bad" (7NB2, 7SB4) samples appeared to lack the top compost layer, and was predominantly fine gravel (suspected to be the expanded shale) for the top 1 to 2 inches. Parent material was shale in 7NG1 and in the non-amended area sample, and was hard clayey silt in the remaining samples.

### 4.5 Site 8

Amendment mix was 0.75-inches of expanded shale and 1.25-inches of compost. The “good” samples (8NG1, 8SG3) appeared to have a mixture of compost and fine gravel (fine gravel presumed to be the expanded shale) to a depth of 6 inches. In the field, sample 8SG3 was noted as having a lot of expanded shale. The two “bad” (8NB2, 8SB4) samples differed in their composition. 8NB2 lacked compost and appeared to consist of a top layer of 2.0-inches of fine gravel (expanded shale) underlain by silty clay. 8SB4 had 2.5-inches of mulch/compost/soil followed by cohesive soil mixed with compost to a depth of 6.0-inches. In the field sample 8SB4 was noted as being heavy on compost and material was loose. Parent material generally consisted of very-stiff to hard clayey silt or silty clay.

### 4.6 Site 9

Amendment mix was 1.0-inches of expanded shale and 1.75-inches of compost. The “good” samples (9NG1) appeared to have a mixture of mulch/compost/soil to 2.5-inches followed by 1.5-inches of fine gravel mixed with cohesive soil to a depth of 4-inches. 9SGS consisted of 3-inches of mulch/compost/soil underlain by cohesive soils. The two “bad” (9NB2, 9SB4) samples appeared to lack the top compost layer, and was predominantly fine gravel (suspected to be the expanded shale) mixed with cohesive soil for the top 3-inches. Parent material was hard clayey silt.

## 5 LABORATORY ANALYSIS

Soil samples were delivered to Holmes Laboratory Inc. in Millersburg, Ohio on June 21, 2021. Laboratory analyses was performed on two amended area samples and one non-amended area sample from each site (18 samples total). Laboratory analysis included:

- Soil pH
- % Organic Matter
- Phosphorus (P), Potassium (K), Magnesium (Mg), Calcium (Ca), and Sodium (Na)
- Soil texture (% sand, clay, silt)
- Moisture Content % (As Sampled, Dried & Sieved)
- Laboratory Additive recommendations (based on the laboratory results)

Copies of the laboratory analytical results are included in Appendix C. Table C – Summary of Laboratory Results is included in Appendix C and provides a summary of all the analytical results. The following sections provide a summary of the laboratory testing.

### 5.1 pH

Soil pH preferences vary depending on the types of vegetation, but typically the ideal soil pH is close to neutral, and neutral soils fall within a range from 6.5 to 7.5. Soil pH results of the samples ranged between 7.2 and 8.5. With the exception of Site 8, the amended soils generally had a higher pH than the native sample. Samples from the native non-amended soils ranged from 7.2 to 8.4 (mean 7.87), while samples from the amended areas ranged from 7.6 to 8.4 (mean 8.04). pH effects the availability of nutrients to plants.

## 5.2 Organic Content

The organic matter content ranged from 2% to 18.4%. The mean organic content in native soils was 3.88%, and the mean in amended soils was 7.19%. In general, the amended soils had a higher organic content than the native soil.

## 5.3 P, K, Mg, Ca, and Na

- Phosphorous is often added to improve vegetative growth. Phosphorous content ranged from 4 to 312 lb./acre. The average for the B sites was at 52 while for the G sites it was 162, with the native soils averaging 13.
- Potassium ranged from 82 to 372 lb./acre. The average for the B sites was at 196 while for the G sites it was 237, with the native soils averaging 172.
- Magnesium ranged from 6.7 to 14.4 lb./acre. The average for the B sites was at 390 while for the G sites it was 480, with the native soils averaging 418.
- Calcium ranged from 2,305 to 9,858 lb./acre. The average for the B sites was at 5,711 while for the G sites it was 5,960, with the native soils averaging 4,249.
- Sodium ranged from 332 to 2,066 lb./acre. The average for the B sites was at 678 while for the G sites it was 982, with the native soils averaging 812. At the XNB2 sites, there was a substantial decrease in sodium (%).

## 5.4 Particle Sizes

- Sand content ranged from 2% to 49%. The average for the B sites was at 25% while for the G sites it was 26%, with the native soils averaging 14%.
- Silt content ranged from 13% to 41 %. The average for the B sites was at 23% while for the G sites it was 25%, with the native soils averaging 30%.
- Clay content ranged from 38% to 70%. The average for the B sites was at 51% while for the G sites it was 48%, with the native soils averaging 55%.

# 6 EVALUATION

Comparing the native versus amended soils at each site, the largest consistent differences were increases in:

- phosphorous
- % sand
- % organic matter
- calcium, and
- cation exchange capacity.

**This confirms the intent of the design (to increase permeability and organic content, as well as increase the nutrient content within the amended soils) was successful.**

It was noted that Sites 5 and 7, which visually appeared the poorest in vegetative growth, both had native soil with higher sand content. The sand content in the amended soils decreased in both the G and B amendment samples at Site 7 and G samples at Site 5, but increased greatly in the B samples from Site 5.

## 6.1 Compost Soil Amendment

The use of compost was recommended because it can increase water holding and retention, improve infiltration and exfiltration, and increase nutrient availability in the soil. Two mulch suppliers were used on the project: Earth'n Wood compost was utilized on Sites 4, 5, 6 and 7 and the Kurtz Bros. was utilized on Sites 1, 2, 3, 8, 9, and 10.

Results show that the organic matter levels are mostly at acceptable ratios now (at least 3% organic matter is desired for good grass growth) – considering the material has degraded further in the two years since it was placed. However, that organic matter was not necessarily available as nutrients to the grass seed when it was installed since the compost wasn't matured.

Compost did not meet the maturity level, nitrogen content, or sieve size specifications, and was at or below the minimum organic content specification. The maturity level of the mulch is an indication of the breakdown of material, and if not to a finished state, can be detrimental to plants.

## 6.2 Compost Soil Blanket

Following the amendment of the soils, 0.5-inches of compost was to be placed followed with seeding per ODOT Item 659, and topped with erosion control matting (ODOT Item 671). The organic content of the seed bed is one of the primary contributing factors to the growth and establishment success of the vegetation. A compost blanket also helps hold moisture.

Common issues with using compost blankets for construction projects on relatively flat slopes, that may have also been experienced during this project include:

- Applying compost too thick can bury seed too deep, or hold seed too far from soil.
- Compost can dry out more quickly than soil.
- Seeded area is damaged due to runoff.

## 6.3 Sand Content / Particle Size

The ideal soil is a loam, with relatively the same percentage of sand, silt and clay (33% each). Both the G and B samples had an average sand content around 25% and clay at 50%. The average sand content in the native soils was 14% and clay at 55%.

## 6.4 Lime / Fertilizer

pH plays a vital role in vegetation establishment because it effects the nutrient availability. The soils within Ohio typically have a low pH value. Adding lime makes pH higher. It is common practice to add lime without testing since Ohio soils are typically more acidic. A pH range of 6.5 to 7.5 is ideal for grass growth. However, we now know that the pH levels were already high enough in the native and amended soils, and almost too high per the analytical results. Therefore, the addition of lime is not recommended.

Fertilizer recommendations were provided by the laboratory, and were generally consistent between the G and B samples. Therefore, the addition of the following fertilizer mix is recommended:

- 1 lb./1,000 $ft^2$ Potassium

- 2.5 lb./1,000 $ft^2$ potash
- 1 lb./1,000 $ft^2$ magnesium

### 6.5 Homogenous Incorporation

Soil profiles indicate varying thicknesses of amendment material, with B samples generally lacking compost or having a high sand content/expanded shale layer. Incorporation can be influenced by both the amount of mixing, as well as the proper amount of amendment being applied in the area. Amendments were placed with a "slinger" machine, although for at least one site (Site 3), the material was removed from the truck with an excavator bucket, placed in piles, and then spread to the desired thickness.

Applying the amendments with the "slinger" or blower machine is more likely to achieve an even thickness throughout the amendment area. Additional incorporation of the amendments (through additional passes with the rototiller) should aid in a more uniform mixture.

### 6.6 Environmental Considerations

Based on our research, common failures of the seed to grow, during construction projects in general, are:

- Erosion of seedbed soils before plants becomes established because soils were not stabilized prior to germination.
- Seeding outside of the optimum growing season. Seeding late in either the spring or fall seeding window may result in poor seed growing conditions. The OEPA Rainwater and Land Development Manual specifies that permanent seeding should be done March 1 to May 31 or August 1 to September 30.
- Improper selection of seed, using the wrong seeding method for the site.
- Inadequate application of seed or insufficient coverage of mulch and tackifier.
- Erosion of seeded areas without immediate repair.

## 7 CONCLUSIONS AND RECOMMENDATIONS

STONE was requested to evaluate the potential causes for poor grass growth, and review the amendment formula intended to be used by ODOT in the future for stormwater runoff reduction. It is understood that the desire is to have one set formula that will be used throughout Ohio.

### 7.1 Causes of Vegetation Issues

No single/constant factor was determined to be solely responsible for the vegetation issues, however, there were several factors that are believed to have contributed to the insufficient vegetation establishment.

- The compost used during construction did not meet the specification required in the construction plans for maturity, nitrogen content, or sieve size. This occurred because the contractor did not provide laboratory testing results for the compost, prior to construction.
- The various soil amendment components (native soil, compost, sand/expanded shale) were stratified in many areas and not homogenously mixed.
- Significant rainfall was received immediately after seeding was performed, that may have washed away the seed.

- Corrective actions (hand broadcasting of seed and hydroseeding) were performed to mitigate the poor grass growth, however, it was performed outside the permanent seeding timeframe recommended by the OEPA.

## 7.2 Construction Procedure

The construction procedures used to install the amended soil at the research sites was amended in response to the vegetation issues. The following procedure was developed to ensure successful soil amendment construction. Soil amendment includes:

1) Deep ripping of the subgrade,
2) evenly distributing the amendments,
3) fully incorporating the amendment materials into the subsoil,
4) ensuring only light compaction is applied to the site,
5) install a layer of soil amendment compost,
6) seed and fertilize,
7) install erosion control matting.

The following amendment mix formula and related specification is being proposed for use by ODOT, resulting mix of 17% sand; 29% compost; 54% native soil.

- Addition of 1-inch of sand.
- Addition of 1.75-inches of soil amendment compost

## 7.3 Construction and Material Specifications

The construction/material specifications used to install the amended soil at the research sites was amended in response to the vegetation issues. The following specifications were developed to ensure successful soil amendment construction.

**Sand Amendment**
Meet ODOT CMS 703.02 – Fine Aggregate.

**Soil Amendment Compost**
1. Compost shall be very mature, originating from an Ohio EPA Class IV Composting facility.
2. 100% of material must pass the ½-inch screen, with 75% passing 1/4-inch screen.
3. 5.5 < pH < 8.5
4. Inert Material < 1%
5. 35% < Organic Content< 65% (dry weight basis determined by Loss on Ignition)
6. 25% <C:N ratio of <30%
7. Maturity> 80% (Solvita Index Value between 7 and 8). Parent material is no longer visible. Compost should be stable with regard to oxygen consumption and carbon dioxide generation.
8. <1,000 MPN/GTS Fecal Coliform and <3 MPN/GTS Salmonella spp.
9. 30% < Moisture Content < 60% wet basis

Test samples of compost taken from the material stockpiled by the supplier for project use. Within 15 calendar days prior to initial application the laboratory test report, submit laboratory results to the Engineer for approval. Compost that does not meet the specification shall not be used.

**Soil Ripping**

Use a solid-shank ripper with teeth, traversing the area with 2 passes in each direction to a depth of 12 inches. Each pass is considered the width of the ripper, with teeth spaced no more than 12-inches apart. This may be accomplished with implements mounted to a tractor or dozer or use of a grade with appropriate implements (scarifier teeth), but must meet the 12-inch depth. If teeth are spaced greater than 12-inches, additional passes are required to meet a furrow spacing of 6 inches. Only perform ripping during dry conditions when soils are friable.

**Amendment Placement and Incorporation**

Spread amendments over the ground surface in a uniform thickness to the specified amendment depth. Incorporate amendments with a rototiller or similar equipment into the soil to a depth of 6 inches. Continue tilling until all soil clods are reduced to a maximum size of 1 inch (25 mm) and the mixture is uniform. Incorporation should only be performed during dry conditions when soils are friable. Six passes (pass is the width of the machine) with a rototiller or similar is anticipated to meet the uniformity requirement.

Prior to amendment placement, but following ripping, remove excess soil, so that after the amendments have been incorporated into the existing soil the ground surface profile will not appreciably change.

**Fine Grading and Limited Compaction**

Maintain the same slope geometry and general elevations as pre-amendment installation. To achieve an approximate compaction of 85 to 90% maximum density, one pass with a rubber-tired or smooth drum roller is anticipated.

**Compost Blanket**

Evenly spread a 0.5-inch thick layer of soil amendment compost over the ground surface.

**Seeding and Watering**

ODOT Class I – Lawn Mixture (ODOT Item 659.09) installed per Item 659. Rake seed into soil amendment compost. Contractor is responsible for establishing a minimum of 70% permanent vegetation coverage within the project schedule. Watering may be necessary.

**Fertilizer**

Apply the following fertilizer and rates. Follow ODOT Item 659.04 specification for application of fertilizer.

- 1 lb./1,000 $ft^2$ potassium
- 2.5 lb./1,000 $ft^2$ potash
- 1 lb./1,000 $ft^2$ magnesium

**Erosion Control Matting**

ODOT CMS Item 712 – Type A Temporary Erosion Control Mat. Install per ODOT Item 671. Do not run machinery/equipment over the amended soils during installation.

# APPENDIX A

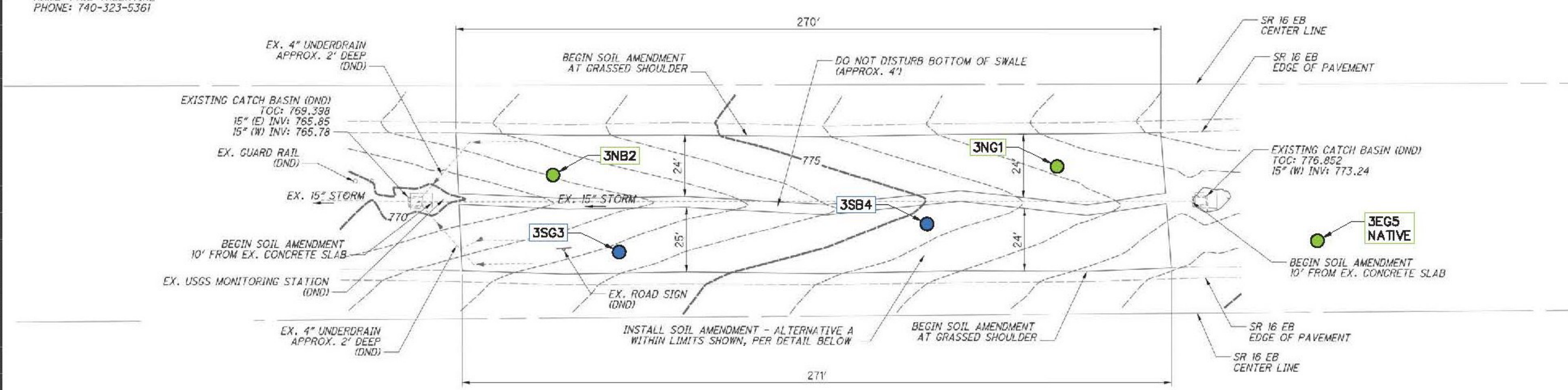
STONE
ENVIRONMENTAL, ENGINEERING & SCIENCE

**SITE LOCATION NOTES:**

1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO SOUTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 5 - MUSKINGUM COUNTY
   NAME: PHIL VALENTINE
   PHONE: 740-323-5361

**LEGEND:**

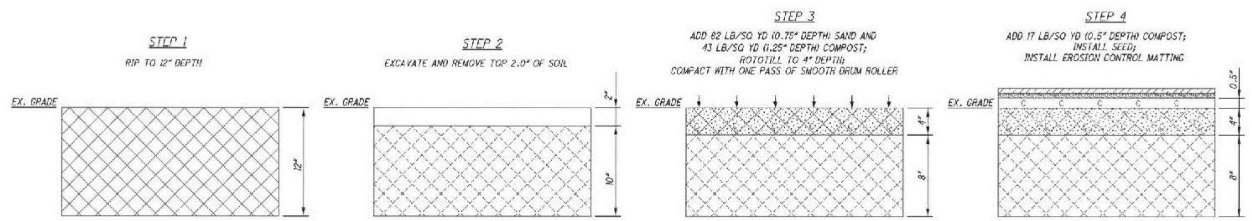
- SOIL SAMPLE SUBMITTED FOR ANALYSES
- SOIL SAMPLE COLLECTED




## ALTERNATE A

4" AMENDMENT DEPTH USING COMPOST AND SAND AS AMENDMENTS

NOT TO SCALE




*LEGEND*

- SOIL RIPPED AND/OR ROTOTILLED
- COMPOST
- SMOOTH DRUM ROLLER (COMPACTION)
- SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
- EROSION CONTROL MATTING (ODOT ITEM 670)
- SAND
- EXPANDED SHALE

FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)

COMPOST = 31%
SAND = 19%
NATIVE SOIL = 50%

HORIZONTAL SCALE IN FEET 0 20 40

CALCULATED JAK
CHECKED AKT

**SOIL AMENDMENT PLAN**
**SITE 3 - STATE ROUTE 16 AT STATE ROUTE 60**

**ODOT RESEARCH**

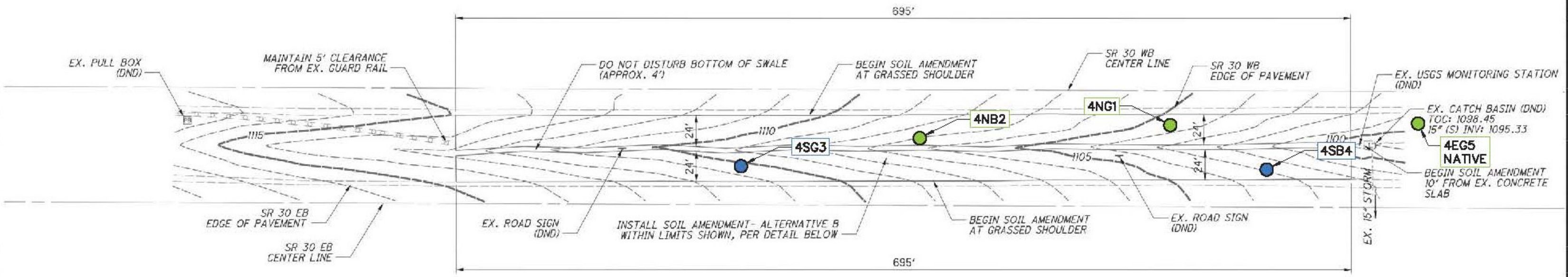
**SITE LOCATION NOTES:**

1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO NORTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 4 - STARK COUNTY
   NAME: DOUG MCELROY
   PHONE: 330-786-4927

   CITY OF CANTON STREET DEPARTMENT
   NAME: STEVE TRZCINSKI
   PHONE: 330-813-1294

**LEGEND:**

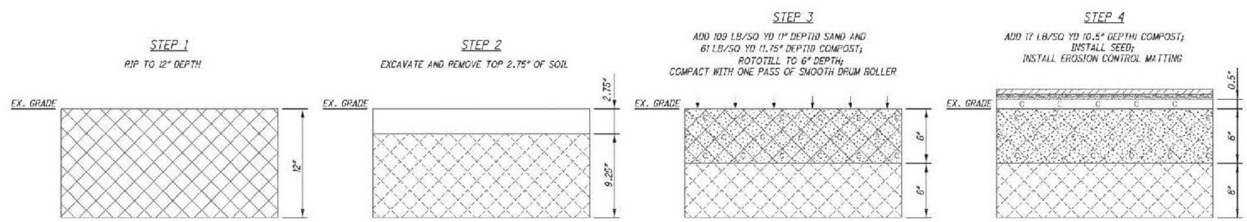
- SOIL SAMPLE SUBMITTED FOR ANALYSES
- SOIL SAMPLE COLLECTED




## ALTERNATE C

6" AMENDMENT DEPTH USING COMPOST AND SAND AS AMENDMENTS

NOT TO SCALE




**LEGEND**

- SOIL RIPPED AND/OR ROTOTILLED
- COMPOST
- SMOOTH DRUM ROLLER (COMPACTION)
- SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
- EROSION CONTROL MATTING (ODOT ITEM 670)
- SAND
- EXPANDED SHALE

**FINAL AMENDED SOIL COMPOSITION**
(% BY VOLUME)

COMPOST = 29%
SAND = 17%
NATIVE SOIL = 54%

HORIZONTAL SCALE IN FEET

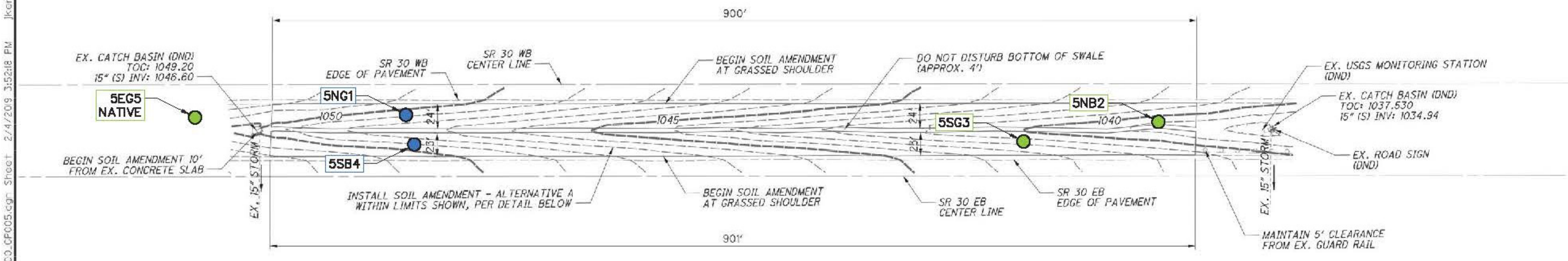
CALCULATED MRB CHECKED JAK

**SITE LOCATION NOTES:**

1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO NORTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 4 - STARK COUNTY
   NAME: DOUG MCELROY
   PHONE: 330-786-4927

**LEGEND:**

- SOIL SAMPLE SUBMITTED FOR ANALYSES
- SOIL SAMPLE COLLECTED




## ALTERNATE A

4" AMENDMENT DEPTH USING COMPOST AND SAND AS AMENDMENTS

NOT TO SCALE

STEP 1

RIP TO 12" DEPTH

STEP 2

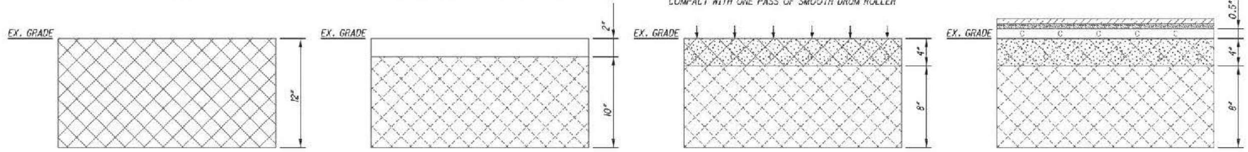
EXCAVATE AND REMOVE TOP 2.0" OF SOIL

STEP 3

ADD 82 LB/SQ YD (0.75" DEPTH) SAND AND
43 LB/SQ YD (1.25" DEPTH) COMPOST;
ROTOTILL TO 4" DEPTH;
COMPACT WITH ONE PASS OF SMOOTH DRUM ROLLER

STEP 4

ADD 17 LB/SQ YD (0.5" DEPTH) COMPOST;
INSTALL SEED;
INSTALL EROSION CONTROL MATTING




LEGEND

- SOIL RIPPED AND/OR ROTOTILLED
- COMPOST
- SMOOTH DRUM ROLLER (COMPACTION)
- SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
- EROSION CONTROL MATTING (ODOT ITEM 671)
- SAND
- EXPANDED SHALE

FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)

COMPOST = 31%
SAND = 19%
NATIVE SOIL = 50%

HORIZONTAL SCALE IN FEET: 0, 25, 50, 100

CALCULATED MRB
CHECKED JAK

SOIL AMENDMENT PLAN
SITE 5 - STATE ROUTE 30 AT 17TH STREET

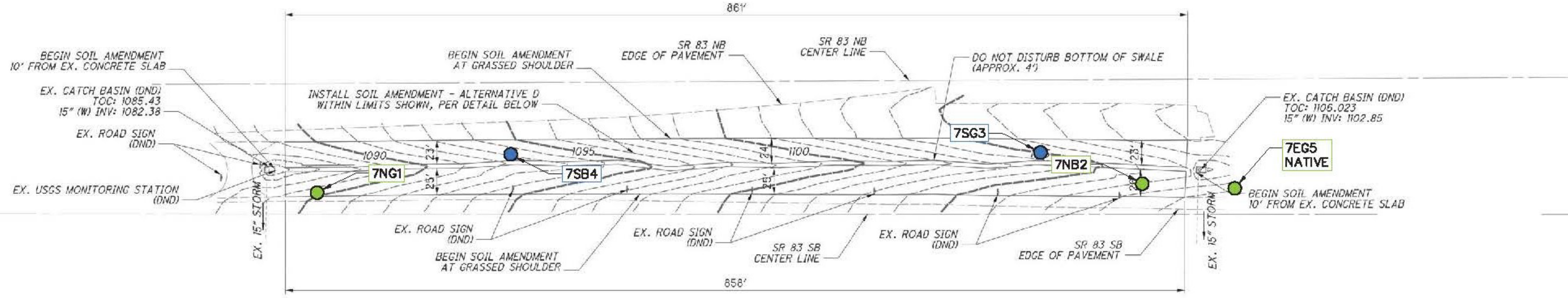
ODOT RESEARCH

**SITE LOCATION NOTES:**

1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO NORTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 3 - WAYNE COUNTY
   NAME: JASON SUTHERLAND
   PHONE: 419-207-2801

**LEGEND:**

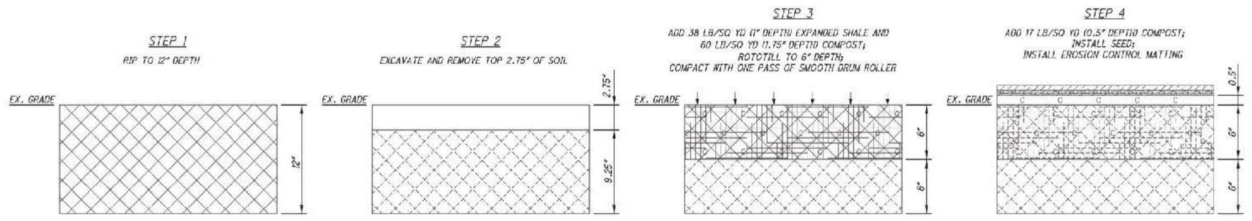
- SOIL SAMPLE SUBMITTED FOR ANALYSES
- SOIL SAMPLE COLLECTED




## ALTERNATE D

6" AMENDMENT DEPTH USING COMPOST AND EXPANDED SHALE AS AMENDMENTS

NOT TO SCALE




LEGEND

- SOIL RIPPED AND/OR ROTOTILLED
- COMPOST
- SMOOTH DRUM ROLLER (COMPACTION)
- SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
- EROSION CONTROL MATTING (ODOT ITEM 671)
- SAND
- EXPANDED SHALE

FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)

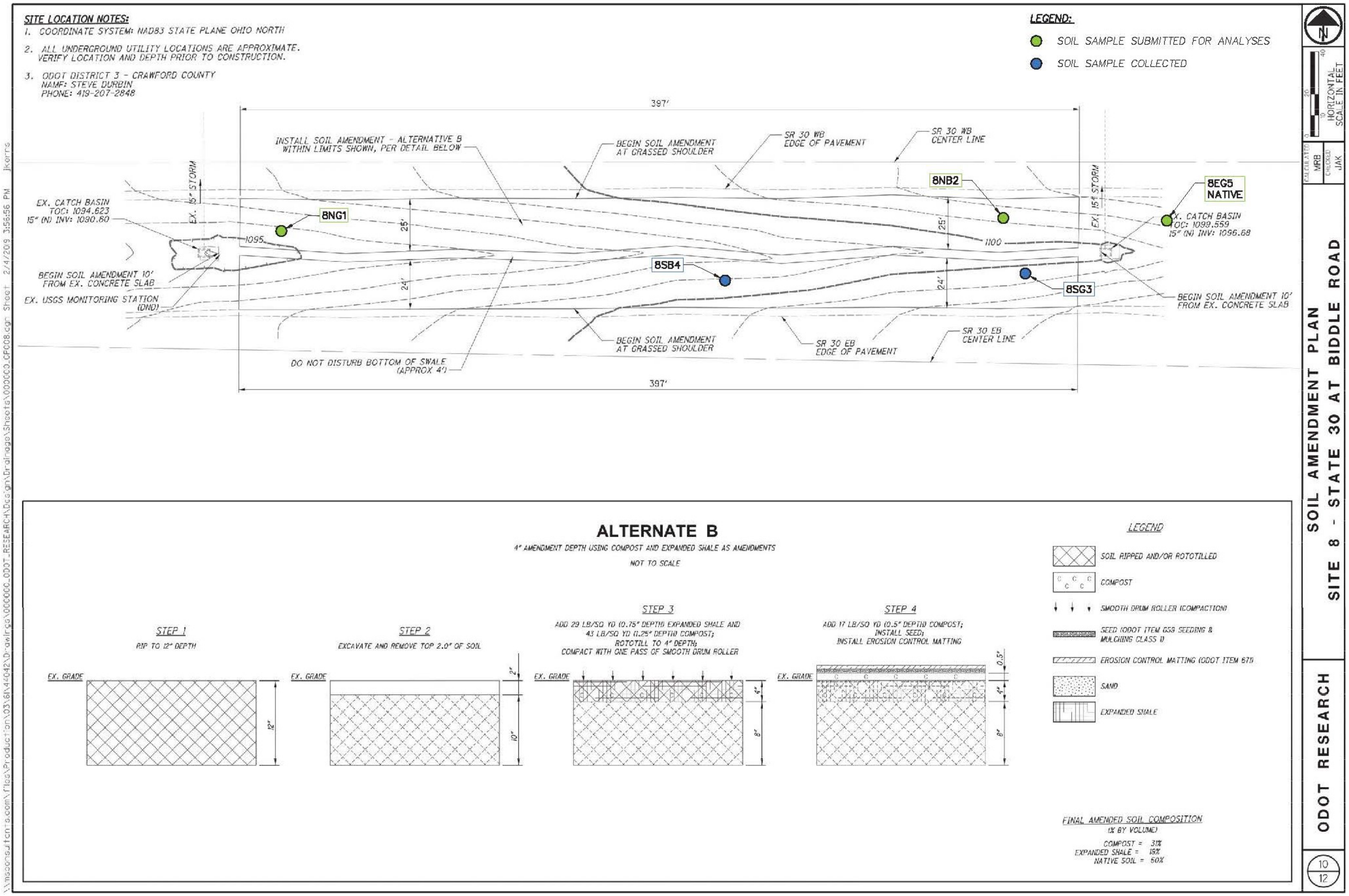
COMPOST = 29%
EXPANDED SHALE = 17%
NATIVE SOIL = 54%

HORIZONTAL SCALE IN FEET: 0 25 50 100

CALCULATED: MRB
CHECKED: JAK

SOIL AMENDMENT PLAN
SITE 7 - ROUTE 83 NEAR SELBY RD.

ODOT RESEARCH

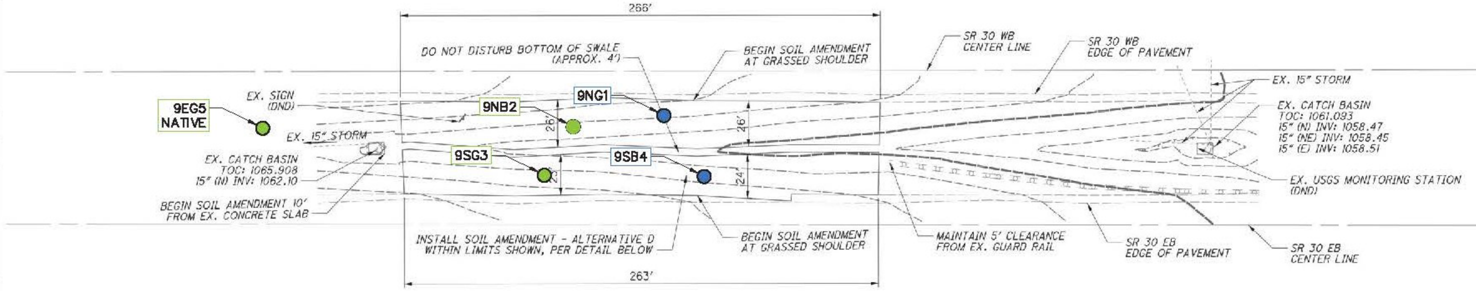

SITE LOCATION NOTES:
1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO NORTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 3 - CRAWFORD COUNTY
NAMF: STEVE DURBIN
PHONE: 419-207-2848
LEGEND:
SOIL SAMPLE SUBMITTED FOR ANALYSES
SOIL SAMPLE COLLECTED
397'
INSTALL SOIL AMENDMENT - ALTERNATIVE B WITHIN LIMITS SHOWN, PER DETAIL BELOW
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 30 WB EDGE OF PAVEMENT
SR 30 WB CENTER LINE
EX. 15" STORM
8NB2
8EG5 NATIVE
EX. CATCH BASIN TOC: 1094.623 15" (N) INV: 1090.60
8NG1
1095
25'
1100
EX. CATCH BASIN TOC: 1099.559 15" (N) INV: 1096.68
8SB4
8SG3
24'
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
EX. USGS MONITORING STATION (DND)
BEGIN SOIL AMENDMENT 10' FROM EX. CONCRETE SLAB
BEGIN SOIL AMENDMENT AT GRASSED SHOULDER
SR 30 EB EDGE OF PAVEMENT
SR 30 EB CENTER LINE
DO NOT DISTURB BOTTOM OF SWALE (APPROX 4')
397'
ALTERNATE B
4" AMENDMENT DEPTH USING COMPOST AND EXPANDED SHALE AS AMENDMENTS
NOT TO SCALE
STEP 1
RIP TO 12" DEPTH
STEP 2
EXCAVATE AND REMOVE TOP 2.0" OF SOIL
STEP 3
ADD 29 LB/SQ YD (0.75" DEPTH) EXPANDED SHALE AND 43 LB/SQ YD (1.25" DEPTH) COMPOST;
ROTOTILL TO 4" DEPTH;
COMPACT WITH ONE PASS OF SMOOTH DRUM ROLLER
STEP 4
ADD 17 LB/SQ YD (0.5" DEPTH) COMPOST;
INSTALL SEED;
INSTALL EROSION CONTROL MATTING
EX. GRADE
12"
2"
10"
4"
8"
0.5"
LEGEND
SOIL RIPPED AND/OR ROTOTILLED
COMPOST
SMOOTH DRUM ROLLER (COMPACTION)
SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
EROSION CONTROL MATTING (ODOT ITEM 671)
SAND
EXPANDED SHALE
FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)
COMPOST = 31%
EXPANDED SHALE = 19%
NATIVE SOIL = 50%
HORIZONTAL SCALE IN FEET
0 20 40
CALCULATED MRB
CHECKED JAK
SOIL AMENDMENT PLAN
SITE 8 - STATE 30 AT BIDDLE ROAD
ODOT RESEARCH
10
12

**SITE LOCATION NOTES:**

1. COORDINATE SYSTEM: NAD83 STATE PLANE OHIO SOUTH
2. ALL UNDERGROUND UTILITY LOCATIONS ARE APPROXIMATE. VERIFY LOCATION AND DEPTH PRIOR TO CONSTRUCTION.
3. ODOT DISTRICT 3 - CRAWFORD COUNTY
   NAME: STEVE DURBIN
   PHONE: 419-207-2848

**LEGEND:**

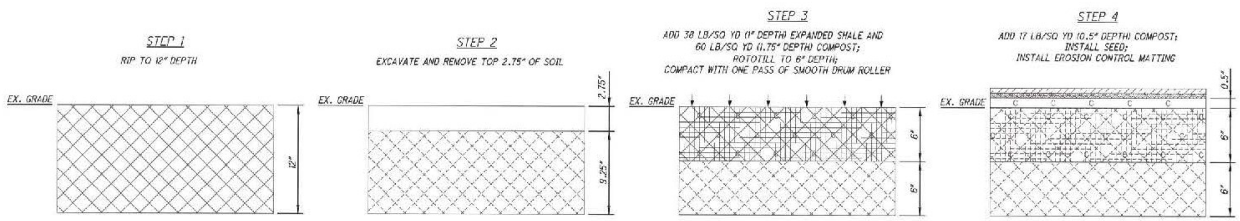
- SOIL SAMPLE SUBMITTED FOR ANALYSES (green)
- SOIL SAMPLE COLLECTED (blue)




## ALTERNATE D

6" AMENDMENT DEPTH USING COMPOST AND EXPANDED SHALE AS AMENDMENTS

NOT TO SCALE




*LEGEND*

- SOIL RIPPED AND/OR ROTOTILLED
- COMPOST
- SMOOTH DRUM ROLLER (COMPACTION)
- SEED (ODOT ITEM 659 SEEDING & MULCHING CLASS 1)
- EROSION CONTROL MATTING (ODOT ITEM 670)
- SAND
- EXPANDED SHALE

*FINAL AMENDED SOIL COMPOSITION*
(% BY VOLUME)

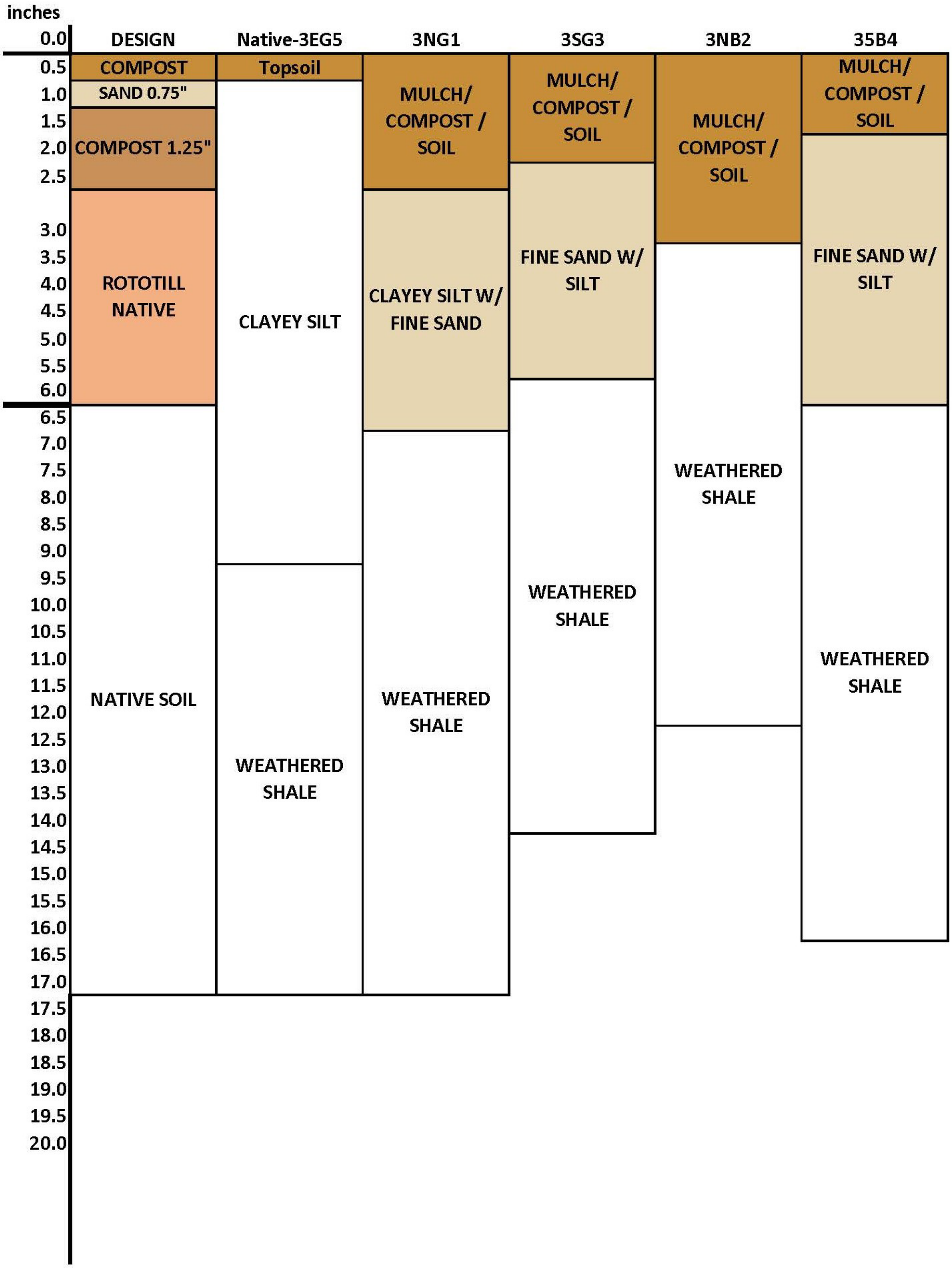
COMPOST = 29%
EXPANDED SHALE = 17%
NATIVE SOIL = 54%

HORIZONTAL SCALE IN FEET: 0 15 30 60

CALCULATED: MRB
CHECKED: JAK

SOIL AMENDMENT PLAN
SITE 9 - ST. RT. 30 AT LOWER LEESVILLE RD.

ODOT RESEARCH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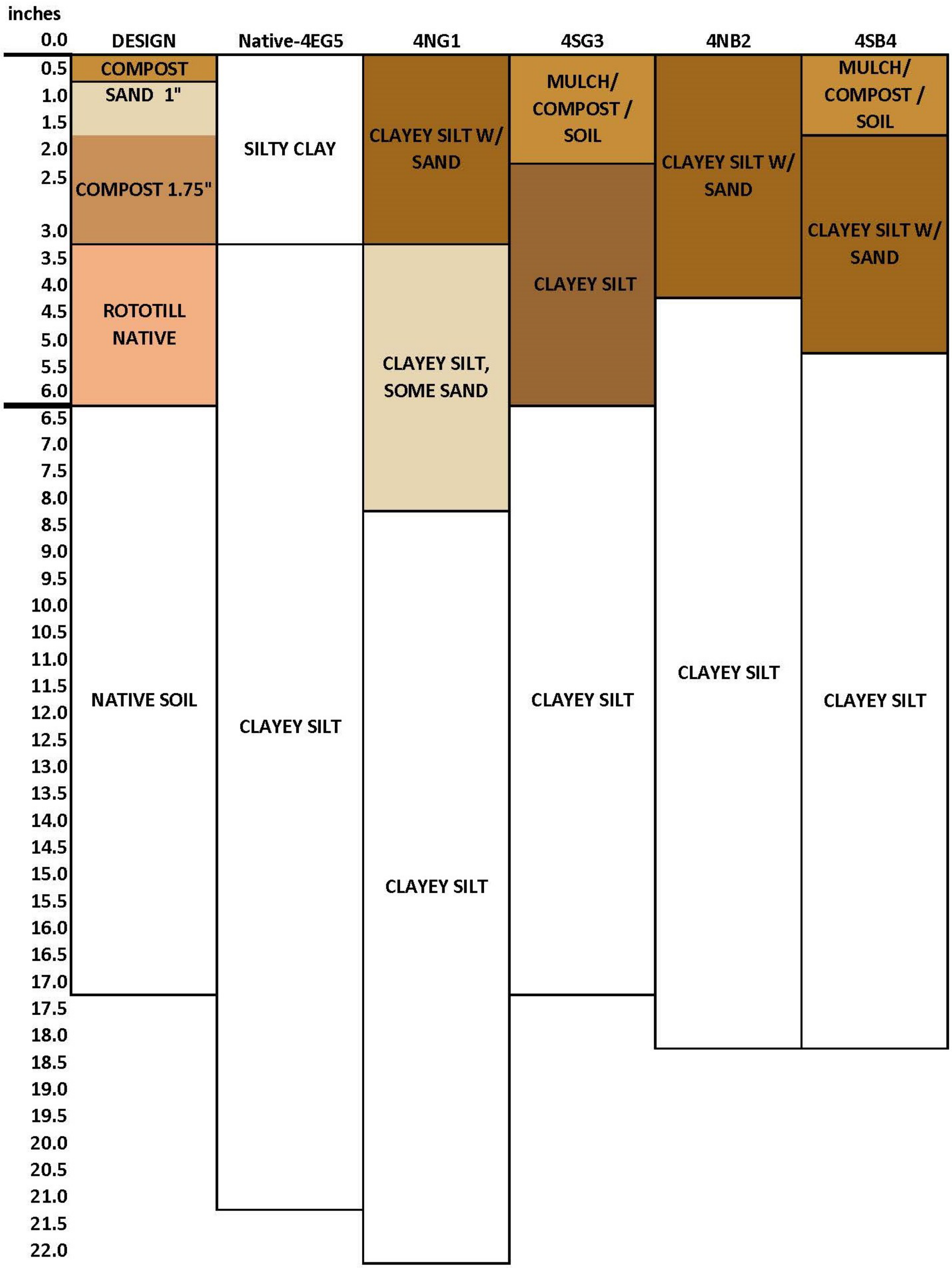
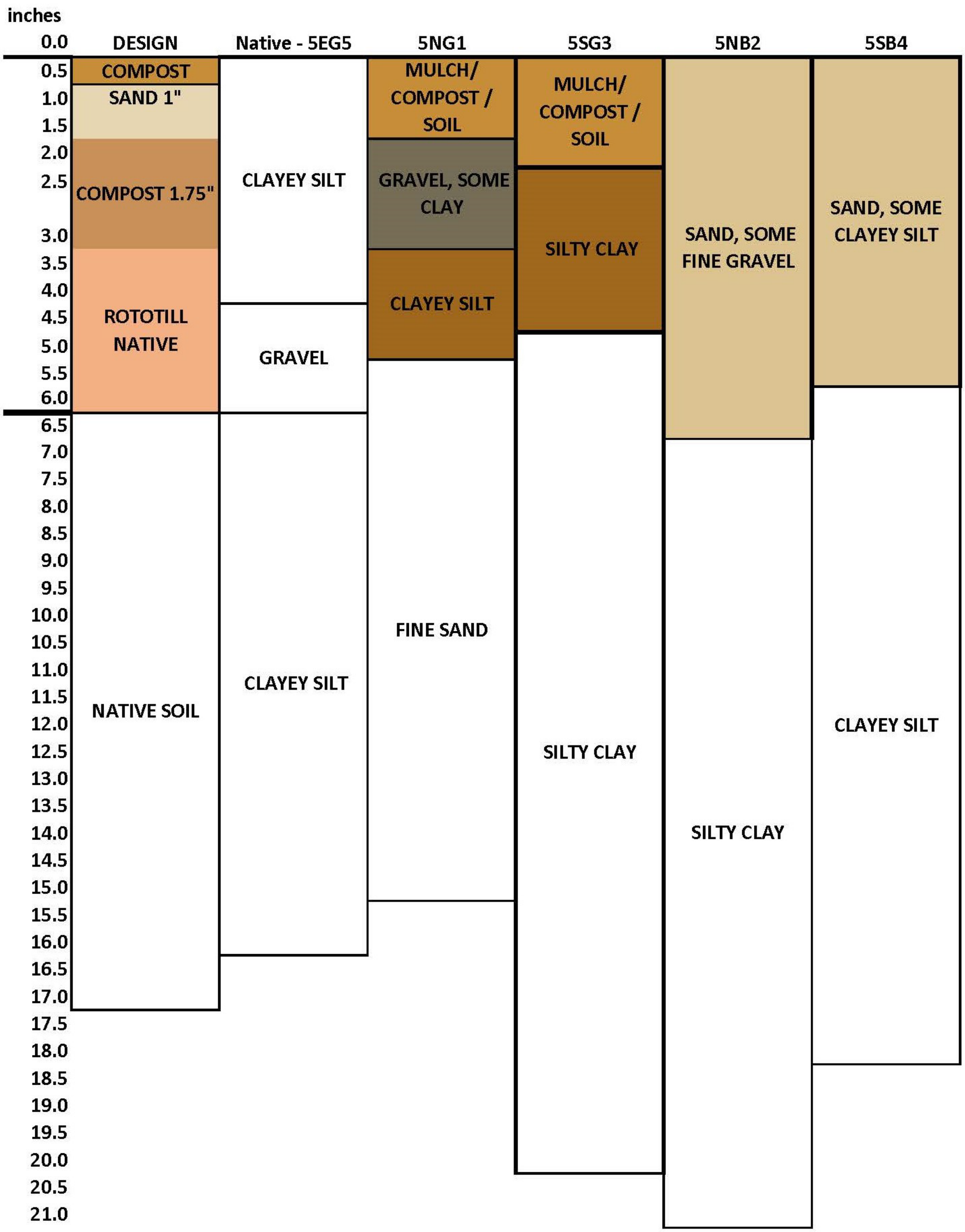
18.5
19.0
19.5
20.0
DESIGN
Native-3EG5
3NG1
3SG3
3NB2
35B4
COMPOST
SAND 0.75"
COMPOST 1.25"
ROTOTILL NATIVE
NATIVE SOIL
Topsoil
CLAYEY SILT
WEATHERED SHALE
MULCH/ COMPOST / SOIL
CLAYEY SILT W/ FINE SAND
WEATHERED SHALE
MULCH/ COMPOST / SOIL
FINE SAND W/ SILT
WEATHERED SHALE
MULCH/ COMPOST / SOIL
WEATHERED SHALE
MULCH/ COMPOST / SOIL
FINE SAND W/ SILT
WEATHERED SHALE



inches
0.0
DESIGN
Native-4EG5
4NG1
4SG3
4NB2
4SB4
COMPOST
SAND 1"
COMPOST 1.75"
ROTOTILL NATIVE
NATIVE SOIL
SILTY CLAY
CLAYEY SILT
CLAYEY SILT W/ SAND
CLAYEY SILT, SOME SAND
CLAYEY SILT
MULCH/ COMPOST / SOIL
CLAYEY SILT
CLAYEY SILT
CLAYEY SILT W/ SAND
CLAYEY SILT
MULCH/ COMPOST / SOIL
CLAYEY SILT W/ SAND
CLAYEY SILT
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0 16.5 17.0 17.5 18.0 18.5 19.0 19.5 20.0 20.5 21.0 21.5 22.0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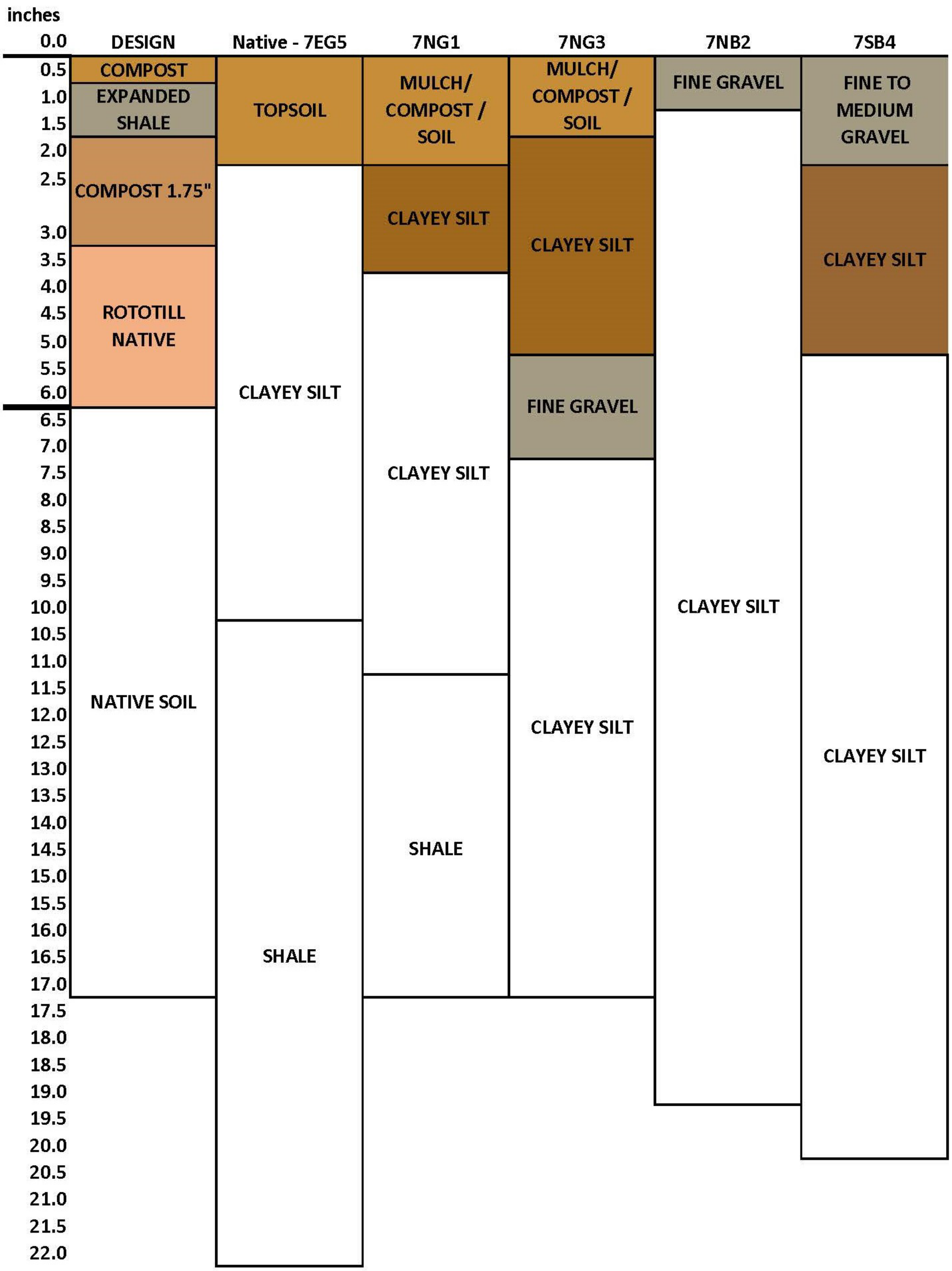
15.5
16.0
16.5
17.0
17.5
18.0
18.5
19.0
19.5
20.0
20.5
21.0
DESIGN
COMPOST
SAND 1"
COMPOST 1.75"
ROTOTILL NATIVE
NATIVE SOIL
Native - 5EG5
CLAYEY SILT
GRAVEL
CLAYEY SILT
5NG1
MULCH/ COMPOST / SOIL
GRAVEL, SOME CLAY
CLAYEY SILT
FINE SAND
5SG3
MULCH/ COMPOST / SOIL
SILTY CLAY
SILTY CLAY
5NB2
SAND, SOME FINE GRAVEL
SILTY CLAY
5SB4
SAND, SOME CLAYEY SILT
CLAYEY SILT


inches
0.0
DESIGN
Native - 7EG5
7NG1
7NG3
7NB2
7SB4
COMPOST
EXPANDED SHALE
COMPOST 1.75"
ROTOTILL NATIVE
NATIVE SOIL
TOPSOIL
CLAYEY SILT
SHALE
MULCH/ COMPOST / SOIL
CLAYEY SILT
CLAYEY SILT
SHALE
MULCH/ COMPOST / SOIL
CLAYEY SILT
FINE GRAVEL
CLAYEY SILT
FINE GRAVEL
CLAYEY SILT
FINE TO MEDIUM GRAVEL
CLAYEY SILT
CLAYEY SILT
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
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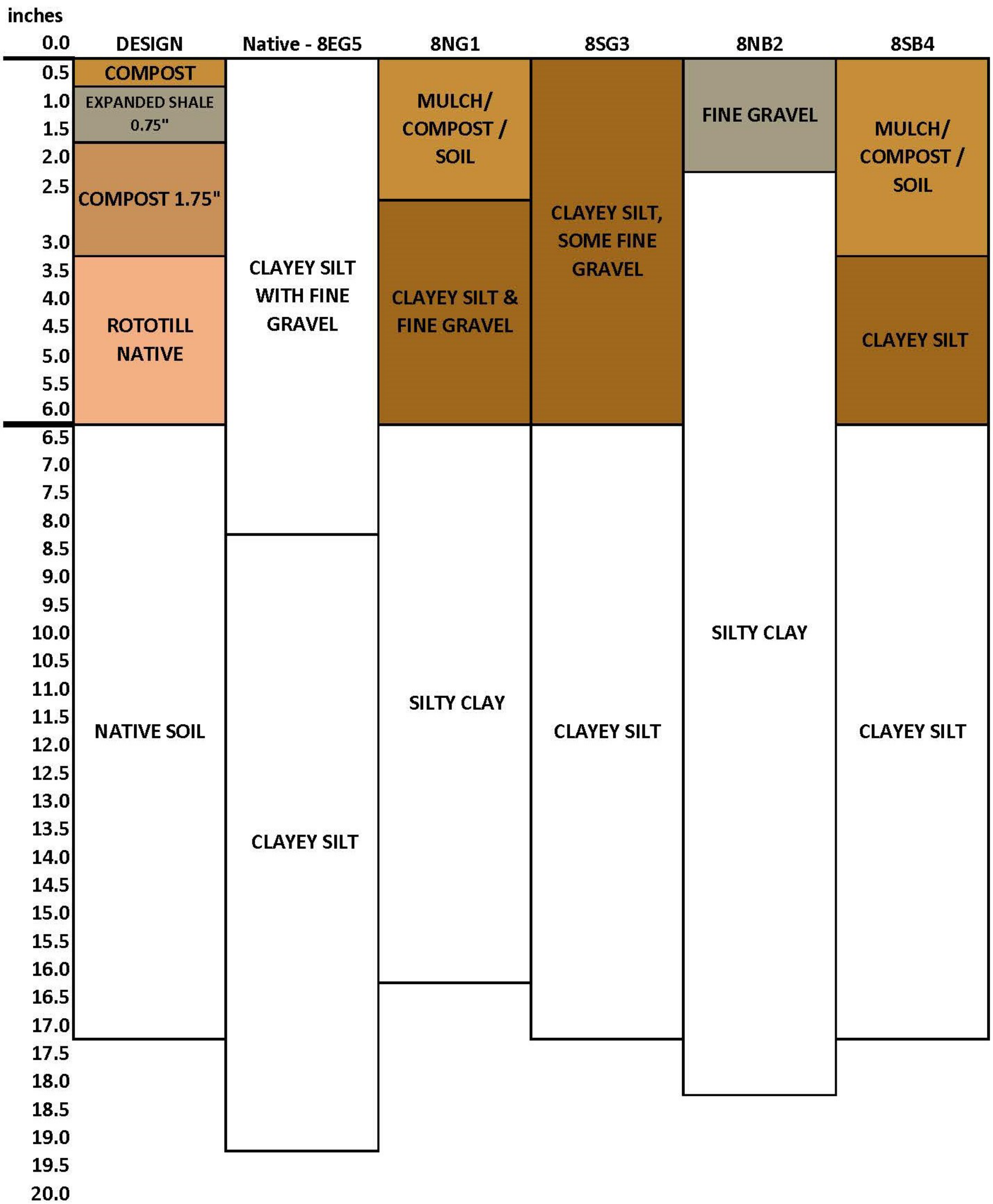
22.0


inches
0.0
DESIGN
Native - 8EG5
8NG1
8SG3
8NB2
8SB4
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1.5
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2.5
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3.5
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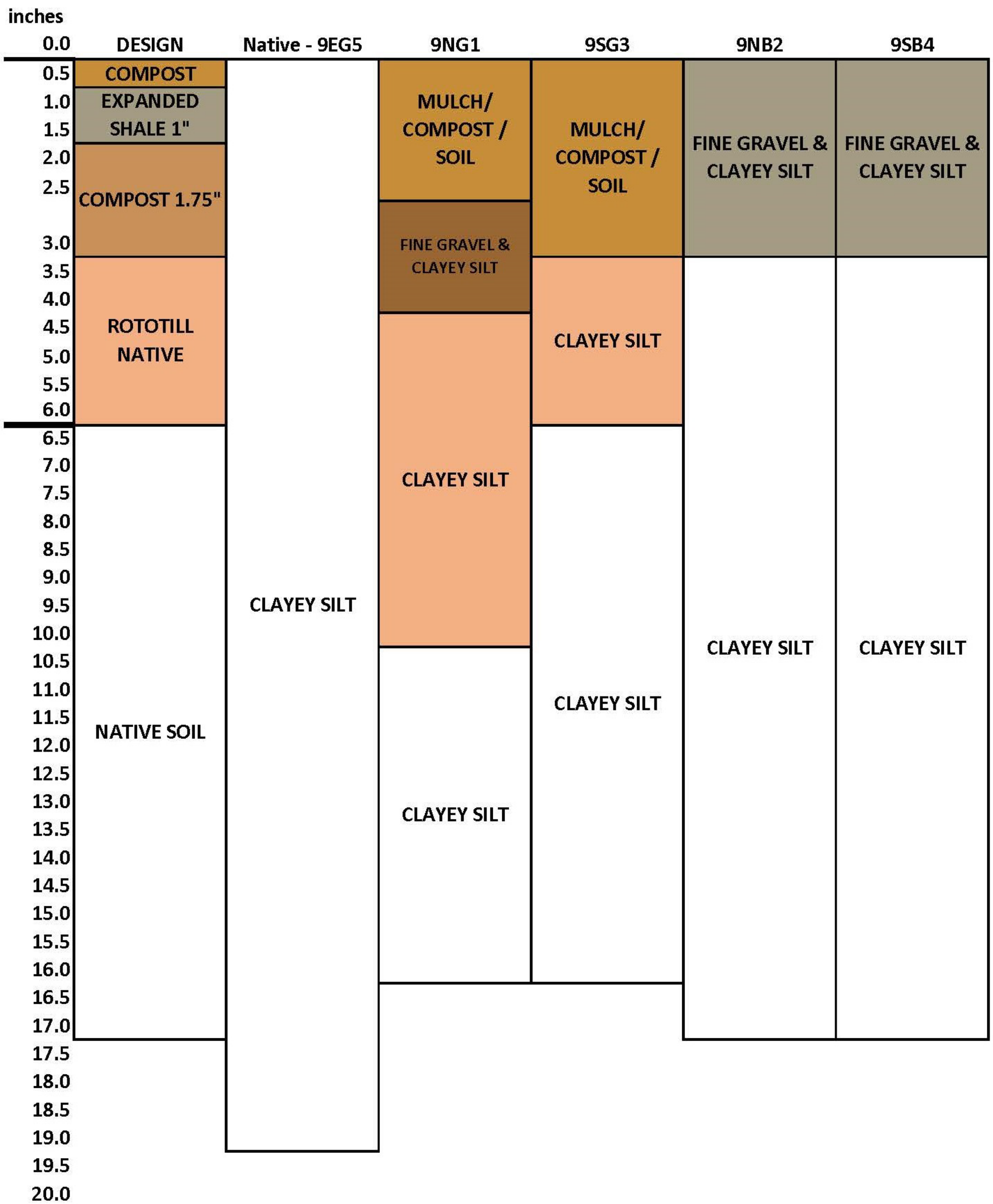
15.5
16.0
16.5
17.0
17.5
18.0
18.5
19.0
19.5
20.0
COMPOST
EXPANDED SHALE 0.75"
COMPOST 1.75"
ROTOTILL NATIVE
NATIVE SOIL
CLAYEY SILT WITH FINE GRAVEL
CLAYEY SILT
MULCH/ COMPOST / SOIL
CLAYEY SILT & FINE GRAVEL
SILTY CLAY
CLAYEY SILT, SOME FINE GRAVEL
CLAYEY SILT
FINE GRAVEL
SILTY CLAY
MULCH/ COMPOST / SOIL
CLAYEY SILT
CLAYEY SILT



inches
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15.5
16.0
16.5
17.0
17.5
18.0
18.5
19.0
19.5
20.0
DESIGN
Native - 9EG5
9NG1
9SG3
9NB2
9SB4
COMPOST
EXPANDED SHALE 1"
COMPOST 1.75"
ROTOTILL NATIVE
NATIVE SOIL
CLAYEY SILT
MULCH/ COMPOST / SOIL
FINE GRAVEL & CLAYEY SILT
CLAYEY SILT
CLAYEY SILT
MULCH/ COMPOST / SOIL
CLAYEY SILT
CLAYEY SILT
FINE GRAVEL & CLAYEY SILT
CLAYEY SILT
FINE GRAVEL & CLAYEY SILT
CLAYEY SILT

# APPENDIX B

ENVIRONMENTAL, ENGINEERING & SCIENCE

**PHOTO LOG**

3 Site Vegetation

3EG5 Core Placement

3EG5 Hand Sampler

3EG5 Soil Revealed

**PHOTO LOG**

3NB2 Core Placement

3NB2 Soil Revealed - Rocky

3NG1 Core Placement

3NG1 Soil Revealed

**PHOTO LOG**

3SB4 Core Placement

3SB4 Soil Revealed - Very Sandy

3SG3 Core Placement

3SG3 Soil Revealed

**PHOTO LOG**

4 Site Vegetation

4EG5 Core Placement

4EG5 Soil Revealed

4NB2 Core Placement

**PHOTO LOG**

4NB2 Soil Revealed

4NG1 Core Placement


4NG1 Soil Revealed

4SB4 Core Placement

**PHOTO LOG**

4SB4 Soil Revealed - Very sandy

4SG3 Core Placement

4SG3 Soil Revealed

5 Site Vegetation - Poor

PHOTO LOG

5EG5 Core Placement

5EG5 Soil Revealed

5NB2 Core Placement

5NB2 Soil Revealed - Very loose structure

**PHOTO LOG**

5NG1 Core Placement - vegetation not good

5NG1 Soil Revealed

5SB4 Core Placement

5SB4 Soil Revealed

**PHOTO LOG**

5SG3 Core Placement - good vegetation relative to site

5SG3 Soil Revealed

7 Site Vegetation (2)

7 Site Vegetation

**PHOTO LOG**

7EG5 Core Placement

7EG5 Soil Revealed - rocky pebbles

7NB2 Core Placement

7NB2 Soil Revealed

PHOTO LOG

7NG1 Core Placement

7NG1 Soil Revealed

7SB4 Core Placement

7SB4 Soil Revealed - clumping and not well mixed

**PHOTO LOG**

7SG3 Core Placement

7SG3 Soil Revealed

8 Site Vegetation (2)

8 SIte Vegetation

PHOTO LOG

8EG5 Core Placement

8EG5 Soil Revealed

8NB2 Core Placement

8NB2 Soil Revealed

PHOTO LOG

8NG1 Core Placement

8NG1 Soil Revealed

8SB4 Core Placement

8SB4 Soil Revealed - mainly compost, little soil, very loose structure

PHOTO LOG

8SG3 Core Placement

8SG3 Soil Revealed - lots of expanded shale

9 Site Vegetation (2)

9 Site Vegetation

**PHOTO LOG**

9EG5 Core Placement

9EG5 Soil Revealed - very loose

9NB2 Core Placement

9NB2 Soil Revealed - very loose no structure

**PHOTO LOG**

9NG1 Core Placement - good vegetation relative

9NG1 Soil Revealed

9SB4 Core Placement

9SB4 Soil Revealed

**PHOTO LOG**

9SG3 Core Placement - good vegetation relative

9SG3 Soil Revealed

**PHOTO LOG**


Site 3 Sample Cores

**PHOTO LOG**


Site 4 Sample Cores 2

PHOTO LOG


Site 5 Sample Cores

**PHOTO LOG**


Site 7 Sample Cores

**PHOTO LOG**


Site 8 Sample Cores 2


Site 9 Sample Cores

# APPENDIX C

# TABLE C - SUMMARY OF LABORATORY SOIL ANALYSIS RESULTS

| SAMPLE ID | 3EG5 | 3NG1 | 3NB2 | 4EG5 | 4NG1 | 4NB2 | 5EG5 | 5NB2 | 5SG3 | 7EG5 | 7NG1 | 7NB2 | 8EG5 | 8NB2 | 8NG1 | 9EG5 | 9NB2 | 9SG3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 7.2 | 8.1 | 8.1 | 7.4 | 7.6 | 7.8 | 8.4 | 8.5 | 7.8 | 8 | 8.3 | 8.4 | 8.3 | 8 | 8.1 | 7.9 | 7.7 | 8.1 |
| Organic Matter (%) | 2 | 7.7 | 5.5 | 5.2 | 4.8 | 5.1 | 4.3 | 4.6 | 4.3 | 3.8 | 2.8 | 6.4 | 3.9 | 4.9 | 17.7 | 4.1 | 4.1 | 18.4 |
| Phosphorus (lb./a) | 11 | 151 | 90 | 10 | 23 | 32 | 4 | 61 | 312 | 4 | 28 | 31 | 33 | 50 | 276 | 19 | 53 | 186 |
| Potassium (lb./a) | 128 | 321 | 194 | 82 | 128 | 143 | 128 | 97 | 199 | 102 | 158 | 117 | 372 | 337 | 372 | 224 | 291 | 245 |
| Magnesium (lb./a) | 367 | 541 | 408 | 214 | 265 | 347 | 311 | 219 | 439 | 332 | 311 | 270 | 571 | 638 | 770 | 714 | 459 | 556 |
| Calcium (lb./a) | 3004 | 5161 | 5044 | 2305 | 3381 | 4162 | 3478 | 4427 | 4447 | 3177 | 3601 | 4718 | 6921 | 7553 | 8976 | 6610 | 9858 | 8701 |
| Sodium (lb./a) | 648 | 332 | 372 | 852 | 1005 | 602 | 423 | 423 | 546 | 867 | 2066 | 1066 | 1025 | 928 | 1015 | 1061 | 678 | 933 |
| Cation Exchange Capacity (meq/100g) | 10.6 | 16.3 | 15.4 | 8.6 | 11.9 | 13.3 | 11.1 | 13 | 14.4 | 11.3 | 15 | 15.4 | 22.4 | 24 | 28.3 | 22.1 | 28.4 | 26.4 |
| Base Saturation (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Potassium (%) | 1.5 | 2.5 | 1.6 | 1.2 | 1.4 | 1.4 | 1.5 | 1 | 1.8 | 1.2 | 1.4 | 1 | 2.1 | 1.8 | 1.7 | 1.3 | 1.3 | 1.2 |
| Magnesium (%) | 14.4 | 13.8 | 11.1 | 10.4 | 9.3 | 10.8 | 11.7 | 7 | 12.7 | 12.2 | 8.6 | 7.3 | 10.6 | 11.1 | 11.3 | 13.5 | 6.7 | 8.8 |
| Calcium (%) | 70.8 | 79.2 | 82 | 66.9 | 71 | 78 | 78.5 | 85 | 77.3 | 70 | 60.1 | 76.6 | 77.3 | 78.7 | 79.2 | 74.8 | 86.8 | 82.4 |
| Sodium (%) | 13 | 4.3 | 5.1 | 21.1 | 18 | 9.6 | 8.1 | 6.9 | 8.1 | 16.3 | 29.3 | 14.7 | 9.7 | 8.2 | 7.6 | 10.2 | 5.1 | 7.5 |
| Ca to Mg Ratio | 4.9 | 5.7 | 7.4 | 6.5 | 7.7 | 7.2 | 6.7 | 12.1 | 6.1 | 5.7 | 6.9 | 10.5 | 7.3 | 7.1 | 7 | 5.6 | 12.9 | 9.4 |
| Mg to K Ratio | 9.3 | 5.5 | 6.8 | 8.5 | 6.7 | 7.9 | 7.9 | 7.3 | 7.2 | 10.6 | 6.4 | 7.5 | 5 | 6.2 | 6.7 | 10.4 | 5.1 | 7.4 |
| Particle Size Analysis: | | | | | | | | | | | | | | | | | | |
| Sand % | 5 | 31 | 29 | 9 | 23 | 31 | 29 | 49 | 23 | 31 | 21 | 30 | 5 | 2 | 29 | 7 | 11 | 29 |
| Silt % | 35 | 25 | 21 | 41 | 29 | 25 | 23 | 13 | 25 | 21 | 29 | 22 | 27 | 28 | 23 | 33 | 29 | 21 |
| Clay% | 60 | 44 | 50 | 50 | 48 | 44 | 48 | 38 | 52 | 48 | 50 | 48 | 68 | 70 | 48 | 60 | 60 | 50 |
| Lime Test Index | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| Lime Recommendation (lb./1000 sqft) | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gypsum Recommendation (lb./1000 sqft) | | | | | | | | | | | 18 | | | | | | | |
| Fertilizer Recommendation: | | | | | | | | | | | | | | | | | | |
| Nitrogen (lb./1000 sqft) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phosphate (lb./1000 sqft) | 3 | 0 | 1 | 3 | 3 | 2 | 3 | 2 | 0 | 3 | 3 | 3 | 2 | 2 | 0 | 3 | 2 | 0 |
| Potash (lb./1000 sqft) | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 1 | 2 | 2 | 3 | 2 | 3 |
| Magnesium (lb./1000 sqft) | 0 | 0 | 1 | 1 | 2 | 1 | 0 | 4 | 0 | 0 | 3 | 4 | 2 | 1 | 1 | 0 | 8 | 5 |
| Moisture Content | | | | | | | | | | | | | | | | | | |
| As Sampled | 15.55 | 14.19 | 16.40 | 20.02 | 13.74 | 14.95 | 17.94 | 16.16 | 16.35 | 8.09 | 13.63 | 37.99 | 11.40 | 21.53 | 17.61 | 13.10 | 8.35 | 19.20 |
| Dried and Sieved | 1.74 | 2.57 | 2.89 | 3.54 | 2.47 | 2.67 | 1.99 | 2.26 | 2.93 | 2.06 | 2.78 | 3.43 | 3.40 | 3.99 | 6.15 | 3.26 | 2.09 | 6.40 |

# APPENDIX D

HOLMES LABORATORY INC.
3559 US 62
Millersburg, OH 44654
www.facebook.com/holmeslab

# SOIL ANALYSIS REPORT

[Quality Testing Since 1978]
(330) 893-2933 * www.holmeslab.com
Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4316
Sample ID: SOIL 3EG5

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 7.2 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 2.1 | |
| Phosphorus | (P1) | lb/a | 11 | |
| Potassium | (K) | lb/a | 128 | Moisture: |
| Magnesium | (Mg) | lb/a | 367 | |
| Calcium | (Ca) | lb/a | 3004 | As Sampled: 15.55 |
| Sodium | (Na) | lb/a | 648 | Dried & Sieved: 1.74 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 10.6 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.5 | |
| Magnesium | (Mg) | % | 14.4 | |
| Calcium | (Ca) | % | 70.8 | |
| Sodium | (Na) | % | 13.0 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 5 |
| Boron | (B) | lb/a | | Silt % = 35 |
| Ca to Mg Ratio | | | 4.9 | Clay % = 60 |
| Mg to K Ratio | | | 9.3 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

## Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 1 | lbs/1000sqft |
| Phosphate(P2O5) | 3 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 0 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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SOIL
ANALYSIS REPORT
[Quality Testing Since 1978]
(330) 893-2933 * www.holmeslab.com
Test Performed : AP

Customer : STONE

Date Reported : 06/25/2021
Lab Number : 21-4317
Sample ID: SOIL
3NG1

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.1 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 7.7 | |
| Phosphorus | (P1) | lb/a | 151 | |
| Potassium | (K) | lb/a | 321 | Moisture: |
| Magnesium | (Mg) | lb/a | 541 | |
| Calcium | (Ca) | lb/a | 5161 | As Sampled: 14.19 |
| Sodium | (Na) | lb/a | 332 | Dried & Sieved: 2.57 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 16.3 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 2.5 | |
| Magnesium | (Mg) | % | 13.8 | |
| Calcium | (Ca) | % | 79.2 | |
| Sodium | (Na) | % | 4.3 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 31 |
| Boron | (B) | lb/a | | Silt % = 25 |
| Ca to Mg Ratio | | | 5.7 | Clay % = 44 |
| Mg to K Ratio | | | 5.5 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

## Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 0 | lbs/1000sqft |
| Potash (K2O) | 2 | lbs/1000sqft |
| Magnesium (Mg) | 0 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Test Performed : AP

Customer : STONE

Date Reported : 06/25/2021
Lab Number : 21-4318
Sample ID: SOIL 3NB2

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.1 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 5.5 | |
| Phosphorus | (P1) | lb/a | 90 | |
| Potassium | (K) | lb/a | 194 | Moisture: |
| Magnesium | (Mg) | lb/a | 408 | |
| Calcium | (Ca) | lb/a | 5044 | As Sampled: 16.40 |
| Sodium | (Na) | lb/a | 372 | Dried & Sieved: 2.89 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 15.4 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.6 | |
| Magnesium | (Mg) | % | 11.1 | |
| Calcium | (Ca) | % | 82.0 | |
| Sodium | (Na) | % | 5.1 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 29 |
| Boron | (B) | lb/a | | Silt % = 21 |
| Ca to Mg Ratio | | | 7.4 | Clay % = 50 |
| Mg to K Ratio | | | 6.8 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

## Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 1 | lbs/1000sqft |
| Potash (K2O) | 2 | lbs/1000sqft |
| Magnesium (Mg) | 1 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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(330) 893-2933 * www.holmeslab.com
Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4319
Sample ID: SOIL
4EG5

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 7.4 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 5.2 | |
| Phosphorus | (P1) | lb/a | 10 | |
| Potassium | (K) | lb/a | 82 | Moisture: |
| Magnesium | (Mg) | lb/a | 214 | |
| Calcium | (Ca) | lb/a | 2305 | As Sampled: 20.02 |
| Sodium | (Na) | lb/a | 852 | Dried & Sieved: 3.54 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 8.6 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.2 | |
| Magnesium | (Mg) | % | 10.4 | |
| Calcium | (Ca) | % | 66.9 | |
| Sodium | (Na) | % | 21.1 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 9 |
| Boron | (B) | lb/a | | Silt % = 41 |
| Ca to Mg Ratio | | | 6.5 | Clay % = 50 |
| Mg to K Ratio | | | 8.5 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

Lime and Fertilizer Recommendations

Gypsum Needed = 5 lbs/1000sqft

For Crop: Lawn

Gypsum addition will increase your soil Calcium Base Saturation. Gypsum (24% Ca & 18% S), will not increase the pH.

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 3 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 1 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Customer : STONE

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748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4320
Sample ID: SOIL
4NG1

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 7.6 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 4.8 | |
| Phosphorus | (P1) | lb/a | 23 | |
| Potassium | (K) | lb/a | 128 | Moisture: |
| Magnesium | (Mg) | lb/a | 265 | |
| Calcium | (Ca) | lb/a | 3381 | As Sampled: 13.74 |
| Sodium | (Na) | lb/a | 1005 | Dried & Sieved: 2.47 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 11.9 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.4 | |
| Magnesium | (Mg) | % | 9.3 | |
| Calcium | (Ca) | % | 71.0 | |
| Sodium | (Na) | % | 18.0 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 23 |
| Boron | (B) | lb/a | | Silt % = 29 |
| Ca to Mg Ratio | | | 7.7 | Clay % = 48 |
| Mg to K Ratio | | | 6.7 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

## Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate(P2O5) | 3 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 2 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4321
Sample ID: SOIL
4NB2

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 7.8 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 5.1 | |
| Phosphorus | (P1) | lb/a | 32 | |
| Potassium | (K) | lb/a | 143 | Moisture: |
| Magnesium | (Mg) | lb/a | 347 | |
| Calcium | (Ca) | lb/a | 4162 | As Sampled: 14.95 |
| Sodium | (Na) | lb/a | 602 | Dried & Sieved: 2.67 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 13.3 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.4 | |
| Magnesium | (Mg) | % | 10.8 | |
| Calcium | (Ca) | % | 78.0 | |
| Sodium | (Na) | % | 9.6 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 31 |
| Boron | (B) | lb/a | | Silt % = 25 |
| Ca to Mg Ratio | | | 7.2 | Clay % = 44 |
| Mg to K Ratio | | | 7.9 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 2 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 1 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4322
Sample ID: SOIL
5EG5

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.4 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 4.3 | |
| Phosphorus | (P1) | lb/a | 4 | |
| Potassium | (K) | lb/a | 128 | Moisture: |
| Magnesium | (Mg) | lb/a | 311 | |
| Calcium | (Ca) | lb/a | 3478 | As Sampled: 17.94 |
| Sodium | (Na) | lb/a | 423 | Dried & Sieved: 1.99 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 11.1 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.5 | |
| Magnesium | (Mg) | % | 11.7 | |
| Calcium | (Ca) | % | 78.5 | |
| Sodium | (Na) | % | 8.1 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 29 |
| Boron | (B) | lb/a | | Silt % = 23 |
| Ca to Mg Ratio | | | 6.7 | Clay % = 48 |
| Mg to K Ratio | | | 7.9 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 3 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 0 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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(330) 893-2933 * www.holmeslab.com
Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4323
Sample ID: SOIL
5NB2

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.5 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 4.6 | |
| Phosphorus | (P1) | lb/a | 61 | |
| Potassium | (K) | lb/a | 97 | Moisture: |
| Magnesium | (Mg) | lb/a | 219 | |
| Calcium | (Ca) | lb/a | 4427 | As Sampled: 16.16 |
| Sodium | (Na) | lb/a | 423 | Dried & Sieved: 2.26 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 13.0 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.0 | |
| Magnesium | (Mg) | % | 7.0 | |
| Calcium | (Ca) | % | 85.0 | |
| Sodium | (Na) | % | 6.9 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 49 |
| Boron | (B) | lb/a | | Silt % = 13 |
| Ca to Mg Ratio | | | 12.1 | Clay % = 38 |
| Mg to K Ratio | | | 7.3 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate(P2O5) | 2 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 4 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4324
Sample ID: SOIL
5SG3

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 7.8 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 4.3 | |
| Phosphorus | (P1) | lb/a | 312 | |
| Potassium | (K) | lb/a | 199 | Moisture: |
| Magnesium | (Mg) | lb/a | 439 | |
| Calcium | (Ca) | lb/a | 4447 | As Sampled: 16.35 |
| Sodium | (Na) | lb/a | 546 | Dried & Sieved: 2.93 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 14.4 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.8 | |
| Magnesium | (Mg) | % | 12.7 | |
| Calcium | (Ca) | % | 77.3 | |
| Sodium | (Na) | % | 8.1 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 23 |
| Boron | (B) | lb/a | | Silt % = 25 |
| Ca to Mg Ratio | | | 6.1 | Clay % = 52 |
| Mg to K Ratio | | | 7.2 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

## Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 0 | lbs/1000sqft |
| Potash (K2O) | 2 | lbs/1000sqft |
| Magnesium (Mg) | 0 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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(330) 893-2933 * www.holmeslab.com
Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4325
Sample ID: SOIL
7EG5

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.0 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 3.8 | |
| Phosphorus | (P1) | lb/a | 4 | |
| Potassium | (K) | lb/a | 102 | Moisture: |
| Magnesium | (Mg) | lb/a | 332 | |
| Calcium | (Ca) | lb/a | 3177 | As Sampled: 8.09 |
| Sodium | (Na) | lb/a | 867 | Dried & Sieved: 2.06 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 11.3 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.2 | |
| Magnesium | (Mg) | % | 12.2 | |
| Calcium | (Ca) | % | 70.0 | |
| Sodium | (Na) | % | 16.3 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 31 |
| Boron | (B) | lb/a | | Silt % = 21 |
| Ca to Mg Ratio | | | 5.7 | Clay % = 48 |
| Mg to K Ratio | | | 10.6 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate(P2O5) | 3 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 0 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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3559 US 62
Millersburg, OH 44654
www.facebook.com/holmeslab

SOIL
ANALYSIS REPORT
[Quality Testing Since 1978]
(330) 893-2933 * www.holmeslab.com
Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4326
Sample ID: SOIL
7NG1

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.3 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 2.8 | |
| Phosphorus | (P1) | lb/a | 28 | |
| Potassium | (K) | lb/a | 158 | Moisture: |
| Magnesium | (Mg) | lb/a | 311 | |
| Calcium | (Ca) | lb/a | 3601 | As Sampled: 13.63 |
| Sodium | (Na) | lb/a | 2066 | Dried & Sieved: 2.78 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 15.0 | |
| Base Saturation | | % | 99 | |
| Potassium | (K) | % | 1.4 | |
| Magnesium | (Mg) | % | 8.6 | |
| Calcium | (Ca) | % | 60.1 | |
| Sodium | (Na) | % | 29.3 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 21 |
| Boron | (B) | lb/a | | Silt % = 29 |
| Ca to Mg Ratio | | | 6.9 | Clay % = 50 |
| Mg to K Ratio | | | 6.4 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

Lime and Fertilizer Recommendations

Gypsum Needed = 18 lbs/1000sqft

For Crop: Lawn

Gypsum addition will increase your soil Calcium Base Saturation. Gypsum (24% Ca & 18% S), will not increase the pH.

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate(P2O5) | 3 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 3 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4327
Sample ID: SOIL
7NB2

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.4 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 6.4 | |
| Phosphorus | (P1) | lb/a | 31 | |
| Potassium | (K) | lb/a | 117 | Moisture: |
| Magnesium | (Mg) | lb/a | 270 | |
| Calcium | (Ca) | lb/a | 4718 | As Sampled: 37.99 |
| Sodium | (Na) | lb/a | 1066 | Dried & Sieved: 3.43 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 15.4 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.0 | |
| Magnesium | (Mg) | % | 7.3 | |
| Calcium | (Ca) | % | 76.6 | |
| Sodium | (Na) | % | 14.7 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 30 |
| Boron | (B) | lb/a | | Silt % = 22 |
| Ca to Mg Ratio | | | 10.5 | Clay % = 48 |
| Mg to K Ratio | | | 7.5 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate(P2O5) | 3 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 4 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Test Performed : AP

Customer : STONE

Date Reported : 06/25/2021
Lab Number : 21-4328
Sample ID: SOIL 8EG5

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.3 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 3.9 | |
| Phosphorus | (P1) | lb/a | 33 | |
| Potassium | (K) | lb/a | 372 | Moisture: |
| Magnesium | (Mg) | lb/a | 571 | |
| Calcium | (Ca) | lb/a | 6921 | As Sampled: 11.40 |
| Sodium | (Na) | lb/a | 1025 | Dried & Sieved: 3.40 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 22.4 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 2.1 | |
| Magnesium | (Mg) | % | 10.6 | |
| Calcium | (Ca) | % | 77.3 | |
| Sodium | (Na) | % | 9.7 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 5 |
| Boron | (B) | lb/a | | Silt % = 27 |
| Ca to Mg Ratio | | | 7.3 | Clay % = 68 |
| Mg to K Ratio | | | 5.0 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

## Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate(P205) | 2 | lbs/1000sqft |
| Potash (K20) | 1 | lbs/1000sqft |
| Magnesium (Mg) | 2 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4329
Sample ID: SOIL
8NB2

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.0 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 4.9 | |
| Phosphorus | (P1) | lb/a | 50 | |
| Potassium | (K) | lb/a | 337 | Moisture: |
| Magnesium | (Mg) | lb/a | 638 | |
| Calcium | (Ca) | lb/a | 7553 | As Sampled: 21.53 |
| Sodium | (Na) | lb/a | 928 | Dried & Sieved: 3.99 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 24.0 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.8 | |
| Magnesium | (Mg) | % | 11.1 | |
| Calcium | (Ca) | % | 78.7 | |
| Sodium | (Na) | % | 8.2 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 2 |
| Boron | (B) | lb/a | | Silt % = 28 |
| Ca to Mg Ratio | | | 7.1 | Clay % = 70 |
| Mg to K Ratio | | | 6.2 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

## Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 2 | lbs/1000sqft |
| Potash (K2O) | 2 | lbs/1000sqft |
| Magnesium (Mg) | 1 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4330
Sample ID: SOIL
8NG1

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.1 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 17.7 | |
| Phosphorus | (P1) | lb/a | 276 | |
| Potassium | (K) | lb/a | 372 | Moisture: |
| Magnesium | (Mg) | lb/a | 770 | |
| Calcium | (Ca) | lb/a | 8976 | As Sampled: 17.61 |
| Sodium | (Na) | lb/a | 1015 | Dried & Sieved: 6.15 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 28.3 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.7 | |
| Magnesium | (Mg) | % | 11.3 | |
| Calcium | (Ca) | % | 79.2 | |
| Sodium | (Na) | % | 7.6 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 29 |
| Boron | (B) | lb/a | | Silt % = 23 |
| Ca to Mg Ratio | | | 7.0 | Clay % = 48 |
| Mg to K Ratio | | | 6.7 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 0 | lbs/1000sqft |
| Potash (K2O) | 2 | lbs/1000sqft |
| Magnesium (Mg) | 1 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4331
Sample ID: SOIL
9EG5

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 7.9 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 4.1 | |
| Phosphorus | (P1) | lb/a | 19 | |
| Potassium | (K) | lb/a | 224 | Moisture: |
| Magnesium | (Mg) | lb/a | 714 | |
| Calcium | (Ca) | lb/a | 6610 | As Sampled: 13.10 |
| Sodium | (Na) | lb/a | 1061 | Dried & Sieved: 3.26 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 22.1 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.3 | |
| Magnesium | (Mg) | % | 13.5 | |
| Calcium | (Ca) | % | 74.8 | |
| Sodium | (Na) | % | 10.2 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 7 |
| Boron | (B) | lb/a | | Silt % = 33 |
| Ca to Mg Ratio | | | 5.6 | Clay % = 60 |
| Mg to K Ratio | | | 10.4 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

## Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 3 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 0 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4332
Sample ID: SOIL
9NB2

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 7.7 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 4.1 | |
| Phosphorus | (P1) | lb/a | 53 | |
| Potassium | (K) | lb/a | 291 | Moisture: |
| Magnesium | (Mg) | lb/a | 459 | |
| Calcium | (Ca) | lb/a | 9858 | As Sampled: 8.35 |
| Sodium | (Na) | lb/a | 678 | Dried & Sieved: 2.09 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 28.4 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.3 | |
| Magnesium | (Mg) | % | 6.7 | |
| Calcium | (Ca) | % | 86.8 | |
| Sodium | (Na) | % | 5.1 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 11 |
| Boron | (B) | lb/a | | Silt % = 29 |
| Ca to Mg Ratio | | | 12.9 | Clay % = 60 |
| Mg to K Ratio | | | 5.1 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 2 | lbs/1000sqft |
| Potash (K2O) | 2 | lbs/1000sqft |
| Magnesium (Mg) | 8 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

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Test Performed : AP

Customer : STONE

STONE Envir.Engineering & Sci
748 Green Crest Dr.
Westerville, OH 43081

Date Reported : 06/25/2021
Lab Number : 21-4333
Sample ID: SOIL 9SG3

| Item | | Units | Test Results | Comments |
|---|---|---|---|---|
| pH | | | 8.1 | |
| Lime Test Index | | | 70 | |
| Organic Matter | | % | 18.4 | |
| Phosphorus | (P1) | lb/a | 186 | |
| Potassium | (K) | lb/a | 245 | Moisture: |
| Magnesium | (Mg) | lb/a | 556 | |
| Calcium | (Ca) | lb/a | 8701 | As Sampled: 19.20 |
| Sodium | (Na) | lb/a | 933 | Dried & Sieved: 6.40 |
| Soluble Salts | (EC) | mmho/cm | | |
| Cation Exchange Capacity | (CEC) | meq/100g | 26.4 | |
| Base Saturation | | % | 100 | |
| Potassium | (K) | % | 1.2 | |
| Magnesium | (Mg) | % | 8.8 | |
| Calcium | (Ca) | % | 82.4 | |
| Sodium | (Na) | % | 7.5 | |
| Hydrogen | (H) | % | .0 | |
| Sulfur | (SO4) | lb/a | | |
| Zinc | (Zn) | lb/a | | |
| Manganese | (Mn) | lb/a | | |
| Iron | (Fe) | lb/a | | Particle Size Analysis |
| Copper | (Cu) | lb/a | | Sand % = 29 |
| Boron | (B) | lb/a | | Silt % = 21 |
| Ca to Mg Ratio | | | 9.4 | Clay % = 50 |
| Mg to K Ratio | | | 7.4 | |
| Nitrate-Nitrogen | (NO3-N) | lb/a | | |

*** Retest every year at the same time and depth ***

## Lime and Fertilizer Recommendations

Lime Needed = 0 lbs/1000sqft

For Crop: Lawn

Actual Units Of Fertilizer Needed For This Crop Growing Year

| | | |
|---|---|---|
| Nitrogen (N) | 0 | lbs/1000sqft |
| Phosphate (P2O5) | 0 | lbs/1000sqft |
| Potash (K2O) | 3 | lbs/1000sqft |
| Magnesium (Mg) | 5 | lbs/1000sqft |

Note : See your local Ag Supplier for assistance with what type of fertilizer to use.
Do not apply more than 1.5 lbs. Actual Nitrogen per time.

# Appendix G: Recommended Construction Notes and Details

## AMENDED VEGETATED FILTER STRIP (AVFS)

THE AMENDED VEGETATED FILTER STRIP (AVFS) CONSISTS OF THE GRASSED PORTION OF THE GRADED SHOULDER AND GRASSED FORESLOPE, WHERE THE UNDERLYING SOILS HAVE BEEN AMENDED WITH COMPOST AND SAND. THE AVFS SHOULD BE IMPLEMENTED IN A STRIP, PARALLEL WITH THE ROADWAY, SO THAT IT CAN RECEIVE SHEET FLOW DIRECTLY FROM THE ROADWAY.

### DESIGN CRITERIA

1. THE AVFS BMP CONSISTS OF THE GRASSED PORTION OF THE GRADED SHOULDER AND GRASSED FORESLOPE, WHERE THE UNDERLYING SOILS HAVE BEEN AMENDED PER THE CONSTRUCTION PROCEDURES AND MATERIAL SPECIFICATIONS INDICATED IN THIS MANUAL.
2. THE AVFS CAN BEGIN A MINIMUM OF 2-FEET FROM THE EDGE OF PAVED SHOULDER, OR AT ANY POINT FURTHER DOWN THE SLOPE. AVFS MUST END A MINIMUM OF 2-FEET ABOVE THE TOE OF SLOPE OR BOTTOM OF DITCH.
3. THE AVFS MUST BE VOID OF EROSIVE GULLIES OR RILLS.
4. ALL RUNOFF MUST BE SHEET FLOW, WITH NO CONCENTRATED FLOWS TO THE AVFS.
5. THE MINIMUM WIDTH OF THE AVFS IS 4-FEET.
6. THE MAXIMUM SLOPE OF THE AVFS OR ANY AREA DRAINING TO THE AVFS IS 3:1.
7. ALL PERVIOUS AREA DRAINING TO THE AVFS, AND THE AVFS ITSELF, MUST MAINTAIN A MINIMUM OF 70% GRASS COVER.
8. DO NOT INCLUDE ANY DITCH BOTTOM AREAS IN THE AVFS AREA, SINCE FLOW IS CONCENTRATED AT THE DITCH BOTTOM.

### TREATMENT CREDIT

AREAS SUCH AS PAVEMENT, GRADED SHOULDER, OR ANY GRASS SLOPE THAT DRAINS TO THE AVFS, AND THE AVFS AREA ITSELF, RECEIVE TREATMENT CREDIT AT THE FOLLOWING RATES:

1. 60% CREDIT FOR PAVEMENT AREA, GRADED SHOULDER AREA, OR ANY GRASS SLOPE ARE THAT SHEETS FLOWS TO THE AVFS.
2. 100% CREDIT FOR THE AREA OF THE AVFS.

### MATERIAL SPECIFICATIONS

SAND

1. MEET ODOT CMS 703.02 - FINE AGGREGATE

SOIL AMENDMENT COMPOST

1. SOIL AMENDMENT COMPOST SHALL ORIGINATE FROM AN OHIO EPA CLASS IV COMPOSTING FACILITY.
2. 100% OF MATERIAL MUST PASS THE 1/2-INCH SCREEN, WITH 75% PASSING THE 1/4-INCH SCREEN.
3. $5.5 < PH < 8.5$
4. INERT MATERIAL < 1%
5. 35% < ORGANIC CONTENT < 65% (DRY WEIGHT BASIS DETERMINED BY LOSS OF IGNITION)
6. 20% < C:N RATIO < 25%
7. MATURITY > 80% (SOLVITA INDEX VALUE BETWEEN 7 AND 8). PARENT MATERIAL IS NO LONGER VISIBLE. COMPOST SHOULD BE STABLE WITH REGARD TO OXYGEN CONSUMPTION AND CARBON DIOXIDE GENERATION.
8. < 1,000 MPN/GTS FECAL COLIFORM AND < 3 MPN/GTS SALMONELLA SPP.
9. 30% < MOISTURE CONTENT < 60% WET BASIS
10. SOIL AMENDMENT COMPOST SAMPLES SHOULD BE TAKEN FROM THE MATERIAL STOCKPILED BY THE SUPPLIER WITHIN 15 CALENDAR DAYS PRIOR TO INITIAL APPLICATION. SUBMIT LABORATORY RESULTS TO THE ENGINEER FOR APPROVAL. SOIL AMENDMENT COMPOST THAT DOES NOT MEET THE SPECIFICATION SHALL NOT BE USED.

SEED

1. MEET ODOT CMS 659.09 - CLASS 1 - LAWN MIXTURE

EROSION CONTROL MAT

1. MEET ODOT CMS 712 - TYPE A - TEMPORARY EROSION CONTROL MAT

### CONSTRUCTION PROCEDURE

1. SOIL RIPPING: USE A SOLID-SHANK RIPPER WITH TEETH, TRAVERSING THE AREA WITH 2 PASSES IN EACH DIRECTION TO A DEPTH OF 12 INCHES. EACH PASS IS CONSIDERED THE WIDTH OF THE RIPPER, WITH TEETH SPACED NO MORE THAN 12 INCHES APART. THIS MAY BE ACCOMPLISHED WITH IMPLEMENTS MOUNTED TO A TRACTOR OR DOZER OR USE OF A GRADER WITH APPROPRIATE IMPLEMENTS (SCARIFIER TEETH), BUT MUST MEET THE 12-INCH DEPTH. IF TEETH ARE SPACED GREATER THAN 12 INCHES, ADDITIONAL PASSES ARE REQUIRED TO MEET A FURROW SPACING OF 6 INCHES. ONLY PERFORM RIPPING DURING DRY CONDITIONS WHEN SOILS ARE FRIABLE.
2. EXCAVATION: REMOVE EXCESS SOIL, SO THAT AFTER THE AMENDMENTS HAVE BEEN INCORPORATED INTO THE EXISTING SOIL, THE EXISTING GROUND SURFACE PROFILE WILL NOT APPRECIABLY CHANGE. THIS MAY NOT ALWAYS BE NECESSARY DEPENDING ON THE SITE CONDITIONS AND OVERALL PROJECT CONSTRUCTION SEQUENCE. HOWEVER, IT WILL LIKELY BE REQUIRED FOR MITIGATION SITES, WHERE THE SOILS ARE BEING AMENDED, BUT THE EXISTING GRADE IS BEING MAINTAINED.
3. AMENDMENT PLACEMENT AND INCORPORATION: SPREAD AMENDMENTS OVER THE GROUND SURFACE IN A UNIFORM THICKNESS TO THE SPECIFIED AMENDMENT DEPTH. INCORPORATE AMENDMENTS WITH A ROTOTILLER OR SIMILAR EQUIPMENT INTO THE SOIL TO A DEPTH OF 6 INCHES. CONTINUE TILLING UNTIL ALL SOIL CLODS ARE REDUCED TO A MAXIMUM SIZE OF 1-INCH (25 MM) AND THE MIXTURE IS UNIFORM. INCORPORATION SHOULD ONLY BE PERFORMED DURING DRY CONDITIONS WHEN SOILS ARE FRIABLE. SIX PASSES (PASS IS THE WIDTH OF THE MACHINE) WITH A ROTOTILLER OR SIMILAR IS ANTICIPATED TO MEET THE UNIFORMITY REQUIREMENT.
4. FINE GRADING AND LIMITED COMPACTION: PERFORM FINE GRADING TO ACHIEVE THE SLOPE GEOMETRY AND ELEVATIONS SPECIFIED IN THE PLANS. TO ACHIEVE AN APPROXIMATE COMPACTION OF 85 TO 90% MAXIMUM DENSITY, ONE PASS WITH A RUBBER-TIRED OR SMOOTH DRUM ROLLER IS ANTICIPATED.
5. COMPOST BLANKET: EVENLY SPREAD A 0.5-INCH THICK LAYER OF SOIL AMENDMENT COMPOST OVER THE GROUND SURFACE.
6. SEEDING AND WATERING: ODOT CLASS I LAWN MIXTURE (ODOT ITEM 659.09) INSTALLED PER ITEM 659. RAKE SEED INTO SOIL AMENDMENT COMPOST. CONTRACTOR IS RESPONSIBLE FOR ESTABLISHING A MINIMUM OF 70% PERMANENT VEGETATION COVERAGE WITHIN THE PROJECT SCHEDULE. WATERING MAY BE NECESSARY.
7. FERTILIZER: APPLY THE FOLLOWING FERTILIZER AND RATES. FOLLOW ODOT ITEM 659.04 SPECIFICATION FOR APPLICATION OF FERTILIZER.
   1.0 LB./1,000 $FT^2$ POTASSIUM
   2.5 LB./1,000 $FT^2$ POTASH
   1.0 LB./1,000 $FT^2$ MAGNESIUM
8. EROSION CONTROL MATTING: ODOT CMS ITEM 712 TYPE A TEMPORARY EROSION CONTROL MAT. INSTALL PER ODOT ITEM 671. DO NOT RUN MACHINERY/EQUIPMENT OVER THE AMENDED SOILS DURING INSTALLATION OF THE EROSION CONTROL MAT.

### MAINTENANCE

MINIMAL MAINTENANCE SHOULD BE NECESSARY TO ENSURE CONTINUED FUNCTIONING OF AMENDED VEGETATED FILTER STRIPS. MAINTENANCE REQUIREMENTS CONSIST OF THE FOLLOWING:

1. ROUTINE MOWING. GRASS WITHIN THE FILTER STRIP SHOULD BE MAINTAINED AT THE SAME RATE AS STANDARD ODOT ROADWAY SIDE SLOPES. GRASS MUST BE KEPT HEALTHY AND FREE FROM BRUSH OR WOODY VEGETATION.
2. INSPECT FOR RILLS AND GULLIES. IF RILLS AND GULLIES OCCUR, THEY MUST BE REPAIRED AND STABILIZED WITH SOIL AND SEED OR SOD. MEASURES MUST BE TAKEN TO ELIMINATE ANY CONCENTRATED FLOW CAUSING EROSIVE RILLS AND GULLIES.

CALCULATED -
CHECKED -

AMENDED VEGETATED FILTER STRIP (AVFS)

ODOT RESEARCH

1
2

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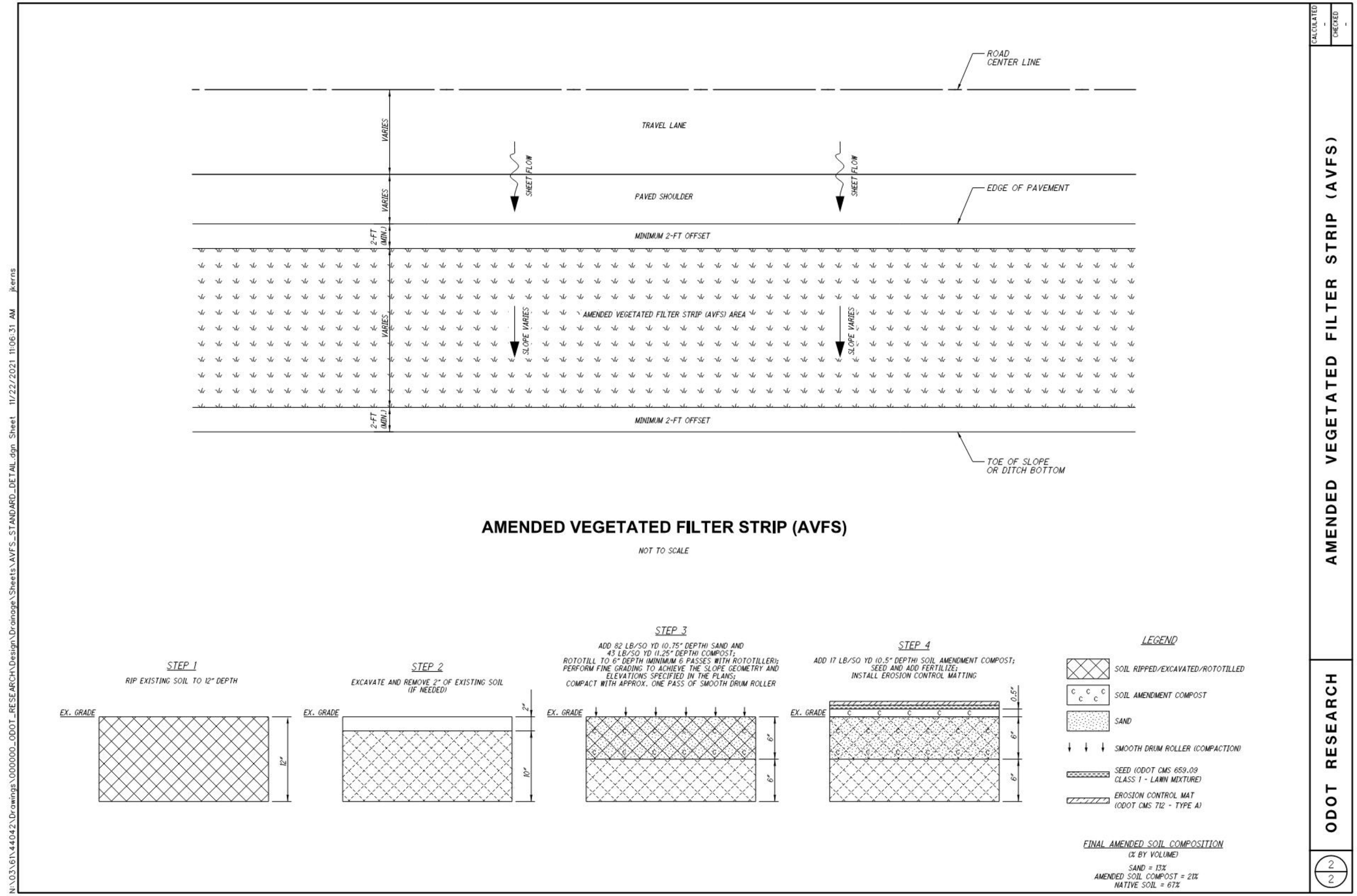
ROAD CENTER LINE
TRAVEL LANE
VARIES
SHEET FLOW
PAVED SHOULDER
EDGE OF PAVEMENT
2-FT (MIN.)
MINIMUM 2-FT OFFSET
AMENDED VEGETATED FILTER STRIP (AVFS) AREA
SLOPE VARIES
TOE OF SLOPE OR DITCH BOTTOM
AMENDED VEGETATED FILTER STRIP (AVFS)
NOT TO SCALE
STEP 1
RIP EXISTING SOIL TO 12" DEPTH
STEP 2
EXCAVATE AND REMOVE 2" OF EXISTING SOIL (IF NEEDED)
STEP 3
ADD 82 LB/SQ YD (0.75" DEPTH) SAND AND 43 LB/SQ YD (1.25" DEPTH) COMPOST;
ROTOTILL TO 6" DEPTH (MINIMUM 6 PASSES WITH ROTOTILLER);
PERFORM FINE GRADING TO ACHIEVE THE SLOPE GEOMETRY AND ELEVATIONS SPECIFIED IN THE PLANS;
COMPACT WITH APPROX. ONE PASS OF SMOOTH DRUM ROLLER
STEP 4
ADD 17 LB/SQ YD (0.5" DEPTH) SOIL AMENDMENT COMPOST;
SEED AND ADD FERTILIZE;
INSTALL EROSION CONTROL MATTING
EX. GRADE
12"
2"
10"
6"
0.5"
LEGEND
SOIL RIPPED/EXCAVATED/ROTOTILLED
SOIL AMENDMENT COMPOST
SAND
SMOOTH DRUM ROLLER (COMPACTION)
SEED (ODOT CMS 659.09 CLASS 1 - LAWN MIXTURE)
EROSION CONTROL MAT (ODOT CMS 712 - TYPE A)
FINAL AMENDED SOIL COMPOSITION
(% BY VOLUME)
SAND = 13%
AMENDED SOIL COMPOST = 21%
NATIVE SOIL = 67%
AMENDED VEGETATED FILTER STRIP (AVFS)
ODOT RESEARCH
CALCULATED
CHECKED
2
2
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# Appendix H: BMP Treatment Credit Examples

# Example 1 – 100% Redevelopment

- EDA = 10.00 acres      Aix = 10.00 acres      Ain = 0.00 acre
- T% = [(10.00 ∗ 20) + (0.00 ∗ 100)] / (10.00 +0.00) = 20%
- Treatment Requirements = 10.00 acres ∗ 20% = 2.00 acres

# Example 1 – 100% Redevelopment

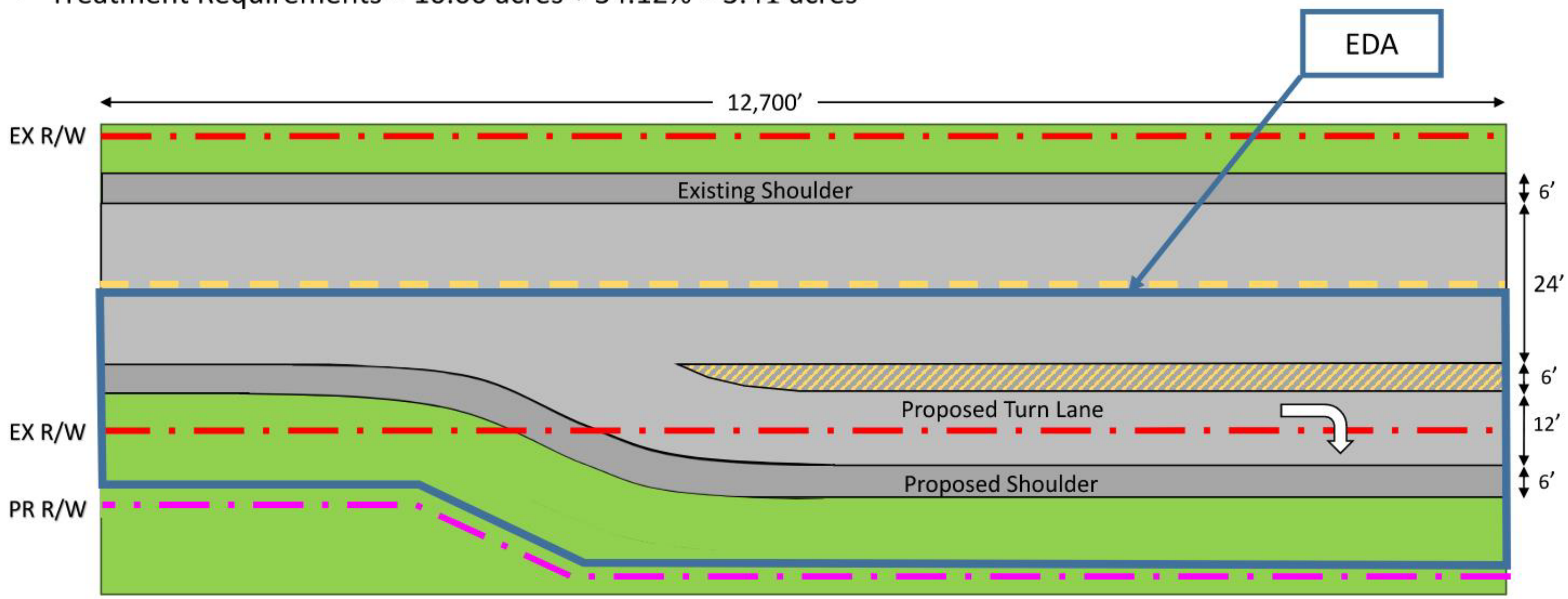
- Credit for tributary area sheet flowing to amended filter strip: $\dfrac{8{,}625' * 6.5'}{43{,}560} * 60\% = 0.77\ acres$
- Credit for amended filter strip area: $\dfrac{8{,}625' * 6.5'}{43{,}560} * 100\% = 1.29\ acres$
- Total Credit for BMP: **2.06 acres**

**Meets Requirement of 2.00 acres**

NOTE:
While tributary area width is greater than amended area width, the maximum tributary width given credit is equal to the width of amended filter strip.

# Example 2 – New Turn Lane

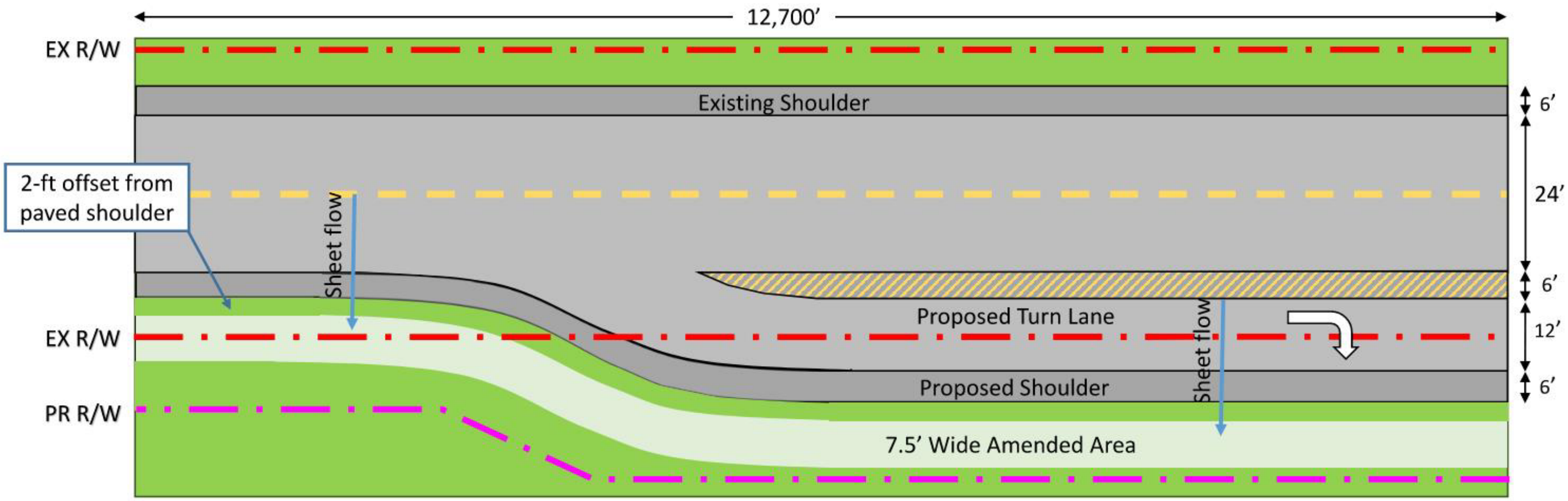
- EDA = 10.00 acres Aix = 7.00 acres Ain = 1.50 acre
- T% = [(7.00 ∗ 20) + (1.50 ∗ 100)] / (7.00 +1.50) = 34.12%
- Treatment Requirements = 10.00 acres ∗ 34.12% = 3.41 acres



# **Example 2** – New Turn Lane

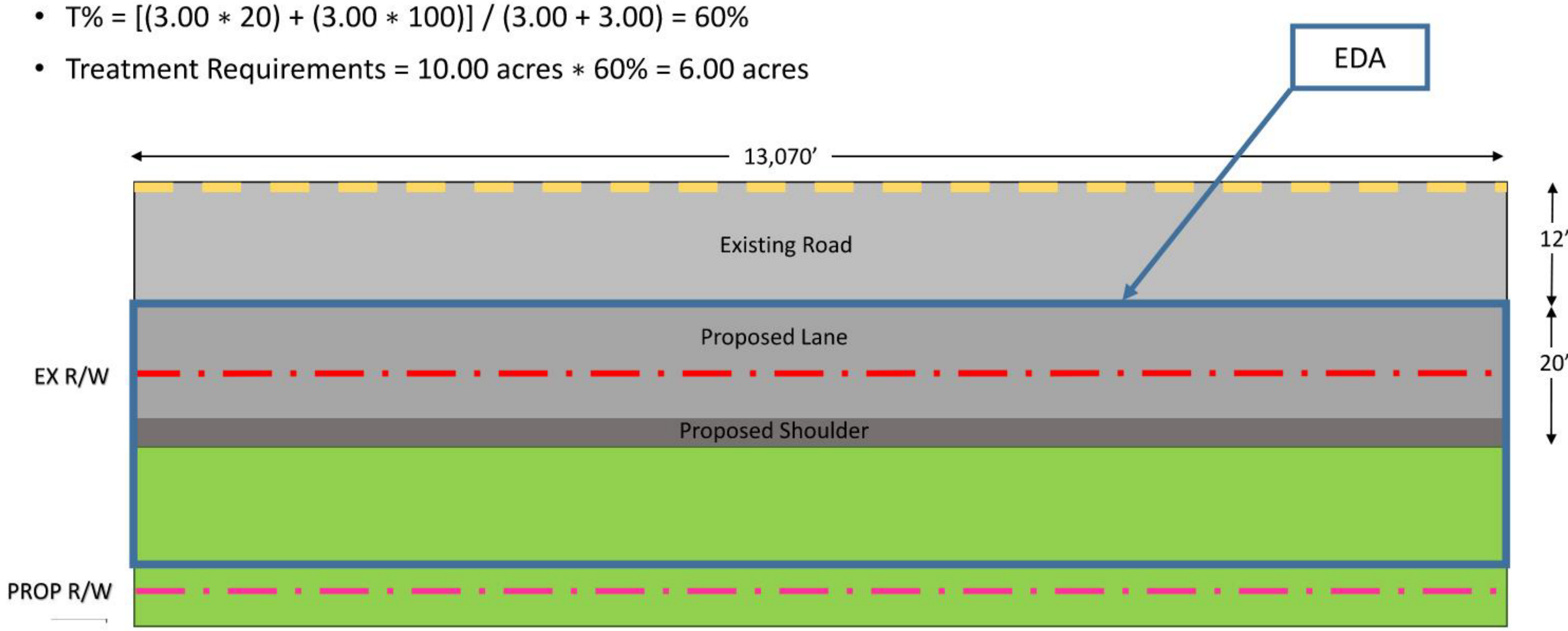
- Credit for tributary area sheet flowing to amended filter strip: $\frac{12{,}700' * 7.5'}{43{,}560} * 60\% = 1.31\ acres$
- Credit for amended filter strip area: $\frac{12{,}7000' * 7.5'}{43{,}560} * 100\% = 2.19\ acres$
- Total Credit for BMP: **3.50 acres** **Meets Requirement of 3.41 acres**

NOTE:
While tributary area width is greater than amended area width, the maximum tributary width given credit is equal to the width of amended filter strip.



# Example 3 – Adding a lane

- EDA = 10.00 acres Aix = 3.00 acres Ain = 3.00 acre
- T% = [(3.00 ∗ 20) + (3.00 ∗ 100)] / (3.00 + 3.00) = 60%
- Treatment Requirements = 10.00 acres ∗ 60% = 6.00 acres



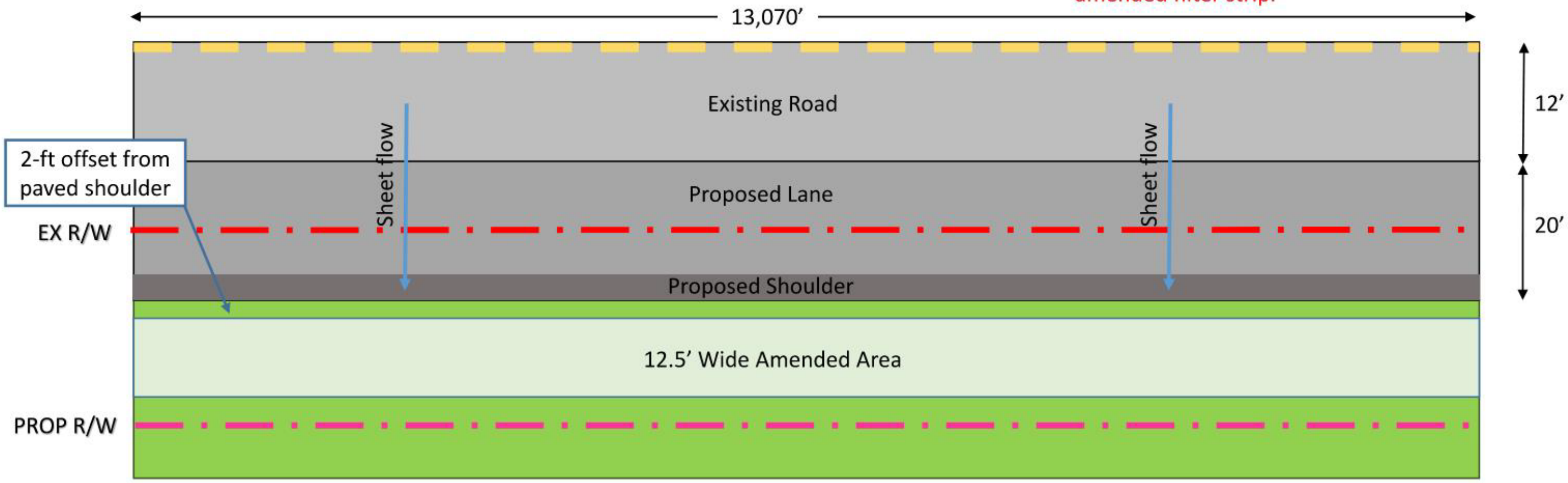
# Example 3 – Adding a lane

Credit for tributary area sheet flowing to amended filter strip: $\frac{13{,}070' * 12.5'}{43{,}560} * 60\% = 2.25\ acres$

Credit for amended filter strip area: $\frac{13{,}070' * 12.5'}{43{,}560} * 100\% = 3.75\ acres$

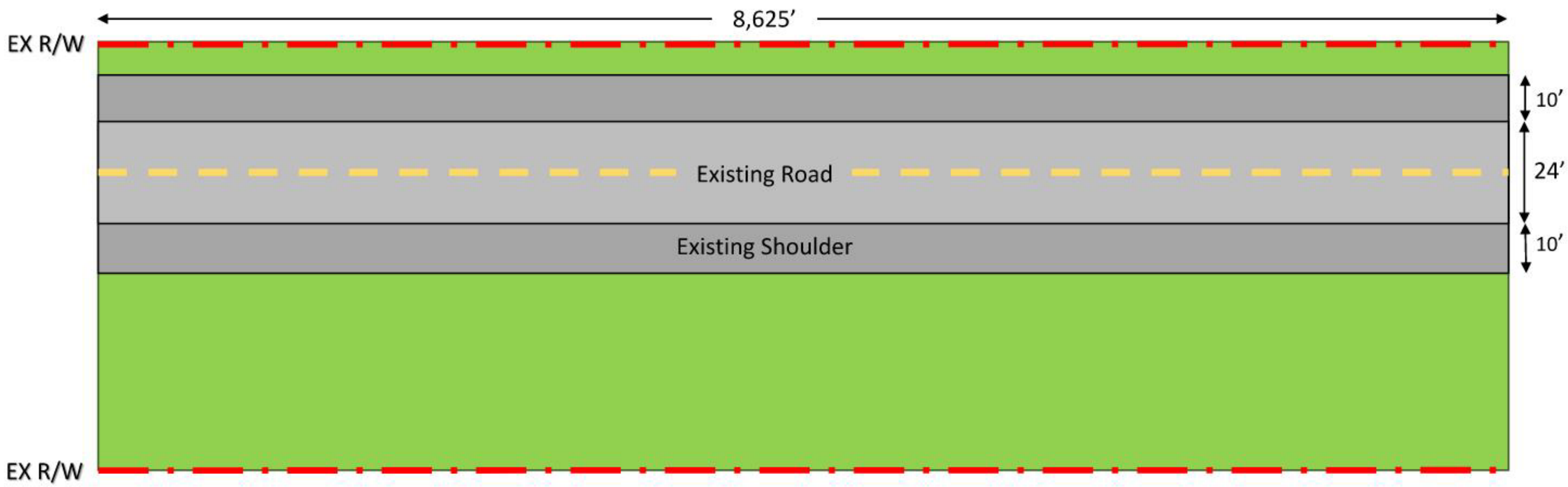
Total Credit for BMP: **6.00 acres** **Meets Requirement of 6.00 acres**

NOTE:
While tributary area width is greater than amended area width, the maximum tributary width given credit is equal to the width of amended filter strip.



# Example 4 – Partial Length Amendment

- EDA = 10.00 acres Aix = 10.00 acres Ain = 0.00 acre
- T% = [(10.00 ∗ 20) + (0.00 ∗ 100)] / (10.00 +0.00) = 20%
- Treatment Requirements = 10.00 acres ∗ 20% = 2.00 acres



# **Example 4** – Partial Length Amendment

- Credit for tributary area sheet flowing to amended filter strip: $\frac{2{,}200' * 24'}{43{,}560} * 60\% = 0.73\ acres$
- Credit for amended filter strip area: $\frac{2{,}200' * 30'}{43{,}560} * 100\% = 1.52\ acres$
- Total Credit for BMP: **2.25 acres** **Meets Requirement of 2.00 acres**

NOTE:
Tributary area width is less than amended area width.